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Analytical Chemistry – today's definition and interpretation

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Definition

Analytical Chemistry is the chemical metrological science. Its major objectives in the late XX century can be summarized in one: obtaining more qualitative, quantitative and structural information of greater quality on any type of matter or system by expending less material, time, effort and economic resources (Fig. 1).

Of the three cornerstones of chemistry, namely theoretical foundations, synthesis and analysis, Analytical Chemistry is deeply concerned with the last.

Today's Analytical Chemistry is composed of three essential, dynamically related parts, namely: (a) basic and applied research and development (R & D); (b) the arsenal of techniques and methods that was formerly referred to as "chemical analysis"; and (c) education.

Samples and analytes are no longer the targets of today's Analytical Chemistry, but rather the underlying analytical problem within a matter of social or R & D concern (Fig. 2). This requires Analytical Chemistry to be interfaced to one or more areas of knowledge, in accordance with current trends in science and technology, in order to fulfil its objectives (Fig. 3).

Interpretation

The results generated by an analytical laboratory and their interpretation influence information, nowadays regarded as the fourth social power (in addition to the legislative, executive and judicial powers), and the fourth essential component of modern economy (in addition to capital, work and raw materials). As such, they are a solid cornerstone for correct, timely decision-making since any scientific-technical R & D activity requires quality analytical information.

The present and future significance of Analytical Chemistry is only questioned by those who rely on past achievements and are completely unaware of its high potential, and by those who regard its present consolidation as a matter of professional concern.

The history of Analytical Chemistry can be divided into three rather than the two ages traditionally considered, namely classic, modern and contemporary, the time bounds of which are rather difficult to define accurately. Instrumentally, these three ages are characterized by the use of the balance (classic), an avalanche of instruments such as polarographs, photometers, potentiometers, mass spec-

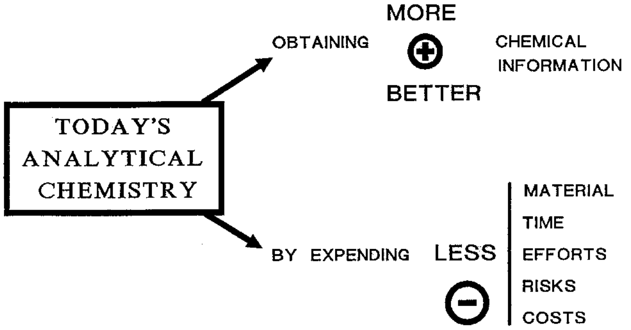

Fig. 1. Basic aim of today's Analytical Chemistry

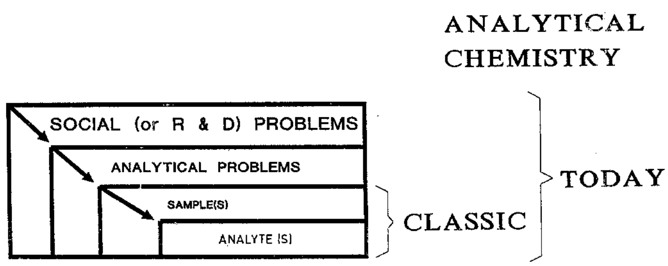

Fig. 2. Generic fields of action of classic and today's Analytical Chemistry

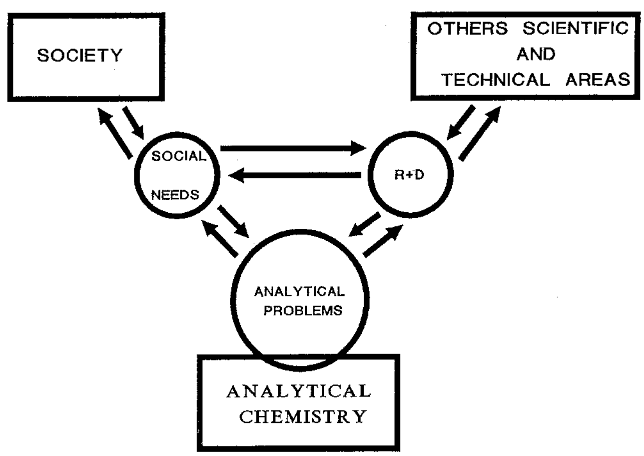

Fig. 3. Relationships between today's Analytical Chemistry, society and other scientific-technical disciplines

