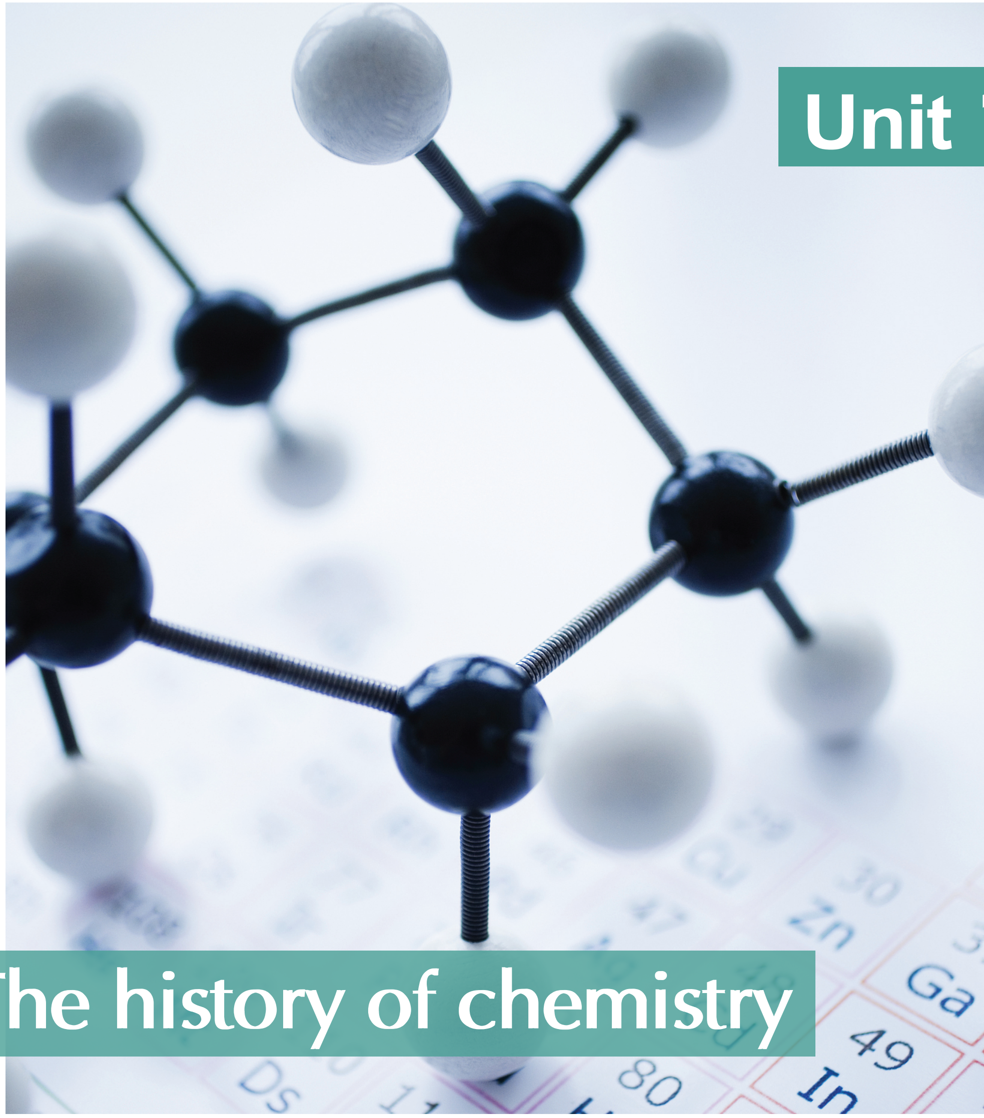
Unit 1



The history of chemistry

In this unit, you will learn:

- **Subject-related knowledge:** The history of chemistry
  Chemical element
- **Academic skill:** Searching for information
- **Reading strategy:** Dealing with unknown words (Part I)

Section A

Pre-reading

1 Read the short passage and fill in the blanks with the words or phrases below. Change the form if necessary.

change   combination   physical science
reaction   rearrange   state of matter
undergo   various structure

Chemistry is the science of matter and the 1) ____________ that occur between different kinds of matter – especially chemical changes when types of matter are 2) ____________ into other types of matter. That is, chemistry is a(n) 3) ____________ concerned with the composition, structure, behavior, and properties of matter and with changes it 4) ____________ during, and as a result of, chemical 5) ____________. It involves study of substances in all of the 6) ____________ (solid, liquid, and gas) and knowledge and understanding of the 7) ____________ of matter (e.g. atoms, molecules, crystals and other aggregates) whether in isolation or in 8) ____________ with others.

2 Oral work

1. What are chemistry and chemical engineering in your eyes? How does chemistry influence our life?
2. Why do you choose chemical engineering as your major? What do you want to achieve in your major study?

