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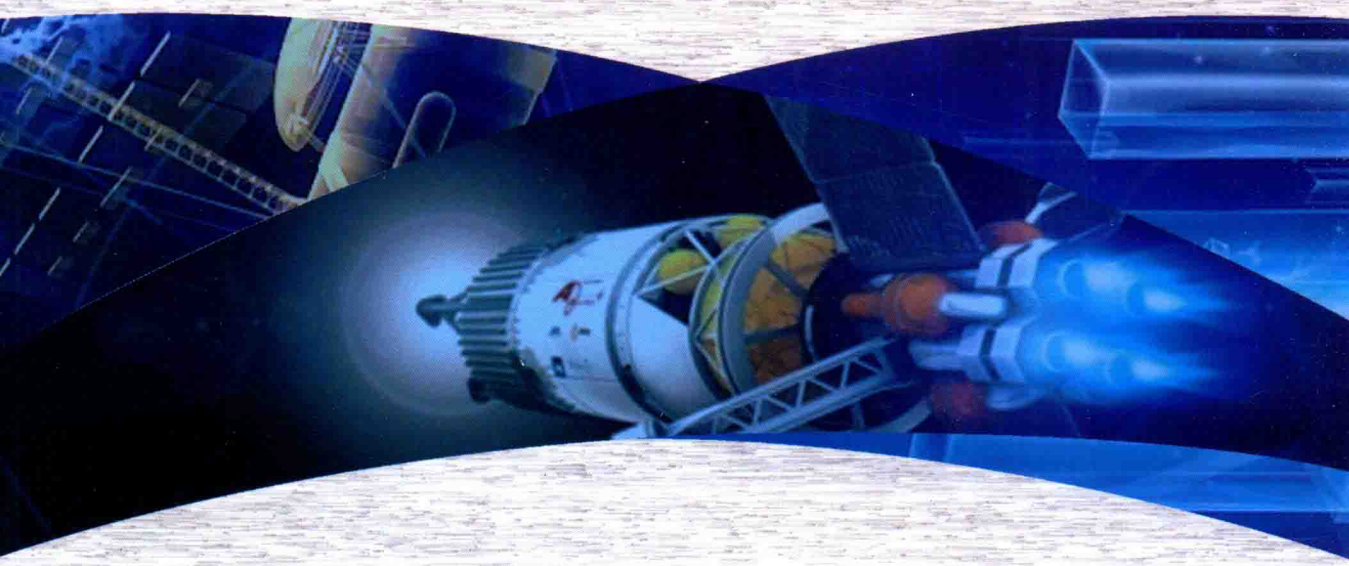
MODERN TECHNOLOGY OF PROPELLANTS FOR MISSILE

(Volume One)

Huang Zhiyong Dou Wenhui



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Modern Technology of Propellants for Missile

(Volume One)

黄智勇　窦文辉　编著

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【内容简介】 本书分上、下两册。上册分四个部分，共13章。第一部分介绍了液体推进剂仪器分析方法，包含仪器分析概述、气相色谱法、色质联用分析方法、近红外分析方法和自动颗粒计数分析方法；第二部分介绍了偏二甲肼分析，包含推进剂概述、偏二甲肼的使用与管理、偏二甲肼分析方法；第三部分介绍了硝酸-27S分析，包含硝酸-27S的使用与管理、硝酸-27S分析方法；第四部分介绍了DT-3分析方法。下册分四个部分，共17章。第一部分介绍了固体火箭推进剂，包括固体推进剂的性能及复合固体推进剂的制造概述；第二部分介绍了液体推进剂污染监测与治理，包括液体推进剂污染来源及特点、污染监测与环境评价、废气治理技术和废水处理技术；第三部分介绍了推进剂现代安全技术，包括安全基本原理、液体推进剂安全技术、固体推进剂安全技术和推进剂突发事故与应急处置；第四部分介绍了液体推进剂个体防护装备与检测方法，包括液体推进剂呼吸防护装备、躯体防护装备、手足部防护装备和个体防护装备检测方法等内容。

