高等学校规划教材

Inorganic Chemistry

无机化学

陆家政　陈　菲　主编

化学工业出版社

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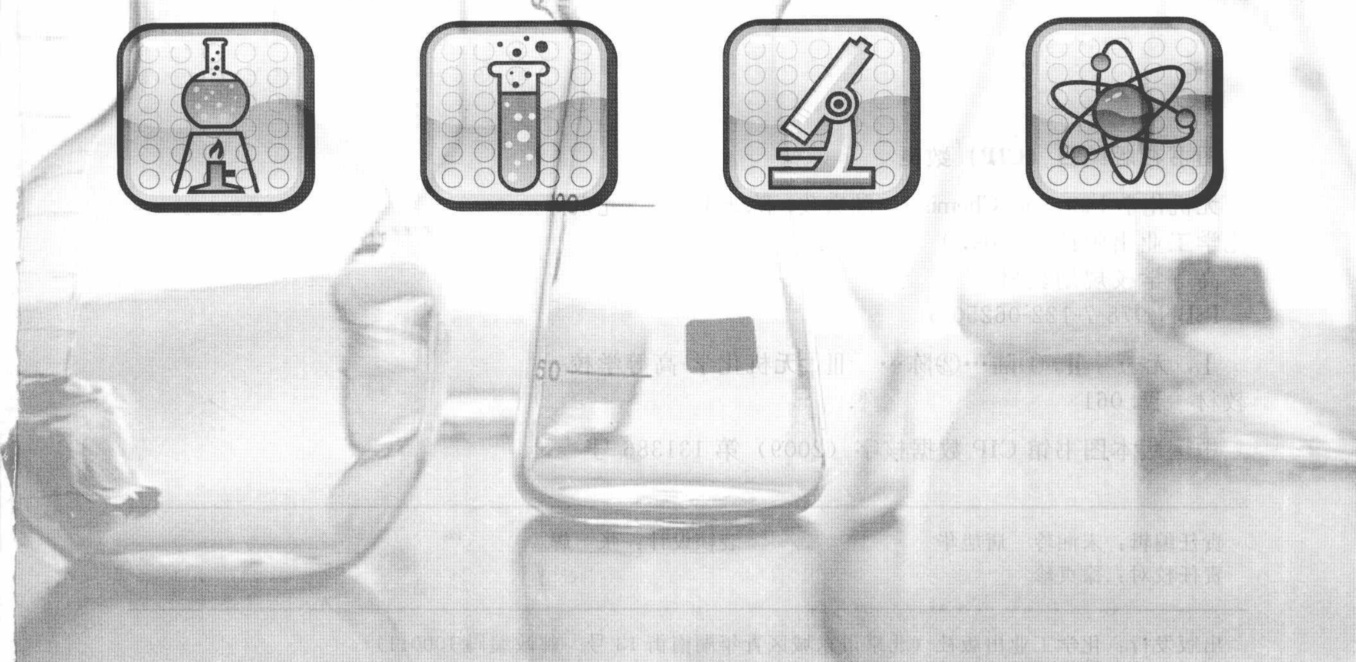

化学工业出版社
·北京·

本书针对药学类专业无机化学的双语课程，将无机化学课程的基本内容进行精选，结合国内高校教学实际，删除原版教材中大量的复杂、繁琐及较深奥的部分，力求使之既能体现无机化学课程的专业基础课特色，又可提高学生的英语应用能力。

鉴于医药学专业学生理论与实验课程并重的特点，全书包含两大部分：Ⅰ Inorganic Chemistry 与 Ⅱ Inorganic Chemical Experiments。Part Ⅰ includings thirteen chapters：1 Introduction，2 Structures of Atoms，3 Chemical bonds，4 Thermochemistry，5 Chemical Kinetics，6 Chemical Equilibrium，7 Solutions，8 Solubility Equilibrium，9 Acid-Base Equilibria，10 An Introduction to Electrochemistry，11 Chemistry of Coordination Compounds，12 Nonmetals and Semimetals，13 Metals。Part Ⅱ includings three chapters：1 Basic Techniques of Experimental Chemistry，2 Typical Chemical Laboratory Apparatus，3 Experiments。

