Part 1

Chemistry and Chemical Engineering

Unit 1 Chemistry

Chemistry is the science concerned with the composition, structure, and **properties** of matter, as well as the changes it undergoes during chemical reactions.

Chemistry is the study of interactions of chemical substances with one another and energy.

Fig. 1-1 Chemistry experiment.

Chemistry (from Arabic "كيمياء", latinized "chem (kēme)", meaning "value") is the science of matter and the changes it undergoes. The science of matter is also addressed by physics, but while physics takes a more general and fundamental approach, chemistry is more specialized, being concerned with the composition, behavior, structure, and properties of matter, as well as the changes it undergoes during chemical reactions. It is a physical science for studies of various atoms, **molecules**, **crystals** and other **aggregates** of matter whether in isolation or combination, which incorporates the concepts of energy and entropy in relation to the spontaneity of chemical processes.

Disciplines within chemistry are traditionally grouped by the type of matter being studied or the kind of study. These include inorganic chemistry, the study of inorganic matter; organic chemistry, the study of organic matter; biochemistry, the study of substances found in biological organisms; physical chemistry, the energy related studies of chemical systems at macro, molecular and submolecular scales; analytical chemistry, the analysis of material samples to gain an understanding of their chemical composition and structure. Many more specialized disciplines have emerged in recent years, e.g. neurochemistry—the chemical study of the nervous system.

Chemistry is the scientific study of interaction of chemical substances that are constituted of atoms or the subatomic particles: protons, electrons and neutrons. Atoms combine to produce molecules or crystals. Chemistry is often called "the central science" because it connects the other natural sciences such as astronomy, physics, material science, biology, and geology.

The genesis of chemistry can be traced to certain practices, known as alchemy, which had been practiced for several millennia in various parts of the world, particularly the Middle East.

The structure of objects we commonly use and the properties of the matter we commonly interact with, are a consequence of the properties of chemical substances and their interactions. For example, steel is harder than iron because its atoms are bound together in a more rigid crystalline lattice; wood burns or undergoes rapid oxidation because it can react spontaneously with oxygen in a chemical reaction above a certain temperature; sugar and salt dissolve in water because their molecular/ionic properties are such that dissolution is preferred under the ambient conditions.

The transformations that are studied in chemistry are a result of interaction either between different chemical substances or between matter and energy. Traditional chemistry involves study of interactions between substances in a chemistry laboratory using various forms of laboratory glassware.

Ancient Egyptians pioneered the art of synthetic "wet" chemistry up to 4,000 years ago. By 1,000 BC ancient civilizations were using technologies that formed the basis of the various branches of chemistry such as: extracting metal from their ores, making pottery and glazes, fermenting beer and wine, making pigments for cosmetics and painting, extracting chemicals from plants for medicine and perfume, making cheese, dying cloth, tanning leather, rendering fat into soap, making glass, and making alloys like bronze.

The genesis of chemistry can be traced to the widely observed phenomenon of burning that led to metallurgy—the art and science of processing ores to get metals (e.g. metallurgy in ancient India). The greed for gold led to the discovery of the process for its purification, even though the underlying principles were not well understood—it was thought to be a transformation rather than purification. Many scholars in those days thought it reasonable to believe that there exist means for transforming cheaper (base) metals into gold. This gave way to alchemy and the search for the Philosopher's Stone which was believed to bring about such a transformation by mere touch.

Greek atomism dates back to 440 BC, as what might be indicated by the book *De Rerum Natura* (*The Nature of Things*) written by the Roman Lucretius in 50 BC. Much of the early development of purification methods is described by Pliny the Elder in his *Naturalis Historia*.

A tentative outline is as follows:

1. Egyptian alchemy (3,000 BCE – 400 BCE), formulate early "element" theories such as the Ogdoad.

2. Greek alchemy (332 BCE – 642 CE), the Greek king Alexander the Great conquers Egypt and founds Alexandria, having the world's largest library, where scholars and wise men gather to study.

3. Arab alchemy (642 CE – 1200), the Muslim conquest of Egypt (primarily Alexandria); development of the Scientific Method by Alhazen and Jābir ibn Hayyān revolutionise the field of Chemistry.

