

History of the Chemical Industry 1750 to 1930 – an Outline

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Introduction

The aim of this survey is to sketch the history of the chemical industry (mainly in Britain), for the period 1750 to 1930, and its relationship with contemporary political, social, and scientific developments; much detail will inevitably be omitted for brevity.

It will be argued that the development of the chemical industry arose largely in response to contemporary social needs; and that whereas the development gained much from scientific discoveries, problems encountered in industry also provided fertile ground for scientific enquiry. It is often supposed that pure science is a necessary precursor of technological development but a study of history reveals many cases in which scientific understanding of technology lags behind the technology, sometimes by a long way.

Political Background

Some major events:

- American War of Independence 1775-1783
- French Revolution and Napoleonic Period
Revolution 1789, First Empire (Napoleon I) 1804-1815
- American Civil War 1861-1865
- Unification of Italy; completed 1870
- Franco-Prussian War 1870-71
- Unification of Germany; foundation of German Empire 1871
- First World War 1914-1918
- Second World War 1939-1945

Emergence of Britain as the dominant world economic power between the end of the Napoleonic Wars (1815) and the First World War, but rise of Germany as a strong economy after 1871.

Emergence of the USA as a powerful economy towards the end of the 19th century, to become the dominant world economic power after the Second World War.

Social Background: Population Growth

In the two centuries from 1550 to 1750 the population of England and Wales increased by about 50% from around 4 to 6 million but then expanded explosively, trebling in the century 1750-1850 and more than doubling again in the next century:

| | | | | | | | | | |
|----------|------|------|------|------|------|------|------|------|------|
| Year | 1550 | 1600 | 1650 | 1700 | 1750 | 1800 | 1850 | 1900 | 1950 |
| Millions | 4.0 | 4.25 | 5.0 | 5.75 | 6.0 | 9.25 | 18.0 | 33.0 | 44.0 |

Source: *Colin McEvedy and Richard Jones 1978
Atlas of World Population History (Penguin)*

Similar trends occurred in other countries. These population explosions created substantial demands for food, clothing, and housing – thereby imposing stress on existing resources.

Social Background: Industrial Revolution

Britain, especially England, was in the forefront of the Industrial Revolution – a complex set of changes which transformed a predominantly agrarian society into one heavily dependent upon manufacturing for world-wide as well as domestic markets, and international trade. T S Ashton in 'The Industrial Revolution 1760-1830' dates the revolution mainly to those years but it had its roots in the 17th century and extended effectively to the end of the 19th century. The 'chemical phase' of the industrial revolution came predominantly after 1830.

Some technological features of the Industrial Revolution were:

- Expansion of coal and metalliferous mining; deep shafts from late 17th century
- Developments in ferrous metallurgy
 - Use of coke instead of charcoal for smelting (Abraham Darby 1709); blast furnaces from ca. 1760; steel production (Bessemer converter 1850, open hearth furnace 1860s, basic process from late 1870s)
 - Iron and steel as constructional materials – Iron Bridge 1779; use in shipbuilding from 1820s
- Introduction of Portland cement by John Smeaton; use for construction of Eddystone lighthouse 1759
- Mechanisation of textile industry; harnessing of water-power from 1730s and, later steam-power (19th century)
- Development of steam engines initially for pumping water from mines but later for driving air-blowers for blast furnaces and mine ventilation, and for general mechanisation, steam locomotion, etc. – some stages:
 - Thomas Savery's 'Miner's Friend' 1699; Newcomen engine 1708; engines with separate condenser and with rotary motion (James Watt and Matthew Boulton 1776-1800); use of high-pressure steam (Richard Trevithick ca. 1803)
- Locomotives from soon after 1800; marine engines from 1820s
- Canal construction 1760-1830; railway construction from 1825
- Coal-gas lighting from 1807; electric power from ca. 1880s.

Scientific Background

The emergence of modern science may be dated from 1660, the year in which the Royal Society was founded.