本书可作为高等院校本科药学及化学类相关专业的无机化学双语教材，也可作为化学专业英语课的教材或参考书。

图书在版编目（CIP）数据

无机化学 Inorganic Chemistry/陆家政，陈菲主编．—北京：化学工业出版社，2009.9

高等学校规划教材

ISBN 978-7-122-06250-5

Ⅰ．无…　Ⅱ．①陆…②陈…　Ⅲ．无机化学-高等学校-教材　Ⅳ．061

中国版本图书馆 CIP 数据核字（2009）第 131386 号

责任编辑：宋湘玲　唐旭华　　　　装帧设计：张　辉

责任校对：徐贞珍

出版发行：化学工业出版社（北京市东城区青年湖南街 13 号　邮政编码 100011）

印　　装：大厂聚鑫印刷有限责任公司

787mm×1092mm　1/16　印张 19¾　彩插 1　字数 529 千字　　2009 年 8 月北京第 1 版第 1 次印刷

购书咨询：010-64518888（传真：010-64519686）　售后服务：010-64518899

网　　址：http://www.cip.com.cn

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定　　价：38.00 元

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前　言

自2001年国家教育部提倡在高等院校实行双语教学以来，很多高等院校都为化学及相关专业的本科生开设了无机化学双语课程。我们在药学专业无机化学课上也进行了积极尝试，课程受到学生的广泛欢迎，但遗憾的是至今很难找到切合相关专业的英文版《无机化学》教材，国外原版教材虽然可保持语言文字上的原汁原味，但往往内容太多，与国内高等院校现行的教学学时相差甚远；国内学者编著的教材可供选择的也为数不多。而我们经过几年的努力，积累了一定的教学经验，因此，联合相关院校组织无机化学双语教学第一线的教师编写了本书。

在本书编写的过程中，对无机化学课程的基本内容进行精选，加强基础，突出重点。删除了以往教材中存在的大量的复杂公式和繁琐计算的推导以及较深奥的理论分析和阐述，力求做到既言简意赅，又具有较完整的无机化学知识体系。竭力保持语言上与外版教材的一致性，又能使其内容更精练、通俗易懂，且更切合目前国内相关专业的教学实际。同时力求使之既能体现无机化学课程的专业基础课特色，又可提高学生的英语应用能力。希望此书的出版能够起到抛砖引玉的作用，为无机化学双语教学质量的进一步提高做出贡献。

全书由陆家政、陈菲主编并统稿。参加编写理论部分的有：陈丽江（第1章），曾宪栋（第2、3章），陈菲（第3章），蔡秀兰（第4章），管小艳（第5章），蒋京（第6章），蒋东丽（第7章），何丽新（第8章），姚秀琼（第9章），曾琦华（第10章），陆家政（第11章），贺丽敏（第12章），伍小云、李君君（第13章）。实验部分由陈菲、陆家政、李雪华和赖泽锋编写。

本书在编撰过程中得到了多方的支持。其中广东药学院教务处将其立项为特色教材予以支持和帮助，在此表示衷心的感谢。

本书可作为高等院校本科药学及化学类相关专业的无机化学双语教材，也可作为化学专业英语课的教材或参考书。

鉴于编者的水平和能力有限，书中尚有不妥之处，恳请专家以及使用本书的老师和同学批评指正。

编　者

2009年6月

目 录

I

Inorganic Chemistry

Chapter 1 Introduction

Chemistry is an integral part of the science curriculum both at the high school and the early college level. At these levels, it is an introduction to a wide variety of fundamental concepts enabling the students to acquire tools and skills useful at the advanced levels. If you study further, you will find that chemistry is studied in any of its various sub-disciplines. So what is chemistry?

Chemistry (from Egyptian kēme, meaning "earth") is the science studying the composition, structure, properties of matter, and the changes it undergoes during chemical reactions. Matter is the physical material of the universe, it is anything that has mass and occupies space. All the matter that you are likely to meet in your everyday life is made of chemical. So chemists seek to understand how chemical transformations occur by studying the physical and chemical properties of matter. And it takes a long time for chemistry to develop and mature from its infancy (see Table 1. 1).

