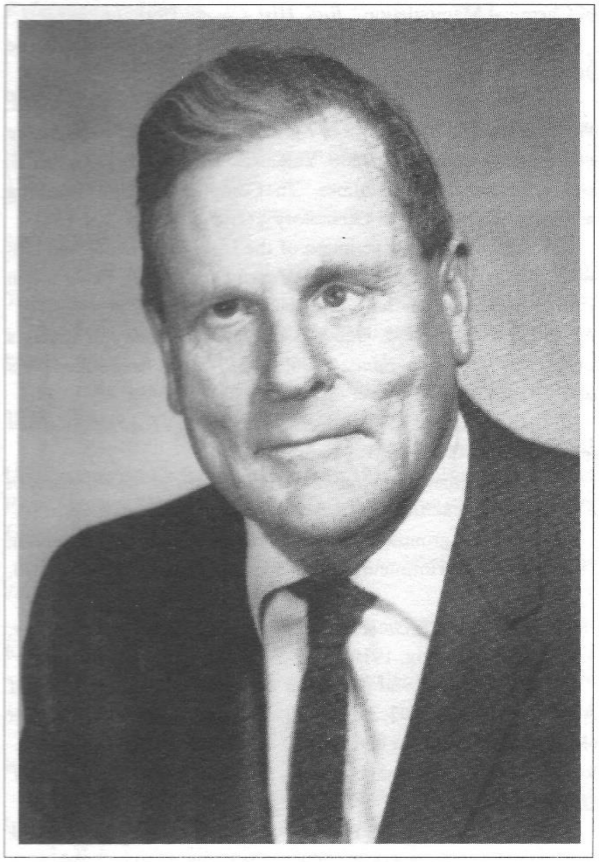
Chapter 12
Henry Marshall Leicester (1906-1991)
Historian of HIST

One of the dominant members of HIST in the post-World War II period was Henry Leicester. He served as Chair from 1947-1951. He left a vast legacy of publications in the History of Chemistry. A good biography is: "Henry Marshall Leicester (1906-1991)," **Bull. Hist. Chem., 10,** 15-21 (1991) by George B. Kauffman (1930-2020) (HIST Chair 1969-70).



Henry Marshall Leicester (1906-1991)

Leicester was born in San Francisco and spent most of his life in the "Bay Area." He died in San Mateo, CA.

Henry entered Stanford University at the age of 16 and received all his Chemistry degrees there: A.B.(1927), M.A.(1928), Ph.D. (1930). This was the period dominated by Robert Eckles Swain (1875-1961), the famous biochemist. Leicester

also received his doctorate in organic/biochemistry. (Swain also founded the Stanford Research Institute.)
Leicester gained valuable experience, both in Europe and America during the next decade. While at Ohio State University (1938-40) he discovered a full set of the *Journal of the Russian Physico-Chemical Society.* His first three papers on the history of chemistry were shortly published in the *Journal of Chemical Education* on "Alexander Mikhailovich Butlerov" (**17,** 203-209 (1940)); "N.N. Zinin, an Early Russian Chemist," (**17,** 303-306 (1940)); and "Vladimir Vasil'evich Markovnikov," (**18,** 53-57 (1941)). Eight more such articles were published with the final one being "Mikhail Lomonosov and the Manufacture of Glass and Mosaics," (**45,** 295-98 (1969)). Leicester both translated works of Lomonosov and published many papers about him, the last one in 1987 on the scientific poetry of Lomonosov. For his many contributions to the history of chemistry he was awarded the 1962 Dexter Award. His acceptance address was "Some Aspects of the History of Chemistry in Russia."

Henry Leicester immediately became active in the affairs of the Division of the History of Chemistry once he joined the College of Physicians and Surgeons, San Francisco in 1941. He served as a constant resource and friend to all members of the Division.