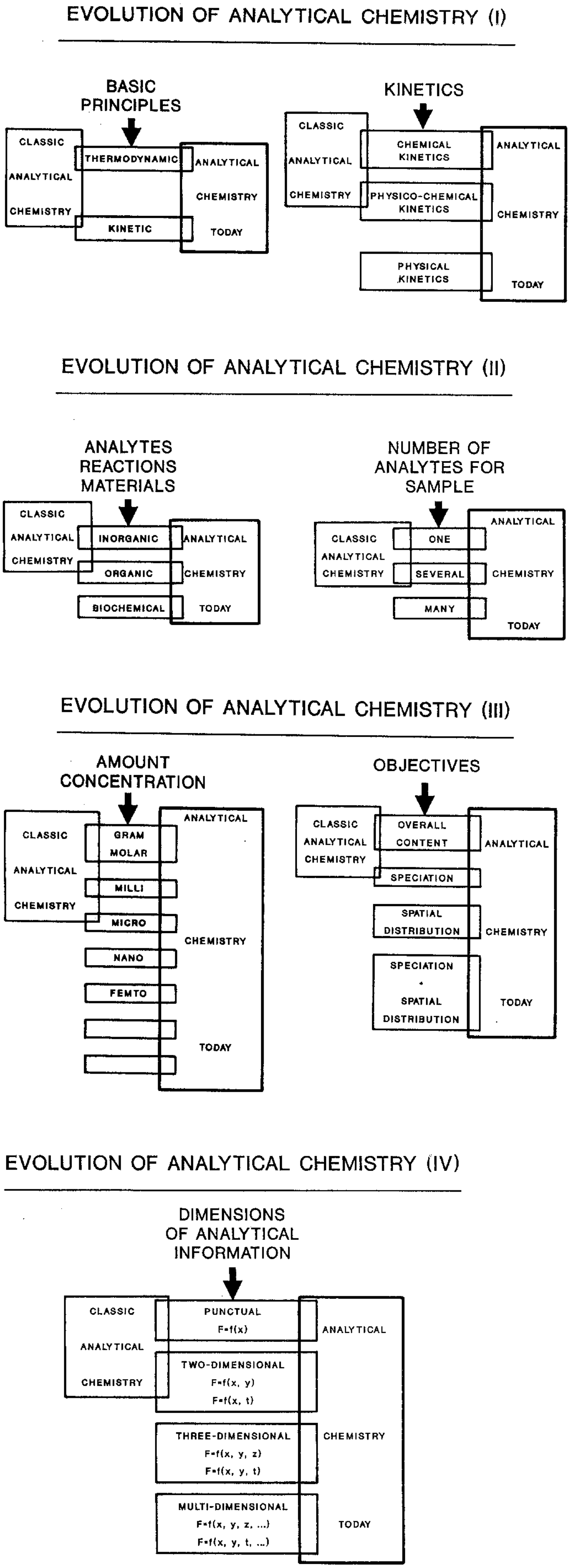

Fig. 4. Evolution of Analytical Chemistry [1]

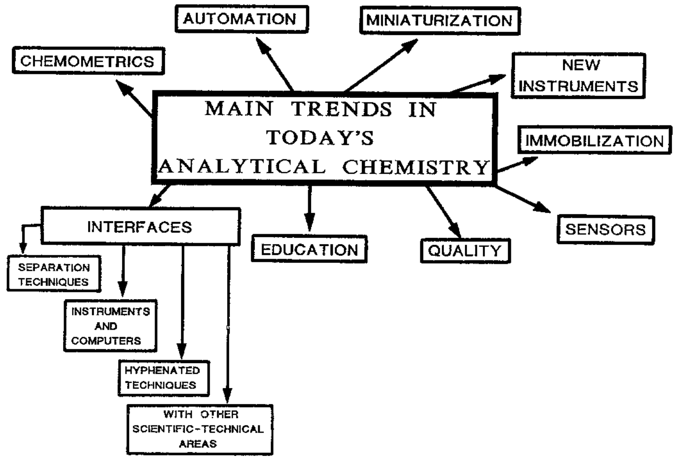

Fig. 5. Fields of action of today's Analytical Chemistry

trometers, fluorimeters, chromatographs, etc. (modern), and the advent of (micro)computers (contemporary), respectively.