4. The House of Wisdom (Arabic: بيت الحكمة; Bait al-Hikma), Al-Andalus (Arabic: الأندلس) and Alexandria (Arabic: الإسكندرية) become the world leading institutions where scientists of all religious and ethnic backgrounds worked together in harmony expanding the reaches of Chemistry in a time

known as the Islamic Golden Age.

5. Jābir ibn Hayyān, al-Kindi, al-Razi, al-Biruni and Alhazen continue to dominate the field of Chemistry, mastering it and expanding the boundaries of knowledge and experimentation.

6. European alchemy (1300 – present), Pseudo-Geber builds on Arabic chemistry.

7. Chemistry (1661), Boyle writes his classic chemistry text *The Sceptical Chymis*t.

8. Chemistry (1787), Lavoisier writes his classic *Elements of Chemistr*y.

9. Chemistry (1803), Dalton publishes his *Atomic Theory*.

The earliest pioneers of Chemistry, and inventors of the modern scientific method, were medieval Arab and Persian scholars. They introduced precise observation and controlled experimentation into the field and discovered numerous Chemical substances.

"Chemistry as a science was almost created by the Muslims; for in this field, where the Greeks (so far as we know) were confined to industrial experience and vague hypothesis, the Saracens introduced precise observation, controlled experiment, and careful records. They invented and named the alembic (al-anbiq), chemically analyzed innumerable substances, composed lapidaries, distinguished alkalis and acids, investigated their affinities, studied and manufactured hundreds of drugs. Alchemy, which the Muslims inherited from Egypt, contributed to chemistry by a thousand incidental discoveries, and by its method, which was the most scientific of all medieval operations."

The most influential Muslim chemists were Geber, al-Kindi, al-Razi, al-Biruni and Alhazen. The works of Geber became more widely known in Europe through Latin translations by a pseudo-Geber in 14th century Spain, who also wrote some of his own books under the pen name "Geber". The contribution of Indian alchemists and metallurgists in the development of chemistry was also quite significant.

The emergence of chemistry in Europe was primarily due to the recurrent incidence of the plague and blights there during the so called Dark Ages. This gave rise to a need for medicines. It was thought that there exists a universal medicine called the Elixir of Life that can cure all diseases, but like the Philosopher's Stone, it was never found.

For some practitioners, alchemy was an intellectual pursuit, over time, they got better at it. Paracelsus (1493–1541), for example, rejected the 4-elemental theory and with only a vague understanding of his chemicals and medicines, formed a hybrid of alchemy and science in what was to be called iatrochemistry. Similarly, the influences of philosophers such as Sir Francis Bacon (1561–1626) and René Descartes (1596–1650), who demanded more rigor in mathematics and in removing bias from scientific observations, led to a scientific revolution. In chemistry, this began with Robert Boyle (1627–1691), who came up with an equation known as Boyle's Law about the characteristics of gaseous state. Chemistry indeed came of age when Antoine Lavoisier (1743–1794), developed the theory of Conservation of mass in 1783; and the development of the Atomic Theory by John Dalton around 1800. The Law of Conservation of Mass resulted in the reformulation of chemistry based on this law and the oxygen theory of combustion, which was largely based on the work of Lavoisier. Lavoisier's fundamental contributions to chemistry were a result of a conscious effort to fit all experiments into the framework of a single theory. He established the consistent use of the chemical balance, used oxygen to overthrow the phlogiston theory, and developed a new system of chemical nomenclature and made contribution to the modern metric system. Lavoisier also worked to translate the archaic and technical language of chemistry into something that could be easily understood by the largely uneducated masses, leading to an increased public interest in chemistry. All these advances in chemistry led to what is usually called the chemical revolution. The contributions of Lavoisier led to what is now called modern chemistry—the chemistry that is studied in educational institutions all over the world. It is because of these and other contributions that Antoine Lavoisier is often celebrated as the “Father of Modern Chemistry”. The later discovery of Friedrich Wöhler that many natural substances, organic compounds, can indeed be synthesized in a chemistry laboratory also helped the modern chemistry to mature from its infancy.

The discovery of the chemical elements has a long history from the days of alchemy and culminating in the discovery of the periodic table of the chemical elements by Dmitri Mendeleev (1834–1907) and later discoveries of some synthetic elements.

