

Basic Education in Analytical Chemistry

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In advance of discussing the basic education in analytical chemistry, the brief history of analytical chemistry is described to recognize its present situation. To understand how to get an accurate and detailed chemical information and recognize that analytical result has to be always correct is emphasized as a goal of the basic education in analytical chemistry. The standard curriculum of analytical chemistry for undergraduates proposed by the Japan Society for Analytical Chemistry in 1999 is shown. The results of the investigation of analytical chemical education at universities in Japan is also discussed.

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In recent years, research in analytical chemistry has concerned mainly on the development and application of physical and physicochemical analytical methods, instrumental analysis, which in their speed and sensitivity have far surpassed the classic methods of gravimetric, and even volumetric analysis.

Almost all researchers in natural science field have been supported by analytical data in 20th century. Analytical methods have been improved by the progress of the analytical instruments based on the physical measurement supported by the electronics. Many Nobel prizes of chemistry and physics were given to the investigations of new method of analytical measurement. The goal of analytical measurement has been always how to get high sensitivity and selectivity.

Now in analysis the final detection is carried out almost instrumentally. Students have to learn many informations about instrumental analysis. But in the case of analyzing real samples the most important problem is how to treat them before the instrumental measurement, that is, decomposition of sample, separation from matrix, preconcentration etc. Instrumental analysis is based on to compare the signal from the sample with that from standard. Recently standard solutions for instrumental analysis are easy to get on the market. But in the basic education in analytical chemistry it is important to teach how to get the accurate amount of a particular substance in a sample absolutely by weighing the precipitation or measuring the volume of the solution. Gravimetric analysis and volumetric analysis are considered to be fundamental still now. Most students studying chemistry in universities specialize in other field than analytical chemistry. But they will discuss their research results on the basis of the analytical data in the future. Analytical data have to be always correct. Incorrect data will lead the conclusion to the wrong way. I would like to emphasize that the basic education in analytical chemistry for future generations of chemists is to teach how to get the accurate analytical data. For this purpose the desirable curriculum of analytical chemistry is considered to be composed of chemical analysis, separation chemistry and instrumental analysis, including experiments to learn the analytical methods and techniques.

Brief History of Analytical Chemistry

Chemistry was founded on the analysis, because it is said that chemistry had been called as Scheidekunst in German, which means to isolate material into components. In the latter half of 18c. balance was used to investigate the chemical change of the substances by weighing. Up to the latter half of 19c. about 90 elements were discovered by the support of analytical chemistry. Inorganic qualitative and quantitative analysis were systematized.

Organic chemistry had a great progress due to the elemental analysis developed by Liebig and the systematized organic analysis based on the specific reaction of functional groups.

Instrumental analysis began with the flame emissive spectrometry by B.Bunsen and R.Kirchhoff who discovered Rb and Cs in 1860. About 100 years after that AAS was developed. IR in 1930s', and new ideaed spectral methods were successively born. MS which contributed to the research of isotopes was applied to the organic analyses for the identification of organic compounds in combination with GC. Electrochemical analyses including polarography were also developed. Analytical instruments, spectrophotometer in 1941, IR in 1943, self-recording IR and direct-reading emission spectrophotometer, self-recording spectrophotometer in 1951, GC and NMR in 1953 and DSC in 1961 and so on, were in the market. Now we know that innumerable instrumental analytical methods including physical and biological assay are supporting researches in wide research fields, medical diagnosis and many kinds of industry as shown in Table 1.

Development of a new concept in analysis was "Characterization" which was discussed by National Research Council in U.S.A. in the period from 1967 to 1970. This is important for the manufacture of materials, research of material science and has to be useful for the reproduction of materials. Characterization is accomplished by integrated analysis which includes elements analysis, organic analysis, state analysis, structure analysis and surface analysis as shown in Table 2.

Table 1 Analytical Chemistry -It's Social Contribution-

* Development of industrial materials
* Support of the research of vital phenomenon
* Diagnosis of Environment
* Medical diagnosis and treatment
* Scientific investigation of offense
* Quality assurance of medical supplies
* Support of improvement of foods in quality

Table 2 Development of a New Concept in Analysis

Characterization
* Discussed by National Research Council in U.S.A. (1967~1970) for the development of solid industrial materials
* important for the manufacture of materials, research of the material science
* useful for the reproduction of materials
Integrated Analysis
* Elemental analysis ; AES, AAS, NAA, ICP-MS
* Organic analysis ; IR, NMR, GS/MS
* State analysis ; XRS, NMR, ESR, XRD, EPMA
* Structural analysis ; SEM, STEM, EDA, XDA
* Surface analysis ; AES, SIMS, XPS

Analytical Chemical Education for Undergraduates at University

As described before now is the time to use instruments for analysis. As any time analytical data are used for the evaluation of original investigation, medical diagnosis, environmental assessment, development of industrial materials and the like, they have to be correct. The important thing is that instrumental analysis is the final step of analysis, that is to say, instrumental analysis is the measurement. Analysis consists of collection of sample, decomposition, separation, concentration, detection and measurement, and treatment and assessment of analytical data. Instead of instrumental analysis, the word "assay" may be better. We apply instrumental analysis to the step of detection and measurement. Students have to learn all these procedures of analysis including instrumental measurement. To understand how to assess the analytical data, they have to know the meanings of accuracy and precision and consider about error which occurs in each procedure. In the future they will try to make an effort to reduce the error to the minimum and choose the most appropriate analytical instruments with the suitable sensitivity for the sample analysis. But I would like to emphasize classic chemical analysis such as gravimetric and volumetric analyses is fundamental in the basic education in analytical chemistry still in these days, because they are absolute analytical methods based on weighing exact weight of the precipitation or measuring exact volume of the solution. Instrumental measurement is based on comparing the signal due to the sample with that due to the standard substance or solution which has sometimes to be standardized by volumetric or gravimetric analysis. In the case of instrumental measurement it is said that most important process is to prepare exact standards. Considering these matters described above such lectures and experiments as shown in Table 3 are offered for undergraduates, in my university, Japan Women's University.

