IMPORTANCE OF TOOLS AND THE PROGRESS OF SCIENCE

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Progress in science over centuries has been driven by an emergence of ideas/ concepts/ paradigms as well as discovery of new tools for observing the physical, chemical and biological world. Although there has been a persistent debate regarding which of the two is more important, the truth is that, both, ideas and tools compete in the world of science [1]. The origins of modern science can be traced to two significant tools, namely, discovery of telescope in the sixteenth century and the microscope in the seventeenth century. The former launched the discipline of observational astronomy leading to the recognition of the heliocentric universe [2], whereas, the latter launched the discipline of biology [3.] The early part of the twentieth century clearly belonged to the power of ideas. The concept of periodicity in the properties of elements, structure of benzene as well as the tetrahedral carbon and structure of the atom were all products of sheer human imagination with little observational evidence. So too was quantum physics, the origins of the concept of macromolecules [4] and our early understanding of the nature of the chemical bond.

However, tools became once again important beginning in early the fifties. Macromolecular crystallography and NMR spectroscopy gave birth to the disciplines of molecular biology and rational organic synthesis based on a precise understanding of chemical structures [5, 6]. Chromatographic tools enabled separation, identification and purification of complex mixtures, PCR and mass spectroscopy gave birth to the science of genomics and proteomics. Imaging tools based on IR, Raman and NMR led to better understanding of biological processes in solutions and in real time. Electron microscopy and tools such as STM, AFM opened up the world of nano science. Surface spectroscopy such as XPS, EXFAS and SIMS gave us deeper insights into catalytic processes.

The value of powerful tools as an adjunct to discovery science is now well recognized. In fact, as many as ten Nobel Prizes in Sciences in the last two decades have been awarded to individuals who discovered new tools, the latest being the 2014 prize for the discovery of super resolved fluorescence spectroscopy which enables optical microscopy in the nanodimensions.

The evolution and growth of polymer science would not have been possible without a continuous refinement of tools. Herman Mark pioneered the application of electron diffraction in 1925 for the study of the structure of cellulose. Synthetic polymers are characterized by the heterogeneity of its chemical compositions, molecular weights, branching and branching distributions, stereochemistry, regiochemistry and sequence of placement of monomers in copolymers. These properties lead to short and long-range order in solid-state structures (morphology), which in turn determine the physical, mechanical, thermal and rheological properties of polymers. The fact that polymers are materials with high degree of heterogeneity in properties makes them also very interesting in terms of applications, providing scientists and engineer's unlimited opportunities for property manipulation. One of the enduring interests in this branch of science is, therefore, to understand the relationship between chemical synthesis, molecular structure and physical properties. It is in this effort that analytical tools such as IR/UV (functional groups), high-resolution proton and carbon NMR (chemical structure, monomer sequence distribution, nature of enchainment, stereochemistry), chromatographic tools, such as, GPC, Light Scattering, and MALDI-TOF and TREF (molecular weight, branching distribution and compositional heterogeneity), WAXD, SAXS, SANS, electron microscopy, AFM (morphology) play a critical role.

As science advances, there is a continuing need to probe structures and properties with ever increasing precision; therefore, we will continue to see rapid advances in analytical techniques. In the area of polymer materials, there will be greater emphasis on non-destructive characterization, property measurements of finished parts as a whole, measurement of spatial properties (compositional, thermal and morphology) at nano-dimensions and analysis of materials in real time under specific conditions of their applications. Imaging techniques are now becoming more important in material science. IR and Raman imaging, Nano FT IR, providing chemical identification at 10 nm spatial resolutions, AFM-IR and nanoscale thermal analysis are being increasingly employed to examine nano composition, stress strain fields at nano-scale and nanoscale phase transitions [7].

Friends, powerful analytical tools are as relevant today as they were one hundred years ago for the advancement of science and technology. However, it is pertinent to remember that fundamental advancements in science occur when our intellect is seized with complex questions. Use of tools provides validation of concepts and new thoughts; however, in today's world tools by themselves do not lead to new science. History of science is also replete with examples where simple tools provided answers to some of the most intriguing questions of science.

I do hope that the deliberations of this seminar enlightens you on the power of modern analytical tools, their intelligent and appropriate use and how they may benefit the study of novel materials.

I wish the seminar all success and thank you for your patient listening.

Further Reading:

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