Table 1. 1 The development of chemistry

The Phases of Development	Worthy	Contribution
The genesis of chemistry (From B. C. 3000)	Ancient alchemists and metallurgists	The process for the metal purification
The early chemistry(From A. D. 800)	Medieval muslims: Geber (815), al-Kindi (873), al-Razi (925), al-Biruni (1048)	The introduction of precise observation and controlled experimentation into the field and the discovery of numerous chemical substances
	Indian alchemists and metallurgists	
The emergence of chemistry in Europe (From Dark ages, A. D. 476～1000)	Paracelsus (1493～1541)	Iatrochemistry
	Robert Boyle (1627～1691)	The Boyle's Law
Modern chemistry (From 1773)	Antoine Lavoisier (1743～1794)	The law of conservation of mass
	John Dalton(1766～1844)	The atomic theory
	Lavoisier ("Father of Modern Chemistry", 1743～1794)	1. The oxygen theory of combustion 2. Fit all experiments into the framework of a single theory 3. The consistent use of the chemical balance 4. Use oxygen to overthrow the phlogiston theory 5. A new system of chemical nomenclature 6. Contribution to the modern metric system
	Friedrich Wöhler (1880～1882)	The discovery that many natural substances and organic compounds can be synthesized in a chemistry laboratory
	Dmitri Mendeleev (1834～1907)	The periodic table of the chemical elements

Chemistry is largely an experimental science, and a great deal of knowledge comes from laboratory research. Knowledge of chemistry is needed in every modern science from astronomy to zoology. Chemists participate in many fields, such as the development of new drugs, and the problem of environmental pollution. And most industries have a basis in chemistry.

Today computer and sophisticate electronic equipment may be used to study the microscopic structure and chemical properties of substances or to analyze toxic substances in the soil or other samples. Indeed, because chemistry has diverse applications and connects the other natural sciences, such as astronomy, physics, material science, biology, and geology, it is often called the "central science."

The disciplines within chemistry are traditionally grouped by the type of matter being studied or the kind of study. However, there are four basic disciplines within chemistry, which are the required courses for any learners on the fields of natural science. These include inorganic chemistry, the study of the properties and behavior of inorganic matter; organic chemistry, the study of the structure, properties, composition, reactions, and preparation of organic matter; physical chemistry, the energy related studies of chemical systems at macromolecular and submolecular scales within the field of chemistry traditionally using the principles and practices of thermodynamics, quantum chemistry, statistical mechanics and kinetics; analytical chemistry, the study of the chemical composition and structure of natural and artificial materials.

Inorganic chemistry is a creative field that has applications in every aspect of the chemical industry-including catalysis, materials science, pigments, surfactants, coatings, medicine, fuel, and agriculture. It covers all chemical compounds except the myriad organic compounds (compounds containing C—H bonds), which are the subjects of organic chemistry. Inorganic chemistry, like many scientific fields, becomes more and more interdisciplinary. But chemists in the fields such as materials science or polymer science still strongly recommend getting a degree in inorganic chemistry. A degree in the basic discipline will give a better understanding of bonding, valence, and orbital theory. In addition, it is also important to learn inorganic chemistry and see how it applies in other areas.

1.1 Observations and Conclusions

Chemistry, like all sciences, is based on observations. It is a challenge to grasp the connotation within the information obtained and make a conclusion. Repeating experiments is an effective way to test your thought. If observations are made carefully, you would make the same conclusion. Other people in other places or at other times would also make the same observations if they did the same experiments. But they might explain their observations in different point. For example, before the seventeenth century, people usually accounted for their observations in terms of religion, while scientists today usually interpret their observations in terms of atoms and molecules.

1.2 The Scientific Method

Scientific methodology has been practiced in some forms for at least one thousand years. The development of the scientific method is inseparable from the history of science itself. Now it is acceptable to use experiment to understand nature. But the ancient Greeks did not rely on experiments to test their ideas. One way is to just talk about it. This method is unreliable. It requires proofs to determine whether a statement is correct. Since Ibn al-Haytham (Alhazen, 965～1039), the emphasis has been on seeking truth. However there are difficulties in a formulaic statement of method. As William Whewell (1794～1866) noted in his *History of Inductive Science* (1837) and in *Philosophy of Inductive Science* (1840), multiple steps are needed in scientific method.

Now all sciences, including the social sciences, employ variations of the scientific method. It is the process for experimentation to explore observations, answer questions and consequently construct an accurate representation of the world. The scientific method will help you to focus on your science fair project question, construct a hypothesis, design, execute, and evaluate your experiment. It requires intelligence, imagination, and creativity. Through the use of standard procedures and criteria we hope to minimize the influences of bias or prejudice in the experiment when developing a theory.

Now there is a hypothetico-deductive model for scientific method.