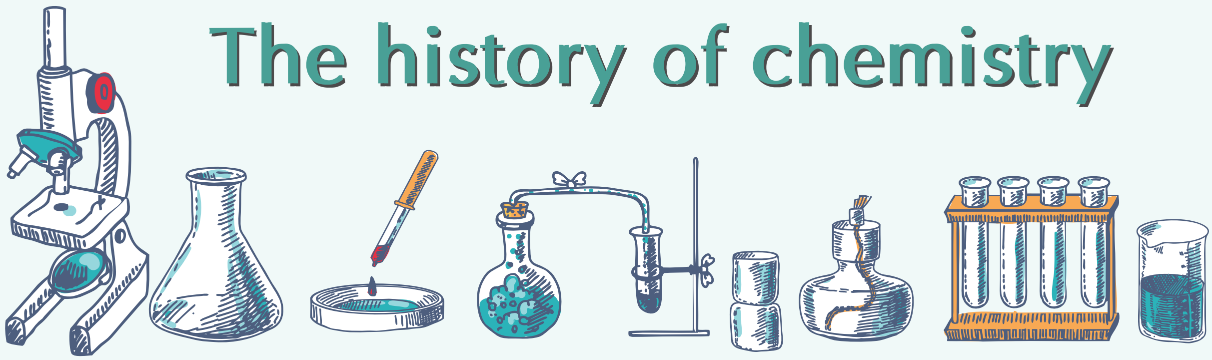
1 The history of chemistry represents a time span from ancient history to the present. By 1000 B.C., civilizations used technologies that would eventually form the basis of various branches of chemistry. Examples include extracting metals from ores, making pottery and glazes, fermenting beer and wine, extracting chemicals from plants for medicine and perfume, rendering fat into soap, making glass, and making alloys like bronze.

2 The protoscience of chemistry, alchemy, was unsuccessful in explaining the nature of matter and its transformations. However, by performing experiments and recording the results, alchemists set the stage for modern chemistry. The distinction began to emerge when a clear differentiation was made between chemistry and alchemy by Robert Boyle in his work *The Sceptical Chymist* (1661). While both alchemy and chemistry are concerned with matter and its transformations, chemists are seen as applying scientific methods to their work.

3 Chemistry is considered to have become an established science with the work of Antoine Lavoisier, who

Text A

The history of chemistry



developed a law of conservation of mass that demanded careful measurement and quantitative observations of chemical phenomena. The history of chemistry is intertwined with the history of thermodynamics, especially through the work of Willard Gibbs.

16th and 17th centuries

4 Practical attempts to improve the refining of ores and their extraction to smelt metals were an important source of information for early chemists in the 16th century, among them Georgius Agricola (1494-1555), who published his great work *De re metallica* in 1556. His work describes the highly developed and complex processes of mining metal ores, metal extraction and metallurgy of the time. His approach removed the mysticism associated with the subject, creating the practical base upon which others could build. The work describes the many kinds of furnace used to smelt ore, and stimulated interest in minerals and their composition. It is no coincidence that he gives numerous references to the earlier author, Pliny the Elder and his *Naturalis Historia*. Agricola has been described as the "father of metallurgy". In 1605, Sir Francis Bacon published *The Proficience and Advancement of Learning*, which contains a description of what would later be known as the scientific method. In 1605, Michal Sedziwój

publishes the alchemical treatise “A New Light of Alchemy”, which proposed the existence of the “food of life” within air, much later recognized as oxygen. In 1615 Jean Beguin published the *Tyrocinium Chymicum*, an early chemistry textbook, and in it draws the first-ever chemical equation. In 1637 René Descartes publishes *Discours de la méthode*, which contains an outline of the scientific method.

19th century

5 Throughout the 19th century, chemistry was divided between those who followed the atomic theory of John Dalton and those who did not, such as Wilhelm Ostwald and Ernst Mach. Although such proponents of the atomic theory as Amedeo Avogadro and Ludwig Boltzmann made great advances in explaining the behavior of gases, this dispute was not finally settled until Jean Perrin’s experimental investigation of Einstein’s atomic explanation of Brownian motion in the first decade of the 20th century.

6 Well before the dispute had been settled, many had already applied the concept of atomism to chemistry. A major example was the ion theory of Svante Arrhenius which anticipated ideas about atomic substructure that did not fully develop until the 20th century. Michael Faraday was another early worker, whose major contribution to chemistry was electrochemistry, in which (among other things) a certain quantity of electricity during electrolysis or electrodeposition of metals was shown to be associated with certain quantities of chemical elements, and fixed quantities of the elements therefore with each other, in specific ratios. These findings, like those of Dalton’s combining ratios, were early clues to the atomic nature of matter.

Early 20th century

7 In 1903, Mikhail Tsvet invented chromatography, an important analytic technique. In 1904, Hantaro Nagaoka developed an early planetary model of the atom, where electrons orbit a dense massive nucleus. In 1905, Fritz Haber and Carl Bosch developed the Haber process for making ammonia, a milestone in industrial chemistry with deep consequences in agriculture. The Haber process, or Haber-Bosch process, combined nitrogen and hydrogen to

form ammonia in industrial quantities for production of fertilizer and munitions. The food production for half the world's current population depends on this method for producing fertilizer. Haber, along with Max Born, proposed the Born-Haber cycle as a method for evaluating the lattice energy of an ionic solid. Haber has also been described as the "father of chemical warfare" for his work developing and deploying chlorine and other poisonous gases during World War I.