In 1661 Robert Boyle (of Boyle's Law fame) published 'The Sceptical Chymist' introducing the concepts of the element, alkali and acid, and refuting older mystical ideas of alchemy (which, however, persisted for a long time). In the next 150 years many empirical discoveries of elements and compounds were made but chemistry lacked a sound theoretical basis until well into the 19th century after promulgation of the ideas of modern combustion theory (Lavoisier 1774), law of conservation of mass (Lavoisier 1782), stoichiometry (Richter 1791), law of constant composition (Proust 1799), atomic theory (Dalton 1803), Avogadro's hypothesis (1811), and valency (Frankland 1852).

The foundations of mechanics were laid by the publication of Newton's 'Principia' in 1687 but other branches of physics remained relatively undeveloped until the 19th century. The early study of heat from the 1760s (e.g. Black – concept of latent heat 1761), and the gradual establishment of the laws of thermodynamics from 1824 (Carnot) to 1850 (Clausius, Kelvin) stemmed from the industrial interest in steam engines; chemical thermodynamics developed from about the 1870s (Gibbs, van't Hoff). The discovery of current electricity by Volta (1794) and the electromagnetic

effect by Oersted (1820) paved the way for the development of electrodynamics by Faraday and Henry in the 1820s and 1830s. Faraday also established the laws of electrochemistry in 1833.

Early Chemical Technology

Already by the middle of the 17th century a number of chemicals were known and a few empirical chemical technologies (some dating from antiquity) were well established on a small scale:

- Smelting of ores of copper, iron, lead and tin; lime-burning
- Production of alcohol by fermentation
- Extraction of alkalis from plant material – soda ash (Na_2CO_3) from maritime plants, potash (K_2CO_3) from terrestrial plants
- Preparation of caustic alkalis (NaOH and KOH) by treatment of soda ash and potash with lime (CaO or $\text{Ca}(\text{OH})_2$)
- Soap-boiling
- Glass-making
- Alum-making
- Production of nitre or saltpetre (KNO_3) for gunpowder
Manufacture by oxidation of limed nitrogenous organic matter, and reacting the resultant $\text{Ca}(\text{NO}_3)_2$ with potash
(Chile saltpetre (NaNO_3) only became available from 1825)
- Preparation of sulphuric acid (oil of vitriol) by distillation of 'green vitriol' ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) obtained by air-oxidation of moist pyrite (FeS_2)

In 1736 Joshua Ward started small-scale production of sulphuric acid by burning a mixture of brimstone (sulphur) and nitre above a shallow layer of water in glass vessels. The scale was increased by John Roebuck in 1747 who substituted large chambers of lead on wooden frames in place of the glass vessels. The process evolved with admission of air and external generation of SO_2 and NO_x ; and with the introduction of a circulatory system and counter-current absorption towers (Glover and Gay-Lussac towers) around 1827 for heat and material exchanges, it became the first continuous chemical process – the lead chamber process, notable for being the first to employ a (homogeneous) catalyst. The process was to become of paramount importance in British chemical industry; the last surviving plant of its type closed about 1973!

The product was a dirty brown acid of 70-78% H_2SO_4 strength known as Brown Oil of Vitriol (BOV); clean 96% acid was produced, when necessary, by distillation and called Rectified Oil of Vitriol (ROV). The terms BOV and ROV are still used today in the chemical industry for sulphuric acids of those strengths.

The lead chamber process was eventually displaced by the contact process patented by Peregrine Phillips in 1831, the first process to employ a heterogeneous catalyst – originally platinum. However, for reasons to emerge later, the process did not come into widespread use until the 1870s.

Chemicals for Textiles

Output of wool and cotton cloth grew substantially in the late 18th and early 19th centuries as a result of the mechanisation of the textile industry and the needs of the expanding population.

