CANADA

DEPARTMENT OF MINES

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MINES BRANCH

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DEVELOPMENT OF CHEMICAL, METALLURGICAL, AND ALLIED INDUSTRIES IN CANADA

IN

RELATION TO THE MINERAL INDUSTRY

BY ALFRED W. G. WILSON, PH.D.

In Two Volumes

VOLUME I

CHEMICAL INDUSTRIES

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PREFACE

Substantial new industries are not developed by chance. Their successful foundation almost invariably demands close and careful study of existing related industries, market requirements, sources of necessary raw materials, transportation facilities, and other interrelated controlling factors. This report has been planned and prepared to aid in the development of new industries in Canada by presenting in concise form general statements showing existing conditions in the fields of metallurgical or chemical manufacturing. The Canadian situation in a number of other industries or groups of industries which utilize mineral or chemical products has also been reviewed. The field that had to be covered is very broad and the various discussions have necessarily been limited to essential facts, so far as these facts could be ascertained with the facilities that were available while the report was in preparation.

The information included in this report represents only a small portion of the results of the investigations on which it is based. The preparatory work involved numerous studies concerning the raw materials of industry, the sources of supply, processes of preparation, methods of utilization, and both technical and commercial requirements.

The review of Canadian industries presented in this report was first planned early in 1916, but special war work prevented the initiation of necessary field investigations until 1917. These were continued during parts of 1918, 1919, and 1920. Almost all of the information contained in this report has been available to those entitled to it ever since it was obtained, provided they applied for it. It did not appear desirable to publish any results of the investigation in report form until after the close of the war. Pressure of other duties and the preparation of certain special reports have delayed the completion of this report until the present.

The investigations upon which the report is based were primarily undertaken to supply information for war purposes. It was also realized that when peace came, it would be very desirable to have accurate information available with respect to the present development of the Metallurgical and Chemical arts in Canada. The initiation of new lines of endeavour and the expansion of old would assuredly depend upon a knowledge of what had been already accomplished.

The mineral industry is our most important basic industry through which raw materials are supplied not only to the two allied industries here under discussion, but also to all other industries. It is doubtful if any other industry, even agriculture, offers so great opportunities for immediate expansion and development of our commerce through the initiation of new enterprises based upon its raw materials. This is particularly true where new industries are designed to produce products which will displace foreign products now imported.

Metallurgical industries are based wholly upon the mineral industry. Those manufacturing industries which fabricate metallic products are therefore all dependent upon mineral products. So also are those which require appliances made with metals.

Chemical industries draw at least seventy-five per cent of their raw materials from mineral resources. Probably less than one-quarter of our chemical manufacturing industries obtain their principal raw materials from the other basic sources of supply. Even in these industries it will be found that certain materials, required in minor quantities but none the less essential, are either minerals or chemical products derived from minerals. Because of this very intimate dependence of practically all chemical industry upon the mineral industry it has been considered desirable to include in this report references to a number of chemical industries whose principal raw materials are derived from basic sources other than natural minerals.

Many other industries, not ordinarily classed either as metallurgical or chemical, not infrequently employ chemical processes and invariably require as raw materials some products of either of these groups.

The various industries operating in Canada have been grouped, for purposes of discussion, according to basic relationships, as explained more fully in the introductory chapter. The extent of the development of each industry or industrial group is briefly stated. Then follow statements of the products made in Canada by that industry, of the raw materials required, and of the sources of these raw materials whether domestic or foreign. Markets, both domestic and foreign, are discussed whenever possible, and frequent reference is made to industrial statistics when such are available.

The several reviews were correct in all essential details at the time they were prepared. In a few cases some changes have taken place in the interval which has elapsed between the date of preparation and the date of publication. Where possible such changes have been noted and it is thought that no important factors have been overlooked. The report chiefly presents conditions as found between the years 1919 and 1922.

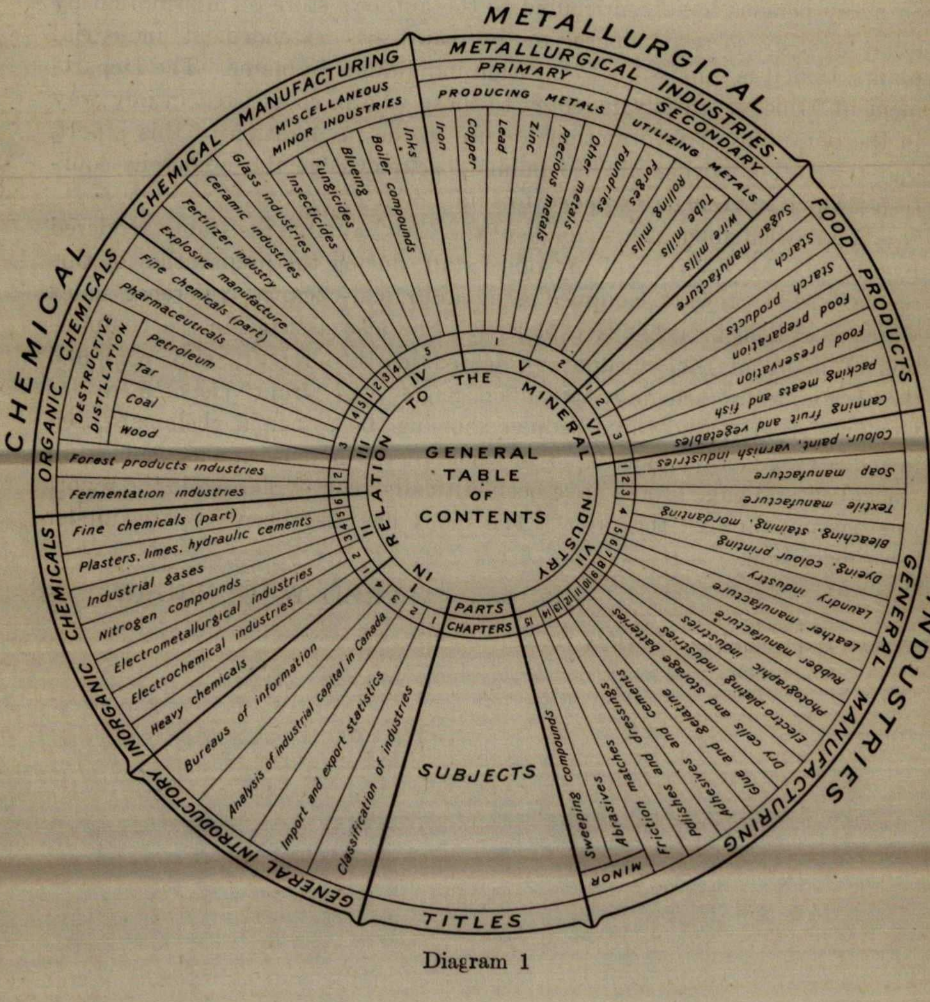
This report deals primarily with facts which are recorded impersonally. The ways and means necessary to promote industrial expansion or development necessarily involve the personal equations of the promoters and others. The opinions here introduced represent the author's personal views and are based upon carefully considered data.

The author is indebted to very many technical men throughout Canada, and at many points in the United States, for numerous courtesies extended to him personally. More than four hundred industrial establishments using metallurgical and chemical processes or utilizing raw materials of mineral origin have been visited to study organization, methods of utilization of raw materials, and the requirements of industry. So many persons have contributed to the author's store of information by interviews, by correspondence, or by courtesies extended at industrial plants, that it is impossible to mention individuals by name. The Department of Mines is greatly indebted to those who have assisted in any way in the obtaining of information for use in the preparation of this report, and the author wishes also to publicly acknowledge the numerous courtesies which have been extended to him.

Acknowledgment is also made of the very valuable assistance rendered by Miss D. M. Stewart, of my office staff, during the preparation of this report. Miss Stewart compiled a metallurgical-chemical reference index which is still in progress of expansion. She also assisted in the compilation of many of the schedules presented in this report, and compiled the Trade Index schedules given on pages 8-27 from Department of Customs reports, and the schedules showing the principal chemicals used in industry given on page 3. The whole of the manuscript as well as all the galley and page proofs have been critically read by her while the report was passing through the press. The index has also been prepared under her supervision.

ALFRED W. G. WILSON.

OTTAWA, December 15, 1923.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Development of Chemical, Metallurgical, and Allied Industries in Canada in Relation to the Mineral Industry

PART I

GENERAL INTRODUCTORY

CHAPTER I

CLASSIFICATION OF INDUSTRIES

The first problem that presents itself in preparing a report of this kind is the evolving of a logical classification of industry. The Mineral industry as a source of raw materials, for utilization in other industries, has been adopted as the primary and guiding concept. The term Mining industry is sometimes used synonymously with Mineral industry, but common usage tends to limit the application of this term to the winning of the ores of metals and to the production of some of the commoner non-metallic minerals. The non-metallic mineral industry also embraces several sub-titles such as Quarrying, Sand and Gravel industry, Building Stone industry, and similar designations.

Raw mineral products are passed to Manufacturing industry for preparation or fabrication for use in the arts. A careful analysis will show that it is impossible to draw a hard-and-fast line between Mining on the one hand and Manufacturing on the other. Using the latter term in its most literal sense, manufacturing begins as soon as waste rock is separated from valuable ores, an operation that often takes place underground. On the other hand ore as such is valueless in the arts. The usefulness of its valuable content begins only after the metal or other desired constituent has been isolated from the useless material. From this point the isolated material is ready for fabrication into useful articles produced by industry. It therefore seems logical to limit the term Manufacturing industry to those industries which are concerned chiefly with the fabrication of final finished products, whether chemical elements such as metals, chemical compounds of the elements, or the more complex artificial products of industry and commerce.

Intermediate between the consuming industries on the one hand and the producing industries on the other are those groups concerned with the processes of preparation. In a few isolated instances valuable metals or mineral products in a form suitable for use in manufacturing are recovered direct through the application of processes dependent upon certain physical properties. The recovery of nugget gold and platinum are examples. Even in these cases it is usually necessary to subject the product to a final chemical process for refining before the material is suitable for use in the arts. In the great majority of cases the natural mineral products have to be subjected to chemical processes for the purpose of securing the desired products, giving rise to the group name Chemical industries.

Chemical industry in its broadest sense embraces all industries employing chemical processes for the production of materials useful in the arts. As applied to products of the mineral industry it is customary to segregate those industries concerned with the production of metals and their alloys from the general Chemical group under the designation Metallurgical industry. This usage has been followed here, and the term Chemical industry is used in the more limited sense to apply to those industries using chemical processes to prepare chemical compounds of the elements for use in the arts.

When consideration is given to the source of energy or to the conditions under which chemical reactions are promoted certain sub-group designations, indicative of the processes employed, may be used to name industrial groups. Thus the prefixes thermo, hydro, or electro, may be used to designate minor groups of metallurgical or chemical industries. Where the source of energy is electric power certain groups of industries employing chemical and metallurgical processes may be associated under the name of Electrochemical industries. These are sometimes subdivided into the Electrochemical group proper, and the Electrometallurgical group. These sub-groups are considered together in this report because it is unnecessary to introduce detailed differentiations or discussions.

A study of the utilization of raw material in industry shows that all substances between source and final disposal pass successively by stages through one or more processes before the desired final product is secured. A very few raw materials are utilized in their natural state, excepting foods. In some instances natural raw products pass through a single stage of manufacturing to a finished product ready for utilization in another industry. These might be designated primary manufactural products. Such materials as sulphuric acid or caustic soda might be so designated. Again raw materials and primary manufactural products are assembled

PRINCIPAL CHEMICALS USED IN INDUSTRY

	INORGANIC CHEMICALS					
	ACIDS					
	HYDROCHLORIC	HYDROFLUORIC	NITRIC	PHOSPHORIC	SULPHURIC	SULPHUROUS
BATTERIES			○		○	
CERAMICS	○	○			○	
COAL DISTILLATION					○	
DYEING, ETC.	○		○		○	○
ELECTRO-PLATING	○	○	○		○	
EXPLOSIVES	○		○		○	
FERMENTATION		○		○	○	○
FERTILIZERS				○	○	
FOOD PREPARATION						○
GLASS		○				
GLUES	○			○	○	○
INSECTICIDES, ETC.						
LAUNDERING						
MEAT PACKING						
PAINT AND VARNISH	○		○		○	
PETROLEUM REFINING	○				○	
PHOTOGRAPHY	○		○		○	
PULP AND PAPER					○	○
RUBBER						
SOAP					○	
STARCH	○	○	○		○	○
SUGAR				○		
TANNING	○				○	○
TEXTILES	○		○	○	○	○
WOOD DISTILLATION	○				○	

	INORGANIC CHEMICALS																										
	ALUM (POTASH)	ALUM (SODA)	ALUMINIUM (POWDER)	ALUMINIUM HYDROXIDE	ALUMINIUM SULPHATE	AMMONIA	AMMONIUM CHLORIDE	AMMONIUM NITRATE	AMMONIUM SULPHATE	ARSENIOUS OXIDE	BARIUM CHLORIDE	CALCIUM ACETATE	CALCIUM CARBONATE	CALCIUM CHLORIDE	CALCIUM HYDROXIDE	CALCIUM HYPOCHLORITE	CALCIUM OXIDE	CALCIUM PHOSPHATE ACID	CARBON TETRACHLORIDE	COPPER SULPHATE	FERROUS SULPHATE	HYDROGEN PEROXIDE	LEAD ACETATE	LEAD ARSENATE	LEAD CARBONATE	LEAD CHROMATE	LEAD NITRATE
BATTERIES							○		○											○							
CERAMICS							○						○												○		
COAL DISTILLATION															○		○										
DYEING, ETC.	○	○		○	○	○	○			○		○		○	○	○	○			○	○	○	○			○	○
ELECTRO-PLATING	○	○		○		○	○		○	○							○			○	○		○		○		
EXPLOSIVES	○	○	○		○	○	○	○	○				○														
FERMENTATION						○							○	○	○												
FERTILIZERS									○									○									
FOOD PREPARATION	○	○											○				○	○									
GLASS										○			○		○		○										
GLUES		○													○		○										
INSECTICIDES, ETC.										○	○				○		○			○				○			
LAUNDERING	○	○											○			○						○					
MEAT PACKING	○	○																									
PAINT AND VARNISH	○	○		○	○	○	○			○			○	○	○	○	○		○	○	○		○		○	○	○
PETROLEUM REFINING															○		○										
PHOTOGRAPHY	○	○				○															○						○
PULP AND PAPER	○	○			○								○			○	○									○	
RUBBER	○	○	○	○						○			○		○		○		○				○		○		
SOAP						○	○		○						○		○		○		○						
STARCH																											
SUGAR													○		○			○									
TANNING	○	○			○	○	○		○	○	○		○	○	○		○			○	○						
TEXTILES	○	○		○	○	○	○		○			○		○	○	○				○	○	○	○				
WOOD DISTILLATION														○	○		○										

	INORGANIC CHEMICALS																									
	LEAD OXIDES	MAGNESIUM SULPHATE	POTASSIUM BICHROMATE	POTASSIUM BITARTRATE	POTASSIUM CARBONATE	POTASSIUM CHLORATE	POTASSIUM CHLORIDE	POTASSIUM HYDROXIDE	POTASSIUM NITRATE	SILVER NITRATE	SODIUM ACETATE	SODIUM BICARBONATE	SODIUM BISULPHATE	SODIUM BISULPHITE	SODIUM CARBONATE	SODIUM CHLORATE	SODIUM CHLORIDE	SODIUM HYDROXIDE	SODIUM HYPOSULPHITE	SODIUM NITRATE	SODIUM PHOSPHATE	SODIUM SILICATE	SODIUM SULPHATE	ZINC (DUST)	ZINC CARBONATE	ZINC OXIDE
BATTERIES	○		○					○																		
CERAMICS	○				○				○						○		○			○			○			
COAL DISTILLATION																		○								
DYEING, ETC.			○		○	○		○			○		○	○	○		○	○	○			○	○	○		
ELECTRO-PLATING	○			○	○		○	○		○		○	○	○	○		○	○	○	○	○		○			
EXPLOSIVES			○			○	○		○			○			○	○	○	○		○			○			○
FERMENTATION				○								○		○	○		○					○				
FERTILIZERS					○		○		○				○							○						
FOOD PREPARATION				○					○			○		○	○		○			○	○	○	○			
GLASS	○				○				○	○			○		○					○			○			○
GLUES																										○
INSECTICIDES, ETC.																	○									
LAUNDERING					○							○			○		○	○	○							
MEAT PACKING									○								○			○						
PAINT AND VARNISH	○		○	○	○	○		○	○	○					○			○	○		○	○	○		○	○
PETROLEUM REFINING															○			○								
PHOTOGRAPHY			○		○					○					○				○							
PULP AND PAPER	○	○												○	○		○	○	○			○	○			
RUBBER	○																							○		○
SOAP	○				○		○	○				○			○		○	○				○	○			○
STARCH															○			○								
SUGAR																										
TANNING		○	○		○							○		○	○		○	○	○				○			
TEXTILES		○				○		○				○		○	○			○				○		○		○
WOOD DISTILLATION								○						○	○			○								

	COAL TAR PRODUCTS															
	ANILINE	BENZENE	CARBON BISULPHIDE	CRESOLS	GASOLINES	HYDROQUINONE	METOL	NAPHTHA SOLVENT	NAPHTHALENE	NAPHTHOLS	NITRANILINE, PARA	PETROLATUM	PHENOL	PICRIC ACID	SODIUM BENZOATE	TOLUOL
BATTERIES																
CERAMICS												○				
COAL DISTILLATION																
DYEING, ETC.	○			○							○			○		○
ELECTRO-PLATING		○	○													
EXPLOSIVES		○		○					○			○	○	○		○
FERMENTATION																
FERTILIZERS																
FOOD PREPARATION															○	
GLASS																
GLUES																
INSECTICIDES, ETC.			○	○	○				○							
LAUNDERING					○			○								
MEAT PACKING															○	
PAINT AND VARNISH	○	○	○		○			○	○	○	○					
PETROLEUM REFINING																
PHOTOGRAPHY				○		○	○		○							
PULP AND PAPER	○															
RUBBER	○	○	○		○			○		○			○			
SOAP								○					○			
STARCH																
SUGAR																
TANNING	○							○								
TEXTILES	○		○	○	○			○								
WOOD DISTILLATION																

	MISCELLANEOUS SUBSTANCES																									
	ACETIC ACID	ACETONE	ALCOHOL (ETHYL)	ALCOHOL (METHYL)	AMYL ACETATE	CHLORINE LIQUID	CORN SYRUP	DEXTRINE	ETHER, ACETIC	ETHER, SULPHURIC	FORMALDEHYDE	FUSEL OIL	GELATINE	GLYCERINE	LINSEED OIL	NEATSFOOT OIL	OLEIC ACID	OLEO OIL	OXALIC ACID	PYROGALLIC ACID	STARCH	STEARIC ACID	SUGARS	TALLOW	TANNIC ACID	WHALE OIL
BATTERIES																										
CERAMICS																										
COAL DISTILLATION																										
DYEING, ETC.	○			○		○		○			○			○					○		○				○	
ELECTRO-PLATING	○		○	○																					○	
EXPLOSIVES		○	○	○					○	○				○					○		○		○			
FERMENTATION	○		○					○			○														○	
FERTILIZERS																										
FOOD PREPARATION	○		○		○			○	○				○	○				○			○		○	○		
GLASS																										
GLUES											○															
INSECTICIDES, ETC.											○															
LAUNDERING	○					○													○		○					
MEAT PACKING													○													
PAINT AND VARNISH	○	○	○	○	○							○			○											
PETROLEUM REFINING																										
PHOTOGRAPHY			○								○									○						
PULP AND PAPER						○		○					○	○							○				○	
RUBBER	○	○	○	○				○		○	○		○								○					
SOAP			○	○							○			○	○	○	○				○	○	○	○		○
STARCH	○																		○							
SUGAR																										
TANNING			○					○			○		○		○	○			○					○	○	○
TEXTILES	○			○		○		○			○		○	○			○		○		○	○		○	○	
WOOD DISTILLATION																										

TABLE 1

in certain classes of manufacturing and converted into finished products which might be termed secondary manufactural products. Such a product is nitro-glycerine, made from glycerine, sulphuric and nitric acids. In the same way finished manufactural products of higher ranks than secondary are common. In some cases the intermediate processes are very complex, and raw materials are drawn from diverse sources, as in the textile industry or the soap industry.

Manufacturing in its literal and broadest sense may be made to include all industrial operations whereby certain products, regardless of origin, are fashioned by labour, manual or otherwise, into useful or desirable forms. Owing to the specialized character of certain operations essential to the preliminary preparation of raw materials for utilization for final manufacturing it has been deemed advisable to segregate these industries under appropriate titles and to limit the term Manufacturing to those industries not otherwise provided for. In the majority of cases those industries here grouped under the general designation Manufacturing will be found to require raw materials from diverse sources, many of which are manufactural products of greater complexity than secondary.

The foregoing statements will enable the reader to appreciate the difficulties of preparing a logical classification when dealing with so complex a subject as that presented in this report, and in part will serve to explain the classification here adopted. As far as possible the groups of industries discussed have been arranged in logical sequence, proceeding from the less complex to the more complex. In many instances the relative degrees of complexity are largely a matter of personal opinion, and another classification than that adopted here would serve the purpose equally well.

The classification of the Canadian chemical, metallurgical, and allied industries which has been adopted to determine the order of presentation of subjects in this report is as follows:—

- Chemical industries, producing chemical products:—
  - Those making primary inorganic products—
    - Heavy chemicals
    - Electrochemical and electrometallurgical products
    - Nitrogen compounds
    - Industrial gases (chiefly)
    - Plasters, limes, and hydraulic cements
    - Fine chemicals (in part)

  - Those making primary organic products—
    - Fermentation products, including industrial alcohol
    - Forest products
    - Destructive distillation products

- Those making primary organic products—*Concluded*
    - Industrial gases (in part)
    - Pharmaceuticals
    - Fine chemicals (in part)
- Industries making and using both organic and inorganic products—
    - Explosive manufacture, including fireworks
    - Fertilizer manufacture
- Industries engaged in secondary manufacture—
    - Ceramic products, including glasses
    - Insecticides and fungicides
    - Blueing
    - Boiler compounds
    - Inks

Metallurgical industries, producing and utilizing metals:—

- Primary, production of metals from ores—
    - Aluminium, antimony, arsenic, calcium, cobalt, copper, gold, iron, lead, magnesium, manganese, molybdenum, nickel, platinum, silver, zinc
- Secondary, utilizing metals—
    - Foundries
    - Forges
    - Rolling mills
    - Tube mills
    - Wire mills

Allied industries, using chemicals and chemical processes:—

- Products primarily intended for food—
    - Sugar manufacture
    - Starch and starch products
    - Food preparation and preservation, including
        - Meat and fish packing
        - Fruit and vegetable canning
- General manufacturing—
    - Colour, paint, and varnish products
    - Soap manufacture
    - Textile manufacture
    - Bleaching, staining, mordanting, dyeing, and colour printing
    - Laundering
    - Leather manufacture
    - Rubber manufacture
    - Photographic products
    - Electroplating
    - Dry cells and storage batteries
    - Abrasive products
    - Glue and gelatine
    - Adhesives and cements
    - Friction matches
    - Polishes
    - Sweeping compounds

The more important subjects presented in this report when discussing these industries are:—

1. Raw materials of the industries under review.
2. Sources of raw materials of the industries under review.
3. Uses of mineral products, including chemicals, in industry.
4. Chemical and metallurgical industries now established in Canada.
5. Chemical and metallurgical products now being produced in Canada.
6. Home markets and the export trade.

CHAPTER II

IMPORT AND EXPORT STATISTICS

References will be made in succeeding paragraphs to the importance of accurate statistical information. A manufacturer planning the development of a new industry needs to know the absorptive capacity of the home market and also requires as much data as possible about foreign markets for the specific product in which he is interested. Lists of the various raw materials or partially prepared products which enter into a number of lines of manufacture are given in the various sections of this report which describe certain industries developed in Canada. It has not been possible, however, to obtain accurate statistical data showing the market each of these industries offers for each of the materials mentioned. Statistical studies which have been made of Canada's home markets have, with very few exceptions, not considered specific products.

The best data at present available with respect to home markets relate to those commodities that are imported from abroad. Imports represent our requirements chiefly for the home market; they also include some commodities which enter into our export trade, usually after passing through manufacturing processes in Canada. It has not been considered necessary or desirable to introduce many statistical data in each section of the report. Such data as are available are compiled annually by the Dominion Bureau of Statistics and issued in separate reports. The latest available statistics relating both to production and importations can therefore be obtained by application to this bureau.

An attempt has been made to show the nature of the Canadian home market for chemical and metallurgical products by compiling a special table based on statistical data relating to imports and exports that have already been published. The tables which follow show the average annual imports and exports of named groups of commodities for the three-year period prior to the war. Corresponding data for the first complete fiscal year following the close of the war are also included for comparison. Later information can be obtained by consulting the annual reports issued by the Department of Trade and Commerce.

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Abrasive materials:						
Abrasives, artificial in bulk, crushed or ground, for the manufacture of abrasive wheels and polishing composition	....	†12,033	.....	....	127,631	.....
Diamond dust or bort, and black diamonds for borers	....	30,855	.....	....	95,246	.....
Emery, in bulk, crushed or ground	....	46,227	.....	....	85,038	.....
Emery and carborundum wheels and manufactures of emery or carborundum	....	123,734	.....	....	563,247	.....
Flint and ground flint stones	92,810 cwt.	52,589	.....	119,140 cwt.	113,913	.....
Iron sand or globules or iron shot and dry putty adapted for polishing glass or granite or for sawing stone	279,021 lbs.	10,609	.....	....	57,809	.....
Pumice and pumice stone, lava, and calcareous tufa, not further manufactured than ground	....	19,252	.....	....	35,815	.....
Sand paper, glass, flint and emery paper or emery cloth	....	175,940	.....	....	310,901	.....
Albumen:						
Albumen, blood, egg albumen and egg yolk	....	34,057	.....	....	129,509	.....
Casein	....	12,491	.....	....	33,319	.....
Alloys and alloy products:						
Babbit metal in blocks, bars, plates, and sheets	....	43,465	.....	....	26,214	.....
Britannia metal in pigs, blocks, or bars	341 cwt.	14,719	.....	155 cwt.	10,876	.....
Britannia metal, manufactures of, not plated	....	28,771	.....	....	16,653	.....
Cobalt alloys	....	....	.....	....	....	.....
Composition metal and plated metal in bars, ingots, or cores for the manufacture of watch cases, jewellery, filled gold and silver seamless wire	....	28,579	.....	....	39,520	.....
Ferro-manganese, ferro-silicon, and spiegeleisen	23,266 tons	636,172	.....	....	....	
Ferro-manganese and spiegeleisen containing more than 15% manganese	....	....	.....	33,282 tons	3,806,242	
Ferro-manganese and spiegeleisen containing not more than 15% manganese, and other ferro-alloys, n.o.p	....	....	.....	15,667 cwt.	482,383	
Ferro-silicon, containing more than 15% silicon	....	....	.....	21 cwt.	450	
Ferro-silicon, containing not more than 15% silicon	....	....	.....	7,758 cwt.	23,436	
Nickel, nickel silver, and German silver, in bars, rods, strips, sheets or plates	541,258 lbs.	136,081	.....	557,579 lbs.	190,245	.....
Nickel, nickel silver, and German silver, in ingots or blocks, n.o.p	73,836 lbs.	21,802	.....	86,079 lbs.	35,218	.....
Nickel, German, and Nevada silver, manufactures of, not plated	....	80,824	.....	....	234,928	.....
Phosphor tin and phosphor bronze, in blocks, bars, plates, sheets, and wire	....	24,488	.....	....	46,769	.....

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*The same item may appear under two entries owing to differences in tariff rates.
†One entry only.

AND ALLIED PRODUCTS.*

2.

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
			2,104,274				7,571
547,183 lbs.	21,572	9,110 lbs.	1,936			32,643 lbs.	6,936
		57,068 lbs.	231,990				
		21,624 tons	2,620,923			34 tons	1,139

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Alloys and alloy products—Continued:						
Stereotypes, electrotypes, and celluloids of newspaper columns in any language other than English and French, and of books, and bases and matrices and copper shells for the same, whether composed wholly or in part of metal or celluloid	754,556sq.in	15,427	......	828,307sq.in	26,985	
Stereotypes, electrotypes and celluloids for almanacs, calendars, illustrated pamphlets, newspaper or other advertisements, n.o.p., and matrices or copper shells for such stereotypes, electrotypes, and celluloids	1,158,788sq.in	65,962	......	1,277,825sq.in	54,019	
Stereotypes, electrotypes, celluloids, and bases for the same composed wholly or partly of metal or celluloid, n.o.p., and copper shells for such stereotypes, electrotypes, and celluloids	476,741sq.in	24,469	......	231,787sq.in	14,575	
Stereotypes, electrotypes, and celluloids, matrices for	574,512sq.in	6,405	......	2,217,159sq.in	11,763	......
Type for printing, including chases, quoins, and slugs of all kinds	....	171,142	......	....	64,768	......
Type metal in blocks, bars, plates, and sheets	....	1,314	......	....	85	......
Yellow metal, in bars, bolts, and sheets, for use in the construction or repair of vessels	972 cwt.	14,799	......	248 cwt.	7,598	......
Ashes pot and pearl, less than 25 lbs.	19,994 lbs.	1,078	5·4	663 lbs.	582	87·8
" " " 25 lbs. and more	219,983 lbs.	9,210	4·2	12,611 lbs.	6,690	53·0
" other	....	....	......	....	....	......
Asphalt, not solid	....	†33,357	......	....	15,725	......
" or asphaltum, solid	912,669 cwt.	744,318	81·5	414,552 cwt.	424,997	$1.03
Asphaltum oil	....	24,335	......	....	33,984	......
Baking powders	647,747 lbs.	179,796	......	6,393 lbs.	1,389	......
Balsam	....	....	......	....	....	......
Blacking, shoe and shoemakers' ink, shoe, harness, and leather dressing, n.o.p.	....	121,652	......	....	220,627	......
Blueing, laundry	....	49,692	......	....	87,039	......
Bones, crude	41,713 cwt.	50,528	$1.21	2,183 cwt.	10,548	$4.83
Candles, paraffine wax	301,459 lbs.	36,091	......	281,831 lbs.	58,032	
" other, n.o.p.	476,633 lbs.	56,901	......	461,353 lbs.	104,176	
Cellulose, nitro-:						
Celluloid, moulded into blanks	....	6,563	......	....	580	......
Celluloid, xylonite, or xyolite, rolled, moulded, or pressed	....	147,491	......	....	671,405	......
Celluloid, manufactures of, n.o.p.	....	74,269	......	....	218,193	......
Collodion for use in films, when imported by photo engravers and manufacturers of copper rollers	523 gals.	‡809	$1.55	493 gals.	1,165	$2.36
Pyroxylin and wood naphtha, preparations of, for coating imitation leather, and for the manufacture of leather belting	....	13,649	......	....	50,173	......
Cellulose, pulps:						
Fibre and manufactures of, n.o.p.	....	133,590	......	....	271,607	......
Soda pulps	....	....	......	1,745,540 lbs.	80,624	4·6
Sulphite pulp, bleached	....	....	......	299,257 lbs.	13,000	4·3
Sulphite pulp, unbleached	....	227,460	......	18,875,030 lbs.	377,513	2·0
Wood pulp mechanically or chemically prepared, n.o.p.	....	....	......	2,769,631 lbs.	52,829	1·9
Wood pulp, chemically prepared	....	....	......	....	....	......
Wood pulp, mechanically ground	....	....	......	....	....	......
Chalk, prepared	....	44,007	......	....	78,160	......
Charcoal	....	72,022	......	....	124,924	......

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
Electrotypes and Stereotypes	6,768	....	8,420	....	3,125	....	21,349
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
579 bbl.	25,586	135 bbl.	25,485	....	....	....	....
....	36,371	....	39,128	....	†105	....	
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
64,733 lbs.	13,112	267,682 lbs.	44,048	†550 lbs.	†136	1,000 lbs.	95
....	12,330	....	7,370	....	†91	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
49,789 cwt.	70,788	115,860 cwt.	210,601	‡6,778 cwt.	‡7,325	....	....
1,222 lbs.	190	181,324 lbs.	24,123	640 lbs.	145	6,299 lbs.	881
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
1,154,443 cwt.	2,203,820	8,332,930 cwt.	30,226,856	....	....	4,300 cwt	21,662
4,863,152 cwt.	3,452,404	3,508,726 cwt.	4,479,915	....	....	....	....
....	....	....	....	....	....	....	....
....	7,547	....	9,522	....	....	....	100

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Chemicals, including dyes:	(Additional chemicals are included in trade groups; See Fertilizers,					
Acetone and amyl acetate	.....	8,217	.....	.....	3,420	.....
Acids:—						
Acetic and pyroligneous, crude, of any strength, not exceeding 30%	18,612 gals.	2,494	.....	4,029 gals.	1,620	.....
Acetic and pyroligneous, above proof strength	2,507 gals.	2,638	.....	3,720 gals.	21,524	.....
Acetic, and pyroligneous, n.o.p., not exceeding proof strength	1,162 gals.	887	.....	43 gals.	20	.....
Boracic, in packages of 25 lbs. and over—	377,719 lbs.	21,554	5·7	354,852 lbs.	48,813	13·8
Hydrochloric	910,934 lbs.	10,286	1·13	95,618 lbs.	7,558	7·9
Hydro-fluo-silicic	680,282 lbs.	30,212	4·4	1,656 lbs.	148	8·9
Nitric	190,449 lbs.	10,379	5·4	128,722 lbs.	18,644	14·5
Oxalic	316,364 lbs.	16,805	5·3	107,246 lbs.	39,868	37·2
Stearic	324,270 lbs.	28,913	8·9	173,559 lbs.	30,202	22·6
Sulphuric	2,056,303 lbs.	16,567	·81	12,185,903 lbs.	206,691	1·7
Tannic	25,450 lbs.	7,646	30·0	33,181 lbs.	23,429	70·6
Tartaric crystals	311,246 lbs.	70,734	22·7	329,558 lbs.	239,501	72·7
Other, n.o.p	846,102 lbs.	108,992	.....	1,678,123 lbs.	327,007	.....
Alcohols:—						
Amyl alcohol or fusel oil or any substance known as potato spirit or potato oil	62 gals.	65	$1·04	58 gals.	398	$6·86
Ethyl alcohol or the substance known as alcohol, hydrated oxide of ethyl, or spirits of wine	869 gals.	360	41·4	5,035 gals.	5,245	$1·04
Ethyl alcohol, when imported by the Department of Inland Revenue, or by a person licensed by the Minister of Inland Revenue, to be denatured for use in the arts and industries and for fuel, light and power	‡20,620 gals.	‡7,359	35·7	6,582 gals.	5,690	86·4
Methyl alcohol, wood alcohol, wood naphtha, pyroxylic spirits, or any substance known as wood spirits or methylated spirits	190 gals.	164	.....	184 gals.	256	.....
Wood alcohol	.....	.....	.....	.....	.....	.....
Aluminium acetate, crude (red liquor), prepared from pyroligneous acid and adapted for dyeing and calico printing	.....	379	.....	.....	28	.....
Aluminium chloride and chloralum	‡2,220 lbs.	‡435	....	152 lbs.	136	.....
Aluminium sulphate—						
Alum, in bulk, ground or unground, but not calcined (K & Na alums)	3,990,922 lbs.	32,454	.....	Included in next total		
Aluminium sulphate or alum cake	4,020,809 lbs.	23,283	.....	" "	"	
Alum in bulk, ground or unground, but not calcined; and aluminium sulphate, or alum cake	11,255,109 lbs.	104,582	.....	25,528,854 lbs.	460,840	.....
Ammonium chloride (sal ammoniac)	939,469 lbs.	45,348	4·8	693,855 lbs.	91,235	13·1
" nitrate	1,611,037 lbs.	96,649	6·0	738,055 lbs.	85,822	11·6
" sulphate	397,097 lbs.	12,578	3·2	140,153 lbs.	6,949	5·0
Aniline dyes, in packages of less than 1 lb. weight	2,094 lbs.	652	31·2	3,412 lbs.	2,948	86·4
Aniline and coal tar dyes, soluble in water, in bulk or packages of not less than 1 lb. weight, including alizarine and artificial alizarine	2,284,613 lbs.	497,164	.....	1,786,202 lbs.	2,025,697	.....
Aniline oil, crude	69,380 lbs.	6,862	9·9	288,756 lbs.	77,662	26·9
" salts	212,833 lbs.	18,826	8·8	8,882 lbs.	3,344	37·6
Antimony salts for dyeing	†970 lbs.	†75	.....	.....	.....	.....
" " viz.: tartar emetic, chloride, and lactate (antimonine)	32,541 lbs.	3,999	.....	36,647 lbs.	13,637	.....

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
Explosives, Paints, Tanning Materials, and other groups.)							
...	...	...	...	...	...	...	...
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...	...	...	...	...	...	...	...
†6,245,086 lbs.	†37,413	5,463,000 lbs.	75,857	...	...	...	...
...	...	...	...	...	...	...	...
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...	...	...	...	...	...	...	...
591,596 gals.	255,601	327,313 gals.	606,550	†40 gals.	†25	...	...
...	...	...	...	...	...	...	...
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...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	20,631,900 lbs.	1,231,524	...	...	...	...
...	...	...	...	...	...	...	...
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...	...	...	...	...	...	...	...

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Chemicals, including dyes—Continued:						
Arsenic sulphide	365,982 lbs.	13,515	3·7	219,175 lbs.	24,671	11·3
Arsenious oxide	34,212 lbs.	977	2·9	2,231 lbs.	678	30·4
Barium peroxide, non-alcoholic, imported by manufacturers of hydrogen peroxide	†66,162 lbs.	†4,529	.....	122,411 lbs.	31,424	.....
Bromides, crude	†1,401 lbs.	†368	.....	6 lbs.	10	$1·67
Bromine	217 lbs.	85	39·3	723 lbs.	988	$1·37
Calcium acetate	.....	.....	.....	.....	.....	.....
" carbide	.....	.....	.....	.....	.....	.....
" chloride and hypochlorite,* in packages of not less than 25 lbs	12,563,307 lbs.	117,579	.....	11,958,547 lbs.	174,362	.....
" chloride and hypochlorite,* in packages of less than 25 lbs	.....	.....	.....	178,423 lbs.	13,751	.....
" oxide (lime)	857,860 cwt.	210,579	24·5	103,799 cwt.	59,140	57·0
" phosphate, monobasic	1,888,277 lbs.	77,598	4·1	3,102,469 lbs.	307,891	9·9
" sulphate (See Gypsum.)						
Carbon bisulphide	.....	.....	.....	81,757 lbs.	6,047	7·4
" dioxide	.....	.....	.....	.....	1,732	.....
Cobalt oxide and cobalt salts	.....	.....	.....	.....	.....	.....
Cocaine	437 ozs.	693	$ 1·59	12,333 ozs.	142,123	$11·52
Copper acetate, basic, dry	1,923 lbs.	332	17·3	3,509 lbs.	1,571	44·8
" sulphate (blue vitriol)	1,975,597 lbs.	95,413	4·8	2,526,718 lbs.	220,607	8·7
Cyanamid (See Fertilizers.)						
Disinfectants and other liquid non-alcoholic preparations for dipping or spraying, n.o.p	.....	71,062	.....	.....	153,287	.....
Dyestuffs	.....	.....	.....	.....	.....	.....
Ether, nitrous, sweet spirits of nitre, and aromatic spirits of ammonia	819 gals.	3,291	.....	316 gals.	3,348	.....
Ether, sulphuric, chloroform, and solutions of hydrogen peroxide	.....	47,761	.....	.....	135,160	.....
Glycerine, crude, imported by refiners	1,073,929 lbs.	146,401	13·6	.....	.....	.....
" imported for explosives	5,061,876 lbs.	895,016	17·7	2,010,398 lbs.	1,179,313	58·7
" n.o.p	156,553 lbs.	29,728	19	21,157 lbs.	4,843	22·9
Indigo	56,518 lbs.	11,508	20·4	.....	.....	.....
" , paste and extract of	101,229 lbs.	16,103	.....	145,445 lbs.	81,953	.....
Iodine, crude	10,645 lbs.	19,673	$1·85	8,481 lbs.	28,332	$3·34
Iron acetate or nitrate liquor, for dyeing and calico printing	.....	3,558	.....	.....	7,767	.....
" sulphate (copperas)	711,195 lbs.	5,177	0·73	776,611 lbs.	15,673	2·0
Lead acetate and nitrate, not ground	580,689 lbs.	32,123	.....	123,031 lbs.	18,291	.....
Magnesium oxide (magnesia)	509,235 lbs.	18,527	3·6	140,527 lbs.	16,606	11·8
Manganese oxide	3,228,492 lbs.	32,375	1·0	3,629,307 lbs.	94,222	2·6
Medicinal, chemical, and pharmaceutical preparations, including proprietary preparations (dry)	.....	1,054,459	.....	.....	1,434,016	.....
Medicinal, chemical and pharmaceutical preparations, including proprietary preparations (all other) non-alcoholic	.....	89,709	.....	.....	92,153	.....
Medicinal, chemical, and pharmaceutical preparations, including proprietary preparations (all other)	.....	139,497	.....	.....	217,717	.....
Morphine	2,321 ozs.	4,965	$2·14	30,087 ozs.	179,195	$5·95
Nicotine sulphate	.....	.....	.....	18,428 lbs.	14,322	77·7
Nitraniline, Para	35,320 lbs.	5,227	14·8	87,298 lbs.	57,661	66·1
Phosphorus	16,454 lbs.	5,141	31·2	53,606 lbs.	26,226	48·8
Platinum and black oxide of copper for use in the manufacture of chlorate and colours	†1 lb.	†608	.....	.....	74	.....
Potassium bicarbonate and carbonate (See Ashes)	26,803 lbs.	508	.....	3,987 lbs.	3,951	.....

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*Chiefly "Bleaching Powder."
†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
....	....	....	....	....	....	....	....
3,603,662 lbs.	102,679	5,462,500 lbs.	358,145	†576 lbs.	†15	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
13,880,934 lbs.	282,045	4,328,600 lbs.	203,084	....	....	....	....
6,237,352 lbs.	186,703	118,376,200 lbs.	4,720,783	‡416 lbs.	‡18	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	33,649	155,877 cwt.	67,052	....	....	....	....
Includes sodium	phosphate.						
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	640,303 lbs.	908,659	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	8,688	....	17,225	....	7,745	....	20,995
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....
589,677 lbs.	80,605	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

TABLE

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Chemicals, including dyes—Continued:						
Potassium bichromate	334,176 lbs.	22,458	6·7	21,143 lbs.	10,798	51·1
“ bitartrate (cream of tartar), in crystals or argols	1,583,227 lbs.	282,702	.....	473,703 lbs.	261,653	.....
“ chlorate, not further prepared than ground	829,758 lbs.	61,412	7·4	22,591 lbs.	9,848	43·6
“ chloride and sulphate	10,736,284 lbs.	195,426	.....	449,657 lbs.	65,423	.....
“ cyanide, sodium cyanide, cyanogen or compounds of bromine and potassium for reducing metals in mining operations	1,092,836 lbs.	165,005	.....	1,591,437 lbs.	424,128	.....
“ ferro- and ferricyanides	174,128 lbs.	17,990	.....	9,242 lbs.	13,020	.....
“ hydroxide, in packages of not less than 25 lbs. each	523,316 lbs.	26,967	5·2	22,855 lbs.	16,714	73·1
“ hydroxide, in packages of less than 25 lbs. each	34,561 lbs.	1,803	5·2	819 lbs.	954	$1·16
“ nitrate (saltpetre)	1,953,437 lbs.	93,975	4·8	883,761 lbs.	161,962	18·3
“ sulphate (See Potassium chloride, etc.)						
Quinine salts	155,812 ozs.	27,046	17·4	184,991 ozs.	160,477	86·7
Radio-active salts	.....	2,027	.....	.....	528	.....
Sodium arsenate, biarsenate, and stannate	35,425 lbs.	1,411	.....	857 lbs.	146	.....
“ bicarbonate	6,265,076 lbs.	59,338	0·95	7,100,060 lbs.	150,772	2·1
“ bichromate	526,428 lbs.	28,667	5·4	1,134,486 lbs.	218,702	19·3
“ bisulphite	850,848 lbs.	9,707	1·2	10,658,446 lbs.	47,587	0·45
“ borate (borax), in bulk of not less than 25 lbs.	3,004,653 lbs.	112,166	3·7	2,311,765 lbs.	181,092	7·8
“ carbonate (sal soda)	9,656,176 lbs.	59,861	0·62	10,671,902 lbs.	171,346	1·6
“ “ crude (soda ash or barilla)	56,246,241 lbs.	432,598	0·77	86,260,061 lbs.	1,915,923	2·2
“ chlorate	608,318 lbs.	31,481	5·2	582 lbs.	144	24·7
“ chloride, imported for the United Kingdom, or any British possession; or imported for the use of the sea or gulf fisheries	2,201,758 cwt.	370,045	16·8	1,899,062 cwt.	755,301	39·8
“ chloride, in bulk, n.o.p.	415,412 cwt.	64,067	15·4	1,096,780 cwt.	315,148	28·7
“ “ n.o.p., in bags, barrels, and other coverings	166,025 cwt.	70,093	42·2	266,457 cwt.	152,110	57·1
“ cyanide (See Potassium cyanide, etc.)						
“ ferro- and ferricyanides, and sulphite	309,702 lbs.	11,231	.....	1,013,801 lbs.	165,271	.....
“ hydroxide, in packages of 25 lbs. and over	14,853,707 lbs.	270,409	1·8	11,379,483 lbs.	522,124	4·6
“ hydroxide, when in packages less than 25 lbs. each	148,484 lbs.	8,281	5·6	93,912 lbs.	9,260	9·9
“ hyposulphite	.....	4,886	.....	.....	9,734	.....
“ “ imported by tanners	538,800 lbs.	6,487	1·2	360,200 lbs.	8,590	2·4
“ nitrate (cubic nitre)	75,151,179 lbs.	1,372,578	1·8	84,033,351 lbs.	3,294,369	3·9
“ nitrite	326,220 lbs.	8,871	2·7	18,615 lbs.	5,272	28·3
“ peroxide	25,634 lbs.	8,063	31·5	60,339 lbs.	19,739	32·7
“ phosphate (See Calcium phosphate monobasic.)						
“ silicate, crystals or solution	11,674,517 lbs.	74,245	.....	25,470,115 lbs.	287,361	.....
“ stannate (See Sodium arsenate, etc.)						
“ sulphate (Glauber's salts)	1,448,510 lbs.	7,000	0·48	551,213 lbs.	10,080	1·8
“ sulphate, crude (salt cake)	21,031,292 lbs.	112,112	0·53	67,617,762 lbs.	626,446	0·93
“ sulphide	1,234,967 lbs.	18,727	1·5	2,062,938 lbs.	88,459	4·3
“ sulphite (See Sodium ferro- and ferricyanide, etc.)						
Sulphur, crude, refined and sublimed	59,156,183 lbs.	615,297	.....	194,634,613 lbs.	2,042,172	.....
Thorium nitrate	.....	.....	.....	.....	152	.....

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
350,950 lbs.	3,636	1,594,400 lbs.	17,082	5,611,958 lbs.	19,993	11,778,900 lbs.	105,365
....	....	....	....	....	....	....	....
....	47,537	....	5,865	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Chemicals, including dyes—Continued:						
Thorium nitrate and cerium nitrate on cotton thread imported by manufacturers of incandescent gas mantles, or of stockings for such mantles	......	5,610	......	......	14,998	......
Tin bichloride	25,164 lbs.	3,703	14·7	124 lbs.	106	85·5
Tin chloride (stannous chloride)	......	6,337	......	......	9,253	......
Zinc chloride and sulphate	673,652 lbs.	20,762	......	428,179 lbs.	32,049	......
Other drugs, dyes, chemicals and medicines	......	1,844,768	......	......	6,604,467	......
Clay, China, ground or unground	414,008 cwt.	142,716	......	217,219 cwt.	127,227	......
" pipe, ground or unground	......	833	......	......	1,148	......
Dextrine, dry	2,252,991 lbs.	78,625	3·5	1,694,894 lbs.	134,771	7·95
" British gum, dry, sizing cream, and enamel sizing	1,580,500 lbs.	58,085	......	907,110 lbs.	70,271	......
Explosives:						
Blasting and mining powder	752,016 lbs.	65,302	......	3,125 lbs.	276	......
Fireworks, firecrackers, and torpedoes, all kinds	......	46,335	......	......	32,002	......
Fuses, non-metallic	......	127,487	......	......	141,762	......
Giant powder, nitro, nitro-glycerine, and other explosives, n.o.p.	1,101,611 lbs.	175,632	......	224,769 lbs.	148,255	......
Gun, rifle, sporting, cannon, musket, and cannister powder	184,834 lbs.	115,986	......	62,790 lbs.	62,244	......
Gun, rifle, and pistol cartridges, or other ammunition, n.o.p.	......	846,197	......	......	239,943	......
Nitrate compounds, adapted for use in the manufacture of explosives	†4,800 lbs.	†300	......	200 lbs.	200	......
Toluol—binitro-, trinitro-, and ammonium perchlorate imported by explosive manufacturers	†591,941 lbs.	†63,884	......	......	......	......
Explosives and fulminates, n.o.p.	......	......	......	......	......	......
Fertilizers:	......	......	......	......	......	......
Bone dust, charred bone, and bone ash	75,484 cwt.	129,301	......	40,498 cwt.	78,519	......
Cyanamid	......	......	......	......	......	......
Fertilizers compounded or manufactured	......	529,143	......	......	984,808	......
Fertilizers, unmanufactured, n.o.p.	......	1,710	......	......	105,361	......
Guano and other animal manures	49,839 cwt.	53,040	......	70,554 cwt.	170,350	......
Kainite and other crude German potash salts for fertilizers	339,333 lbs.	3,096	......	176,000 lbs.	8,852	......
Manures, vegetable	930 cwt.	422	45·4	4,457 cwt.	13,980	$3·14
Phosphate rock	......	27,900	......	......	87,524	......
Slag, blast furnace	......	92,866	......	......	18,666	......
Glass and Glassware:	......	......	......	......	......	......
Balls, and cut, pressed or moulded crystal glass tableware, blown glass tableware, and other cut glass ware	......	630,629	......	......	439,536	......
Carboys or demijohns, bottles, decanters, flasks, jars, and phials	......	539,432	......	......	715,769	......
Common and colourless window sheet	49,848,522 sq. ft.	1,363,326	......	17,785,624 sq. ft.	1,514,377	......
Dry plate sheet, cut to size, imported by manufacturers	......	13,535	......	......	63,229	......
German looking glass (thin plate), unsilvered or for silvering	......	513	......	......	......	......
Dry plates, photographic	......	60,426	......	......	22,728	......
Lamps, incandescent—bulbs and tubing for, also gas light mantle stockings	......	133,016	......	......	199,245	......
Lamp chimneys, glass shades or globes	......	377,867	......	......	184,054	......
Ornamental figured and enamelled coloured sheet and memorial or other ornamental window sheet, n.o.p.	......	44,820	......	......	14,599	......