8 In 1905, Albert Einstein explained Brownian motion in a way that definitively proved atomic theory. Leo Baekeland invented bakelite, one of the first commercially successful plastics. In 1909, American physicist Robert Andrews Millikan – who had studied in Europe under Walther Nernst and Max Planck – measured the charge of individual electrons with unprecedented accuracy through the oil drop experiment, in which he measured the electric charges on tiny falling water (and later oil) droplets. His study established that any particular droplet's electrical charge is a multiple of a definite, fundamental value – the electron's charge – and thus a confirmation that all electrons have the same charge and mass. He spent several years investigating and finally proving linear relationship between energy and frequency proposed by Albert Einstein, providing the first direct photoelectric support for Planck's constant. In 1923 Millikan was awarded the Nobel Prize in Physics.

Late 20th century

9 In 1970, John Pople developed the Gaussian program, greatly easing computational chemistry calculations. In 1971, Yves Chauvin offered an explanation of the reaction mechanism of olefin metathesis reactions. Karl Barry Sharpless and his group discovered stereoselective oxidation reactions including Sharpless epoxidation, Sharpless asymmetric dihydroxylation, and Sharpless oxyamination. In 1985, Harold Kroto, Robert Curl and Richard Smalley discovered fullerenes, a class of large carbon molecules superficially resembling the geodesic dome designed by architect R. Buckminster Fuller. In 1991, Sumio Iijima used electron microscopy to discover a type of cylindrical fullerene known as a carbon nanotube. This material is an important component in the field of nanotechnology. In 1994, Robert A. Holton and his group achieved the first total synthesis of taxol. In 1995, Eric Cornell and Carl Wieman produced the first Bose-Einstein condensate, a substance that displays quantum mechanical properties on the macroscopic scale.

New words and expressions

extract /ɪk'strækt/ *vt.*
to separate a substance from another substance 提取；萃取

ore /ɔː(r) / *n.* 矿；矿石

glaze /gleɪz/ *n.*
coating for ceramics, metal, etc. 釉；光滑面

ferment /'fɜːment/ *vt.*
if food or drink is fermented, a chemical change happens to it and the sugar in it produces alcohol 使发酵

protoscience /ˌprəʊtə'saɪəns/ *n.*
a set of beliefs or theories that have not yet been tested adequately by the scientific method but which are otherwise consistent with existing science 原始科学

alchemy /'ælkɪmɪ/ *n.*
a type of science that people used in the Middle Ages 炼金术

thermodynamics /ˌθɜːməʊdaɪ'næmɪks/ *n.*
the science of the relationship between heat and other forms of energy 热力学

furnace /'fɜːnɪs/ *n.* 火炉；熔炉

metallurgy /me'tælədʒɪ/ *n.*
the scientific study of metals and how they are used 冶金学；冶金术

smelt /smelt/ *vt.*
to extract (metals) by heating 熔炼；冶炼

equation /ɪ'kweɪʒən/ *n.*
a mathematical statement that two expressions are equal 反应式；方程式

proponent /prəʊ'pəʊnənt/ *n.*
a person who publicly supports an idea, policy, plan, etc. 支持者

ion /'aɪən/ *n.* 离子

electrochemistry /ɪˌlektrəʊ'kemɪstrɪ/ *n.* 电化学

electrodeposition /ɪˌlektrəʊˌdepə'zɪʃən/ *n.* 电沉积

chromatography /ˌkrəʊmə'tɒgrəʃɪ/ *n.* 色谱法

nucleus /'njuːklɪəs/ *n.*
(*plural* **nuclei**) 原子核

ammonia /ə'məʊnjə/ *n.* 氨

munitions /mjʊː'nɪʃənz/ *n.*
military weapons and equipment such as guns, bullets, and bombs 军需品；军火

