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Introduction

1.1
Analytical Chemistry – The History

Already in ancient Egypt, knowledge of chemistry existed and was used when embalming pharaohs and dignitaries. Greek philosophers such as Plato (428–347 BC), Aristotle (384–322 BC) or Empedocles began to look for rules to explain natural phenomena. Plato believed that diverse atoms could be differentiated by their constitution. According to this theory, the atoms of an element could be changed into those of another element by simply modifying the form. *Aristotle* postulated that all elements and the substances formed by them were composed of a kind of original substance. This original substance, however, could, in the course of time, take on many forms, such as shape and color. Empedocles, who lived sometime between 490 and 430 B.C., explained that all substances were composed of four elements, namely fire, earth, water and air.

Ever since the beginning of alchemy in the Middle Ages, men have sought for a material with which to best convert metal fastest and most simply and that could be exploited best. That was the stone of wisdom. The ability to illustrate this was generally regarded as an Act of God's mercy, even if someone owned a functioning specification, it would have been useless without God's intervention. The Phlogiston Theory was introduced by the German physician and chemist Georg Ernst Stahl (1659–1734) in 1697. According to this theory, all flammable substances contained Phlogiston (gr. phlox, the flame). When it was burned and/or oxidized the flame escaped as a gas-shaped something. Phlogiston was a hypothetical substance that could be used without having necessarily to be proven. This assertion was applied to all appearances of fire in nature and ruled the thoughts of chemists for almost one hundred years. A substance would burn more readily, the more Phlogiston it had.

The spiritual aspect went hand in hand with the scientific aspect. Aristotle added a fifth, supernatural element to these four. The quintessence as the most inner core of all substances and to which a sustaining and healing power was attributable. Quintessences were gained by extraction, that is, by separating all ineffective or unpurified ingredient. These were material essences which were the sum of a body's own effective powers and/or qualities. The idea of a microcosm and a

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macrocosm stated that everything that occurred in the universe (macrocosm) had its correspondence and effect on earth (microcosm). As early as in Babylonian astronomy the planets were linked to certain materials (e.g., moon – silver, sun – gold). The constellation of the planets was important for chemical reactions to be successful.

The Renaissance witnessed the birth of attempts to renew chemistry. People wanted to get rid of everything, one by one, which was not rationally explicable. The making of gold and the associated magic, astrology and magic methods could not be reconciled with chemistry which was grounded in insights and based on reason. More and more chemists turned their backs on alchemy and finally began to fight against it. The chemists upheld research and the critical ability to think, reason, as the highest judge of the truth of a theory. In parallel to chemistry, analytical chemistry developed its own experimental skills. The first quantitative determination in chemistry was conducted by A.L. Lavoisier (1743–1794) and as early as the nineteenth century, analytical chemistry had become an established branch of chemistry. In a book published in 1894, W. Ostwald described "The Scientific Foundations of Analytical Chemistry". In this book he introduced dissociation constants, solubility products, ion products, water ion products and indicator equilibrium into analytical chemistry.

Analytics today determines the success of science, technology and medicine and is an interdisciplinary field. At the beginning of this development, analytical investigations were limited to the composition of substances and/or of mixed substances with regard to their main components. At the same time the need for generalization of analytical methods, not only on the basis of the theory of chemical reactions, but also on the basis of the physical theory of the structure of atoms and molecules arose. Later, procedures were developed to analyze trace amounts of an element or a chemical compound in a mixture. Determination of the structure of molecules and investigation of the structure of solids also became important fields for the analyst.

1.2 Analytical Chemistry and Its Role in Today's Society

Analytics is an interdisciplinary, scientific discipline also termed "analytical chemistry". The terms quantity and quality owe their existence to the results of analytics. Analytical issues are all-pervasive, and by no means only a part of scientific discipline. Rather, analytics often has a predominant role in the industrial value chain. Increasingly, more quality characteristics are being allotted to products and processes, which increasingly correspond to the need for analytics in all areas of life. Our society is demanding analytically secured data and judgments instead of empirical or traditional foundations for general or industrial decision-making. In this manner medical diagnostics, for example, is being shaped more and more by methods of analytical and bioanalytical chemistry. Buzzwords such as food security or water contamination, greenhouse gases or doping tests, gene analysis or certification of genuineness are visibly tied to the performance of analytical chemistry, visible for every citizen. Good analytics create trust and thus are a prerequisite for production and marketing.

Responsible political and economic decisions have long been based on ecological insights, that is, findings based on environmental analytics. The concept of sustainability will be even more important in future, and this draws on analytical competence even more than any concept of human action has ever done. In a nutshell: More and more ideological, medical, legal and economic decision-making rests on analytical data. This applies both to the governmental control of such areas as health, the environment, security and resources, and to the control of trade and economic processes. Similarly, the decisive spurt in the development of high technology (microchips, high-tensile materials, medical diagnostics) is always based on highly developed analytics. Increasing globalization and the progressive growing together of the countries of Europe have reduced trade barriers at their borders. The goal is to facilitate a free and unprohibited exchange of products and services. With this development, it is becoming more necessary than ever, however, to make the quality of goods transparent, because only supplementary information on the composition, purity or reliability of goods makes them salable commodities.

In order to guarantee uniform procedures across national borders when collecting analytical information, international guidelines, such as Good Laboratory Practices (GLP), Good Manufacturing Practices (GMP) or standards for good analytical work (e.g., International Organization of Standardization – ISO 17025) have been introduced.

These aspects make it clear that analytics is of fundamental significance and that this trend will continue. Analytics is the common task of several partners including universities, industry, analytics laboratories, the equipment industry and the authorities. Thus Europe will in future increasingly need the respective analysts, laboratories, educational and research institutions, more than ever before.

Only 40% of German universities have specialist analytical departments in the faculty of chemistry. This is the result of a study by the Society of German Chemists (SGCh). In some 50% of these it is tied to the subject "inorganic chemistry" since, traditionally, beginners in chemistry were introduced to the subject by way of simple analytical laboratory tasks. A cross-discipline like analytical chemistry, with increasing research roles in the whole area of material sciences, food science and medicine suffers from such a wrong allotment or subordination.

The concept of sustainability, which also takes a central position in the code of conduct of the GDCh (https://www.gdch.de/home.html, accessed May 2012), requires an extended concept of education: Beyond the difficult issue of the sciences the education must take into consideration the consequences of insights and their material implementation. Herein lies one of the most demanding tasks of the universities that have to convey high chemical analytical understanding. The specialist areas/faculties of chemistry and the university management are called upon to reinforce analytical chemistry in the further and new development of the curricula and to ensure and make use of their interdisciplinary function. Research promotion should clearly set priorities. Chemical analytical research is dependent on taking a leading position in methodology development and in giving preference to the application of expressly demanding issues. Only a quality-oriented promotion of research in stable interdisciplinary research structures of analytics can create the prerequisites that pave the way for industry (equipment manufacturers and users) in increasingly more areas to successfully offer automated or reliable practicable methods, and to market and use these globally.

It is therefore in the long-term interest of universities, politicians and the economy to firmly establish strong structures of education and research in analytical chemistry.

> Excerpt from: Society of German Chemists (GDCh) – Memorandum Analytics 2003.
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> The Gesellschaft Deutscher Chemiker (GDCh) is the largest chemical society in continental Europe with members from academe, education, industry and other areas. The GDCh supports chemistry in teaching, research and application and promotes the understanding of chemistry in the public.

> I'm not afraid of storms, for I'm learning to sail my ship.
>
> *Aeschylus*