国家精品课程教材

■ 高等学校理工科化学化工类规划教材

ANALYTICAL CHEMISTRY

分析化学（双语版）

大连理工大学分析化学教研室　编著

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序 言

分析化学是人们获得物质组成、结构和信息的科学，即表征和测量的科学。现代分析化学已远远超出化学学科的领域，正逐步将化学与数学、物理学、计算机科学、生物学等学科结合起来，发展成为一门综合性科学。该学科的快速发展促使分析化学课程不断更新，从而确保学生可以掌握最新的分析化学发展动态。

分析化学是高等理工科院校化学、化工及相关专业的一门基础课。在保证教学要求的基础上，既要使学生理解和掌握教学内容，对课程整体及学科发展前沿有所了解，又要扩展学生的知识面，提高专业水平。教育部提出的双语教学模式已成为培养高素质人才的有效措施之一。

由大连理工大学国家精品课程建设团队——分析化学教研室组编的"分析化学"(双语版)教材正是对教育部提出的关于在高等院校一些专业按一定比例开设双语课程的积极响应。编者不仅长期工作在本科生分析化学教学第一线，而且具有多年从事双语教学的经验。即将出版的分析化学(双语版)教材也是在多年使用、数次更新的自编讲义基础上编写的，具有很好的前期积累。

目前，国内分析化学专业的双语教材还比较少。编者的工作对即将开展或已经开始从事分析化学双语教学的高校具有很好的借鉴作用。相信本教材的出版会在一定程度上促进国内分析化学双语教学工作的开展，并为提高本科生的专业英语水平起到积极的推动作用。

2008 年 11 月

前　言

目前，双语教学模式与其他教学模式的区别主要体现在两个方面：一方面是在教材的选取上，或直接采用原版教材，或采用中文版教材，加外语补充材料；另一方面是在授课方式上，有的采用全外语授课，或部分外语授课，有的在使用原版教材的基础上采用全中文授课。各高校大多根据学生的外语水平及师资情况在上述几种情况中选择。

原版教材内容体系一般比较庞杂，与国内教学要求难以完全符合。如果采用中文版教材，再提供外语补充材料，则双语教学体现得不充分，效果不明显。最好的选择是请既懂专业又有良好外语写作能力的教师（或中方和外方直接合作），按照国内的教学要求有针对性地编写。本教材无疑是满足时代要求的一种有益尝试。

大连理工大学分析化学教研室多年来致力于分析化学课程体系的改革与建设，已经建立起包括教材、电子教案、网络课程、多媒体软件等多种教学资源的分析化学立体化课程体系，其核心课程“分析化学”已经入选国家级精品课程。

分析化学的双语教学是分析化学课程体系建设的重要组成部分。我校分析化学双语教学工作始于 1985 年，在 20 余年的教学过程中，经过教研室几代教师持续不断的探索，逐渐积累了一些教学经验，对英文讲义内容不断补充、修改及更新，并于 2003 年获大连理工大学教材建设出版基金项目支持，由赵常志等对校内讲义进行了更新编写。在多年对教学材料不断积累和完善的基础上，2006 年教研室组织启动了分析化学双语教材的编写工作。

本教材在章节顺序和内容安排上参照了《分析化学》（第三版，大连理工大学分析化学教研室组编，刘志广主编）中文教材，将众多分析方法按大类编写，同时加强仪器分析内容，突出工科特点，在符合发展趋势及社会需要的同时重视学习的规律和逻辑性。英文内容以高等学校化学化工专业本科生少学时分析化学课程教学大纲为依据，参考多种国外原版教材，以使语言表述准确、地道。为使学生在习惯用英文进行专业思考的同时，又熟悉相应的中文用语，在每章末列出该章用到的主要专业名词的中文解释，以及用中文书写的重点内

容概述。

本书由大连理工大学分析化学教研室统一组织编写，刘志广教授确定了编排思路及大纲，并负责中文部分的编写。参加本书编写工作的有：丁保军（第1～3、5、7章）、宿艳（第4、6章）、潘玉珍（第8～10章），全书由丁保军统稿并最终定稿。感谢教研室新老同事对本书的出版所作出的贡献！中国科学院大连化学物理研究所张玉奎院士为本书的编写提出了宝贵的意见，并为本书作序，在此表示深深的感谢和诚挚的敬意。

本书的出版得到了大连理工大学教材建设出版基金和双语课程建设项目的资助，得到了大连理工大学出版社的大力支持，在此表示衷心的感谢。

本书是我们双语教学的一个阶段性总结，也是首次正式出版，恳请各位专家、同行及广大读者提出宝贵建议和意见，可以通过以下方式和我们联系：

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编 者

2008年11月

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Chapter 1 Introduction
绪 论

教学基本要求

了解分析化学学科的特点、作用及发展方向；
掌握分析化学的分类及分析的基本步骤。

Learning objectives

To know about the characteristics, the role and developing directions of analytical chemistry;
To grasp the classification of analytical chemistry and the analytical process.