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† One entry only.
Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	908,190	...	6,036,522	...	351,567	...	715,657
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	16,272	...	213,432,531	...	4,515	...	228,177
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	164,349	...	37,506,294	...	46,275	...	502,219
...	1,720,824	...	...	...	5,216	...	...
...	...	...	...	...	...	...	...
...	...	1,037,569 cwt.	2,857,446	...	...	...	...
...	...	...	232,067	...	...	...	2,211
...	...	...	669,712	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	26,120	...	36,145	...	14,491	...	11,822
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
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...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911-14.			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Glass and glassware—Continued:						
Painted or vitrified, chipped, figured, enamelled, and obscured white	......	30,605	......	......	2,949	......
Plain, coloured, opaque, stained or tinted, or muffled sheet	......	114,444	......	......	21,884	......
Plate glass, not bevelled, in sheets or panes, not exceeding 7 sq. ft. each, n.o.p	1,756,053 sq.ft.	296,253	......	954,310 sq. ft.	409,618	......
Plate glass, not bevelled, in sheets or panes exceeding 7 sq. ft. each, and not exceeding 25 sq. ft. each, n.o.p	1,410,826 sq.ft.	264,300	......	278,671 sq. ft.	166,731	......
Plate glass, not bevelled, n.o.p	1,919,480 sq.ft.	430,381	......	648,399 sq. ft.	406,523	......
Plate glass, bevelled, n.o.p	12,426 sq. ft.	2,500	......	8,075 sq. ft.	6,796	......
Plates or discs, optical	......	†11,520	......	......	40,374	......
Sheet and bent plate, n.o.p	......	114,861	......	......	138,486	......
Silvered	......	146,217	......	......	164,239	......
Spectacles, eye-glasses, and lenses	......	37,755	......	......	110,765	......
Stained or ornamental windows	......	22,058	......	......	7,319	......
Other articles, unfinished, not plate or sheet, and manufactures of, n.o.p	......	436,917	......	......	934,935	......
Glucose or grape sugar, glucose syrup and corn syrup, or any syrups containing any admixture thereof	5,401,891 lbs.	125,070	......	2,584,336 lbs.	151,866	......
Glues, including gelatine:						
Fish offal or refuse	......	16,061	......	......	34,463	......
Gelatine and isinglass	600,704 lbs.	143,930	......	679,219 lbs.	411,466	......
Glue, liquid	......	63,496	......	......	142,291	......
Glue, powderd or sheet	3,109,905 lbs.	240,894	......	906,202 lbs.	152,900	......
Glue stock	......	......	......	......	......	......
Mucilage and adhesive paste	......	33,917	......	......	60,013	......
Grease:						
Axle grease	4,240,970 lbs.	206,007	4·9	5,150,420 lbs.	415,368	8·1
Foots (cotton seed or olive refuse)	632,800 lbs.	27,477	......	44,300 lbs.	6,496	......
Grease and degras for stuffing or dressing leather	2,452,026 lbs.	110,933	......	1,945,850 lbs.	255,034	......
Grease and grease scraps	......	......	......	......	......	......
Grease, rough, the refuse of animal fat, for the manufacture of soap and oils only	12,869,673 lbs.	831,496	6·5	17,253,689 lbs.	1,875,751 lbs.	10·9
Gums and resins:						
Amber, Arabic, Australian, copal, damar, elemi, kaurie, mastic, sandarac, senegal, tragacanth, gedda, barberry, pontianac and lac, crude, seed, button, stick, and shell	......	459,091	......	......	1,144,257	......
Burgundy pitch	152,297 lbs.	7,316	4·8	65,737 lbs.	3,691	5·6
Camphor	50,024 lbs.	18,265	36·5	69,925 lbs.	91,646	$1·31
Chicle or Sappato gum, crude	6,924,722 lbs.	2,200,349	31·8	1,967,521 lbs.	1,141,543	58
Chicle gum	......	......	......	......	......	......
Dragon's blood	875 lbs.	702	80·2	850 lbs.	1,184	$1·39
Opium, crude	4,857 lbs.	24,477	$5·04	34,263 lbs.	534,555	$15·60
Opium, powdered	314 lbs.	1,811	$5·76	123 lbs.	2,247	$18·27
Resin, 100 lbs. and over	271,748 cwt.	672,327	$2·48	337,099 cwt.	1,216,508	$3·61
Other gums, n.o.p	12,733 lbs.	3,010	......	35,857 lbs.	7,634	......
Gypsum, crude	3,305 tons	16,195	$4·90	114 tons	2,071	$18·17
" ground, not calcined	70,873 cwt.	11,735	16·6	2,418 cwt.	3,152	$1·30
" calcined (Plaster of Paris), and prepared wall plaster	526,426 cwt.	187,935	......	21,741 cwt.	18,607	......
Horns and hoofs	......	......	......	......	......	......
Ink, printing	......	102,939	......	......	157,571	......
" writing	......	52,725	......	......	50,337	......

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
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....	....	....	....	....	....	....	....
113,143 lbs.	3,955	....	....	†17,142	†397	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	21,537	....	93,147	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
3,514,369 lbs.	99,315	3,788,300 lbs.	194,695	28,307 lbs.	993	1,709,000 cwt.	153,738
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
†32,710 lbs.	†16,806	759,817 lbs.	699,333	5,415,386 lbs.	2,508,069	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
377,616 tons	447,591	69,034 tons	82,047	....	....	....	....
....	8,643	....	129,795	....	‡593	....	....
....	....	....	....	....	....	....	....
....	21,222	....	34,949	....	†206	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Oils—Animal:						
Cod oil	111,942 gals.	55,042	49·2	170,114 gals.	275,478	$1·62
Cod liver oil	23,456 gals.	16,715	71·3	288 gals.	952	$3·31
Seal oil	42,932 gals.	22,842	50·9	162,374 gals.	222,119	$1·41
Whale and spermaceti oil	7,997 gals.	3,643	......	1,642 gals.	3,259	......
Other fish oil	62,912 gals.	25,478	......	34,036 gals.	40,143	......
Lard oil	63,396 gals.	26,024	41·0	25,546 gals.	35,866	$1·40
Neatsfoot oil	16,950 gals.	12,182	71·9	3,690 gals.	5,077	$1·38
Other animal oil, n.o.p	18,887 gals.	9,595	......	238,777 gals.	375,156	.....
Oils, creosote	....	....	......	....	....	......
Oils, Mineral:						
Aniline (See Chemicals.)						
Asphaltum (See Asphaltum oil.)						
Carbolic or heavy oil	844,882 gals.	112,467	13·3	130,878 gals.	33,712	25·8
Coal and kerosene, crude	....	....	......	....	....	......
" " distilled, purified or refined	16,363,699 gals.	1,040,692	......	3,901,449 gals.	433,796	......
Gasoline under ·725 specific gravity at 60° temperature	31,332,421 gals.	4,091,455	......	2,825,812 gals.	739,449	......
Gasoline and naphtha	....	....	......	....	....	......
Illuminating oils, composed wholly or in part of the products of petroleum, coal, shale or lignite, costing more than 30 cents per gallon	190,754 gals.	74,457	......	228,433 gals.	175,779	......
Lubricating oils, composed wholly or in part of petroleum, and costing less than 25 cents per gallon	5,276,766 gals.	687,756	......	2,339,785 gals.	463,888	......
Lubricating oils, n.o.p	1,089,541 gals.	343,504	......	3,466,108 gals.	1,492,374	......
Petroleum, crude, fuel and gas oils (·8235 specific gravity or heavier) at 60° temperature	131,149,637 gals.	4,265,324	......	139,635,201 gals.	7,923,246	......
Petroleum, crude, gas oils other than naphtha, benzine, and gasoline, lighter than ·8235 but not less than ·775 specific gravity at 60°	23,034 gals.	2,301	......	47,135 gals.	5,824	......
Petroleum, crude, in its natural state, ·7900 specific gravity or heavier at 60°, imported by oil refiners	....	....	......	260,819,944 gals.	14,666,967	......
Petroleum imported by miners or mining companies	....	....	......	4,710 gals.	1,922	......
Petroleum products, n.o.p	4,236,210 gals.	468,607	......	29,882,932 gals.	5,574,659	......
Vaseline and similar products	....	23,243	......	....	173,798	......
Oils—Vegetable:						
Castor	218,669 gals.	65,690	30·0	56,079 gals.	135,006	$2·41
Cocoa butter	†1,119,602 lbs.	318,651	28·5	4,032,783 lbs.	1,242,185	30·8
Cocoanut, palm, and palm kernel, not edible, peanut and soya bean for manufacture of soap	398,309 gals.	342,875	......	2,390,107 gals.	3,089,637	......
Cocoanut, n.o.p	†29,548 gals.	†33,539	......	28,950 gals.	45,123	......
Cotton seed, crude, for the manufacture of refined cotton seed oil	‡2,548,306 gals.	‡1,210,494	......	4,596,811 gals.	7,403,369	......
Cotton seed, refined, edible, and peanut for canning fish	40,362 gals.	23,511	......	86,944 gals.	179,758	......
Cotton seed, n.o.p	999,697 gals.	473,774	47·4	169,650 gals.	287,419	$1·69
Flax seed or linseed, raw or boiled	2,072,433 lbs.	190,945	......	70,299 lbs.	12,657	......
Olive, for manufacturing soap or tobacco or for canning fish	17,395 gals.	21,846	$1·26	2,896 gals.	11,824	$4·08
Olive, n.o.p	177,219 gals.	246,014	$1·39	17,533 gals.	52,664	$3·00
Palm, bleached, and Shea butter	454,960 lbs.	58,504	......	1,654 lbs.	546	......
Rosin and Chinawood	....	234,897	......	....	806,496	......
Sesame seed	2,110 gals.	1,676	70·4	996 gals.	1,903	$1·91
Vegetable, n.o.p	378,873 gals.	169,572	......	143,375 gals.	236,512	......
Oils, other, n.o.p., including essential oils	....	474,116	......	....	1,000,517	......

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
218,029 gals.	73,428	297,305 gals.	399,666	†11,338 gals.	†3,642	10,826 gals.	12,957
....	....	....	....	....	....	....	....
13,638 gals.	5,273	83,523 gals.	121,802	....	....	8,945 gals.	9,842
1,567,874 gals.	604,826	43,352 gals.	66,144	....	....	....	....
93,453 gals.	33,875	120,060 gals.	124,476	†44 gals.	†11	....	....
....	....	....	....	†20 gals.	†5	....	....
188,720 gals.	196,181	83,466 gals.	147,749	....	....	....	....
1,115,870gal.	63,523	1.744,858 gals.	203,780	12,307 gals.	‡3,248	....	....
....	....	....	....	....	....	....	....
‡11,075 gals.	‡2,172	221,336 gals.	24,011	†305 gals.	†67	54,782,951gals.	2,683,041
21,456 gals.	3,333	2,742,047 gals.	273,633	106,352 gals.	9,488	45,062 gals.	3,978
....	....	....	....	....	....	....	....
24,325 gals.	4,786	361,081 gals.	106,464	96,163 gals.	18,989	346,592 gals.	75,158
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....	....	....	....	....	....	....	....
....	....	743,574 gals.	857,334	....	....	230,782 gals.	372,506
460,277 gals.	120,868	1,081,389 gals.	250,785	57,305 gals.	39,499	59,815 gals.	51,128

TRADE STATISTICS OF CHEMICALS

TABLE

	Imports					
	Average 3 Fiscal Years 1911-14			1918-19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Paints, Pigments, Colours and Varnishes:						
Blanc fixe and satin white	3,179,149 lbs.	34,936	......	8,577,631 lbs.	114,554	......
Brocade and bronze powders	......	25,910	......	......	39,330	......
Gold liquid paint	......	11,401	......	......	6,765	......
Lamp black, bone black, carbon black, and ivory black	2,416,046 lbs.	89,651	......	3,217,286 lbs.	314,362	......
Lead, red, dry and orange mineral (paint)	1,139,660 lbs.	51,976		1,074,249 lbs.	101,243	......
" " " " " (colours)	1,084,207 lbs.	44,227				
" white, dry	1,626,294 lbs.	82,306	5·1	300,772 lbs.	25,420	8·5
" " ground in oil	927,750 lbs.	48,482	5·2	48,612 lbs.	5,160	10·6
Liquid fillers, anti-corrosive and anti-fouling paints, and ground and liquid paints, n.o.p	5,112,044 lbs.	448,734	......	3,472,288 lbs.	423,285	......
Litharge	18,036 cwt.	78,025	$4.33	18,418 cwt.	163,156	$8.86
Ochres, ochrey earths, siennas and umbers	3,371,887 lbs.	39,805	......	3,171,616 lbs.	71,979	......
Oxide of cobalt, copper, and tin, n.o.p., (metallic colours)	347,898 lbs.	113,074	......	125,514 lbs.	65,203	......
Oxides, fire proofs, rough stuffs, fillers, and colours, dry, n.o.p	9,646,644 lbs.	302,668	......	4,999,708 lbs.	445,738	......
Paints and colours, ground in spirits, and all spirit varnishes and lacquers	4,355 gals.	10,949	......	13,910 gals.	41,193	......
Paris green, dry	984,277 lbs.	144,291	14·7	73,622 lbs.	32,224	43·8
Putty	466,431 lbs.	10,199	2·2	341,777 lbs.	14,745	4·3
Ultramarine blue, dry or in pulp	458,703 lbs.	28,922	......	398,269 lbs.	86,610	......
Varnish, lacquers, japans, japan dryers, liquid dryers, and oil finish, n.o.p	96,180 gals.	175,767	......	39,537 gals.	78,030	......
Whiting, gilders' whiting, and Paris white	278,910 cwt.	107,444		197,298 cwt.	180,721	......
Zinc white, dry, (colours)	1,293,247 lbs.	33,409	2·6	16,650,072 lbs.	1,393,513	......
" in vehicle	9,614,011 lbs.	402,913	4·2			
Mineral pigment, iron oxides, ochres, etc.	......	......	......	......	......	......
Paints and varnishes of all kinds	......	......	......	......	......	......
Pitch, bone, crude	......	3,367	......	......	3,223	......
" coal and pine (See Tar.)						
Polish or composition, knife and other, n.o.p	......	194,586	......	......	273,381	......
Rubber and rubber products:						
Balata, crude, unmanufactured	†208 lbs.	†172	82·7	1,110 lbs.	1,071	96·5
Belting	......	98,510	......	......	188,299	......
Boots and shoes	......	101,089	......	......	194,576	......
Clothing, and clothing made water-proof with India-rubber	......	1,323,925	......	......	144,855	......
Elastic, round or flat, including garter elastic	......	175,343	......	......	252,895	......
Fillets of cotton and rubber not exceeding 7" wide, imported by card clothing manufacturers	......	‡283	......	......	2,877	......
Rubber, recovered	......	......	......	3,038,586 lbs.	509,997	......
" substitute	......	......	......	1,473,386 lbs.	178,544	......
Hard rubber, in sheets, but not further manufactured, also hard rubber in strips or rods but not further manufactured, imported for use in Canadian manufactures	5,245,721 lbs.	853,811	......	31,683 lbs.	25,707	......
Hard rubber, unfinished, in tubes for fountain pens	......	7,460	......	......	30,983	......
Hose, including cotton or linen lined with rubber	......	131,079	......	......	135,145	......
Mats and matting	......	90,853	......	......	4,828	......
Packing			......		119,296	......
Rubber and gutta-percha, crude caoutchouc or India-rubber unmanufactured	4,849,097 lbs.	4,205,456	......	19,227,232 lbs.	7,794,260	......

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†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911–14		1918–19		1911–14		1918–19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
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......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
4,773,980 lbs.	27,298	1,861,700 lbs.	23,666	......	......	......	......
......	111,945	......	1,776,359	......	13,399	......	89,876
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	23,850	......	14,332	......	3,304	......	5,751
......	142,590	......	2,058,715	......	1,857	......	3,829
......	3,883	......	13,784	......	254	......	24,777
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	8,627	......	195,556	......	893	......	6,481
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......
......	......	......	......	......	......	......	......

	Imports					
	Average 3 Fiscal Years 1911–14			1918–19		
	Quantity	Value	Unit price	Quantity	Value	Unit price
		$	c.		$	c.
Rubber and rubber products—continued:						
Rubber thread, not covered	14,449 lbs.	25,688	.....	44,150 lbs.	65,156	.....
Tires of rubber for vehicles of all kinds	.....	1,320,762	.....	.....	1,045,140	.....
Waste or junk	1,844,688 lbs.	223,440	.....	3,392,417 lbs.	337,358	.....
Other manufactures of India-rubber and gutta-percha, n.o.p., and rubber cement	.....	1,003,182	.....	.....	1,287,601	.....
Soap:	.....	.....	.....	.....	.....	.....
Castile	2,968,526 lbs.	178,239	6·0	91,141 lbs.	17,711	19·4
Common or laundry	6,567,109 lbs.	365,148	.....	4,765,079 lbs.	444,241	.....
" soft, and liquid	402.468 lbs.	16,460	.....	134,636 lbs.	11,556	.....
Harness	12,115 lbs.	1,048	8·7	1,645 lbs.	338	20·5
Pearline and other soap powders	2,398,823 lbs.	123,581	.....	577,784 lbs.	44,740	.....
Toilet	.....	390,412	.....	.....	594,516	.....
Whale oil	57,378 lbs.	1,985	3·5	16,351 lbs.	1,549	9·5
Other soap, n.o.p., including pumice, silver and mineral soaps, sapolio, and like articles	.....	182,889	.....	.....	153.217	.....
Starch	2,696,813 lbs.	106,015	.....	2,541,926 lbs.	142,902	.....
Tallow	311,462 lbs.	27,005	8·7	1,155,688 lbs.	161,983	14·0
Tanning materials:						
Camwood and sumac, and extracts of	692,050 lbs.	14,695	.....	296,770 lbs.	14,053	.....
Hemlock bark, extract of	.....	.....	.....	.....	.....	.....
Logwood, fustic, oak, oak bark, and quebracho, extracts of	31,625,546 lbs.	840,926	.....	36,721,785 lbs.	2,016,442	.....
Nut galls, and extracts thereof	15,258 lbs.	1,924	.....	8,791 lbs.	3,869	.....
Terra japonica, gambier or cutch	3,148,888 lbs.	108,086	.....	907,874 lbs.	94,201	.....
Tanning or dyeing articles in a crude state n.o.p.	8,524,597 lbs.	165,575	.....	1,766,304 lbs.	148,899	.....
Tar, coal and pine, crude, 15 gallons and over	2,848,824 gals.	120,103	.....	.....	.....	.....
Pitch, coal and pine	1,512,732 gals.	88,502	.....	.....	.....	.....
Tar, coal, crude, 15 gallons and over, and coal pitch	.....	.....	.....	2,035,249 gals.	117,033	.....
Tar, pine, crude, 15 gallons and over, and pine pitch	.....	.....	.....	167,426 gals.	57,430	.....
Turpentine, raw or crude	74,538 lbs.	5,125	6·9	59,451 lbs.	4,284	7·2
Turpentine, spirits of	1,043,909 gals.	561,753	53·9	920,363 gals.	565,174	61·4
Vinegar above proof strength	15,623 gals.	3,168	.....	34,010 gals.	3,850	}
" proof strength and under	179,015 gals.	68,399	.....	48,171 gals.	17,729	
Wax:						
Bees	107,254 lbs.	33,439	31·2	246,109 lbs.	106,030	43·1
Paraffine (*See* also Candles)	1,471,671 lbs.	72,532	4·9	1,505,538 lbs.	190,941	12·7
Sealing	.....	18,858	.....	.....	16,526	.....
Vegetable and mineral, n.o.p.	783,755 lbs.	103,693	.....	634,875 lbs.	163,402	.....
Other	.....	72,060	.....	.....	51,582	.....

†One entry only.
‡Average where two entries only.

AND ALLIED PRODUCTS—*Continued.*

2—*Continued.*

Exports							
Domestic				Foreign			
1911-14		1918-19		1911-14		1918-19	
Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
	$		$		$		$
....	....	....	3,016,974	....	....	....	29,705
†5,061,919 lbs.	†413,953	1,436,560 lbs.	129,925	†63,982 lbs.	†8,924	....	....
....	92,758	....	200,304	....	262,376	....	1,853,514
516,891 lbs.	25,101	4,017,985 lbs.	560,025	9,436 lbs.	879	641 lbs.	140
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
107,603 lbs.	4,144	1,629,927 lbs.	148,224	‡2,243 lbs.	‡117	....	....
1,987,389 lbs.	130,292	1,379,153 lbs.	173,491	†700 lbs.	†68	169,830 lbs.	21,015
....	....	....	....	....	....	....	....
2,458 bbl.	27,993	....	12,965	†71 bbl.	†847	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
Tar	49,190	....	73,559	....	201	....	400
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
246 gals.	57	....	....	‡194 gals.	‡140	....	....
....	....	61,709 cwt.	620,960	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

CHAPTER III

AN ANALYSIS OF INDUSTRIAL CAPITAL IN CANADA[1]

The statistical tables which follow are published to show the place which British and foreign industries and extra-Canadian capital have attained in Canadian industrial development. The figures given, which are for the fiscal year ending March, 1919, and have been prepared by the Dominion Bureau of Statistics, are exceedingly conservative, for during the calendar years 1919 and 1920 the influx of extra-Canadian industries became more pronounced than ever before. For example, during these years in Toronto alone there were established 46 additional United States industries, as compared with 18 Canadian and 4 British (Report of Toronto Harbour Commission, 1920). When the compilation of 1920 figures is complete it may be found that the 34 per cent shown in the first table as the proportion held by United States capitalists in Canadian industries has increased to nearly 50 per cent, and that the British percentage has increased little or not at all.

It seems hardly necessary to comment on this situation. If foreign capital is attracted to such a remarkable extent by Canadian resources and industrial opportunities, surely they are worth more careful consideration by the United Kingdom. To put it briefly, unless the share held by foreign capital in the control and exploitation of the majority of Canadian manufactures and raw materials is to be predominant, British enterprise and Empire capital must assume their share of both the responsibility and the reward.

Table 3.—Stocks, Bonds and Other Securities Held by Incorporated and Joint Stock Companies Engaged in the Manufacturing Industries of Canada in 1918—Par Values

Nature of Security	Owned by 8,130,368 individual holders in			
	Canada	Great Britain	United States	Other Countries
	$	$	$	$
Stocks	790,512,678	136,686,566	494,706,199	13,838,322
Bonds	144,246,283	15,104,859	60,961,360	2,614,200
Other securities	10,684,697	1,966,400	275,618	768,800
Totals	945,443,658	153,757,825	555,943,177	17,221,322
Approximate percentage	56	9	34	1

N.B.—There are in addition to the securities above mentioned "Bearer Bonds," to the value of $25,984,786, and "Bearer Stocks" to the value of $3,395,000, the location of which cannot be definitely stated.

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[1] Prepared by the Dominion Bureau of Statistics and issued by the Commercial Intelligence Service, Department of Trade and Commerce, in 1922.

Table 4.—Distribution of Ownership of Stocks, Bonds, and Other Securities held by Incorporated and Joint Stock Companies in specified manufacturing industries in Canada in 1919, at par valuation[1]

Industry	Par Value of Issued Securities held by Residents of				Total
	Canada	Great Britain	United States	Other Countries	
	$	$	$	$	$
Lumber	126,012,126 61%	22,359,270 11%	54,794,285 27%	1,596,702 1%	204,762,383 100%
Pulp and paper	135,783,020 68%	8,405,006 4%	48,696,870 24%	8,519,128 4%	201,404,024 100%
Agricultural implements	39,660,962 58%	7,135,900 9·8%	21,003,000 31%	819,100 1·2%	68,618,962 100%
Foundries and machine shops	47,934,478 70%	5,725,736 8·4%	14,703,711 21%	37,895 0·2%	68,401,820 100%
Building and construction	21,608,880 46·4%	20,988,800 45%	3,905,250 8·4%	93,700 0·2%	46,596,630 100%
Electrical apparatus	15,873,808 36%	5,492,016 12%	21,572,290 49%	1,167,500 3%	44,105,614 100%
Cotton textiles	35,717,100 88·7%	2,385,550 6%	2,044,920 5%	135,600 0·3%	40,283,170 100%
Meat packing	20,558,790 57%	57,300 0·2%	14,809,820 41·4%	501,300 1·4%	35,927,110 100%
Rubber	13,539,474 40%	735,550 2%	17,037,400 50%	2,632,200 8%	33,944,624 100%
Flour and cereal mills	30,950,044 91·5%	1,348,385 3·8%	1,079,550 3·2%	489,050 1·5%	33,867,029 100%
Patent or proprietary medicines	3,280,819 12%	488,797 1·8%	23,639,650 86%	38,691 0·2%	27,447,957 100%
Paints and varnishes	9,861,028 44%	340,600 1·5%	10,415,500 47%	1,848,100 7·5%	22,465,228 100%
Sugar refining	12,841,196 67·2%	1,594,824 8·4%	3,221,612 17·2%	1,345,000 7·2%	19,002,632 100%
Automobile manufacture	5,912,800 39%	....	9,410,200 61%	....	15,323,000 100%
Car construction (except railway car shops)	5,526,000 40·4%	....	8,100,000 59·6%	....	13,626,000 100%
Artificial abrasives	53,700 0·4%	50,500 0·4%	11,400,075 99·1%	2,500 0·1%	11,506,775 100%
Drug and chemical trade	3,680,869 36%	3,821,997 37%	2,707,100 27%	....	10,209,966 100%
Automobile accessories	645,580 6·44%	15,200 0·15%	9,369,400 93·41%	....	10,030,180 100%
Brass and copper foundries	5,446,420 55%	9,700 0·1%	4,434,900 44·9%	....	9,891,020 100%
Condensed milk	2,274,300 48·5%	89,400 0·5%	1,888,980 40%	552,870 11%	4,705,550 100%
Petroleum refining	2,079,400 46·7%	10,800 0·2%	2,353,295 53·1%	550	4,444,045 100%

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[1] Compiled from twenty-one separate tables prepared by the Dominion Bureau of Statistics in which Stocks, Bonds, and other Securities are listed separately at par valuation. Percentage distribution of ownership is given approximately.

The distribution of the ownership of the various kinds of securities issued by Chemical, Metallurgical, and Mining companies incorporated in Canada has also been investigated by the Dominion Bureau of Statistics. The following three tables (Nos. 4a, 4b, and 4c), presenting conditions as at December 15, 1921, have been adapted from information supplied by this Bureau. Much additional statistical information on these subjects will be found in the reports on Chemical and Allied Products in Canada for 1919, 1920, and 1921, and also in the Industrial Review section of the annual report of the Mineral Production of Canada during the calendar year 1921.

Table 4a.—Distribution of Ownership of Securities issued by Chemical and Allied Companies incorporated in Canada as at December 15, 1921

Industry	Par Value of Issued Securities held by Residents of				Total
	Canada	Great Britain	United States	Other Countries	
	$	$	$	$	$
Chemical and Allied Products—					
Coal tar and its products	235,250	926,549	733,000	....	1,894,799
Approximate percentage	12	49	39	....	100
Acids, alkalies, salts, and compressed gases	14,650,220	7,100,788	18,627,016	43,800	40,421,824
Approximate percentage	36	18	46	....	100
Explosives, ammunition, fireworks, and matches	3,810,989	7,761,044	7,483,946	104,391	19,160,370
Approximate percentage	20	40	39	1	100
Fertilizers	741,350	16,500	29,000	....	786,850
Approximate percentage	94	2	4	....	100
Medicinal and pharmaceutical preparations	4,223,484	252,685	20,920,525	724,325	26,121,019
Approximate percentage	16	1	80	3	100
Paints, pigments, and varnishes	12,184,900	379,400	8,959,175	18,200	21,541,675
Approximate percentage	56	2	42	....	100
Soaps, washing compounds, and toilet preparations	3,726,878	5,449,066	32,403,821	5,907	41,585,672
Approximate percentage	9	13	78	....	100
Inks, dyes, and colours	249,230	12,000	1,378,090	6,280	1,645,600
Approximate percentage	15	1	84	....	100
Wood distillates and extracts	1,879,450	4,321,383	....	....	6,200,833
Approximate percentage	30	70	....	....	100
Miscellaneous chemical industries	2,199,650	167,200	35,441,233	218,900	38,026,983
Approximate percentage	6	....	93	1	100
Total for chemicals and allied products	43,901,401	26,386,615	125,975,806	1,121,803	197,385,625
Approximate percentage	22	13	64	1	100

Table 4b.—Distribution of Ownership of Securities issued by Metallurgical Companies incorporated in Canada as at December 15, 1921

Security	Par Value of Issued Securities held by Residents of				Total
	Canada	Great Britain	United States	Other Countries	
	$	$	$	$	$
Nickel-Copper Smelters and Refineries—					
Stocks	1,211,686	24,021,606	45,049,700	2,868,610	73,151,602
Bonds	3,020,936	19,218,823	754	306,152	22,546,665
Other Securities	926,139	66	....	3,634,995	4,561,200
Total	5,158,761	43,240,495	45,050,454	6,809,757	100,259,467
Approximate percentage	5	43	45	7	100
Silver-Cobalt Smelters—					
Stocks	1,933,505	....	5,025	....	1,938,530
Bonds	194,900	....	20,100	....	215,000
Total	2,128,405	....	25,125	....	2,153,530
Approximate percentage	99	....	1	....	100
Copper, Lead, Zinc—					
Stocks	14,283,700	....	12,000,420	....	26,284,120
Bonds	3,000,000	....	3,991,400	....	6,991,400
Total	17,283,700	....	16,491,820	....	33,275,520
Approximate percentage	51	....	49	....	100
Total, All Metallurgical Plants—					
Stocks	17,428,891	24,021,606	57,555,145	2,868,610	101,874,252
Bonds	6,215,836	19,218,823	4,012,254	306,152	29,753,065
Other Securities	926,139	66	....	3,634,995	4,561,200
Total	24,570,866	43,240,495	61,567,399	6,809,757	136,188,517
Approximate percentage	18	32	45	5	100

Table 4c.—Distribution of Ownership of Securities issued by Mining Companies incorporated in Canada as at December 15, 1921

Industry	Par Value of Issued Securities held by Residents of				Total
	Canada	Great Britain	United States	Other Countries	
	$	$	$	$	$
Metal Mining—					
Copper-gold-silver mining and milling[1]	9,905,844	3,201,082	38,031,198	44,114	51,182,238
Gold quartz mining and milling[2]	114,520,383	3,960,862	51,268,921	213,356	169,963,522
Gold placer and hydraulic mining	153,247	11,766,154	17,573,188	28,885	29,521,474
Iron mining and briquetting[3]	6,885,270	3,974,733	4,794,447	31,540	15,685,990
Molybdenite mining and milling[4]	4,086,529	2,700	3,158,305	248,169	7,495,703
Nickel-copper mining and milling[5]	5,308,766	43,240,495	45,050,454	6,809,757	100,469,472
Silver-cobalt mining and milling[6]	52,867,834	6,092,631	14,789,731	673,691	74,423,887
Silver-lead-zinc mining and milling[7]	26,099,377	616,313	10,193,511	2,603,555	39,512,756
Total for Metal Mines and Mills	219,827,250	72,854,970	184,859,755	10,653,067	488,195,042
Approximate percentage	45	15	38	2	100
Non-Metal Mines—					
Asbestos mining and milling	19,724,969	1,467,300	7,927,280	82,500	29,202,049
Coal mining	86,727,930	18,721,941	25,879,964	7,656,638	138,986,473
Gypsum mining and milling	1,484,550	400	1,484,500	68,350	3,037,800
Natural gas	13,237,270	2,803,999	6,825,823	....	22,867,092
Petroleum	3,388,922	7,050	2,882,689	....	6,278,661
Salt	1,469,080	76,600	305,300	....	*2,593,980
All other non-metallics	5,721,154	171,479	2,250,402	580	8,143,615
Total for Non-Metal Mines	131,753,875	23,248,769	47,555,958	7,808,068	*211,109,670
Approximate percentage	62	11	23	4	100
Structural Materials and Clay Products—					
Cement	35,116,930	4,297,246	809,100	405,400	40,628,676
Clay products	19,505,891	563,688	1,580,780	....	21,650,359
Lime burning	1,924,434	43,600	1,203,450	....	3,171,484
All other structural materials	9,329,940	160,500	503,610	....	9,994,050
Total Structural Materials and Clay Products	65,877,195	5,065,034	4,096,940	405,400	75,444,569
Approximate percentage	87	7	5	1	100
Grand total	417,458,320	101,168,773	236,512,653	18,866,535	774,749,281
Approximate percentage	54	13	31	2	100

[1] This group was composed of 10 producing, 5 operating but not producing, and 49 idle companies. There was also included the value of the stocks, etc., issued by the Granby Consolidated Mining, Smelting and Power Co., because the most important department of that company was copper production. It might be pointed out that the stocks of this company which operated coal and other non-metallic properties have been excluded from other compilations dealing with those groups so that duplication has been avoided.

[2] Includes 32 producing, 25 operating but not producing, and 93 idle incorporated companies.

[3] Includes 1 producing, 11 idle companies. Stock of Algoma Steel Company which operates iron properties not included here.

[4] Includes 10 idle molybdenite and 2 idle tungsten incorporated mining companies.

[5] Includes all stocks of nickel-copper companies and refers to mining, smelting and refining.

[6] Includes all silver-cobalt mining, milling and reduction companies situated at Cobalt, Gowganda and South Lorrain, Ontario, 22 producing, 7 operating but not producing, and 26 idle incorporated companies. Excludes stock of 3 silver smelters operating in Ontario.

[7] Comprises 19 producing, 8 operating but not producing, and 34 idle incorporated mining companies. Includes stock of the Consolidated Mining and Smelting Co., Trail.

*Includes $743,000 distribution of which was unknown.

The capital actually invested in these various industries is not necessarily the same as that shown by the total par valuations of the various securities. This fact is shown by two additional tables relating to the Metallurgical industries also prepared by the Dominion Bureau of Statistics. Table 4d shows the capital actually invested in these industries on December 15, 1921, while Table 4e shows the investment by residents of certain named countries, this latter table being derived from the data given in Table 4d by applying the actual percentages of investment derived from Table 4b.

Table 4d.—Capital Actually Employed in the Metallurgical Plants of Canada, 1921

	Nickel-Copper Smelters and Refineries	Silver-Cobalt Smelters	Copper, Lead and Zinc Smelters and Refineries	Total
	$	$	$	$
Lands, buildings, plant machinery and tools...	22,303,585	1,433,442	31,823,524	55,560,551
Materials on hand, supplies, finished products and ore on dump..........	10,467,385	2,105,786	9,234,445	21,807,616
Cash, trading and operating accounts and bills receivable..........	4,062,590	444,096	812,092	5,318,778
Total..........	36,833,560	3,983,324	41,870,061	82,686,945
Approximate percentage..........	44	5	51	100

Table 4e.—Actual Investment in the Metallurgical Industry in Canada by Residents of the Countries Indicated

	Canada	Great Britain	United States	Other Countries	Total
	$	$	$	$	$
Nickel-copper..........	1,895,087	15,885,578	16,550,423	2,502,472	36,833,560
Silver smelters..........	3,935,524	....	47,800	....	3,983,324
Copper-lead-zinc..........	21,353,731	....	20,516,330	....	41,870,061
Total..........	27,184,342	15,885,578	37,114,553	2,502,472	82,686,945
Approximate percentage......	33	19	45	3	100

Similar information has been compiled showing the capital invested in the chemical and allied group of industries and in mining. In 1919 the total par valuation assigned to the securities of the companies reporting under the chemical group was $175,979,843, while the total capital was $111,760,019.[1] Data for 1919 and 1920 are not available. The mining industry in 1921 was credited with a par valuation of securities of $774,749,281 as compared with a total investment of capital in these securities amounting to $559,514,154.[2] Parallel compilations covering the several industries tabulated in Table 3 are not at present available.

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[1] Chemicals and Allied Products, 1919 and 1920, pp. 10 and 11.

[2] Report on the Mineral Production of Canada for 1921, pp. 126 and 129.

CHAPTER IV

BUREAUS OF INFORMATION

Persons requiring information about Canada's resources, development, markets, or industries may find the following directory of Public Service bureaus of some assistance. Inquiries should be addressed to the Department or Branch most immediately concerned with the subject of inquiry. It should be noted that each of the provinces formulates its own laws regulating mining, workmen's compensation, and company incorporations of provincial status. The provinces of Nova Scotia, New Brunswick, Quebec, Ontario, and British Columbia also control both surface and mining rights on Crown lands. The Federal Government at Ottawa formulates laws regulating mining on Dominion lands, employment, or company incorporations having interprovincial or Dominion status. The mining rights of Crown lands in the provinces of Manitoba, Saskatchewan, and Alberta, and in Yukon, the Provisional Districts of Mackenzie, and Franklin (including the Arctic islands) are at present vested in the Dominion of Canada. Factory laws and regulations may be either Federal or Provincial.

Table 5

DOMINION OF CANADA.[1]

Geology, natural history and mining resources:
  Geology and natural history.
    Geological Survey Branch, Department of Mines.

  Mineral resources and technology, or raw materials of industry.
    Mines Branch, Department of Mines.

Mining laws and regulations relating to territory under Federal jurisdiction.
  Mining Lands Branch, Department of the Interior.

Water-power resources and developments:
  Dominion Water Power Branch, Department of the Interior.

Agricultural resources and investigations:
  Department of Agriculture.

Forest resources and utilization:
  Forestry Branch, Department of the Interior.

Fishery resources:
  Department of Marine and Fisheries.

General information on natural resources:
  Natural Resources Intelligence Service, Department of the Interior.

Commercial information:
  Commercial Intelligence Service, Department of Trade and Commerce.

Statistical information of all Canadian activities:
  Dominion Bureau of Statistics, Department of Trade and Commerce.

Customs and excise laws:
  Department of Customs.

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[1] Address all inquiries to Ottawa, Canada.

Sanitary regulations, food regulations, stream pollution, etc.:
Department of Public Health.

Employment regulations and factory laws:
Department of Labour.

Incorporation and incorporations:
Under-Secretary of State.

Laws of Canada:
Department of Justice.

PROVINCES OF CANADA.[1]

Laws regulating incorporations, employment, workmen's compensation, etc.
Department of the Attorney-General for the particular province concerned.

Natural resources:
Manitoba—The Provincial Secretary, Winnipeg.
Saskatchewan—The Provincial Secretary, Regina.
Alberta—The Provincial Secretary, Edmonton.

Mining laws, regulations, and mineral resources:
Nova Scotia—Department of Mines, Halifax.
New Brunswick—Department of Lands and Mines, Fredericton.
Quebec—Department of Lands, Forests, and Mines, Quebec.
Ontario—Department of Mines, Toronto.
British Columbia—Department of Mines, Victoria.

It should also be noted that the Canadian railways have organized a number of information bureaus. These offices undertake to advise inquirers about land location and settlement, and to supply information concerning industrial opportunities and natural resources. The two principal railways maintain information offices at many points in the United States, in Europe, and in other parts of the world. The principal information offices in Canada are:—

Canadian National Railways, Department of Colonization and Development, Montreal, Quebec.

Canadian Pacific Railway, Department of Colonization and Development, Montreal, Quebec.

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[1] Address inquiries to the provincial capitals.

PART II

CHEMICAL INDUSTRIES

PRIMARY INORGANIC PRODUCTS

INTRODUCTORY

The industries grouped under this caption embrace all those which are engaged in the production of finished manufactural products through the controlled application of chemical forces to raw materials. A general survey of the field of industry shows that the number of different commercial products made by chemical processes is very great. No enumeration of the exact number of chemical products made for commercial purposes is possible. There are probably many thousands such, and new products are being added continually.

For purposes of study, however, it is possible to group the several industries making these products into a comparatively small number of classes. The order of arrangement selected has been more or less arbitrarily chosen for purposes of presentation. The industrial groups first described might be termed Primary Chemical Manufacturing Industries, because for the most part their products are made directly from natural raw materials, and most of these products are made primarily for use in other industries. The second group of chemical industries will include those making secondary finished chemical products from primary chemicals alone or in combination with natural raw materials. The third great group of industries comprises those that are usually termed General Manufacturing. In this group chemical processes play a most important part, but the principal raw materials are usually natural products, and chemicals and chemical processes play a minor though more or less essential part.

In the following discussions no specific reference is made to water as an essential commodity in nearly all chemical industry. The use of heat in chemical industry and the sources from which it is obtained are not considered.

Changes in matter brought about by agencies which do not affect the composition of the material concerned are termed physical changes. Changes in matter brought about by agencies which affect the composition of the material concerned are termed chemical changes. The science of chemistry, in its broadest application, is the science which deals with chemical changes. Finished products produced by manufactural operations from any kind of raw materials are the result of the application of forces which promote physical changes alone, chemical changes alone, or, more frequently, both physical and chemical changes in the raw materials.

Logically it would appear that Chemical Manufacturing consists of the production of finished manufactural products through the promotion and control of chemical changes in raw materials. Actually chemical and physical processes are so intimately related that no such distinction can be made. There are very few industries in which physical processes alone are predominant. The production of refined cane sugar from raw sugar by solution, filtration, and evaporation is a process in which a minimum of chemical change is employed, but even here the clarification of syrups is promoted by chemical means. In the manufacture of beet sugar an important percentage of the sugar is recovered by chemical means. In the majority of industrial processes chemical changes play a much more important part, but always in association with operation of physical processes. It is therefore not desirable, nor indeed feasible, to draw any sharp distinction between manufacturing processes in which chemical processes predominate and those in which physical processes are the more active. The term Chemical manufacturing, as here used, is thus intended to include all types of manufacturing in which both chemistry and physics play important parts, without regard to the relative predominance of either type of process.

In enumerating accessory products, or materials used in these industries, detailed references to materials used in the construction of apparatus, often requiring continuous replacement, are omitted.

In many places in this report explanatory references are made to processes that are employed in chemical manufacturing, but it has not been considered advisable to include any technical descriptions of processes that are in operation in Canadian plants. Technical discussions of the methods of utilizing minerals and other raw materials in the different industries are reserved for consideration in special bulletins dealing with specific subjects. Trade specifications for different raw materials and products have also of necessity been omitted in these discussions, since they can be more appropriately considered in special reports dealing with single products or industries.

This part of the report is confined to a discussion of the manufacture of primary inorganic chemicals; the third part discusses primary organic chemicals; the fourth part deals with secondary products and chemical manufacturing. The last two sections of the series, parts six and seven, deal with Allied Industries, in which chemicals and chemical processes play an important part.

ALKALI INDUSTRY
PRODUCTS, BY-PRODUCTS AND INDUSTRIAL USES
(AMMONIA-SODA PROCESS)

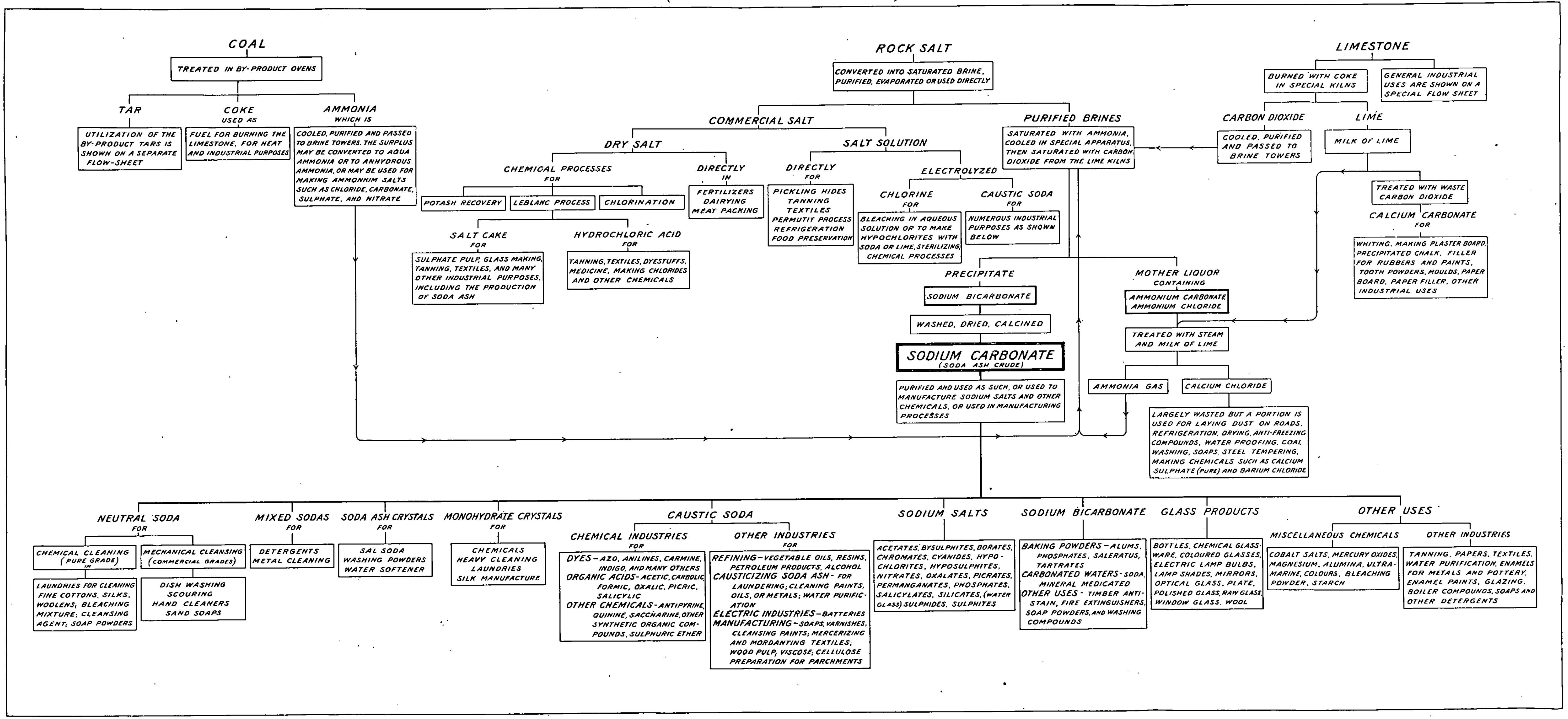

Diagram 2

CHAPTER I

HEAVY CHEMICALS

Chemical industry and industries using chemical products are, for the most part, founded upon the production of certain acids and alkalies. These products, directly or indirectly, are essential materials in the production of innumerable other products. Certain of these are usually made in large quantities from crude raw materials and, relatively to other chemicals, at a comparatively low unit cost. The products of this group of industries are termed heavy chemicals, and the industry is often referred to as the *Acid and Alkali Industry*.

The principal acids made are sulphuric, nitric, hydrochloric, and, occasionally, hydrofluoric. The principal alkali products are sodium sulphate, sodium carbonate, and sodium hydroxide; the principal byproducts are sodium thiosulphate and bleaching powder. Hydrochloric acid, also, is largely a byproduct of the alkali industry. The corresponding salts of potash are made by methods similar to those employed for making the sodium salts above enumerated, but their relatively higher cost tends to place them among the group of fine chemicals.

The principal raw materials of this group of industries are sulphur, Chili saltpetre, common salt, limestone, and coal or coke. The complete cycle of operations in an alkali works, using these raw materials, involves the production of sulphuric acid, sulphate of soda, hydrochloric acid, soda ash, caustic soda, and bleaching powder. All these products are not often made at the same works to-day owing to improved processes and to market conditions.

The following notes, largely non-technical in character, are intended only as a brief review of the Canadian situation with respect to these raw materials and products, and to the markets for the products.

SULPHURIC ACID

Pure sulphuric acid is a colourless odourless strongly corrosive liquid of an oily consistency, having a specific gravity of 1·8384 at 15° C. It begins to boil at 290° C. and the boiling point rises to 338° C. At about 400° C. the vapour dissociates into sulphur trioxide and water. At a higher temperature, about a red heat, there is still further dissociation with the production of sulphur dioxide and free oxygen. It freezes to a colourless crystalline solid at 10·5° C. The acid is extremely hygroscopic and can be mixed with water in all proportions; when strong acid is mixed with water there is a considerable amount of heat liberated and there is a decrease in volume.

Commercial sulphuric acid is frequently discoloured by impurities, so much so that the colour may become a deep brown. The common impurities are iron, arsenic, and lead sulphate.

There are a number of commercial grades of acid commonly produced and marketed. The industrial applications of this product are very numerous and probably every degree of dilution finds application in some process. Pure acid, 100 per cent H_2SO_4, is termed oleum. This product may contain varying amounts of sulphur trioxide in solution. "Contact acid" is made by the "contact process" and commonly contains 98 per cent H_2SO_4; "Oil of vitriol" or "66° acid" contains 93·19 per cent H_2SO_4 and is the grade commonly shipped in tank cars; "Tower acid" or "60° acid," and "Chamber acid" (or 50° to 55° acid) also find many industrial applications.

Raw Materials

The essential raw materials for the manufacture of sulphuric acid are water, oxygen, and sulphur. The two former are obtained from natural supplies, the oxygen of the atmosphere being utilized. Sulphur may be obtained as a natural mineral product, or it may be secured through the proper treatment of certain mineral sulphides, pyrites, the sulphide of iron, being the most important. All processes of manufacture involve the production of sulphur dioxide. This gas is a waste product in preliminary metallurgical operations for recovering metals from natural sulphides (particularly sulphides of copper, nickel, zinc, and lead) and this waste gas may also be utilized for the production of sulphuric acid.

Certain accessory materials are also required in the manufacture of this acid. Where the chamber process is employed natural nitrate of soda is used for the production of oxides of nitrogen which act as "oxygen carriers." In the contact process catalytic agents are required. The two commonly employed are ferric oxide and finely divided platinum. The finely divided platinum used for this purpose is specially prepared by soaking asbestos fibre, or magnesium sulphate, with a solution of chloride of platinum and then heating to a temperature high enough to drive off the chlorine. The resultant contact mass usually contains between seven and eight per cent of metallic platinum in a very fine state of division.

The accessory materials required for the construction of apparatus and for the operations of plants of different types are too extensive to be enumerated here.

Processes

The first step in every process is the production of sulphur dioxide by the oxidation of natural sulphur, or by oxidizing the sulphur present in certain metallic minerals, such as pyrites, blende, or galena. This gas is then treated in suitable equipment for the production of sulphuric acid by further oxidation and hydration. Two general types of processes are employed, known respectively as the chamber process and the contact process. Each of these processes is carried out in specially designed and constructed apparatus.

In the chamber process sulphur dioxide is brought into contact with oxygen (air) and water in the presence of nitrous oxides. These nitrous gases are made by the decomposition of sodium nitrate with strong sulphuric acid and function as "oxygen carriers" to promote the formation of the sulphuric acid from sulphur dioxide and atmospheric oxygen in the presence of water (as steam). Chamber acid, owing to the nature of the process, is always dilute. Where greater strengths are required it is necessary to employ some method of concentrating. This is usually done by heating in specially devised equipment constructed of acid resisting materials, such as sheet lead, platinum, acid proof alloys, chemical stoneware, acid proof brick, or fused silica products.

In the contact process sulphur dioxide and oxygen are combined, in the presence of a catalyzer, to produce sulphur trioxide. This product is then brought into contact with water to produce sulphuric acid. It is possible to make acid of any required strength directly by this method. In its operation it is essential that all gases employed be thoroughly cleaned by scrubbing and filtering before they come in contact with the catalyzing agent. Vapourized sulphur, flue dust, oxide of arsenic, and compounds of phosphorus or of mercury, which might be present in the gases produced by the roasting of pyrites, or other sulphide ores, would destroy the catalyzer if allowed to come in contact with it.

Where sulphur dioxide obtained from metallurgical operations is utilized the gases are first cleaned and then converted into sulphuric acid by the chamber process.

Industrial Uses

Sulphuric acid is probably the most important single chemical product manufactured. It enters into the manufacture of numerous other products and finds application, directly or indirectly, in almost every industry. Only a few of the principal industrial applications are listed here.

Oleum (sulphuric anhydride or Nordhausen fuming oil of vitriol) is used in the manufacture of certain explosives, and of certain products used in the dye industry (organo-sulphonic acids in the manufacture of alizarin, eosine, indigo, etc.); for purifying ozokerite; for making shoe-blacking; for raising the strength of weaker but concentrated acid as required.

Concentrated sulphuric acid is used in the explosives industry for producing many nitro-compounds, such as nitro-glycerine, pyroxylin, nitrobenzene, picric acid, and related products; for making nitric ether; for making organo-sulphonic acids; for manufacturing indigo; for drying air for laboratory purposes and for drying air or other gases in manufacturing processes; for purifying natural gas and petroleum products, such as benzene, coal oil, paraffin oil, and other mineral oils; for purifying colza oil; for the manufacture of fatty acids.

Dilute acid, chiefly chamber acid, is used in the manufacture of a great number of important products. The two principal applications are the making of artificial manures, and especially monobasic calcium phosphate (superphosphate fertilizers), and the manufacture of salt cake (sulphate of soda) and hydrochloric acid. Salt cake is a basic material from which are made such products as soda ash, bleaching powder, glass, soap, and many other articles. Chamber acid finds application in the manufacture of a number of acids such as acetic, boric, carbonic, chromic, citric, hydrochloric, hydrofluoric, nitric, phosphoric, stearic, sulphurous; in the making of fine chemicals such as bromine and iodine; for the production of sulphates of the metals aluminium, ammonium, barium, calcium, copper, iron, magnesium, mercury, zinc, and others; in the metallurgy of cobalt, copper, gold, nickel, platinum, silver, and zinc; in the tin plating and galvanizing industry for cleaning the surfaces of iron or steel articles; for cleaning other metal surfaces such as copper and silver; for the operation of galvanic batteries; in the preparation of electrolytes for plating; in the manufacture of various ethers; in the manufacture of many organic colour compounds; for making artificial parchment; for purifying mineral oils; in the manufacture of starch, syrups, and sugar; in the production of glucose; for the production of carbon dioxide, particularly in the manufacture of aerated waters; in the preparation of certain byproducts in the meat packing industry; for destroying fabric fibres in the reclaiming of rubber; in various processes connected with dyeing, in calico printing, tanning, and the textile trades; as a chemical reagent in both laboratory and factory; and in many other operations.