In the earlier days the cleansing and bleaching of cloth was achieved by the processes of bucking (soaking in alkali for a week), souring (soaking in buttermilk for a week), and crofting (exposing the cloth for several weeks to sunshine and rain in bleachfields on south-facing slopes). In the late 18th century sulphuric acid for souring, and chemical bleaching (initially using

chlorine in caustic alkali and, later, bleaching powder) came to be used; the use of chemicals speeded up the whole process considerably and reduced the amount of working capital tied up in unfinished goods. ('Bleachfield' on the University of York campus was a crofting site and by about 1850 a bleachworks stood there).

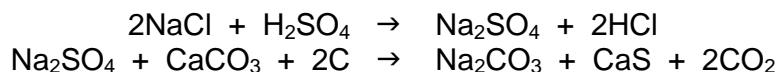
In addition to the direct use of alkali more was needed for the manufacture of soap (production of which, mainly for textile use, rose from about 1500 tons in 1785 to over 50000 tons in 1830). Still more alkali was needed for glass manufacture, production of which for windows in housing increased as a further consequence of the population explosion.

The usual source of soda ash was barilla (the ash of certain maritime plants) from Spain but its supply was restricted, especially during the Napoleonic wars. In France, where shortage of alkali had also been experienced, a prize was offered by the French Academy as far back as 1775 for a process to convert readily available salt (NaCl) to soda ash (Na₂CO₃) (it was well known that soda ash could be converted to salt). The first process suitable for working on an industrial scale was devised by Nicolas Leblanc who took out a patent in 1791 and opened several works in northern France; but in the revolutionary period the industry did not prosper there and, in poverty, Leblanc killed himself in 1806.

From 1806 Leblanc's process was worked on a very small scale in England (on Teeside) but was severely handicapped by a heavy excise duty on salt. It was only after the repeal of the salt tax in 1823 that the process was really economic and then the alkali industry became firmly established by Muspratt in north west England and by Tennant in Glasgow (St Rollox). Some other centres developed too. By 1840, synthetic soda had largely replaced barilla in Britain.

The Leblanc Process

The process was a messy batch process. Salt was treated with sulphuric acid; the resulting 'salt cake' (sodium sulphate) was mixed with limestone and coal (or, better, coke) and roasted to produce 'black ash' – an impure mixture of sodium carbonate and calcium sulphide:



The sodium carbonate was extracted with water and the solution was evaporated to dryness in open pans; if necessary for higher purity (e.g. for glass manufacture), the product was re-crystallised.

The operation of the Leblanc process was environmentally noxious. In the early days the acid fumes from the initial stage was vented to the atmosphere, and the smelly residual wet sludge from the black ash extraction stage was dumped.

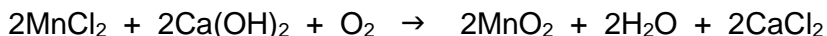
The emission of HCl fumes was a nuisance to neighbours in spite of the palliative use of tall chimneys (as high as 145 m at St Rollox), and litigation was frequent. Gossage introduced scrubbing towers in 1836 and they were increasingly used to absorb the descending water streams. Their use became general after the passing of the 1863 Alkali Act which made the absorption of at least 95% of the acid fume obligatory; the Act also set up an Alkali Inspectorate to enforce the measure.

Initially the acid absorbate was often discharged to rivers but it came to be recognised as a useful source of chlorine for absorption in lime (CaO) to make bleaching powder, a product

introduced by Tennant in 1799. The chlorine required for this purpose was released from the hydrochloric acid solution by heating with the mineral pyrolusite (MnO_2)



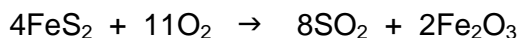
Partially successful efforts were made by Gossage as early as 1837 to regenerate the scarce manganese dioxide by:



But it was not until the 1860s that the recovery process was perfected by Weldon who used excess lime. Also in the 1860s the Deacon process for catalytic oxidation of gaseous HCl and Cl_2 (using CuCl_2 catalyst) came into use. Using these processes the manufacture of bleaching powder as an adjunct to alkali manufacture became firmly established in the 1860s and bleachfields disappeared.