One of his greatest contributions to HIST was the co-founding of the journal *Chymia* and his service as Editor and Board member. He edited volumes 3-12. A full chapter will be devoted to *Chymia.*

Leicester was a zealous biographer and furnished 7 of the entries in Wyndham Miles' *American Chemists and Chemical Engineers* (1976): James Blake, Tenney Lombard Davis, Edward Curtis Franklin, Gilbert Newton Lewis, Harry Wheeler Morse, Willard Bradley Rising and John Maxon Stillman. He wrote 17 of the entries for Charles Gillispie's *Dictionary of Scientific Biography* (1970-78): Jons Jacob Berzelius, Stanislao Cannizaro, William Mansfield Clark, Henri Etienne Sainte-Claire Deville, Rudolph Fittig, Otto Folin, Germain Henri Hess, Harry Clary Jones, Adolph Wilhelm Hermann Kolbe, Hermann Kopp, Sergei Vasilievich Lebedev, Joseph Achille Le Bel, Henry Louis Le Chatelier, Matthew Moncrieff Pattison Muir, Paul Muller, Soren Peter Loritz Sorensen, Artturi Ilmari Virtanen, Otto Wallach, Adolph Otto Reinhold Windaus, Hans Fischer and Paul Karrer.

The Historical Background of Chemistry (1956)

Henry Leicester was a voracious collector and reader of the chemical literature. He published *A Sourcebook in Chemistry, 1400-1900* (1952) with his longtime collaborator Herbert S. Klickstein (1921-1975) M.D. who was associated with the Edgar Fahs Smith Library at the University of Pennsylvania. It contains 82 classic papers in chemistry from the alchemical period to the discovery of radioactivity.

With all this grist for his mill, Leicester constructed a history of chemical concepts. The overall stance of the work is that chemical concepts evolved over time and that many people contributed to the "final" form accepted by 1900.

The story of the initial domestication of "fire" is lost to antiquity, but the cave paintings show evidence of chemical manufacture 30,000 year ago. Artifacts of metal and stones and wood and pottery "utensils" have now been studied to determine the state of artisanal practice in Egypt, Mesopotamia and China. Contemporary "written" evidence tended to obscure the actual "trade secrets."

Leicester was sensitive to the cultural beliefs and practices of the Iron Age. The earliest iron used by humans resulted from the accidental discovery of meteorites. Gold and copper occur in metallic form in the Middle East and were often found in tombs. Smelting of metallic ores with charcoal existed by at least 4000 BCE. Mixed ores of copper and tin resulted in **bronze**, a much harder and more useful material. Adventitious gold alloys with silver resulted in "electrum," a common form of gold in ancient Egypt and Greece. The craft of metallurgy (smiths) was an established guild by Roman times.

Ancient civilizations also created vessels from sand (glass) and from clay. Beautiful colored "glazes" were applied and finished in "furnaces." Colored minerals, such as "lapis lazuli," were collected and traded.

Leicester constructed a unique blend of religious and philosophical ideas that helped to understand Egyptian and Babylonian notions of reality. He thought geometrically and recognized positive, negative and zero. He was fully aware of the historical work of Tenney L. Davis (1890-1949) HIST Chair 1935-39. A good example was "Primitive Science, the Background of Early Chemistry and Alchemy," (*J. Chem. Ed.,* **12,** 3-10 (1935)). When Davis died, Leicester took over editing *Chymia.*

From the Greek culture Leicester noted the emphasis on balance and equilibrium. He also considered Heraklitos' notion of "change." "Like a river, everything flows." He discussed one of the classic "experiments" of the Greek natural philosopher Empedocles. The "klepsydra," or water clock, regulated time by the falling of water from a perforated cone. For the experiment, the cone was inverted and water was allowed to rise in the cone. When the hole was plugged, the cylinder reached an equilibrium position. When the plug was removed, air "rushed out of the opening." This established the "materiality of air." (In the late 18th century Count Rumford demolished the notion of the "materiality of heat.")

An extensive discussion of Ptolemaic natural philosophy is presented in Chapter 5. Hero of Alexandria carried out many experiments on heated air and water(steam). One of his conclusions was that "wind" is material air in motion: It has force! Egyptian artisans were very skilled and papyrus documents have survived that contain recipes, such as the preparation of calcium polysulfide. Chemical analytical practices, such as the "touchstone" are memorialized in our current vocabulary. The lowly "bain marie" dates from the Alexandrian period and is often attributed to Mary the Jewess.