Imports and Exports

The average imports for the three years 1911-14 were 2,056,303 lbs., valued at $16,567, an average unit price of ·81 cent per pound. In the year 1918-19, 12,185,903 lbs. were imported, valued at $206,691, an average unit price of 1·7 cents per pound.

During one of the three years 1911-14 the export of 6,245,086 lbs. was reported, valued at $37,413. In 1918-19, 5,463,000 lbs., valued at $75,857, were exported.

None of the published returns indicate the strength of the acid imported or exported, and there is no intimation that the returns published are based on an acid of uniform strength.

The following tables show statistical data with respect to the Canadian annual production, imports, and exports:—[1]

Table 6. Sulphuric Acid in Canada, 1912-1919.

—		1912	1913	1914	1915	1916	1917	1918	1919
MATERIALS USED:									
Sulphur..........	Tons	4,773	4,281	2,227	4,716	20,566	25,994	25,552	2,245
Pyrites*..........	"	27,680	31,774	33,331	55,586	62,681	66,128	75,941	54,879
Production 66° Bé**..	"	44,651	47,227	41,919	75,838	124,920	153,530	190,621	63,596
Imports.............	"	2,486	73	166	141	2,403	216	5,954	1,437
Exports.............	"	None	1,247	3,743	9,635	1,576	9,478	5,600	5,447

*Canadian pyrites as shipped contains on yearly averages 37—40% sulphur.

**Record includes a small production of oleum and other grades the strength of which is not specified. Production records of 50° Bé. and 60° Bé. acid have been reduced to 66° Bé. acid for statistical purposes.

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[1] Compiled by the Division of Mineral Resources and Statistics.

Canadian Situation

Native sulphur is not found in Canada in commercial quantities. Where this material is used it has to be imported. The supply for Nova Scotia points was formerly imported from Sicily, but at present it is secured from Louisiana or Texas. Quebec and central Ontario obtain supplies from Louisiana or Texas. British Columbia supplies come from Japan chiefly.

Pyrites, the principal metallic sulphide which is used as a source of sulphur for the manufacture of sulphuric acid, is available in Canada in large amounts. Before the war there was a large surplus production available for export. It was utilized in certain chemical works in central Ontario and in British Columbia. It was also available in Quebec, but in recent years it was not utilized for acid making in this province, imported sulphur proving more convenient. Newfoundland pyrites was formerly imported for acid making in Nova Scotia, but at present native sulphur alone is used. At present very little pyrites is being used in Canada for the production of sulphuric acid.

With respect to accessory materials required in the industry nitrate of soda is imported from Chili for use in the chamber process. The platinum, or the platinum product required for the contact process, is also imported. The life of a unit is long and the amount required is small but expensive owing to the high cost of platinum.

There are nine plants in Canada for the manufacture of sulphuric acid distributed as follows: one in Nova Scotia, one in Quebec, four in Ontario, and three in British Columbia. Three of these plants are producing acid for private use only; six plants, one in Quebec, three in Ontario, and two in British Columbia, produce acid for commercial distribution as such as well as for private use. The plant in Nova Scotia, three plants in Ontario, and two in British Columbia use the chamber process, and where necessary concentrate their acid. One plant in each of the provinces of Quebec, Ontario, and British Columbia uses the contact process, there being a total installation of six contact units.

The normal consumption of sulphuric acid in Canada prior to the war was between forty-five and fifty thousand tons of 66° Bé. acid or the equivalent. This consumption naturally increased greatly during the years 1915-16-17-18, but there was an apparent falling off in 1919, when the production was 63,596 tons. Only a very small quantity is exported. The imports are low and irregular.

Two Canadian plants are producing sulphuric acid for the manufacture of ammonium sulphate as a byproduct in connection with the operation of byproduct coke oven installations. Two firms operating coke ovens of this type at present purchase sulphuric acid as required. One plant in Ontario, formerly used in explosive manufacture, was reopened for a time; the acid produced was utilized in making fertilizers and certain other chemical products. One plant in British Columbia is making acid for use in the metallurgy of zinc.

Sulphuric acid is shipped in bottles, carboys, iron drums, and tank cars. Its corrosive character renders it somewhat dangerous to handle and freight rates are high. It is customary to manufacture this product in the vicinity of the absorbing market. The existing Canadian plants are able to provide for present demands and have considerable annual capacity in reserve.

It would be feasible to greatly increase our present output of sulphuric acid by utilizing the waste gases produced in the metallurgical operations of the copper-nickel plants in the Sudbury region were it possible to market the product. At present commercial conditions and the cost of marketing the product make this impracticable.

NITRIC ACID

Strong nitric acid free from impurities is an almost colourless liquid at ordinary temperatures, fuming when exposed to the air, and very strongly corrosive. Under the influence of strong light it may become pale amber yellow in colour, and the same effect is produced by heating slightly, or through the presence of small amounts of organic matter as impurities. The pure acid has a specific gravity of 1·53, its melting point is —41·3° C. and it boils at 86° C. It is soluble in water or in alcohol in any proportion. It is more mobile than sulphuric acid and nearly one-third lighter in weight.

This acid is sold as fuming nitric acid when it has a specific gravity of 1·48 (47·1° Bé.) or higher, corresponding to about 86 per cent pure acid. There are also a number of commercial grades with specific gravities ranging between 1·33 (36° Bé.) and 1·436 (44° Bé.). The first of these contains 52·30 per cent pure nitric acid (HNO_3) and the last 73·67 per cent. "Dynamite acid" is a name sometimes applied to acids of strength higher than 88 per cent, which are used for the production of the mixed acids (nitric 34 per cent, sulphuric 62 per cent) used in making nitroglycerine.

Raw Materials

Nitric acid is usually made from sodium nitrate (or Chili saltpetre) and sulphuric acid. Sodium nitrate is a natural salt found in certain arid regions, the world's supply coming chiefly from Chili. This salt frequently contains small amounts of sodium chloride which must be eliminated by purification before use, if it is desired to produce pure nitric acid.

This acid can also be produced by the fixation of atmospheric nitrogen. (See chapter III, page 74.)

A third process of manufacture is by the oxidation of ammonia gas (NH_3) obtained as a byproduct in coal tar distillation, or by one of the processes for fixing atmospheric nitrogen.

Processes

Commercial nitric acid is usually prepared by the action of sulphuric acid on sodium nitrate ($NaNO_3 + H_2SO_4 = NaHSO_4 + HNO_3$). The operation is usually carried out in specially constructed cast iron retorts.

The retorts are heated before charging with sodium nitrate, the temperature being such that the whole charge is heated slightly above the boiling temperature of nitric acid. Sulphuric acid (about 92—95 per cent H_2SO_4) is then added, and the temperature is maintained for a time, and then gradually raised to promote a gradual and steady distillation of nitric acid. The acid distilled from the retorts is condensed in series of special earthenware or glass Woulfe bottles, or in condensers of special design. There are a number of types of apparatus in use for carrying out this process, the different designs having been developed to promote the efficiency of the operations in various ways and to increase the recoveries.

The processes for making nitric acid by the fixation of atmospheric nitrogen are described in the chapter on Production of Nitrogen Compounds (page 74).

Nitric acid can also be produced by the oxidation of ammonia (NH_3), as in the Haber process, or by modifications of this process. Further reference to this subject is made in the above mentioned chapter.

Industrial Uses

Nitric acid is strongly corrosive, this action being due to oxidation in part, and in part to the formation of certain nitrogen compounds. This fact makes it an important agent for the promotion of organic synthesis, and in the manufacture of certain dyestuffs and explosives. Nitrates or nitrogen compounds, made by the use of nitric acid, are essential to the production of almost every explosive. It is used for making synthetic dyestuffs, azo, diazo, and amido compounds, and pyroxylin (nitrated cellulose).

Nitrates of the metals are all soluble in water and are used in electroplating. Certain nitrates of the metals are used in the preparation of coloured fires and other forms of fireworks, owing to their high oxidizing power. Certain other salts, particularly nitrate of soda and nitrate of potash, but also nitrate of lime or nitrated lime, are important fertilizers. The nitrates of soda and potash are obtained chiefly from natural deposits; the nitrated lime products are artificial.

This acid also finds applications in metallurgy, in medicine, in engraving and etching, and in many minor industries.

Canadian Situation

Nitrate of soda has not been found in Canada in commercial quantities. The supplies used in this country are imported from Chili, either directly or through the United States. Deliveries are made both on the Atlantic and on the Pacific seaboard by boat and in the central provinces by rail. Sulphuric acid, as previously noted, is prepared in this country.

Nitric acid has not been made in Canada on a commercial scale, either directly from the nitrogen of the atmosphere or by the oxidation of ammonia.

Nitric acid is a dangerous material to handle or to transport. When shipped it is usually stored in glass bottles or carboys. As far as possible it is utilized as close to the points of production as possible. Nitrates of the metals, on the other hand, may usually be transported without serious danger when reasonable precautions are taken. Nitrates suitable for use as fertilizers can be readily transported. This fact is of considerable importance in relation to the possible expansion of this chemical industry in Canada.

The agricultural areas of Canada, where increased quantities of nitrate fertilizers will be in demand in the future, are for the most part located long distances from the regions where cheap hydro-electric power can be developed. Cheap hydro-electric power will, in the future, be the basis of a large air nitrate industry, and it is along this line that there appears to be opportunity of expanding this industry in Canada. It will be necessary, however, to manufacture products that can be distributed to the market without serious difficulty and at reasonable rates.

At the present time there are four nitric acid plants in Canada, two being located in Quebec, one in Ontario, and one in British Columbia.

No statistical data with respect to the normal annual production of this acid in Canada are available. The average importation for the three years prior to the war was 194,086 pounds. There is no record of any exports, and the strength of the acid imported is not given.

HYDROCHLORIC ACID

Hydrochloric acid is the name usually applied to the aqueous solution of hydrogen chloride. This solution is a clear colourless liquid, fuming when saturated, slightly yellow in colour when not absolutely pure, pungent and irritating to the mucous membranes. Anhydrous hydrogen chloride is a colourless gas at ordinary temperatures. When cooled under pressure it can be condensed into a liquid. The boiling point is − 83·1° C., and the melting point − 112·5° C. The solubility of anhydrous hydrogen chloride in water varies with the atmospheric temperature. Solutions containing more than 20·17 per cent of the anhydrous chloride lose both gas and water on heating. Solutions containing this percentage or less distil at 110° C. without change. A solution of this strength has a specific gravity of 1·10, corresponding to 13·3° on the Baumé scale. The commercial grade of this solution usually sold as "muriatic" acid, contains about 27·92 per cent anhydrous hydrogen chloride, corresponding to 18° Bé., or a specific gravity of 1·417. The stronger acid sold as C.P. grade (chemically pure) contains 34·26 per cent anhydrous hydrogen chloride, and has a specific gravity of 1·1745, corresponding to 21·5° Bé. Fuming acid may be of a higher specific gravity and contains more anhydrous hydrogen chloride. Acids of various degrees of dilution are required in industry.

Raw Materials

The principal raw materials used for the manufacture of this acid are common salt (sodium chloride, NaCl) and sulphuric acid. When these products are used the principal product of the operation is sodium sulphate (salt cake and Glauber's salt) and the resulting hydrochloric acid may be regarded as byproduct. One process uses sulphur dioxide gas, usually made from pyrites, in place of sulphuric acid.

owing to complex distortion of the rocks, through faulting and folding, a definite pronouncement regarding possible tonnage commercially available must await further underground exploration.[1]

Apart from surface indications, considerable additional information has been secured through the drilling of numerous deep wells. During the period 1899-1906, a local organization known as the New Brunswick Petroleum Company drilled upwards of 80 wells, chiefly in Westmorland county between the Petitcodiac and Memramcook rivers. The majority of these wells were comparatively shallow, varying in depth up to 1,100 feet, although one at least reached a depth of more than 3,000 feet. In a number of these wells, small showings of petroleum were encountered, but the writer has no definite information regarding the number or character of the oil shale bands passed through.

Since 1909, Maritime Oilfields, Ltd., succeeded by its subsidiary, New Brunswick Oil and Gas Fields, Ltd., has successfully carried on an extensive drilling programme in the Stony Creek oil and gas field, 9 miles south of Moncton, and elsewhere. The wells in the Stony Creek field are located on a structural terrace, and vary in depth from 1,800 to 3,200 feet. Their aggregate shut in capacity has exceeded 100,000,000 cubic feet of gas every 24 hours. The gas is found in a large number of interbedded sandstones, ranging in thickness up to 100 feet, and grouped along indefinite horizons through a vertical range of 2,000 feet.

More recently, drilling to the dip of this gas area has resulted in a moderate production of high quality paraffin base petroleum, and during 1920 the year's production exceeded 6,300 barrels. The greatest thickness of the Albert shale series recorded by any log from the Stony Creek field is approximately 2,800 feet, and in this log the occurrence of some 16 oil shale bands is noted. Of these it is considered that six bands, with an aggregate thickness of 72 feet, are of commercial quality, while the remainder, aggregating in thickness 123 feet, are of somewhat poor quality. Interbedded with these oil shale bands are numerous other sandy, marly and limey shales and thin limestones, which show wide variation in thickness, character, and texture. The total original thickness of the Albert shale series, estimated to be not less than 7,000 feet, would doubtless include a much larger number of oil shale bands of commercial grade. It is considered that the richer bands of oil shale occur in the lower horizons of the series.

Owing to lateral variation, however, it has been found that, even when the horizontal distance between individual wells does not exceed 1,000 feet, serious difficulty exists in correlating individual beds recorded in the logs. This appears to indicate that, in parts of the field at least, rapid changes in thickness and in character of oil shale bands and associated strata may be anticipated. This tendency is in conformity with the habit of associated sandstones and shales of the Carboniferous series of eastern New Brunswick, many of which were laid down in basins of limited extent.

Between 1911 and 1913 other private interests, said to be identified with Sir Wm. Mackenzie, tested the area along the southern margin of the Albert shale basin, by means of diamond drills. It is said that upwards of 14 holes, varying in depth from 700 to 1,500 feet, were drilled in the

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[1] Wright, W. J., Geol. Surv. Can., Summ. Rept. 1913 (pp. 223-227).

vicinity of Rosevale P.O., between the east and west branches of Turtle creek, while upwards of 10 other holes were drilled at scattered points. During the period 1919-21, eight other exploratory wells, some of which reached a depth of more than 3,000 feet, have been drilled in other parts of the Carboniferous basin of eastern New Brunswick, by the D'Arcy Exploration Company. The depth of most of these wells exceeds 2,000 feet.

Throughout the geological basin occupied by the Albert shale series notable erosion has taken place. In parts of the basin, several thousand feet of the series have been removed, and subsequently replaced by, unconformable beds of Middle and Lower Carboniferous age. Obviously, under such conditions, only extensive and systematic drilling will indicate the extent to which associated oil shale bands have been affected.

Oil shale bands, associated with the Albert shale series, vary in thickness from a few inches to more than 25 feet. In most instances the shale kindles readily and burns freely. Small splinters, when ignited by a match, frequently support combustion for considerable periods. In general, the oil shales weather through various shades of grey, but the colour of freshly broken surfaces ranges from grey to a typical chocolate brown or brownish black. The shales frequently contain thin laminæ or partings of asphaltic bitumen resembling albertite.

In point of geological age, and in certain other respects, the oil shales of New Brunswick correspond somewhat closely with those of Scotland. In each instance two general types of oil shales are recognized, viz., plain and curly. A sub-variety, usually referred to as paper shale, is apparently a weathered form of plain oil shale. It is thin-bedded, or papyraceous, separating readily into thin, flexible sheets of considerable surface dimensions. In many instances, the surface of the sheets are almost covered with imprints of fossil fish remains. Plain oil shales are usually flat-surfaced, showing more or less well-defined lamination. On the other hand, curly shale usually occurs as massive bands, somewhat curled and contorted. It is very tough, breaks with a conchoidal fracture, and is usually especially rich in hydrocarbons, a condition which may have rendered it more easily crumpled than poorer grades of shale. As a rule, the New Brunswick shales are free from grit, and, although easily cut with a knife, do not yield thin, somewhat flexible shavings as do the Scotch shales.

In view of the similarity which exists between the oil shales of Scotland and those of New Brunswick, each may probably be attributed to a somewhat similar origin. In both countries there is little in the shale which is soluble in benzene, carbon disulphide, ether and other similar solvents, and it would therefore appear that petroleum derived by destructive distillation may be attributed to matter of organic origin[1]. To express this carbonaceous substance, the term kerogen has been suggested.

Apparently, material from which the shale beds were derived was originally deposited in the form of fine clays on the bottom of lagoons and swamps. If the theory of Steuart is accepted, there was associated with these sediments vegetable matter converted into a pulp as a result of maceration and microbe action in water, richer materials of many kinds,

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[1] Carne, J. E., "The Kerosene Shales Deposits of New South Wales".
Steuart, D. R., The Chemistry of the Oil Shales. Oil Shales of the Lothians, Geol. Surv. Scotland, 1912.

lbs., valued at $409,642, an average unit price of 0·76 cent per pound. No exports of this commodity are reported by the Department of Customs.

The average importation of Glauber's salt during each of the three years prior to the war was 1,448,510 lbs., valued at $7,000, an average unit price of 0·48 cent per pound. In 1918-19, 551,213 lbs., valued at $10,080, were imported, at an average unit price of 1·80 cents per pound. In 1919-20 the imports were 710,177 lbs., valued at $8,871, an average unit price of 1·11 cents per pound.

At the present time the Canadian kraft pulp industries consume about 40,000 tons of anhydrous sodium sulphate annually and the demand is steadily increasing.

Canadian Situation

Natural sodium sulphate occurs as one of the constituents of the brines in certain alkaline lakes in the provinces of Manitoba, Saskatchewan, Alberta, and British Columbia. It also occurs in the beds of the lakes in layers, usually associated with other salts and with peaty material. A pure Glauber's salt can be obtained by evaporating the brines or by dissolving the soluble salts already deposited, and separating the sulphate of soda by differential crystallization. Glauber's salt contains 55·9 per cent water of crystallization. It will be necessary to develop processes of eliminating this water on account of the high freight rates to eastern markets, before it is commercially practicable to develop these deposits. Theoretically this appears easy, but there are a number of practical difficulties in the way of development which have not yet been overcome. Several attempts have been made to develop some of these deposits, but only one company appears to have attained any marked measure of success.

The principal raw material for the production of the artificial sulphate of soda is common salt. As already noted in discussing the raw materials for making hydrochloric acid, this material is available in the provinces of Nova Scotia, Ontário, and Alberta.

At the present time there are three firms equipped to produce anhydrous salt cake from sodium chloride, two plants being located in Ontario, and one in British Columbia. Canadian production has amounted to 6,000 tons per annum, but normally is much less than this, being largely dependent upon the ability of the home market to absorb hydrochloric acid.

SODA ASH

Crude commercial sodium carbonate is known as soda ash. It is a yellowish or greyish white material, in powder or lump form, containing 98—99 per cent sodium carbonate (Na_2CO_3) and slight quantities of sodium chloride, caustic soda, sodium sulphate, sodium sulphite, calcium or magnesium carbonate as impurities. The finished product is often ground before packing for shipment.

Processes

In the ammonia-soda (Solvay) process soda ash is made from common salt by treating a saturated solution with ammonium carbonate or with ammonia gas, and carbon dioxide under pressure. The resulting product is sodium bicarbonate, which is insoluble in the saturated brine and therefore is precipitated. The bicarbonate ($HNaCO_3$) is separated from the brine by filtration, washed and treated in special calcining furnaces to form the carbonate. In the operation of the Solvay process ammonia gas is usually obtained as a byproduct from coke ovens. The ammonia liquors, available as a waste product in municipal gas works, are also suitable for use in this process. The ammonia used in the process, which remains in the liquors as ammonium chloride, is recovered by treatment with lime. The final waste product is a solution of calcium chloride. Carbon dioxide is obtained by burning limestone with coke under careful control to obtain the maximum yield of gas. The lime obtained is used in the process of recovering ammonia from the waste liquors.

Soda Ash by the Ammonia-Soda Process

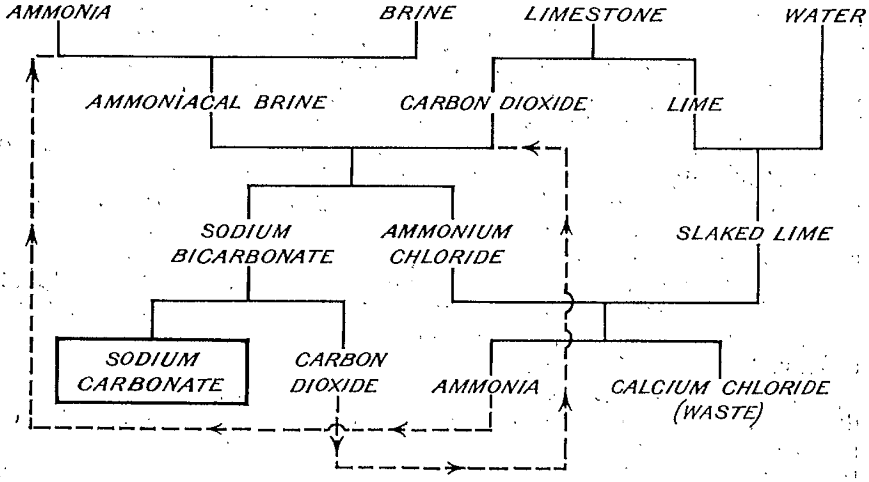

Diagram 3

Soda ash is also made by the Leblanc process. The raw products required are sodium sulphate, calcium carbonate (limestone), and coal. Mixed in proper proportions these materials are heated to fusion into a thick pasty mass, a special type of reverberatory furnace being employed. At this temperature reactions take place which result in the formation of sodium carbonate. When the reactions are completed the product is drawn from the furnace and cooled. In this stage the product is a more or less black porous mass, currently termed "black ash." The black ash is subjected to lixiviation with water, the resulting liquors after filtration contain sodium carbonate in solution, together with small amounts of sodium hydroxide and other sodium salts as impurities. The liquors are evaporated to a density sufficient to cause the sodium carbonate to crystallize.

The crystallized carbonate is then treated in a special calcining furnace, usually of the reverberatory type.

Incidentally the residues after lixiviation contain calcium sulphide. If these residues are treated with carbon dioxide the sulphide is decomposed

Soda Ash by the Leblanc Process

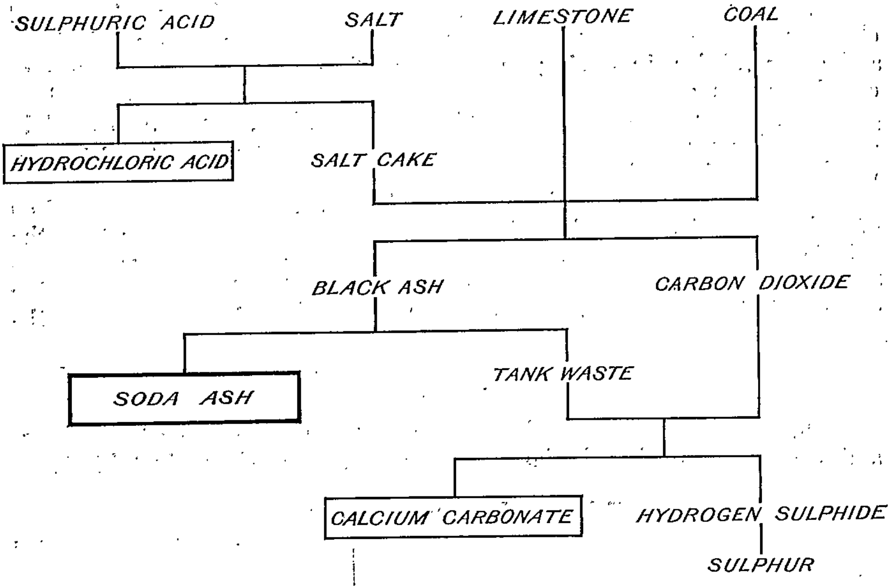

Diagram 4

with the formation of hydrogen sulphide and calcium carbonate. The hydrogen sulphide can be converted directly into sulphuric acid by oxidation, or can be treated to recover elemental sulphur.

It is sometimes necessary to subject crude soda ash to a further refining process to eliminate impurities that are objectionable in certain industries where pure soda ash is required. Refining is usually accomplished by dissolving the crude soda ash in hot water, precipitating the impurities where possible by treatment with bleaching powder, settling, decanting the clear solution, and concentrating the resulting clear liquor by evaporation.

Crystallized sodium carbonate ($Na_2CO_3 \cdot 10H_2O$) is marketed under the commercial name of washing soda.

Sodium bicarbonate ($HNaCO_3$) is made from the crystallized carbonate by special treatment with carbon dioxide.

Industrial Uses

Soda ash is one of the most important products of the Alkali industry, and is an essential material in many manufacturing processes. It enters into the composition of glasses; washing, laundering, and cleaning compounds may contain it; it is used in the manufacture of soaps, and certain grades of paper. It finds applications in paint manufacture, in the production of leather, in the dyeing of textiles, in the making of enameled metal products, in the refining of oils, and in metallurgy. It can also be used for the production of caustic soda, or for the production of numerous sodium salts. Washing soda and sodium bicarbonate are made from it.

Washing soda finds special applications in laundering, washing, and cleaning preparations, in the washing and bleaching of cotton, wool, linen, and other fabrics, in dyeing or printing fabrics, in the manufacture of certain grades of glass and soap. Some boiler compounds designed to prevent the formation of scale contain this product. It is also used in photographic work, in paper making, and for making fine chemicals of which sodium is the base.

Sodium bicarbonate finds its principal application in the compounding of baking powders, and in culinary operations. It is also used as the vehicle to supply carbon dioxide in the manufacture of numerous preparations for making aerated beverages. It finds applications in the tanning and textile industries, in electroplating with gold or platinum, and in the manufacture of fire extinguishers.

Imports

The average imports during the three fiscal years prior to the war, and the imports during the last two fiscal years are shown in table 7.

Table 7.—Imports of Soda Ash

—	1911-14		
	Quantity	Value	Unit price
	lbs.	$	cts.
Soda ash	56,246,241	432,598	0·77
Sal soda	9,656,176	59,861	0·62
Sodium bicarbonate	6,265,076	59,338	0·95

—	1918-19			1919-20		
	Quantity	Value	Unit price	Quantity	Value	Unit price
	lbs.	$	cts.	lbs.	$	cts.
Soda ash	86,260,061	1,915,923	2·2	52,016,313	1,075,084	2·1
Sal soda	10,671,902	171,346	1·6	10,619,962	158,059	1·5
Sodium bicarbonate	7,109,060	150,772	2·1	7,443,148	164,198	2·2

Canadian Situation

The basic raw material of the alkali industry is sodium chloride. This mineral, as already indicated, is available in Nova Scotia, Ontario, and Alberta. The ammonia-soda processes also require limestone and by an escarpment of Pre-Cambrian rocks. The area is traversed by a number of large streams, notably the Abitibi, Mattagami, and Missinaibi. Along these Palæozoic sections, including strata of Ordovician, Silurian, and Devonian age, are exposed.

The possibility of discovering well petroleum in Palæozoic rocks of the James Bay coastal plain, has recently drawn attention to certain petroliferous shales which outcrop on the Abitibi and Mattagami rivers. These shales, which belong to the Ohio formation, are well exposed at the Long rapids on the Abitibi river, and to a limited extent above the Long rapids on the Mattagami river. Sections exposed along the Abitibi are marked by a series of low folds, the general strike of which is approximately east and west. The maximum thickness of shale observed at any point was approximately 55 feet.

In places the shales are covered by a comparatively light overburden of boulder clay and other unconsolidated materials. The construction of the proposed extension of the Timiskaming and Northern Ontario railway would bring the deposits within reach of rail transportation.

In 1911[1] these shales were examined by the writer, and samples subsequently tested in the laboratory showed a content of petroleum ranging from 7 to 16 Imperial gallons per long ton. The maximum yield of ammonium sulphate was equivalent to 16 pounds per long ton of shale. Partial analyses of three other samples, collected by Dr. M. Y. Williams,[2] indicated a yield of from 3·5 to 12 Imperial gallons (4·2 to 14·4 U.S. gallons) crude petroleum per ton of shale. The calculated yield of ammonium sulphate, based on the nitrogen content, was equivalent to from 18·8 to 38·6 pounds per ton. The amount recoverable in actual commercial practice would be considerably less.

Provinces of Manitoba and Saskatchewan

NOTE.—During the field season of 1921, the writer undertook a reconnaissance with a view of determining the probable economic importance of the Cretaceous shales of the Pasquia hills, Porcupine, Duck and Riding mountains. A complete report embodying the results of this work is in course of preparation.[3]

During recent years, attention has been directed to reported occurrences of oil shales of Cretaceous age in the provinces of Manitoba and Saskatchewan. Forty-one samples of the shales, representative of a wide area, were collected by the writer during the field season of 1921, and were subsequently tested in the laboratory. The maximum yield of crude petroleum from any sample was 10·9 Imperial gallons (13·1 U.S. gallons), while the maximum yield of ammonium sulphate was equivalent to 3 pounds per ton of shale. The specific gravity of the crude petroleum varies from ·944 to ·984. All shales examined carry a high percentage of water, the average content of 15 samples being equivalent to 15·4 Imperial gallons (18·4 U.S. gallons) per ton.

It appears, therefore, that the shales examined in the provinces of Manitoba and Saskatchewan are of little present economic importance as a possible source of petroleum or ammonium sulphate. Should conditions at any time warrant commercial development, open cut mining

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[1] Report on James Bay Surveys, 1912, S. C. Ells.

[2] Geol. Surv. Can. Summ. Rept. 1919, Part G.

[3] Mines Branch, Dept. of Mines, Memorandum Series No. 3, 1921.

could be undertaken in many areas under favourable conditions. Over very considerable areas, shales examined are covered by a comparatively light overburden, consisting chiefly of boulder clays and gravel, which could be readily removed by hydraulicing methods.

Province of British Columbia

The occurrence of oil shales has been reported[1] near Harper's camp in the Cariboo district, near Lytton, and along Calder creek, a tributary of Flathead river. Detailed exploration of these occurrences has not been undertaken, but from present information it appears that the maximum yield of crude petroleum from any sample tested does not exceed 7 Imperial gallons per ton.

On Graham island, the most northerly of the Queen Charlotte group, viscous hydrocarbons have a wide distribution throughout sedimentary and intrusive rocks of Cenozoic and Mesozoic age. Semifluid bitumen is seen as thin films along bedding planes and joint surfaces, as veinlets in various fractured rocks, and in amygdules of certain basalts, as at Tian point. This condition was observed by the writer in 1905, and has subsequently been fully described by J. D. Mackenzie in a report[2] dealing with the geology of Graham island.

The presence of traces of bitumen over a wide area on Graham island was, at one time, interpreted as a possible indication of petroleum pools. Mackenzie considers that the bitumen originates in the Maude formation, a series of dark coloured, fine-grained, thinly laminated and highly fossiliferous argillites, of Lower Jurassic age. He considers that the possibility of discovering commercial pools of petroleum, associated with sediments of Graham island, may be regarded as remote, but suggests the possibility that oil shale bands of commercial value may be found associated with the Maude formation.

Provisional District of Mackenzie

From time to time, during the past 30 years, the occurrence of oil shale has been reported[3] along the Mackenzie river between Fort Norman and Fort Good Hope. These shales are associated with rocks of Devonian age, but little information is as yet available regarding their thickness, extent, and value as a possible source of petroleum and various by-products. The outcrops occur some 1,500 miles to the north of the city of Edmonton, the nearest large centre of population, and apart from other considerations, their geographical position thus renders them of little present economic importance.

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[1] Ann. Rept. of Min. of Mines, B.C., 1903, p. 24.
Ann. Rept. of Min. of Mines, B.C., 1904, pp. 23, 24.

[2] Can. Geol. Surv. Mem. 88, 1916.

[3] McConnell, R. G. "An Exploration in the Yukon and Mackenzie basins, N.W.T.", Geol. Surv. Can. Ann. Rept., new series, vol. IV, pt. D, 1888-89 (1890), p. 31.
Kindle, E. M. and Bosworth, T. O., "Oil Bearing Rocks of Lower Mackenzie Valley", Geol. Surv. Can. Summ. Rept., 1920, Pt. B.

Provisional District of Franklin

Among the specimens collected by Captain Bernier during the voyage of the SS. Arctic in 1908, were black oil shales, which were picked up on the beach of Melville island. These specimens are rich in hydrocarbons, kindling readily when ignited by a match. They are apparently of the same class and probably of the same horizon as the oil shales of New Brunswick, Newfoundland, and Bear island, Spitzbergen.

The results of a sample determined in the laboratory of the Mines Branch showed 64 pounds of ammonium sulphate and 140 Imperial gallons of crude oil per ton of shale.

CONCLUSION

In referring to possible commercial development of oil shales in North America, many writers have cited the admitted success which, until recent years, has attended the Scotch oil shale industry.[1] But new and well recognized factors are already reflected in declining output throughout at the Scotch oil shale works. Among these factors may be mentioned higher operating costs, increasing production of well petroleum from new and from established fields, the potential importance of recognized, but as yet unproductive oil bearing areas, and an increasing production—accompanied by declining market values—of ammonium sulphate derived from sources other than oil shale. Certain of these factors may be of temporary significance only.

Certain of the oil shale deposits of Canada warrant careful investigation. These deposits represent a large aggregate tonnage of valuable shale, and there is good reason to suppose that, under reasonably favourable conditions, they will eventually prove of sufficient merit to constitute the basis of a large and lucrative industry.

Commercial development of these deposits will be determined by the question of supply and demand, for it may be assumed that efficient retorts, adapted to the treatment of various types of shale, will be developed. Apparently mining charges will constitute the most important single factor in production costs, and for the immediate present, will adversly affect development. Exceptional instances may exist where shales carry reasonably high values, and where conditions affecting mining operations are unusually favourable.

Should conditions not appear favourable to commercial development in the immediate future, certain of the oil shale deposits of Canada should, nevertheless, be regarded as constituting potentially a valuable national asset.

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[1] Beilby, G. "Thirty Years of Progress in the Shale Oil Industry." Jour. Soc. Chem. Ind., Vol. XVI., pp. 876-886, 1897.

Caldwell, W., "The Working of Oil Shale at Pumpherston." Trans. Inst. Min. Engr. Vol. XXXVI, pp. 581-589, 1909.

Craig, Perkin and others, "The Scotch Oil Shale Industry," 1918.

Ells, R. W., "Bituminous Shales of Nova Scotia and New Brunswick, with notes on the Oil Shales of Scotland." Summ. Rep. Geol. Surv. Can. for 1908 and 1909.

Ells, R. W., "Joint Report on the Bituminous or Oil Shales of New Brunswick and Nova Scotia, also on the Oil Shale Industry of Scotland." Bulletins 55 and 1107, Can. Dept. of Mines, 1909.

VIII

CHEMICAL PRODUCTS FROM NATURAL GAS

R. T. Elworthy

Canada has large resources of natural gas, second only in importance to those of the United States. The chief fields are in western Ontario and Alberta, and the annual production in each province is between ten and fifteen thousand million cubic feet.

The supplies of gas from the Ontario fields are, however, decreasing. The old wells are falling off in output and the high cost of drilling new wells and small return upon capital outlay have retarded the development of new sources. The proper use of natural gas in Ontario is undoubtedly for domestic fuel, and the activities of the provincial authorities have chiefly been in economic enquiries and in securing the greatest efficiency of the combustion apparatus. There is great room for improvement in the efficient use and combustion of natural gas. People regard it as a never-failing gift of nature and use it in a correspondingly spendthrift manner.

The condition of affairs in the west is somewhat different. Although certain fields in the southern part of Alberta, such as the Bow Island field, are showing signs of exhaustion, new borings give indications of large resources. In the Athabaska region great quantities of gas have been struck. During the next decade, with the increased exploratory drilling for oil, many gas fields are bound to be opened up and millions of cubic feet of gas will be allowed to waste.

These supplies of gas are situated too far from centres of population to be used as fuel. What can be done with them?

In a recent and most suggestive paper[1] before the Institute of Petroleum Technologists on oil field wastes, Beeby Thompson states his opinion that the greatest waste is sustained in hydrocarbon gases. He says:—

> Responsible Washington Officials have volunteered the information that in a few years prior to 1912 not less than 425,000,000,000 cubic feet of gas were allowed to discharge unheeded to waste in the mid-continent oil fields alone, equal to about 9,600,000 tons of oil, or say 14,000,000 tons of good quality coal, whilst gasoline to the value of millions sterling was simultaneously lost. In 1913 a single well in the Cushing oil field gave 1,500,000,000 cubic feet of gas, equal to 34,000 tons of oil, before being shut in, and four others were discharging 126,000,000 cubic feet daily into the atmosphere, equal to about 2,800 tons of coal.

Beeby Thompson suggests the following uses for waste gas:—

(*a*) Transmission in pipe lines to industrial centres.
(*b*) Development of local industries like glass-making, lime-burning, cement works, irrigation.
(*c*) Generation of electric power on a large scale.
(*d*) Production of carbon black.
(*e*) Fixation of nitrogen from the air.
(*f*) Isolation of special constituents.

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[1] Jour. Inst. of Petroleum Technologists, Vol. 8, pp. 1–49, Jan. 1922.

In 1911-14 the bulk shipments averaged 12,563,307 lbs., valued at $117,579, annually. In 1918-19, 11,958,547 lbs., valued at $174,362, were imported.

There is no record for the small package shipments for the three years before the war. In 1918, 178,423 lbs., valued at $13,751, were imported.

In the fiscal year 1919-20 a variation was made in the method of recording these importations. The records for that year include two items as calcium chloride, and two items as chloride of lime and hypochlorite. It is to be assumed that the entries in this latter group refer to chlorinated lime.

Table 8.—Imports of Bleaching Powder

—	Pounds	Value
		$
Calcium chloride in packages of not less than 25 pounds	3,443,324	29,543
Calcium chloride in packages of less than 25 pounds	8,706	963
Chloride of lime and hypochlorite of lime in packages of not less than 25 pounds	20,443,025	368,737
Chloride of lime and hypochlorite of lime in packages of less than 25 pounds	188,579	13,911

Canadian Situation

Limestone suitable for the process is available in a number of localities. Chlorine gas is usually obtained by the decomposition of common salt. As already noted one Canadian firm is manufacturing caustic soda by the electrolysis of brine. The waste chlorine is utilized at the same works for the manufacture of bleaching powder.

CHAPTER II

ELECTROCHEMICAL AND ELECTROMETALLURGICAL INDUSTRIES

This group of industries comprises those which utilize the chemical and thermal effects of electric power for the production of various metallic and chemical products from raw materials of suitable character.

The process of decomposing chemical compounds by the passage of an electric current is called electrolysis. This phenomenon only takes place when the compound or its solution is an electric conductor, and such compound or solution would be termed an electrolyte. Electrolysis may take place in aqueous solution, or in an igneous solution of fused salts. Electrolysis then depends chiefly upon the chemical effects of electric current, the thermal effects being utilized to heat aqueous electrolytes, and to maintain the fusion of igneous electrolytes. Only direct current can be used for processes dependent upon electrolysis.

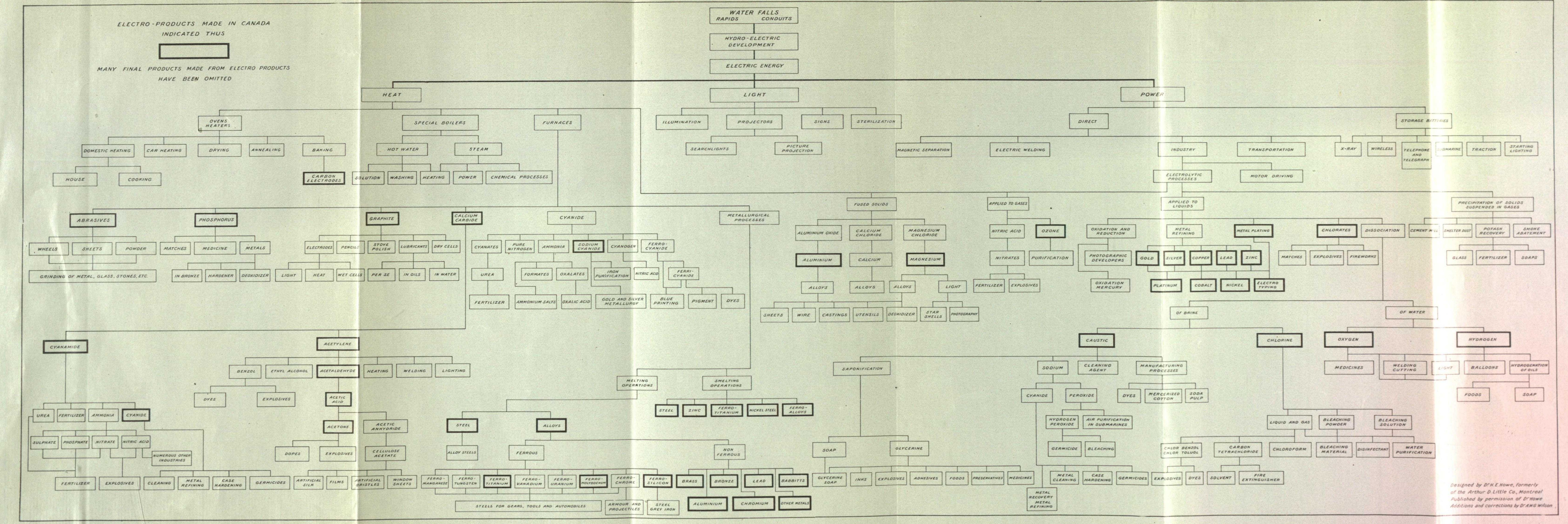
The art of recovering metals from compounds by utilizing either the chemical or the thermal effects of the electric current is termed electrometallurgy. The term includes processes for the separation of metals from their ores, for the production of metallic alloys, for electric deposition of metals, for electro-plating, and for the production of electrotype plates. Processes which involve the fusion of non-metallic products to promote chemical reactions that produce new compounds, as in the manufacture of carbides and abrasives, are sometimes classed as electrometallurgical, although strictly speaking they are electrochemical. Processes where metals are recovered or utilized by electrolysis require the use of direct current. Processes where the thermal effects of the current are utilized to promote high temperatures or fusion may use either an alternating or a direct current, the former being usually given the preference.

The accompanying diagram, showing the principal electro products and their uses, affords a general survey of the development of this industry, and its future possibilities. A better understanding of the immense development that has taken place in this group of industries in recent years, and of the opportunities available for research and expansion can be obtained by a perusal of the following paragraphs. No attempt has been made to give other than very brief explanatory notes. The data given are confined largely to statements of the products made by the use of the electric current from materials noted, without reference to the various special types of equipment that are required and without discussing practical operating difficulties and necessary precautions. Where raw materials mentioned are available from Canadian sources the names have been italicized.

PRODUCTS AND RAW MATERIALS

Electrochemical processes are utilized for the preparation of a very large number of products, both chemical compounds and elements. They are also used in a number of industrial arts. These numerous applications

ELECTRO-PRODUCTS AND SOME OF THEIR USES



Designed by Dr H. E. Howe, formerly
of the Arthur D. Little Co., Montreal
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Additions and corrections by Dr A.W.G. Wilson

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Diagram 5

can be best reviewed briefly by considering the product and the raw materials at the same time, rather than by listing each separately.

Aqueous Electrolytes

Electrolysis of aqueous solutions of salts results in the separation of the base from the acid portion of the salt, both of which may then be in a condition where they can be recovered separately, or where one or both will enter into new combinations. The simplest application of electrolysis is for the production of *hydrogen* and *oxygen* by the decomposition of water, either or both of which can be utilized industrially.

CAUSTIC SODA AND CHLORINE are prepared by the electrolysis of aqueous solution of *sodium chloride.* This method of preparing caustic soda has become one of the most important branches of the alkali industry. Caustic so prepared can be kept free from impurities, and is used as one of the bases from which to prepare the numerous sodium salts required by industry. Similar salts are also prepared from the carbonate produced by the soda ash process described elsewhere. The electrolytic cells used for this process have to be specially designed to facilitate the recovery of chlorine, and to prevent its escape into the atmosphere, on account of its irritating and poisonous effects. The chlorine produced by this process is cooled and condensed to liquid form for industrial use, or is brought into contact with fresh lime in special chambers to make *bleaching powder,* or *calcium hypochlorite,* a product which finds numerous industrial applications. Electrolytic chlorine can be used for making carbon tetrachloride, chloroform, chloral, chlorides of ethylene or acetylene, chloride of sulphur and certain organic chlorides used in the aniline dye industry. Chlorine can be liquefied under pressure when cooled. Liquid chlorine is stored in special steel containers or in storage tanks mounted on railway trucks for transportation in bulk. Large quantities are now shipped in this way to sulphite pulp mills where it is utilized in the preparation of solutions for bleaching wood pulp. Liquid chlorine is also used for purifying domestic water supplies. Chlorine is a byproduct of caustic soda manufacture and new methods of utilizing it are needed if the production of soda is to be increased to keep pace with the demand. Corresponding compounds of potassium can be made by the use of potassium chloride solution as an electrolyte. BROMINE and IODINE can be prepared from natural brines in much the same way as chlorine is recovered from sodium chloride brines.

CHLORATES and PERCHLORATES are made by the electrolysis of corresponding chlorides. When the temperature of the aqueous electrolyte is kept above 45° C. the chlorine liberated by the action of the current reacts with the alkali produced and a chlorate or a perchlorate results. In making chlorates the electrolyte is usually a 25 per cent solution of sodium chloride or of potassium chloride. Small amounts of sodium or potassium chromates respectively are added to the electrolyte in commercial practice to neutralize the action of nascent hydrogen which would otherwise appear at the cathode. Other substances used for a similar purpose are aluminium salts, clay, silicic acid, fluorides of the alkalies, or vanadium compounds. Perchlorates are produced by using a lower current density, lower temperature, and slower electrolytic action. The usual method of operation is to produce a chlorate in the electrolyte until a definite degree of saturation is reached; then the temperature of the electrolyte is lowered and the current density is decreased, and the chlorate is oxidized to the perchlorate. PERCHLORIC ACID is made by making the corresponding ammonium salt and then decomposing by chemical means. Corresponding salts of bromine and iodine can be made by much the same methods.

SODIUM HYPOCHLORITE in dilute solution can be made by electrolyzing sodium chloride in cold solutions. This method is used for producing a bleach to whiten wood pulp and other cellulose products, and sometimes as a disinfectant for laundry use.

There are a large number of other chemical compounds that can be prepared by electrolytic methods. These include many complex organic compounds where the electric current is used either to promote reduction or to facilitate oxidation. The following lists include many of these:—

INORGANIC COMPOUNDS: Acids (chromic, persulphuric); alum, chrome; aluminium chloride (anhydrous); chromates, bichromates, chromic oxide; copper hydroxide and cuprous oxide; hydrogen peroxide; lead compounds (arsenate, carbonate, peroxide, sulphate); perborates; permanganates; persulphates; potassium or sodium ferricyanides; zinc oxide.

ORGANIC COMPOUNDS: Anthraquinone; bromoform; chloral; formaldehyde; hexamethylenetetramine; iodiform; isopropyl alcohol; methyl acetone; paraformaldehyde; paraldehyde; saccharine; vanilla; electrolytic reduction or electrolytic oxidation products of nitro-benzene and its homologues.

The raw materials from which these products are made are largely natural mineral products such as *sodium chloride*, potassium chloride, *chrome ore;* compounds made from natural products, both mineral and organic; or metals obtained from ores.

SECONDARY CELLS, such as storage batteries and dry cells, are dependent on applications of chemical effects of the electric current. The construction and operation of these cells is discussed elsewhere.

Electrolytic processes are used in metallurgy for the recovery of certain metals from their ores, for the refining of these and other metals, and for electro-plating with metals and some alloys. The last group of processes is discussed more fully in the section dealing with the electro-plating industries. Brief references only are made to the two other applications of electrolysis.

COPPER can be recovered from an electrolyte made by leaching suitably prepared copper ore with *ferrous sulphate* solution. In another group of processes sulphur dioxide is used as a depolarizer during the decomposition of copper sulphate electrolytes. A very large proportion of the world's annual production of copper is refined by electrolysis, the electrolyte being *copper sulphate* solution containing a little free sulphuric acid. Copper is recovered by furnace processes directly from the ores. It is delivered to the refinery in cakes as blister copper, which are melted and cast into anodes. Both copper sulphate and copper cyanide are used in copper plating.

LEAD is refined electrolytically by the use of a *fluosilicate* electrolyte, impure anodes having first been prepared from the lead ores by furnace processes.

ZINC is recovered electrolytically from a *zinc sulphate* electrolyte, the latter being prepared from the zinc ore by a process which involves preliminary roasting, leaching, and purifying of the electrolyte. Zinc sulphate electrolytes are also used for coating surfaces with zinc electrolytically.

IRON is prepared from certain iron ores by using a solution of perchloride of iron as an electrolyte. Pure iron is sometimes prepared by electrolysis with ferrous ammonium sulphate solution as the electrolyte. Other salts have also been used for this purpose with more or less success.

The following metals are refined by electrolysis, aqueous solutions of certain salts being used as the electrolyte. The salt most frequently used in commercial practice is indicated although other electrolytes have been proposed and used in some cases.

ANTIMONY has been recovered by using sodium sulphide in a leaching solution. A solution of the fluoride has also been used, the electrolyte containing sodium and potassium fluorides and some free hydrofluoric acid.

BISMUTH has been refined from electrolytes containing sodium tartrates or oxalates. The fluosilicate has been used, and in laboratory determinations the nitrate. It is not prepared commercially by an electrolytic process.

CADMIUM has been refined by using the sulphate as the electrolyte, much the same way as in the refining of zinc. The metal is not in demand commercially.

COBALT could probably be refined by using sulphate solutions much the same way as nickel. Electro-plating with cobalt ammonium sulphate and certain other salts as the electrolyte finds commercial applications.

GOLD is refined by using a solution of the chloride containing free hydrochloric acid as the electrolyte. Complex electrolytes containing the cyanide are used for plating. Processes for recovering gold from its ores by leaching and subsequent electrolysis have been proposed but do not appear to have been commercially applied. An electrolyte so prepared could ordinarily contain gold as a chloride or a cyanide.

NICKEL is not recovered commercially from its ores by electrolysis although several processes have been proposed. Refined nickel can be produced commercially by electrolysis. The electrolytes used either contain sulphate of nickel with some copper sulphate and sulphuric acid, or nickel, iron, copper, and sodium chlorides. Anodes made from partly roasted nickel-copper matte are used in one process, and partly refined nickel anodes in the other. Electro-plating with nickel is an important industrial art.

The salts most frequently used in the electrolyte are nickel ammonium sulphate and nickel sulphate. Other salts have also been employed for this purpose.

SILVER is not recovered from its ores by leaching and subsequent electrolysis. It is refined by the use of an electrolyte containing silver nitrate and free nitric acid. Silver plating is usually accomplished by the use of electrolytes containing silver cyanide and potassium cyanide. Other more complex baths are also used for plating where certain special results are required.

TIN is not recovered electrolytically from its ores, although both leaching and fusion processes have been proposed. Byproduct tin is recovered from scrap, using a caustic soda solution as an electrolyte. Sodium chloride, sodium stannate, stannic tetrachloride, and ferric chloride have also been used in various electrolytes that have been proposed and tried out. Plating with tin by electrolysis has also been tried. An alkaline electrolyte containing stannic chloride, caustic potash and potassium cyanide, and an acid electrolyte containing stannous chloride and sodium pyrophosphate have been used successfully. Electrolytes containing organic acids and salts in solution have also been used.

Igneous Electrolytes

A number of metals of industrial importance are recovered by the electrolysis of igneous solutions, the operations being conducted in such a way that the resulting metal is not subjected to oxidation by exposure to the air while hot. The igneous solution used as the electrolyte consists of a fused salt of the metal required, or of a fused salt in which the ore of the metal required can be dissolved, the salt being one which requires a higher potential for decomposition than the ore under treatment. Chlorides and fluorides are generally used in the formation of igneous electrolytic baths.

ALUMINIUM is prepared by the electrolysis of aluminium oxide in a bath of fused cryolite, a natural sodium aluminium fluoride. The electrolyte sometimes contains additions of sodium fluoride, calcium fluoride, or aluminium fluoride. The oxide is prepared from the mineral bauxite by a preliminary purification. The electrolyte is prepared by mixing aluminium oxide, cryolite, and fluorspar in the proper proportions, and then subjecting them to the action of hydrofluoric acid. After treatment the product is dried and fused in the electric furnace. When the furnaces are in operation additions of aluminium oxide must be made to the bath to maintain the proper composition and to prevent a rise in voltage.

