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Some Trends in Modern Analytical Chemistry

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Abstract

Twelve trends in analytical chemistry are considered, mostly general ones: movement towards out-of-laboratory, speciation, non-destructive analysis, automatization and miniaturization, pattern recognition, moving towards more active application of achievements of physics or biochemistry. Directions of the changes in analytical techniques, e.g., their hybridization, are also discussed. There are changes even in analytical community and approaches to education.

Keywords: Analytical chemistry; Trends; Analytical techniques; Community of analysts

Introduction

Valcarcel Cases [1] has noted three most important, to his opinion, modern trends in analytical chemistry: automatization, miniaturization, and simplification of analysis. Seven trends were mentioned in my quest Talanta editorial [2]. The more comprehensive description of twelve significant directions will be given in this article.

I do not intend to mention the permanent challenges, known trends, namely the willness to improve sensitivity, selectivity, and accuracy and the trends to rapid and cost-effective analysis.

Chemical analysis is becoming more and more on-site (moves "to the field"). Needs for such analysis are very strong. There are analyses that cannot be, in principle, done in the laboratory (methane in coal mines, chemical weapons in the field and many other cases). Many such analyses are carried out on a wide scale, e.g., determination of glucose in blood at home using portable glucometers.

There are already many tools for out-of-laboratory analysis: mobile laboratories (palliative tools), portable instruments, chemical sensors, test kits. Spectrometric devices for remote analysis can be mentioned separately, for example, diode laser spectrometric instruments for the detection of explosives, illicit drugs or chemical weapons. As to test kits, there are now many different chemical and biochemical test tools in different forms: indicator tubes, ampoules, tablets, paper stripes, and others.

From the determination of the total content of elements to speciation analysis, that is to detection and determination of chemical and physical species of analytes. This trend is obvious in elemental analysis: we determine different oxidation states of As, Cr, Fe, Mo or different chemical forms of these and other elements, especially Hg, Sn, and Se. Speciation analysis is of importance for environmental analysis, geochemistry, materials science, and in many other fields. Well known is, e.g., the different toxicity of various Cr, Hg, or As species. Similar analytical tasks will be topical for many other elements. (By the way, "speciation analysis" is also significant for some organic compounds, for instance for substances having optical isomers of different pharmaceutical activity.)

Methodology of speciation elemental analysis is usually based on a combination of separation (chromatography) and determination (spectrometry) steps. This approach cannot be considered as ideal; for example, a shift in an equilibrium during the separation of species is possible; in this case, the pattern of species distribution will be wrong. Direct detection and determination of species is, of course, more effective; however, there are not so many techniques for this purpose. Stripping voltammetry, partially ESR and Messbauer spectrometry are used in elemental speciation analysis (and NMR for organic compounds).

Trend to the non-destructive analysis of solid samples

This direction is not novel, it was always significant in industry, archeology, forensic science, arts and other areas, but its practical implementation was not easy (however, Archimedes carried out such an analysis in the 3th century BC). The number of techniques available for non-destructive analysis is now increasing; however, not so fast. X-Ray methods are most important, especially XRF; in some cases, neutron activation analysis, ESR or Messbauer spectrometry can be used.

Automation of analysis

Automation is mostly needed for the widespread analysis of unitype samples and, vice versa, not convenient for the analysis of small number of very different samples. Approaches to automatization are various for solving industrial and laboratory problems. In metalurgical plants, there are systems including tools for fast sampling, pneumo mail for samples transportation to a laboratory, automatic analysis using, e.g., XRF and atomic emission spectrometers, facilities for sending results to workers and tools for storing and treatment of analysis results. Automatic analytical systems in chemical and petroleum industry are usually based on gas chromatigraphy. Automatic systems for laboratory analysis often include continious flow (agriculture, pharmaceutical industry) or flow injection analysis. Laboratory robots are also used though not so often.

Everybody knows about the automatization of analytical instruments (autosamplers, databases, data treatment, control of instruments using microprocessors and so on).

Miniaturization of analytical tools and the analysis as a whole

Miniaturization makes it possible to descrease demands in working space, reagents, water, power etc. This trend is absolutely clear in respect to analytical devices whose size is decreasing similarly to computers. In 1960s or 1970s, for example, IR spectrometers were heavy and bulky (and standed on the floor), now they are benchtop, their dimensions decreased but the potential is growing. Mass spectrometers show the similar picture.

During the last 15-20 years, many mini-analysers and more versatile mini-devices, which can be considered as hand-held devices, have been developed, especially for gas analysis (not so many for water analysis). Mini-photometers, electrochemical devices, portable instruments for detection of explosives and narcotics (based mostly on ion mobility spectrometry) and even mass spectrometers can be mentioned. Pistol-form instruments based on IR, XRF and AES are widely used.