The crafts of fabric and dyeing were advanced in Egypt. These skills were passed down from generation to generation and exist today. Many materials were known in the artisanal world of Alexandria, including arsenic, mercury, cinnabar, stibnite, pyrite, litharge, alum, ochre and natron. Sophisticated chemical apparatus such as alembics, cucurbits and distillation heads were in use.

Although the procedures were little more than "stabs in the dark," the use of "destructive distillation" became common in Arabic practice. (French chemists were still playing this game in the 18th century.) Some of the common substances from this era include sal ammoniac, camphor, malachite, mica and vitriol. Although the title implies more, the “Book of Secrets” was actually a good collection of known recipes. New materials, such as borax, and more general classifications, such as salts, were now being employed. Solutions that produced chemical changes were now called “sharp waters” and included both strong acids and bases. Sodium carbonate was called *al-qili!* The greatest of the Arabic chemists was called Avicenna in the West.

Chapter 8 introduces the chemistry of Constantinople. One of the most feared substances in the Mediterranean was “Greek Fire.” It was used to inflame ships and could not be quenched with water. Leicester guesses that it included saltpeter and bitumen. Manuscript collections of artisanal recipes have survived from this period. Some of the most important ones described the distillation of ethanol from wine: *aqua ardens*. Improvements in the apparatus, adding a specific cooled receiver coil, resulted in even stronger *aqua vitae.* Another “distillate” from this era was obtained from iron sulfate: vitriolic acid (H_2SO_4). Nitric acid was obtained from saltpeter. *Aqua regia* was obtained by adding sal ammoniac to nitric acid. Another product of the era was “gun powder: a mixture of sulfur, charcoal and saltpeter.” By the 15th century many of these recipes were known in Italy, France, Spain and England.

While better knowledge of the Jabirian *corpus* needed to wait until the 20th century work of William Newman, practical knowledge of processes like “cupellation” were clearly described. Another helpful contribution from this era was *The New Pearl of Great Price* by Petrus Bonus (14th century). It was widely printed in the 16th and 17th century.

Leicester discusses the great advances in technical chemistry in the 16th century in Chapter 10. He cites *The Great Book of Distillation* by Hieronymus Brunschwygk (1450-1513). An interesting woodcut from this book is:

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N ſollicher maſſen magſtu ouch eyn fens ſy vff einer ſiten in d wyte ein halb elle

Fig. 8. Water bath and stills with *Rosenhut*. (From H. Brunschwygk, *Liber de arte distillandi de simplicibus*.)

Serious technical treatises on mining, smelting and assaying were produced by writers such as Porta, Biringuccio, Agricola and Ercker. Quantitative methods, including good balances, were in use. Agricola also published a valuable treatise on minerals that is still worth reading today: *De natura fossilium* (1546). Zinc, cobalt and bismuth were discussed, refuting the alchemical notion that there could be no more than 7 metals! The greatest of the 16th century chemists, Paracelsus (1493-1541), published many works that combined practical knowledge with arcane theories. Paracelsus was a physician that introduced many mineral remedies into medical practice: “iatrochemistry.” My favorite 16th century chemist was the pseudonymous “Basil Valentine.” His *Triumphal Chariot of Antimony* (1604) is still worth reading and contains both good recipes and careful discussion of the chemical reactions of antimony. (See my chapter on the history of antimony in *Antimony* (2023).) The final key author mentioned is Andreas Libavius (1540-1616) and his monumental books: *Alchemia* (1597) and *Syntagma* (1611).

Leicester christens the early 17th century as the “age of chemical pharmacists.” He cites Jean Beguin (d. 1620) and his *Tyrocinium Chymicum* (1610). The greatest of the early 17th century chemists was Johann Rudolph Glauber (1602-1670). He is still remembered for his *Furni Novi Philosophici* (1650).