New words

property ['prɒpətɪ] *n.* 特性，属性；财产，地产；所有权；[戏]道具
molecule ['mɒlɪkjuːl] *n.* 分子；微小颗粒
molecular [mə'lekjələ(r)] *adj.* 分子的，由分子组成的
submolecular [sʌbmə'lekjulə] *adj.* 亚分子的
supermolecular [suːpərmə'lekjulə] *adj.* 超分子的
crystal ['krɪstl] *n.* 结晶（体）；晶体；水晶；水晶饰品
adj. 水晶的；水晶般的；透明的；清楚的
aggregates ['ægrɪgɪt] *n.* 合计；聚集体；骨料；集料（可成混凝土或修路等用的）
adj. 总数的，总计的；聚合的；[地]聚成岩的
vt. 使聚集，使积聚；总计达
incorporate [ɪn'kɔːpəreɪt] *vt.* 组成公司；包含；使混合；使具体化
vi. 包含；吸收；合并；混合
entropy ['entrəpɪ] *n.* 熵，平均信息量；负熵
spontaneity [⌨spɒntə'neɪətɪ] *n.* 自发性，自然发生；自发行为（行动）
organic [ɔː'gænɪk] *adj.* 有机（体）的；有组织的，系统的；器官的；根本的
inorganic [⌨ɪnɔː'gænɪk] *adj.* [化]无机的；无组织结构的；无生物的；无活力的
organism ['ɔːgənɪzəm] *n.* 有机体；生物体；微生物；有机体系，有机组织
biochemistry [⌨baɪəʊ'kemɪstrɪ] *n.* 生物化学；生物化学成分
analytical [⌨ænə'lɪtɪkl] *adj.* 分析的，分析法的；善于分析的
neurochemistry [njʊərə'kemɪstrɪ] *n.* 神经化学
subatomic [⌨sʌbə'tɒmɪk] *adj.* 小于原子的，亚原子的，次原子的

particle ['pɑːtɪkl] *n.* 微粒，颗粒；[数，物]粒子，质点；极小量；小品词

proton ['prəʊtɒn] *n.* [物]质子

electron [ɪ'lektrɒn] *n.* 电子

neutron ['njuːtrɒn] *n.* [物]中子

geoglogy [dʒɪ'ɒlədʒɪ] *n.* 地质学；（某地区的）地质情况；地质学的著作

genesis ['dʒenəsɪs] *n.* <正>创始，起源，发生

practice ['præktɪs] *n.* 练习；实践；（医生或律师的）业务；惯例

vi. 实行；惯常地进行；练习；实习

vt. 实行，实践；执业；练习；惯常地进行

alchemy ['ælkəmɪ] *n.* 炼金术；炼丹术；（改变事物、物质的）魔力（方法）；（事物、物质的）神秘变化

millennium [mɪ'lenɪəm] *n.* 一千年；千年期；千禧年

复数形式：millennia or millenniums

rigid ['rɪdʒɪd] *adj.* 严格的；僵硬的；（规则、方法等）死板的；刚硬的，顽固的

crystalline ['krɪstəlaɪn] *adj.* 水晶的；似水晶的；结晶质的；清澈的

n. 结晶性，结晶度

lattice ['lætɪs] *n.* 格子框架；类似格子框架的设计

vt. 把……制成格子状；用格子覆盖或装饰

oxidation [ˌɒksɪ'deɪʃn] *n.* 氧化

dissolve [dɪ'zɒlv] *vt.* 使溶解；使液化

vi. 溶解；融化，液化，分解

dissolution [ˌdɪsə'luːʃn] *n.* 溶解，融化

ionic [aɪ'ɒnɪk] *adj.* 离子的

ambient ['æmbɪənt] *adj.* 周围的，包围着的；环境

preferred [prɪ'fəd] *adj.* 首选的

glassware ['glɑːsweə] *n.* 玻璃器具类

pioneer [ˌpaɪə'nɪə] *n.* 拓荒者；开发者；先驱者；创始者

vt. 开拓，开发；做（……的）先锋；提倡

synthetic [sɪn'θetɪk] *adj.* 合成的；人造的；模拟的，虚构的

n. 合成物；合成纤维；合成剂

"wet" chemistry 湿化学（It is a form of analytical chemistry that uses classical methods such as observation to analyze materials. It is called wet chemistry since most analyzing is done in the liquid phase. Wet chemistry is also called bench chemistry since many tests are performed at lab benches.）