lattice /'lætɪs/ *n.* 晶格；格构

chlorine /'klɔːriːn/ *n.* 氯

bakelite /'beɪkəlaɪt/ *n.* 酚醛塑料

droplet /'drɒplɪt/ *n.* 小滴；微滴

photoelectric /ˌfəʊtəʊɪ'lektrɪk/ *adj.* 光电的

olefin /'əʊlɪfɪn/ *n.* 烯烃

stereoselective /ˌsterɪəʊsɪ'lektɪv/ *adj.* 立体有择的；立体定向的

oxidation /ˌɒksɪ'deɪʃən/ *n.* 氧化（作用）

epoxidation /epɒksɪ'deɪʃən/ *n.* 环氧化作用

dihydroxylation /daɪ-haɪˌdrɒksɪ'leɪʃən/ *n.* 双羟基化反应

oxyamination /ɒksɪəæmɪ'neɪʃən/ *n.* 羟氨基化

fullerene /'fʊləriːn/ *n.* 富勒分子

geodesic dome 网格球顶

electron microscopy 电子显微镜

cylindrical /sɪ'lɪndrɪkəl/ *adj.* 圆柱形的

nanotube /'nænəʊtjuːb/ *n.* 奈米管；纳米管

nanotechnology /'nænəʊˌtek'nɒlədʒɪ/ *n.* 纳米技术

synthesis /'sɪnθɪsɪs/ *n.*
(*plural* **syntheses**)（通过化学或生物反应进行的）合成

taxol /'tæksɒl/ *n.* 紫杉醇

condensate /kən'denseɪt/ *n.*
atmospheric moisture that has condensed because of cold 冷凝物；聚合物

quantum /'kwɒntəm/ *n.* 量子

Reading comprehension

The following table presents you an overview of the historical development of chemistry. Read Text A and complete the table to draw the outline in time sequence.

Time	Year	Scientist(s)	Achievements
16th and 17th centuries	1556		published *De re metallica* "father of metallurgy"
	1605		published "A New Light of Alchemy"
		Jean Beguin	
	1637	René Descartes	
19th century	/		proposed the atomic theory
	/	Svante Arrhenius	
	/	Michael Faraday	
early 20th century	1903		invented chromatography
			developed an early planetary model of the atom
	1905	Fritz Haber and Carl Bosch	
	/		proposed Born-Haber cycle
	1905	Albert Einstein	
	/		invented bakelite
	1909	Robert Andrews Millikan	
late 20th century	1970	John Pople	
		Yves Chauvin	
	/		discovered stereoselective oxidation reactions
	1985		discovered fullerenes
	1991	Sumio Iijima	
	1994		achieved the first total synthesis of taxol
		Eric Cornell and Carl Wieman	

Language focus

1 Study the affixes or word roots below and fill in the blanks with the example words. Change the form if necessary.

Tips

- *oxy- / oxi-* means "containing or using oxygen", e.g. *oxidation, oxyacid, oxyacetylene*
- *thermo-* means "using or relating to heat", e.g. *thermodynamics, thermometer, thermoplastic*
- *electro-* means "electricity or processes involving electricity", e.g. *electrolysis, electrodeposition, electronic*
- *photo-* means "related to light or photography", e.g. *photoelectric, photosynthesis, photochemistry*
- *-graphy* means "a form or process of writing, representing, etc.", e.g. *chromatography, radiography, spectrography*

1. We use a(n) ____________ to check for a fever, to record data during a chemistry lab, or to help us decide how to dress before leaving for school in the morning.
2. Nonetheless, micropayments and ____________ transactions have come in 2010.
3. Like humans, most animals rely on visible light for seeing, and plants rely on it for ____________.
4. It is obvious that rare earths (稀土) can suppress the ____________ and sulfuration of metals and alloys at high temperatures.
5. ____________ is the study of the effects of work, heat and energy on a system.
6. ____________ is a process used by scientists to separate complex chemical mixtures at the "nano" or molecular level by virtue of differences in absorbency.

2 Match the words or expressions in Column A with the definitions in Column B and translate them into Chinese in Column C.

Column A	Column B	Column C
___ 1. munitions	A. the scientific study of metals and how they are used	________
___ 2. thermodynamics	B. an atom with an electrical force created by adding or removing an electron (电子)	________
___ 3. condensate	C. a method of separating and analyzing mixtures of chemical substances by chromatographic absorption (吸附)	________
___ 4. metallurgy	D. the science of the relationship between heat and other forms of energy	________
___ 5. atomic theory	E. the branch of chemistry concerned with the study of electric cells and electrolysis	________
___ 6. ion	F. military weapons and equipment	________
___ 7. chemical equation	G. the science of making or working with things that are so small that they can only be seen using a powerful microscope	________
___ 8. electrochemistry	H. the symbolic representation of a chemical reaction in the form of symbols and formula	________
___ 9. chromatography	I. the assumption that matter is composed of discrete units called atoms	________
___10. nanotechnology	J. atmospheric moisture that has condensed because of cold	________

3 Complete the following sentences with the words or phrases below. Change the form if necessary.

apply to   be intertwined with   compose   refine   make advance
no coincidence   proponent   quantity   time span   extract

1. In analytical chemistry, ____________ analysis is the determination of the absolute or relative abundance (often expressed as a concentration) of one, several or all particular substance(s) present in a sample.