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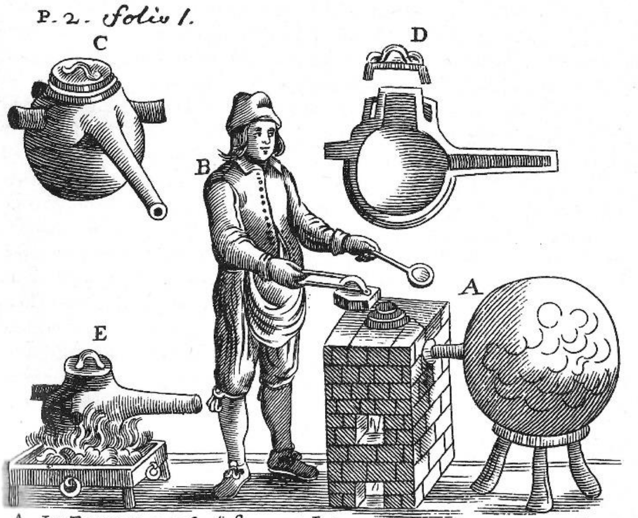


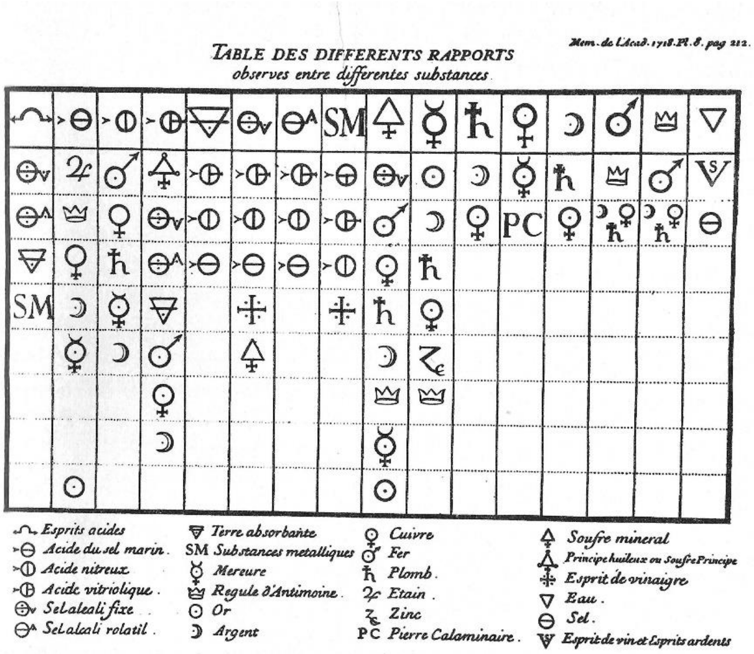
A . Le Fourneau auec ſon jnſtrument de fer et ſon recipient . B . L'artiſte qui de ſa main droicte oſte le couuercle , et de la gauche iette la matiere dedans C la figure exterteure du vaiſſeau . D . La figure jnterieure . E . vn autre vaiſſeau qui eſt ſur les chai

Fig. 9. Distillation apparatus of Glauber. (From French translation of Glauber's *Furni Novi Philosophici*.)

Another of the notable chemists of this era was Jan Baptist Van Helmont (1577-1644). He called himself a “philosophus per ignem.” He routinely used the balance in all his experiments. This did not prevent him from missing the contribution of “invisible” reactants, such as oxygen and carbon dioxide, to the final product. But he did wonder where the additional weight came from. Eventually he did determine that these substances were material and called them “Gas.”

One of the most important advances in chemical natural philosophy occurred when Evangelista Torricelli (1608-1647) invented the “barometer” and proved the existence of a chemical vacuum. Further experiments on air were carried out by Robert Boyle (1627-1691) and Robert Hooke (1635-1703). They were greatly aided by employing the new “vacuum pump” of Otto von Guericke (1602-1686.) The later 17th century saw the founding of groups of natural philosophers, such as the Royal Society of London and the Academie des Sciences in Paris.