pottery ['pɒtərɪ] *n.* 陶器；陶器厂（作坊）；<集合词>陶器类；陶器制造（术）

glaze [gleɪz] *vt.* 装玻璃；上釉于；上光

vi.（目光）变得呆滞无神；变得光滑

n. 上釉的表面；釉料；光滑面；(浇在糕点上增加光泽的) 蛋浆
ferment [fə'ment] *n.* 酶，酵素；发酵剂；骚动，动乱
vt. & *vi.* 使发酵；使骚动；酝酿
pigment ['pɪgmənt] *n.* 颜料，色料；[生]色素
vt. 给……着色
vi. 呈现颜色
cosmetic [kɒz'metɪk] *n.* 化妆品；美发油，发蜡；装饰品；美容术
adj. 化妆用的；美容的；装点门面的；表面的
perfume ['pɜːfjuːm] *n.* 香水；香料；香味，香气
vt. 使……充满香气；喷香水于……
tan [tæn] *n.* 黄褐色，棕黄色；鞣料；马戏团；晒黑的皮色
vt. (使) 晒成棕褐色；鞣 (革)
vi. 晒成棕褐色；
adj. 黄褐色的，棕黄色的；鞣皮的
leather ['leðə] *n.* 皮，皮革；皮革制品
vt. 用皮革包盖；制成皮，蒙上皮
adj. 皮的，皮革的，皮革制的
render ['rendə(r)] *v.* 致使，造成；给予；递交；表达
alloy ['ælɔɪ] *n.* 合金；(合金中的) 劣等金属；搀杂品；成色
v. 合铸，熔合 (金属)；铸成合金；在……中搀以杂质，使 (金属) 减低成色
bronze [brɒnz] *n.* 青铜；青铜色；铜牌；青铜艺术品
adj. 深红棕色的，青铜色的；青铜制的
vt. 镀青铜于
vi. 变成青铜色，被晒黑
metallurgy [mə'tælədʒɪ] *n.* 冶金，冶金学，冶金术
metallurgist [mə'tælədʒɪst] *n.* 冶金家，冶金学者
Philosopher's Stone 点金石，魔法石
atomism ['ætəmɪzəm] *n.* 原子论，原子说
Ogdoad ['ɒgdəʊæd] *n.* 八元神
vague [veɪg] *adj.* 模糊的；(思想上) 不清楚的；(表达或感知) 含糊的；暧昧的
n. 模糊不定状态
alembic [ə'lembɪk] *n.* 蒸馏器
lapidary ['læpɪdərɪ] *adj.* 宝石的；简洁优雅的；刻在石上的；利落的
n. 宝石匠，玉石雕刻师
alkalis ['ælkəlɪs] *n.* 碱金属；碱 (alkali 的名词复数)
affinity [ə'fɪnətɪ] *n.* 密切关系；类同；类似，近似
recurrent [rɪ'kʌrənt] *adj.* 复发的，复现的；周期性的，经常发生的；回归的；循环的
incidence ['ɪnsɪdəns] *n.* 发生率；影响范围；[数]关联，接合；[物]入射，入射角
plague [pleɪg] *n.* 瘟疫；灾害，折磨