2. The results of this research can be ____________ new developments in technology.
3. He was an early ____________ of the theory that matter is composed of particles called atoms and that these are the limit to which matter can be subdivided.
4. The advancements in society ____________ the advancements in science. To understand how changes in society occurred, and will continue to change, one has to have a basic understanding of the laws of physics and chemistry.
5. Citric acid (柠檬酸) can be ____________ from the juice of oranges, lemons, limes or grapefruits.
6. We guess the mistakes are due to the small sample bias and the short ____________ of our data.
7. Some analysts say, the decline in crude oil prices will reduce the purchasing expenditure of Chinese oil ____________ companies, by over one billion U.S. dollars.
8. With assistance from a high tech robot, National Institutes of Health researchers ____________ in treating Parkinson's diseases for humans.
9. Protein molecules ____________ all the complex working parts of living cells.
10. It is ____________ that chemistry is referred to as an "innovation engine".

4 Translate the following paragraph into English.

化学的历史悠久，事实上，人类的化学活动可追溯到有历史记载以前的时期。化学家从事两种不同类型的活动：有些化学家研究并试图了解自然界，而另一些化学家则在创造自然界不存在的新物质或发现完成化学变化的新途径。自人类出现在地球上的那一刻起，就有了这两方面的活动，但上世纪其步伐大大加快了。

Critical thinking

1 Group discussion: The changing of scientific knowledge

Scientific knowledge is not static: It changes and evolves over time as scientists build on the ideas of others to come up with revised (and often improved) theories and ideas. In Text A, for example, we saw how people's understanding of atomic theory changed as more information was gathered about the atom. There are many more examples in the field of science. Think about some other examples that scientific knowledge has been changed because of new ideas and discoveries:

– What were these new ideas?
– Were they controversial? If so, why?
– What role (if any) did technology play in developing these new ideas?
– How have these ideas affected the way we understand the world?

2 Read the following quotation and then work in groups to discuss the questions.

Russian chemist Dmitri Mendeleev, who developed the periodic classification of the elements, published a periodic table in 1869. In his version of the periodic table of 1871, he left gaps in places where he believed unknown elements would find their place. He even predicted the likely properties of three of the potential elements.

"As long as chemistry is studied, there will be a periodic table. And even if someday we communicate with another part of the universe, we can be sure that one thing both cultures will have common is an ordered system of the elements that will be instantly recognizable by both intelligent life forms."

John Emsley, *Nature's Building Blocks: An A-Z Guide to the Elements*

1. Discuss in groups of four or five and then share in the whole class: How can the periodic table help us quickly determine electron configurations (电子组态) and quantum numbers?
2. Tell your group members at least one example of using the periodic table to predict certain characteristics of elements.

Research task

Academic skill: Searching for information

Information can come from virtually anywhere – media, blogs, personal experiences, books, journal and magazine articles, expert opinions, encyclopedias, and web pages, etc.

1. Types of information

Type	Use
Magazine	• To find information or opinions about popular culture. • To find up-to-date information about current events. • To find non-scholarly articles about topics of interest within the subject of the magazine.
Academic journal	• To get help for your scholarly research. • To find out what has been studied on your topic. • To find bibliographies that point to other relevant research.
Database	• To find articles on specific topics. • To find online journal or news articles.
Newspaper	• To find editorials, commentaries, expert or popular opinions. • To find current local, national or world news.
Library catalog	• To find virtually any topic. • To find hard copies of current or back issue of journals, books, newspapers or magazines.
Website	• To find information from all levels of government – central to local. • To find expert or popular opinions. • To find information of various types of media, e.g. illustrations, audio and video information.

2. Searching for information

Author / Title searches

Searching by author and / or title obviously assumes that you are searching for a particular author, book or article, probably in either a database or a library catalog. Here are some tips:

- When searching by author, put the author's last name first, e.g. "Kotler, Philip", not "Philip Kotler", if he is from an English-speaking country. Search the author's full name in Chinese order if he is a Chinese. Sometimes, the author could be an organization, so give the full name of the organization as it commonly appears, e.g. “World Bank”.

- When searching by title, it helps if you enter the title as correctly as possible.

Keyword searches

It is basically a way of searching through subject or topic. Most library catalogs and databases will include an option to search by keyword as an alternative to author and title. The first step of keyword search is to decide the key word(s) or phrase(s). Normally, the word(s) or phrase(s) which can cover the topic you search can be selected as keyword(s). A good research topic usually contains two or three concepts. For example, you need to write a paper on “The Impact of Cognitive Styles on Design Students’ Spatial Knowledge”. We can break the topic into concepts, like “cognitive styles” and “spatial knowledge”, which can be used as keywords. Then type them in a search bar in a database, EBSCOhost for instance. In a database, there are usually two ways of search, i.e., basic search and advanced search.

Basic search (see Fig. 1) generates a large number of sources for you to differentiate, which is an exhausting task. But advanced search (see Fig. 2), which provides more choices for further conditioning, can make the work lighter. There are many variables that can be chosen to refine the search. And you can define the relationship between the keywords by choosing “and”, “or” or “not” based on the results you intend to obtain.