The 18th century was blessed with many outstanding chemists. The first great example was Hermann Boerhaave (1668-1738). His *Elementa Chemiae* (1732) dominated this century. It is still worth reading today. Boerhaave discussed the sources of chymical action, including light, heat, fire and air. He also discussed "menstruums." One of the outstanding theorists of the 18th century was Etienne-Francois Geoffroy (1672-1731). His Table of "Rapports" is a triumph. It should be celebrated today.



Mem. de l'Acad. 1718. Pl. 8. pag 212.

TABLE DES DIFFERENTS RAPPORTS
observes entre differentes substances.

⌒	>⊖	>⦶	>⊕	🜃	⊖v	⊖^	SM	🜍	☿	♄	♀	☽	♂	♕	▽
⊖v	♃	♂	🜏	>⊕	>⊕	>⊕	>⊖	⊖v	☉	☽	☿	♄	♕	♂	▽ˢ
⊖^	♕	♀	⊖v	>⦶	>⦶	>⦶	>⊕	♂	☽	♀	PC	♀	☽ ♀ ♄	☽ ♀ ♄	⊖
🜃	♀	♄	⊖^	>⊖	>⊖	>⊖	>⦶	♀	♄						
SM	☽	☿	🜃		✢		✢	♄	♀						
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⌒	*Esprits acides*	🜃	*Terre absorbante*	♀	*Cuivre*	🜍	*Soufre mineral*
>⊖	*Acide du sel marin.*	SM	*Substances metalliques*	♂	*Fer*	🜏	*Principe huileux ou Soufre Principe*
>⦶	*Acide nitreux*	☿	*Mercure*	♄	*Plomb.*	✢	*Esprit de vinaigre*
>⊕	*Acide vitriolique.*	♕	*Regule d'Antimoine.*	♃	*Etain.*	▽	*Eau.*
⊖v	*Sel alcali fixe*	☉	*Or*	Ƶ	*Zinc*	⊖	*Sel.*
⊖^	*Sel alcali volatil.*	☽	*Argent*	PC	*Pierre Calaminaire.*	▽ˢ	*Esprit de vin et Esprits ardents*

Fig. 10. Geoffroy's Table of Affinities. (From *Mémoires de l'académie royale des sciences*, 1718, p. 212.)

This progressive analysis of known chemical reactions was carried on by Torbern Bergman (1735-1784). As the number of known reactions increased, this type of table became problematic, but it pointed the way to both qualitative as well as quantitative chemistry.

The 18th century also saw a massive advance in the understanding of different gases. Sweden was the center of intense progress in chemistry. Carl Wilhelm Scheele (1742-1786) investigated hydrofluoric acid gas, hydrogen cyanide gas, oxygen and chlorine. Joseph Black (1728-1799) produced "fixed air" (CO_2) from marble. Henry Cavendish (1731-1810) studied "inflammable air." (H_2) But the greatest of the "pneumatic chemists" was Joseph Priestley (1733-1804). His invention of the “pneumatic trough” allowed chemists to quantitatively control the use of gases in chemical reactions. He thoroughly studied the oxides of nitrogen. Other gases studied by Priestley include carbon monoxide, sulfur dioxide, hydrogen chloride and ammonia.

The 18th century concluded with a massive effort by the French Academie des Sciences to rationalize chemistry. The key actors included Antoine Laurent Lavoisier (1743-1794), but equal partners were Guyton de Morveau (1737-1816), Claude Louis Berthollet (1748-1822) and A.F. de Fourcroy (1755-1809). Their joint publication, *Methode de nomenclature chimique* (1787), is a landmark. (Leicester was a great admirer of Lavoisier. More recent scholarship has recognized the role of the Society of Arcueil and the “Academie”.)

One of the greatest achievements in the history of chemistry was the construction of the theory of “stoichiometry” by Jeremias Benjamin Richter (1762-1807). He published his *Anfangsgrunde der Stochyometrie* in 1792. At this point the theory of chemical atoms had not been accepted, or even seriously been presented. All chemicals were “quantified” by mass. Nevertheless, chemical reactions could be rationalized by determining in the laboratory how much of one acid was needed to “neutralize” a standard base. This concept, the “equivalent mass,” allowed the notion of determinate atomic composition to be envisioned. While Richter was the “prophet,” Joseph Louis Proust (1754-1826) was the analytical chemist that convinced other chemists that the concept was true (and remains true today). (So why is it that pedagogical chemists hate stoichiometry so much?!)