MAGNESIUM is prepared by the electrolysis of the natural salt potassium magnesium chloride (carnallite). It can also be prepared from the fused chloride. During the operation of a cell anhydrous magnesium chloride is added from time to time to maintain the electrolyte.

CALCIUM is made from fused anhydrous calcium chloride. BARIUM and STRONTIUM can also be produced by the electrolysis of the fused chlorides.

SODIUM is prepared by the electrolysis of the fused hydroxide. The two principal processes employed are the Castner and the Griesheim. These differ in the design of the cell employed and in the method of collecting the metallic sodium. Both the nitrate and the chloride have also been used in processes for recovering sodium. Processes have been devised for using this latter salt as fused electrolyte, the sodium being collected indirectly in molten lead from which it was afterwards recovered. Modifications of these are now in use for the production of caustic soda. The metal has also been recovered successfully by the direct electrolysis of the fused chloride in a special type of furnace, but this process is not in general use.

POTASSIUM is prepared from the fused hydroxide much in the same way as sodium, but special care has to be taken to prevent the oxidation of the metal.

LEAD and ZINC have been prepared by the electrolysis of fused salts, but the methods are not commercially successful.

Some of the rare metals have been recovered by the electrolysis of aqueous solutions of selected salts. INDIUM may be recovered from the neutral sulphate; the nitrate and the chloride have also been used, the bath being slightly acidified with an organic acid such as formic, or with sulphuric acid in the presence of ammonium sulphate. THALLIUM has been recovered in the same way from an electrolyte containing ammonium thallium oxalate. LITHIUM has been recovered by the electrolysis of organic salts.

Other rare metals are prepared by the electrolysis of fused salts, the operation being carried out under conditions which prevent the oxidation of the metal. BORON has been prepared from boric acid dissolved in fused sodium biborate. CERIUM, LANTHANUM, LITHIUM, NEODYMIUM, PRASEODYMIUM, SAMARIUM, and URANIUM have been recovered by the electrolysis of the fused chloride of the corresponding metal. MANGANESE can be recovered by the electrolysis of the fused chloride or fluoride dissolved in a fused chloride of an alkali. TITANIUM has been recovered by the electrolysis of the dioxide in solution in fused calcium chloride. VANADIUM can be recovered by the electrolysis of the fused fluoride.

Electrothermal Processes

Electrothermal processes for the recovery of metals from their ores utilize the electric current only as a source of heat to promote fusion and to raise the temperature of the products treated to a point where desired chemical reactions will take place. The methods are commercially applied to the production of many of the rarer metals, or those which are difficult of reduction. The operation usually takes place in the presence of carbon (coke) and fluxes. CHROMIUM, MANGANESE, MOLYBDENUM, TITANIUM, TUNGSTEN, URANIUM, and VANADIUM can be recovered by this method.

SILICON and ZIRCONIUM are also reduced from the oxides by treatment in an electric furnace. PHOSPHORUS is obtained by the fusion of calcium phosphate (apatite, bone ash, or rock phosphate) in the presence of silica and carbon. ARSENIC has been obtained by heating mispickel in an electric furnace of special design (Westman process). TIN is not at present recovered by this process. Processes have also been developed for the production of the metals COPPER, NICKEL, and ZINC from their ores, especial attention having been given to zinc. These processes are not in successful commercial operation in America, but both nickel and zinc are being recovered in this way in small amount in foreign countries.

PIG IRON for industrial purposes is usually produced in blast furnaces, by smelting the ores with carbon in some form (coke, charcoal), limestone being used as a flux. The carbon content of the charge serves not alone to produce heat but also to reduce the oxides of iron present. Electrothermal methods of supplying the heat, the ore being reduced with carbon, have been in course of development during the last twenty-five years and they are now in successful operation in Europe, particularly in Sweden and Norway, where fuels are scarce and hydro-electric power is abundant and cheap.

GRAPHITE for industrial use is prepared from petroleum coke or anthracite coal in a special type of resistance furnace. Certain varieties of soft graphite made by the electrothermal process are the basis of important lubricants and paints. Graphitized carbon electrodes, made from petroleum coke or anthracite, are one of the essential requirements of many electrochemical industries. Anthracite for the making of electrodes is crushed and subjected to preparatory treatment in an electric furnace. The prepared anthracite is then mixed with a suitable binder, moulded into electrodes, and afterwards baked in special furnaces heated with electricity.

The electrothermal effects of the electric current are applied to the production of a number of alloys and chemical compounds of industrial importance.

STEEL is made from pig iron and scrap by fusion with fluxes in electric furnaces. ALLOY STEELS of all kinds are made in this way, the various alloying metals being added to the steel bath as ferro-alloys.

FERRO-ALLOYS are made in the electric furnace either directly from ores, or by the fusion of metals previously prepared. The more important ferro-alloys are those of *chromium, manganese, molybdenum, silicon, tungsten,* and *vanadium.* Alloys with *aluminium, boron, cerium, magnesium, titanium,* and *uranium* are also made.

NON-FERROUS ALLOYS of all kinds can be made in electrically heated furnaces. The method is commonly used for making *aluminium alloys, brasses, bronzes,* and *gun metal.* It is sometimes used for making *white metal alloys* and *bearing metals. Stellite,* an alloy of chromium, cobalt, and tungsten, is used for high speed cutting tools, and for making certain kinds of so-called "stainless steels." *Cuprovanadium, silicon-manganese,* and a number of other similar products are also made by electrothermic methods.

The thermal effects of the current are applied to promote the formation of new compounds or for refining and purifying products, both applications being of great industrial importance.

CARBON BISULPHIDE is made by fusing and vaporizing sulphur, and passing the vapour through red hot carbon, the operation taking place in a furnace of special design, and the heat being supplied by an electric current.

CALCIUM CARBIDE is made by fusing lime and coke in an electric furnace. The raw materials of this process are *coal* and *limestone*. The product finds many uses, and is made in large quantities. Other carbides could be made by a similar method if required.

CYANAMIDE is made from calcium carbide and pure *nitrogen* in special furnaces electrically heated.

NITRIC ACID, NITRATES, NITRITES, AMMONIA, and CYANIDES can be made from atmospheric nitrogen by processes which involve the use of electric power. These are discussed at more length in the section on Nitrogen.

OZONE is made by the use of a silent discharge of current at high potential between suitably arranged electrodes past which dry air at room temperature is forced. Ozone is used for bleaching, disinfecting, and other industrial purposes.

ARTIFICIAL ABRASIVES, which find numerous applications in the grinding and polishing of metals, glasses, and other materials, form another important group of products produced by electric power.

Carborundum is made from coke, sand, and hardwood sawdust to which a little sodium chloride has been added. This mixture is heated in a furnace of special design. The intense heat that is generated in the centre of the mass, by the passage of the current, results in the formation of carbide of silica (SiC) in crystal form, this constituting the artificial abrasive known commercially as *carborundum*. In addition to the crystals a quantity of amorphous carbide of silica is produced at each heat, which is used industrially as a refractory. This is one of several closely related compounds of silicon and carbon which are formed during the operation, some of which are utilized (silicon monoxide, "siloxicon," "fibrox"). A modification of the process makes it possible to produce vessels or other articles which are essentially carborundum, by previously shaping or moulding the article in carbon, and then subjecting it to the action of vaporized silicon. Articles of this kind are marketed under trade names such as "silfrax," "silundum," and other designations. Carbide of silicon as an abrasive is marketed under several different trade names, *carborundum* being the first designation used. "*Carbolon*," "*carbosolite*," "*crystolon*," and "*electrolon*" are essentially the same products, the different names being given by different producers. These products are also used as refractories where articles capable of withstanding high temperatures are needed in industrial operations.

Another important abrasive produced by applications of the thermal effect of the electric current is *artificial corundum.* Its discovery and development as an industrial product is due to the many attempts which have been made to develop methods for manufacturing artificial rubies and sapphires. The first artificial abrasive of this composition was made by heating crushed emery with charcoal or coke. The natural mineral contains iron and silica which were removed by the process, practically pure aluminium oxide being produced. Some of the iron is also recovered as ferrosilicon. Later methods employed aluminium oxide or materials containing the oxides in quantity. When the natural oxides are subjected to the intense heat of the electric furnace a dense fused product of essentially pure aluminium oxide is produced, and this constitutes the abrasive. Modern practice utilizes bauxite as the raw material. This is first calcined to drive off the combined water. A small amount of coke or charcoal and silica are mixed with the fused oxide, unless these are present in the original bauxite in sufficient quantity to remove the iron and other impurities. A low grade ferrosilicon is usually produced in commercial practice, which is marketed as a byproduct. The calcined material is charged to a special type of electric furnace and fused by the passage of the current. Artificial corundum is marketed under a variety of trade names, the chief of which are " *aloxite,*" " *alundum,*" " *coralox,*" " *boro-carbone,*" "*exolon,*" "*natite*" and "*artificial alumina.*" "*Oxalumina*" is made from aluminium bearing clay and ores; "*Adamite*" contains about 80 per cent aluminium oxide, and some silicates; " *Werlein's artificial abrasive* " is an aluminium-silicon compound.

ROUGE and CROCUS powders are made by calcining ferrous sulphate in crucibles. The heat is usually supplied by the combustion of a fuel, but electric heat could be used for the purpose.

CRUSHED STEEL, made by hardening special steels, and CRUSHED CAST IRON are also used as abrasives for special purposes. The metal for making these products can be prepared in an electric furnace, or furnaces heated by combustion could be used.

The heating effect of the electric current is used for a number of industrial operations. Electrodes made from petroleum coke or anthracite coal are baked with electric heat, a process which makes the electrochemical industries possible. Abrasives, shaped into wheels and sharpening stones by moulding and pressure, are held together by the use of special binding materials, the whole being solidified by drying or vitrifying in electric furnaces. Other similar operations performed in electric furnaces are the drying and baking of varnish enamels, the fusion and vitrifying of ceramic enamels, glasses, and other similar products.

ELECTRIC POWER is used for heating vessels, containers, and catalysts used in a number of chemical operations. Starting with coal and limestone as raw materials, calcium carbide is made. Calcium carbide and water yield acetylene gas. Treated in special electrically heated furnaces in the presence of suitable catalysts it is possible to produce a number of products by synthesis. *Acetaldehyde, acetic acid,* and *acetone* are made in this way in commercial quantities. Accessory materials required in these operations are mercury, sulphuric acid, caustic soda, and lime. The heating effect of the electric current is used for fusing quartz (pure silica sand) for the purpose of making tubes, evaporating dishes, and other articles required in the chemical industries.

ELECTRICAL PRECIPITATION of solid dust particles, carbon, and metallic salts contained in stack gases, smoke, and fumes discharged from industrial plants is now an important commercial process. Similar methods are used to prevent the dissemination of injurious dusts and fumes, and for the recovery of liquids disseminated in fine vapours. The static effects of an intermittent unidirectional current at high potential are used for this purpose.

Accessory Materials

The electrochemical industries naturally consume large quantities of accessory materials for the construction of apparatus and equipment. Electrolytic processes, where the electrolytes are aqueous solutions, may use containers made of glass, porcelain, lead, carbon, wood, cement, or cellulose products. Bitumen, tar, or bituminous paints, sulphur and sand mixtures, paraffin, and graphite mixtures are used as protective coatings. Wires, rods, bars, sheets, woven wire sheets, and plates of several different metals are used in different operations. Copper is the metal most in demand for conductors, but aluminium might be used in certain places; lead is used chiefly for lining tanks, and as electrodes in some operations; nickel is occasionally used for electrodes; silver or platinum is used only in certain special processes; other metals are only rarely required. Carbon is often used in making electrodes (either gas carbon or artificial graphite) and less frequently artificial magnetite. Porous diaphragms are made from ceramic materials, either baked clays or special porcelains. Carbon, carborundum, alundum, and other such materials are used occasionally.

Electrolysis of igneous solutions necessitates the use of materials insoluble in the electrolyte for containers and electrodes. Cast iron or nickel sheets are used in some cases. Other operations require the use of bricks or cements made from silica or calcined magnesite for lining the furnaces. Sometimes such materials as carborundum, alundum, or zirconium oxide are employed. Carbon or graphite electrodes are generally used especially at the higher temperatures.

Electrothermal operations necessitate the use of various refractories or carbon as furnace linings, and graphite, carbon, or anthracite electrodes. Furnaces may be constructed of bricks of several kinds, or of cement, bar iron tie rods or cast iron or sheet steel jackets being used where required. In some operations a portion of the charge itself (either in a natural condition or fused) serves as a refractory to protect the walls of the furnace, which is then of relatively simple construction. Conductors are almost invariably copper products, wires, rods, bars, plates, or castings. Aluminium wires and rods could be used at some points.

Furnaces for baking, vitrifying, and similar operations, are usually constructed of cement or brick, refractory linings being used where required.

When electric heat is used for promoting catalytic operations asbestos, magnesium oxide, glass wool, or diatomaceous earth may be used as heat insulators. Units of these kinds suffer little deterioration by use, and the actual consumption of replacement materials is necessarily small.

Electric power for use in these industries can be provided by steam plants or from hydro-electric generating stations. Power is usually transmitted at relatively high voltages, whereas electrochemical operations are usually carried on with currents at low pressure, therefore transformers are almost always required. Alternating current is usually delivered to transmission lines and therefore those electrochemical operations which require direct current at low voltage necessitate the installation both of transformers and converters.

Statistical Data

The general tables of statistical information given on another page include available data with respect to imports and exports of such electrochemical products as are mentioned in the Canadian tariff. Further generalized data will be found in the reports on Chemicals and Allied Products issued by the Dominion Bureau of Statistics. The latest available at the time of publication is the list for 1919 and 1920 and that for 1921. Statistical information with respect to the electrolytic production of metals, and with respect to the electrothermal production of steel, metals, alloys, abrasives, and carbide will be found in the annual reports on Mineral Production issued by the Dominion Bureau of Statistics.

The statistical data available are not prepared in such a way as to give information with respect to our annual requirements of many individual products. The annual production of many products is given and where the exports and imports are itemized it is possible to obtain an approximation as to the annual consumption of a few individual products. No data with respect to unabsorbed stocks of products at the time of preparing the statistical reports are issued.

As a rule, chemical products made by electrical processes are not distinguished in statistical reports from those made by other processes.

There are no segregated statistical data relating to the development of electrochemical industries in Canada. The total amount of available electric power devoted to these industries is not shown in any published statements.

Canadian Situation

A perusal of the preceding sections of this report has shown that a very wide range of commercial chemical products are manufactured from relatively common raw materials by electrochemical processes. All these processes require electric current; in some cases power is required in large blocks, in other cases the power requirements are relatively small. Most of the industries require continuous power deliveries, and very few operate with a variable load. The power factor for these industries is therefore high. While power requirements are not the only condition which will determine the location of any group of electrochemical industries, they are, nevertheless, important controlling factors, and where other conditions, especially with respect to labour, raw materials, and markets, are equal, or nearly so, a cheap source of power will be the determining factor in deciding on location. In view of this fact the following abstracts from a report issued by the Dominion Water Power Branch are of special importance and significance in their bearing upon the possible future developments of the electrochemical industries in Canada.[1]

"The water-wheels installed throughout the Dominion total 2,762,880 horse-power. A detailed analysis of the relationship between this installed power, taking into consideration local pondage and load factors, and the corresponding available water-power indicates that *at present recorded available water-powers* of the Dominion will permit of a turbine installation of *41,700,000 horse-power.* In other words, the present turbine installation represents only *6·6 per cent* utilization of the present recorded water-power resources. In support of this statement it may be said that the detailed analyses made of the water-power resources of the provinces of New Brunswick and Nova Scotia have disclosed most advantageous reservoir and pondage facilities for regulating stream flow, and it is estimated that, allowing for the diversity factor between installed power and customer's demands, the two provinces possess respectively 200,000 and 300,000 commercial horse-power as against the lower figures given in the table." "The total available and developed water-power resources of Canada are presented as follows:—

Table 9.—Available and Developed Water-power Resources of Canada

Province	Available 24-hr. power at 80 p.c. efficiency		Turbine installation h. p.
	At ordinary min. flow h.p.	At est. flow for max. dev. (dependable) for 6 mos. h.p.	
1	2	3	4
British Columbia	1,931,142	5,103,460	305,315
Alberta	475,281	1,137,505	33,187
Saskatchewan	513,481	1,087,756	....
Manitoba	3,270,491	5,769,444	104,147
Ontario	4,950,300	6,808,190	1,212,650
Quebec	6,915,244	11,640,052	1,105,385
New Brunswick	50,406	120,807	30,180
Nova Scotia	20,751	128,264	46,948
Prince Edward Island	3,000	5,270	1,869
Yukon and Northwest Territories	125,220	275,250	13,199
	18,255,316	32,075,998	2,762,880

"Practically every large industrial centre throughout the Dominion is now served with hydro-electric energy, and has within easy transmission distance ample reserves of water-power. *Over 90 per cent of the prime motive power of the central electric station industry of Canada is hydro power.*" * * * * * "With a water-power development of 315 horse-power per 1,000 population, Canada stands well to the fore in respect to availability and utilization of hydro-power resources, being surpassed on this basis by Norway alone. The enormous water-power reserves still untouched form a substantial foundation for the progressive exploitation and development of other natural resources." * * * * * * * "About 1·65 times as much electric

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[1] Central stations in Canada, 1920, published by Dominion Bureau of Statistics, Ottawa, 1923, p. 4, *et seq.* Consult also "Directory of Central Electric Stations in Canada," Dominion Water Power Branch, Ottawa.

energy per capita was generated by central electric stations in Canada as in the United States" (in 1920). * * * "In Canada 97.2 per cent of the total electricity produced by central stations was generated by water-power and only 2·8 per cent by fuel, while in the United States only 37.1 per cent was generated by water-power, and 62·9 per cent by fuel stations." * * "The comparison of hydraulically developed electricity per capita was much more favourable to Canada, being 660 kilowatt hours, as against 153 kilowatt hours per capita in the United States."[1]

The capital invested in the central electric station industry in Canada is placed at $448,273,642, being much greater than that invested in any of the other basic industries of the country, except steam railways[2] (in 1920).

There are two electrochemical centres in Canada in the vicinity of large central power developments. One of these is in the vicinity of Niagara Falls, Ontario, and the other at Shawinigan Falls, Quebec. Electrochemical operations are also carried on at other points in Canada, but on a relatively smaller scale. Power from the Niagara district is used for municipal lighting, for street railway operation, and for general industrial purposes as well as for electrochemical industries. While the total amount of power available will be about 730,000 horse-power, the demands on this power for other purposes are so great that the amount available for electrochemical industries will be a relatively small proportion of the whole. The actual amount now in use in electrochemical industries has not been made public. In the basin of the St. Maurice river, Quebec, of which Shawinigan Falls is the industrial centre, there are potential and developed power resources in excess of one million horse-power, only about one half of which is now in use. This power also is used for municipal and general industrial purposes, but to a less extent than in the Niagara district. About one quarter of the power now available is used for electrochemical industries, and there are additional possible resources in excess of half a million horse-power that will be made available as required.

There are a number of other localities where large blocks of cheap power could be developed if required for industries of this type should commercial conditions ever make it desirable to do so.

The electrochemical industries established in Canada are briefly mentioned in the following sentences. Reference has been made in another section to the electro-plating industry. There are two electrolptic copper refineries in Canada with an annual rated capacity of 19,000 tons; one nickel refinery with a capacity of 7,500 tons; one lead refinery with a capacity of 50,000 tons; one zinc refinery with an annual capacity of 30,000 tons. Aluminium is made at one plant from imported bauxite ores; and magnesium was, at least for a time, made in another plant in the same district. Gold is refined electrically at the Royal Mint and at one small private plant; silver is refined electrolytically at one small private plant. Phosphorus is made at one plant, using local silica, imported calcium phosphate, and coke purchased from a manufacturer using either imported or domestic coal.

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[1] *Loc. cit.*, p. 12.

[2] *Loc. cit.*, p. 14.

Caustic soda is made at one plant by the electrolysis of sodium chlorine brines. The chlorine is absorbed by lime to make bleaching powder, or is liquefied for industrial use. One other plant also makes chlorine for its own use and another company makes hypochlorite bleaching solutions at two points for use in its own plants. One manufacturer produces chlorates and perchlorates of sodium or potassium, chiefly for the use of manufacturers of explosives. One plant produces acetaldehyde, acetic acid, and acetone by a synthetic process, using electric power as a source of heat.

Reference has been made in another section to the plants engaged in the production of electric iron, electric steels, and alloys. Ferrosilicon is produced in one plant from native silica, and is also obtained as a by-product in the manufacture of abrasives. Ferromolybdenum was produced for a time at two plants, but at present there is no production. Carborundum is made at four plants owned by three different firms; aluminium oxide abrasives are made at six plants owned by five firms. Graphite and graphite electrodes are made at one plant; anthracite electrodes are made at four plants by three firms, one of these manufacturing for its own use only. Calcium carbide is made commercially at three plants, and for use within the maker's works by one manufacturer. Cyanamide is made at one plant, which has an annual capacity of 60,000 tons. Some sodium cyanide is made at this works from a portion of the cyanamide, the balance being exported.

CHAPTER III

PRODUCTION OF NITROGEN COMPOUNDS

Nitrogen is an essential constituent of the foods required both by plants and by animals. It is also essential to the formation of numerous industrial products. In nature it forms about 79 per cent by volume of the atmosphere. It also occurs in nitre, Chili saltpetre, ammonium compounds, and in the tissues of animals and plants. It is invariably present in soils which support plant life, compounds being formed in the soil by the action of nitrifying bacteria.

Since nitrogenous compounds are essential constituents of both plant and animal tissues it follows that they must form important components of the foods of all living organisms. The chief importance of these compounds obviously depends upon the ability of living plants to assimilate them from the soils upon which their growth takes place. Since these compounds are essential to plant life, and since repeated cropping of any given area tends to exhaust the supply present in the soil, it becomes necessary to resort to artificial means to replace the amounts of nitrogenous compounds that are being abstracted from the soil by successive crops. It is for this reason that nitrogenous fertilizers are essential to the maintenance of a successful agricultural industry and this is the basis of the demand for commercial fertilizers.

Compounds of nitrogen constitute our most important explosives, whether for use in peace or war. Dynamite, blasting powders, and various other explosives that are used in all mining or quarrying operations, in road building and in railway construction, are nitrogen compounds. Nitrogen is essential to the manufacture of the numerous nitrocellulose products which constitute celluloid, artificial ivory, photographic films, artificial leather, many lacquers, and similar substances. It is present in dyes, and some of its compounds are used in making glass, sulphuric acid, and numerous other commercial products.

In combination with hydrogen, as ammonia, it is used in refrigeration plants, either for the production of artificial ice, or to operate cold storage plants. Ammonia is utilized in the manufacture of important chemicals and it also finds many applications within the household.

In combination with carbon and certain bases cyanides are formed. These are used in certain metallurgical processes for extracting gold and silver from their ores, and they have also found important agricultural uses as insecticides.

SOURCES OF NITROGEN

Organic Nitrogen Compounds

Organic nitrogen compounds are used principally as fertilizers for plant food or as nitrogenous feed for domestic animals. These materials consist of animal and plant refuse, such as decayed leaves, manure, abattoir tankage, dried blood, fish scrap, leather scrap, cottonseed meal, oil cake, and similar products. Some kinds of organic nitrogenous fertilizers have been used by agriculturalists for many centuries. The use of industrial waste products is of comparatively recent origin. These products have now come to be recognized to have greater value if used as animal foods. Their diversion in this direction in recent years has materially diminished the available supply of organic nitrates for use as agricultural fertilizers.

Inorganic Nitrogen Compounds

Inorganic nitrogen fertilizers are of constantly growing importance. They are derived from three principal sources.

Natural Nitrates. Nitrates of soda or potash are present in the soils of certain arid regions of the earth. These are extracted and used locally, or exported to the markets of the world. They have been used in small quantities for many centuries. The discovery of the deposits of sodium nitrate in Chili early in the last century marks the beginning of the world's trade in this commodity. They have been utilized on a constantly increasing scale for the last ninety years. At present they supply about one-third of the world's total requirements for nitrogenous fertilizers.

Byproduct Coke Ovens. The nitrogen content of bituminous coal is in part recovered among the byproducts of gas and coke ovens. It is commonly liberated as ammonia gas which is absorbed in water. The ammonia can be recovered from the aqueous solution as such or as a compound of ammonia with an acid. It is commonly converted into the sulphate, in which form it enters into many fertilizers. The recovery of byproduct ammonia and its utilization as a commercial fertilizer is a development of the last half century. Nearly one-third of the world's requirements of inorganic nitrogenous fertilizers are supplied from byproduct coke ovens.

Nitrogen Fixation Processes. The third important source of inorganic nitrogen is the atmosphere. Chemical and electrochemical processes have been developed during the last two decades by which nitrogen from the air can be combined with other elements to form useful compounds. These methods of producing nitrogen compounds are termed nitrogen-fixation processes. The plants now established are capable of producing more than one-third of the world's total annual requirements.

Reference is made in another section of this report to the Fertilizer industry and to the sources of its raw materials. In still other sections of the report references are also made to the occurrence of residual byproducts which are available for use in making fertilizers. The principal contributing industries of this kind are meat packing, industries preparing refined oils (of animal or vegetable origin), coal distillation, and coal tar distillation. Natural nitrates are not found in Canada in commercial quantities. A further discussion of the sources of supply of organic nitrogenous materials or of the recovery of ammonia produced during the distillation of coal or coal tar is unnecessary. Some reference, however, is made to the processes for the fixation of atmospheric nitrogen.

Nitrogen Fixation

In his presidential address before the British Association for the Advancement of Science, in 1900, Sir William Crookes pointed out that the nitrate fields of Chili would undoubtedly be exhausted within a measurably short time. Such exhaustion must inevitably result in a decrease of the world's food supply unless means were found to utilize the vast store of nitrogen available in the atmosphere. That nitrates could be made from the nitrogen of the air was known prior to 1900, but this address really marks the beginning of the investigations which led to commercial development of processes for fixing atmospheric nitrogen. The first successful commercial process was put in operation in 1905 at Notodden, Norway (Birkeland and Eyde process).

Many processes have been proposed for fixing atmospheric nitrogen. Some are in successful operation on a commercial scale, some are in process of development, and others have not got beyond the laboratory stage. Reference will be made here only to four types of processes, three of which have been operated commercially. These, in the order of their development, are the Arc process, the Cyanamide process, the Synthetic Ammonia process, and the Cyanide process.

Arc Process

This was the first method to be developed to the commercial stage of production. The raw materials are air and water, with abundance of electric power as another essential. The process depends upon the fact that nitrogen and oxygen of the air will unite to form oxides of nitrogen if heated to a high temperature in the electric arc. The phenomenon was known long before practical methods of applying it were suggested or developed. It is accomplished by passing a stream of air through an electric arc under suitable conditions to insure the heating of as large a volume of air as possible. Only a small portion of the gases present are combined while passing through the zone of high temperatures. The mixed gases must then be cooled rapidly to prevent the decomposition of the nitric oxide formed. When cooled quickly another portion of oxygen is absorbed from the mixture making the dioxide. The stream of gases is then brought into contact with a thin film of water or dilute nitric acid in special apparatus. Absorption takes place with the formation of nitrous and nitric acids. The nitrous acid present is converted into nitric acid by suitable means.

Several types of arc furnaces have been devised to promote the reactions upon which the process is based. These differ greatly in methods of construction and operation. The Birkeland and Eyde furnace, the first to be successfully operated commercially, maintains a broad thin disc of flame through which the stream of air passes. This is accomplished by drawing the arc between the flat poles of an electro magnet. A disc-like flame results, the arc being turned at right angles to its normal direction by the action of the magnetic poles. In commercial units a disc-like flame about 6·5 feet in diameter is maintained. The Schönherr furnace uses a long steady arc past which the air stream passes. In commercial units an arc over 20 feet in length may be maintained. In the Pauling furnace the electrodes are arranged at right angles to each other and the air stream under pressure is introduced between them in such a way that the arc is blown into a sheet of flame. These three types of furnaces are all in successful commercial operation on a large scale. Several other types have also been proposed, and some have been utilized commercially, but only on a small scale. Mention should be made of the Wielgolaski furnace, a modified form of the Schönherr type, since a small one was installed in British Columbia and operated experimentally for a short time.

The successful operation of furnaces using an electric arc is dependent upon the availability of very cheap electric power in large blocks. About 67,000 kilowatt hours of electric energy are required to fix one ton of nitrogen, the efficiency being only about three per cent and the heat losses enormous.

These processes yield an aqueous solution containing nitrous and nitric acids. The nitrous acid can readily be converted to nitric acid. A basic nitrate of calcium, suitable for use in fertilizers, is produced by treatment with milk of lime. It is also possible to make concentrated nitric acid and nitrate salts of other bases, as required.

Cyanamide Process

The raw materials used in this process are coal, limestone, air, and electric power. Coal is converted into coke, and the limestone is burned to lime. Lime and coke are converted into calcium carbide in electric furnaces. The carbide, after cooling, is ground fine and packed into ovens of a special form. Pure nitrogen, obtained from the air by compression and fractional distillation, is introduced to these ovens, all the air being expelled. Electric power is then applied to bring the mass to a yellow heat. The nitrogen combines with the calcium carbide to form calcium cyanamide. When the conversion is as complete as possible the ovens are cooled and the crude cyanamide is removed, crushed, and finely ground. It is then heated with water to remove any unaltered carbide. The power consumption of this process is about 15,000 kilowatt hours per ton of nitrogen fixed, and the efficiency is much higher than in the arc process.

Crude calcium cyanamide can only be used in limited quantities as a fertilizer material. This cyanamide, however, is a basic product from which a large series of other important products, some of which are more suitable for use as fertilizers, can be made. These products include ammonia, ammonium sulphate, and ammonium phosphate. The accompanying flow sheet shows the principal products that can be derived from calcium cyanamide. It also indicates, in a general way, the processes employed to make these products, and their industrial uses.

UTILIZATION OF ATMOSPHERIC NITROGEN

CHART SHOWING INDUSTRIAL POSSIBILITIES OF THE CYANAMIDE PROCESS

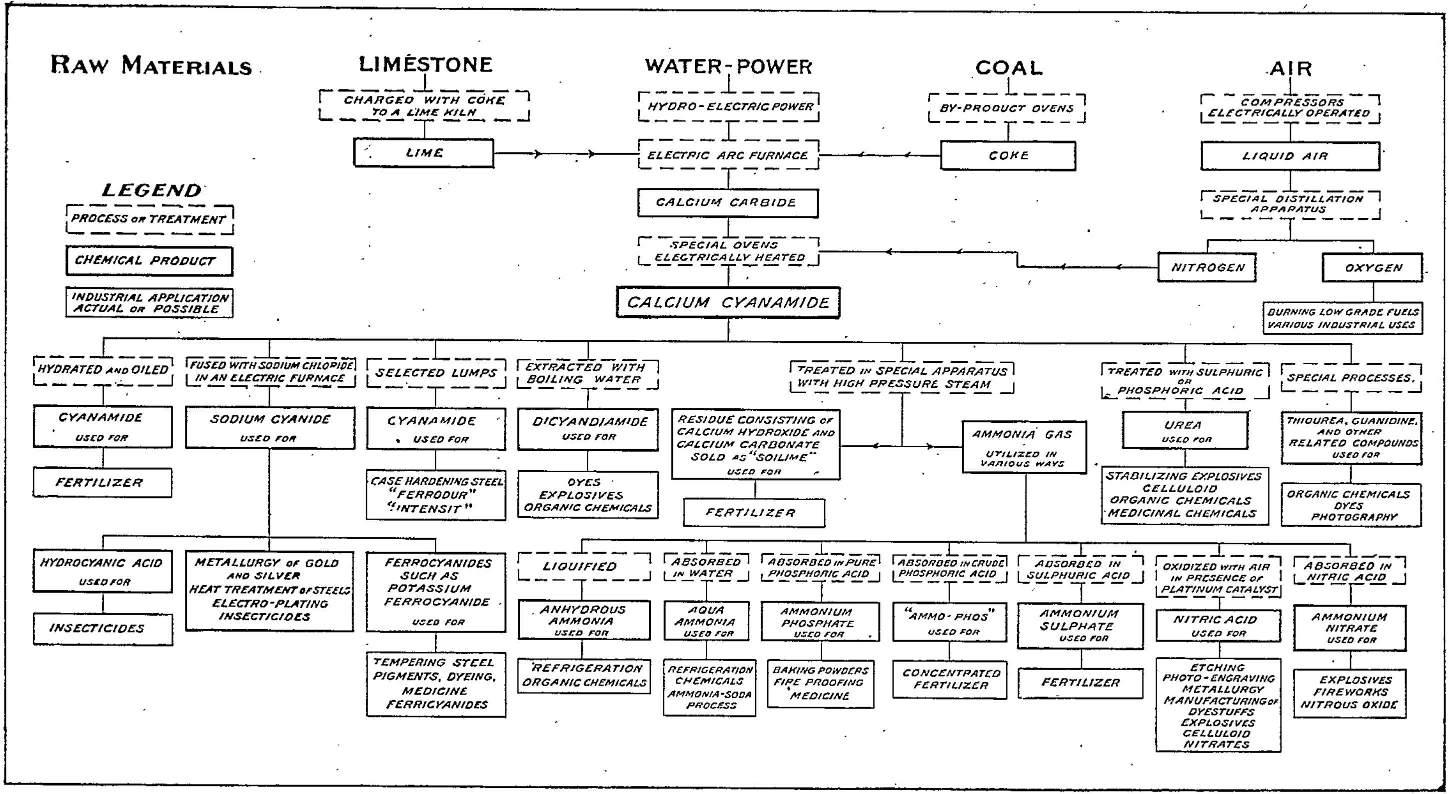

Diagram 6

Synthetic Ammonia Processes

Nitrogen and hydrogen in the presence of a catalytic substance capable of promoting a reaction between them will unite to form ammonia. This reaction is the basis of the direct synthetic ammonia process commonly known as the Haber process. The successful operation of the process is dependent upon the use of an effective catalyst. The original Haber process, which was developed in Germany prior to the war, operates under a pressure of about 200 atmospheres and at a temperature of about 500° C. The principles of operation had all been worked out prior to the war, but the plant in operation in 1914 was only a small commercial unit. During the war, when supplies of nitrates from Chili were shut off, the plant capacity was enormously enlarged. During the war similar processes were developed in France, Italy, and the United States, varying both in the temperatures and the pressures at which the operations were conducted and in the catalyst used. In England an experimental plant was erected to use the Haber process. In France a good deal of attention has been given to the Claude process in which ammonia is synthesized from nitrogen and hydrogen under a working pressure of 1,000 atmospheres. In the United States much work has been done under Government auspices upon a process which is a modification of the Haber process, and also upon the cyanamide process.[1]

Hydrogen for use in the Haber process is prepared from water gas by treatment with steam in the presence of a catalyst (Bosch process). It may also be made electrolytically by the decomposition of water. Nitrogen is obtained from the air either by admixture with the water gas or by the production of a pure producer gas. Nitrogen can also be obtained by fractional distillation from liquid air. When hydrogen is made from water gas, or when producer gas is used to introduce nitrogen, elaborate precautions must be taken to purify the mixed gases by eliminating carbon monoxide and carbon dioxide. These operations usually take place under pressure. The purified mixed gases should contain approximately three parts of hydrogen by volume to each part of nitrogen.

The synthesis of ammonia from the purified gases is accomplished in special apparatus through which the gases are circulated. The catalyst to be employed is so placed in a converting unit that a maximum amount of contact surfaces will be exposed to the gases, while the freedom of circulation will be reduced as little as possible. The best operating temperatures lie between 450° C. and 600° C. and the reaction is exothermic. Provision must be made to maintain the catalyst at a suitable temperature. The outgoing gases, containing the synthesized ammonia, are led through heat interchangers by which they lose heat to the incoming stream, the proper balance being maintained so that the catalyst becomes neither cooled nor overheated. The ammonia is removed from the circulating gases by absorption or liquefaction, the gases after stripping being returned to circulation. The yield varies to about 18 per cent under the best oper-

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[1] Consult Report on the Fixation and Utilization of Nitrogen, prepared by the Nitrate Division, Ordnance Office, War Department, Washington, 1922.

ating conditions. The apparatus used for this process is of very complicated design and a very high degree of operating skill is required.

Ammonia is obtained in anhydrous liquid form. It can be converted into nitric acid by oxidation in suitable apparatus. It can be used to make ammonium salts and for all other purposes to which this product is applied.

Cyanide Process

There are a number of methods by which crude cyanides can be obtained from certain raw materials. This process has not yet been developed to a commercial scale, but, since the raw materials are abundant and relatively cheap, and since there is a considerable demand for cyanides for use as insecticides and in metallurgical processes, this method of preparation may become industrially important. Ammonia can also be made from cyanides by treatment with steam, and since the demand for ammonia and products that can be made from it is greater than that for cyanides, the process may also offer some possibilities in this direction if it is ever able to compete with ammonia made by other methods.

The process depends upon the fact that a cyanide of the base is formed if a mixture of a carbonate of an alkali or an alkaline earth is heated with carbon in the presence of nitrogen. Experimental work has shown that the carbonates of sodium or of barium are best for use in the process. Bucher proposes to mix thoroughly pulverized soda ash and carbon with finely divided iron, the mixture being briquetted and charged into an externally heated retort. When heated to about 1,000° C. in the presence of nitrogen crude sodium cyanide is formed. Another method uses the same materials, in slightly different proportions, but omits the briquetting, and uses a revolving retort.

The raw materials most suited for use would be soda ash and metallurgical coke. Iron would be supplied as scale or as pulverized cast iron. Nitrogen would be obtained from the air.

Canadian Situation

Natural nitrates are not found in Canada in commercial quantities. Artificial nitrates are not at present made for domestic consumption. There are two air fixation plants in Canada, both belonging to United States firms, located here on account of power conditions. One of these, using the cyanamide process is located at Niagara Falls, Ontario. It has an annual capacity of 12,000 tons of fixed nitrogen. Almost the entire production is exported as cyanamide to the United States, where it is converted into ammo-phos, a high grade fertilizer constituent, urea, which is used largely in certain manufacturing industries, and smaller quantities of other chemicals. The other plant is located near Vancouver, British Columbia, and is at present idle. It is said to have a capacity of 800 tons of fixed nitrogen per annum.

No statistical studies have been made showing the annual nitrogen requirements even of the principal industries requiring compounds of this element. Undoubtedly agriculture is the largest consumer through fertilizers. Explosive manufacturing and acid production (sulphuric, nitric) also require considerable quantities of nitrates, and small quantities are required by other industries. The fertilizer industry obtains a portion of its requirements from organic wastes locally produced. It also obtains some ammonium sulphate from the byproduct coke plants. The balance of its requirements and some of the demands of other industries using nitrates are met by the importation of nitrate of soda from Chili. A small quantity of nitrate of potash is also imported from Europe. Some data with respect to these importations are given in the tabular statement of imports of chemicals on another page. The average importations of nitrate of soda from Chili for the three years prior to the war were equivalent to about 5,862 tons of fixed nitrogen annually. For the three years after the close of the war this average annual importation was reduced to 2,167 tons. The fixed nitrogen in imported nitrate of potash for each of the three years prior to the war averaged 135 tons per annum, while for the three years after the armistice the average was reduced to about 48 tons.

There are several byproduct coking plants in Canada producing ammonium sulphate much in excess of the home demand for this product. The annual production naturally varies with the demand for coke. Information with respect to plant capacity is given in the section on Coal Distillation and exports are given in the tabular statement already mentioned.

Summary

The foregoing very brief sketch of the present development of nitrogen fixation processes has been introduced to show the raw materials that are required by this group of industries in relation to Canada's position. It will have been noted that in addition to power requirements and equipment the principal raw materials are limestone, coal, air, water, and, for one group of processes, sodium chloride, this latter being the natural mineral product from which soda ash is made. All these materials of suitable grade are available in quantity in Canada at certain points. Canada, however, is at present lacking in one very essential and exceedingly important requirement. There are no trained technical experts available to design equipment and develop processes, none to supervise and direct, and there are no local opportunities to obtain experience in technical operations of this kind. It is true that there is a small production of fixed nitrogen from byproduct coke ovens. This production is, however, a byproduct of the coking industry, itself in turn dependent upon the demand for coke. It is unlikely that byproduct nitrogen can ever equal the demand. An independent source of supply is necessary.

The importance to Canada of self-contained essential industries is obvious. Nitrogen is essential to numerous industries and no native source capable of supplying our requirements has yet been developed. The demand made by agriculture for fertilizers must necessarily expand as the country develops. Our mining industry creates a demand for explosives which in the natural course of events will increase gradually. The building of roads, lumbering, clearing operations, development of water powers, and other activities also create a demand for explosives. During the great war the entire production of explosives in this country was dependent on imported nitrogen as well as imported sulphur.

In addition to fertilizers and explosives, other products are made by prosperous industries whose maintenance is directly dependent upon a supply of certain compounds of nitrogen. It is therefore unfortunate that almost the whole of the nitrogen requirements of all these industries must be imported. At the present time we do not know our exact annual requirements, in other words the size and value of the home market cannot be determined. No accurate data are available to enable us to determine the probable cost of producing our own nitrogen requirements. In fact it is probable that the imported materials can be purchased cheaper than one could make equivalent products. The time is not far distant, however, when these foreign purchases will be impossible, and they might at any time be discontinued under war conditions.

The natural importance of controlling an adequate supply of nitrogen cannot be exaggerated. Our present dependence on foreign sources for supplies of this important chemical is such that the question is worthy of attention from those responsible for the welfare of the nation.

In conclusion, attention is drawn to the fact that the entire British Empire is dependent upon foreign sources for a considerable quantity of its nitrogen. These nitrogen requirements and the sources of supply are worthy of further inquiry than has already been made, having in view the fact that the natural conditions in Canada would appear to offer favourable opportunity for the development of a nitrogen industry designed to supply the needs of the Empire. While the Canadian market alone may not be competent, at present, to support an air fixation market, the Empire market could undoubtedly do so.

CHAPTER IV

INDUSTRIAL GASES

Industrial applications are made of a number of products, which are in a gaseous state under ordinary conditions of temperature and pressure. These products include natural and artificial compounds, and chemical elements, the latter being very frequently prepared from natural substances by chemical and physical processes. In the brief discussion which follows the gaseous substances mentioned are those ordinarily used in industry. Gases used for military purposes are not included, except in so far as they may also be used industrially. Each important gas is mentioned separately in alphabetical order, regardless either of its relative importance, or of its technology.

ACETYLENE. Acetylene is a highly inflammable colourless gas, containing carbon and hydrogen. Pure acetylene is almost odourless, but the commercial gas possesses a distinctive odour due to the presence of impurities. When required for industrial or commercial purposes it is prepared by the interaction of water and calcium carbide. This gas is soluble in alcohol, acetone, and other organic liquids. Advantage is taken of this property to store the gas in convenient containers for distribution and commercial purposes.

Industrially, where large quantities of the gas are required it is generated at the point of application by the use of specially designed apparatus. When required in portable form it is absorbed in acetone and the solution is stored in special containers.

Acetylene gas is used for illuminating purposes, in private houses, in public buildings, in industrial plants, and for municipal lighting purposes. The total number of public and private installations of these several kinds in Canada has not been tabulated, but there are at least fifteen municipalities in which acetylene generating plants have been established for municipal lighting purposes.

Dissolved acetylene stored in convenient containers is employed for small lighting plants and for lighting railway coaches or boats. Formerly it was employed for lighting automobiles. The principal application of acetylene in this form is probably for high pressure oxy-acetylene welding.

Individual lamps of many varieties have been developed for the more or less automatic generation of acetylene from water and calcium carbide stored in suitable containers integrally attached to the lamp. Bicycle lights, and some motor car lights and carriage lamps are of this type. It is also used extensively in miner's lamps. The most important application is for lights, beacons, and other marine signals as aids to navigation. Acetylene lighted buoys and beacons have been developed in which the generation of the gas is automatically controlled. When the storage capacity is made large enough some of these signals will remain in continuous operation for about a year without attention.

Acetylene gas is also industrially important in chemical manufacturing as the basis of other chemical compounds. Acetic acid, acetone, and ethyl alcohol can all be made directly from this gas by special processes.

Calcium carbide is made by two firms in three plants in Canada. It is available in convenient containers at almost every important point in the country. There are at least eight plants engaged in the production of dissolved acetylene for distribution in containers for commercial purposes. There is one large plant in Quebec capable of producing acetic acid and acetone directly from acetylene. The requirements of this country for acetylene gas for all purposes can be amply supplied from internal sources, and there is a surplus available for export.

AIR. Natural air consists of a mixture of many gases. Nitrogen constitutes about 78 per cent of the whole, oxygen 21 per cent, and the balance is made up of small amounts of the rare gases—argon, neon, helium, krypton, and xenon—and gases derived from natural or industrial sources, such as hydrogen, carbon dioxide, carbon monoxide, marsh gas, ammonia, nitric acid, sulphur dioxide, water vapour, and other substances in minute quantities. Air can be liquefied at low temperatures under a pressure of about 40 atmospheres. Liquid air is a mobile pale blue coloured fluid. It boils at a temperature which varies with its composition, the average being about —190° C.

Liquid air is prepared by cooling and compressing atmospheric air. Several types of apparatus have been devised and are in commercial use for the manufacture of this product.

Liquid air is used chiefly for the manufacture of nitrogen and oxygen for industrial use. Liquid air containing about 60 per cent oxygen is used in mine rescue apparatus to resuscitate partially asphyxiated persons. It has also been used as an explosive and it finds a number of uses in chemical and physical laboratories, especially for the production of extremely low temperatures.

Liquid air is made in Canada at one plant incidentally in the manufacture of nitrogen required to produce cyanamide. Liquid air is also made by one firm to meet the limited local market demand for this product.

AIR GAS. Air gas consists of a mixture of air and hydrocarbon vapour derived from gasoline or benzol, or related volatile liquid hydrocarbons. In the manufacture of this gas care must be taken not to produce an explosive mixture. Air gas containing two per cent or slightly less of hydrocarbon vapour will burn with a non-luminous flame. Percentages between two and seven must be avoided owing to their explosive character. Above seven per cent the gas burns with a luminous flame. This gas is usually used with gas mantles for illuminating purposes. The units are usually small and suitable for domestic or hotel lighting systems.

This product is sometimes named *gasoline gas*. The name air gas is also sometimes applied to producer gas made with air only, without the use of steam.

No data are available with respect to the installations of air gas plants in Canada. It is believed that a number of these are in use for lighting large houses and some country hotels where electric light is not available.

AMMONIA. This compound is usually gaseous at ordinary atmospheric pressure. It is readily soluble in water, and it can easily be liquefied. Industrially either the hydrous solution (aqua ammonia) or the condensed liquid product (anhydrous ammonia) may be employed, each form having its own special applications.

Ammonia for industrial purposes is almost invariably obtained as a byproduct in the destructive distillation of bituminous coal, during the manufacture of metallurgical coke or coal gas. It is made in this way in Canada (see page 132). Ammonia can also be produced from atmospheric nitrogen by several different and rather complicated chemico-physical processes to which some reference is made in chapter III (page 77).

Ammonia for industrial uses is obtained in Canada only from the waste ammonia liquors of coal gas plants in some of the larger cities and towns. That produced incidentally during the manufacture of metallurgical coke in byproduct ovens is recovered as ammonium sulphate and marketed as such.

The aqueous solution of ammonia, chemically ammonium hydroxide, is used industrially in the manufacture of ammonium compounds. It also finds applications in the textile industry, in the manufacture of soaps, and in laundering.

Anhydrous ammonia is used in the manufacture of certain chemicals, but its principal industrial application is for refrigeration in cold storage plants and abattoirs.

Ammonia liquors are produced in Canada at five or six points. Aqua ammonia and anhydrous ammonia appear to be produced only by one firm in Toronto. A considerable quantity of anhydrous ammonia must be imported annually, but the customs returns are not compiled in a form to furnish information on this point.

ARGON. This is a colourless inert gas which is present in the atmosphere in the proportion of about 0·9 per cent by volume. It can be liquefied only under high pressure and at a temperature of —186° C. It is obtained from the atmosphere by a complex process of compression and cooling by which liquid air is first produced. Liquid air is then subjected to fractional distillation at low temperatures, argon being one of the fractions recovered. It may also be obtained by the use of a high tension electric current so arranged that sparks pass rapidly through a vessel containing air and a solution of caustic soda. The electric spark causes the nitrogen of the air to be oxidized to nitrous acid, which is absorbed by the caustic soda, forming sodium nitrite. The gaseous residue will be chiefly argon and oxygen. The latter can be removed by passing the residual mixture over red hot finely divided copper or by absorption with potassium pyrogallate. Where argon is required on a commercial scale it is usually made by the differential distillation of liquid air.

Argon is used industrially for filling incandescent lamp bulbs. Its use lengthens the life of the filaments employed in making the lamps and improves the quality of the light emitted.

This gas is not prepared commercially in Canada. The quantity used for the manufacture of incandescent lamps is small, and is usually imported in steel cylinders.

BLUE GAS. See Water Gas.

CARBON DIOXIDE. Carbon dioxide is a colourless gas which is easily liquefied and which is readily soluble in water, to which it imparts a slightly acid taste. The gas will not support combustion and for this reason is an important constituent of some fire extinguishers.

Carbon dioxide occurs in a natural condition in the neighbourhood of volcanic regions, and issues from fissures and springs. It also occurs in solution in spring waters in limestone regions and in certain mineral springs. Occasionally the natural gas is employed for aerating table waters. Commercial and industrial supplies of this gas are usually manufactured directly where required. There are a number of processes in use for preparing this product, but only brief references can be made to the more important of these in order to indicate the different raw materials that are required.

Natural carbonates such as dolomite, magnesite, or limestone, are easily decomposed by heating to a moderate temperature in suitable kilns. The reaction is promoted somewhat by the use of steam. Where large quantities of the gas are required, particularly in chemical manufacture, this method is usually employed. It is also employed in connection with the manufacture and refining of sugar. There are at least four plants of this type operating in Canada, three being used in sugar refining.

Carbon dioxide is also made from natural carbonates, particularly magnesite and limestone, by treatment with dilute hydrochloric or dilute sulphuric acid. Marble dust is very frequently employed for this purpose. Where magnesite and sulphuric acid are employed the residual liquor may be concentrated and magnesium sulphate can be recovered as a byproduct. As a substitute for sulphuric acid the residual nitre cake for the manufacture of sulphuric acid has been used.

Carbon dioxide is produced in large quantities by the fermentation processes in the manufacture of alcohol and beer. It is possible to collect this gas if the vats are covered and sealed against air leaks. If obtained in this way it can be compressed and liquefied. Gas so obtained is used for aerating beers. If required for other purposes it is necessary to subject it to a special deodorizing or purifying process.

Carbon dioxide is also prepared on a large scale by the use of coke or anthracite coal and heated copper oxide. In this process the monoxide is first made by passing air through the heated carbonaceous fuel in a retort. The resulting gas is passed through a second retort containing heated copper oxide, which converts it into carbon dioxide. The resulting dioxide is then divided into two parts, one of which may be utilized, the other of which is again passed through the heated coke or coal, being again converted into the monoxide. The products of the first cycle contain nitrogen from the original air, and they are therefore discarded until only pure carbon dioxide is obtained. Once the cycle is established, a continuous supply of carbon dioxide can be obtained, the copper oxide being regenerated by alternately passing air over it.

In another process coke is burned under a boiler, the air supply being controlled so as to promote the production of the maximum amount of carbon dioxide; the steam generated is used to drive the power plant. The flue gases are conducted to apparatus where carbon dioxide is absorbed in sodium carbonate solution, the waste gases being allowed to escape. The absorptive solution is then heated by exhaust steam to liberate pure carbon dioxide, which is cooled and compressed. The absorbing and cooling operations are cyclic and heat interchangers are employed.

This gas in a less pure condition can also be prepared by extraction from mixtures of other gases in which it is present, particularly from furnace gases and lime kiln gases. These methods are not discussed here.

In some works the gas is used directly without further treatment. Where the gas is intended for distribution to consumers it is usually cooled, compressed, and liquefied for storage in special steel containers. When it is to be used immediately and when the distance it has to be conveyed is small the expense of transferring may be reduced by omitting the containers and preparing it in solid form. In this form it is sometimes compressed in wooden moulds.

One of the principal commercial uses of carbon dioxide is in the manufacture of sodium carbonate and bicarbonate by the Solvay ammonia-soda process, and in the Claus-Chance process for the recovery of sulphur. The former process is in use at one plant in Canada, the latter has not been introduced.