1.1 The nature of analytical chemistry 分析化学的性质

Analytical chemistry is a scientific discipline that develops and applies methods, instruments, and strategies to obtain information on the composition and nature of matter in space and time. (Edinburgh-Definition of WPAC 1993)

It is an important branch of chemistry, is a science by which people can obtain the chemical composition and structural information of matter.

In order to investigate problems in the field of both natural and social sciences, an analytical approach is in general first used. That is to say, the analysis is the first pieces of information which have been combined, the problem as a whole can finally be understood. The analysis of matter is carried out in a similar order. The matter is divided first into components, chemical species such as atoms, ions or molecules. Physical analysis now often allows the investigation of matter in its original state, without preparation or digestion 'in situ'. The primary purpose or aims of analytical chemistry involves finding out the amount and types of chemical species present in a system. After knowing the constituents of the matter, one can estimate or evaluate the constitution of original matter in question, just as in the processes described above.

In the recent sixty years, the technological development of instrumental analysis was so wide and rapid that today the field of analytical chemistry has even expanded toward 'computer-based analytical chemistry'. In other words, the various characterizations of matter can be carried out nowadays also in total analysis systems (including both classical analysis and instrumental analysis). Nowadays, there is a widespread belief that the decades surrounding go down in history as the 'information age'. Considering the breathtaking advances which have been made in collecting, storing, manipulating, transmitting, and presenting information, this view has merit. Analytical chemistry is such an information science that produce, obtain, evaluate and process different chemical information.

1.2 The role of analytical chemistry 分析化学的作用

Analytical chemistry is applied throughout industry, medicine, and all the sciences and is very close to our modern lives and societies. It also plays a vital role in many research areas in chemistry, biochemistry, biology, environmental monitoring, geology, physics and the other sciences. It is a problem analyzer and solver.

The science of analytical chemistry has benefited in a number of ways from the burst of technology. Local area networks connecting analytical instruments, the Fourier transform manipulation of spectral information, and the comparative searching of analytical data to identify an 'unknown' are only a few examples of this contribution. However, analytical chemistry should be viewed as one of the strongest pillars of the 'information age' for several important reasons. While collecting, storing, manipulating, and transmitting information are vital activities, the generation of new, accurate information, which concentrates on enhancing the understanding of critical problem and opportunity areas facing mankind, is the promise of analytical chemistry. In fact, those tasks constitute only one definition of analytical chemistry. The focused approach of defining a problem, addressing it through multiple techniques or interdisciplinary methods if needed, and assuring that results are accurate and reproducible, constitutes analytical science. Past and future applications of this methodology to biotechnology, the chemical industry, materials science, food science, reaction mechanisms, and environmental issues have the potential to produce multiplicative levels of advancement when combined with the other technologies on which the 'information age' is being built. We live in an 'information age' which has brought great changes to society and also to the capabilities of analytical chemistry.

Many chemists, biochemists, and medicinal chemists devote much time in the laboratory gathering qualitative and quantitative information about systems that are important and interesting to them. In this enterprise and many others, analytical chemistry plays a central role. All branches of chemistry and many other scientific fields draw on the ideas and techniques of analytical chemistry. The interdisciplinary nature of chemical analysis makes it a vital tool in medical, industrial, government, and academic laboratories throughout the world.

Many new technologies are on the horizon that will markedly affect the capabilities of the analytical scientist of the future. Fiber optics, lasers, chemometrics, and nanotechnology are just a few of these. The problems of society are more complex and challenging than ever before, especially in areas such as environmental technology, biotechnology, advanced materials, and the entire information age revolution. As we continue to employ the analytical approach to new challenges, with new methods and new techniques, the analytical chemist as a problem solver will continue to be a key player in industry, academia and government. Analytical chemistry is a central discipline to all other branches of science. New technologies continue to improve the capabilities of analytical chemistry.

1.3 The classification of analytical chemistry 分析化学的分类

In order to better understand the detailed relationship between analytical chemistry and society, we need to consider some of the traditional classifications of analytical chemistry.

(1) The first and the most direct classification is with the material itself, of which a few examples, corresponding to the material to be analyzed or the sample material, are *water analysis*, *rock analysis*, *food analysis*, and so forth.

In the industrial area, *steel analysis* or iron analysis is fundamentally important in order to ensure a high steel quality, which is the basis of other industries. There have been experts of analysis of steel and iron in big companies around the world from the time when wet chemical analysis was in use.

Clinical analysis is vitally important for health, and a modern hospital must be able to perform reliable *blood and urine analyses* in order to make a proper diagnosis of the patient. All automated physical analytical instruments are available. *Pharmacological analysis and biological analysis* are related fields. In recent years, environmental analytical chemistry has become very popular, and air, water, soil, and biological materials are all included for environmental investigation, which is naturally very important for our society.