The dumping of the sulphide sludge was not only environmentally offensive, it represented the total loss of sulphur from the sulphuric acid produced by the lead chamber process which played a key role in the alkali industry. However, effective recovery of sulphur from the sulphide waste lay in the future.

Originally the sulphur came from Sicily but in 1838 the price of the raw material doubled owing to monopolistic behaviour; within a very short time the mineral pyrite (FeS_2) was substituted; it was roasted in air to generate sulphur dioxide:

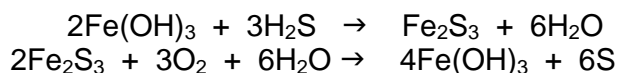


And the iron oxide byproduct was disposable to iron works. Another source of sulphur of importance later on was 'spent oxide' from gasworks which could also be used in the pyrite burners.

Coal Carbonisation: Coke, Gas and Byproducts

At this stage it is appropriate to comment on coal carbonisation. Coke was produced for metallurgical use from early in the 18th century, and from early in the 19th century the potential of coal gas for lighting was appreciated; distribution was facilitated by the availability of cast iron pipes. By the 1820s many English towns were lit by gas and the coal gas industry expanded greatly over the next few decades; coke ovens primarily for chemical and metallurgical coke also increased in number.

Gas from coal carbonisation contains hydrogen sulphide. Initially it was not purified but soon the messy process of washing with lime water was adopted. Later on bog iron ore, hydrated iron oxides periodically revived by aeration, was used in purifier boxes where the following reactions took place:



After prolonged use and the rise of the sulphur content to about 50%, the 'spent oxide' was discharged for use in lead chamber sulphuric acid plants.

Other products of coal carbonisation were ammonia and coal tar. Coke ovens and gas works became the main source of ammonia until the advent of synthetic ammonia (1913 in Germany, 1923/24 in England). The rise of the gas industry (1825-1860) coincided with the main phase of railway construction, and the coal tar found a ready use as a wood preservative for sleepers.

Already from 1815 coal tar was being distilled to produce light oil for lamps and it was appreciated that coal tar was a complex mixture of unknown composition. Investigation of distillates represented a challenge for the emerging chemistry of the day. Soon many aromatic organic compounds were isolated including naphthalene in 1819, anthracene in 1832, aniline (by Hofmann in Germany) and phenol in 1834, and benzene and toluene (methylbenzene) in 1848. This was about the time that a firm theoretical basis for chemistry was being established and it may be noted that the Chemical Society was founded in 1841, and the Royal College of Chemistry (under Hofmann) in 1845. The discoveries paved the way (with Hofmann in the forefront) for the development of systematic aromatic chemistry, and for Perkin's discovery of the first synthetic dye (mauve, or aniline purple, 1856). Perkin went into commercial production in 1857; this was the start of the synthetic dyestuff industry which was soon to become important, and which established another link between the chemical industry and the textile industry. Progressively during the 19th century tar distillation, by tar producers and by independent distillers, became an important fringe sector of the chemical industry producing aromatic organic chemicals for synthetic dyestuffs.

In passing, it may be noted that water-soluble dyestuffs (mostly of vegetable origin before the advent of the synthetics) required the use of a mordant to fix them to cloth. This was usually alum ($X_2SO_4Al_2(SO_4)_3 \cdot 2H_2O$ where $X = K$ or NH_4). Much alum was produced on the Yorkshire coast and in the Cleveland Hills from alum shales containing pyrite and bituminous matter; the inefficient process in which sulphuric acid was generated during combustion of the shales, was operated from around 1600 to about 1860 but was displaced after Spence at Widnes introduced a process to make aluminium sulphate using chamber acid to react with shales.

The production of mordants and synthetic dyes strengthened the links between the chemical and textile industries.