Pure carbon dioxide gas is used for the manufacture of many brands of artificial mineral waters, aerated waters, soda waters, and beers. Many plants of this kind are distributed throughout this country.

This gas is also used in refrigeration plants, especially on ships. It is more advantageous than ammonia for this purpose. This use is, however, being superseded by a cooling system using ethyl chloride as the refrigerant.

There are also a number of miscellaneous minor uses such as in fire extinguishers, to compress fluid steel in ingots, to destroy insects and vermin in grain storage elevators. The liquid form has been used as a source of power for operating pneumatic railway signals and torpedoes. Beer is carbonated and clarified with the liquid gas. White lead and a number of other chemical products can be made by its use. It is also utilized in the refining of sugar, in the making of bread and cakes, and for the sterilizing of milk.

Some references have already been made to the use of this gas in a number of Canadian industries. The number of industrial establishments in which it is used in some form is very large and no attempt has been made to prepare tabulated lists of consumers. The liquid gas stored in containers for distribution to individual small consumers is prepared at four points in Canada by two firms. Very small quantities are also imported annually.

CARBON MONOXIDE. This gas is formed by the combustion of carbon (coal) in a limited supply of oxygen. It can also be made by passing carbon dioxide over incandescent carbon and by a number of other chemical reactions. When required for industrial purposes it is usually made in a gas producer. This gas is the principal important constituent of producer gas, and it is also an important constituent of water gas and other gaseous fuels.

Apart from the industrial uses of the various gaseous fuels which contain carbon monoxide, to which reference is made in other paragraphs, this gas has several other uses. The most important of these is probably in the refining of nickel by the Mond process. It can also be used for the formation of formic acid, oxalic acid, and acetic acid. In these operations the other principal chemicals required are caustic soda and methyl alcohol. Another chemical product made from carbon monoxide and chlorine, and used in the manufacture of certain dyestuffs, is carbonyl chloride, better known as phosgene. This gas may also be used as a reducing agent.

The Mond process for refining nickel is not operated in Canada, but nearly one quarter of the nickel recovered from Canadian ores is refined by this process in Great Britain. None of the other chemicals made from carbon monoxide and mentioned in a preceding paragraph are produced in Canada. No data are available to indicate our annual requirements of these chemicals.

CARBURETTED WATER GAS. See Water Gas.

CHLORINE. This gas is heavy and of a greenish yellow colour at ordinary temperatures. It is intensely irritating to the mucous membranes and is poisonous. Chlorine is prepared as a byproduct in the manufacture of caustic soda from common salt by electrolysis. There is a surplus production of byproduct chlorine and new industrial uses are being devised to absorb this surplus. It is also prepared industrially by the oxidation of hydrochloric acid, itself a byproduct, with manganese dioxide under suitable conditions.

Chlorine readily forms hypochlorites with caustic soda, slacked lime, or similar hydrates. These compounds are active bleaching agents and are made for use in the pulp and paper industry, and for bleaching textiles. Chlorinated lime is also used in many metallurgical operations. The aqueous solution of chlorine is also useful as a textile bleaching liquor.

Chlorine can be liquefied under a pressure of four atmospheres at 15° C. Liquefaction is accomplished by using specially designed pumps in which the compression piston head is lubricated with sulphuric acid. It is also liquefied by absorption processes, tin tetrachloride or carbon tetrachloride being used as absorbers. Liquid chlorine for industrial purposes is stored in steel containers of various sizes. Where large quantities are required special tanks, of 15 tons capacity, mounted on railway trucks, are used.

Liquid chlorine is now widely used to purify domestic water supplies; large quantities are also used for preparing sulphite pulp bleach, and the Canadian demand for this purpose is increasing. Chlorine in liquid form also finds a market in other industries, particularly textile bleaching and chemical manufacture.

The chlorine manufacturer not only produces bleaching powder and liquid chlorine, but also produces a number of other chemicals which find various industrial applications. These include carbon tetrachloride (important as a fire-extinguishing compound); chloroform; chlorides of aluminium, antimony, tin, or sulphur; hydrochloric acid; benzaldehyde; benzoic acid; chloracetic acids; chlorbenzols; and other products.

In Canada chlorine is made as a byproduct of caustic soda manufacture at one plant. A large proportion of the output is liquefied, stored in tank cars, and shipped to the sulphite pulp mills. A portion of the output is used for the manufacture of chlorinated lime. A considerable quantity of chlorinated lime is also imported into Canada. The annual amount and value of these importations cannot be determined because the records available do not separate this item from chloride of lime, an entirely different compound.

Hypochlorite bleaching solutions are also made directly at two sulphite pulp mills by an electrolytic process, to be used as a bleaching agent. Chlorine gas is not produced and recovered as such in these plants.

About forty thousand dollars worth of liquid chlorine was imported in 1920, chiefly for water purification and use as a bleaching agent. It is probable that the newsprint industry and the gradual improvements that are being made in municipal water supplies for domestic purposes will greatly expand the home market for this product.

COAL GAS. This is the name applied to the gaseous product formed when bituminous coal is subjected to destructive distillation in highly heated chambers or other closed containers. The ordinary commercial coal gas consists of mixtures of a number of gases and vapours, most of which are inflammable. The proportions in which the different constituents are present in the gas vary considerably with the conditions of production.

Coal gas may be made by treating bituminous coal in clay retorts heated externally by means of producer gas, coal, or coke. The majority of the gas plants used for municipal lighting and heating are of this type. Coal gas is also made by the treatment of soft coal in special kinds of retorts termed byproduct ovens, the heat being supplied by the combustion of a portion of the distillation products. Byproduct gas finds its chief application in the steel industry for heating purposes, and it is also used occasionally in other large industrial establishments.

Apart from the clay retorts, fire brick, structural steel, and other similar materials used in the construction of banks of retorts or byproduct coke ovens, the principal raw material of this industry is bituminous coal. Coal for this purpose should be high in volatile constituents, low as possible in ash, and free from sulphur. Usually a coking coal is preferred.

Gas retorts and fire brick could be made in some parts of Canada, but many of the plants now in operation were constructed almost entirely from imported materials. The reasons for these importations differ, but the principal factor is geographic location with respect to the best markets from which to purchase supplies, coupled with the fact that materials of established suitability are naturally preferred by purchasers. Such Canadian materials as are suitable are not yet well known. The available materials are also, in many cases, too far from the point where they are required, and the market demand is not such that quantity production can be attained.

The iron and steel equipment required is also, for the most part, imported because of limited demand, special design, and other conditions imposed by geographic location with respect to sources of supply. Local coals are used in retort plants in both eastern and western Canada. Retort plants in Ontario, and at some points in Quebec and Manitoba are dependent upon imported coals. Two of the byproduct plants use coals produced near the plants, and the other two use imported coals.

Retort gas is used industrially for small heating and annealing furnaces, for melting, for welding, and in similar operations in small plants. The principal use is for lighting and in culinary operations. It also finds a limited application in house heating. Coal gas is often mixed with inflammable gases made by other processes, water gas, carburetted water gas, or oil gas being used for this purpose.

Coal gas for municipal purposes is washed and purified to remove ammonia, cyanogen compounds, and sulphuretted hydrogen. The purification is usually accomplished by the use of ferric oxide. Some plants use a natural iron ore, limonite, for this purpose. In other plants the iron oxide required may be chemically prepared. No data are available showing the quantities of limonite ore and iron oxides used annually for this purpose. In nearly every plant native materials are used.

Retort plants have been erected in twenty-four Canadian towns and cities and in one city in Newfoundland. Fifteen of these plants are located in Ontario, two in Quebec, five in British Columbia, one in Nova Scotia, and one in New Brunswick. Coal gas alone is utilized only in eight of the municipalities. Carburetted water gas, oil gas, or water gas are added to the coal gas in sixteen plants. In some cases the supplementary equipment is of sufficient capacity to supply all the gas needed without the use of the retorts. In such cases the relative costs of coal and oil and the variations in the demand for gas may determine which plant to use.

Statistical data with respect to the capacities of these plants are not available. The total amount of soft coal used annually for the production of coal gas is approximately 425,000 tons. The municipal gas systems also absorb a small tonnage of anthracite coal, and in excess of nine million gallons of oil, nearly all of which is imported.

Coal gas made in byproduct ovens in Canada is used partly for coking operations, but chiefly in the open hearth furnaces and soaking pits of the steel works. There are four byproduct plants in Canada, one being located in Nova Scotia, two in Ontario, and one in British Columbia. Both plants in Ontario are operated on imported coals. The other two plants use coal from local mines. These plants are operated chiefly for the production of metallurgical coke, and a more extended reference is made to them in the section dealing with Coal Distillation (page 130).

HELIUM. This gas is next to hydrogen the lightest gas known. It is colourless and inert, and can be liquefied only at a very low temperature. It occurs in minute quantities in the atmosphere and is also present in certain minerals. Its presence in natural gases from certain localities has been known for some years. During the war it was proposed to use this gas as a substitute for hydrogen for inflating balloons and dirigible air ships. Its lightness, non-inflammability, and general inertness render it particularly adaptable for this purpose. Commercial methods for recovering this gas from natural gas were developed in Canada and in the United States, and a considerable quantity had been prepared at the time the armistice was declared. Further investigations are in progress to develop other industrial applications of this gas.

An investigation of helium sources within the British Empire, made under the direction of Dr. J. C. McLennan, head of the Department of Physics, University of Toronto, has shown that the largest available supply of this gas within the Empire is located in Alberta.[1] No commercial development has yet taken place in Canada, but the production of this gas on a large scale for use in the aeronautical service of the country is practicable.

HYDROGEN. This is a colourless, tasteless, odourless, highly inflammable gas which can only be liquefied with difficulty under high pressure and at a very low temperature. It is the lightest gas known. It can be generated by many different processes. Industrial hydrogen is usually made by the electrolysis of water, or by the use of ferrosilicon and caustic soda. It is stored under pressure in steel bottles. It is used with oxygen in the oxy-hydrogen blowpipe for welding, cutting metals, and it also finds other applications where a high temperature is required. Hydrogen is used for inflating balloons and airships of various kinds. It also finds applications in certain industrial chemical operations, including the hydrogenation of oils for the manufacture of certain food products.

Hydrogen for industrial purposes is made by at least two firms in Canada, one in Ontario and one in British Columbia. There are also several plants equipped to produce hydrogenated oils.

Available records do not indicate any importations of this gas.

ILLUMINATING GAS. There are a number of combustible gases that are used for illuminating purposes. Gases consisting chiefly of carbon monoxide or hydrogen are not self illuminating. When used for illuminating purposes it is necessary to employ some form of gas mantle which is heated to incandescence by the combustion of the gas. These gases can also be enriched by the addition of volatile hydrocarbons which will liberate free carbon in the flame. The carbon being heated to incandescence renders the flame luminous. Gases such as coal gas, oil gas, or natural gas, which are rich in hydrocarbons, are self luminous. These gases are also used with gas mantles, the complete combustion being promoted by the construction of the burner employed, which introduces additional air to consume the carbon. The various kinds of gases used for illuminating purposes are briefly discussed under the titles acetylene, coal gas, natural gas, oil gas, producer gas, and water gas.

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[1] See Mines Branch Bulletin, Publication No. 522.

NATURAL GAS. This name is commonly applied to a natural gaseous fuel which issues from strata containing petroleum. Accumulations of gas are found beneath impervious strata above the petroleum bearing strata, and these natural reservoirs are tapped by means of bore holes. Natural gas is also occasionally found escaping from fractures or through porous strata. The composition of this gas varies from place to place, and may even vary in the same well at different times. The principal constituent is usually methane, but there are also small amounts of other gases containing carbon and hydrogen. Recently certain natural gas areas have been found to produce a natural gas containing small amounts of helium—to which reference is made in another paragraph. Some natural gas wells produce nearly pure nitrogen, and less frequently carbon dioxide, both of which are useless as fuels.

Natural gas is used as a fuel for many types of industrial heating, such as the operation of reverberatory furnaces, retort furnaces, annealing furnaces, glass furnaces and pots, metallurgical furnaces. It is also used as a source of power and light in factory operation, and as a source of light and heat for domestic purposes. The calorific value of natural gas is usually much higher than that of any ordinary artificial gas and it is one of the best fuels known.

Natural gas rich in methane could be used for the manufacture of industrial alcohol, but no commercial developments of this kind are yet in operation. It is used in some localities, where there is a limited demand for other purposes, for the manufacture of carbon black, a product for which there is a large demand. No carbon black is at present made in Canada. Large quantities of this product are imported annually, but the exact amount cannot be determined from the published statistics which include four different kinds of black pigments in the one item.

Natural gas in commercial quantities is being obtained in the provinces of New Brunswick, Quebec (very small), Ontario, and Alberta. It also occurs in the Mackenzie River basin and probably in a number of other areas, particularly in the western provinces. Detailed statistical information with respect to this industry is published annually by the Dominion Bureau of Statistics.

NITROGEN. This is a colourless, odourless, tasteless, and inert gas which constitutes about 78 per cent of the atmosphere. It can be liquefied at —118° C. under heavy pressure. Liquid nitrogen is a colourless mobile fluid. The gas is prepared from air either by fractional distillation of liquid air, or by removing the oxygen by chemical means. Where nitrogen is required mixed with hydrogen it can be prepared from producer gas. Nitrogen as ordinarily prepared contains a small amount of other gases such as argon, carbon dioxide, and oxygen as impurities.

The principal industrial use of nitrogen gas is for the manufacture of certain chemical products by processes that are termed nitrogen fixation processes. Atmospheric nitrogen can be used for the manufacture of ammonia, nitric acid, nitrous acid, cyanides, and cyanamides, and a number of compounds derived from one or more of the above products. It is probable that future industrial developments on a large scale will utilize several of these processes for the manufacture of nitrogen fertilizers, explosives, and certain chemicals required for metallurgical industries. A further reference to this subject is made in the chapter on Production of Nitrogen Compounds.

Nitrogen does not support combustion and is inert. It is therefore sometimes used for protecting inflammable liquids during transfer and storage. It is also used for filling small incandescent lamp bulbs, though for this use argon is being increasingly employed.

There is one plant in Ontario engaged in the production of cyanamide and sodium cyanide, utilizing nitrogen derived from the air.

NITROUS OXIDE. This gaseous compound is colourless and of a sweetish taste. When cooled under pressure it can be liquefied. It is prepared industrially by heating ammonium nitrate or by heating a mixture of sodium nitrate and ammonium sulphate under suitable conditions. Its principal use is as an anesthetic in dentistry and in surgery. It may be used alone or mixed with oxygen and is popularly known as "laughing gas." Commercially the gas for use as an anesthetic is specially treated to free it from other oxides of nitrogen and from chlorine. It is stored in steel cylinders under pressure.

This gas is used in nearly every dental laboratory in the country and in many hospitals. There do not appear to be any records of importations, and, so far as the author is aware, the gas is not made in Canada. There are no statistical data showing the amount required annually.

OIL GAS. Gas made by the destructive distillation of petroleum is termed oil gas. The operation is similar to that for the production of coal gas, but it is possible to prepare this gas in small plants. The gas may also be compressed for storage without serious detriment. When coal gas is compressed a considerable portion is deposited as liquid hydrocarbons, and the residual gas when burned is found to have lost its luminous character. Oil gas when compressed loses less of the hydrocarbons and retains its luminous properties. Several systems have been invented for making this gas. The Pintsch process used for making Pintsch gas is one of these.

Oil gas is compressed and stored in portable iron containers under a pressure of 8 to 10 atmospheres. In this form it is used for lighting railway coaches, stations, vessels, lighthouses, and other marine signals.

There are several small plants of this type in operation in Canada, but no list of the installations is available.

Oil gas compressed to about 100 atmospheres pressure, so that the greater portion of it liquefies, is stored in steel bottles and utilized industrially as "Blau gas." Available information indicates only one plant of this type in Canada.

OXYGEN. This is a colourless, odourless, tasteless gas which can be liquefied under pressure at —190° C. Liquid oxygen is a slightly bluish liquid which can be solidified at —227° C. This gas constitutes about one-fifth of the air and is the substance that supports the combustion of all fuels. Pure oxygen can be made for industrial purposes by the fractional distillation of liquid air. It is also made by the electrolysis of water, being recovered at the same time as the hydrogen.

Industrial oxygen is compressed or liquefied and stored in steel drums or bottles. It is used with hydrogen or acetylene in the oxy-hydrogen or oxy-acetylene blow lamp for the production of high temperatures. These lamps are used for cutting and welding steel and other metals including platinum. Pure oxygen gas is administered in cases of asphyxia, due to noxious gases or drowning. It is also occasionally used in medical practice as a stimulant, especially in anaesthesia. In recent years a method of using liquid oxygen as an explosive has been devised.

Oxygen is essential for the promotion of combustion. Ordinarily all fuels are burned by the use of oxygen of the air. There is a large quantity of low grade coal, high in ash, available that cannot be economically burned under present conditions. On the other hand oxygen is a by-product in the manufacture of air nitrates for fertilizer and other purposes. If the manufacture of air nitrates becomes a well established industry in the future there will be available a large supply of byproduct oxygen. It has been proposed to utilize this oxygen to burn these low grade fuels for the generation of heat, steam, and power. The development of a cheap method of making oxygen from the air or from water would also make it practicable to use lower grade fuels industrially.

Oxygen as a byproduct is produced in one plant where only the nitrogen is utilized, the oxygen being discarded. There are at least six plants which prepare bottled oxygen for industrial use. There are no records of importation, consumption, or production.

Oᴢᴏɴᴇ. This colourless gas is an allotropic form of oxygen possessing a very characteristic odour. It will support combustion more actively than oxygen, and is a very active oxidizing and bleaching agent. It can be liquefied under suitable conditions of temperature and pressure. Liquid ozone is an opaque blue liquid which boils at —119° C. It can be made electrically in a variety of ways, by the electrolysis of water, and by the use of high tension electric discharges. Chemically it can be prepared by heating barium peroxide with sulphuric acid under suitable conditions, or by passing oxygen over heated peroxides. When required for commercial purposes it is almost universally made electrically, by passing a current of air or oxygen between two specially formed high tension electrodes.

Ozone has the property of destroying the objectionable odours of organic origin arising from various industrial operations such as tanning, manufacture of glue, manufacture of certain organic chemicals, or odours arising from decaying vegetable or animal refuse. It is frequently used in certain factories for deodorizing, being generated at or near the place where it is required.

The most important commercial use of ozone is the sterilizing of local and domestic water supplies. The greater portion of the organic impurities in water can be removed by filtration, but the final purification is accomplished by introducing ozone in such a way that it will come into contact with as much of the water as possible. It will remove all objectionable tastes and odours due to organic materials and completely sterilizes it if it is properly applied.

Ozone is also beginning to find industrial applications in many technical operations. It is used for bleaching, deodorizing, or removing objectionable flavours from oils, fats, tallows, and waxes. It has the property of hardening raw flaxseed oil and it will cause other oils to thicken. Oils thus treated are used in the paint and varnish industry. As a bleaching agent it has been used in various textile industries for treating fine cotton and linen fabrics. It is not so suitable as chlorine for bleaching silk or wool, and the cost is higher. It has been used for clarifying sugar solutions. It is also used in the cold storage and brewing industries, and it has been proposed to use it for sterilizing sewage.

There is no information available with respect to the utilization of ozone industrially in Canada, though the abundance and relatively low cost of electric power in many localities should make it practicable to utilize ozone for sterilizing some water supplies. There are no records of any importations of ozone in compressed or liquid form.

PRODUCER GAS. Producer gas is a gaseous fuel made by blowing air, or air and steam through incandescent coal, coke, or other fuel such as charcoal or peat. It consists principally of a mixture of carbon monoxide and nitrogen, with small amounts of hydrogen and marsh gas. The reactions take place in a specially designed furnace. The calorific value of the gas prepared in ordinary producers is low—usually below 200 B. Th. U.

Producer gas is used industrially for many purposes where a cheap fuel easily controlled is required. Its principal use is probably for heating various types of melting furnaces, reverberatory furnaces, pottery furnaces, retorts, and other kinds of industrial furnaces, and in other metallurgical operations. This gas is also used for power purposes in gas engines.

There are a number of producer gas plants operated in Canadian manufacturing establishments, but no statistical data are available as to their number, distribution, or fuel requirements.

SULPHUR DIOXIDE. This is a colourless gas with a pungent and characteristic odour. When inhaled, even in very dilute mixtures with air, it has an irritating effect on the mucous membranes. It occurs naturally in volcanic regions and is present in the air of cities through the combustion of fuels containing sulphur. Very large quantities of this gas are also discharged into the air by smelting and refining plants treating sulphide copper or zinc ores. The gas is readily soluble in water forming sulphurous acid which oxidizes to sulphuric acid. It can be liquefied easily at a pressure of about three atmospheres when cooled to —10° C. The gas is prepared on a large scale for industrial purposes by the combustion of sulphur or of the sulphur content of pyrites in air. Extensive reference has already been made to the principal industrial applications of the products made from this gas in the sections on Heavy Chemicals and on the Pulp and Paper industry.

The liquid gas is stored in steel bottles or steel tanks for transportation purposes. Certain European countries require that these storage vessels shall be capable of withstanding an internal pressure of 30 atmospheres, but there are no regulations of this kind in force in Canada.

Sulphur dioxide in the gaseous form is used for the manufacture of sulphuric acid and sulphates, to make sulphite pulp, in certain metallurgical operations, in the manufacture of starch, in bleaching, and in numerous other industries. Its use in the different industries is discussed in other sections.

Liquid sulphur dioxide can be easily stored and transported. In this form it could be used in the sulphite pulp industry, and in many other industries much more conveniently than it can be made locally by burning sulphur. The liquid form is now used chiefly in refrigerator plants. It is also used as a solvent in the manufacture of glue, for bleaching delicate textile fabrics and straw, as a disinfectant, and in certain chemical manufacturing processes, such as refining of petroleum, tanning leather, or refining sugar. It is occasionally used in fire extinguisher liquids, and in the manufacture of certain chemicals.

Where the gas is required in manufacturing it is usually made locally. The industries requiring this gas in Canada all operate their own plants. Liquid sulphur dioxide is not made in Canada and there are no records of importations. Large quantities of this gas are discharged into the air at smelting plants, notably in the Sudbury region. It is probable that in the future it may be profitable to recover a portion of this gas in liquid form and utilize it in the manufacture of sulphite pulp. While this waste gas could also be used for making sulphuric acid, this product could not be marketed profitably under present conditions, and the quantity that could be produced would be much in excess of present requirements. There is a possibility of recovering elemental sulphur from waste sulphur dioxide gas in smelter stack gases by treatment with carbohydrates, or producer gas and steam. The subject is worthy of further and complete investigation.

WATER GAS. This is a mixture of hydrogen and carbon monoxide made by decomposing steam with incandescent carbon. This gas burns with a pale blue, non-luminous flame. It is used as a fuel, for developing power, and also for admixture with coal gas. The principal materials required are coke or anthracite coal and steam. There appears to be only one water gas plant in operation in Canada, and this is used as an auxiliary to a coal gas plant. All other plants produce carburetted water gas.

Water gas can be made luminous by the addition of hydrocarbons that will liberate free carbon in the flame as the gas burns. This is accomplished by vapourizing suitable petroleum oils in a heated carburetter, mixing the resultant oil gas with water gas, and heating the mixed gases. The final product is called carburetted water gas. There are a number of systems in use for the production of this gas. The systems used in Canadian plants are the Lowe, the Springer, and the Merrifield-Wescott-Pearson. There are twenty-five carburetted water gas plants in Canada, thirteen of which are used as auxiliaries to retort gas plants. Twelve plants are used for municipal purposes independently of other gas systems. Petroleum oils used for the manufacture of carburetted water gas in Canada are all imported. Anthracite coal is also imported. Coke used for this purpose may have been made from either domestic or imported coals in local retort plants.

CHAPTER V

PLASTERS, LIMES, AND HYDRAULIC CEMENTS

The production of structural materials from non-metallic mineral products constitutes one of our most important groups of industries. Among these materials plasters, limes, and cements are of first importance. All of these products are made by the suitable heat treatment of natural minerals, found in large deposits. This treatment promotes certain chemical changes which cause the final product to possess the property of hardening when subjected to certain well established conditions. This hardening property is due to a chemical change that can be promoted almost at will by the subsequent treatment. Heat to promote these chemical changes is obtained by the use of coal, petroleum, fuel oil, or natural gas. Plasters and limes are also made with wood fuel. Fuel and water are accessory raw materials required by this group of industries.

Raw Materials and Processes

Plasters: Plasters are made from gypsum, a mineral which occurs in large bedded deposits. Pure gypsum is a hydrous calcium sulphate containing 20.9% water ($CaSO_4.2H_2O$). Commercial gypsum, as mined, is rarely pure. It usually contains silica, anhydrite, calcite, and clayey products, the percentages varying locally. The presence of impurities naturally affects the character of the plasters that can be made from any given deposit of natural gypsum. For some varieties of plasters impurities amounting to 25% of the whole can be tolerated. When gypsum is burned by externally applied heat at a low temperature (150°—200° C.), most of the combined water is driven off, the residue constituting a partly dehydrated calcium sulphate. This product, when finely ground, constitutes the plaster of Paris of commerce. If certain impurities were present in the original gypsum, or if they were added, the finished product has somewhat different properties from plaster of Paris, and it is known commercially as cement plaster. Both plaster of Paris and cement plaster possess the property of re-absorbing water and setting or hardening. It is this property which makes these products of value commercially as structural materials. Certain variations in the method of manufacture and subsequent treatment give rise to closely related products which are marketed under such trade names as hard finish plaster and hard burned plaster.

Limes: Limes are oxides of calcium or magnesium obtained by subjecting the natural carbonates to heat. Limestone is the natural raw material from which calcium limes are made. Pure limestone is calcium carbonate, which contains 56 per cent calcium oxide and 44 per cent carbon dioxide. On heating to a temperature of about 900°—950° C. the carbon dioxide is driven off and the oxide of calcium, or lime, remains. This oxide has the property of setting or hardening if treated with water and then exposed to the air or any gas containing carbon dioxide. Pure limestone yields a pure lime when calcined. Such a product is called "quicklime." Natural limestones commonly contain some magnesium carbonate. Where the relative proportions of the two carbonates are nearly equal the natural rock is designated dolomite. At the other extreme we find deposits of almost pure magnesium carbonate, known as magnesite. Magnesium carbonate can also be decomposed on heating with the production of magnesium oxide. The intermediate rocks between limestone on the one hand and magnesite on the other give rise to different varieties of lime when calcined. Limes which carry less than 10 per cent of magnesium oxide are commercially rated as high calcium limes, while those that contain magnesium oxide in excess of this amount are designated magnesian limes.

When a lime is treated with water the oxides of calcium and magnesium present are converted into hydrates. This operation, known as "slaking," is accompanied by the evolution of heat. The hydrated lime, when exposed to the air, slowly absorbs carbon dioxide and reverts to the carbonate. Pure lime shrinks notably on drying. This is counteracted in practice by adding sand to the lime paste made in slaking, the product constituting lime mortar. Magnesian limes slake more slowly than pure limes. They also give off less heat, swell less, and set more rapidly. Magnesian limestones and dolomites which contain silica and clay materials as impurities, on burning yield a product that will set under water if the impurities are present in sufficient quantity. Such a product constitutes a hydraulic cement, to which further reference is made in a subsequent paragraph.

Magnesite, when burned, yields magnesium oxide. Pure magnesite contains 47·6 per cent magnesium oxide, and 52·4 per cent carbon dioxide. Magnesites are less widely distributed than limestones, particularly the purer varieties. The calcining operation is also more difficult to perform. The oxide is therefore more costly than lime, and its industrial applications are more specialized and limited. If the rock is burned at a light red heat the magnesium oxide formed has a relatively low specific gravity, absorbs water, and sets in air about the same way as lime does, and the paste can be moulded into shapes or otherwise applied. If the rock is calcined at a high temperature, the magnesium oxide produced has a higher specific gravity, does not form plaster like the low burned material, and does not absorb carbon dioxide from the air to form the carbonate. Magnesite bricks are usually made from mixtures of the heavy dead burned material and the lighter material burned at lower temperatures. The presence of 15 per cent to 20 per cent of the latter makes it possible to mould the bricks to the desired shapes. Such bricks harden slowly in the air, and, when sufficiently dry, are burned at a low red heat.

Magnesium oxide possesses the property of cementing or hardening when mixed with a solution of magnesium chloride, the product formed being oxychloride of magnesium. These materials are utilized as magnesia cement to make artificial stone, floors, floor tiles, and similar products from broken stones of various kinds and colours. The same material is used for cementing abrasive materials to make grindstones, emery wheels, and other kinds of polishing stones.

Hydraulic Cements: Hydraulic cements are mortars which have the property of setting under water. There are a number of different materials which will form cements having this property in common. An impure limestone, containing a certain amount of silica and clay material, and iron oxide, will, when calcined, yield a cement that will slake slowly and harden. Such a product is called a hydraulic lime. If the percentage of impurities present lies between 15 per cent and 40 per cent the lime present will practically all unite with the silica, alumina, and iron to form complex compounds, and there will be little or no free calcium oxide in the finished product. This material is not affected by water after burning as there is no free lime to slake. If it is ground into a fine powder this powder will harden rapidly if mixed with water, and will even set under water. A cement made from natural rock in this way is termed a natural cement.

It is possible to make mixtures of rocks containing lime (or lime and magnesia), silica, alumina, and iron oxide in suitable proportions to produce a product similar to natural cement. The raw materials used in commercial practice are limestones or marls to supply the lime, and clays or shales to supply the necessary silica, alumina, and iron oxide. The raw materials are dried, ground to fine powder separately, mixed in proper proportions to give the finished product desired, and charged into a special type of kiln. Modern practice uses long cylindrical rotary kilns, lined with fire brick, and fired with pulverized coal, natural gas, or oil. The mixture is calcined in the kiln at a temperature around 1,650° C. During the burning the lime unites with the silica, alumina, and iron oxide to form complex silicates and other compounds. The product as it leaves the kilns is in more or less nodular masses called " clinker." The clinker is then ground to an impalpable powder in special equipment. This fine powder has the property of hardening or setting when mixed with water in suitable proportions. In commerce it is known as Portland cement and it possesses the property of setting under water. In commercial practice it is customary to add a small quantity of gypsum to Portland cement clinker at the beginning of the final grinding. The finished product then contains a certain proportion of ground gypsum. This has the effect of retarding the rate of setting of the Portland cement, making it possible to shape and mould the material as desired. In structural work broken stone and sand are usually used with Portland cement, the latter serving chiefly to cement these materials together and to hold them in place.

Cement clinker is an artificial product consisting of silicates, aluminates, and ferrites of lime, or of lime and magnesia. Somewhat similar products are made incidentally as slags in iron blast furnaces, and they occur naturally in volcanic regions (as volcanic ashes). These products, if finely ground and mixed with water have the property of hardening much as does Portland cement, although the rate of hardening may be slower, and the hardened product may not be so strong. If slaked lime is added the hardening property may be improved. In some localities where volcanic ashes or blast furnace slags are available a cement is made by grinding these and adding a little slaked lime. This type of product is called Puzzolan cement.

Commercial Uses

Pure gypsum yields plaster of Paris on calcining. High grade plaster of Paris finds a large number of industrial applications which can be only briefly mentioned. The principal uses are as follows: Dental plaster modelling, moulds for many purposes, plate glass moulds for polishing, pottery moulds, hat moulds, foundry work, rubber stamp moulds, interior decoration for walls and ceilings, surgical casts, plaster ornaments, making match heads, in the construction of safes, in engraving or polishing jewels and jewelry, filler for paper, gypsum paint or whiting, in palaeontological and archaeological research.

Impure gypsum, or gypsum to which impurities have been added before or after calcining, yields a product called cement plaster if burned below 200° C. Cement plasters may be improved and strengthened by the addition of hair or wood fibre. A retarder is also added to delay the time of setting. Such plasters find many applications in interior work in dwelling houses and office buildings. The product is marketed under a number of trade names. If the calcining takes place at a red heat or over, and borax or alum is added and the mixture reheated, the product sets slower than ordinary plaster, but finally becomes much harder. Such plasters are termed hard finish plasters. Similar products are marketed under trade names such as Keene's cement, Mack's cement, Parian cement, and others. There are a number of other products made from calcined gypsums used principally for interior work. Such are alabastine, lieno plaster board, partition blocks, and similar materials.

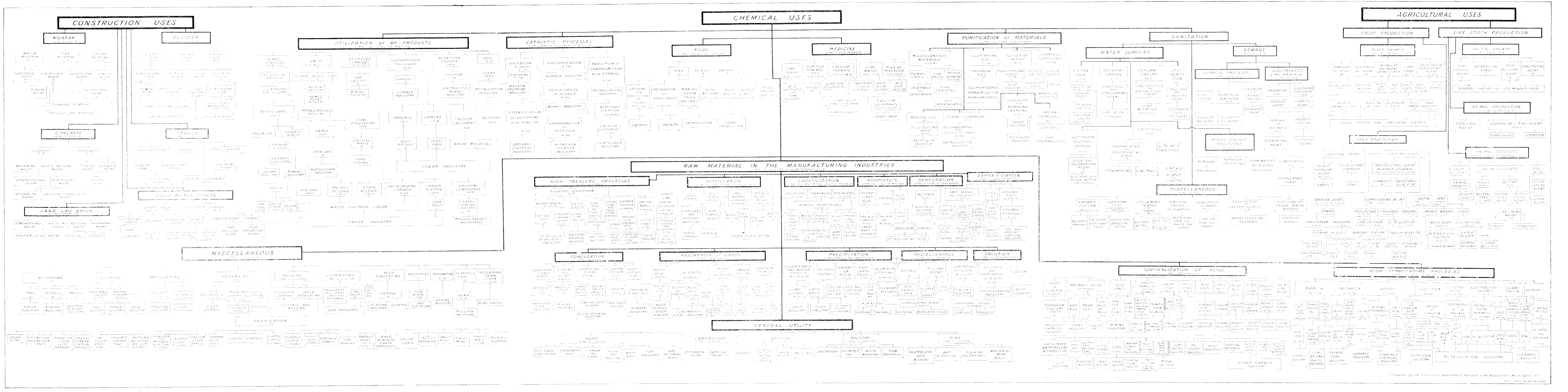
The best known use of lime is undoubtedly for the production of lime mortars. Since lime shrinks on drying and hardening it is never used alone. In making mortar the lime is slaked with water and allowed to cool, forming lime paste. Mortar is made by adding from two to four parts of sand to this paste. When lime is slaked under ordinary conditions by ignorant workmen the product is not necessarily uniform or satisfactory. If properly slaked the lime will absorb about one-third of its own weight of water. The best results are obtained if this slaking is done under competent supervision with suitable machinery. Some producers are now marketing a scientifically slaked lime called "hydrated-lime." The product is a dry white powder, which is packed in sacks or bags for marketing. It makes an excellent lime paste when water is added.

Lime is used in the manufacture of sand-lime bricks. These are made by mixing sand or gravel with a small amount of slaked lime, forcing the mixture into a mould under heavy pressure and then drying and hardening the product.

Lime also finds a large number of applications in the arts and industries. To enumerate these alone would require a great deal of space. The accompanying schedule showing many of the uses of limes has been included, through the courtesy of the National Lime Association, to show many of these applications.

Hydraulic cements, and particularly Portland cement, are used in the construction of dams, buildings, floors, sidewalks, and roadways, bridge piers, bridges, and in many other ways. Dry cement powder is used occasionally as a mineral filler for insecticides.

CHART SHOWING SOME OF THE INDUSTRIAL APPLICATIONS OF LIMES



Prepared by the Chemistry Department, National Lime Association, Washington, D.C.
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Diagram 7

Statistical Data

Statistics of the annual production in Canada of gypsum, ground gypsum, calcined gypsum, lime, sand-lime brick, and cements, are given annually in the reports on Mineral Production. No statistical data are available showing the annual requirements of the various other industries which use lime as a raw material. Data with respect to imports and exports of these commodities are also available in the annual reports of the Dominion Bureau of Statistics.

Canadian Situation

Natural deposits of gypsum occur in the provinces of Nova Scotia, New Brunswick, Ontario, Manitoba, and British Columbia. Gypsum has been quarried in all the provinces mentioned, though the last available reports indicate that no work is now in progress in British Columbia. Available records show the existence of 20 producers in Canada, 10 of these being located in Nova Scotia, 5 in New Brunswick, 3 in Ontario, and 2 in British Columbia. Eight of these plants were idle during the last few years. Most of these firms are engaged only in quarrying gypsum and selling it in lump form, or as crushed, or as ground gypsum. There are five firms, operating six plants, engaged in the production of calcined gypsum products.

Natural deposits of limestone, or magnesian limestone, occur in all the provinces of Canada, and there are lime burning plants in each province. The latest available records show 1 plant in Nova Scotia, and 1 proposed, 6 in New Brunswick, 2 in Prince Edward Island, both of which were idle at last reports, 24 in Quebec (7 idle), 45 in Ontario (13 idle), 8 in Manitoba (3 idle), 1 idle in Saskatchewan, 5 in Alberta (2 idle), 5 in British Columbia (1 idle). The total number of plants, including those that are idle, is 97. No data are available showing the total number of kilns available, the types of kilns in use, and the annual capacity of the kilns. Ten of these plants are equipped for the production of hydrated lime.

In addition to the above there are four firms operating special lime kilns for the production of lime for use in the manufacture of soda ash and calcium carbide.

There are 18 plants in Canada for the manufacture of sand-lime brick, having a daily rated capacity of about 650,000 bricks. One of these is located in Quebec, 10 in Ontario, 3 in Manitoba, 2 in Saskatchewan, and 2 in Alberta.

Materials suitable for the manufacture of hydraulic cements occur in all the provinces of Canada. Portland cement plants have been established in the provinces of Quebec, Ontario, Manitoba, Alberta, and British Columbia. An additional plant is proposed for the eastern provinces, but none has yet been constructed. One plant, located in Nova Scotia, makes Puzzolan cement from blast furnace slag.

There are 9 corporations operating in Canada owning 21 mills for the production of cement. Omitting the mill making Puzzolan cement, one making natural cement in a vertical kiln, and one mill that has been idle for some years, there are 18 mills available, equipped with 109 cylindrical kilns, having a rated capacity of 46,000 barrels of cement per day. The sizes and capacities of the several kilns vary greatly; the shortest kiln reported is 60 feet in length, while the longest measures 185 feet over all. The number of kilns actually in operation varies with the demand. During the last few years many of the plants have been idle and the others have not been working to capacity.

CHAPTER VI

FINE CHEMICALS (INORGANIC)

General

Many chemical products are classified as fine chemicals, in contradistinction to those which have been described in the preceding chapters of this report as heavy chemicals. It is not possible to formulate a precise definition of the term " fine chemical " which will be of universal application. There are a number of chemical products, such as those used as developers in photography, or the synthetic drugs, which are universally regarded as fine chemicals. There are other products upon whose classification it is much more difficult to decide.

There seems to be a general consensus of opinion that chemical products which are made on a comparatively small scale under special conditions of manufacture by highly skilled labour working under competent technical supervision shall be called fine chemicals. Usually the products are of a high grade of purity and are correspondingly free from impurities; often they are rare products made only by a few manufacturers and the unit costs are comparatively high owing to the conditions of manufacture, complexity and cost of the operation of the processes, and rarity and relative costliness of the raw materials.

The Association of British Chemical Manufacturers classify fine chemicals in five groups, as follows: Analytical, Pharmaceutical, Photographic, Rare Earth, and Synthetic Essences and Perfumes.

The first four groups of fine chemicals can be further subdivided into inorganic and organic products. In this chapter brief reference is made to inorganic fine chemicals; the organic fine chemicals are considered in chapter V at the end of part III of this report.

Inorganic Fine Chemicals

The number of inorganic or fine chemicals made for analytical work is very large and no attempt is made to enumerate them. Most of those marketed are made chemically pure, but in some cases routine laboratory determinations may be made with products which while nearly pure are not absolutely so. Analytical chemicals are usually made from purified hydroxides or carbonates of the metals, and purified acids. The basis of both series of products is the natural minerals containing the elements desired.

Inorganic pharmaceutical chemicals for medicinal purposes are made in the same way as analytical chemicals and from the same raw materials. Since they are for human use and are often applied internally they must be pure, or at least free from deleterious substances. The pharmaceutical manufacturer of inorganic fine chemicals often purchases inorganic chemicals either crude or of a technical grade and submits them to a refining process instead of making the products directly from raw materials. A classification of the principal chemicals used as pharmaceuticals is given in part III, chapter IV.

Photographic fine chemicals of inorganic origin are made in the same way as those for analytical purposes or for the pharmacist.

Salts of the rare earths are made by complex chemical processes from the rare natural minerals in which these substances are found.

The fifth group of fine chemicals does not include any inorganic compounds.

Table 10.—Fine Chemicals made in Canada (inorganic)[1]

Acids (hydrobromic, hypophosphorous, phosphoric, sulphurous); ammonium compounds (bromide, chloride, hydrosulphide, iodide, magnesium phosphate, nitrate); antimony chloride; arsenic compounds (iodide, tribromide); bismuth compounds (iodide, oxychloride); calcium sulphide; copper compounds (bromide, carbonate, chloride, cyanide, nitrate, oxide); gold compounds (chloride, sodium chloride); iron compounds (arseniate, bromide, iodide, perchloride, phosphate, sulphide); lead compounds (iodide, peroxide); magnesium compounds (chloride, phosphate); mercuric compounds (cyanide, iodide, oxide); mercurous compounds (iodide, nitrate, sulphate); potassium compounds (carbonate, chloride, iodide, nitrate, sulphate, sulphide); silver compounds (chloride, nitrate, oxide); sodium compounds (amalgam, arseniate, bromide, iodide, nitrate); sulphur iodide; zinc compounds (bromide, carbonate, iodide, sulphate).

Canadian Situation

No systematic studies have yet been made of the fine chemical situation in Canada. The preceding list names many products that were made here at one time. During the war production of most of these compounds ceased, and it has not been possible to ascertain how far it has since been resumed.

No statistical studies have been made of this industry in Canada. These products were made only by two or three firms. How many firms are now engaged in producing such products is unknown. Canada, for the most part, imports all the chemicals used for analytical purposes, for pharmaceutical purposes, and for photography. Where salts of the rare earths are required they are always imported.

Trade statistics based on Customs returns do not present any reliable information with respect to the market for these products in Canada.

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[1] The products listed were all manufactured in Canada at one time. They are not all now being produced, but manufacture could be resumed if warranted by commercial conditions.

PART III

CHEMICAL INDUSTRIES

PRIMARY ORGANIC PRODUCTS

INTRODUCTORY

There are a number of important industries whose principal raw materials are natural products of organic origin. Most of the materials are derived from plant life, but in a few instances they may be of animal origin. Inorganic chemicals are required in many cases to carry out the necessary chemical processes in making the products of this group of industries, but they play a relatively minor part, although they are essential to the successful application of the processes in which they are used.

The industries discussed in this section have been classified into five groups. The first group comprises those which use ferments as essential to their processes. The most important product is Industrial Alcohol. The second group comprises those industries which are based upon forest products, especially timber. The principal subject discussed is the production and utilization of cellulose. Some reference has also been made to other industries which produce cellulose products, although the cellulose used may be obtained from other sources than timber, all cellulose utilized commercially being of vegetable origin. The third group comprises those industries which make products by the destructive distillation of raw organic materials. The destructive distillation of wood has been included in this section in preference to discussing the subject under the caption of Forest Products industries. This third group also includes the destructive distillation of coal, coal tar, and petroleum. The fourth group comprises the numerous preparations that are used in pharmacy and medicine, and the fifth group includes fine chemicals of organic origin that are used chiefly in photography, and to a less extent in medicine and in other industries.

The raw materials of the first two groups of industries are derived from living plants and animals. The principal raw materials of the third group, the destructive distillation industries, with the exception of woods and plants, are natural mineral products. Coal is considered to have originated from prehistoric plant life, while petroleum is generally considered to have been derived from animal remains. Shale oils, on the other hand, which are closely related to petroleums, are obtained by the destructive distillation of shales which are supposed to contain organic materials derived from plants. Pharmaceutical preparations are derived chiefly from vegetables, although numerous fine chemicals derived from mineral products are also included in every book on this subject. Fine chemicals of organic origin, other than those included in pharmaceuticals, are derived chiefly from the products obtained by the fractional distillation of coal tar.

In the industrial utilization of these materials many other minerals or products derived from minerals are required. The discussions in the text have been confined to brief reviews of the salient features of the industries mentioned, special references being made to the mineral products that are essential to these industries. The discussion of the last two groups of industries has necessarily been very brief.

CHAPTER I

FERMENTATION INDUSTRIES

Fermentation is defined as the chemical decomposition of an organic compound with the formation of less complex compounds through the agency of a ferment. A ferment may be an unorganized complex organic compound capable of causing fermentation under suitable conditions—termed a chemical ferment or enzyme—or it may be a living organism—such as one of the many kinds of bacteria or yeasts. The fermentation industries then comprise that group of industries which employ ferments for the production of organic compounds of commercial importance by the decomposition of more complex organic products.

The fermentation industries form a group of very important chemical industries. The principal raw products utilized by these industries are of vegetable origin, and usually products of the agricultural industry, such as grains and cereals, potatoes, grapes, sugar cane, sugar beets, and other products containing natural sugars or starch which can be converted into sugars. These industries, for the most part, do not utilize minerals or chemicals made from minerals in their direct processes, though such materials may play a secondary part in some operations. They furnish a considerable market for manufactural products made from minerals and mineral chemicals, and a brief reference is therefore made to them and to their development in Canada. In another section of this report a more extended reference is made to the possibility of developing an Industrial Alcohol industry in this country.

The fermentation industries comprise such industrial operations as the production of wine, beer, alcohol, and vinegar; the souring of milk and cream for the production of casein; the preparation of coffee, cocoa, tea, and tobacco; the extraction of natural indigo; the retting of flax; the tanning of hides; and the preparation of many medicinal products. The most important of these is probably the production of industrial alcohol. Vinegar and lactic acid are also made in this way. In this section reference is made only to the production of alcohol, vinegar, and lactic acid. Commercial casein is usually made by the use of inorganic chemical precipitants and is therefore mentioned in a separate section.

Wine Production

Commercial wines are made from the juices of grapes, extracted by special processes, fermentation being promoted by pure cultures of wine yeasts. Similar products are made from the juices of many other fruits, but rarely on a commercial scale, except in the case of cider made from apple juice. Unfermented fruit juices are occasionally clarified, given a preliminary preservative treatment, and bottled.

The wine industry offers a limited market for certain types of coagulants such as egg albumen, ox blood, gelatine, isinglass, milk, or casein, which are used for "fining." Occasionally a soluble sodium compound of casein is used for this purpose. Excess acidity is corrected by the use of pulverized limestone or carbonate of lime, or by adding potassium tartrate. Gypsum has been used to assist in the improvement of the colour. The industry absorbs a considerable number of bottles annually, and it therefore offers a market for the products of the glass industry.

No statistical data are available with respect to the chemical requirements of this industry in Canada. The 1920 edition of the Canadian Trade Index contains the names of 13 firms making fermented wines, 37 firms making cider, and 12 firms making unfermented wines or grape juice, one firm making both fermented and unfermented wines.

Malting and Brewing

This industry produces beer from malt by the process of brewing. Beer is an alcoholic beverage containing less alcohol (3—6 per cent) than wines and larger quantities of vegetable extracts. The principal raw materials are certain grains (usually barley, but corn, rice, wheat, or oats can be used), hops, brewer's yeast, and water. Most grains contain large quantities of starch which is not subject to alcoholic fermentation. It is therefore necessary to cause the grain to germinate naturally under suitable conditions. This process, known as malting, results in the formation of diastase, an enzyme capable of decomposing starch into maltose and dextrine, the first of these being a sugar.

In practice the germinated grain or malt is ground or crushed in warm water to permit the diastase to come into contact with as much starch as possible. A certain proportion of the starch is converted into maltose and the mixture is then heated to decompose the diastase, the resulting liquid constituting the wort. After the wort has been cooled a certain amount of a pure yeast culture is added and this causes the maltose to be converted into a less complex sugar, dextrose, through the action of an enzyme, maltase, present in the malt and in the yeast. This dextrose is in turn converted into alcohol and carbon dioxide by the action of zymase, another enzyme present in the yeast. These operations require accurate temperature control to obtain the best results, and elaborate artificial heating and cooling equipment is usually employed.

This industry does not utilize inorganic products except indirectly. It offers a very large market for bottles. The cooling equipment requires either anhydrous ammonia or liquid carbonic acid to produce low temperatures, and brine solutions, either sodium chloride or calcium chloride for refrigeration. Carbonic acid gas is also used for charging. Isinglass or gelatine is used for clarifying. Certain special varnishes, made from shellac, are used for dressing the insides of wooden barrels, tanks or vats to prevent the wood becoming soaked with the various solutions. Resinous pitch is also employed for lining barrels and vats.

Statistical data with respect to the annual requirements of this industry, either for bottles or other products, are not available. The Canadian Trade Index for 1920 contains the names of 64 firms engaged in the production of beers of various kinds.

Distilled Liquors and Alcohol

Alcohol produced by the fermentation process in the manufacture of wines and beers is retained in association with the extracts and liquors in which it is produced, and the maximum conversion attainable is not usually desired. Where fermentation processes are used for the production of distilled liquors the maximum amount of alcohol possible is produced by the fermentation, and the liquid containing the alcohol is then subjected to fractional distillation. Where a pure product is required the distillation process may be repeated two or more times, the final product being "rectified spirit" which contains 94—96 per cent pure ethyl alcohol.

Raw materials for the production of distilled liquors consist of wines, materials containing sugars, and materials which contain starch. Alcohol can also be made from products convertible into glucose, or synthetically from ethylene (C_2H_4) or acetylene (C_2H_2).

The distillation of wines results in the production of brandy. Brandy is also made by the use of spirits made from starch products.

Sugar is made chiefly from the juice of the sugar cane and from sugar beets. Sugar itself is not used directly for the production of alcohol or distilled liquors. Cane molasses obtained after the raw sugar has been removed, sugar beets, and beet molasses are subjected to alcoholic fermentation and afterwards distilled. Cane "bagasse," which consists largely of fragments of sugar cane from which most of the juices have been expressed, is also allowed to ferment, and is then extracted, the resulting liquors being subject to distillation. Fruit juices containing sugars may be treated in the same way. The principal product of this phase of the industry is probably rum. Cherry brandy, plum spirit, and gin are closely related products made in a similar manner.

The larger part of the production of distilled liquors and alcohol is obtained from starch bearing materials. In America the grains—wheat, barley, rye, and corn—were formerly largely used for this purpose. In Germany potatoes are the principal source of starch. Rice can also be employed.

Grains are malted to produce diastase, or malt is added to prepared grains, the object being to convert the starch into a sugar, which is then fermented with yeast to produce alcohol. In the distilling industry the operations are carried on in such a way as to obtain the maximum conversion of the starch into sugar and then into alcohol. Potatoes are mashed and boiled under pressure, steam usually being employed for this purpose, and are so treated that the starch cells are broken and the starch itself is almost completely gelatinized. Corn is treated in a very similar manner. Starch prepared in this way, from potatoes or from corn, is then treated with finely ground malt, specially prepared for the purpose, in order to supply diastase for the conversion into sugar.

The liquors obtained by the treatment of starch with diastase constitute the distiller's wort. This wort is treated with pure yeast culture to promote fermentation. The resulting fermented mash is distilled for the production of spirits. In addition to spirits containing a high proportion of ethyl alcohol there are usually produced a considerable quantity of fusel oils which are subsequently separated by redistillation. This fusel oil consists largely of amyl alcohol, but also contains other members of the series. Aldehyde due to the oxidation of ethyl alcohol, amine bases, and formic acid are also present. The first of these byproducts is utilized industrially for the preparation of certain varnishes and lacquers. It is also used as a solvent for nitrocellulose, and for other purposes.

Redistillation is necessary for the production of spirits free from undesirable byproducts. Distilled liquors are sometimes designated "grain spirit" or "potato spirit," according to the source of the starch. Where pure ethyl alcohol for industrial purposes is required it is necessary to subject the product to a further distillation process termed rectification. Rectified spirits contain 94—96 per cent ethyl alcohol. Absolute alcohol is made by removing the balance of the water by special treatment.

The residues where grains or potatoes are used contain nitrogenous materials, and are utilized for the manufacture of special foods for cattle. The residues from molasses fermentation, after the alcohol and related products have been removed by distillation, contain some nitrogen and an important percentage of potash salts. They are usually dried and used directly as fertilizer materials, or they may be subjected to further treatment for the production of certain potash salts, ammonia, or compounds of cyanogen.