With an Olympus of previous chemists in existence, a humble Mancusian, John Dalton (1766-1844), proposed that the law of constant proportions could be explained if substances were composed of discrete “chemical atoms.” Dalton knew they were small because they could penetrate solutions. Each type of chemical atom had a different weight. That explained why the mass equivalents varied so much. Dalton knew very little about his “atoms,” but his concept was pure gold. Every later discovery could be added to the fundamental idea as a logical articulation!

While Dalton announced the chemical “gospel,” Thomas Thomson (1773-1852) preached the word and convinced the rest of the chemical world. Even Humphrey Davy finally agreed! Dalton was not aware of “all chemical truth.” But he got one big verity right. Three other busy working chemists, William Hyde Wollaston (1766-1828), Jons Jacob Berzelius (1779-1848) and William Henry (1774-1836), took Dalton's concept and produced a viable synthesis of chemistry that could be improved by careful experiments and theoretical refinements.

While major advances in the understanding of "electricity" were made in the 18th century by natural philosophers such as Benjamin Franklin (1706-1790), Joseph Priestley and Luigi Galvani (1737-1798), Allesandro Volta (1745-1827) employed the chemical potential of metallic junctions to produce the "battery" in 1800. This work was immediately applied by Humphrey Davy to chemical systems and led to the isolation of metals such as sodium and potassium. Michael Faraday (1791-1867), Davy's "assistant," systematized this work and produced the first truly general theory of "electrochemistry."

The 19th century was characterized by the discovery of many new "elements" and even more new "compounds." While Dalton retained a synoptic view of "all chemical atoms," other practicing chemists started to "specialize" in "mineral (inorganic) chemistry" and in "organic chemistry." Justus von Liebig (1803-1873), Jean-Baptist Dumas (1800-1884) and Friedrich Wohler (1800-1882) developed analytical and synthetic methods that allowed the detailed study of compounds containing only carbon, oxygen, hydrogen and nitrogen. From a Daltonian perspective, the task of the chemist was to determine which atoms comprised each substance and to envision how the atoms were arranged in space. This programme was prosecuted throughout the 19th century. Some of the most successful "organic chemists" were Auguste Laurent (1808-1853) and Charles Gerhardt (1816-1856).

Other 19th century chemists studied compounds containing both the organic quartet and other elements. Three examples were Robert Bunsen (1811-1899), Edward Frankland (1825-1899) and Hermann Kolbe (1818-1884). Two other major figures were Charles Wurtz (1817-1884) and A.W. Williamson (1824-1904). Many substances were analyzed. Progress on the structural side required a commitment to geometry. Friedrich August Kekule (1829-1896), Archibald Scott Couper (1831-1892) and Alexander Crum Brown (1838-1922) introduced symbols that expressed, not just typical relationships, but actual atomic "connectivities." This path was the progressive one and Louis Pasteur (1822-1895), J.A. Le Bel (1847-

1930) and Jacobus Henricus van't Hoff (1852-1911) brought the subject of "Chemistry in Space" to a coherent conclusion.
Inorganic chemistry had many goals in the 19th century. One of the major goals was the discovery of new "elements." While many people contributed to this effort, Leicester noted Carl Auer von Welsbach (1858-1929) as one of the most successful in unraveling the "rare earths." Standard chemical analysis of complex mixtures is difficult and time consuming, but it remains important in the present. Robert Bunsen and Gustav Robert Kirchoff (1824-1887) developed a spectroscopic approach where each element emitted a unique spectrum in a flame. (Flame photometry is still a quick way to visualize trace contaminants.) This approach led to the discovery of new elements on earth and the observation of known elements in the universe. Leicester called attention to the highly quantitative work of Jean Servais Stas (1813-1891) in Brussels.