Another offshoot of the availability of chemicals from coal tar, and the development of organic chemistry, was the evolution of an explosives industry from 1850 making products such as picric acid (trinitrophenol) and TNT; nitrocellulose and nitroglycerine were also developed around the same time and the British Dynamite Company was established in Scotland at Ardeer in 1871.

Chemistry and Agriculture

In the 1840s Lawes in England (who set up the Rothamstead Agricultural Research Station in 1843) and Liebig in Germany investigated the nutritional needs of plants and discovered that N, P and K were essential elements. In 1841 Lawes took out a patent for the production of superphosphate and soon afterwards established a factory for its manufacture; the process involved the conversion of insoluble phosphates in the form of bones or mineral phosphates to a mixture of calcium sulphate and soluble calcium phosphates by reaction with sulphuric acid. This was the start of the artificial fertiliser industry, later to become an important sector of the chemical industry.

Carbon Dioxide under Pressure

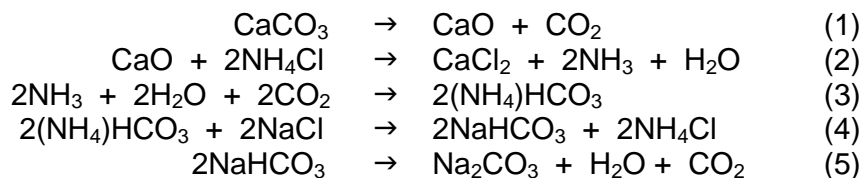
The handling of carbon dioxide under pressure was a key factor in two important developments in the alkali industry in the second half of the 19th century; these were the establishment of the ammonia-soda process, and the recovery of sulphur from Leblanc process sulphide waste.

Problems had been encountered in attempting to use carbon dioxide industrially owing to anomalous behaviour which was not properly understood until 1869 when Andrews, using carbon dioxide, studied critical phenomena.

The Ammonia-Soda Process

The process, essentially involving the reaction of carbon dioxide with an ammonia-saturated solution of salt, was first proposed by Fresnel (better known for his work on optics) in 1811. Various attempts were made in Britain (Thom in Scotland 1836, Muspratt in the 1840s, Deacon 1856) to achieve a workable process but all were on a small scale and none was really successful. The effective establishment of an economic, large-scale process was achieved in Belgium in 1865 by Solvay who overcame the engineering problems of gas handling and absorption. A licence for the exclusive operation of the process in Britain was acquired in 1872 by Mond who, with Brunner, started a works in Cheshire in 1874. In the meantime some variants of the Solvay process were also established in England but were later taken over and shut down by Brunner, Mond & Co.

The full process comprised a number of stages:



giving the net reaction:



Stages (3) and (4) were operated in a continuous cycle. In principle, the ammonia was not consumed and only top-up quantities were required; the only waste product was the calcium chloride which, being soluble, could be discharged to drain.

The ammonia-soda process prospered and production of soda increased rapidly. Although more capital-intensive than the Leblanc plants, it was less labour-intensive, more economical in use of raw materials, and had no serious waste problems. It presented a serious economic challenge to the Leblanc alkali industry and it was to be the soda process of the future.

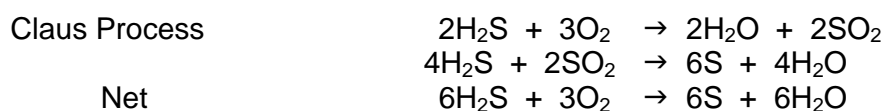
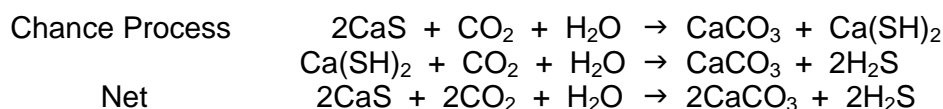
In the 1870s the Solvay process was not only established in England but also in the now unified Germany and the post-civil war USA, countries that had never had Leblanc plants and had been significant export markets for Britain. Consequently, British exports of alkali declined. For the Leblanc producers the competition was intense.