Fig. 1 Basic search

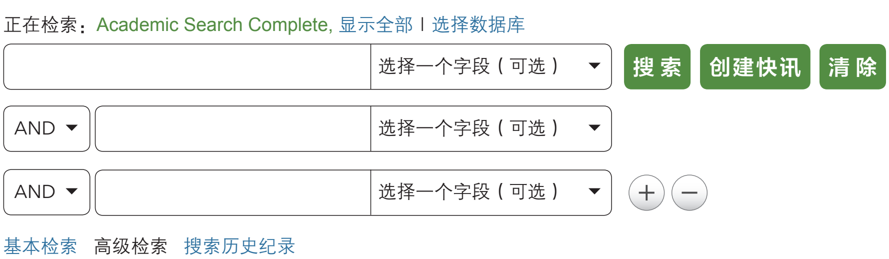


Fig. 2 Advanced search

As "cognitive styles" is a broader topic and "spatial knowledge" is more specific, they can be typed in the upper and middle search bars respectively. More relevant results will appear. You can then refine the search by selecting a specific variable. In this case, "subject" (主题语) can be chosen to filter the results (See Fig. 3).

Fig. 3

Snowball search

It is a good way if your topic has a key work or author. You can trace the citations of that author using a specialized citation database, such as the Social Science Citation Index to obtain other key works or authors. You will follow the stream of research up to the near present and see the way in which the work or the author has influenced the subsequent studies.

3. Evaluating information

Once you have found information that satisfies the requirements of your research, you should evaluate it. Evaluating information encourages you to think critically about the reliability, validity, accuracy, authority, timeliness, point of view or bias of information.

When evaluating information, you can use the five criteria AAOCC, namely, Authority, Accuracy, Objectivity, Currency and Coverage. They can be applied to check all information.

1) Authority of information

- Who published it?
- What institution published it?
- Does the publisher list his or her qualifications?

2) Accuracy of information
   - Who provided it, and can you contact him or her?
   - Does it provide enough details?
   - Has it been cited correctly?
3) Objectivity of information
   - What is the purpose of it, or why was it published?
   - Is it biased?
   - What opinions (if any) are expressed by the author?
4) Currency of information
   - When was it published?
   - When was it updated?
   - How up-to-date is it?
5) Coverage of information
   - Do citations in it complement the research?
   - Is it all text or a balance of text and image?
   - Is it free or is there a fee to obtain it?

Task

In Text A, we read the following two sentences:

- In 1605, Sir Francis Bacon published *The Proficience and Advancement of Learning*, which contains a description of what would later be known as the scientific method.
- In 1637 René Descartes publishes *Discours de la méthode*, which contains an outline of the scientific method.

As we know, *The Proficience and Advancement of Learning* by Bacon and *Discours de la méthode* by Descartes are not only influential works in the history of modern philosophy, but also very important to the development of natural sciences. Now try to find more information about their discourses on **scientific method** and make an oral report to the class using the sources mentioned above.

Section B

Reading strategy

Dealing with unknown words (Part I)

The ability to deal with unknown words is a key reading skill in the reading process. It is a vital skill because you are almost certain to find unknown or unfamiliar words in any text. The skill is not necessarily to "know" the words, but to guess the meaning of them so that you can read and understand the whole text. Here are several different ways that can help you guess the meaning of an unknown word.

Guessing by explanation

Sometimes, you will find that the meaning of an unfamiliar word is given to you in the text. Typically, the phrase or sentence immediately before or after the unfamiliar word may give you a hint about the word. In this case, what you need to do is keep on reading and do not stop at the moment you find the unfamiliar word, and then guess the meaning from the context. For example:

In 1906, Mikhail Tsvet invented chromatography, an important analytic technique.

When you read the word "chromatography", you may stop because you are not familiar with it; but keep on reading and soon you will find this term is explained in the part after the comma "an important analytic technique".

Guessing by synonyms and antonyms

This is a very useful skill to learn. What you should do here is look at other words which relate to that word and work out what it may mean. These words may be either synonyms (words with a similar meaning) or antonyms (words with an opposite meaning). For example:

Haber has also been described as the "father of chemical warfare" for his work developing and deploying chlorine and other poisonous gases during World War I.

Here you should understand that "chlorine" is similar to the part after it – "other poisonous gases". Even though you do not know exactly what gas chlorine is, this does not interfere with your understanding of the text. So guessing instead of consulting is the best way to understand the sentence during your reading process.

Sometimes, when you come across an unknown word, you can also ignore the meaning besides guessing it. If the word starts with a capital letter, it is in all probability a proper name. In this case, you should waste no time in trying to understand what the word means. Likewise, if the word is in italics, it is also almost certainly a scientific / technical term that you do not need to know the exact meaning. For example:

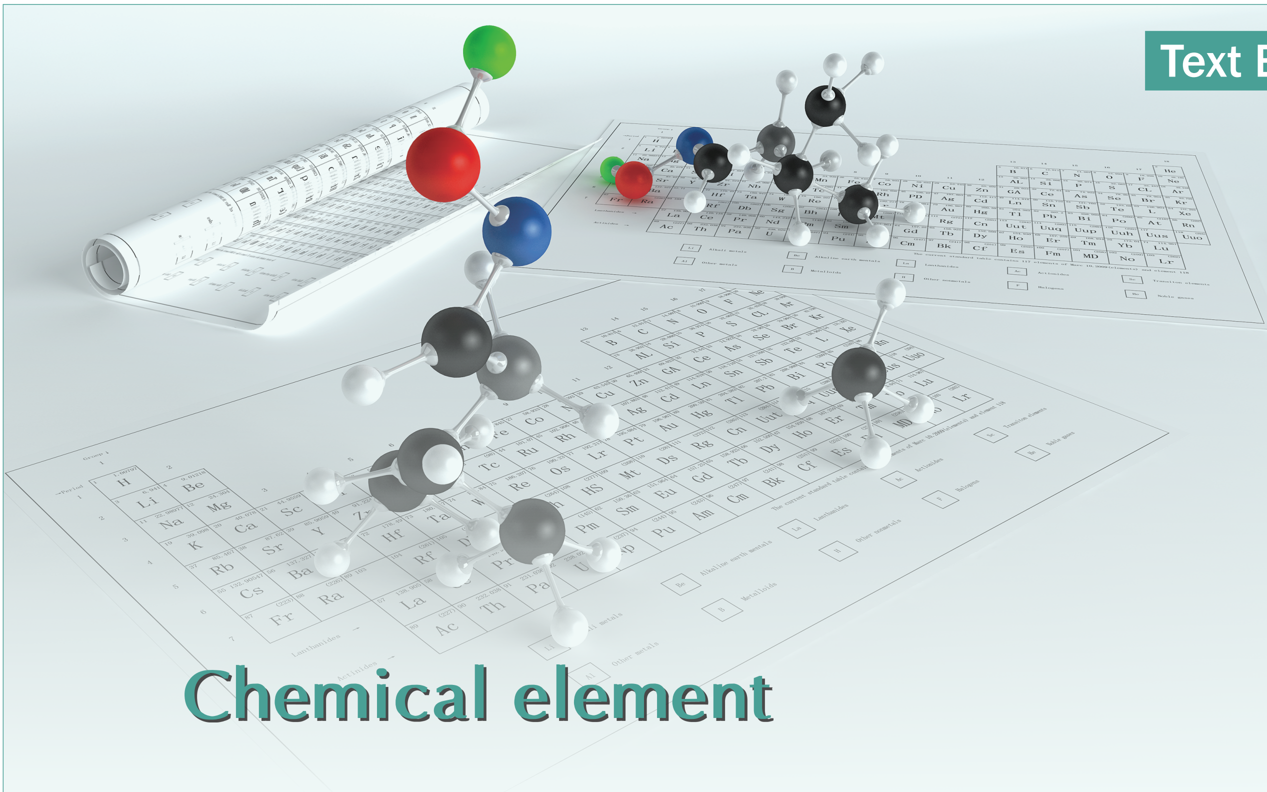
In 1905, Albert Einstein explained Brownian motion in a way that definitively proved atomic theory.

"Brownian" is a word that you should learn to ignore because it is in capital and therefore it might refer to the name of a kind of "motion", and it is totally OK if you do not know the meaning or origin of it.

Task

Read Text B and apply the skills above to deal with the underlined words.

Text B



Chemical element

1 A chemical element is a chemical substance consisting of atoms having the same number of protons in their atomic nuclei (i.e. the same atomic number, Z). There are 118 elements that have been identified, of which the first 94 occur naturally on the Earth with the remaining 24 being synthetic elements. There are 80 elements that have at least one stable isotope and 38 that have exclusively radioactive isotopes, which decay over time into other elements. Iron is the most abundant element (by mass) making up the Earth, while oxygen is the most common element in the crust of the Earth.

proton *n.* 质子
atomic nuclei 原子核
isotope *n.* 同位素
crust *n.* 地壳

2 Chemical elements constitute approximately 15% of the matter in the universe: The remainder is dark matter, the composition of which is unknown, but it is not composed of chemical elements. The two lightest elements, hydrogen and helium, were mostly formed in the Big Bang and are the most common elements in the universe. The next three elements (lithium, beryllium and boron) were formed mostly by cosmic ray spallation, and are thus rarer than those that follow. Formation of elements with from 6 to 26 protons occurred and continues to occur in main sequence stars via stellar nucleosynthesis. The high abundance of oxygen, silicon, and iron on the Earth reflects their common production in such stars. Elements with greater than 26 protons are formed by supernova nucleosynthesis in supernovae, which, when they explode, blast these elements far into space as planetary nebulae, where they may become incorporated into planets when they are formed.

3 When different elements are chemically combined, with the atoms held together by chemical bonds, they form chemical compounds. Only a minority of elements are found uncombined as relatively pure minerals. Among the more common of such "native elements" are copper, silver, gold, carbon (as coal, graphite, or diamonds), and sulfur. All but a few of the most inert elements, such as noble gases and noble metals, are usually found on the Earth in chemically combined form, as chemical compounds. While about 32 of the chemical elements occur on the Earth in native uncombined forms, most of these occur as mixtures. For example, atmospheric air is primarily a mixture of nitrogen, oxygen, and argon, and native solid elements occur in alloys, such as that of iron and nickel.

