Having noted that each field of chemistry brings a unique perspective to the study of chemistry, we now ask a second deceptively simple question. What is the analytical perspective? Many analytical chemists describe this perspective as an analytical approach to solving problems. Although there are probably as many descriptions of the analytical approach as there are analytical chemists, it is convenient for our purpose to define it as the five-step process shown in Figure 1.

Three general features of this approach deserve our attention. First, in steps 1 and 5 analytical chemists may collaborate with individuals outside the realm of analytical chemistry. In fact, many problems on which analytical chemists work originate in other fields. Second, the analytical approach includes a feedback loop (steps 2, 3, and 4) in which the result of one step may require reevaluating the other steps. Finally, the solution to one problem often suggests a new problem.

Figure 1: Flow diagram showing one view of the analytical approach to solving problems (modified after Atkinson).

Analytical chemistry begins with a problem, examples of which include evaluating the amount of dust and soil ingested by children as an indicator of environmental exposure to particulate based pollutants, resolving contradictory evidence regarding the toxicity of perfluoro polymers during combustion, and developing rapid and sensitive detectors for chemical and biological weapons. At this point the analytical approach may involve a collaboration between the analytical chemist and the individual or agency working on the problem. Together they determine what information is needed. It also is important for the analytical chemist to understand how the problem relates to broader research goals or policy issues. The type of information needed and the problem’s context are essential to designing an appropriate experimental procedure.

These examples are taken from a series of articles, entitled the “Analytical Approach,” which was a regular feature of the journal Analytical Chemistry, a bimonthly publication of the American Chemical Society. The first issue of each month continues to publish a variety of engaging articles highlighting current trends in analytical chemistry.

To design the experimental procedure the analytical chemist considers criteria such as the desired accuracy, precision, sensitivity, and detection limits; the urgency with which results are needed; the cost of a single analysis; the number of samples to be analyzed; and the amount of sample available for analysis. Finding an appropriate balance between these parameters is frequently complicated by their interdependence. For example, improving precision may require a larger...
amount of sample. Consideration is also given to collecting, storing, and preparing samples, and to whether chemical or physical interferences will affect the analysis. Finally a good experimental procedure may still yield useless information if there is no method for validating the results.

Chapter 3 provides an introduction to the language of analytical chemistry. You will find terms such accuracy, precision, and sensitivity defined there. See Chapter 7 for information about collecting, storing, and preparing samples.

The most visible part of the analytical approach occurs in the laboratory. As part of the validation process, appropriate chemical and physical standards are used to calibrate any equipment and to standardize any reagents.

See Chapter 14 for a discussion about validating analytical methods. Calibration and standardization methods, including a discussion of linear regression, are covered in Chapter 5.

The data collected during the experiment are then analyzed. Frequently the data is reduced or transformed to a more readily analyzable form. A statistical treatment of the data is used to evaluate accuracy and precision, and to validate the procedure. Results are compared to the original design criteria and the experimental design is reconsidered, additional trials are run, or a solution to the problem is proposed. When a solution is proposed, the results are subject to an external evaluation that may result in a new problem and the beginning of a new cycle.

Chapter 4 introduces the statistical analysis of data.

As noted earlier some scientists question whether the analytical approach is unique to analytical chemistry. Here, again, it helps to distinguish between a chemical analysis and analytical chemistry. For other analytically oriented scientists, such as a physical organic chemist or a public health officer, the primary emphasis is how the analysis supports larger research goals involving fundamental studies of chemical or physical processes, or improving access to medical care. The essence of analytical chemistry, however, is in developing new tools for solving problems, and in defining the type and quality of information available to other scientists.

Exercise \(\PageIndex{1}\))

As an exercise, let’s adapt our model of the analytical approach to the development of a simple, inexpensive, portable device for completing bioassays in the field. Before continuing, locate and read the article “Simple Telemedicine for Developing Regions: Camera Phones and Paper-Based Microfluidic Devices for Real-Time, Off-Site Diagnosis” by Andres W. Martinez, Scott T. Phillips, Emanuel Carriho, Samuel W. Thomas III, Hayat Sindi, and George M. Whitesides. You will find it on pages 3699-3707 in Volume 80 of the journal Analytical Chemistry, which was published in 2008. (Use this link to access the article’s abstract from the journal’s web site. If your institution has an on-line subscription you also will be able to download a PDF version of the article.) As you read the article, pay particular attention to how it emulates the analytical approach. It might be helpful to consider the following questions:

- What is the analytical problem and why is it important?
- What criteria did the authors consider in designing their experiments?
- What is the basic experimental procedure?
• What interferences were considered and how did they overcome them?
• How did the authors calibrate the assay?
• How did the authors validate their experimental method?
• Is there evidence of repeating steps 2, 3, and 4?
• Was there a successful conclusion to the problem?

Do not let the technical details in the paper overwhelm you. If you skim over these you will find that the paper is well-written and accessible. Click here to review your answers to these questions.

This exercise provides you with an opportunity to think about the analytical approach in the context of a real analytical problem. Practice exercises such as this provide you with a variety of challenges ranging from simple review problems to more open-ended exercises. You will find answers to exercises at the end of each chapter.

Contributors

• David Harvey (DePauw University)