But the mostly small producers using the Leblanc process (of whom there were now a fairly large number) fought back. For a while they had the advantage that most of their plants were fully depreciated whereas the large ammonia-soda plant had to bear heavy capital servicing

charges. Also, of considerable importance, they had the very big advantage of being able to sell the byproduct bleaching powder. They exploited this advantage further by forming the Bleaching Powder Association in 1883 to operate a cartel (which was quite legal in those days) to keep prices up. They also appreciated the need for cost-saving and thoughts turned to sulphur recovery.

Sulphur Recovery from Leblanc Wastes

Sulphur recovery became a reality in 1887 with the introduction of the Chance and Claus processes involving the treatment of the alkali waste with carbon dioxide, and combustion of the resulting hydrogen sulphide in a limited supply of air:



The recovered sulphur was available for internal recycle in the Leblanc works, or for sale to other sulphuric acid manufacturers. A market for pure sulphur had emerged as a result of the establishment in 1875 of the contact process for the manufacture of sulphuric acid, some 40 years after its invention. This was in response to the need for high quality concentrated sulphuric acid and oleum for use in the expanding synthetic dyestuffs industry.

Now, with bleaching powder and sulphur as its byproducts it seemed for a time that the Leblanc industry could survive in competition with Brunner, Mond & Co. To strengthen their position more, the 45 Leblanc process operators and three salt producers amalgamated to form the United Alkali Company (UAC) which concentrated on its most efficient plants and closed many others. But the relief was short-lived; very soon two new developments undermined UAC's newly particular strengths.

Frasch Sulphur

In 1890 very pure Frasch sulphur from the Gulf states of America came on the market so the advantage enjoyed by UAC of being able to supply pure sulphur was diminished. However, recovered sulphur from Leblanc wastes could still be recycled internally.

Electrochemical Industry

As previously noted, the foundations of electrochemistry and electrodynamics go back to the 1830s. After much development from the 1850s, reliable industrial electricity generators appeared in the 1880s and electrochemical applications followed. In 1888 Castner, an American who had failed to prosper at home, came to England to set up an electrochemical plant for the manufacture of sodium at Oldbury; the sodium was intended for the production of aluminium from aluminium chloride, but already in 1886 Hall in America and Héroult in France had devised the modern process of aluminium manufacture by electrolysis of alumina (Al_2O_3) dissolved in molten cryolite (Na_2AlF_6) – an aluminium smelter was set up by the British Aluminium Company at Foyers in Scotland in 1895. Castner found alternative uses for sodium in the production of sodium peroxide (a bleach for straw hats popular in this period) and sodium cyanide; the latter was soon in much demand in America, Australia and South Africa for gold refining. In order to

obtain pure caustic soda (NaOH) for sodium production Castner devised the process of brine electrolysis using a mercury cathode; this led to the setting up of the Castner-Kellner Alkali Company in Runcorn in 1896 to produce caustic soda, and bleaching powder from the chlorine byproduct. This was a serious blow to UAC whose virtual monopoly of bleaching powder supply was now broken and who also experienced further competition in the alkali field itself. To make matters worse, Castner-Kellner soon merged with the Brunner, Mond & Co.

Mention may also be made of a continuous electrothermal process (replacing an older thermal batch process) introduced around 1890 for the manufacture of phosphorus used in match production; and electrothermal production from 1895 of calcium carbide for which there was soon a significant demand for use in acetylene (ethyne) lamps, (later on, however, most carbide was imported).

The Demise of the Leblanc Alkali Process

Towards the end of the 19th century it was becoming clear that the Leblanc process had no future and the UAC itself developed a version of the ammonia-soda process with plants at Widnes and Fleetwood. The UAC survived until its eventual merger into ICI in 1926, along with Brunner, Mond & Co and others. The Leblanc process finally disappeared in the early years of this century.

It is arguable in retrospect that the efforts to sustain an obsolescent process did lasting harm to the British chemical industry. At a time when resources were diverted from progressive activity, Germany and the USA were building up powerful modern chemical industries. In this they were supported by educational systems which were sympathetic to industry.