本书可供学习“导弹推进剂理论与技术”专业课程的本科生和研究生作为双语教材，也可供从事导弹推进剂研究的技术人员参考使用。

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前　言

双语教学是我国高等教育国际化趋势的发展需要，教育部先后于2001年、2004年、2005年和2007年出台了关于高等学校本科双语教学的文件，明确提出要提高双语教学课程的质量，扩大双语教学课程的数量，推动双语教学课程建设，探索有效的教学方法和模式，提高大学生的专业英语水平和直接应用英语从事科学研究的能力。

与传统的英语教学相比，双语教学更重视英语与学科专业的渗透，让学生全方位地应用英语。双语教学不仅仅让学生以英语为工具来获取知识，更重要的在于能够让学生了解国外先进的教育理念、教学模式和教学方法。同时，双语教学通过以第二语言学习学科知识为目的，塑造学生的跨文化意识，学生逐步达到双语思维，从而提高多维创新能力。

毋庸置疑，目前双语教学遇到较大困难。其中一个重要原因就是缺乏适合专业内涵及学生实际情况的教材。实践证明，解决双语教学教材问题的方法包括引进适合专业教学的原版教材、根据专业实际情况编写、翻译中文教材等。本书就是结合环境工程专业，针对液体推进剂分析和推进剂管理与使用两门课程开展双语教学而编写的。

本书是在中文讲义的基础上翻译而成的，教学讲义分别是苟小莉编写的《液体推进剂现代分析技术》，黄智勇编写的《偏二甲肼分析》《硝酸-27S分析》及《DT-3分析》，崔虎编写的《固体火箭推进剂》，张剑编写的《液体推进剂污染监测与治理》，吕晓猛编写的《火箭推进剂现代安全技术》和韩启龙编写的《液体推进剂个人防护设备及检测方法》。本书分上、下册，上册各部分及下册第1～3部分由黄智勇翻译，下册第4部分由窦文辉翻译，全书由窦文辉统稿。对于各位老师在中文讲义编写中所付出的辛勤劳动，以及对译者在翻译过程中提供的有益帮助表示衷心感谢。本书的出版得到了第二炮兵工程大学训练部的大力支持，在此一并表示感谢。

由于水平有限，肯定会有疏漏和翻译不当之处，敬请读者和专家批评指正。

编　者

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PART Ⅰ INSTRUMENTAL ANALYSIS

CHAPTER 1 GENERALIZATION OF INSTRUMENTAL ANALYSIS

Instrumental analysis is widely used in the controlling and management of manufacturing procedure, exploration and promotion of new material. Analytical chemistry, which is the foundation of modern technology of analysis, is a course to study the analyzing methods of the chemical compositions of matters and theories concerned. This branch of science underwent three great revolutions in its development. With the development of the basic theory of analytical chemistry, especially the development of basic concept of physical chemistry, analytical chemistry is transformed from a technique to a branch of science. The second revolution is due to the development of physics and electronics which changed the state of taking chemical analysis as the main means and developed instrumental analysis. At present, analytical chemistry is undergoing the third revolution. With the development of production, science and technology, analytical chemistry is now applied in all fields of science and technology.

Instrumental analysis technology is based on the measurement of the physical properties of matters. Because this technology needs some special instruments, it is called "instrumental analysis". With the development of science and technology, deep changes take place in analytical chemistry in the aspects of methods and experimental technology, especially the appearance and wide applications of new instrumental analytical methods, thus the instrumental analysis accounts for more proportion in analytical chemistry and becomes the important supporter of modern experimental chemistry. In the area of quality analysis for liquid propellant, the traditional analytical methods are gradually replaced by the instrumental analysis. The analysis for liquid propellants, such as hydrazine species and nitro oxidant, depends more and more on instrumental methods. Some basic principle and experimental technique of the more instrumental analytic technology are becoming the basic knowledge and basic technique of analyzing staff of liquid propellant.

