Experimental Technology

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Most of the important advances in scientific knowledge have followed improvements in experimental techniques. Tools created by physical scientists and engineers are leading to new discoveries in science and technology. These tools include lasers, nuclear magnetic resonance, synchrotron radiation, mass spectrometry, extremely high pressures, and devices for observing atoms at surfaces. Here I discuss some of the results of using these tools.

When substances are subjected to pressures of millions of atmospheres, their volumes diminish by as much as a factor of 10. Their normal crystal and electronic structures are drastically changed. Nonmetals usually become conductors. Among these nonmetals is sulfur, which becomes a superconductor at low temperatures and remains a superconductor at temperatures at which other elements lose that capability.

At high pressures, chemical reactions are seen that do not occur under ambient conditions. Neon combines with helium to form $NeHe_2$. Argon reacts with hydrogen to form ArH_4 and with oxygen to form ArO_6. When the pressure is lowered, most of the compounds formed under high pressure decompose. In the future, however, substances may be discovered that are metastable and have valuable properties, such as diamond.

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It has long been known that atoms at surfaces behave differently from those deep in a crystal. To study such phenomena, more than 25 experimental techniques have been developed and used in a host of applications. These include scattering; absorption or emission of photons, electrons, atoms, and ions; and scanning tunneling microscopy and atomic force microscopy. These techniques have allowed observation of unique chemical, optical, electrical, magnetic, and mechanical properties.

Many studies have been designed to understand the processes involved in catalysis. For instance, the surface of clean crystalline platinum may change markedly if it is exposed to various gases and they are captured by it. Similar effects are noted with some hydrocarbons. And phenomena have been noted with other elements that help form a basis for understanding and improving industrial catalysis.

The techniques and applications of mass spectrometry have evolved greatly in recent years. For example, routines for determining the molecular weights of proteins and their amino acid sequences have been developed. These methods can be used to check the accuracy of DNA sequencing of genes. To analyze the contents of tiny biological samples, a preliminary separation by capillary electrophoresis is used. This is coupled with the introduction of about 4×10^{-11} liters of a segment of the sample into a multistage mass spectrometer that is capable of precisely measuring the molecular weights of proteins and protein fragments.

Simpler mass spectrometers employing the electronic ionization of small molecules are widely used, and databases that facilitate nearly instantaneous identification of more than 220,000 chemicals have been created. Mass spectrometers are also being used as a basic tool in anthropology, climatology, geology, and geophysics.

Computer control of instrumentation, coupled with electronic means of collecting and analyzing large amounts of data, has facilitated research on complex phenomena in both the physical and biological sciences. Combinatorial chemistry has vastly expanded the ability of biochemists to quickly discover many potential pharmaceuticals and to improve their quality. Gene chips have already demonstrated their power as tools for discovering the complex responses of plants to stimuli. Exploitation of the ability to change the DNA content of plants and animals has only begun. As this research proceeds, its societal effects will be enormous.

The development of new or improved experimental techniques is flourishing and is a prerequisite to the continuing discovery of fruitful frontiers in science and technology.