Semi-Synthetic Materials

A new branch of the chemical industry, which was to develop in time into the synthetic fibres and films industry, had its beginnings with the chemical modification of cellulose – partly as a spin-off from explosives manufacture: celluloid made from cellulose nitrate and camphor (1870s), viscose (cellulose xanthate) made by dissolving cellulose in carbon disulphide (1880s), and cellulose acetate (1890s/1900s) were the primary products from which films and fibres or both could be formed.

Nitrogen Fixation

In 1892 Sir William Crookes in his Presidential Address to the British Association drew attention to the prospect of declining agricultural fertility because of nitrogen shortage, and called for the development of a process for the fixation of atmospheric nitrogen. In the early years of this century the electric arc (Birkeland-Eyde) and the cyanamide (Frank and Caro) processes were developed on the continent and enjoyed brief lives (up to about 1920). But the process of lasting importance was the high-pressure catalytic Haber-Bosch process which was established in Germany in 1913 after a lengthy study by Haber of the thermodynamics of the $N_2-H_2-NH_3$ system; Bosch's contribution was the industrial development of the process including the thermochemical method of producing the pure nitrogen and hydrogen needed. (Nobel Prizes in Chemistry were awarded to Haber in 1918 and Bosch in 1931). The ammonia synthesis process was complemented in 1914 by the Kuhlman-Ostwald process for the catalytic oxidation of ammonia to obtain nitric acid. These processes were established in Britain (by Brunner, Mond & Co) in the 1920s, notably at Billingham (Teeside) where a very large fertiliser industry developed.

Dyestuffs

As noted earlier the synthetic dyestuffs industry started in 1857 with the manufacture of aniline dyes by Perkin. In the decades to follow, the range of synthetic dyes was extended considerably as great advances were made in organic chemistry – incidentally Kekulé postulated his ring structure of benzene in 1865, the year Hofmann returned to Germany. One dye of importance was alizarin, obtained from the plant madder which was very extensively used still in 1870; methods of alizarin synthesis were devised in 1868/69 by Gräbe and Liebermann in Germany and by Perkin in England, and commercial production started in both countries in the 1870s – on a larger scale in Germany. It was from this time that the German industry expanded rapidly with profits from alizarin manufacture an important source of finance for dyestuffs research and development; this factor, together with the greater availability of trained chemists in Germany compared with Britain, soon made Germany pre-eminent in synthetic dyestuffs production (Switzerland also became an important dyestuffs-producing country from the 1870s as a result of the establishment there of émigré producers from France escaping patent restrictions!). Thus Britain suffered a relative decline in the dyestuffs field even though there was expansion of production here too – some of it by German and Swiss firms. Britain actually became a net importer of synthetic dyes.

When World War I broke out in 1914 Britain was importing monthly from Germany 250 tons of alizarin, 100 tons of indigo, 1200 tons of aniline dyes, plus small quantities of a large number of other dyes. At this time the UK dyestuffs industry comprised 12 independent firms (of which 2 were German); with government backing, the number was reduced in 1915 with the formation of British Dyes around Read, Holliday & Sons (active since 1860). In 1919 British Dyes merged with Levinstein Ltd (formed 1895 from several other companies including the successor of Perkin & Sons) to form British Dyestuffs Corporation (BDC); and another merger in 1919 resulted in the formation of Scottish Dyes which was absorbed into BDC in 1925.

Thermo-setting Resins and Plastics

In 1902 resinous materials obtained by the condensation of phenol and formaldehyde lacquers and moulding powders (e.g. Bakelite) took place in Britain, Germany and the USA. In 1914 a factory was set up in England and it produced materials for electrical goods during the war. Afterwards phenol-formaldehyde (PF) moulding powders and adhesives (e.g. for brake linings and, later, for plywood) were produced in increasing quantities. Several companies involved merged in 1926 to form Bakelite Ltd.