Since the beginning of 1990s, microfluidic devices on microchips were developed, mostly for capillary electrophoresis, but not exclusively. The main field of their current applications is biomedical analysis, including the one based on polymerase chain reaction.

Use of multistep analysis

This trend is not universal and strategic one, it is a way to overcome some difficulties in the analysis of very large amount of samples.

The number of analyses is growing in many areas of application due to the willness to improve the quality of manufactured products and service or improve the life quality. The number of components to be determined is also increased and novel objects of analysis and control are appeared. In other words, scales of analytical investigation and analytical control are permanently growing. Analysis of environmental samples can serve as an example.

How analytical chemistry can answer this grow? The extensive way, that is increasing the number of analysts, number of instruments and laboratories, is not promising even with automation and other modern improvements. We need principally different approaches. Multistep analysis and control is one of the palliative ways. The main peculiarity of this is screening samples on the first (or on several first) steps. The number of samples which go to the next step can be significantly diminished.

Pattern recognition

Pattern recognition is sometimes carried out instead of regular component analysis; this approach changes the paradigm of chemical analysis. Many identificantional and classificational tasks can be solved without detection or determination of sample components; wine testers or perfume specialists (and, of course, dogs) identify their object without any conventional chemical analysis. At present, such identification can be rendered more objective using sophisticated instrumentation, e.g., with electronic noses or electronic tongues, and chemometrical approaches.

Change of roots

Modem analytical chemistry borrows principles, approaches, technical decisions, tools mostly not from chemistry but from physics, biochemistry, or engineering. The roots of many widely used spectrometric analytical techniques or gas sensors are located, for example, in physical sciences; biosensors were bom on the boundary of biochemistry and molecular biology and so on. It is obviously that this trend is of great importance.

The most frequent keywords in titles of published papers in 1950-1970 and other decades are of interest; top places in scientific publications are occupied by different techniques, the changes took place, at least, every ten years:

1950–Infrared Spectrometry, Spectrophotometry, Colorimetry, Polarography, Titration Precipitation, Spectrographic.

1970–Gas Chromatography, Electrodes, Spectrophotometry, Atomic Absorption, Polarography, Infrared Spectrometry.

1990–Liquid Chromatography, Mass Spectrometry, Gas Chromatography, Electrochemistry, Electrodes, Fluorescence.

2010–Liquid Chromatography, Mass Spectrometry, Electrochemistry, Sensors, Biosensors, Gas Chromatography, Fluorescence.

In the 1950s, the titles of publications contained mostly the words titration, precipitation, colorimeters, photometry, polarography, in the 1960s-photometry, solvent extraction, spectrochemical analysis, polarography, in the 1970s-gas chromatography and atomic absorption spectrometry, in the 1990s-liquid chromatography, solid phase extraction, in 2000-mass spectrometry and sensors.

Relative importance of different analytical techniques is permanently changing, and their hierarchy will not be stable in the future. The competition of methods existed always and, of course, is reasonable. However, quite different is the hierarchy of the number of real analyses performed by the use of various analytical techniques or the numbers of instruments which have been sold. For example, AAS is practically used everywhere but the number of publications on this technique is now small.

Hybridization of techniques and instruments

This process is developing in several directions: 1) combination of sample treatment and determination (flow injection analysis and its analogs); 2) combination of separation and determination (analytical chromatography, capillary electrophoresis); and 3) combination of different determination techniques (complicated devices for surface analysis).

We can mention the shift of priorities in samples to be analysed. Peak of publications was increasing approximately in the sequence: mineral raw materials, metals and alloys, high purity materials, environmental samples, food, drugs, biomedical samples, but the number of analyses of metals or electronic materials and so on remains very large.

Growing difficulties in education

When chemical methods of analysis predominated (XIXth and the first half of XXth centuries), education in analytical chemistry was a natural part of education in chemistry. At present, when analyses are mostly carried out by using physical, and partially biochemical, methods, it is necessary to find the compromise, the balance between chemistry and modern analytical methods which are often based not on chemistry. In the future, this situation will be, probably, more sharp.

Changes in the community of analysts

At present, there are, at least, three groups of analysts: 1) researchers and educators, 2) analysts of practical laboratories and 3) developers of analytical instruments and other tools for analysis. It is possible to predict that researchers, educators and developers will exist in a great number; the number of analysts who perform routine analyses will be decreased due to automatization of analyses, application of continuously working sensors, etc., Wide popularization of analytical chemistry is very desirable.

Conclusions

Beside considered trends, there are other ones, sometimes also significant, for instance, the development and widening application of tools for remote analysis and analytical control. Analytical chemistry is a dynamically developing field, its potential is quickly increasing and its importance is permanently growing.

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