(2) The classification of chemical species to be analyzed is another item. Again giving only a few examples, *total analysis* is used to find all species in the sample, so that the sum of the weight of each component equals the original sample weight. The total analysis of a rock is a good example. Recently, moon rock analysis received concern from a great number of people around the world. However, often some particular constituents, element(s) or molecule(s), are required to be analyzed. *Elemental analysis* is used today to analyze all elements in both organic and inorganic compounds. Analyses such as for NO_x, SO_x, and O_3 give information on air pollution, and *PCB analysis* and *dioxin analysis* are also needed to improve our environmental safety. These molecules, in particular, consist of numerous numbers of isomers, some of which are known to be more toxic than others. *Radioactive analysis* has an obvious importance for our society, as it includes the analysis of ^{90}Sr, ^{137}Cs, ^{235}U and ^{249}Pu, which are either nuclear fission products or nuclear

power materials.

(3) Today analytical chemistry encompasses *qualitative analysis* and *quantitative analysis* and *structure analysis* depending on the different aims. *Qualitative analysis* indicates whether a particular element or compound is in the sample, *quantitative analysis* gives the amount of the species in the sample or analytes(*analytes* are the components of a sample that are to be determined), whereas *structure analysis* indicates the molecular structure or crystal structure of matter. Qualitative analysis is often an integral part of the separation step, and determining the identity of the analytes is an essential adjunct to quantitative analysis. Physical methods of analytical chemistry such as *spectrochemical analysis* have been developed so widely that they are applicable to perform a structural analysis. That means that the importance of analytical chemistry for our present society has expanded greatly, and will continue to grow further in the future.

(4) According to the size of samples, analytical chemistry methods are classified into macro analysis(>0.1 g, solid; >10 mL, liquid), semimicro analysis(0.01~0.1 g; 1~10 mL), micro analysis(0.1~10 mg; 0.01~1 mL) and ultramicro analysis(<0.1 mg; <0.01 mL).

(5) Analytical chemistry methods can be classified into *chemical analysis* and *instrumental analysis* according to the different principles. The performing of the former depends on chemical reactions, which is the basis of analytical chemistry, including gravimetric methods and volumetric methods etc.; the latter employing some special instruments includes electrochemical methods, spectroscopic methods, chromatography etc.. Chemical analysis needs only simple equipments, such as analytical balance, pipette and other glassware, but it has high accuracy (commonly, the relative error is between 0.1%~0.2%) and usually is used to determine the analyte whose content is higher than 1%. The characteristics of instrumental analysis are high sensitivity, simple operation, fast speed, automatization. Instrumental analysis is the developing direction of modern analytical chemistry. It is used to perform a micro analysis or a trace analysis.

1.4 The total analytical process
分析全过程

The exact question to be answered or the exact problem to be solved by the chemical measurements has to be defined in agreement with the user (customer) of the chemical test data. The general problem will often be related to an issue that is beyond the field of expertise of the analytical chemist (analyst) and often even outside the chemical domain. Moreover the client does not always fully appreciate the opportunities and technological aspects of analytical chemistry. In an intensive discussion between the analyst and the client it should be made clear what is the real basis of the analysis before starting the problem solving procedure.

Client and analyst have to define the object of study together: *what has to be* analyzed and what *can be* analyzed. At this stage, questions have to be answered like:

- What is the nature of the object or sample, and is it the elemental or molecular composition, or is it the presence of functional groups one is interested in?

• Does one need a quantitative analysis or a qualitative analysis do? What is the accuracy required in the case of a quantitative analysis?

• How much material is available for the analysis, and what is the approximate concentration of the compound of interest (the analyte)?

• What is the gross or 'matrix' composition?

• Is a single component analysis sufficient or is it desirable to do multi-component analysis?

• How much time is available between supplying the sample and the time at which the result has to be available, or in other words: what is the acceptable delay time (waiting time plus analysis time)?

• Will there be a recurrent supply of samples of this kind and, if so, with what frequency; or is it a unique analysis?

• Is it desirable to look for a continuous monitoring system and/or to look for a fully automated system?

• How crucial is the dependability of the analytical system or method?

• Can destruction of the object of study be tolerated, or should the integrity of the sample be preserved?

This survey of questions is by no means exhaustive and only aims at an impression of the kind of dialog needed to get the proper information in order to reach a proper choice of the analytical method.

The selection of procedure is of crucial importance. It determines the cost of analysis both in terms of instrumental effort and personnel. But it is also influenced by framework conditions, such as size of sample, time availability, and the information content one gets out of the analytical investigation.

After finishing the above preparation in advance, the quantitative analytical process can be started. The process can roughly described by the following main steps:

1. Sampling

The importance of the sampling stage can not be overemphasized. If the test portion is not representative of the original material, it will not be possible to relate the analytical result to that in the original material, no matter how good the analytical method is or how carefully the analysis is performed. Sampling is always an error-generating process, in which the homogeneity of the original sample material plays a major part. An analytical operator should never start an analytical procedure without knowledge of the history of the sample (sampling process, storage of sample, preservation, pretreatment, etc.) and of its representativity of the bulk material to which the analytical results will be related.