The Scientific Method

The scientific method is the systematic, organized gathering of data; the objective formulation and testing of hypotheses (ideas, concepts, theories) with that data; and the stating of conclusions that can be evaluated independently by others. Do you know how to ride a bicycle? If so, you know that riding and not falling is a learned set of muscular reflexes; you "just ride it" without thinking about it. A chemist involved in academic research or in solving an industrial problem has an analogous set of reflexes—mental ones—that are, or should be, the scientific method. Reflexes can, however, guide our behavior without us thinking about them, and so it's good to occasionally articulate what the ideal scientific reflexes are just to be sure that we really do remember them.

The scientific method was already taking shape in the early 18th century. Issac Watts' (1674–1748) *The Improvement of the Mind* contains statements like "be not too hasty to erect general theories from a few particular observations", and—admonishing scientists to use clear language—"lest you feed upon husks instead of kernels". Nevertheless, the evolution of philosophical arguments into scientific logic occurred over a prolonged period. A modern reference breaks the scientific method into several facets, including developing a suitable and unambiguous descriptive language; grouping or classifying similar objects to augment their scientific descriptions; using experiments and measurements—preferably quantitative—to test hypotheses; repeating experiments to probe repeatability of data; obtaining consensus through others' confirmation experiments; and showing connections by cause and effect. These logical concepts have grown to govern our thinking in investigating chemical phenomena of any kind.

Analytical chemists especially relate to these principles. In developing analytical methods, for example, concepts of precision, accuracy, validation, traceability, selectivity, specificity, and the like are based on systematic, repeated quantitation of observations, which test a hypothesis that a proposed method adequately measures an analyte. In another vein, analytical chemistry, as a science of quantitative experimental design, provides a fundamental pillar for applying the scientific method throughout chemistry.

Does the scientific method have limits? Of course, when we apply it without rigor. A hypothesis based on sheer guesswork can appear to be supportable with a limited body of data. This occurs, for example, when the researcher ignores or discounts previous consensus literature. An analysis of data that includes an overdose of intuition or "what-ought-to-be" thinking can lead to a claim of verifying a hypothesis, which—given further data—proves to be unsupportable. Of course, these illustrations could also be given as examples of how chemistry progresses by leaps and stumbles. The crux of whether a researcher truly errs, in my opinion, is when claims of success are made without serious attention to the remaining, undeniable uncertainties. The bottom line then is in the writing of a research report. This editor wants to leave the reader with a reminder that the scientific method is practiced not only in the laboratory but also in the writing of research reports and papers. Try applying its tenants to your next research manuscript or monthly report!