4 The history of the discovery and use of the elements began with primitive human societies that found native elements like carbon, sulfur, copper and gold.

Big Bang 宇宙大爆炸
helium *n.* 氦
lithium *n.* 锂
beryllium *n.* 铍
boron *n.* 硼
stellar nucleosynthesis 恒星核合成
supernova nucleosynthesis 超新星核合成
planetary nebulae 行星状星云
graphite *n.* 石墨
argon *n.* 氩

Later civilizations extracted elemental copper, tin, lead and iron from their ores by smelting, using charcoal. Alchemists and chemists subsequently identified many more, with almost all of the naturally-occurring elements becoming known in the 1900s.

5 The properties of the chemical elements are summarized on the periodic table, which organizes the elements by increasing atomic number into rows ("periods") in which the columns ("groups") share recurring ("periodic") physical and chemical properties. Save for unstable radioactive elements with short half-lives, all of the elements are available industrially, most of them in high degrees of purity.

Description

6 The lightest chemical elements, hydrogen and helium, both are thought to be created by Big Bang nucleosynthesis during the first few minutes of the universe in a ratio of around 3:1 by mass (or 12:1 by number of atoms), along with tiny traces of the next two elements, lithium and beryllium. Almost all other elements found in nature were made by various natural methods of nucleosynthesis. On the Earth, small amounts of new atoms are naturally produced in nucleogenic reactions, or in cosmogenic processes, such as cosmic ray spallation. New atoms are also naturally produced on the Earth as radiogenic daughter isotopes of ongoing radioactive decay processes such as alpha decay, beta decay, spontaneous fission, cluster decay, and other rarer modes of decay.

7 Of the 94 naturally-occurring elements, those with atomic numbers 1 through 82 each have at least one stable isotope, (except for technetium, element 43 and promethium, element 61, which have no stable isotopes). Isotopes considered stable are those for which no radioactive decay has yet been observed. Elements with atomic numbers 83 through 94 are unstable to the point that radioactive decay of all isotopes can be detected. Some of these elements, notably bismuth

nucleogenic *adj.* 核能基因的
cosmogenic *adj.* 宇宙发生的
bismuth *n.* 铋

(atomic number 83), thorium (atomic number 90), uranium (atomic number 92) and plutonium (atomic number 94), have one or more isotopes with half-lives long enough to survive as remnants of the explosive stellar nucleosynthesis that produced the heavy elements before the formation of our solar system. For example, at over 1.9×1019 years, over a billion times longer than the current estimated age of the universe, bismuth-209 (atomic number 83) has the longest known alpha decay half-life of any naturally-occurring element. The heavy elements (those beyond plutonium, element 94) undergo radioactive decay with half-lives so short that they do not occur in nature and must be synthesized.

8 As of 2010, there are 118 known elements (in this context, "known" means observed well enough, even from just a few decay products, to have been differentiated from other elements). Of these 118 elements, 94 occur naturally on the Earth. Six of these occur in extreme trace quantities: technetium, number 43; promethium, number 61; astatine, number 85; francium, number 87; neptunium, number 93; and plutonium , number 94. The 94 elements have been detected in the universe at large, in the spectra of stars and also supernovae, where short-lived radioactive elements are newly being made. The first 94 elements have been detected directly on the Earth as primordial nuclides present from the formation of the solar system, or as naturally-occurring fission or transmutation products of uranium and thorium.

9 The remaining 24 heavier elements, not found today either on the Earth or in astronomical spectra, have been produced artificially: They are all radioactive, with very short half-lives; if any atoms of these elements were present at the formation of the Earth, they are extremely likely, to the point of certainty, to have already decayed, and if present in novae, they have been in quantities too small to have been noted. Technetium was the first purportedly non-naturally occurring element synthesized, in 1937, although trace amounts of technetium

thorium *n.* 钍
uranium *n.* 铀
plutonium *n.* 钚
technetium *n.* 锝
promethium *n.* 钷
astatine *n.* 砹
francium *n.* 钫
neptunium *n.* 镎
fission *n.* 裂变
transmutation *n.* 演变

have since been found in nature (and also the element may have been discovered naturally in 1925). This pattern of artificial production and later natural discovery has been repeated with several other radioactive naturally-occurring rare elements.

Lists of the elements are available by name, symbol, atomic number, density, melting point, and boiling point as well as ionization energies. The nuclides of stable and radioactive elements are also available as a list of nuclides, sorted by length of half-life for those that are unstable. One of the most convenient, and certainly the most traditional presentation of the elements, is in the form of the periodic table, which groups together elements with similar chemical properties (and usually also similar electronic structures).

The Periodic Table of the Elements

Group→ ↓Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
Lanthanides			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
Actinides			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

ionization energy 电离能