(1) Define the problem carefully

(2) Gather informations and resources (background research)

(3) Form hypothesis

(4) Perform experiment and collect information or data about the system

(5) Analyze data

(6) Interpret data and deduce a prediction that serve as a starting point for new hypothesis

(7) Publish results

(8) Retest (frequently done by other independent scientists)

Note that this method can never absolutely verify 3. It can only falsify 3. And the iterative cycle inherent in this step-by-step methodology goes from point 3 to 6 back to 3 again.

In all science disciplines, the words "hypothesis," "model," "theory" and "law" possess different connotations in relation to the stage of acceptance or knowledge about a series of phenomena.

Based on the informations that was gathered, the researcher formulated a hypothesis, a tentative explanation for a set of observations, or alternately a reasoned proposal suggesting a possible correlation among a set of phenomena. Scientists are free to use whatever resources they have, such as their own creativity, ideas from other fields, induction, Bayesian inference, and so on, to imagine possible explanations. The history of science is filled with stories of scientists claiming a "flash of inspiration", or a hunch. Further experiments are then devised to test the validity of the hypothesis in as many ways as possible, and the process begins anew.

Any useful hypothesis will enable predictions, by reasoning deductive reasons. It might predict the outcome of an experiment in a laboratory setting or the observation of a phenomenon in nature. The prediction can also be statistical and only talk about probabilities. If the predictions are not proved by observation or experience, the hypothesis is not yet useful for the method, and must wait for others to rekindle its line of reasoning.

Model is reserved for situations when it is known that the hypothesis has at least limited validity. An often-cited example is the Bohr model of the atom. In an analogy to the solar system, this model describes the electrons as moving in circular orbits around the nucleus. It does not depict accurately what an atom "looks like," but the model succeeds in mathematically representing the energies of the quantum states of the electron in the hydrogen atom.

If the experiments bear out the hypothesis it may come to a theory or law of nature. If the experiments do not bear out the hypothesis, it must be rejected or modified.

In science, a scientific law is a concise verbal statement or a mathematical equation that summarizes the relationship of phenomena that is always the same under the same conditions. We tend to think of the laws of nature as the basic rules under which nature operates. That is, the laws of natured describe the behaviour of matter. For example, Sir Isaac Newton's second law of motion ($F=ma$) means that the mass or in the acceleration of an object is always proportional to the object's force.

In science, a theory is a unifying explanation of the general principles of certain phenomena with considerable evidence or facts to support it. Hypotheses that survive many experimental tests of their validity may evolve into theories.

A scientific theory or law represents a hypothesis, or a group of related hypotheses confirmed through repeated experimental tests. Science progresses by cycles of suggested theories and tests by experiment. No matter how elegant a theory is, its predictions must agree with experimental results if we are to believe that it is a valid description of nature. So as soon as a new theory has been suggested, new experiments should be launched to test it. If the experimental results support the theory, it is accepted. If they do not, it must be modified or a new theory invented. Accepted scientific theories and laws become a part of our understanding of the universe and the basis for exploring less well-understood areas of knowledge. In part because of the unavailable necessary technology, probing or disproving a theory can take years, even centuries. For example, it took more than 2000 years to work out atomic theory proposed by Democritus, and ancient Greek philosopher.

A theory can be proved wrong, but it can never be proved right. And theories are not easily discarded; new discoveries are first assumed to fit into the existing theoretical framework. It is only when, after repeated experimental tests, the new phenomenon cannot be accommodated; scientists seriously question the theory and attempt to modify it.

There is always the possibility that a new observation or a new experiment will conflict with a long-standing theory. The overturning of an important theory opens new frontiers in science. For example, before the sixteenth century, people thought that Earth was the centre of the universe. Through many years of observation, Copernicus published his observations of the planets. He found that Earth and the other planets revolve around the sun. This was the beginning of the scientific revolution.

1.3 Units of Measurement

Measurement is also central to the sciences and engineering; modern technology and development are based on measurements. Generally, there are two kinds of measurements: quantitative measurements and qualitative measurements.

Qualitative measurements do not involve numbers. It involves an indepth understanding of human behaviour and the reasons that govern human behaviour. Qualitative research bases on the reasons behind various aspects of behaviour. Simply put, according to what, where, and when of quantitative research, it investigates the why and how of decision making.