Table 3 Analytical Chemical Education at Japan Women's University

Lecture	
* Chemical analysis	Analytical Chemistry I
* Separation analysis	Analytical Chemistry II
* Practice to solve problems	Analytical Chemistry Seminar
* Instrumental analysis	Instrumental Analysis
Experiment	
* Qualitative analysis, Volumetric analysis	
Experiment of fundamental chemistry (a part of the subjects)	
* Spectrophotometry, Ionselective Electrode	
Experiment of Inorganic and Analytical chemistry	
* AAS, IR, HPLC, GC, ICP-MS, ICP-AES, SIMS, electrochemical analysis, decomposition technique	
Experiment of Instrumental Analysis	
* Analysis of environmental samples by means of AAS, GC, HPLC, IC	
Experiment of Environmental Analysis	

Investigation of Analytical Chemical Education at Universities in Japan by the Japan Society for Analytical Chemistry

The Japan Society for Analytical Chemistry had a committee to discuss the matter for the establishment of a new and common curriculum of analytical chemistry for undergraduates in 1995. The first work was the investigation of the present situation of undergraduate education of analytical chemistry at universities in Japan.

As for the faculty of science six credits given for the lectures of analytical chemistry are most popular and 8 credits are next for the undergraduates belonging to the department of chemistry and the like.

The contents of the lecture and the experiment briefly consist of chemical analysis (classical analysis) and instrumental analysis. The ratio of chemical analysis in lecture holds 1/2 to 2/3 at almost all universities, whereas that in experiment holds 2/3 to 3/4 at national and public universities and about 1/2 at private universities. Four credits are given for experiment on average.

On the other hand as for faculty of engineering 4 to 6 credits are given for the lecture in general for the undergraduates belonging to the department of chemistry and the like. The ratio of chemical analysis in lecture holds 1/3 to 2/3. Two or three credits are given for the experiment. The ratio of chemical analysis in experiment is 1/2 to 2/3 on an average. About 1/4 of universities achieve just chemical analysis.

Subjects taken in lectures and in experiments were investigated as for faculty of science and that of engineering. The results are shown in Fig.1 and 2. Though not so many differences are observed between both faculties, if remotely compared two subjects, "solvent extraction" and "assessment of analytical data", are adopted in faculty of science in many universities. Chromatography is adopted more in f. of engineering than f. of science. Whereas electrochemical analysis is adopted more in f. of science. Structure analyses, IR, MS, NMS, and the like, are considered to be taken mainly in the field of organic chemistry or physical chemistry.

In present situation the ratio of instrumental analysis taken in the subjects of laboratory experiment is not sufficient. It seems to be important to increase the ratio of instrumental analysis by keeping the balance between classical chemical analysis and instrumental analysis. Though qualitative analysis is a important subject to understand properties of elements about 2/3 of universities don't take it in the subjects of laboratory experiment. Especially the contents of experiment is a important problem to be discussed.

The Japan Society for Analytical Chemistry proposed a standard curriculum of analytical chemistry by taking account of

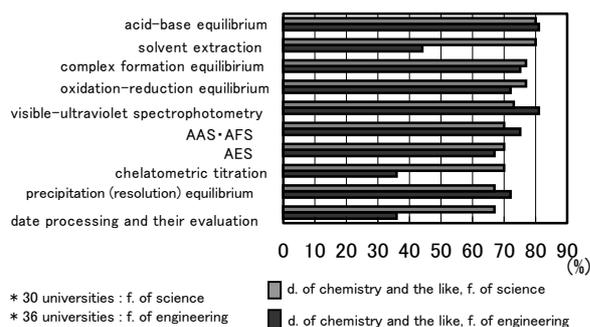


Fig. 1 Subjects in Lecture

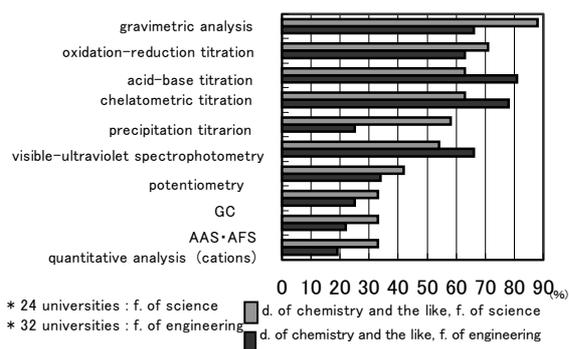


Fig. 2 Subjects in Experiment

the recent trend of analytical chemistry as shown in Table 4. A standard textbook is to be published in 2002.

Table 4 The Standard Curriculum of Analytical Chemistry proposed by JSA

I The Elements of Analytical Chemistry
1.1 What is Analytical Chemistry?
II Chemical Analysis
2.1 Volumetric Analysis (including fundamental chemical equilibrium)
2.2 Separation and Concentration
2.3 Chromatography and Electrophoresis
III Physical Analysis
3.1 Elements Analysis -Atomic Spectrometry-
3.2 Molecular Spectrometry
3.3 Electrochemical Analysis
3.4 Thermal Analysis
3.5 Microbeam-Surface Analysis
3.6 Structure Analysis
IV Biological Analysis
V Analytical Chemistry in Future

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