After the famous chemical congress at Karlsruhe in 1860 great progress was made in assigning accurate atomic weights to each element. As the chemical behavior of each element was correlated with its atomic weight, correlations were observed between similar elements. Many people contributed to this programme, but the "prize" went to Dmitrii Ivanovich Mendeleev (1834-1907). He constructed a "periodic table" of the elements that clearly identified groups of chemically similar elements and revealed obvious "gaps" in the known elements. When these "eka-elements" were soon discovered, the power of the Periodic Table was established. As with all early efforts, there were a few irregularities that needed to be straightened out, but, like the theory of Dalton, it was the way forward.

In addition to the two substance-focused areas of research, organic and inorganic, chemists also created a natural philosophy of chemistry. Wilhelm Ostwald (1853-1932) called this approach "General Chemistry." (It is now called "Physical Chemistry. My own professorial title is Professor of Chemical Physics.) All the power of both experimental and theoretical science was brought to bear on chemical systems. One research area was the properties of gases. Henri Victor Regnault (1810-1878) was the master of such experiments. His data are still accepted today. A semi-quantitative theory of gases was constructed much later in the 19th century by J.D. van der Waals (1837-1923). Real progress in understanding liquids needed to wait until the 20th century.

Chemical reactions were studied in an attempt to construct a general theory. Significant progress was made by Cato Maximillian Guldberg (1836-1902) and Peter Waage (1833-1900). They formulated the "Law of Mass Action" in the form in which it is still used! Both chemical equilibrium and the rates of chemical reactions depend on the "concentration" of each reactant and product. (This approach is a natural development of the stoichiometry of Richter.) Further progress was made by van't Hoff and by Svante Arrhenius (1859-1927). These "early" theories are well worth studying in the present, even though they have been improved at the highest levels of opaque theory.

Throughout the 19th century chemists discussed the fact that certain substances increase the rate of chemical reactions without being consumed. Wilhelm Ostwald proposed that no "occult" processes need be invoked: simple additional chemical reactions needed to be added to the "mechanism" for the reaction. The rise of truly mechanistic chemistry may be his greatest contribution to current chemistry.

One of the central theories of physical chemistry is Thermochemistry. Many physicists contributed to the discussion throughout the 19th century. The final version was constructed by Josiah Willard Gibbs (1839-1903) of Yale. Gilbert Newton Lewis (1875-1946) and Merle Randall (1888-1950) organized this already perfect pure theory into a useful form for chemists.

The physical chemistry of solutions is still industrially important, although largely ignored by pedagogues. Van't Hoff made major advances in our understanding. Three processes are essential for an understanding of solutions: osmotic pressure, freezing point lowering, and Brownian motion. Albert Einstein explained all three! Liquids and solutions are in constant microscopic motion. In dilute solution, solutes undergo random trajectories. The entropy of solution dominates the effects under these conditions. For more concentrated solutions, approximate theories are required. (They were provided by Paul Flory in the 1940s).

Electrolyte solutions add another variable: charge. Johann Wilhelm Hittorf (1824-1914) studied the transport of ions in solution subject to a potential difference. Friedrich Kohlrauch (1840-1910) extended the experiments and improved the theory. He employed alternating currents in his work. The greatest electrochemist of the 19th century (excepting Faraday) was Walther Nernst. He achieved a general theory of electrolyte solutions that is still taught at the elementary level today. More advanced theories are too complicated for academic work.

Leicester was also interested in the development of Chemistry as a profession. At the start of the 19th century, France was the center of the chemical world. There were many places in and around Paris where the best chemistry could be prosecuted: Arcueil, Le Jardin du Roi, L'Academie Royal des Sciences, L'Ecole des Mines. Great chemists like Berthollet, Gay-Lussac, Hauy and Dumas were in their prime. As the century progressed the center of chemical activity shifted to Sweden (Berzelius) and Germany (Liebig). Both men trained hundreds of skilled laboratory chemists. English chemists founded the Chemical Society in 1841. The French followed suit in 1857 and the Germans in 1867. The Italians organized in 1871 and the Americans in 1876. Chemical journals were published by all these societies.

The general book closes with a brief chapter on Biochemistry. Leicester soon published a full book on the history of Biochemistry. This book will be reviewed in the next chapter of this history.