Figure 4 illustrates the conceptual evolution of Analytical Chemistry from various points of view [1]. The basic principles of Classic Analytical Chemistry were essentially thermodynamic in nature, with some kinetic touches. Kinetics is by now as significant to Analytical Chemistry as is thermodynamics. Chemical kinetics was virtually the sole type of kinetics dealt with in minimizing the adverse effects of slow reactions or taking advantage of the assets of kinetic methods of analysis. Nowadays, physical and physico-chemical kinetics play major roles in Analytical Chemistry: the time dimension has propitiated the development of impressive approaches such as time-domain electroanalytical techniques, pico-second spectroscopy and methods based on fast detectors.

The typically inorganic materials of the classic age are currently complemented by organic and biochemical reactants. The growing potential of Analytical Chemistry is being accompanied by a marked increase in the number of analytes that can be determined most efficiently and conveniently in a single sample. The limits of detection and/or determination of many analytes have also been lowered to spectacular levels, particularly with the inception of such novel analytical techniques as immunoassays. The goals of analytical determinations have also evolved in a spectacular fashion in response to the pressing needs faced; thus, the overall content of a given analyte in a sample is no longer adequate and must be supplemented by such information as the different forms in which the analyte may be present in the sample and the proportion in which each occurs. The so-called "speciation" is a key not only to environmental control, but also to other areas such as clinical chemistry (e.g. determination of the overall and ionic calcium content, free and HDL cholesterol, etc.), food chemistry (e.g. determination of free and bound sulphur dioxide in wine), and pharmaceutical chemistry (e.g. resolution of mixtures of enantiomers). Analyses of solid materials should now include the determination of spatial arrangements, for which surface analysis techniques are particularly useful. The integration of several analytical techniques allows for speciation and determination of spatial arrangements.

The best testimony to the extensive development of Analytical Chemistry is probably the wealth of information provided by analytical processes based on different techniques. Thus, while gravimetries and titrimetries provide one-dimensional information (isolated data), instrumental techniques afford two-dimensional information [e.g. F(x,y) or F(x,t), where x denotes the measured signal, y the instrumental variable concerned and t time]. Analytical processes that provide multi-dimensional information will predictably have a brilliant future. The higher the information level obtained, the more essential becomes the use of a powerful (micro)computer.

Figure 5 summarizes the main fields of action of today's Analytical Chemistry in relation to the basic objectives stated as defined above. Some, such as automation and miniaturization, two fundamental keys to the development of new analytical instruments, are liable to integration. Also, chemometrics can be regarded as an area of automation, while immobilization is essential to the development of sensors and new analytical separation techniques.

Interfaces are of paramount significance to Analytical Chemistry today. They can be of pure physico-chemical nature (e.g. in separation techniques), electronic (between instruments and computers, which exert a passive or active control on the former), and inter-disciplinary (with other scientific-technical areas).

No doubt, the development of reliable (bio)chemical sensors is quite an interesting goal since they allow for simplified, highly enhanced analytical processes.

Of special note in this context is the growing significance of quality to analytical laboratories, so much so that it calls for open minds and major changes in work policies from laboratory officials in order to meet the increasing needs of present society's market economy.

As far as education is concerned, Analytical Chemistry tutors should at any rate narrow the gap between what is taught and what is actually being used at the moment, not only to instruct analytical chemists, but also to make basic concepts of this discipline accessible to other professionals. This pedagogical process should be guided by education rather than by information.

Conclusions

Analytical Chemistry is thus the science of chemical measurements. As such, it can and must help to solve social and R & D problems by resolving underlying analytical problems. In so doing, this discipline must be placed in the scientific-technical context where it belongs and isolationist positions must be avoided. Today's and tomorrow's Analytical Chemistry does not begin at the laboratory door and ends at the printer or plotter.

Research and development (R & D) strategies, existing analytical methods and techniques and constructive education are the essential ingredients of Analytical Chemistry if it is to fulfil its generic informative objective veraciously, efficiently and rapidly with little human and economic expenditure.

References

1. Valcarcel M (1990) Quim Anal 9:215