1.1 GENERALIZATION OF MODERN ANALYTICAL TECHNOLOGY

The development of science and technology requires highly analytical chemistry in increasing the precision and accuracy of measurement. In order to meet the precision requirements of weapons, the requirements of component analysis in liquid propellant field are increased continuously. So the application of modern technology of instrumental analysis in the analysis of liquid propellant, especially the combination technology of separation technologies, such as gas chromatography, and verification methods, such as mass spectrum, can combine their advantages together, and cooperate with each other to improve the precision and accuracy of method and resolution capacity of impurity mixture in liquid propellant. It also acquire some functions which cannot be got with any single means only.

According to analytical methods, analytical chemistry can be classified into chemical analysis and instrumental analysis. Instrumental analysis is classified into three varieties: electrochemical analysis, chromatographic analysis and photometrical analysis. Modern analytical technology mainly means the above-mentioned three technologies.

The electrochemical analytical technology is based on the electrochemical properties of solutions, including potentiometric analysis method, electroweight analysis method, Coulomb analysis method, voltampere method, polarogram method and conductivity method.

The chromatographic analysis technology is used to attain the separation of all components in a mixture according to the differences of their physical or chemical properties. The separated components can be analyzed qualitatively or quantitatively. Sometimes separation and determination are conducted at the same time and sometimes separation is earlier than determination. Chromatographic method includes gas chromatography and liquid chromatography.

Photometrical analysis is based on the transaction between the substance and electromagnetic radiation, including atomic emission spectroscopy, atomic absorption spectrum, ultra-visible absorption spectrum, infrared absorption spectrum, nucleus magnetic resonance spectroscopy and fluorescence method.

The varieties of modern analytical methods are various. According to the actual condition of liquid propellants, some commonly used analytical methods and technologies shall be discussed in this book.

- Gas chromatographic method
- Gas chromatography-mass spectrum combination method
- Near infrared spectrum method
- Automatic counter of particulates

1.2 CHARACTERICS OF MODERN ANALYTICAL TECHNOLOGY

Modern analytical technology is to acquire the chemical constituent, content and chemical structure, of substances by means of measuring the parameters and their changes of some physical or physicochemical properties of substances with instruments. The analytical objects of the modern technology of analysis are generally in semimicro grade (0.01—0.1 g), micro grade (0.1—10 mg) or supermicro grade (<0.1 mg). Modern instrumental analysis for the sample components analysis is characterized as simple, rapid operation and most instruments transfer the concentration changes or the physical property changes of components into some kind of electric properties, such as resistance, conductivity, electropoential, capacity and current, etc. so it is easy for the modern instrumental analysis to be automated and intellectualized to get rid of the manual operation in the traditional laboratory. Its basic characters include:

1) High sensitivity. Most instrumental analysis is suitable for micro analysis and trace analysis, such as the water, dimethylammine and unsymmetrical hydrazone in UDMH.

2) Small quantity of sample. Chemical analysis needs sample in the range of 10^{-1}—10^{-4} g; instrumental analysis needs sample in the range of 10^{-2}—10^{-8} g. For example, the chemical analysis for UDMH needs sample in the range from 500—1000 mL while the instrumental analysis needs only 50—100 mL.

3) Higher analytical accuracy at low concentration. The relative error is lower in the range of 1%-10% when the content of impurity is in the scope of 10^{-5}%—10^{-9}%.

4) High speed. Chromatographic method needs 5 minutes for one UDMH sample while chemical analysis needs 3—5 days.

5) Non-destructive analysis is possible. Sometimes the determination of non-destruction can be conducted. Surface or microarea analysis with some method can be conducted.

6) Analysis of multi information or special function can be conducted. Qualitative and quantitative analysis can be conducted simultaneously.

7) Strong specialty. For example, the ion selective electrode can determine the concentration of a given ion.

8) Convenient for remote checking, remote controlling and automation. Instantaneous and on-line analysis can be conducted to control producing procedures and environmental monitorings.

9) Simple operation. Omit many complex chemical operating procedures. With the increase of automation and programming, the operation shall be simpler.

10) Instrument is complicated and expensive.