Urea-formaldehyde (UF) resins were patented in 1918 for use as adhesives and impregnants for textiles, and these became important applications; after development in the 1920s UF moulding powders (resins mixed with wood flour or cellulose pulp) also became important. A leading player in this field was the British Cyanides Company which in 1936 became British Industrial Plastics.

Such were the beginnings of the plastics industry in Britain. An important contribution to bringing thermo-setting resins and plastics to market was the availability from the 1920s of methanol (for methanal production) and urea as byproducts of the ammonia synthesis process at Billingham. As part of the gas preparation, steam was reduced by coke to produce H₂-gas containing H₂, CO and CO₂; after removal of the CO₂ (by water absorption) the CO content of the residual gas was reduced by passage under pressure through a catalytic converter producing methanol; urea was produced by reaction of recovered CO₂ with product ammonia.

The Growth of Companies and the Formation of ICI

The aftermath of the First World War was a difficult time for the chemical industry everywhere, and one of consolidation. Large companies had emerged in the USA (DuPont, Allied Chemical, Dow Chemical, American Cyanamid, Hercules Powder, Monsanto etc.) and cartels involving major German companies and the Swiss CIBA, Geigy and Sandoz were rife in Europe. The spirit of the age was for mergers and organisational growth; for many companies survival depended upon suitable alliances.

In 1920 several small explosives companies amalgamated to form Nobel Explosives; the formation of BDC in 1919, and its expansion in 1925 has already been noted.

In 1925 the German companies AGFA, Bayer, Badische Anilin und Soda Fabrik (BASF), Griesheim and Höchst amalgamated into a new, very large company – EG Farbenindustrie, incorporating not only dyestuffs as the name suggests but heavy chemical industry too. This union was perceived as a threat by large sectors of the British chemical industry and led to negotiations in 1926 to form a rival bloc which started life on 1 January 1927. This was the origin of Imperial Chemical Industries (ICI), an amalgamation of:

- British Dyestuffs Corporation
- Brunner, Mond & Co
- Nobel Explosives
- United Alkali Company

Conclusion

This is a convenient point at which to end this sketch of the early history of (mainly) British chemical industry. It has traced in outline the development of the industry from early beginnings through to the middle 1920s. By this time many features of modern chemical industry had been established including: continuous processes; catalytic processes; industrial electrochemistry; high pressure chemical technology; chemical engineering (with the concept of unit operations) as a distinct discipline; and large chemical companies with substantial R&D capabilities.

It has been noted that the chemical industry in the 19th century grew up as a chemical phase of the industrial revolution, and that the ultimate objective of the industry was to serve social purposes – notably through connections with the textile industry (through sulphuric acid, alkalis, soap, dyestuffs and fibres) and the fertiliser industry. These connections remain strong to this day and have indeed intensified with the development of an increased range of products including fully synthetic fibres, reactive dyes, liquid detergents, etc. Sulphuric acid production was a pillar of the early alkali industry and also had important applications elsewhere, as in superphosphate production and as an auxiliary in aromatic nitrations for dyestuffs and intermediates. Alkali production was also important for glass manufacture. The population explosion background cannot be overstressed.

At various stages the chemical industry took advantage of pure chemical research activity (as in the dyestuffs field) but equally, industrial problems and empirical discoveries often provided topics for fruitful academic study – catalysis is one notable example. The interaction of pure science and technology is another strand continuing to the present day.

Since 1930 there has, of course, been much further development of chemical industry. Four important fields of activity may be signalled to be discussed in Part II:

- The development of the pharmaceuticals industry mainly as an offshoot of the dyestuffs industry;

- The expansion of the fibres and films sector with the introduction of fully synthetic materials (e.g. nylon, PET);
- The expansion of the plastics industry with the introduction of thermoplastics (e.g. Perspex, PVC);
- The phenomenal rise after World War II of the petrochemicals industry, which deserves a history to itself.