The production of alcohol from wood fibre, which is composed largely of cellulose, is a problem that has received a good deal of attention. The conversion of cellulose into dextrose, both by the use of strong sulphuric acid and strong hydrochloric acid, has been accomplished. Ethyl alcohol has been obtained in the usual manner by the fermentation of the dextrose and subsequent distillation. The spirit obtained from wood cellulose is apt to contain methyl as well as ethyl alcohol, but it can be used industrially as methylated spirits.

A process has been developed for the production of ethyl alcohol from acetylene. This gas is produced by the interaction of water and calcium carbide—electric power, coke, and limestone being the essential raw materials for industrial production on a large scale. The gas is converted into acetaldehyde in the presence of catalytic agents, such as sulphuric acid, glacial acetic acid with a salt of mercury, ferric-mercuric sulphate, or certain other chemicals. The acetaldehyde is then hydrogenated by reduced nickel into ethyl alcohol. The process is said to be in successful commercial operation in Switzerland. Alcohol can also be prepared synthetically from acetylene by an electrolytic process.

Ethylene can also be hydrated into alcohol. This has been successfully accomplished at the coke ovens of the Skinningrove Iron and Steel

Works, at Saltburn, England. A yield of 1·6 gallons of ethyl alcohol per ton of coal coked was obtained.

Distilled liquors are used largely for beverage purposes. Small quantities are also required for medicinal purposes, or find application in the industrial arts chiefly as solvents. The production of distilled liquors in Canada has been greatly curtailed during recent years and it is probable that most of the plants now engaged in this industry will be converted to the production of industrial alcohol if the prohibitive excise taxes which have hitherto prevailed are removed. There are thirteen firms engaged in the distillation industry. Six of these firms also produce alcohol for industrial purposes, and three other firms produce industrial alcohol only.

Industrial alcohol is undoubtedly the most important product of the fermentation industries. It forms the base from which more than two hundred products are made, and is also used very extensively as a solvent in many industries for the manufacture of numerous products. The development of an industrial alcohol industry in this country would materially reduce the costs of many products that are now imported, and would broaden the market for many industrial products.

The successful development of a commercial process that would make it possible to utilize the waste liquors from the sulphite pulp mills of this country would be of immense industrial importance. The immediate difficulties appear to be due to the low percentage conversion that can be obtained and the large volume of liquors that must be handled. These troubles together with certain technical difficulties of manipulation have hitherto retarded developments in this direction. The extraordinary high excise duties and the corresponding lack of demand for large quantities of industrial alcohol for manufacturing purposes all have combined to prevent the profitable utilization of these waste products in this way.

A more extended discussion of Industrial Alcohol and its commercial utilization is given on another page.

The manufacture of alcohol by distillation does not offer a market for any large quantity of minerals or mineral products. Small quantities of hydrofluoric acid or ammonium fluoride are used as an antiseptic to prevent secondary fermentation and to otherwise aid in the alcoholic fermentation. Some of the accessory products used in brewing are also used in this industry. The consumption of glass bottles was formerly very large. Alcohol for industrial purposes is handled in barrels, drums, and tank cars.

Vinegar

This product consists of weak aqueous solutions of acetic acid—between 4 and 10 per cent—in association with fruit flavours. It is made by the oxidation of alcohol through the agency of certain bacteria. These bacteria will only grow and develop in weak alcoholic solutions which contain other materials—nitrogenous products and mineral salts—suitable for food. Commercial vinegar is made from low grade wines, from dilute spirits (to which suitable foods for the acetic acid making bacteria have been added), from specially prepared malt, from fermented fruit juices (particularly apple and pear juice), and from sugar beets.

Where sugar containing materials are used alcohol is first produced by the addition of yeast to promote fermentation and to convert as much of the sugar as possible into alcohol. When the fermentation is complete the resulting liquor is decanted and clarified and then treated with the acetic acid bacteria in specially prepared vats or vessels, so constructed that air to supply oxygen has direct access to as large a surface of liquid as possible.

Vinegar made in this way is used chiefly as a condiment in the preparation of food, and as a preservative in pickling fruits, vegetables, and meats. Occasionally vinegar is used in the manufacture of white lead.

There are more than thirty-two firms in Canada engaged in the manufacture of vinegars. The principal vinegars manufactured are malt, cider, and spirit. There are no statistical data available showing the quantities produced annually. The average quantity of vinegar imported in the three fiscal years preceding the war was 15,623 gallons above proof strength, valued at $3,168, and 179,015 gallons of proof strength and under, valued at $68,399. In the fiscal year 1918-19, 34,010 gallons above proof strength, valued at $3,850, and 48,171 gallons of proof strength and under, valued at $17,729, were imported. In two years before the war 388 gallons of imported vinegar, valued at $280, were exported, and in the same period 492 gallons of domestic vinegar valued at $114 were exported. No exports are recorded in the first year after the armistice.

The vinegar manufacturing industry does not utilize inorganic chemicals or other products to any great extent. In one process of making spirit vinegar sulphuric acid is used to hydrolize starch to glucose previous to the fermentation of the glucose. In this process pulverized limestone is used to neutralize any free acid which may be present when the conversion is complete. So far as the writer is aware this process is not employed in Canada. The industry requires a limited number of containers. Glass bottles are used for this purpose, to a limited extent. Bulk shipments are usually handled in kegs or barrels.

Lactic Acid

This acid, as the name implies, is the acid that is produced by the souring of milk. Commercial lactic acid is prepared by heating a solution of glucose (grape sugar) with lactic acid bacteria under suitable conditions.

The solution of glucose is made from starch obtained from grains such as corn or from potatoes by treatment with malt as in the manufacture of alcohol. A nitrogenous food prepared from nitrites and other salts, or a prepared vegetable albumen is supplied to support the life of the bacteria. Pure cultures of the proper bacteria to produce lactic acid are added to the solution and the fermentation is carried out at a temperature not lower than 45°C. nor higher than 55°C. At this temperature the ferments which produce alcohol or those which produce butyric acid do not thrive. Since the lactic acid bacteria are themselves destroyed by the acid they make, if it exceeds one per cent, it is necessary to add small quantities of powdered limestone to neutralize the excess acid, calcium lactate being formed. The operation is a delicate one, since if more than half of one per cent of the acid is removed by neutralization at any one time there will be a tendency to form butyric acid, which is not desired. The operation is continued until all the sugar has been converted.

Calcium lactate obtained in this way is purified by crystallization, and lactic acid is obtained by treatment with sulphuric acid, and afterwards concentrating and purifying.

Commercial lactic acid is a clear syrup-like solution containing 22—24 per cent acid. It is used in the tanning and leather industries, in the textile industry, as a mordant in dyeing, and medicinally. It is also used for the production of certain metallic salts.

So far as the writer is aware this acid is not made commercially in Canada. The available records do not indicate how much is imported annually.

CASEIN MANUFACTURE

Casein is a complex organic compound found in the milk of mammals and in the juices and seeds of certain leguminous plants. It occurs in milk in combination with calcium, the compound being present in colloidal suspension. Technical casein is prepared from sweet milk. Since it must be free from fat the milk is first treated in a centrifugal separator to remove the cream, after which a small amount of caustic soda in solution (or sodium carbonate) is added. The mixture is then treated several times in the separator to remove all fat. After treatment in the centrifugal separators the resulting liquid is placed in a vat and mixed with dilute sulphuric or hydrochloric acid, the liquid being thoroughly agitated and the acid being added slowly until precipitation is complete. Under this treatment the lime-casein compound in the milk is decomposed and the casein is separated as a solid which is allowed to settle in the bottom of the treatment tank. The liquid is removed by decantation or siphoning, and the curd is washed repeatedly in cold water until all traces of acid have been removed.

Casein curd prepared in this way is drained, pressed between cloths to remove the excess water, broken into small pieces and thoroughly dried in vacuum drums.

Casein is insoluble in alcohol, ether, and water. Chemically it acts both as an acid and as a base, forming salts with members of either group. The salts formed with the alkali bases are soluble, as are many of the other salts.

Casein and casein preparations find a number of industrial applications. The principal uses are as a varnish preparation, as an adhesive, in the preparation of plastic materials which are used as substitutes for celluloid, horn, or ivory, as a sizing material in the manufacture of paper and in the textile industries, in food preparations, and in "fining" certain products of the fermentation industries. Casein glue which can be rendered waterproof is an important material in the manufacture of aeroplane propeller blades, veneer plywood, etc. "Galalith" is a hornlike substance prepared from casein by treatment with formaldehyde, which finds many applications in industry, particularly as an insulating material.

The principal accessory materials used in the production of technical casein and its products are sulphuric or hydrochloric acids. Acetic acid, citric acid, lactic acid, phosphoric acid, or tannic acid can also be used. Either caustic soda or sodium bicarbonate is used as the alkali. In addition the following products are required occasionally: alcohol; ammonium hydroxide; borax; calcium compounds (hydroxide, tannate); camphor; formaldehyde; magnesia; sodium compounds (arsenate, biborate, bicarbonate, silicate, tungstate).

The average value of imported casein for the three years prior to the war was $12,491. During the same period 547,183 lbs., produced in Canada, and valued at $21,572, were exported annually. In the fiscal year 1918-19 the imports were valued at $33,319, and the exports amounted to 9,110 lbs., valued at $1,936. In the fiscal year ending March 31, 1920, the imports amounted to 1,234,635 lbs., valued at $159,177. Of this quantity 1,187,183 lbs. came from the United States, and 3,360 lbs. from Great Britain, the balance 44,092 lbs. being credited to "other countries." No exports are recorded for the year 1919-20.

There are no statistical records available showing the quantity produced in Canada, nor the average annual requirements. The largest single consumer is probably the paper industry. The large quantity imported last year would indicate that there is available a large domestic market which could be supplied by home production. Casein is essentially a byproduct of the dairy industry since it is prepared from milk from which the cream has been removed. Available records show only six firms in Canada who produce casein.

INDUSTRIAL ALCOHOL

There are a number of closely related chemical compounds, which are classed as alcohols. Some of these alcohols are not of commercial importance as yet, and some of them have only limited applications. There are two, however, ethyl alcohol (C_2H_5OH) and methanol (CH_3OH), which find numerous uses in the arts and industries and these are correspondingly important commercially. Ethyl alcohol is readily produced from a variety of substances, has a heating value of 12,700 B.Th.U., is relatively easier to make, is more valuable industrially, and is in greater demand than methanol. When alcohol is mentioned it is usually ethyl alcohol that is meant. Methanol, formerly known as wood alcohol because it is obtained from the destructive distillation of wood, has a heating value of 9,594 B.Th.U., is relatively less plentiful than ethyl alcohol, is made from a narrower range of raw materials, and has fewer industrial applications. The manufacture and commercial uses of methanol are described elsewhere in this report (see section on Wood Distillation).

Industrial alcohol is the commercial name applied to ethyl alcohol that has been prepared for industrial use. Alcohol can be produced by the fermentation of any organic substance which contains sugar or starch. It is a potable drug and is well known as an important constituent of numerous beverages. Owing to the physiological effects of alcohol when its use as a beverage is abused numerous legislative restrictions affecting its manufacture and sale have been brought into effect in recent years in nearly all countries. Alcohol, and beverages containing alcohol have also been subjected to exorbitant and indiscriminate taxation for many years in Canada particularly, in the United States to a less degree, and with more discrimination in other countries. Until very recent years there has been no distinction made in Canada between alcohol for industrial purposes and that contained in beverages. This circumstance has prevented the development in this country of the very large group of chemical industries which use alcohol as a basic material. Restrictive legislation which does not discriminate between the use of alcohol for beverage purposes and its use for manufacturing is retroactive and is not in the public interest. Public welfare demands the minimum of restrictions on both the manufacture and the use of ethyl alcohol in industrial operations. The more enlightened legislation contained in the Canadian Inland Revenue Act of July, 1920,[1] will tend to improve conditions in this respect. The development of several essential chemical industries and their profitable continuation depend primarily upon the wise control of the production, distribution, and uses of ethyl alcohol. A glance at the table listing industries using alcohol and at the names of the varieties of products made from it, will quickly demonstrate the immense importance of this product in promoting national development and progress.

Denatured Alcohol

Alcohol for industrial purposes must be kept separate and distinct from alcoholic beverages. It has been found possible to treat it with certain other products in such a way that it cannot be used as a beverage, while it is still suitable for certain manufacturing purposes. Alcohol so treated is termed " denatured " alcohol. Because it is possible to denature alcohol and to thus render it unfit for beverage purposes it becomes possible to modify restrictive legislation so as to restrain the use of alcoholic beverages without imposing undue handicaps on the development of chemical industries based on alcohol or the use of alcohol industrially.

There are a number of chemical products which can only be made from alcohol that has not been subjected to denaturing treatment. In such cases it is necessary to impose rigid restrictions on its use to prevent its misuse for beverage purposes. There are, however, numerous industrial operations in which denatured alcohol can be used. Rigid restrictions are not necessary in these cases, except in the supervision of the initial manufacturing and denaturing.

Denatured alcohol is prepared by adding to the pure product small quantities of one or more designated chemicals which render the resultant mixture unfit to drink, and which cannot be easily removed from the alcohol by distillation or other means. The substances used for this purpose are either poisonous or are repugnant to taste and smell. No one denaturant can be used for all purposes since the denaturant itself might injure the

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[1] An Act to amend the Inland Revenue Act, 10-11 George V., Chap. 52, Part X.

final products to be manufactured. The kind of denaturant used will thus depend in part upon the purpose for which the alcohol is required. Sometimes industrial alcohol is only partially denatured.

Denatured alcohol, as defined in the Inland Revenue Act,[1] means alcohol in suitable admixture with such denaturants as to render it, in the judgment of the minister, non-potable and to prevent recovery of the ethyl alcohol. The United States act defines denatured alcohol as ethyl alcohol to which has been added some material which prevents its use for internal administration.

The Canadian act further provides for "specially denatured alcohol" which is defined to mean alcohol in suitable admixture with such special denaturants as have been approved by the minister.

The United States act provides for completely denatured and specially denatured alcohols. The former is defined as alcohol which has been denatured by a limited number of fixed formulae, for sale to the general public with very little supervision. All of the products produced by these formulae are injurious to the human system. The latter is defined as alcohol which is not as completely denatured as the "completely," and can only be obtained under a heavy bond for use in manufacturing processes in which the alcohol is always protected by the bond.

Denaturing alcohol for industrial purposes appears to have been first legalized in Great Britain about 1855. A tax had been levied on alcohol for a number of years previously, but in this year the use of methylated spirits for industrial purposes was permitted. The denaturant was a 10 per cent addition of impure methanol containing acetone and other chemicals produced in the destructive distillation of wood. Alcohol so treated was not subject to the alcohol tax. Holland legalized denatured alcohol for industrial purposes in 1865, and still greater freedom was authorized in 1872. France recognized the importance of denatured alcohol in 1872, and in 1881 further modified the laws relating thereto. Germany allowed tax free industrial alcohol in 1879, followed in subsequent years by further legislation which tended to reduce the restrictions on the use of this chemical in manufacturing and increased the number of denaturants permitted. This legislation has been an exceedingly important factor in the development of many of the German chemical industries because for many years industrial alcohol was obtainable there more cheaply than in any other country. Tax free alcohol for industrial purposes was authorized in Austria in 1888, in Italy in 1889, in Sweden in 1890, in Norway in 1891, in Switzerland in 1893, in Belgium in 1896.

The history of alcohol legislation in the United States shows many changes and variations. The first tax on distilled spirits was levied as a revenue measure in 1791, fifteen years after the Declaration of Independence. Numerous modifications have taken place from time to time, tending chiefly to the imposition of closer restrictions and higher taxes. In 1917 the tax rate was $3.20 per proof gallon for spirits in beverages, and $2.20 per proof gallon for non-beverage purposes. At this rate 95 per cent pure alcohol for manufacturing purposes was taxed $4.18 per gallon.

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[1] 10-11 George V., Chap. 52, July, 1920, p. 6.

Restricted exemptions from the application of these taxes were provided from time to time for special purposes, and various provisions with respect to denaturants were also made at irregular intervals. The National Prohibition Act, passed in 1920, under sections 1 to 19, of Title III., provides for tax free alcohol for industrial purposes.[1] Six formulae for completely denatured alcohol and 58 formulae for specially denatured alcohol have already been allowed by the Commissioner of Internal Revenue. Additional formulae for tax free specially denatured alcohol may be allowed from time to time.

The Canadian Inland Revenue Act of 1906[2] provided for a tax of $1.90 on every gallon of proof, the equivalent of 49·28 per cent absolute alcohol, and proportionally for greater or less strength, and denaturing with wood spirits was permitted. This tax was raised to $2.40 by the amended act of August, 1914,[3] the equivalent of $4.63 per gallon of 95 per cent pure alcohol, or about twelve times the cost of manufacture. Under the legislation of July, 1920,[4] "denatured alcohol and specially denatured alcohol as defined in the next preceding section which is intended for use in the arts and industries, or for fuel, light, or power, or for any mechanical purpose, may be manufactured in Canada free from excise duty."* * * * * * "Denatured alcohol shall be sold, delivered and transported without restriction to dealers, manufacturers, and other persons." * * * * "Specially denatured alcohol shall only be sold or delivered under a departmental permit to dealers and manufacturers to be used in the arts and industries in cases where denatured alcohol would be unsuitable, and shall only be moved or transported under such conditions as the Minister may by regulations prescribe." The Department of Inland Revenue is charged with the control of the actual manufacture of denatured alcohol for the purpose of ensuring the quality of the denaturants as well as the respective percentages employed in producing the different grades. Under departmental regulations the use of methanol, benzol, nitro-benzol, and pine oil for the production of completely denatured alcohol by prescribed formulae has been authorized. The use of iodine for the production of a specially denatured alcohol has also been authorized. Prescribed formulae for the use of these denaturants have been issued as departmental regulations. Provision has been made in the act for the authorization of additional formulae if suitable representations are made to the responsible administering department.

Raw Materials

Industrial alcohol can be made from three classes of raw organic materials, which may be designated sugars, starches, cellulose, and it can also be made from certain mineral products. The sugar group comprises such products as molasses from sugar cane, sugar beets, fruit juices, juices of certain palms, and similar products. The starch group comprises potatoes, yams, grains of all kinds (especially rice, wheat, barley, and Indian

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[1] See U. S. Treasury Department Regulations.

[2] Chapter 51, Revised Statutes of Canada, section 154.

[3] Chapter 6, 5 George V., section 154.

[4] Chapter 52, 10-11 George V., section 369.

corn), acorns, or chestnuts. The cellulose group comprises such materials as sawdust, waste sulphite liquors, straw, and cellulose fibres of certain plants or parts of plants. It is also possible to make alcohol synthetically from ethylene gas, a byproduct of coal carbonization as well as a constituent of some natural gases, or from acetylene gas, the primary materials in the latter case being coke, limestone, and electric power. These latter methods are still in the experimental stages and are not factors in the present industrial production. They offer especial opportunities for future industrial development in Canada because of the great available supplies of raw materials and potentially cheap electric power.

Processes of producing alcohol by fermentation from sugars and starches have already been briefly discussed in the section dealing with the Fermentation industries. Alcohol can be produced from cellulose products by first converting the cellulose content into glucose (hydrolizing) by special treatment, either with sulphuric or sulphurous acid, or by other means. The resulting sugar is subjected to alcoholic fermentation until the maximum conversion is obtained. On the completion of the fermentation the alcohol is recovered by distillation and rectification.

The list of organic substances, both natural and artificial, from which ethyl alcohol can be produced is very large. The subjoined tabulation includes only the more common materials that have been used for this purpose. Many of these products, however, are obviously unsuited for the production of cheap alcohol for industrial use. Many of the products are not available in sufficient quantities in any one locality to make it practicable to produce alcohol from them at a profit. This is particularly true of most fruits and of certain trade wastes such as sawdust. A number of processes have been patented and exploited to utilize sawdust, but the technical difficulties have not all been completely surmounted and the processes must be regarded as being still in the development stages. With respect to sulphite liquors as a source of cheap alcohol the outlook is more promising, especially for the larger mills. There are about 45 plants in Europe now producing industrial alcohol from this trade waste, 21 of these plants being in Sweden. There is also one plant in the United States producing sulphite alcohol. The most recent proposal is to further utilize the residue after the extraction of the alcohol as a fuel. It has been stated that the fuel recovered is more than sufficient to operate the alcohol plant.[1]

Table 11.—Sources of Ethyl Alcohol

GRAINS: Barley, buckwheat, maize (Indian corn), millet, oats, ragee, rice, rye, wheat.

BERRIES: Blackberry, blueberry, currant, gooseberry, huckleberry, mulberry, raspberry, strawberry.

FRUITS: Acorn, apple, apricot, banana, cactus fruit, cherry, date, fig, grape, horsechestnut, melon, orange, peach, pear, pineapple, plum, pomegranate, prune, watermelon.

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[1] Ethyl alcohol and coal from sulphite waste liquor, N. E. Clementson, Pulp and Paper Magazine, Mar. 24, 1921, pp. 317-322.

ROOTS: Carrot, cassava, mangel, sugar beet, turnip.

STEMS: (Leaves and underground stems included) Agave, artichoke, cactus, cocoanut palm, date palm, fern (bracken), grasstree, mahua, palms (nipa and sago), peat, potato, seaweed, sorghum, sotol, straw, sugar cane (and bagasse), sugar corn stems, zamia palm, other trees containing starch or cellulose.

TRADE WASTES: Beet molasses, cane molasses, corn cannery refuse, fruit cannery refuse, garbage (city refuse), gases (from coke plants), sawdust, sulphite liquor.

SYNTHETIC: Calcium carbide (coke, limestone, and electric power), ethylene (byproduct from coal or coke ovens, and also a constituent of some natural gases).

Uses of Industrial Alcohol

Industrial alcohol is utilized in so many industries and in such a great variety of ways that it is impossible to present a complete list of its applications here. The principal applications of this product may, however, be grouped under one or more of the three following heads: fuel, solvent, or raw material for the manufacture of chemicals.

As a *fuel* it may be used as a source of heat, light, or power. Its heating value, which is high, is rated at 12,700 British thermal units. It is now used in comparatively small units for each of the three purposes mentioned above. Its applications to these uses on a larger scale are dependent not only upon the cheapening of production, but also upon the relative cheapness and availability of supplies of competing fuels. It is probable that alcohol will form an important constituent of motor fuels in the future.

As a *solvent* alcohol finds numerous applications in many industries. It evaporates readily from its solutions and is thefore valuable where it is desired eventually to dispose of the solvent. Nitrocellulose is soluble in alcohol and solutions are utilized in the manufacture of photographic films, celluloid and celluloid products, collodion (liquid skin), smokeless powders, gas mantles, artificial silks and leathers, carbon lamp filaments, and other articles. Many dyes and flavouring extracts used in the preparation of foods are applied in liquid form by the use of alcohol as a solvent. Calico printing is accomplished by using dye solutions. It is used as a solvent for certain gums and resins in the manufacture of spirit varnishes, and as a vehicle for wood dyes, metal and wood polishes, wood lacquers, and fabric dopes. It is used as a solvent for numerous drugs and medicinals, in the manufacture of liniments and lotions, and for the production of flavouring extracts from essential oils such as lemon, peppermint, rose, vanilla, or wintergreen.

In *chemical manufacture* it is used for making such products as ether, ethyl acetate and many other ethyl compounds, acetic acid vinegar, chloroform, iodoform, mercury fulminate, antipyrine, sulphonal, and it also finds very wide application in the manufacture of aniline dyes.

The accompanying chart, published through the courtesy of the U.S. Industrial Alcohol Company of New York, shows only a few of the many uses of this very important chemical product.

There are at the present time nine firms licensed to produce industrial alcohol in Canada, five of these are located in Ontario, three in Quebec, and one in British Columbia. So far as records now available indicate there is only one Canadian firm now manufacturing chloroform, ethyl bromide, and ethyl chloride. This production is a comparatively recent development. Formerly chloroform and certain ethers were made in Canada for the home market, but production became unprofitable owing to the high alcohol tax of the acts of 1906 and 1914 and production ceased. Alcohol as a solvent is used by many Canadian industries, particularly the paint and varnish trade, and in the manufacture of drugs and pharmaceuticals. Its use as a fuel is both limited and local. A considerable quantity is used during the winter months in non-freezing solutions for automobile radiators.

Industrial alcohol produced in Canada at the present time is made either from grains or from molasses, the latter being obtained from sugar refineries in Canada, and also imported. One firm proposes to utilize potatoes, but there are no records available showing production of potato spirit.

The statistical tables in part I of this report show the imports and exports of alcohol and of a number of products in the manufacture of which alcohol is used as a solvent, or in which alcohol is required for manufacturing processes. The Dominion Bureau of Statistics reports the production of 1,777,289 proof gallons[1] valued at $893,528 in 1919, and 2,223,428 proof gallons valued at $1,595,584 in 1920.

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[1] A proof gallon contains 49·28 per cent pure alcohol by weight.

CHART SHOWING SOME OF THE MANY USES OF ALCOHOL

PREPARED BY
U.S. INDUSTRIAL ALCOHOL COMPANY

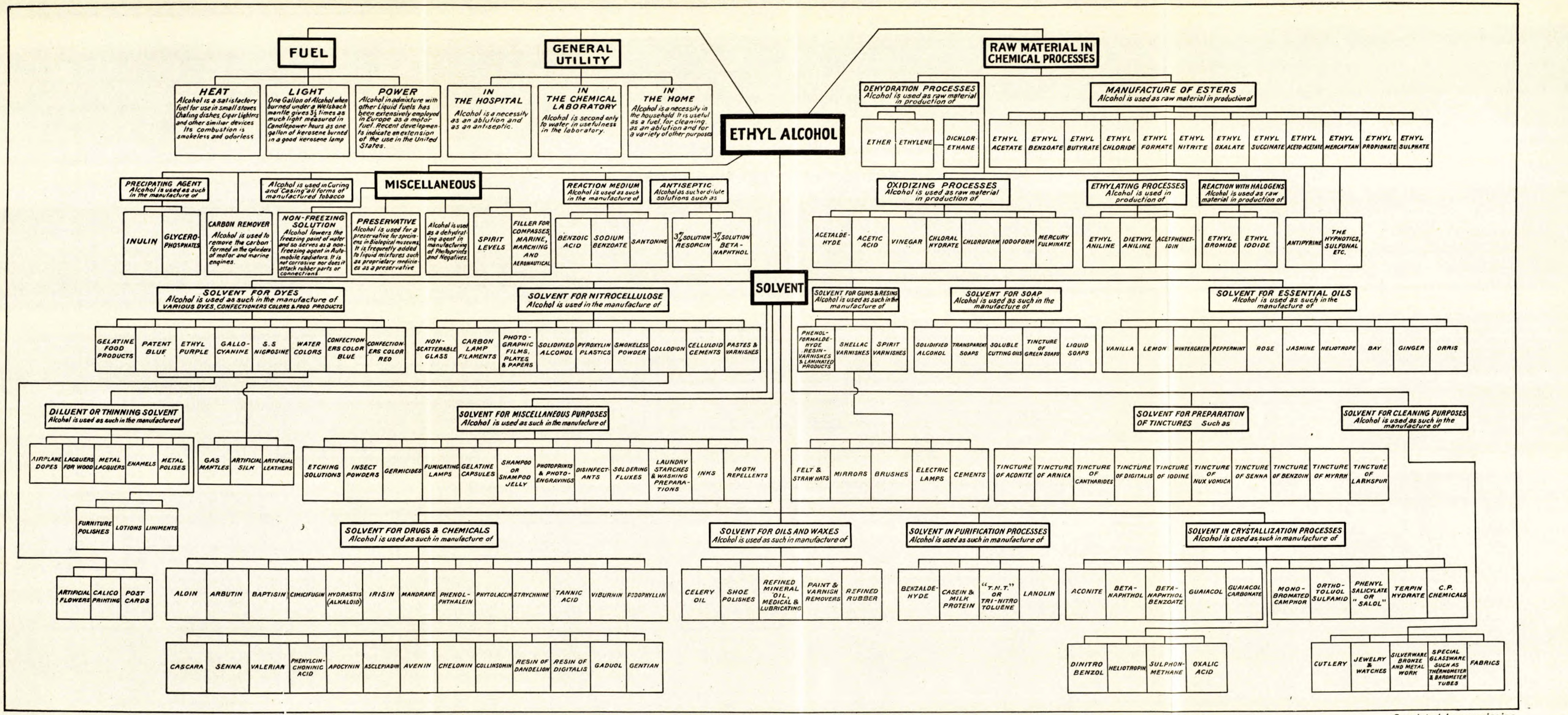

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Diagram 8

CHAPTER II

FOREST PRODUCTS INDUSTRIES

The arboreal products of forests furnish raw materials for a number of important groups of industries. The industries primarily dependent upon forest woods are the lumbering industry in all its branches, the wood cellulose industry (otherwise the pulp and paper industry), the wood distillation industry, and certain extracting operations. There are in addition a number of secondary industries making byproducts of commercial importance from the waste material of the primary groups. These byproducts are also occasionally made directly from fresh raw material gathered for the purpose.

The principal products of the lumber industry are firewood, poles, lagging, posts, rails, ties, lumber, lath, shingles, barrel staves and other cooperage stock, box shooks, and mine timber of all kinds. A discussion of the manufacture of these products in Canada does not come within the scope of this report.

The principal products of the wood cellulose industry and of the wood distillation industries are made by chemical and physical processes from wood as the principal raw material. Both these groups of industries have been extensively developed in Canada. The development of the wood cellulose industry is discussed in a following section; the wood distillation industry is discussed in the section on Destructive Distillation.

The principal products obtained by extraction from a limited variety of woods or barks are tannin extracts, turpentine, and rosin. Tannin products are also obtained as byproducts form certain kinds of bark where the tree trunks have been converted into lumber products. Oak bark for tanning was formerly produced in Canada, and there is still a small production of hemlock bark. So far as the writer is aware there is no Canadian production of tannin extracts from native forest products or from waste products. All tannin extracts required by the leather producing industries are imported. Turpentine and rosin are not produced in Canada by extraction processes.

The utilization of wood waste for the manufacture of byproducts is a very important subject which offers opportunities for further chemical investigation and possibly of extensive commercial development. Sawdust is already utilized in a small way in the composition of materials for the manufacture of moulded and pressed articles and plaster blocks; it is occasionally mixed with clays used for making tile or brick when it is desired to make these products light and porous; and sawdust, slabs, and other waste products of white pine, poplar, and fir are converted into wood flour which is used as an absorbent for nitro-glycerine in the production of dynamite. Sawdust and wood scrap have been used for the production of glucose, which may serve as a cattle food, or may be used for the manufacture of ethyl alcohol by fermentation. Oxalic acid has been made from sawdust. Refuse wood has also been used for the production of producer gas.

Cellulose also is a base for the manufacture of a number of important secondary products in addition to those which belong to the pulp and paper group. The most important of these are known as fibre products, including fibre boards, indurated ware, and insulating products. It also forms a base for the production of vulcanized fibre and artificial silks. The northern spruce, which possesses a compact structure and long fibre, seems particularly well adapted to the production of cellulose suitable for making artificial silk. These silks are usually made from cotton cellulose it is true, but wood cellulose has been used, more particularly for the manufacture of viscose. Ethyl alcohol can also be produced from the waste liquors obtained in the manufacture of wood cellulose. Fibre products and vulcanized fibre are made in Canada, but so far as the writer is aware no other cellulose byproducts are made in this country. It is not feasible to discuss these subjects further in this report.

Attention might be called to the possibility of developing a byproduct industry through the utilization of the now abandoned stumps and roots of some of the cut over pulpwood forests. Softwood distillation plants have not hitherto been successfully established in Canada. Still it might prove to be commercially feasible to combine softwood distillation with extraction and other processes in such a way as to develop a commercially successful enterprise in some localities where raw materials are abundant and cheaply available. Spruce stumps would yield turpentine and products closely related to turpentine, spruce oils similar to pine oils and suitable for ore concentration, spruce gum by extraction, creosote oils, tars and pitch by destructive distillation, a certain amount of chemically prepared cellulose fibre suitable for kraft or other papers, and possibly tannin extracts. In some localities the cleared land would have a market value as farm land; in other localities it would be suitable only for re-foresting. Undoubtedly the field operations would have to be carried on with portable equipment and crude apparatus. The crude products could be refined at suitable central plants.

At the present time one Candian plant is recovering turpentine as a byproduct in the manufacture of sulphate pulp from spruce and jack pine. During a certain stage of the digesting of the wood chips in the alkaline solutions used the gases liberated contain volatile turpentine oils which are recovered by condensation, and afterwards rectified in a special still. Another plant is employed experimentally in the production of turpentine and colophony directly from the viscous exudation obtained by tapping the bark of the Douglas fir. This product yields turpentine oil as the primary product of distillation. The residue consists of colophony or resin, which may be utilized as such, or which may be subjected to destructive distillation at a higher temperature, yielding rosin spirit, rosin oil, and pitch.

PULP AND PAPER INDUSTRY

The basis of paper manufacturing is cellulose of vegetable origin. Cellulose for paper making may be obtained from numerous trees and grasses. The principal sources of supply in America are the woods of red and black spruce, Canada balsam, and poplar. Cellulose is also obtained from cotton and linen rags, or may be made directly from cotton or flax straw. Wheat, oat, and rye straws are also used for producing certain grades of pulp used in making box board. A recent report is to the effect that an attempt is soon to be made to utilize waste straws in the Prairie Provinces of Canada for the production of pulp and newsprint.

The processes in use for preparing cellulose for paper making, except in the case of ground wood fibre, are entirely chemical. In the manufacture of paper from cellulose the paper maker requires a large number of prepared materials of mineral origin, and also quantities of chemical products as fillers and for the purpose of imparting certain physical properties to his finished product. The paper maker also employs a number of mineral and chemical products in the preparation of the equipment and appliances used in his plant. The principal mineral and chemical products used in the pulp and paper industry, are given in the following list.

Table 12.—Mineral and Chemical Products used in the Pulp and Paper Industry

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

MATERIALS USED IN EQUIPMENT: Asbestos; bricks (chemical, fire); *cement, Portland;* clays (*china,* fire, *local*); coal; *litharge; pitch; pulpstones;* rolls (granite, lava, sandstone); *silica sand; soapstone;* sodium silicate.

MATERIALS USED IN CELLULOSE PRODUCTION: *Acid, sulphuric; chlorine gas; dolomite; lime* (*burnt, chlorinated*); *limestone; magnesite;* sodium compounds (*carbonate, chloride, hydroxide, sulphate*); sulphur.

MATERIALS USED IN PAPER PRODUCTION: Acid, tannic; alums (potash, soda); alumina; aluminium sulphate (papermaker's alum, or alum cake); aniline colours and pigments; barytes (ground); blanc fixe; calcium sulphate (pearl hardening); *casein;* cellulose hydrate; *cement, Portland;* chrome colours; *clay, china;* dyes, natural; *gelatine; glycerine; gypsum* (*ground*); magnesia; mineral pigments (chromium oxide, *iron oxides,* lead chromate, *ochres* and *umbers,* organic pigments and lakes, smalt, ultramarine); Prussian blue; resins; satin white; *soaps;* sodium compounds [*carbonate* (*anhydrous, crude, crystals*), hyposulphite, silicate, *sulphate,* sulphite]; *starch; talc.*

Statistical Data

Statistical data showing the actual consumption of the different mineral and chemical products required by this industry are not available. The magnitude of the industry indicates that large quantities of certain products, such as sulphur, sodium sulphate, blanc fixe, and clays must be required annually. As most of these materials are imported, but could be produced in Canada, it is obvious that this industry offers a home market for these products. Before it can be stated that additional mineral and chemical products for the use of the pulp and paper industry can be profitably prepared in this country it will be necessary to carefully survey the market to ascertain the actual demand for each commodity that could be prepared from native resources.

Canadian Situation

The pulp and paper manufacturing industry in Canada is rapidly expanding. At present there are 109 mills in operation, four in construction and three temporarily idle. The milling capacity available at the end of 1920 provided for a daily output of approximately 4,000 tons of groundwood pulp; 2,600 tons of sulphite, about one-third being unbleached, and the balance bleached; 700 tons of sulphate; 15 tons of soda pulp; and 2,700 tons of newsprint paper. In addition to these principal products Canadian mills are producing a great variety of special papers, the chief of which are kraft, manila, tag, envelope, wrapping, poster, wall, writing, ledger, lithograph, book, wall board of various kinds, ship and fibre boards, bristol board, corrugated paper, egg case fillers, carpet paper, jute, felt, building papers, indurated fibre ware, toilet tissue, crepe, tissue, and a number of other specialties. The total daily capacity of Canadian mills producing miscellaneous papers is 480 tons, in addition to a capacity of 650 tons of various kinds of mill board and related products.

General Notes

The sulphur requirements of this industry alone are at present in the neighbourhood of 90,000 tons annually, all of which must be imported at a delivery cost probably not far from $25 per ton. Sulphur is essential for the manufacture of sulphite pulp, one of the constituents of newsprint paper, the largest single item of production made by this industry. The pulp and paper industry can never be self-contained until its dependence on foreign sources of sulphur has been eliminated. The author has elsewhere discussed the possibility of substituting native pyrites as a source of sulphur in the manufacture of sulphite pulp.[1] It may be stated that there are no insuperable obstacles to the introduction of pyrites burning plants into the sulphite mills, and the principal technical difficulties have already been overcome. A higher degree of technical skill is required to operate a pyrites burning plant than is needed by the ordinary sulphur burning equipment.

Another source of supply of sulphur from Canadian sources will undoubtedly be from the waste gases of the nickel industry at Sudbury. At present no commercial process has been developed whereby this waste product can be successfully utilized by the sulphite pulp manufacturer. The

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[1] Pyrites in Canada, Mines Branch Report 167. Pyrites in the Sulphite Mill, Pulp and Paper Magazine, Jan. 31st, 1918, p. 95.

great importance of an independent native source of sulphur not only for this industry, but also for other industries in which it figures as an essential raw material, warrants the inauguration of extensive scientific research in an attempt to develop a process by which the sulphur content of these waste gases may be made available for the use of industry.

Other Cellulose Industries

Cellulose is obtained from grasses and other plants as well as from woods. Plants which are cultivated as sources of cellulose are cotton, flax, hemp, jute, esparto, China grass, ramie, and others. The cellulose of cotton and linen and that in the pith of certain plants is nearly pure.

Cellulose is not soluble in water nor in other ordinary solvents. It will, however, hydrolyze in the presence of the salts of certain metals, and the hydrated cellulose forms a thick viscous solution. It may be oxidized to oxycellulose by the use of dilute nitric or chromic acids; if boiled with the dilute acids for some time it becomes converted into hydrocellulose. If heated with strong acetic acid it forms acetyl compounds, cellulose acetates, which are amorphous substances soluble in chloroform, glacial acetic acid, ethyl benzoate or nitrobenzene and insoluble in water or alcohol. If heated with strong sulphuric acid it swells and dissolves forming a paste-like substance as a precipitate when water is added. If the acid is diluted and heated to 120° C. the cellulose is converted into dextrose. Dextrose in turn can be converted into ethyl alcohol by the use of ferments and attempts have been made to make alcohol from wood waste by applying these chemical reactions commercially. If cellulose is heated with nitric acid under proper conditions cellulose nitrates are produced. Cellulose also forms compounds with sodium hydroxide, cupro-ammonium hydroxide, and zinc chloride. These products are homogeneous viscous solutions. These and other chemical products derived from cellulose are the basis of a number of cellulose industries to which only a very brief reference can be made.

Explosives. Cellulose is heated with sulphuric and nitric acids under suitable conditions to produce cellulose nitrates that are used as the basis of a number of explosives. The cellulose usually used for this purpose is cotton, although other celluloses have also been used, including those obtained from woods. Gun cotton is the best known product.

Collodion. Cotton wool which has been cleaned with sodium hydroxide is weakly nitrated to form gun cotton. This product is soluble in a mixture of alcohol and ether and the solution constitutes collodion. The product is known to many people through its sale in minute quantities at high prices as "artificial skin." It is used industrially in photography and in medicine. It is also used for coating mantles for incandescent lamps, films, and in certain kinds of varnishes. Collodion is formed into fine silk threads by a special process, and these are woven into fabrics either alone or in combination with other textile fibres. Large quantities of collodion silks have been made in France and Germany.

Cellulose Acetate. This product is made by heating cellulose with dilute acids to convert it into hydrocellulose. The hydrocellulose is then treated with anhydrous acetic acid. It can also be produced by the direct use of cellulose and acetic acid. The material finds many industrial uses, such as the manufacture of films, artificial silks, and varnishes, to which further reference is made below.

Cellulose Formate. This product is made by hydrolyzing cellulose with sulphuric acid and then treating with formic acid. The product is similar to cellulose acetate and has been used for artificial silks.

Pyroxylin. This product is made by heating cellulose with sulphuric and nitric acids under suitable conditions to produce a pure nitrated cellulose. This material is washed free from acids and allowed to dry and constitutes pyroxylin which has a number of industrial uses.

Celluloid. Cellulose is nitrated to pyroxylin. The pyroxylin in a suitable condition is mixed with camphor and the mixture is warmed and subjected to kneading and pressure. The two substances unite to form a transparent product which is not explosive, though it is highly inflammable, and which possesses characteristic properties. This material is marketed under the name of celluloid. The industrial applications of celluloid are very numerous, and cannot be discussed here. Other substances than camphor have been proposed as solvents for the pyroxylin, such as certain derivatives of phenol, cresol, or naphthol, and other coal tar products. There are also a number of synthetic products such as bakelite produced without the use of cellulose that are marketed as substitutes for celluloid, or which have found industrial applications of their own. Another celluloid substitute that has come on the market is cellulose acetate. These substitutes are mentioned to draw attention to them because it is not always possible for the layman to distinguish between true celluloid and these later products.

Artificial Silks. Collodion is made from cellulose by nitrating in the usual way and preparing the alcohol-ether solution. This solution is squirted into minute threads by suitable apparatus. The squirted threads are either received in water where they solidify and are drawn off as produced, or they pass into a warm air chamber where the solvents quickly vaporize and the threads can be drawn off. These threads are then spun together to make stouter threads which are used for textile production.

In another process a cuprammonium solution of cellulose is made and artificial silk threads are prepared from the resulting viscous solution.

Viscose is an artificial product prepared by treating cellulose with a concentrated solution of sodium hydroxide, squirting the product into threads which are received in a solution of ammonium chloride. This latter substance precipitates the cellulose, which retains its fibre form. These threads are twisted to form stronger threads, and are then used in textiles.

Cellulose acetate is dissolved in suitable solvent, squirted into fine threads which are received in alcohol or ammonium chloride to harden them. These fine silk-like fibres are then twisted into threads and the threads are used for making textile fabrics. Cellulose acetate silk is used for coating fine copper wires for electrical purposes, such as magnet wires and the wires used on induction coils.

Varnishes. Solutions of cellulose products are used for dopes and varnishes. The products chiefly used in this way are pyroxylin, viscose, cellulose acetate, and collodion with suitable solvents as vehicles.

Films. Photographic films and films for projection lanterns were formerly largely made from celluloid. Owing to the inflammable nature of this product and the consequent fire risk in moving picture theatres, many attempts were made to render the films slow burning by the addition of other chemicals. In recent years, however, the discovery of cellulose acetate and the possibility of making films of this material have changed the situation. " Cellite " films are made by mixing cellulose acetate with camphor or with some of the substitutes for camphor. Cellulose formate and certain other similar cellulose compounds can also be used in this way.

Conclusion. The foregoing review is intended to give the general reader some understanding of the very numerous industrial applications of cellulose. Most of the products mentioned here are made from cellulose derived from sources other than wood. It is within the limits of possibility, as noted elsewhere in this report, that the splendid long fibre spruce of Gaspé, northern Quebec, and Newfoundland will yield cellulose that could economically be used for some of these products. With the exception of certain explosives and collodion none of them are now made in Canada. Collodion films and silks are not produced here at present, but one plant has been projected and may be erected shortly. Some cellulose varnishes are on sale here but it is not known whether they were actually made in Canada or were imported in bulk and repacked for retailing.

CHAPTER III

DESTRUCTIVE DISTILLATION INDUSTRIES

There are a number of very important industries founded on the fact that many complex organic compounds, when subjected to heat treatment in closed vessels, can be decomposed and a new series of compounds produced. The process by which this change is brought about is designated dry distillation or destructive distillation, in contrast with other distillation processes where the products finally recovered have not been changed chemically during process of treatment. The principal materials subjected to destructive distillation are usually solids, less frequently liquids. The final products are either gases or liquids at ordinary temperatures. Many kinds of organic materials when submitted to destructive distillation will yield other products. The principal raw materials which are habitually subjected to destructive distillation processes on a large scale are woods, both hard and soft, bituminous coals, and petroleum. Each of these three classes of materials gives rise to a series of extremely important commercial products that find many uses in the industrial arts or which are in turn the basis of other products of importance and value.

These processes form the basis of the most important of the chemical industries of the world. In this report each of the three groups of raw materials is considered in turn. The discussion is necessarily confined to a very brief general statement with respect to the processes employed, the products obtained, and the industrial uses of the principal products. In each case the subject is viewed from the standpoint of the present development in Canada and the Canadian market. It is not possible to deal with the subject in its entirety in a report of this kind, and the possibility of future development and expansion cannot be dealt with here.

The subject is presented under four sub-titles: Distillation of Woods; Distillation of Coals; Distillation of Coal Tar; Distillation of Petroleum. While other substances than those covered by these designations yield decomposition products on distillation, the industries based on their treatment are relatively insignificant. So far as known they have not been developed in Canada, and all discussion is therefore omitted.

WOOD DISTILLATION

A number of industrially important commercial products are obtained from various woods by subjection to heat treatment under suitable conditions. All modern processes treat the woods within closed containers or retorts. The heat may be applied by introducing steam within the container, or externally by using coils in which steam or oil is circulated, or by direct firing. Where wood is treated by steam distillation to remove the more volatile constituents other constituents may, in some cases, be recovered by the use of solvents. Where heat is applied externally the wood substances (such as cellulose, lignin, resin or gums) are broken down into chemically simpler compounds which are volatile, the final product being charcoal, and the process being designated " destructive distillation."

Raw Materials

In general, woods used as raw materials for the distillation processes can be grouped in either of two classes, softwoods and hardwoods. The former include all the coniferous trees such as pines, firs, spruce, and cedar. The latter include such woods as maple, birch, beech, and oak.

Treatment Processes

Coniferous softwoods are sometimes subjected to steam distillation to remove the volatile turpentines and to increase the yield of these products, before being subjected to the charring heat necessary to bring about the destructive distillation. The principal final products of softwood distillation are methanol,[1] turpentine, turpentine oils, rosin, rosin spirits, rosin oils, pine oils, pine tar, wood pitch, and charcoal. Steam distillation may be followed by extraction with a mineral oil solvent to recover the resin. The treated chips are then available for the manufacture of wood cellulose in place of being decomposed by destructive distillation.

Destructive distillation of hardwoods usually proceeds without preliminary steam treatment. The series of final commercial products obtained is greater than in the case of softwoods. The principal final products are acetic acid, acetone, ketones, methanol, creosote oils, tar, pitch, and charcoal (see chart). Some of these products form the bases of other compounds, and the total number of chemical products, that can be prepared from the primary products of hardwood distillation for industrial purposes, is very large.

The destructive distillation of hardwoods has been successfully established in Canada for nearly twenty-five years. So far as the writer is aware indirect heating with steam or oil is not used in this country. Softwoods and hardwoods were formerly employed for the production of charcoal by the old processes, but no other products were recovered. At present softwood distillation with the recovery of the principal byproducts has not been developed to a successful commercial stage. The following notes therefore apply only to the hardwood distillation industry in so far as it has been developed in this country.

The woods used in Canada in the hardwood distillation industry are principally maple and birch, with small amounts of beech. The wood is prepared for distillation by cutting and piling for seasoning, followed by sawing into short lengths and splitting where necessary preparatory to charging into the special retorts. The retorts used are of the horizontal type into which charging cars, loaded with split wood in short lengths, can be run directly. The operation is usually completed in twenty-four hours.

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[1] Methyl alcohol or wood alcohol.

CHART OF THE HARDWOOD DISTILLATION INDUSTRY

MAPLE - BIRCH - BEECH

SPLIT OR SAWED BLOCKS - AIRTIGHT RETORT - HEAT

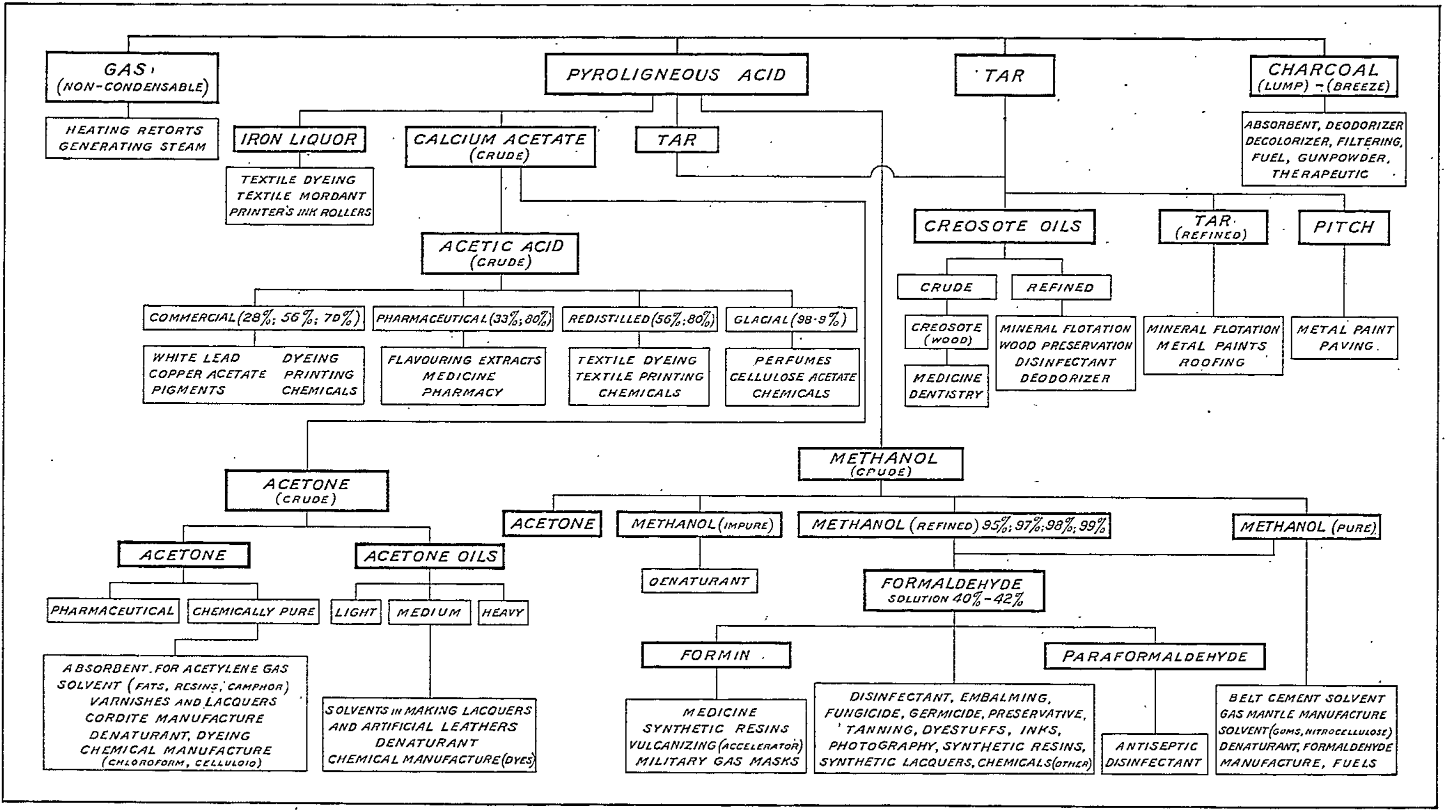

Diagram 9

Products of Wood Distillation

The total yields of byproducts obtained from woods depend upon the woods used and upon the treatment to which they are subjected. Rapid heating in small retorts to a high temperature increases the gas yield, decreases the amount of residual charcoal, and also diminishes the acetic acid and tar. Slow heating, usually accomplished in large retorts, results in relatively lower yields of gas, and greater yields of the condensable distillates (oils and acetic acid) and charcoal.