1.3 DEVELOPMENT OF MODERN ANALYTICAL TECHNOLOGY

Since the emergence of instrumental analysis in 1930s, the content of analytical chemistry has been enriched and a series of fundamental changes has been made for the analytical chemistry. With the development of science and society, analytical chemistry is facing deeper, wider and more serious changing. The replacement of modern analytical instrument, application and renewing of new methods and new technology of instrumental analysis are the important changes. Modern instrumental analysis is playing a very important role in the analysis for liquid propellant.

Optical analysis method has been developed as an analytical method based on the knowledge of the photometric properties of substances. After Newton separated white light into spectrum in the 17th century, scientists made a lot of researches on spectrum. In the first half of the 19th century, scientists had connected a characteristic spectrum with a substance and proposed the qualitative analysis concept. On this basis, German chemist Benson and physicist Jerhuff produced the first optical spectrometer cooperatively to realize the transition from spectroscopic principle to the spectroscopic analysis and formed a new analytical method, i. e. spectroscopic method. In late 19th century, the possibility of quantitative analysis with spectrum was researched. In 1874, Lokai got the conclusion from great amount of experiments that the quantitative analysis of spectrum could only depend on the intensity of spectral line. Till the 20th century, the intensity of spectral line is determined through photoelectrical method. After that, the photomultiplier was used to the quantitative analysis of spectrum. At the same time, another method in spectroscopy, using the absorption spectrum of substance, was developed.

The combination of computer and analytical instrument formed the intellectualization of analytical instrument and accelerated the data processing. It made many tasks, hardly completed before, such as automation of laboratory, rapid browser of spectroscopy and complex mathematic statistic, completed easily nowadays. The collection and transformation of information mainly depend on sensors. This led to the development of sensors in instrumental analysis and formed chemical sensors of optical conductive fiber and all kinds of biological sensors. Combination technology of instrument has become an important developing direction of instrumental analysis. Combining all these methods, especially the combination of separation method, such as chromatography, and inspection methods, such as infrared spectroscopy, mass spectrum, nuclear magnetic resonance and atomic absorption spectroscopy, accumulates the advantages of all methods and avoids their own disadvantages to conduct the sample analysis.

The development of analytical instrument and methods revitalized the analytical chemistry and made the analytical chemistry change from typical analysis, chemical analysis

oriented, to the modern analysis, instrumental analysis oriented. The application of instrumental analysis is widened gradually into the concerned courses. Analytical instrument shall be developed in the direction of small-sized, special type, combination, automation and intellectualization. Modern technology of analysis shall accumulate all new materials, new apparatus, microelectronic technology, laser, artificial intelligence, digital picture processing and chemical metrology to make the ability of analytical chemistry of getting the substance information involving quality, quantity, state, shape, structure and microarea increased greatly.

In order to adapt to the development of science, the modern instrumental analysis shall be developed with the following trends.

1) Methods innovation. The sensitivity, selectivity and accuracy of instrumental analysis methods should be improved further

2) Intellectualization of analytical instrument. Computer can be used to calculate the analytical results, and also can be used to store the analytical methods and standard data, to control the operation of instrument and to realize the automation of operation.

3) New dynamic inspection and non-destructive inspection. Off-line inspection cannot reflect the real situation of manufacturing and live environment instantaneously, directly and accurately nor control the production, ecology and life procedure in time. With the advanced technology and analytical principle, studying and establishing effective, real-time, on-line, highly sensitive, highly selective and non-destructive inspection methods shall be the main flow of instrument development in the 21th century. At present, biological sensors, enzyme sensors, immunity sensors, DNA sensors, cell sensors come into being continuously. Nanometer sensors provide an opportunity for living organism analysis.

4) Combination of many methods. The combination of many instrumental methods can exert the advantages of all methods and make up for the disadvantages of each method.

5) Expanding the time space multidimensional information. With the booming of environmental science, universe science, energy science, life science, clinic chemistry and biological medicine, the modern instrumental analysis is used not only to characterize and measure the separated component, but also to provide chemical information for substances as much as possible. With the deepening of the knowledge for the objective matter, some areas not well-known before, such as multidimensional, unstable and boundary condition, are gradually put on the schedule. Using modern nuclear magnetic resonance spectrum, mass spectrum, and infrared spectrum can provide fine structure, space arranging constituent and instantaneous changing for organic molecules and supply important basis for people to understand the chemical reaction mechanism and life.