Quantitative measurements, over qualitative observations, are numerical observations of a value, or quantity, such as volume, length etc. It is the systematic scientific investigation of quantitative properties, phenomena and their relationships. Quantitative research is widely used in both the natural and social sciences, from physics and biology to sociology and journalism. Quantitative measurements are made with instruments. The application of instruments extends the human senses of sight, smell, taste, touch, and hearing. For example, you can measure your weight with a scale, time with a watch or clock and the speed of a car with a speedometer. To simplify the process of keeping records, standardized symbols and equations are used by chemists in recording their measurements and observations. This form of representation provides a common basis for communications with other chemists.

Every measurement has two parts, a number and a unit. In science, units are essential to state measurements correctly. To say that the length of a pen is 12. 5 is meaningless. We must specify that the length is 12. 5 centimeters (cm).

The definition, agreement and practical use of units of measurement have played a crucial role in human endeavour from early ages up to this day. A unit of measurement is a standardized quantity of a physical property, used as a factor to express occurring quantities of that property. Units of measurement were among the earliest tools invented by humans. Disparate systems of measurement used to be very common. Now a global standard, the International System of units (the modern form of the metric system) has been or is in the process of being adopted throughout the world.

Traditional Systems

Prior to the global adoption of the metric system many different systems of measurement had been in use. The earliest known uniform systems of weights and measures seem to have all been created sometime in the 4th and 3rd millennia BC among the ancient peoples of Mesopotamia, Egypt and the Indus Valley, and perhaps also Elam in Persia as well. Many of these were related to some extent or other. Often they were based on the dimensions of parts of the body and the natural surroundings as measuring instruments. As a result, units of measure could vary not only from location to location, but from person to person.

Metric Systems and SI Units

A unit of measurement is an agreed-on standard with which other values are compared. Agreement on such standards is not easy to achieve, because different standards have been used within the scientific community. Five thousand years ago in Egypt, people use the cubit, the length of a person's arm from the elbow to the tip of the middle finger, as the unit for the measurement of length. Different sized people had different rulers. Now people in the United States use the English system of units-inches, feet, ounces, pounds, and so forth, which are based on various familiar human lengths. For example, the foot is the length of a typical human foot; the yard is the distance from the tip of the nose to the end of an extended finger. Scientists, on the other hand, use the meter, an international standard unit that was originally defined as 10^{-7} times the length of a line from the North Pole to the equator. In everyday life, volume can be measured in pints, quarts, and gallons, but the scientific standards are the cubic meter and the liter (10^{-3} m^3). For people to be able to reproduce each other's measurements, they must agree on standard units. The units used for scientific measurements are those of the metric system.

The metric system was first developed in France in 1791. After that a number of metric systems of units have evolved and are used as the system of measurement in most countries throughout the world. For many years scientists recorded measurements in metric units, which are related decimally, that is, by powers of 10. In 1960, the General Conference of Weights and Measures, the international authority on units, has attempted to work exclusively with a single set of units. It proposed a revised metric system called the International System of Units (abbreviated SI Units, from the French Systême International d'Unités) for use in scientific measurements. The SI system has seven base units from which all other units are derived. Table 1.2 lists these base units and their symbols. An important feature of modern systems is standardization. The size of each SI base unit is defined exactly and universally recognized. For example, the standard of mass is the mass of a platinum-iridium cylinder kept in a vault near Paris. All other SI units of measurement can be derived from these base units. For example, volume is not a base unit in the SI system because it can be obtained from the base unit for length. A cube with 1 m on a side has a volume of 1 m^3. In chemistry the common volume is smaller than a cubic meter, so volumes are often expressed using the liter, which is defined to be exactly 10^{-3} m^3.

Scientists all over the world use SI units. The purpose of adopting SI units was to make communication easier between scientists and engineers working in different scientific subjects and in different countries.

Table 1.2 SI base units

Physical quantity	Name of unit	Abbreviation	Physical quantity	Name of unit	Abbreviation
Mass	Kilogram[1]	kg	Temperature	Kelvin	K
Length	Meter	m	Luminous intensity	Candela	cd
Time	Second	s[2]	Amount of substance	Mole	mol
Electric current	Ampere	A			

1. The official spelling is kilogramme.
2. The abbreviation sec is frequently used.

Base and Derived Units

Different systems of units are based on different choices of a set of fundamental units. Using physical laws, units of quantities can be expressed as combinations of units of other quantities. Thus only a small set of units is required. These units are taken as the base units. Other units are derived units. Which units are considered base units is a matter of choice. The most widely used system of units is the International System of Units, or SI. There are seven SI base units (See Table 1.3). All other SI units can be derived from these base units.