The principal primary products are non-condensable gases which are used for fuel, condensable liquors—pyroligneous acid and tars—and charcoal as a final product. The pyroligneous acid and the tar are usually recovered together and separated by decantation, each to be subjected to further treatment. Each of these liquids naturally contains small portions of the other.

The pyroligneous acid yields methanol, calcium acetate on treatment with lime, and a residual product from which flotation oils and iron acetate liquor are made. The latter product is used in the textile industry for dyeing and mordanting. Calcium acetate, on further treatment, yields acetic acid and acetone products of which there are several commercial grades, and from which many additional products can be made. Methanol as obtained from the pyroligneous acid liquors is subjected to further refining to produce the several commercial grades. This product finds very extensive uses in the arts and industries as a solvent, as a denaturant for ethyl alcohol, for industrial purposes, as a fuel, in the manufacture of formaldehyde, and as the base from which a number of other important products are prepared.

The tar portion of the condensable distillate is subjected to further refining by fractional distillation in special apparatus and yields a number of products. Those produced in Canada may be classed as creosote oils, refined tar, and hardwood pitch. Many other special compounds can be obtained if desired.

The final product charcoal is used principally as a fuel, though small amounts are employed for many other purposes.

The accompanying chart of the Hardwood Distillation industry will serve to show a few of the numerous products that are made by this industry, and it also shows the principal industrial uses of the more important final products. There are, however, many other products that can be recovered during the refining processes. The market for these products is limited and no attempt appears to have been made to produce them in this country.

The principal products marketed by the hardwood distillation industry, as now established in Canada, are charcoal, several grades of methanol, methanol acetate, calcium acetate, acetone, acetone oils, acetic acid, acetic anhydride, formaldehyde, and sodium acetate, tar and hardwood pitch, and some wood oils suitable for application in mineral flotation processes. The principal raw material required by the industry in addition to the wood is burnt lime for the manufacture of crude calcium acetate from which acetic acid, acetone, and related products are made. The refining operations require the use of a number of accessory chemical compounds for purifying byproducts. The principal chemicals used for this purpose are hydrochloric and sulphuric acids, fresh charcoal, calcium chloride, calcium oxide, iodine, manganese dioxide, potassium hydroxide, potassium bichromate or permanganate occasionally, phosphorus pentoxide, metallic sodium, and sodium bisulphite, carbonate or hydroxide less frequently.

Statistical Data

Available trade returns indicate a considerable export trade in some of the commodities produced by this industry. The corresponding records of importation show only comparatively light importations. It is therefore to be inferred that the Canadian market requirements for the principal products of this industry are well supplied by home production. If future trade conditions warrant further expansion there are still available suitable forest areas, particularly in the province of New Brunswick and in eastern Quebec, with some less extensive hardwood tracts in Ontario. Statistical data are not available to show the annual production and consumption of the various products made by this industry. Available records with respect to the imports and exports for certain years are given in the statistical tables under appropriate titles.

Canadian Situation

The present hardwood distillation industry in Canada is owned and operated by one corporation. There are nine plants available for the production of crude products, five of these being in Ontario, and four in Quebec. One of the Ontario plants also includes a refinery, and another refinery operates in Quebec. This firm also operates its own lime kilns in Ontario.

Reference should also be made to two closely related industries which exist in this country. In British Columbia one firm is experimenting in the preparation of turpentine products, flotation oils, resin and pitch from the resinous gum of the Douglas fir, the latter being obtained by tapping. In eastern Canada small quantities of hemlock oil and cedar oil are prepared at irregular intervals by individuals operating crude portable stills, the raw materials being the leaves and twigs of native hemlock or native cedar trees respectively. Spruce oil can be made in the same way. Hemlock and spruce oils are used in the manufacture of certain perfumes and liniments. Cedar oil is used extensively in the manufacture of polishes for furniture and floors, and also as an insecticide. The total quantity produced is small and the market available is limited.

COAL DISTILLATION

Coal may be defined as an amorphous mineral containing complex hydrocarbon compounds and some free carbon. It occurs in beds and has been derived from the remains of prehistoric vegetation. In colour it varies from brown to black, and in texture it may be either massive and compact or in layers. This mineral is our most important natural fuel. In nature all gradations are found from loose incoherent material like peat to compact and almost incombustible graphitic anthracite. For commercial purposes coals are frequently classified as anthracite, bituminous coals, and lignites. These differ chiefly in the amount of volatile constituents which are liberated on heating. Graphitic anthracites contain about 1 to 3 per cent volatile constituents, ordinary anthracites as used for domestic purposes from 3 to 10 per cent, semi-anthracites and semi-bituminous coals from 5 to 20 per cent, bituminous coals from 20 to 50 per cent. Lignites which often retain distinct traces of the old vegetable structure, are characterized by their loose structure, lamination, colour, and the presence of proportionally large amounts of water.

Raw Materials

Bituminous coals are almost wholly employed in the coal distillation industry. Anthracites are too low in volatile constituents to be of importance. Lignites yield too much moisture and only limited amounts of other products. Among the many varieties of bituminous coals that are available those which give the largest yield of volatile products are naturally in most demand.

Commercially it is customary to subdivide bituminous coals into two sub-classes on the basis of the coke yield. Those which yield a compact coke suitable for industrial uses are termed coking coals, while those which yield a loose incoherent coke product are termed non-coking coals. The coal distillation industries are dependent upon coking bituminous coals for their importance and success. In heating these coals by distillation processes the variety of chemical products that may be obtained greatly exceeds that which can be obtained from any other known material.

Treatment Processes

The treatment of bituminous coals by these processes was primarily based on the desire to obtain inflammable gases for lighting and heating or coke for metallurgical work. In the preparation of illuminating gases small quantities of coal were heated in closed retorts, the maximum quantity of gas was produced, a portion of the residual coke was used as a fuel to heat the retort, and the balance was sold as a domestic fuel because it was too weak and was otherwise unsuitable for metallurgical purposes. On the other hand, if metallurgical coke was required the gases and other volatile constituents were burned and coke only was recovered. It is only in comparatively recent years that plants have been designed to recover the maximum of products with the minimum of waste. Modern plants use the incondensable volatile constituents partly for heating the retorts in which the distillation takes place, and partly for industrial purposes; the condensable volatile constituents are recovered, and the residual coke is used for metallurgical purposes.

In a modern byproduct plant a series of gas-tight retorts or chambers are built side by side in such a way as to conserve heat as much as possible. The coal to be treated is placed within a retort, sealed from contact with the air, and then heated slowly to a suitable predetermined temperature. The volatile constituents, which are given off as the temperature rises, are collected in flues, so arranged that a portion of their heat is transferred to the incoming gaseous fuel. The partly cooled distillation products are conducted to suitable treating units for the separation and recovery of the desirable products. The principal products primarily recovered are benzol and related compounds, tar, and ammonia. The cleaned gases are then available for fuel. A portion is returned to the retorts to be used for heating, this portion being preheated as much as possible by the waste heat of the gases in the collecting flues. The other portion is available for any operations where a flexible fuel supply is needed for heating or lighting. Byproduct oven gas is used for heating various types of steel furnaces, for raising steam, illumination, and for domestic purposes. When the charge of coal placed in the retort ceases to discharge volatile constituents the connection with the collecting flue is closed, the retort is opened, and the residual coke is discharged and cooled by quenching with water. This coke is then available for metallurgical purposes or for heating. Most of the coke made in this way is used in iron blast furnaces, some of it is used in copper smelting and in the smelting of nickel ores. It is also used for lime burning and for many other purposes.

Products of Coal Distillation

The yields of different products obtained in coking ovens vary with the nature of the bituminous coal used, with the type of oven and with the temperature at which coking takes place. No general data as to the various yields can therefore be given. Nova Scotia coals, as treated at Sydney, are said to yield about 10 gallons of tar per ton of coal, 5 to 6 pounds of ammonia which is recovered as ammonium sulphate weighing 20 to 24 pounds. The gas yield per ton of coal coked is about 11,000 cubic feet, about half of which is required to heat the ovens, the other half being available for industrial purposes. The coke yield will vary from 65 to about 70 per cent of the weight of the coal charged.

Byproduct oven gas is usually washed with water to remove ammonia and other water-soluble constituents. These wash waters constitute the so called gas liquors and are one of the principal sources of ammonia and ammonium salts. The washed gases contain not only incondensable gases, which collectively are called fuel gases, but also a number of other highly volatile compounds that are liquids at ordinary temperatures. The principal components of this class are benzene, toluene, xylene, and carbon bisulphide. These are frequently removed by cooling and washing the gas with special oils, the different compounds being recovered subsequently by fractional distillation.

Tar is probably the most important of the byproducts obtained from coal distillation. It contains a large number of important compounds which are separated and recovered by fractional distillation. Coal tar distillation is discussed in the following section of this report.

PRODUCTS DERIVED FROM COAL

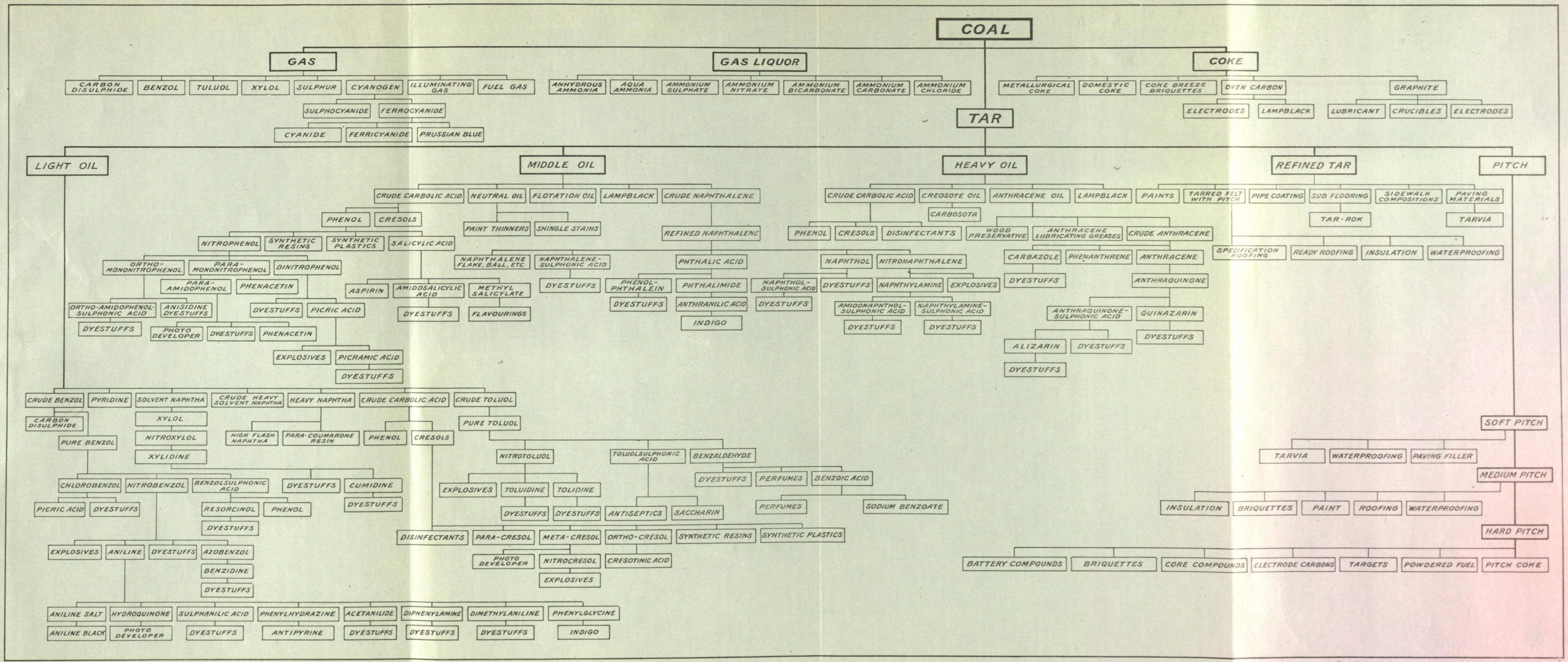

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Diagram 10

The destructive distillation of coal for the production of illuminating gas for domestic purposes is briefly discussed under the sub-title Coal Gas in the section dealing with Industrial Gases. Coal is also treated in beehive coke ovens for the production of metallurgical coke. All the other valuable products of the destructive distillation process are burned in the process, and this method of producing coke is therefore considered to be very wasteful of natural resources. It is not considered necessary to describe the process here.

Statistical Data

The quantity of coal used annually for the production of metallurgical coke naturally varies from year to year. In 1918 domestic coal mines supplied 1,348,232 tons of coal, and 635,010 tons were imported for the manufacture of coke. The average yield from all classes of ovens was 63·4 per cent of the coal charged. At the present time (1922) the consumption of coal in domestic coking plants is much below the capacity of available ovens owing to general business conditions.

There are, according to the Dominion Bureau of Statistics, about fifty plants in Canada making artificial illuminating gas from coal. The total amount of coal used in these plants is about 425,000 tons per annum, and the quantity of tar produced must be in excess of 3,500,000 imperial gallons. No statistical data have been prepared on this subject and the above figures are estimates only. A large proportion of the coal used is imported from the United States.

The question of the utilization of the tars and other byproducts obtained from the destructive distillation of coals is discussed in a following section of this report.

Canadian Situation

Coal is subjected to destructive distillation in Canadian plants for three different purposes—to produce metallurgical coke alone; to produce metallurgical coke and byproduct gases for industrial use; and to produce artificial gas for domestic purposes with or without the production of byproduct coke. When coke is produced some plants convert all their coke into carburetted water gas, which is mixed with the gases obtained by distillation.

Gases and tars are not recovered from between 26 and 30 per cent of the coal treated in distillation plants for the production of metallurgical coke. These plants use beehive ovens chiefly, though some retorts are also used. In these plants all products other than coke are consumed. The beehive ovens are all located in the Crowsnest Pass area; the retort ovens are located chiefly in Nova Scotia, there being also one plant in British Columbia that is at present idle.

Byproduct coke ovens are employed in the treatment of between 70 and 74 per cent of the coal used for the production of metallurgical coke. There are four plants of this kind in Canada, located as follows: Sydney, Nova Scotia; Hamilton, Ontario; Sault Ste. Marie, Ontario; and Anyox, British Columbia. At all of these plants the gases are stripped for the production of benzene, toluene, xylene, solvent naphtha, and naphthalene. Sulphate of ammonia is recovered in crude form, and the tars are also recovered. Two plants, one in Nova Scotia and one in Ontario, sell their tars in the crude state to treating works. The other plant in Ontario uses the tar for firing open hearth steel furnaces. At Anyox about one-third of the tar produced is burned under boilers and two-thirds is shipped to a treatment plant at Vancouver.

The byproduct plant at Sydney uses coal from Glace Bay, Nova Scotia. The plants at Hamilton and Sault Ste. Marie use coals imported from the United States. The plant at Anyox, B.C., uses coal mined at Cassidy, Vancouver Island. The average quantity of tar recovered at all of the plants is 5·8 imperial gallons per ton of coal treated.

COAL TAR DISTILLATION

General

Tar is a black to brown opaque, viscous, or oily liquid, obtained by the destructive distillation of organic substances. It is heavier than water and not miscible with it. There are great differences between tars obtained from different sources and between tars obtained from the same source by different processes. The principal constituents of wood tars are phenols and their derivatives; the principal constituents of tars obtained from peat, lignite, and bituminous shales are hydrocarbons of the paraffin series or others closely related to them; the principal constituents of tars obtained from coal are aromatic hydrocarbons, of which the simplest compound is benzene. All tars contain a large number of other constituents, as well as the principal components. They also usually contain other compounds derived from primary constituents by their decomposition by heat during the process of production. Tar therefore varies in composition according to the amount of heat used in its preparation, according to the process employed, and according to the length of time its several constituents are exposed to the action of heat during the progress of destructive distillation of the materials from which the tar is derived.

Tars which contain products of the paraffin series are not suitable for the manufacture of coal tar crudes from which coal tar colours can be made. The tars that are most valuable for making the intermediate products from which dyes are made are those containing hydrocarbons of the aromatic series. All tars contain phenols, some tars contain both products related to the paraffin series and products of the aromatic series. Such tars are suitable only for the manufacture of burning oils, lubricating oils, and sometimes yield solid paraffin.

Raw Materials

The principal primary raw materials for the production of coal tars containing products of the aromatic series are bituminous coals. These are distilled in gas works, in gas retorts, giving rise to gas tars of various kinds. They are also distilled in byproduct ovens designed for the production of metallurgical coke.

Tar is also obtained as a byproduct from gas producers, from blast furnaces where coal is charged, in the manufacture of water gas, and in the oil gas process.

Coal tar from gas plants and from coke ovens is available for distillation in Canada in considerable quantities. Tar from water gas and oil gas plants is produced in small amount, but there is no production at iron blast furnaces.

Properties and Constituents of Coal Tar

Coal tar is black and viscous; it possesses a disagreeable odour; the specific gravity of different coal tars varies from about 1·08 to 1·28. It is a very complex mixture of organic compounds, most of which belong to the aromatic (benzene) series. The chemical composition and the physical properties vary widely as they depend upon the coal used, upon the process, upon the character of the apparatus, and upon the temperatures used. As a rule tars produced by low temperature carbonization have a lower specific gravity than those produced when the corbonization temperatures are higher. Heavy tars contain larger amounts of free carbon.

The constituents of coal tar may be grouped into four general classes:

Hydrocarbons which contain hydrogen and carbon in different ratios, the most important of which are benzene, toluene, xylene, naphthalene, and anthracene.

Phenols which contain hydrogen, carbon, and oxygen, the most important of which are carbolic acid and cresol. These products are weakly acid and are known as "tar acid."

Nitrogenous compounds which contain hydrogen and nitrogen. These products are basic and will therefore dissolve in acids. A large number of individual substances have been determined, but none of them are present in large enough quantities to be profitably extracted, except under very exceptional circumstances.

Miscellaneous substances which contain sulphur, nitrogen, or oxygen, ammonia, water, carbon bisulphide, and products derived from the decomposition of hydrocarbons. Ammonia and carbon bisulphide may be in part recovered during treatment of the tars, the other substances are for the most part impurities which must be removed.

The total number of separate compounds which are present in coal tar is stated to be about 218.

Uses of Coal Tar

Crude coal tar is used for a number of industrial purposes. It may be burned directly under boilers, or it may be used to make illuminating gas. It is used for road making and for manufacturing roofing felts and papers, being subjected to short preparatory treatment. It serves as a cementing material both for road making and in the manufacture of briquettes; usually a preliminary treatment to remove the lighter constituents has been applied to tars used for cementing. Pitch has been prepared directly from tar without distillation, but this is not usual commercial practice. Tar has been used for medicinal purposes, as an antiseptic, for denaturing alcohol for certain purposes, and lampblack and coke are made from it at times.

The principal use of coal tar is probably for the production of the coal tar crudes from which the intermediates that form the basis of the dye industry are made.

Processes and Products

Many of the constituents of coal tar can be recovered by fractional distillation. This process depends upon the fact that when two or more substances having different boiling points are mixed it is possible to separate the material having the lower boiling point from the other by heating the mixture to a temperature at which that substance will volatilize. It will then vaporize first, will escape from the containing vessel, and can be condensed in suitable apparatus. Near the end of the operation the escaping vapour will probably be contaminated with products whose boiling temperature is slightly higher. At this point the boiling will usually decrease for a time until the temperature rises near the vaporization temperature of the constituent with the next lowest boiling point. The constituents of coal tar have vaporization points which vary greatly; benzene boils at 80° C., while anthracene boils at 370° C. By keeping the fractions separate it is feasible to effectively separate many of the constituents.

Tar is subjected to fractional distillation in special retorts, usually vertical, with concave bottoms, bricked in, and provided with flues so that hot gases pass around the stills. There is also supplied much auxiliary apparatus to condense and collect the different fractions, to clean the stills and pipes, and to keep the operations moving forward satisfactorily. Tar retorts vary in capacity from 10 tons to about 35 tons per charge.

Heat is supplied by the combustion of coal, oil, tar, or gas, depending upon conditions of fuel supply at the different plants.

The process of distillation is carried on until a temperature of about 400° C. has been reached. Approximately 55 per cent of the original charge will then remain as a thick black mass which becomes solid pitch on cooling. Where this pitch is required for road work or for making roofing pitches or felts it is softened by running in some waste creosote oils from a previous batch of materials.

Once the operation is started the flow of condensed distillates is maintained as nearly constant as possible. As the operation continues the temperature gradually rises, and the specific gravity of the distillates increases. The apparatus is so arranged that the distillates can be diverted into different receivers. In current practice three separate portions are obtained, light oil up to 170° C., heavy oil up to 270° C., and anthracene oil or "green grease" up to 400° C. In some plants five fractions are obtained, named respectively, first light oil to 105° C., light oil to 210° C., carbolic oil to 230° C., creosote oil to 270° C., anthracene oil to 400° C. Other fractionating points may also be used.

The first distillate contains chiefly hydrocarbons of the benzene series. It is agitated alternately with dilute sulphuric or hydrochloric acid to remove basic substances, and with alkalies to remove tar acids; it is then subjected to several washings with water to complete as far as possible the removal of impurities. After removal of impurities the fraction is subjected to repeated fractional distillation in special stills to separate the principal constituents. The principal products recovered are benzene, toluene, and xylene. Both crude and rectified products are marketed.

The carbolic oils yield naphthalene on standing. This is removed by use of a filter press or a centrifuge. The oil is then treated with hot sodium hydroxide which forms compounds with the phenols and makes it possible to remove them. A second crop of crude naphthalene is obtained from the oil after the removal of phenol. The crude naphthalene thus obtained is washed with hot sodium hydroxide, agitated with dilute sulphuric acid, followed by a little dilute alkali to remove the acid, and then distilled. The sublimate is caught in a special condensing chamber lined with cotton or other fabric.

Phenols and cresols are separated from the carbolic oils by treatment with dilute sodium hydroxide. The resulting solution is purified by blowing steam through it. The sodium compounds formed are then decomposed by adding sulphuric or hydrochloric acid. The salts and the phenols are then separated by fractional distillation in special apparatus. Commercially pure white carbolic acid is obtained in this way. The residues are not usually subjected to further treatment to remove other phenols and cresols present, but the mixture is used directly for preserving timber.

Anthracene is separated from the anthracene oils by a special process, the yield being approximately 10 per cent.

There are numerous other products present in the different fractions, but these are rarely separated. The greater portion are mixed in various proportions and are used for industrial purposes.

It is to be noted that different kinds of creosotes are produced for commercial purposes from different kinds of tars, and these creosotes are applied industrially for different purposes. Creosotes are used for timber preservation, for sheep dips and insecticides, for the manufacture of certain greases, for lighting, and in one process for the recovery of benzol. Crude carbolic and cresylic acids are recovered together and used for timber preservation.

Refined tar for road treatment is prepared by distilling of the light oil and middle oil. When the liquid reaches a predetermined specific gravity, usually 1·05 at 15° C., the heat is turned off the still and the contents are allowed to cool to about 120° C. At this point crude creosote oil having a specific gravity of about 1·063, from which all anthracene has been removed, is added to the still, in the proportion of 115 gallons of heavy creosote to 2,000 pounds of tar in the original charge. The mixture is agitated with air to insure thorough mixing and is then run off into a receiver to cool. The specific gravity of the finished product ranges between 1·12 and 1·16.

Tar for roofing felts and papers is prepared much in the same way, the specific gravity being about 1·05 at 15° C. at the end of the distillation operation. When the still has cooled to 105° C. crude creosote oil is run in and the mixture agitated. This oil has a specific gravity of 1·045 at 15° C., and the proportion commonly used is 85 gallons to every 2,000 pounds of tar in the original charge.

The diagram which accompanies this section shows many of the principal products obtained by the treatment of coal tar distillation products and also indicates some of their applications.

The principal primary products that are obtained from coal tar are anthracene, benzene, creosote oil, cresol, cresylic acid, cumol, naphthalene, phenol, pyridine, toluene, and xylene. These are termed coal tar crudes. These products are the basis from which are derived about 300 compounds, known as coal tar intermediates through the application of suitable treatments with acids and alkalies. These intermediates are the basis of the coal tar dyes. A discussion of the dye industry is beyond the limits of this report.

A number of coal car crudes are used for the manufacture of explosives. The principal products used for this purpose are benzene, toluene, xylene, napthalene, phenol, cresol, and anthracene.

Statistical Data

The production of coke oven tar has been recorded annually for some years in the reports on mineral production issued by the Department of Mines. This record is being continued in the reports of the Dominion Bureau of Statistics. The coke made by these ovens is used in the iron and steel industry, and in copper smelting. The annual output of coke, and consequently of the tar also, fluctuates with the market demand for these metals. The production reached a maximum of over 14,000,000 gallons in 1920. Since that date the recovery has declined, but during the last year it is again rising.

The production of gas tar from the various plants which manufacture illuminating gas for domestic use in different municipalities throughout Canada has not been determined. The author has estimated that these plants require about 425,000 tons of gas coals annually. This amount of coal would yield approximately 4,250,000 gallons of tar.

Benzene, toluene, xylene, and naphthalene are the principal coal tar crudes made in Canada. Statistical data with respect to the production of these products and with reference to other products of the tar distillation industry are issued by the Dominion Bureau of Statistics.

Coal tar intermediaries for the production of dyes are not made in Canada. Aniline was made for a short time from imported aniline oil. Some attempts have been made to produce other colours, but so far as known none of the enterprises have been commercially successful.

The size of the Canadian market for dye products is not known, and no systematic attempt has ever been made to ascertain our requirements. In this connection attention is drawn to the report on "Artificial Dyestuffs used in the United States" by Thomas H. Norton.[1] A similar investigation of the Canadian situation would be of benefit to Canada. It is

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[1] Bureau of Foreign and Domestic Commerce, Washington, Special Agents Series, No. 121, 1916.

reasonably certain that the manufacture of coal tar dyes would not be commercially practicable in Canada, but such an investigation would be the first step in ascertaining the size of the dyestuff market within the Empire. Present information on this subject is very vague. Attempts to ascertain the British market, made during the war, were not successful.

Canadian Situation

Coke oven tars are produced at four plants in Canada, one being located in Nova Scotia, two in Ontario, and one in British Columbia. The plants in Ontario use imported coals. The other two plants use local coals.

Gas tar is produced at 24 plants in Canada and in St. Johns, Newfoundland. One of these plants in Nova Scotia and one in New Brunswick use local coals. Two in Quebec use either Nova Scotia coal or imported coal. Fifteen plants in Ontario use imported coals and five in British Columbia use local coal.

Carburetted water gas, oil gas, or water gas are produced in 16 plants and it is presumed that these plants have a small output of tars. The output of producer plants is not known and the number of plants is not on record.

Tar distillation plants are located at Sydney, Halifax, St. John, Montreal, Toronto, Hamilton, Sault Ste. Marie, and Vancouver, nine in all, there being two plants in Montreal.

The principal products made at these plants in Canada are roofing tars, road tars, crude creosote, crude carbolic acid, and light oils, products for timber preservation, sheep dips, sprays, fungicides, and insecticides. The light oils, occasionally some middle oils, and crude products are exported to foreign refineries.

PETROLEUM DISTILLATION

Petroleum is a thick heavy inflammable oily liquid found in certain localities at or near the surface of the earth. It is also variously known as crude oil, rock oil, or mineral oil. The colour varies from light amber to yellow, dark reddish brown, greenish black, or black. It nearly always shows a greenish fluorescence and possesses a very characteristic odour. Petroleum is generally lighter than water, the specific gravity varying from 0·771 to 1·060.

Raw Materials

Petroleum as it occurs in nature is a very complex mixture of a number of liquid and volatile hydrocarbon compounds. It may also contain free carbon and compounds of nitrogen, oxygen, and sulphur. The proportions in which these different compounds are present differ with different oils. There are also differences in the number of compounds that can be recovered from any given oil. These compounds belong chiefly to the paraffin series. Some oils contain both paraffin and asphalt, while others contain asphalt only. Refiners generally recognize two leading classes, those with a paraffin base yielding solid hydrocarbons of the paraffin series on distillation and those with an asphaltic base, which are rich in asphalt and yield little or no paraffin on distillation.

The geological conditions under which deposits of petroleum occur are well known. These deposits are not confined to any one formation, and are found widely distributed in different parts of the world. Crude petroleum is obtained by drilling wells through overlying strata to tap accumulations of oil in natural reservoirs below. These natural reservoirs are rarely open spaces, but more frequently are they beds of porous strata, the interstices of which are filled with natural accumulations of oil. The escape of the oil under natural conditions has been prevented by the occurrence of impervious overlying strata, by the presence of water in strata in surrounding areas, or by both. The depths to which these wells have to be sunk vary from less than 100 feet in rare instances to more than 4,000 feet.

Treatment Processes

Petroleum oils are separated into various constituent products by fractional distillation. The method used varies with the character of the oil and with the products desired. Under suitable conditions it is possible to recover a number of different products by fractional distillation only, without decomposition. Most oils, however, are subjected to a process of dry distillation which results in the partial decomposition of some of the products, and the formation of others. This method—termed "cracking"— leads to the production of a number of oils which are of a lower specific gravity than would normally have been obtained from the oil treated.

Primary distillation is usually performed in horizontal steel cylinders mounted in brick work. The stills are heated by direct firing from the end or side. The fuel used may be oil, coal, or petroleum coke, this latter being a residual end product of the operations. Condensers and other accessory apparatus are so arranged that the condensed distillates obtained are split into a number of predetermined fractions, as the temperature of the still rises. Where desirable, these several products are subjected to re-distillation for division into smaller fractions and for purification. In some plants the crude oil is heated in the first, or crude oil stills until only tar remains. This latter is accumulated and distilled separately. In some of the more modern plants the distillation process is carried through in the crude stills to the production of coke.

Products of Petroleum Distillation

The principal products primarily obtained from an oil with a paraffin base are naphtha (including gasoline), burning oils, lubricating oils, wax, and coke. These products are subjected to further refining, subdivision, and purification by treatment in special stills or other apparatus. Where oils with an asphaltic base are distilled the products obtained are similar to those already mentioned. The burning oils are not usually as good, the lubricating oils are heavier and have a lower flash point, and the residues consist of asphalt instead of tar and cylinder stock.

Natural Products Associated with Petroleum

Natural gas is very frequently found in association with crude petroleum deposits. It also occurs independently. Inflammable natural gas consists of gaseous hydrocarbons of the paraffin series and also usually contains small percentages of nitrogen, carbon dioxide, olefins, and occasionally oxygen. Some natural gases contain very light hydrocarbons (gasoline) which can be extracted by the use of suitable solvent oils or by compression and cooling. Such gases are said to be "wet" and the gasoline recovered from it is termed casing head gasoline. Natural gas is used as a fuel, for lighting, and for the manufacture of carbon black. (See also Natural Gas in section on Industrial Gases.)

Shale Oil. Certain shales contain large percentages of bituminous material. Such shales yield paraffin oils when subjected to dry distillation. The formation of these oils during the distillation processes is apparently due to the decomposition of the organic matter present. The products obtainable from the distillation of suitable shales are ammonia (recovered in aqueous solution and converted into the sulphate), phenols, naphtha, burning oils, paraffin oils, and wax.

Ozokerite. A number of deposits of a natural paraffin have been found at several points in America, Europe, and elsewhere. The material is yellowish brown to green or black in colour, translucent to opaque, and has a greasy feel. Ozokerite is sometimes distilled principally for the recovery of the paraffin wax. It may also be refined without distillation. The refined product is marketed as ceresin.

Asphalt. Natural deposits of pitch are found in many localities throughout the world. These are generally called asphalt. A similar material is obtained as a residue from petroleum refining when the distillation process has been stopped before coking takes place. The material may be semi-fluid or solid. The colour of natural asphalts varies from brown to black. Asphalts consist of mixtures of hydrocarbons, complex carbon compounds derived from them, and some free carbon. Some of the principal varieties of asphalt having special properties, are severally known as albertite, elaterite, gilsonite, grahamite, impsonite, nigrite, or wurtzilite. Natural asphalts are refined by fusing. The heavier mineral impurities will then settle out. Natural asphalts are used chiefly for road construction. Asphaltic residues obtained in the distillation of crude petroleum are used chiefly for making weatherproof papers and felts, and for roofing.

Canadian Situation

Crude petroleum has been produced commercially for many years in the province of Ontario in the district between lakes Erie and Huron. Small quantities have also been produced in New Brunswick near Moncton, and in Alberta. Exploratory drilling is in progress in many places in western Canada, and recent reports are to the effect that oil has been discovered in one locality. The Fort Norman oil field in the Mackenzie River basin has also been under investigation; its area and capacity have yet to be determined.

CHAPTER IV

PHARMACEUTICALS

General

All chemical substances whether natural or artificial products affect living protoplasm in some way. The study of the action of chemical substances, except food products, on all kinds of living organisms from unicellular bacteria and amoebae to man constitutes the science of pharmacology. Closely allied to this science is *therapeutics*. The latter is concerned with the remedial properties and conditions of application of products, while the former is concerned with the remedies themselves, their derivation, and properties.

Substances which are used as drugs or which exert effects upon animal tissues or organs are termed pharmacological products. Pharmaceutical chemistry is therefore the branch of chemistry relating to pharmacy. It includes the study of the occurrence and properties of drugs, methods of analyzing them, the preparation of medicines, particularly with reference to the ingredients used and their arrangement, and includes the study of toxicology and antidotes for poisons.

Pharmaceuticals may then be defined as the products which are used in pharmacology and therapeutics, and the manufacturer who is engaged in the making of these products is a pharmaceutical manufacturer.

Raw Materials

The substances that are used in the preparation of pharmaceuticals come from three main sources, minerals, plants, and animals.

(1) Chemical elements may be used alone or in combination. Iron, mercury, bismuth, carbon, iodine, and many other inorganic products derived from natural minerals, or compounds of these, have therapeutic value and are used by the pharmacist. Chemical compounds such as alcohol, ether, chloroform, and numerous other artificial products are also employed.

(2) Plants supply many chemical substances which cannot be made artificially, such as the exudations from which resins, gums, and oils are extracted. Plants also produce and store within their tissues alkaloids, glucosides, and vegetable acids that are utilized for medicinal purposes. A very few of these have also been made synthetically from coal tar chemicals.

(3) Animals supply special gland secretions from which products of therapeutic value are made, such as thyroid extract, pancreatin, pepsin, and other ferments. Musk, cod liver oil, and the various serums and antitoxins that are obtained from animals by special treatments may also be classed as pharmaceutical preparations.

The general enumeration that has been given in the three preceding paragraphs is sufficient to indicate that the source of raw materials used for the production of pharmaceutical preparations is very wide.

The preparation of chemical salts of the elements for pharmaceutical purposes consists largely in preparing these salts by the usual methods, and afterwards purifying them completely for therapeutic application.

The various products obtained from plants are secured by different methods. Experience and investigation have shown that desirable constituents of plants are sometimes concentrated at certain points. The parts of plants used to secure vegetable drugs may therefore consist of buds, flowers, twigs, bark, roots, exudations, galls, or woods of certain specific kinds. The desirable products are removed from the raw materials by processes of solution and extraction. Various solvents, such as water, alcohol, ether, or others, acids or alkalies, or salts of metals, are used for this purpose. The extracts are then subjected to such treatment as may be necessary to obtain the product finally desired.

The products obtained from animals are also obtained by various methods which have been determined by experiment.

The number of substances used for the preparation of pharmaceuticals is very great. One manufacturer informed the author that he had between seven and eight thousand products in his stock room. A list of raw materials used in this industry is therefore beyond the scope of this report. It is sufficient to add that many fine chemicals derived from natural mineral products are required by the industry.

Products

A classification of pharmaceutical products was proposed by Buchheim and is given in the Encyclopaedia Britannica, eleventh edition. In this classification those substances having similar actions are grouped together, each group being named from the best known member. The following brief statements are abstracted from this article. No attempt has been made to indicate whether the products mentioned are made in Canada.

1. *Acids.* This includes sulphuric, hydrochloric, nitric, phosphoric, tartaric, citric, acetic, lactic, carbolic, salicylic, tannic, and many others.

2. *Alkalies.* This includes potassium and sodium hydroxides, aqua ammonia, carbonates and bicarbonates of sodium, potassium or lithium, lithium citrate, calcium carbonate or hydroxide, magnesia and magnesium carbonate, soaps, and other products of a similar nature.

3. *Easily absorbed Salts.* Sodium chloride is the best known of these. The group also includes sodium nitrate, potassium chloride or nitrate, and the alkaline bromides or iodides.

4. *Salts absorbed with difficulty.* This group includes the sulphates of sodium, potassium, and magnesium, acetates and tartrates of potassium or sodium, magnesium citrate, sodium phosphate, and similar salts.

5. *Heavy Metals.* These include aluminium, antimony, arsenic, bismuth, chromium, copper, gold, manganese, mercury, lead, platinum, and silver. Both soluble and insoluble compounds are used to obtain various physiological effects.

6. *Halogens.* This group includes iodine, bromine, and chlorine, both in the free state and in combination with other elements.

7. *Sulphur.* Sulphur in itself has no action but it forms sulphides, sulphites, or sulphuretted hydrogen with secretions, and these products have pronounced physiological effects.

8. *Phosphorus.* This includes compounds of this element such as phosphides and probably hypophosphites.

9. *Oxygen.* In addition to pure oxygen the group includes hydrogen peroxide, potassium permanganate, powdered charcoal, and some other oxidizing agents.

10. *Carbonic Acid.* Carbon dioxide, carbon monoxide, and nitrous oxide are included in this group.

11. *Water.* This substance acts as a dilutent and as a solvent and has other effects. Mineral waters which contain salts in solution also belong to the group, although their effects are due largely to the salts in solution (see groups 3, 4, and 5).

12. *Tannic Acid.* This substance is present in many vegetable pharmaceuticals, such as gall nuts, oak bark, bearberry leaves, catechu, kino, red gum, logwood, witch hazel, and others, all of which are used in making astringents.

13. *Local Irritants.* This group is further subdivided into: (*a*) Those which act upon the alimentary canal, such as quassia wood, calumba root, taraxacum, gentian, chiretta, and many others, and (*b*) those which act on the skin, the best known of which is cantharides (Spanish fly). The active chemical in this case is a colourless crystalline substance, cantharidin. Similar substances belonging to the group are chrysarobin, mustard, pepper, and others.

14. *Male Fern.* This group includes male fern, santonin, cusso, pomegranate bark, pumpkin seeds, and many other substances which contain active principles that have a specific poisonous action on intestinal parasitic worms.

15. *Ethereal Oils.* This includes numerous substances which owe their action to the ethereal or essential oils which they contain. Some of these substances are cloves, pimento, myrtle, eucalyptus, caraway, fennel, dill, coriander, rosemary, lavender, peppermint, spearmint, nutmeg, cinnamon, sandalwood, turpentine, juniper berries, valerian, sumbul, and others; oleoresins, such as copaiba, cubebs, and Canada balsam; gum-resins, such as asafœtida, myrrh, ammoniacum, and galbanum; and true balsams, such as benzoin, storax, tolu, and Peru. The various camphors, such as laurel and Borneo camphor, menthol, and cumarin, which are oxidized derivatives of essential oils, also belong to this group.

16. *Phenol.* This group includes carbolic acid, sulpho-carbolates, creosote, wood tar, coal tar, oil of cade, thymol, salicylic acid, benzoic acid, naphthol, hydroquinone, cresol, guaiacol, ichthyol, saccharin, and many others.

17. *Alcohol.* This group includes a very large number of chemical products. Ethyl alcohol may be taken as the type. Other products are methanol, amyl alcohol, propyl alcohol, butyl alcohol, ether, acetic ether, paraldehyde, sulphonal, chloroform, methyl chloride, ethyl chloride, chloral hydrate, butylchloral hydrate, and numerous derivatives from these.

18. *Nitrates.* This group includes amyl nitrite, ethyl nitrite, methyl nitrite, nitroglycerine, sodium and potassium nitrites, erythrol-tetranitrate, and many other compounds made with nitrous or nitric acid.

19. *Alkaloids.* The principal substances in this group are morphine and related products derived from opium, such as codeine, narcotine, and laudanine. Other alkaloids are strychnine, brucine, caffeine, cocaine, atropine, hyoscyamine, homatropine, duboisine, daturine, nicotine, piturine, lobeline, pysostigmine, conine, gelsemine, sparteine, aconitine, delphinine apomorphine, emetine, quinine, phenacetin, acetanilide, phenazone, and many similar substances come within this group.

20. *Digitalis.* This group includes a large number of substances which have an action similar to that of foxglove leaves, including the active principles of stropanthus, squill, *Urechites suberecta, Convallaria majalis, Nerium Oleander, Helleboris niger, Antiaris toxicana* (Upas tree), and many others.

21. *Picrotoxin.*

22. *Saponin.* This includes many allied bodies which form an abundant soapy-looking froth when shaken up with water. They occur in plants such as *Quillaia saponaria, Polyala senega,* sarsaparilla, and others known collectively as the soapworts.

23. *Cyanogen.* This group includes compounds of cyanogen, such as hydrocyanic acid, potassium and sodium cyanide, cherry-laurel water, amygdalin, bitter almonds, and other products which contain this substance.

24. *Ferments.* This group includes such products as pepsin, diastase, pancreatic ferments, papain, pineapple ferment, taka-diastase, and others.

25. *Animal Glands and Secretions.* This includes products obtained from thyroid glands, suprarenal bodies, pancreas, spleen, bile, bone marrow, ovaries, and some others.

26. *Antitoxins.* These are substances which antagonize the toxins formed in the body by pathenogenic organisms, the toxins of snake venom and other animal poisons, and vegetable toxins, such as abrin, ricin, and related products.

27. *Neutral Fats.* This group includes cod liver oil, almond oil, olive oil, lard, lanolin, linseed oil, wax, spermaceti, and other fat oils. Paraffins, glycerine, and vaseline are not fats but they may be included although they do not act as foods; they have much the same effect otherwise as the fats and oils of vegetable or animal origin.

28. *Sugars, Starches, Gums, Gelatine.* These materials are used chiefly for their dietetic values.

Statistical Data

The pharmaceutical industries in Canada have been partially investigated by the Dominion Bureau of Statistics. The report issued by this bureau in 1922[1] shows the quantities and prices of some of the principal chemicals and other materials used by the industry in the years indicated. Annual reports are being issued.

The total value of the materials listed was $5,854,106 in 1919, this amount including $1,255,520 for containers, and $2,677,936 for unclassified materials, drugs, and chemicals. In the year 1920 these amounts were $7,029,594 for materials, which included $1,669,026 for containers, and $2,677,936 for miscellaneous products. In 1921 the total value of the materials used was reduced to $4,466,000.

The products of individual pharmacists throughout the country are not included in these enumerations.

Canadian Situation

According to the Dominion Bureau of Statistics[2] there were 97 firms in 1919, 100 in 1920, and 103 in 1921, engaged in the manufacture of patent and proprietary medicinal preparations, pharmaceuticals, toilet preparations, and the numerous other products made by these industrialists. In 1920 there were 61 plants in Ontario, 29 in Quebec, 7 in Manitoba, and one each in the provinces of Nova Scotia, New Brunswick, and British Columbia.

These enumerations appear to include wholesale establishments only. Many exactly similar preparations, but in less variety, are made by numerous individual pharmacists throughout the country, especially in the towns and larger villages. The total number of firms and individuals making these products is much larger than here given.

No attempt has been made to ascertain exactly what products are made in Canada by this industry and what raw materials are required. It is known that many crude products and refined chemicals are imported and that extracts, tinctures, tablets, and other products are made here from materials assembled from abroad. It is also known that numerous refined chemicals derived from products of mineral origin are required by the Canadian industries. There has, however, been no opportunity to properly investigate this market for these products, and its requirements are largely unknown.

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[1] Chemicals and Allied Products, 1919 and 1920, Dominion Bureau of Statistics, 1922, pp. 82-83.

[2] *Loc. cit.*, p. 81.

CHAPTER V

FINE CHEMICALS (ORGANIC)

General

Many chemical products are classified as fine chemicals, in contradistinction to those which have been described in the preceding chapters of this report as heavy chemicals. It is not possible to formulate a precise definition of the term "fine chemical" which will be of universal application. There are a number of chemical products, such as those used as developers in photography, or the synthetic drugs, which are universally regarded as fine chemicals. There are other products upon whose classification it is much more difficult to decide.

There seems to be a general consensus of opinion that chemical products which are made on a comparatively small scale under special conditions of manufacture by highly skilled labour working under competent technical supervision shall be called fine chemicals. Usually the products are of a high grade of purity and are correspondingly free from impurities; often they are rare products made only by a few manufacturers and the unit costs are comparatively high owing to the conditions of manufacture, complexity and cost of the processes, and rarity and relative costliness of the raw materials.

The Association of British Chemical Manufacturers classify fine chemicals in five groups, as follows: Analytical, Pharmaceutical, Photographic, Rare Earths, and Synthetic Essences and Perfumes.

The first four groups of fine chemicals can be further subdivided into inorganic and organic products. In this chapter reference is made to organic fine chemicals; the inorganic fine chemicals have been briefly discussed in chapter VI, part II.

Organic Fine Chemicals

A discussion of organic fine chemicals, their raw materials, and uses would necessitate a review of nearly the whole of organic chemistry. In other chapters references are made to ethyl alcohol and some of its derivatives, to methanol and associated products, to photographic chemicals, to pharmaceuticals, and to essences and essential oils. The numerous chemical products made from coal tar crudes, including some of the intermediates as well as the final products, are also classed as fine chemicals.

In the chapters above mentioned some reference has been made to chemicals which are made in Canada for use in the industry under discussion. A supplementary list showing a few organic fine chemicals that are known to have been made here is given below.

Table 13.—Fine Chemicals made in Canada (organic)[1]

Acid acetylsalicylic (aspirin); ammonium compounds (benzoate, oxalate, salicylate, tartrate); amyl acetate, butyrate, and nitrite; bismuth com-

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[1] The products listed were all manufactured in Canada at one time. They are not all now being produced, but manufacture could be resumed if warranted by commercial conditions.

pounds (ammonium citrate, oxalate, salicylate, subgallate); caffeine citrate; cellulose nitrate; camphor monobromide; chloroform (pure); collodion; diarsenol; ethers [acetic, butyric, nitric, sulphuric (including anaesthetical)]; iron compounds (ammonium tartrate, citrate, quinine citrate, quinine strychnine citrate, strychnine citrate, potassium tartrate, oxalate); lithium compounds (benzoate, salicylate); mercury compounds (oleate, salicylate); methyl salicylate; neo-diarsenol; neo-phenarsenyl; phenarsenyl; potassium compounds (antimony tartrate, citrate, tartrate); quinine and compounds (bisulphate, hydrochloride, phosphate, valerianate); sodium compounds (acetate, benzoate, citrate, oxalate, salicylate, sulphocarbolate); strychnine compounds (citrate, nitrate, sulphate); zinc compounds (acetate, oleate, sulphocarbolate).

Canadian Situation

No systematic studies of the fine chemical manufacturing industries in Canada have been made. The preceding list names a few products that were being made here prior to the war. During the war production of most of these compounds ceased, and it has not been possible to ascertain how far it has since been resumed. In other chapters references have been made to some fine chemicals which are utilized in the industries discussed. Analytical chemicals are not known to be made in Canada. Pharmaceutical chemicals are made by a number of firms, but the exact products made and those imported have not been ascertained. Photographic chemicals of organic origin are not made in Canada. Essential oils are for the most part imported and synthetic perfumes are not known to be made here, with the exception of methyl salicylate.

Statistical studies have not been made by any official bureau, and available import records give no important information with respect to the Canadian consumption or requirements of these classes of chemical products. A few groups of products of this class are mentioned in published trade returns, indicative of the fact that a considerable market for these products exists in Canada.

PART IV

CHEMICAL INDUSTRIES

MANUFACTURING GROUP

INTRODUCTORY

There are a number of industries whose finished products are obtained by the application of complex chemical processes to various kinds of raw materials. In some cases primary chemical products are made from natural mineral or organic products within the industry merely for the purpose of making secondary or higher and more complex compounds for fabrication into finished products. The finished products are usually complex chemical compounds, mixtures of more or less complex compounds with natural materials, or more or less complex mixtures of natural materials. The products used may be either inorganic or organic; the processes are always chemical and often physical as well.

The principal feature common to the group of industries considered in this part of this report is that both processes and products depend upon chemical means. The sources of raw materials, the processes used, and the finished products are very diverse.

The industries considered in this part of this report are the manufacture of explosives and fertilizers, the ceramic group including glass production, the latter being discussed in a separate chapter, and a number of miscellaneous minor industries making more or less complex chemical products for industrial uses. The minor industries discussed are the manufacture of insecticides, fungicides, blueing, boiler compounds, and inks. A few other products might have been included here, but it was not considered desirable to extend the list further.

CHAPTER I

EXPLOSIVE MANUFACTURE

An explosive may be defined as a product in which the constituent elements are capable of re-combination or dissociation in a very short space of time, through chemical reactions, whereby large quantities of gas at high temperatures are suddenly released. The release of these gases results in sudden and violent increases in pressure and is usually accompanied by shock. Each explosive is a chemical product or a mixture of chemical products which must be prepared with accuracy and precision. The manufacturing of these products is therefore a highly specialized industry. Usually an explosive factory is given over to the manufacture of a single product only, though this product may be prepared for the market in a variety of forms. In such a factory the ingredients of the explosive may be merely assembled and blended, or they may be first produced from raw materials assembled for that purpose.

Raw Materials

The subjoined list includes the names of the principal chemicals that are used in the preparation of the various kinds of explosives made in this country. It may be noted that the basis of manufacture of most explosives is sulphuric acid. While this acid is made in Canada from native pyrites, much of that used in the manufacture of explosives is made from imported sulphur. During the whole period of the late war Canada was largely dependent upon imported sulphur for the manufacture of the principal explosives produced for military purposes, a dependence which still continues. Canada is also dependent upon foreign supplies of nitrates from which to make nitric acid for the manufacture of these products.

A large number of explosive mixtures or compounds are put upon the market for specific purposes, and under trade names which are not necessarily indicative of their chemical composition. In the subjoined list of chemicals used in the manufacture of explosives account has been taken of the composition of the principal explosives sold under trade names, but no attempt has been made to make the list sufficiently comprehensive as to include all of these. The list includes not only the names of the raw materials used in the industry, but also the names of a number of compounds made from these chemicals to be used as constituents of explosive mixtures.

Table 14.—Principal Materials used in the Manufacture of Explosive Compounds or Mixtures, and in Fireworks

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

MINERALS: Asphaltum; bauxite; *graphite; kieselguhr; pyrites; sand; slate (pulverized)*; sulphur.

METALS: *Aluminium (powder)*; magnesium (powder); mercury; *silver; zinc.*

ACIDS: *Hydrochloric, nitric,* oxalic, picric, *sulphuric.*

INORGANIC CHEMICALS: *Aluminium sulphate (crystals)*; ammonium compounds (chloride, *hydroxide,* nitrate, oxalate, perchlorate, sulphate); antimony sulphide; barium nitrate; calcium compounds (*carbonate,* chlorate, *silicide, sulphate*); *ferric oxide;* magnesium compounds (*carbonate, oxide,* sulphate); *manganese dioxide;* potassium compounds (*alum,* bichromate, *chlorate,* chloride, nitrate, *perchlorate,* sulphate); sodium compounds (biborate, *bicarbonate, carbonate, chlorate, chloride, hydroxide,* nitrate, *perchlorate,* sulphate, sulphide); zinc oxide.

ORGANIC CHEMICALS: *Acetone;* alcohol (*ethyl*); ammonium picrate; *benzene; nitro derivatives of benzene; cellulose* (cotton, wood); cresols; diphenylamine; ethers; fulminates (*mercury, silver*); *glycerine; mineral jelly; naphthalene; nitrated starch; nitrated wood; nitro-cellulose; nitroglycerine;* nitro-naphthalene; *nitro-toluene;* oils (*mineral,* vegetable); *paraffin; phenol;* resinates (potassium, sodium); *toluene; vaseline.*

MISCELLANEOUS PRODUCTS: Charcoal (*poplar, willow*); *clays; coal; corn meal; corncob meal;* cotton; *glass (powdered)*; gums; *parchment paper;* peanut shell meal; resins; rice hulls; *sawdust; starch; sugar;* turmeric; vegetable ivory meal; *wheat flour;* wood meal.