All in all, modern analytical technology is being developed towards high speed, good accuracy, high sensitivity and good adapting to the special analysis.

CHAPTER 2 GAS CHROMATOGRAPHIC ANALYTICAL TECHNOLOGY

2.1 GENERALIZATION

Chromatography is a separation method. Different substances have different distribution coefficients in two phases. When two phases make relative movements to each other, the repeated distributions of these substances in two phases many times realize the separation of substances.

2.1.1 CLASSIFICATION OF CHROMATOGRAPHY

Chromatography is classified according to the following criteria.

1. Classified according to the states of two phases

In Tswett experiment, calcium carbonate is fixed, called stationary phase and petroleum ether is moving, called mobile phase. According to the state of mobile phase, the chromatography is called gas chromatography if the mobile phase is gas; it is called liquid chromatography if the mobile phase is liquid and it is called supercritical fluid chromatography if the mobile phase is supercritical fluid.

According to the state of stationary phase, gas chromatography can also be classified into gas-solid chromatography and gas-liquid chromatography. Similarly, liquid chromatography is classified into liquid solid chromatography and liquid chromatography.

2. Classified according to separation principle

In chromatography, the properties of stationary phase play a decisive role in the separation of a mixture.

The distribution chromatography is named according to the solubility of different components in the stationary solution. Gas-liquid chromatography in gas chromatography and the liquid-liquid chromatography in liquid chromatography all belong to distribution chromatography.

The absorption chromatography is named according to the absorption and desorption ability of components on the absorbents. The gas-solid chromatography in gas

chromatography and liquid-solid chromatography in liquid chromatography belongs to absorption chromatography.

3. Classified according to the type of stationary phase

The column chromatography is named when the stationary phase is inside column, including packaged column chromatography and open tube column chromatography. The packaged column chromatography is named when the stationary phase is filled fully inside glass or metallic tube. It is called open tube column or capillary chromatography when the stationary phase is on the inner wall of the tube.

It is called flat-bed chromatography when the stationary phase is in the plate state, including paper chromatography and thin layer chromatography. The former uses filtering paper absorbing water as stationary phase and the latter uses the absorbent coated on the glass plate as the stationary phase.

4. Classified according to the material of stationary phase

The ion exchange chromatography takes the ion exchange agent as the stationary phase. The dimension exclusion chromatography takes the porosity glass or the porosity polymer with certain scope of aperture as the stationary phase and the bonded phase chromatography takes the chemical bonded phase (bond the stationary solution on the multi carrier by means of chemical reaction, such as silica gel) as the stationary phase.

There are many kinds of chromatography, which can be classified with different classification methods. Generally, the following two methods are used for classification, the state of stationary phase and the state of mobile phase, seen as table 2 - 1.

Table 2 - 1 Classification of chromatography according to the states of two phases

Mobile phase	Name	Stationary phase	Name of chromatography
Gas	Gas chromatography(GC)	Solid	Gas—solid chromatography(GSC)
		Liquid	Gas—liquid chromatography(GLC)
Liquid	Liquid chromatography(LC)	Solid	Liquid—solid chromatography(LSC)
		Liquid	Liquid—liquid chromatography(LLC)

2.1.2 ANALYSIS FLOW OF GAS CHROMATOGRAPHY

Fig. 2 - 1 is the analysis flowchart of gas chromatography. The nitrogen (N_2) and hydrogen (H_2), provided by high pressure cylinder, enter the cleaning device through the reducing valve to eliminate the impurities and water inside, and then the pressure and flow of carrier gas are controlled by pressure stabilizing valve and needle shaped valve. In the end the carrier gas enters the chromatographic column through gasification room. After the flow of carrier gas, the temperature in gasification room, column, detector and the baseline of recorder are stabilized, the sample shall be injected into the gasification room through injector and the liquid sample shall be gasified at once and carried into column by means of the carrier gas. Because the absorption ability and solubility of different components of