vt. 使染瘟疫；使痛苦，造成麻烦
blight [blaɪt] *n.* 凋萎病；坏因素；毁坏；衰退
vt. 使凋萎；使颓丧；损害；妨害
vi. 患枯萎病；枯萎，颓丧
Elixir of Life *n.* 仙丹
hybrid ['haɪbrɪd] *n.* 杂种；杂交生成的生物体；混合物；混合词
adj. 混合的；杂种的
iatrochemistry [aɪˌætrə'kemɪstrɪ] *n.* 化学疗法
rigor ['rɪgə] *n.* 严格；严酷；严密
bias ['baɪəs] *n.* 偏见；偏爱，爱好；倾向；斜纹
vt. 使倾向于；使有偏见；影响；加偏压于
adj. 斜纹的；斜的，倾斜的；斜裁的
adv. 偏斜地，倾斜地；对角地
gaseous ['gæsɪəs] *adj.* 气态的，似气体的；无实质的
conservation [ˌkɒnsə'veɪʃn] *n.* 保存；保护；避免浪费；对自然环境的保护
conservation of mass 质量守恒定律
conservation of energy 能量守恒定律
combustion [kəm'bʌstʃən] *n.* 燃烧，烧毁；氧化
overthrow [ˌəʊvə'θrəʊ] *vt.* 打倒，推翻；使屈服，征服；使瓦解；撞倒
n. 推翻，打倒；打翻；倾倒
phlogiston [flɒ'dʒɪstən] *n.*（旧时人们认为存在于可燃物中的）燃素，热素
nomenclature [nə'menklətʃə] *n.* 系统命名法；命名（过程）；（某一学科的）术语；专门名称
metric ['metrɪk] *adj.* 米制的，公制的，十进制的；度量的；距离的
n. 度量标准；[数学]度量；诗体，韵文，诗韵
archaic [ɑː'keɪɪk] *adj.* 古代的；过时的，陈旧的；古体的；古色古香的
synthesize ['sɪnθəsaɪz] *vt.* 综合；人工合成；（通过化学手段或生物过程）合成；（音响）合成
vi. 合成；综合
culminate ['kʌlmɪneɪt] *vt.* & *vi.* 达到极点

Unit 2 Chemical Engineering

Chemical engineering is the key to many issues affecting our quality of life. Industry is increasingly focused on high value chemicals and products which deliver the right molecule to the right place at the right time. Chemical engineers conceive and design processes to produce, transform and transport materials—beginning with experimentation in the laboratory and followed by implementation of technologies in full-scale production.

Chemical engineering is a branch of engineering that uses principles of chemistry, physics, mathematics, and economics to efficiently use, produce, transform, and transport chemicals, materials, and energy. A chemical engineer designs large-scale processes that convert chemicals, raw materials, living cells, microorganisms, and energy into useful forms and products.

Chemical engineers are involved in many aspects of plant design and operation, including safety and hazard assessments, process design and analysis, control engineering, chemical reaction engineering, construction specification, and operating instructions.

Fig. 2-1 Chemical engineers design, construct and operate process plants.

2.1 Etymology

A 1996 *British Journal for the History of Science* article cites James F. Donnelly for mentioning an 1839 reference to chemical engineering in relation to the production of sulfuric acid. In the same paper however, George E. Davis, an English consultant, was credited for having coined the term. Davis also tried to find a Society of Chemical Engineering, but instead it was named the Society of Chemical Industry (1881), with Davis as its first Secretary. The *History of Science in*

United States: An Encyclopedia puts the use of the term around 1890. "Chemical engineering", describing the use of mechanical equipment in the chemical industry, became common vocabulary in England after 1850. By 1910, the profession, "chemical engineer", was already in common use in Britain and the United States.

Fig.2-2 George E. Davis.

2.2 History of chemical engineering

Chemical engineering emerged upon the development of unit operations, a fundamental concept of the discipline of chemical engineering. Most authors agree that Davis invented the concept of unit operations if not substantially developed it. He gave a series of lectures on unit operations at the Manchester Technical School (later part of the University of Manchester) in 1887, considered to be one of the earliest such about chemical engineering. Three years before Davis' lectures, Henry Edward Armstrong taught a degree course in chemical engineering at the City and Guilds of London Institute. Armstrong's course failed simply because its graduates were not especially attractive to employers. Employers of the time would have rather hired chemists and mechanical engineers. Courses in chemical engineering offered by Massachusetts Institute of Technology (MIT) in the United States, Owens College in Manchester, England, and University College London suffered under similar circumstances.

Starting from 1888, Lewis M. Norton taught at MIT the first chemical engineering course in the United States. Norton's course was contemporaneous and essentially similar to Armstrong's course. Both courses, however, simply merged chemistry and engineering subjects along with product design. "Its practitioners had difficulty convincing engineers that they were engineers and chemists that they were not simply chemists." Unit operations was introduced into the course by William Hultz Walker in 1905. By the early 1920s, unit operations became an important aspect of chemical engineering at MIT and other US universities, as well as at Imperial College London. The American Institute of Chemical Engineers (AIChE), established in 1908, played a key role in making chemical engineering considered an independent science, and unit operations central to chemical engineering. For instance, it defined chemical engineering to be a "science of itself, the basis of which is ... unit operations" in a 1922 report; and with which principle, it had published a