Products

The explosive industries of Canada are engaged largely in making products suitable for use in the mining of coal and metallic ores, in quarrying, in road and railroad excavating, for petroleum and natural gas production, and for clearing land of stumps and occasionally of boulders. There are several firms producing sporting powders and small arms ammunition is made by others. Fireworks and signals are manufactured at several points. In addition a number of military explosives are produced. The useful applications of explosives are numerous and no one product is suitable for all purposes. The principal products of this industry in Canada are gunpowders for sporting, military, and industrial purposes; blasting powders; dynamites and nitroglycerine; several nitro-compounds; fulminates; fuses; squibs; detonators; caps; fireworks; railway and marine signals.

Statistical Data

Statistical data showing the quantities of the several products made, and the quantities of chemicals required by this industry, annually, are not available.

The returns compiled from the records of the Department of Customs show that quantities of these products are imported annually. Some of these data are included in the tables presented on pages 8-27. Certain of the products imported are required for the manufacture of explosives and are not produced in Canada. The importations include large quantities of sporting ammunition, blasting explosives, percussion caps, detonators, fireworks, and other products which could easily be produced in this country. The available returns do not classify these products in specific detail, and it is not possible to determine the exact quantities of each product imported. In some instances the local demand for a specific product may be too limited to warrant the manufacture of that product here.

Canadian Situation

There are eighteen firms engaged in the manufacture of explosive products in Canada. Eleven firms are primarily engaged in the production of chemical explosives, three of these making fulminate of mercury only. Seven other firms and two firms of the first group, nine in all, are making such products as fireworks, fuses, detonators, or signals. These products contain chemical products which possess certain of the characteristics of explosives, and which demand the same care and technical skill in the production.[1] One firm is engaged in the manufacture of small arms ammunition.

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[1] Consult annual reports of the Chief Inspector of Explosives, Department of Mines, for detailed information.

CHAPTER II

FERTILIZER INDUSTRY

General

Artificial manures form a group of chemical products that are of inestimable importance to the future of the agricultural industry of Canada. Such products are essential to intensive farming and to increased food production. The percentage of available agricultural land in Canada in a virgin condition has been gradually diminishing, and during the last decade the area of unoccupied lands has been steadily shrinking. There are still large areas, particularly in the western provinces, which are capable of producing heavy grain yields for many years to come without the aid of artificial manures. But, on the other hand, all the older occupied areas show diminished production wherever the use of fertilizer materials has been neglected. The continued increases in the total annual values of agricultural products have undoubtedly been attained largely through the utilization of additional areas of virgin soil, and through increase of agricultural population. The time will come, and in fact has come to large areas in the older provinces and in the older parts of the newer provinces, when the continuous removal of essential plant food constituents from the soil by cropping without replacement will deplete these soils. It is possible to temporarily restore the soil fertility by special treatment, without the direct use of fertilizers, by promoting natural processes of mineral decomposition and soil formation, but such procedure is slow, means idle land yielding no income, and therefore heavier overhead charges against the productive areas, and at best is only temporarily successful.

Present conditions demand maximum production per acre as well as per individual worker. Maximum yields can only be obtained by maximum cultivation, which in turn indicates the use of the best available crop foods. The crop yield per acre and the crop yield per individual worker can both be greatly increased by the application of the proper fertilizer constituents, if these applications are made scientifically and with due regard to the needs of the particular soil area under treatment.

The fertilizer industry in Canada is only in its infancy. The present market for artificial fertilizers is restricted to a few areas, chiefly in the immediate vicinity of the larger cities. The great majority of agriculturists, with the exception of those technically trained and a comparatively few others, are not at present in the market to secure products of this kind. Owing to this condition it is probable that the development of a large fertilizer industry in this country will also involve the development of a market by the maintenance of an intelligent and systematic campaign of educational advertising.

The development of large fertilizer industries appears to offer one of the best opportunities available in Canada for extensive industrial expansion in a direction where there is promise of a large home market, as well as a possible export market.

The principal constituents of artificial manures are of three types—nitrogen fertilizers, phosphates, and potashes. Some soils are improved by the addition of indirect fertilizers such as gypsum (or land plaster), ground limestone, or similar products. Very recent investigations have shown that on certain soils sulphur, sulphuric acid diluted, or a product supplying sulphur is beneficial when applied in limited amount. The following sections enumerate the principal raw materials of the fertilizer manufacturing industry and discuss briefly the Canadian situation with respect to each material.

Nitrogen Fertilizers

Nitrogen fertilizers are of two types—those derived from animal wastes, and natural or artificial chemical salts. The first group includes abattoir wastes (such as dried blood, tankage) and fish guano; the second, such products as nitrate of soda, sulphate of ammonia, and nitrogen products made from atmospheric nitrogen such as cyanamide, nitrite of soda, and nitrite or nitrate of lime.

Abattoir Wastes. There are abattoirs located in all the principal centres of population throughout Canada. These plants produce a number of waste animal products which are valuable fertilizer constituents. All the larger plants conserve their wastes and either utilize them in fertilizer manufacture themselves, or transfer them to fertilizer plants. In many of the smaller centres waste animal products are destroyed. The quantity available in any one locality is small, but an investigation would be necessary before it could be stated whether it would be commercially feasible to save this waste by preliminary treatment and then ship to larger works for final preparation.

Statistical data as to the quantity of abattoir wastes produced annually are not available. At the present time a considerable portion of this material is exported, chiefly to the United States.

The principal products available for use in fertilizer manufacture are dried blood (usually the clot only and not the entire blood) and tankage (the latter includes all waste and scrap not otherwise useful, all fats and oils having been extracted). Hoofs and horns are occasionally converted into fertilizer by fine grinding. Modern practice now tends to convert many of these products into nitrogenous foods for domestic animals, and the amount available for use in fertilizers is thus proportionally diminished. It should be commercially practicable to utilize the local animal wastes of abattoirs in small communities in this way when it is not feasible to make them into fertilizers or to ship them to larger centres.

The total number of large firms in Canada operating abattoirs is, according to available lists, sixty-seven, plants being listed in all the provinces except Prince Edward Island. There are known to be a large number of smaller organizations or individuals not included in the list. No records are available to show what waste products suitable for fertilizer manufacture are produced by these smaller firms, nor what disposal is made of the waste.

Fish Guano. The waste product from the fisheries is variously known as fish scrap, fish guano, or fish meal. With this material may be included whale guano made from the waste scrap of the whaling industry.

The operation of our fisheries on the Atlantic and Pacific coasts, and on the Great Lakes of the interior results in the production of much waste material containing oil and nitrogenous matter, the latter suitable for fertilizers. When the subject was investigated by the author there was found to be one firm operating in Nova Scotia and three in British Columbia utilizing fish waste, the products being glue, fish oil, and nitrogenous scrap. This latter was in part used for stock and poultry foods, and in part for fish guano which was sold in the United States. The whaling company was making similar products. These plants were operated during a portion of the year only, dependent upon the availability of supplies of raw material, which are for the most part seasonal. One plant is now in continuous operation throughout the year.

On lakes Erie and Superior there is a considerable quantity of similar waste available seasonally, all of which is discarded and destroyed. Similar conditions will probably prevail on Great Slave lake as the fisheries develop.

An experimental investigation on the utilization of the fish waste for the Great Lakes fisheries was made on behalf of the Commission of Conservation, by J. B. Fielding in 1916.[1] Mr. Fielding estimated the available fish waste in Canada at 250,000 tons.

A second investigation made on behalf of the Advisory Council for Industrial Research in 1917 showed over 300,000 tons of raw material produced, of which it was estimated that probably half would be available for conversion. This investigation does not appear to have included the fish waste available from the fresh water fisheries, which as noted above amounts to a considerable tonnage yearly. The waste yields oil, protein foods for stock and poultry, and fish guano for fertilizer manufacture. The subject is being investigated further on behalf of the Research Council, and presumably a report will be issued on the results.[2]

Natural Guano. This material is not found in Canada in commercial quantities. Supplies are occasionally imported for special purposes. Its high cost precludes its use in ordinary farming operations, though it may be occasionally used for special crops and in truck farming.

Nitrate of Soda. Chili saltpetre, or crude nitrate of soda, is not found in Canada. All supplies are imported either directly for delivery at Atlantic and Pacific coastal points, or indirectly through the United States for delivery at interior points.

Sulphate of Ammonia. This product is made from ammonia obtained as a byproduct in the distillation of coal and during the manufacture of coke. It is produced at one plant in Nova Scotia, two in Ontario, and one in British Columbia. It could also be produced in small quantities at the larger gas works, where soft coal is distilled in several of our larger communities. At present the waste ammonia liquors from these gas works

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[1] Utilizatiion of Fish Waste in Canada, J. B. Fielding, Commission of Conservation, Ottawa, 1918.

[2] Annual Report of the Administrative Chairman, Honorary Advisory Council for Scientific and Industrial Research, March, 1918.

are utilized for other purposes. At the smaller works they are discarded.

A large proportion of the sulphate of ammonia produced in Canada is exported.

Air Nitrates. Processes have been developed to a commercial scale for the fixation of atmospheric nitrogen. Atmospheric nitrogen is said to be "fixed" when a chemical compound has been produced that contains nitrogen derived from the air. Present processes produce two types of compounds—those in which both atmospheric nitrogen and oxygen have been combined with hydrogen to form nitric or nitrous acid, and the group in which atmospheric nitrogen has been combined with carbon and a base to form compounds known as cyanamides ($CN{\cdot}NH_2$). The most common compound of this type is calcium cyanamide ($CN{\cdot}NCa$ or $CaCN_2$).

These products are made by the use of electric power, and their profitable production demands very cheap power and large scale operation. The principal products are nitrates (of soda, lime, less frequently potash), nitrites, and calcium cyanamide. The subject is discussed more fully in the chapter on the production of nitrogen compounds.

Ammonia gas can be made from cyanamides. This gas can then be oxidized to form nitric acid. Acid thus formed can be neutralized with another portion of ammonia producing ammonium nitrate, a material that can be utilized as a fertilizer constituent.

At the present time there is only one plant in Canada engaged in the production of air nitrates. This plant is located at Niagara Falls, Ontario, and makes calcium cyanamide, the present capacity being about 75,000 tons per annum. Another plant was projected in British Columbia, and an experimental unit was erected; it has since been abandoned.

Canada possesses a number of large water powers suitable for development for the production of air nitrates. These occur chiefly in the provinces of Quebec, Ontario, and British Columbia. The greater number are located in sparsely populated regions, but many of them are accessible from existing railway lines. While these large units are unsuited for ordinary industrial development, where small blocks of power must be distributed to a number of users they are eminently suited for the development of an industry which requires large blocks of power for continuous service.

The development of the agricultural industry not only in Canada, but throughout the Empire will undoubtedly create an expanding demand for air nitrates for fertilizer manufacture. National foresight would appear to require that a number of Canadian water powers within the national domain, especially selected because of their suitability, should be set aside as a reserve to be devoted to this industry as the need arises.

Phosphates

The group of materials containing phosphorus that are used as fertilizers or in fertilizer manufacture comprises the following materials: apatite, a natural mineral [$(CaF)\ Ca_4P_3O_{12}$ or $3Ca_3P_2O_8\ CaF_2$]; tetra-calcium phosphate ($4CaO \cdot P_2O_5$); tri-calcium phosphate ($3CaO \cdot P_2O_5$); di-calcium phosphate ($2CaO \cdot P_2O_5 \cdot 4H_2O$); mono-calcium phosphate ($CaO \cdot P_2O_5 \cdot H_2O$). These materials, with the exception of the last mentioned, are not soluble in water. These substances are found in certain natural mineral deposits. Apatite and rock phosphate also occur in artificial products (basic slags) made from natural minerals.

Apatite. This mineral occurs in Canada, particularly in central Ontario and in the counties of Pontiac and Ottawa, Quebec. It is usually found associated with mica. The Canadian production reached its maximum in 1889, when 30,988 tons, valued at $10.21 per ton, were produced. There has been no large production since 1893, and during the last few years very little has been sold. The decline in production was coincident with the development of the high grade deposits of phosphates in Florida. Production since 1892 has been associated with the mica production, and the apatite shipped was in the nature of a byproduct. The mines are not developed in advance of mining and no estimate of the available tonnages of unmined apatite is possible. It does not appear probable that these mines can produce apatite profitably for fertilizer manufacture at present prices and there is no assurance that large supplies are in reserve.

Rock Phosphates. Deposits of mineral phosphates occur in many parts of the world. No sedimentary deposits of commercial grade have yet been reported in Canada. Thin bedded deposits of low grade (25-27 per cent P_2O_5) have been found in the Rocky Mountains in the vicinity of Banff, Alberta, but these are difficultly accessible and are not suitable for the manufacture of superphosphates by the present methods. Exploration of the region south of Banff, along the Spray river, Kananaskis lake and Elk River valley towards the Crowsnest Pass, has shown that these deposits become thinner and contain less phosphoric acid.

Certain shale beds in the carboniferous strata of southern New Brunswick also contain natural phosphates. Applications of these shales to marsh lands have proved efficaceous in a number of instances. Systematic searches for commercial phosphate deposits do not appear to have been made in eastern Canada.

At the present time supplies of this material for use in Canada are all imported. They are obtained chiefly from Florida, though similar material of lower grade is also produced in Tennessee and Kentucky. The development of a fertilizer industry in western Canada would at present necessitate the importation of rock phosphate from deposits in the states of Montana or Idaho.

Basic Slay. Basic slag is a byproduct of the steel industry. Phosphorus, occurring in apatite or other minerals in the ores, fuel, and fluxes used in the iron industry, gradually accumulates in the pig iron, and is finally removed in the later processes of steel manufacture. This basic converter slag may contain phosphorus equivalent to as much as 40 per cent of tri-calcium phosphate. Basic slag is usually ground to 100 mesh or finer and used in this form as a fertilizer constituent, without further treatment.

Bones, Bone Black, Bone Ash. Animal bones contain tri-calcium phosphate (about 44 per cent) as well as nitrogenous organic material (about 28 per cent). Untreated bones also contain fat which can be removed by suitable treatment. Ground bones containing the original fats are of little value as a fertilizer. If the fat has been extracted the finely ground bone material is a valuable fertilizer supplying both phosphorus and nitrogen.

Bones are calcined to form bone black, which is used for clarifying solutions, particularly in the manufacture of sugar. Exhausted bone black from the sugar refineries forms a valuable fertilizer material.

Bone ash, made by completely calcining bones, or bone black, consists largely of tri-calcic phosphate, and is used as a fertilizer material.

A limited supply of these materials is available in Canada, partly from the abattoirs, and partly from collections of junk dealers and sugar refinery residues. No statistical data as to the quantity produced annually have been compiled.

Superphosphates. Superphosphates (or acid phosphate) are made by the treatment of tri-calcic phosphate with the proper proportion of sulphuric acid. They form one of the principal constituents of most artificial manures and are also used alone for treating certain soils. The present Canadian consumption is approximately 50,000 tons per annum.

Formerly Canadian requirements were all imported. A small quantity was made in Canada from imported rock phosphate during the years 1918-19. More recently a plant having a capacity of 75,000 tons per annum was constructed in Ontario, the intention being to export any surplus production above Canadian requirements. This plant has only been operated intermittently owing to market conditions.

The raw materials required for the manufacture of this product are rock phosphate and sulphuric acid. As already stated deposits of sedimentary rock phosphate of commercial grade are not at present known to occur in Canada. The deposits of apatite known are undeveloped, the cost of mining is high, and it is very doubtful if any large tonnage of phosphatic material can be secured annually from these deposits. Certainly no large quantity is available to-day. It will therefore be necessary to secure phosphate rock by importation. The sulphuric acid situation has already been discussed under that caption.[1]

Potashes

Four potash salts produced from natural deposits in Germany were used principally in fertilizers prior to 1914. These are:—

Kainite—a double salt of potassium and magnesium ($KCl \cdot MgSO_4 \cdot 3H_2O$), containing when pure 18·9 per cent potash (K_2O). The commercial product contained a good deal of sodium chloride and was sold with a guarantee of a minimum potash content of 12·4 per cent.

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[1] A bulletin on the occurrence of Phosphate in Canada, by H. S. Spence, has been issued by the Mines Branch.

Manure salts were essentially mixtures of sodium chloride, magnesium sulphate, and potassium chloride. They were sold as a low grade fertilizer material, and the potash content varied from 20 to 30 per cent.

Muriate of potash—the commercial name for the chloride (KCl). This is a high grade refined product containing about 80 per cent potassium chloride, and the balance sodium chloride. This product was also used in the manufacture of a number of potash salts, such as the hydroxide, carbonate, nitrate, chlorate, and perchlorate.

Sulphate of potash. This salt was also a high grade, partly refined product containing about 90 per cent potassium sulphate. This product also found applications in chemical industry and was used in the production of certain other potash salts.

In addition to the above small quantities of potash salts were obtained from wood ashes and from the residues available after the manufacture of beet sugar.

Supplies of potash salts for use in Canada were almost wholly derived from Germany, some were imported directly, some through Great Britain, and the balance through the United States, the latter amounting to nearly half the total imports. Data with respect to the importations are given in the statistical tables.

An estimate made in 1918 shows that our annual requirements of potash salts are the equivalent of approximately 1,200 tons of potash (K_2O). Certain phases of the subject were investigated by the author in 1918. The results of the investigation were published in a bulletin issued by the Mines Branch in 1919, entitled "Potash Recovery at Cement Plants."[1]

Apart from importations from French Alsace and the United States the available sources of supply of potash salts in Canada are as follows:—

Cement Mills. It was estimated in 1918 that the annual losses of potash salts in cement mill flue dust in Canada amounted to 4,280 tons in 1917 and 2,700 tons in 1918. Naturally the annual losses are dependent on the annual production of cement and vary from year to year. It is possible to recover at least 60 per cent of the potash salts in the flue gases. The potash salts recovered from cement flue gases will normally be in the form of sulphate, owing to the presence of sulphur in the fuel used in the process of cement burning. It is possible to convert nearly all the sulphates into chlorides by using suitable reagents during the process of cement burning without affecting the value of the cement. The question of cost of recovery in comparison with the market value of the product will determine whether the introduction of any process of potash recovery will be profitable. One Canadian mill in Ontario has introduced a spray recovery system, but this has not been operated commercially and is now idle.

Kelp. Methods of recovering potash and other salts from sea weeds, and especially from the giant kelp of the Pacific coast, have been under investigation for a number of years. About 9 per cent of the total potash salts produced in the United States in 1918 were from this source. Kelp occurs in large areas on the Pacific coast of British Columbia. Experimental

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[1] Mines Branch Bulletin, No. 507. Out of print.

work on a small scale has been carried on, but no commercial development has yet followed. Crude estimates of the supplies available indicate that they probably greatly exceed our present annual needs. It has not been demonstrated that the material can be treated profitably on a commercial basis at the present market prices for the products obtained.

Wood Ashes. Hardwood ashes contain low percentages of potash salts, rarely in excess of 5 per cent. A small production of this material is still available in Quebec and Ontario at irregular intervals, but it cannot be regarded as an important or reliable source of commercial supply.

Potash Silicates. There occur in Canada a number of deposits of siliceous minerals containing potash, notably orthoclase feldspar, labradorite, and nepheline. Successful commercial methods for recovering the potash content and the aluminium content of these materials have not yet been developed, apart from the manufacture of cement, although many processes have been tried.

Natural Potash Salt Deposits. Deposits of natural salts containing potash and potash brines have been found in Canada only in one locality. A recent discovery of potassium chloride in association with a deposit of rock salt has been reported from the vicinity of Malagash, Nova Scotia. Development work has not reached a stage at which it is possible to predict whether the salt is present in quantities large enough to make the deposit of commercial importance. From time to time rumours and reports of the discovery of potash salts in brines from the Rocky Mountain region of Canada have appeared. Investigation has failed to substantiate these reports in any case.

Other Fertilizer Materials

Deposits of gypsum are known in the provinces of Nova Scotia, New Brunswick, Ontario, Manitoba, Alberta, and British Columbia. A certain amount of ground gypsum or land plaster is already produced from Canadian deposits and there are sufficient resources available to take care of all the probable needs of the agricultural industry.

Deposits of limestone occur in every province of Canada. Ground limestone for use as a fertilizer material is also produced at a number of localities, and the quantity can easily be increased to meet all needs.

The use of sulphur materials has not become standard practice in the fertilizer industry and they do not need to be considered here.

Imports and Exports

The principal products imported and exported by this industry are presented in tabular form on another page under the caption Fertilizers. Reference should also be made to the item calcium phosphate, monobasic, in the import list of chemicals. Statistical data covering the annual imports, exports, and home production will be found in the annual reports of the Dominion Bureau of Statistics.

Fertilizer Manufacture in Canada

There are about seventy-nine firms in Canada operating eighty-two plants engaged in the manufacture of fertilizers. Only two firms have complete plants including acid chambers. One of these, in British Columbia, is in active operation, the other, in Ontario, was in operation for a few months, and has closed temporarily. Six plants, one each in Nova Scotia, New Brunswick, and Quebec, and three in Ontario are provided with rock grinding and acidulating machinery, but are not provided with acid plants. Thirty-three plants make ammoniacal fertilizers from organic waste materials, and market a number of grades of mixed fertilizers, but do not prepare phosphates. Two of these plants are located in Nova Scotia, five in Quebec, twelve in Ontario, three in Manitoba, one in Saskatchewan, two in Alberta, and eight in British Columbia. Twelve of these plants handle fish guano from fish scrap, and the rest utilize abattoir waste. There are forty-one plants which purchase all their raw materials and confine their operations to dry mixing only. These plants are distributed throughout the Dominion, there being six in Nova Scotia, five in New Brunswick, eight in Quebec, thirteen in Ontario, and nine in British Columbia.

Summarizing the foregoing statements there are nine fertilizer plants in Nova Scotia, six in New Brunswick, fourteen in Quebec, twenty-nine in Ontario, three in Manitoba, one in Saskatchewan, two in Alberta, and eighteen in British Columbia. In addition to the foregoing there are several abattoirs who prepare their tankage for fertilizer production, but who dispose of it in bulk to grinding and mixing plants, or export it to the United States.

It should also be noted that for business reasons several organizations find it desirable to operate under more than one firm name, mixed fertilizers of identical composition being marketed under special brand designations. These have been included in the foregoing summary as if they were separate and independent organizations.

CHAPTER III

CERAMIC INDUSTRIES

The ceramic industries produce many kinds of useful and ornamental objects from numerous varieties of clays, sands, and related natural products. The art of decorating these objects by modelling, painting, glazing, enameling, or similar means naturally constitutes a phase of the industry. Ceramic materials and art methods are also employed for preserving, finishing, or decorating objects not primarily products of the ceramic art, particularly articles formed from metals.

Raw Materials

The principal raw materials of the industry are clays and shales, of which there are many varieties, feldspars and quartz. The natural minerals utilized in the industry number about one hundred and thirty. Most of these are only rarely required and are used for the production of certain special objects or effects. In addition there are at least one hundred and sixty-five chemical elements and compounds which find applications in this industry.

The subjoined lists are limited to those materials used by the several branches of the industry as developed in Canada, and relate chiefly to the production of glazes and enamels. Some Canadian works import prepared glazes and enamels in powdered form and do not make their own. No attempt has been made to investigate the nature and extent of the importations. The names of the metallic oxides more commonly used for preparing coloured enamels have been included in the lists, although manufacturers may be purchasers of products made from the oxides, and not of the oxides themselves.

Table 15.—Principal Products used in Ceramics

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

MINERALS: *Barytes; calcspar; clays* (ball clay, *fire clay, kaolin, some shales*); cryolite; feldspars (*albite, orthoclase*); *fluorspar; gypsum; pyrolusite;* quartz (flint, *silica sand, ground silica, quartzite*).

CHEMICAL COMPOUNDS: Acids (boric, *hydrochloric,* hydrofluoric, *sulphuric,* titanic); ammonium compounds (carbonate, chloride); barium compounds (carbonate, chloride, chromate); cadmium sulphate; calcium borate; *cobaltous chloride;* lead compounds (antimonate, borate, *carbonate, chromate*); *magnesium carbonate;* oxides (aluminium, antimony, chromium, *cobalt,* copper, *iron, lead,* magnesium, manganese, *nickel,* tin, zinc); *plaster of Paris;* potassium compounds (acid antimonate, aluminate, bichromate, carbonate, nitrate); sodium compounds [aluminate, biborate, *carbonate* (*calcined*), *chloride,* meta-antimonate, nitrate, silico-fluoride, sulphate]; whiting.

Products of the Ceramic Industry

The best known branch of the industry is probably the making of bricks from plastic clays and shales. Numerous varieties of bricks, adaptable to many industrial uses are also made from non-plastic materials. The principal kinds of structural materials made from non-plastic materials are sand-lime brick, clinker brick, slag brick, and other varieties of closely related products, such as concrete brick, blocks, and roofing tiles. The refractory products made in Canada are silica brick, three kinds of fire brick, and special fire clay shapes for locomotives and other boilers.

Other products of the ceramic industry are vitrified brick; drain pipe and sewer pipe of many kinds; tiles in great variety, used principally on walls, floors, and roofs of buildings; delf and porcelain wares; enameled and sanitary wares; enameled metal products of many kinds; ornamental and art objects.

Statistical Data

The statistical data available place the total value of the importations of clays and clay products at $7,520,000 in the fiscal year ending March 31st, 1918, $6,965,251 in 1919, and $6,371,567 in 1920. In the calendar year 1919 the total value placed upon the products of this industry manufactured in Canada was $7,906,366; building brick and fireproofing contributed 71·2 per cent to this total and sewer pipe and tile 21·3 per cent. The pottery products were valued at $890,320, but only $185,475 of this amount is credited to Canadian clays, the balance representing the value of products made from imported clays.[1]

The trade statistics based on the customs returns furnish a partial classification of the various products imported. Much more detailed information is desirable in order to ascertain the nature and extent of the home market for such products as could be manufactured profitably in this country. Much detailed statistical information with respect to the industry is given in the annual reports of the Division of Mineral Resources and Statistics of the Mines Branch, and the records are being continued by the Dominion Bureau of Statistics.

No statistical data are available showing in detail the various raw materials, other than clays, imported for the manufacture of ceramic products in Canada. The extent of the home market for chemical compounds used in this industry cannot be ascertained from existing records.

Canadian Situation

The Canadian market for the higher art products of this industry is very limited, and home manufacture is therefore largely confined to the commoner varieties of products. These products are chiefly those used in building and construction. A limited range of products for household use and house decoration are also produced.

The principal domestic products are clay bricks, floor tiles, building blocks, drain tile, and sewer pipe, all made in many varieties. Fire clay

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[1] Mines Branch, Division of Mineral Resources and Statistics, Report for 1919.

products, refractory linings, crucibles, porcelain products for electrical insulation, calcined and dead burned magnesite, silica brick, sanitary ware, jugs, crocks, churns, water coolers, and related products are also made in a few plants. The available lists of manufacturers of these products show eight firms engaged in the manufacture of clay sewer pipe, twenty-two firms producing a number of varieties of refractory and other special products, and about four hundred and seventy-five firms engaged in the manufacture of building blocks and other clay products. Complete lists of manufacturers are maintained in the Mineral Resources Division of the Mines Branch.

Glazes and enamels are applied to clay products, particularly certain grades of brick, tiles, sewer pipe, porcelain products, sanitary ware, and household utensils at nine potteries in Canada. Ceramic enamels are applied to numerous metal objects, such as household utensils, sinks, bath tubs, and hospital equipment in at least eight plants.

The clays, feldspars, and silica deposits of Canada, and the suitability of these different products for industrial purposes have been very fully investigated and a series of special reports on these materials has been prepared.[1] It is therefore unnecessary to refer to the Canadian resources in these materials.

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[1] See Mines Branch list of publications.

CHAPTER IV

GLASS INDUSTRIES

Glass is an amorphous product made by the fusion of silica, usually in the form of natural or artificial sand, with one or more salts of the alkali metals, and one or more salts of certain basic metals. The commoner forms of glass, such as window glass, bottle glass, or plate glass are well known. There is also a great variety of special glasses used in the manufacturing arts and for decorative purposes; which are less well known.

Raw Materials

The principal raw material in almost all glasses is silica. This is usually supplied in the form of sand. Silica may be obtained from natural deposits of loose sand, or by the crushing of sandstones or quartzites. The highest grades of transparent glass require a nearly pure sand. Common glasses can be made from less pure material. The presence of small amounts of clay products does not necessarily affect the final product, but the presence of iron oxide is undesirable, except for use in the cheapest grades.

Natural silicates, such as feldspars, which contain alumina and potash salts in combination with silica, can be used in the manufacture of some grades of glass. Certain salts of boron or phosphorus can be used for making a silica-free glass.

The alkali salt usually employed in glass making is sodium carbonate (soda ash). The sulphate (salt cake) is also used, particularly in the manufacture of window and plate glass. It is more difficult to use than the carbonate and it has not hitherto been employed in Canadian plants. Small amounts of sodium nitrate are required, chiefly as a reducing agent. The corresponding salts of potassium, particularly the carbonate and nitrate, are sometimes used.

The principal basic material used is calcium, supplied as the carbonate (limestone) or as the oxide (burnt lime), or as the hydroxide (hydrated lime). Lead oxide, usually in the form of red oxide, or as litharge, is used to increase the refractive power of the glass and to improve the brilliance of the product. A number of other basic chemicals, such as salts of antimony, arsenic, barium, magnesium, or zinc, are employed to produce certain desired effects in the manufacture of special glasses.

The principal raw materials used in the Canadian glass industry are silica and soda ash—both materials being produced locally and also imported. Local limestones are used. Relatively smaller quantities of pyrolusite, sodium nitrate, arsenious oxide, nickel and cobalt oxides, potassium chlorate, and a few other chemicals are also required.

Table 16.—Principal Materials used in the Glass Industry

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

MINERAL PRODUCTS: *Apatite;* clays (*china, fire*); cryolite; *feldspar; fluorspar; hematite; limestone; pyrolusite; silica.*

CHEMICAL OR METALLURGICAL PRODUCTS: Acid, boric; aluminium oxide; antimony; antimony compounds (oxide, sulphide); *arsenious oxide;* auric chloride; barium compounds (carbonate, sulphate); cadmium sulphide; calcium compounds [carbonate, *hydroxide* (*hydrated lime*), *oxide* (*lime*), phosphate (bone ash)] carbon (*coke*, or *organic materials* such as *oats, bark, sawdust*); *chromium oxide; cobalt oxide;* copper oxide; ferric compounds (*oxide, sulphate*); lead oxides [*red, yellow* (*litharge*)]; magnesium oxide; manganese dioxide; *nickel oxide;* potassium compounds (carbonate, dichromate, nitrate); selenium; silver nitrate; smalt; sodium compounds [biborate, *carbonate* (*soda ash*), nitrate, *sulphate* (*salt cake*), uranate]; sulphur; uranium oxide; zinc oxide; zirconium oxide.

Products of the Glass Industry

Glasses are sometimes named on the basis of their principal basic constituent as lime glass, lead glass, or potash glass. White glass, or opal glass, and coloured glasses are made by the addition of certain special materials, added to produce the desired texture and colour effects. The name flint glass is generally applied to any clear transparent glass, though it was formerly applied only to potash glass. Optical glass, as the name implies, is a special glass used for making lenses for optical instruments.

Glass production in Canada is confined almost wholly to the making of lime glass, used in the production of window glass, wire glass, and bottles of various kinds. Special varieties of certain glasses for the manufacture of electric lamp bulbs, lamp shades, and similar products are also made.

Statistical Data

Segregated statistical data showing the requirements of this industry in Canada are not available. Customs statistics show imports and exports of finished products but the items are not given separately in such a way that unsatisfied home markets for specific products can be ascertained. Import returns are tabulated elsewhere in this report pages 18-20). In the three fiscal years prior to the war the average valuation assigned to imported glass products was $4,832,498. During the three fiscal years after the war the total valuations of imports were $5,265,149, $5,254,203, and $6,839,656 respectively, certain mixed items in the tariff records being omitted.

The average importations in the three years before the war included common and colourless window sheet, 49,848,522 square feet; unbeveled plate in sheets or panes not exceeding 7 square feet each, 1,756,053 square feet; unbeveled plate in sheets or panes exceeding 7 square feet each, but not exceeding 25 square feet each, 1,410,826 square feet; unbevelled plate n.o.p., 1,919,480 square feet; and beveled plate, 12,426 square feet. The total average valuation of these two grades of glass alone amounted to $2,356,760 annually, exclusive of bent plate, which was valued at $114,861.

Canadian Situation

There are six firms in Canada engaged in the production of glass. One of these makes only certain grades of window glass, including wire glass. One firm specializes in globes, shades, and bulbs for electric lamps. The other four produce bottles, fruit containers of several types, lamp chimneys, and related products. A new firm has recently been organized to produce plate and window glass, large quantities of which are now imported.

The Canadian Trade Index contains the names and addresses of thirty-seven other Canadian firms engaged in the production and sale of glass products, fabricated from various grades and kinds of glasses, nearly all of which are imported,but none of these firms actually make the glass which they utilize.

The Canadian market for coloured glasses and for other special glasses is limited, and these are almost wholly imported.

The trade statistics, compiled from the import returns issued by the Department of Customs, and tabulated in another part of this report, would appear to indicate that the home market for certain glass products, especially window and plate glass, is broad enough to warrant the establishment of additional plants. In this connection a special investigation of the sources of silica for the manufacture of glasses has been carried out by the Mines Branch, and a report on silica in eastern Canada is now available. On the other hand the plants making these products have recently shut down, the alleged reason being their inability to compete with foreign importations under present conditions.

CHAPTER V

MISCELLANEOUS MINOR INDUSTRIES

INSECTICIDES AND FUNGICIDES

The modern agriculturist finds it necessary to protect his orchards and many crops by the use of suitable poisons, which enable him to control the ravages of insect pests or to prevent damage by fungi. Many merchants find it necessary to protect their stocks of perishable goods both from the ravages of insects and from rodents, and nearly every householder must also protect his possessions from similar pests. These needs have caused the development of an important group of subordinate chemical industries engaged in the production of poisonous mixtures and solutions suitable for these purposes.

The poisons used, with few exceptions, are chemical products derived from minerals. In many cases non-poisonous chemicals or minerals are used in association with the active poison to serve as carrying media to facilitate application and to retain the poison in a suitable position long enough for the pest which it is desired to destroy to come in contact with it. The several different poisons employed are necessarily adapted to meet varied conditions and to combat different kinds of pests.

Uses of Insecticides and Fungicides

Nearly all insects can be destroyed by subjecting them to treatment with poisonous gases or vapours, but it is not always feasible to use fumigants for this purpose. Chemicals used in this way are carbon bisulphide, sulphur dioxide, hydrocyanic acid, and formaldehyde.

Many insects, such as the locust, grasshopper, cucumber beetle, larvæ of many moths, and others, chew their food. These are best destroyed by spreading a suitable poison upon their food in such a way that it is masticated and taken into the stomach. It is there rendered soluble by the intestinal secretions and causes the death of its host. Compounds of arsenic with some one of several metals are most frequently used for this purpose—arsenate or arsenite of lead, aceto-arsenite of copper (Paris green), arsenate of lime, arsenate or arsenite of soda, arsenious oxide. The dry powdered roots of white hellebore, which contains a poisonous alkaloid, are also used for this purpose.

Insects which feed by sucking plant juices, such as aphids and plant lice, are combated by the use of chemicals which have a corrosive effect upon their body tissues, or by the use of fine powders which clog their breathing apparatus and cause death by asphyxiation. Such mixtures are lime-sulphur solutions, fish-oil soaps, kerosene or crude petroleum emulsions, caustic soda or potash solutions, carbolic acid, crude cresol emulsions, nicotine solutions, and other products are used to combat this type of insect.

A special group of insecticides are employed under such names as cattle dips, mange cures, or other designations to combat insect pests that are injurious to farm animals, such as horses, cattle, hogs, sheep, or dogs. Insoluble arsenical salts in suspension, lime-sulphur dips, kerosene emulsions, fish-oil soap emulsions, carbolic acid, pyrethrum powder, and other products are used for this purpose. Sulphur and mercurial ointments are also employed occasionally.

Fungi are low forms of plant life which are parasitic upon other living plants from which they draw nourishment as hosts. They develop from a unicellular fruit known as a spore, which in a way corresponds to the complex multicellular seeds of the higher plants. The plant itself consists of a more or less complex mass of thread-like interlocking fibres termed a mycelium. The mycelia of fungi may grow upon the surface of the host or within its tissues. Fungicides are designed either to destroy the spores of fungi and thus prevent their growth and the development of the mycelia, or they are intended to destroy the mycelia themselves and prevent the development of the plant to maturity and the production of spores. Compounds of copper, particularly copper sulphate in combination with lime, are widely used for this purpose. A preparation of lime and sulphur, potassium sulphide solution, mercurious chloride, and formaldehyde are also used under certain circumstances.

Insecticides and fungicides are usually applied as sprays, aqueous suspensions of the chemicals being specially prepared for this purpose. They may also be compounded as dry powders and dusted on. The use of these products has resulted in the development of a large variety of accessory appliances for spraying or dusting, ranging from the small hand blower used in applying pyrethrum powder to large power sprays and dusting machines operated by hand power or gasoline engines. These appliances are usually made from metal products. This industry therefore offers a large market not only for certain kinds of chemical products which are required annually, but also for a fair quantity of metal products which are needed in the manufacture of accessory apparatus, whose life extends over several seasons.

Raw Materials

The principal chemicals used in the manufacture of the products required by this industry are named in the following lists without regard either to the particular class of pest against which they are used, or to the method of preparation for use, or to the method of application. Many consumers purchase the necessary raw materials and make their own mixtures in accordance with well known formulae.

Table 17.—Materials used in Insecticides or Fungicides
(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

ARSENIC COMPOUNDS: Arsenates (*calcium, lead,* sodium); arsenites (barium, calcium, *copper,* lead, zinc); calcium arsenite and arsenate mixed as London purple; *copper aceto-arsenite* (*Paris green*); *oxides* (*arsenic, arsenious).*

OTHER CHEMICALS: *Acid, sulphuric; ammonia;* calcium compounds (*hypochlorite, oxide* as fresh burned lime); carbon bisulphide; copper compounds (*sulphate,* carbonate); *formaldehyde;* lead compounds (acetate, nitrate; mercuric chloride; nicotine, crude; *nicotine sulphate; paraformaldehyde;* potassium compounds (hydroxide, sulphide); sodium compounds (*carbonate, cyanide, hydroxide*); sulphur (flour, flowers).

PETROLEUM PRODUCTS: *Kerosene; paraffin oil; petroleum, crude.*

TAR PRODUCTS: Asphaltum; *coal tar; coal tar oil (neutral, high boiling); cresylic acid, crude; gas tar; phenol, crude;* pine tar.

ADULTERANTS: Barium compounds (carbonate, sulphate); *calcium sulphate (gypsum or land plaster); cement; dust* (from roads); *flour; lime.*

MISCELLANEOUS MATERIALS: *Grease (low grades)*; oils (castor, *fish,* rosin); pyrethrum powder; quassia chips (extract of); rosin; soaps (*fish-oil, potash, soda); tobacco extract;* Veratrum album (ground roots of, sold as white hellebore).

Statistical Data

The production and sale of insecticides and fungicides in Canada have not been studied statistically, and there are no reliable data available covering the home market for these products. It has been stated authoritatively that over $300,000 per annum is spent for sprays in the orchard districts of Nova Scotia alone.

The report on Chemicals and Allied Products, 1919 and 1920, issued by the Dominion Bureau of Statistics, gives the values of the materials used in making insecticides as $11,541 in 1919 and $80,420 in 1920. The selling value of the products for the respective years are placed at $32,924 and $140,701 respectively. In addition the import figures of the Department of Customs show 45,678 pounds of Paris green valued at $16,255 imported in 1919, and 2,811 pounds valued at $1,192 in 1920. Importations of other arsenical compounds do not appear to have been listed separately.

There are reasons for believing that the Canadian agricultural industry consumes much larger quantities of insecticides than are indicated by the above figures, but accurate statistical data are not segregated in such a way that the extent of this market for the different products can be ascertained.

Canadian Situation

The list of manufacturers of insecticides given in the report of the Dominion Bureau of Statistics for 1919 and 1920 names two firms in Quebec, and four in Ontario. The names of a number of firms manufacturing arsenical compounds, coal tar products, and wood distillation products that are marketed as insecticides, fungicides, and cattle dips are not included in the above list. There are eight additional plants known to be making these products, and one in British Columbia mixing orchard sprays, so that at least fifteen Canadian firms are engaged in making the products of this industry. In addition, some persons purchase the requisite materials in the open market and mix their own sprays, dusting powders, or dips for individual use, or for use by local groups or coöperative organizations.

At the present time a large quantity of arsenious oxide produced in Canada is exported, and certain arsenical salts are imported in relatively smaller quantities.

BLUEING

The laundry industry of this country (both public and domestic) consumes annually a large quantity of blueing, which is used to increase or intensify the white appearance of undyed bleached cotton and linen fabrics. Quantities are also used in textile mills and in the manufacture of granulated sugar and other white powders.

Commercial blueing is made in a variety of ways. The blue colour is due to the presence of a blue dye or a blue coloured inorganic salt. Sulphate of indigo, aniline blue, *soluble Prussian blues,* and ultramarine are used for this purpose. Potassium ferrocyanide and ferric chloride in proper proportions may be used to make Prussian blue directly. Other chemicals used in the compounding of laundry blueing are *sodium sulphate,* sodium biborate, and oxalic acid. Liquid blueing consists of solutions of some one of the colours indicated. Solid blueing in the well known balls and cakes is produced by the use of *starch, glucose,* or gum arabic as a body.

There are no statistical data available with respect to this industry. The annual consumption in public and domestic laundries, in textile mills, and in the manufacture of sugar and other products whose whiteness is intensified by the use of blueing must be very large. While our records only contain the names of three firms making these products, it is probable the number of manufacturers is greater.

The trade statistics of the Department of Trade and Commerce show importations of laundry blueing valued at $55,448 in 1914, which had risen to an average value of $108,380 in the three years following the armistice.

BOILER COMPOUNDS

The natural waters obtained from streams, lakes, or wells for use in steam boilers contain salts of lime and magnesia, and sometimes other compounds in solution. As the water is evaporated and used as steam these salts tend to concentrate in the boiler and to form a scale on the tubes and shells. Boiler compounds are designed either for treating the feed water to remove as much as possible of the undesirable constituents, for the purpose of preventing the formation of a coherent scale within the boiler, or to facilitate the removal of scale already formed.

The usual impurities in boiler water can be retained in soluble form or can be precipitated before the water is charged to the boiler by the use of sodium hydroxide or calcium hydroxide. Soda ash is also used with sodium hydroxide, or it may be applied alone. Other chemicals that are occasionally used in boiler compounds are alum, ammonium chloride, sodium bicarbonate, sodium sulphate, stannic chloride. A compound containing sodium tannate is suitable for use with some waters. This is usually compounded by using sodium carbonate with a solution containing tannic acid, obtained from spent tan bark, catechu, or other source of tannin. Potash salts may be used in place of sodium salts with satisfactory results.

Some classes of scale can be loosened or the adherence can be prevented by the use of kerosene. Paraffin oil and other petroleum oils heavier than kerosene are sometimes used, but natural petroleum is unsuitable because of the presence of tars and volatile constituents. Colloidal substances, such as sugar, molasses, gum arabic, or dextrine, are present in some boiler compounds.

It is customary for some manufacturers to add colouring substances to boiler compounds to disguise the ingredients. Turmeric, gamboge, potassium permanganate, and aniline colours, either blues or reds, may be used with this object in view. They serve no useful purpose other than to make it possible to obtain a high price for a cheap compound from ignorant purchasers.

The Dominion Bureau of Statistics reports six Ontario firms engaged in the production of boiler compounds in 1920. The selling value of the products is given as $188,144 in 1919 and $253,683 in 1920. The value of the raw materials used in the industry is stated to have been $70,305 in 1919 and $90,868 in 1920. No information is available with respect to manufacturers of these compounds in the other provinces, and data relating to the consumption of soda ash and other chemicals by this industry have not been segregated.

The Canadian Trade Index lists seventeen firms dealing in boiler compounds. Two of these are located in Quebec, fourteen in Ontario, including four firms listed by the Dominion Bureau of Statistics, and one in Alberta. Available lists do not show any manufacturers preparing these compounds in Nova Scotia, New Brunswick, Manitoba, Saskatchewan, or British Columbia.

INKS

Inks are defined as coloured fluids used for writing, drawing, or printing. Writing fluids usually have only a slight viscosity, while printing inks are more viscous and resemble paints or varnishes; drawing inks are only slightly more viscous than writing inks and will be included with the latter.

Writing fluids consist either of clear solutions of any colouring matter suitable for the purpose, or suspensions of an insoluble coloured compound in an extremely fine state of division. The main bulk of the fluid portion of writing inks is water, to which, in some cases, a small amount of a water soluble colloid such as gum arabic (gum senegal) has been added. The earliest kind of ink used was made from charcoal and glutinous vegetable exudations, or gum, or gelatine. The same type of ink survives to-day for some uses, and is more familiarly known as India ink or Chinese ink. The cheaper varieties consist of charcoal and glue; higher grades are composed of lampblack made from sesamum oil, resin or resinous woods mixed with gelatine, to which a small amount of gum camphor and substances containing essential oils has been added. Another ancient ink is made from sepia, a natural colouring matter derived from squids or cuttlefish. Sepia ink may be made in the same way as India ink, or it may be suspended in a suitable fluid for writing.

The principal requirements of a modern writing fluid are good colour, permanency, stability, and non-corrosive properties. The colour of an ink depends upon the chemicals used in its preparation. Carbon inks and inks containing ferric gallate or ferric tannate are black and practically permanent. Inks made from aniline colours fade rapidly in sunlight and less rapidly in the dark. The stability depends upon the chemicals used; an ink which does not decompose on standing and in which solids do not collect is the most desirable. Inks which contain free acids tend to corrode pens, or the paper, or other material upon which the writing is placed; it is obvious that non-corrosiveness is an essential characteristic of good inks. Writing inks should not be too viscous, otherwise they will not flow easily and will tend to clog pens. They should be capable of penetrating the fibre of the paper on which they are used but should not pass through; they should dry rapidly after application; in the bottles or ink stands they should neither ferment nor support the growth of moulds.

Varieties of Inks

Black ink, as ordinarily prepared, is made from nut galls and ferrous sulphate. Nut galls contain tannic acid which can be removed by crushing the galls and steeping in water. The aqueous solution is then exposed to the air to partially oxidize the tannic acid to gallic acid. The same result can be obtained by fermentation. The addition of ferrous sulphate results in the formation of a ferric gallate which is a blue-black insoluble compound that remains in suspension in the solution, which also contains ferrous gallate and ferrous tannate. The suspension of the colouring matter is facilitated by the use of a little gum arabic. Pure gallic acid and pure tannic acid can be used with ferrous sulphate to produce a black ink. Ink made in this way when first used has little colour. The black colour develops in the fibre of the paper upon which the writing is placed after it has been exposed to oxidation by the air. It is therefore customary to add preliminary colouring matter, such as a blue-black dye (alizarin) to the ink. Such an ink gives a blue-black line which turns black on exposure to the light for a few hours. The standard ink adopted by the United States government, and by several other governments, is made with tannic acid, gallic acid, ferrous sulphate, dilute hydrochloric acid, phenol, soluble blue dye, and water. Formerly a little gum arabic was used also, but this has been discontinued as unnecessary. Many commercial inks are made from similar ingredients, although the relative proportions of each are not the same. Another black ink sometimes made is prepared by using a solution of logwood (haematoxylin) and potassium bichromate, to which small quantities of chrome alum and oxalic acid are added. If kept acid this ink is stable, but if made alkaline it does not maintain its stability.

Carbon inks, when fluid, consist of finely divided carbon (lampblacks, carbon black) suspended in water by the use of a colloid. They are slightly brownish in tone except when made with some carbon black. Solid carbon ink (India or Chinese ink) has been mentioned above.

Coloured inks are usually aqueous solutions of corresponding aniline dyes, and lack permanency. Soluble Prussian blue can be used to make a blue writing fluid.

Inks for copying or for use on typewriter ribbons contain glycerine, syrup, or similar substances, to keep them moist, and they are usually thicker or more concentrated than writing inks. Mimeograph inks may contain shellac and borax in addition to the ordinary colouring matters. Marking inks may contain carbon, they may contain chemicals that act upon the cellulose of the fabric upon which they are used producing permanent coloured compounds, they may contain permanent dyes and a mordant, or they may consist of a natural plant juice or extract which acts as a dye when suitably prepared.

Stamp inks may contain glycerine, oleic acid, or castor oil, as well as the colouring compound. A white ink usually contains zinc oxide in suspension.

Sympathetic inks contain a chemical salt in solution which is invisible under ordinary conditions when used for writing on ordinary fabrics. Such writing is made visible by suitable means, according to the particular salt used in the writing fluid. Some salts become visible if dried thoroughly by warming the paper, disappearing again when exposed to ordinary moist air; others show colour when exposed to the action of light; others require the application of another chemical, either ammonia fumes or dilute solutions of salts.

Evanescent inks contain a coloured compound which is not permanent in character, the colour soon disappearing after use. Iodide of starch in suspension can be used as a writing fluid, and the colour will disappear in a few days. Certain aniline colours are also very fugitive.

Printing inks are much more viscous and usually slower drying than writing inks. In addition to suitable pigments they contain an oil or varnish body which may be made from various ingredients, oils, fats, greases, or waxes and resins, as well as a solvent and a drying medium. Petroleum, petroleum residues, and solvents, such as benzine, toluene, fractional distillates of petroleum, chloroform, carbon bisulphide, carbon tetrachloride, or acetone, are used in various mixtures. Products sometimes added to impart drying properties are linseed oil, chinawood oil, or turpentine. Other ingredients are rosin, gum dammar, and soap. The blacks are made from lampblack, vine blacks, and carbon black; the coloured inks by the use of aniline dyes or mineral pigments, such as ochres, cinnabar, venetian red, and similar products.

Table 17a.—Chemicals Used for Making Inks

(Names of products produced in Canada are in italics. A portion or all of the consumption may, nevertheless, be imported.)

CHEMICALS: Acids (*acetic, carbolic,* gallic, gallotannic, *hydrochloric,* oxalic, pyrogallic, *sulphuric,* tannic, tartaric); ammonium compounds (chloride, vanadate); aniline hydrochloride; *calcium hydroxide;* cupric chloride; ferrous compounds (*sulphate,* lactate); *glycerine; silver nitrate;* sodium compounds (biborate, *chlorate*).

COLOURS AND PIGMENTS: Aniline colours (various blacks, browns, blues, greens, reds, and yellows, eosine, erythrosine, indigo-carmine, nigrosines, tartrazine); blacks (carbon, *lampblacks,* vine); inorganic chemical pigments [Antwerp blue, carmine, Chinese blue, chrome green, *chrome yellow,* cobalt blue, crimson lake, emerald green, lithopone, orange lead, Prussian blue (soluble), titanium oxide, *white lead,* zinc oxide], mineral pigments (burnt sienna, burnt umber, cinnabar, *Indian red, red lead,* orange mineral, *venetian red,* vermilion, *yellow ochre*); vegetable colours (gamboge, madder, logwood).

GUM AND RESINS: Arabic; *beeswax;* dammar; mastic; shellac; white wax.

OILS AND FATS: Castor; chinawood; *linseed;* rosin; *mutton suet; oleic acid; petroleum; petroleum residues.*

SOLVENTS: *Acetone; benzene;* carbon compounds (bisulphide, tetrachloride); chloroform; *petroleum distillates; toluol; turpentine.*

MISCELLANEOUS: Gall nuts; *glue; gelatine; soaps;* tannin containing barks or extracts (selected); *molasses; sugar; syrup.*

Statistical Data

The five components of inks which are used in largest quantity are probably gall nuts or other materials containing tannin, ferrous sulphate. carbon black or lampblack, glycerine, and linseed oil. The other materials used are in special products and are required in relatively smaller quantities. There are no statistical data available showing any details of the requirements of this industry in raw materials, and the total annual production of inks in Canada is not known. The annual consumption of writing fluids in a country like Canada should be about 100,000 gallons. Available Customs statistics show an average importation of writing inks valued at $52,692 and $42,964 in the three (fiscal) year period prior to the war, and subsequent to the armistice respectively. The reason for the decrease in importations since the war is not apparent, but it may be due to increased production at home. The importations of printing inks for the same two periods averaged $103,489 and $194,545 respectively. Most of the importations come from the United States and Great Britain.

Canadian Situation

A report issued by the Dominion Bureau of Statistics lists ten firms manufacturing printing and lithographing inks, eight firms making writing fluids, and one firm making ink powders. The Canadian Trade Index lists eleven firms making printing and lithographing inks, twelve making writing fluids, and ten making stamp and stencil compounds. There are also nine firms producing carbon papers, and seven making typewriter ribbons.

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