Table 1.3 Prefixes used with SI units

Prefix	Symbol	Meaning	Example	Prefix	Symbol	Meaning	Example
yotta	Y	10^{24}	1 yottameter (Ym) = 1×10^{24} m	deci-	d	10^{-1}	1 decimeter (dm) = 0.1m
zetta	Z	10^{21}	1 zettameter (Zm) = 1×10^{21} m	centi-	c	10^{-2}	1 centimeter (cm) = 0.01m
exa-	E	10^{18}	1 exameter(Em) = 1×10^{18} m	milli-	m	10^{-3}	1 millimeter (mm) = 0.001m
peta	P	10^{15}	1 petameter (Pm) = 1×10^{15} m	micro-	μ①	10^{-6}	1 micrometer (μm) = 1×10^{-6} m
tera-	T	10^{12}	1 terameter (Tm) = 1×10^{12} m	nano-	n	10^{-9}	1 nanometer(nm) = 1×10^{-9} m
giga-	G	10^{9}	1 gigameter (Gm) = 1×10^{9} m	pico-	p	10^{-12}	1 picometer (pm) = 1×10^{-12} m
mega-	M	10^{6}	1 megameter(Mm) = 1×10^{6} m	femto-	f	10^{-15}	1 femtometer (fm) = 1×10^{-15} m
kilo-	k	10^{3}	1 kilometer (km) = 1×10^{3} m	atto-	a	10^{-18}	1 attometer (am) = 1×10^{-18} m
hecto-	h	10^{2}	1 hectometer(hm) = 1×10^{2} m	zepto-	z	10^{-21}	1 zeptometer (zm) = 1×10^{-21} m
deka-	da	10^{1}	1 dekameter(dam) = 1m	yocto-	y	10^{-24}	1 yoctometer(ym) = 1×10^{-24} m

① This is the Greek letter μ (pronounced "mew").

The sizes of the SI base units are not always convenient. For example, a meterstick is a little longer than a yardstick. Using a meterstick to measure the diameter of a penny or the distance between two cities would be awkward. Like metric units, SI units are modified in decimal fashion by a series of prefixes to make larger and smaller units from the base units. For example, one centimetre is 10^{-2} meter, or one-hundredth (0.01) of meter. Table 1.3 shows the SI prefixes with their symbols.

Sample How many micrograms (μg) in a milligram (mg)?

Solution: 1000 micrograms=1 milligram, and 1000 milligrams=1 gram.

1.4 Advice on Studying Chemistry

Here are some useful advices for learners.

(1) Find other students who are in your class to study with.

(2) Schedule a regular time to study each day. Don't wait until the week before an exam to begin studying. Don't stay up all night the night before the big game. In Chemistry, explanations are usually based on concepts and skills learned previously. Don't let yourself get behind.

(3) Do the assignments before coming to class. Read slowly and carefully. Try to understand, not memorize. (However, some memorization is necessary, you cannot learn to think without knowing something to think about.) Make sure you understand the worked-out examples, and do the chapter problems and check your answers to them in (bracket) parentheses. Write down any questions you have so don't forget them when you get to class.

(4) After each class, review what you have just learned before beginning the next assignment.

(5) Pay careful attention to vocabulary. An important part of a first course in any subject is learning the meaning of the terms used in the field (which, unfortunately, do not always mean the same thing in other fields). If you don't remember the meaning of a term when you meet it again later, use the index to find the definition. If you come across unfamiliar words, look up their meaning in a chemical dictionary. Different people have different learning styles so choose the one that suit you.

Key Words

chemistry ['kemistri] 化学
matter ['mætə] 物质
inorganic chemistry [ˌinɔːgænik 'kemistri] 无机化学
organic chemistry [ɔː'gænik 'kemistri] 有机化学
physical chemistry ['fizikəl 'kemistri] 物理化学
analytical chemistry [ˌænə'litikəl 'kemistri] 分析化学
hypothesis [hai'pɔθisis] 假设
prediction [pri'dikʃən] 预言
model ['mɔdl] 模型
law [lɔː] 定律
theory ['θiəri] 理论
quantitative ['kwɔntitətiv] 定量的
qualitative ['kwɔlitətiv] 定性的
metric system ['metrik 'sistəm] 国际公制，米制
unit ['juːnit] 单位