Free atoms: A whole new basic chemistry

Most of the atoms that exist on earth are bound in molecules or crystals; only a few elements can exist as single atoms. The chemical reactions that are studied in laboratories are usually between molecules.

Studying what happens between molecules throws little or no light on the behavior of free atoms, says Philip Skell of Pennsylvania State University. In an oxygen molecule, for instance there are two atoms tightly bound together. Studying the molecule in the hope of finding out what the single atoms could do, says Skell, is like observing two people who are tied together in the hope of finding out what each would be capable of if not bound. The same argument holds for metals where large numbers of atoms are bound in crystalline structures. Furthermore, he says, you may suppose that in a water molecule you have a single oxygen atom, but really you don't: You have a water molecule that you can imagine being made with a single oxygen atom, but once it is made, it tells nothing about the behavior of the free oxygen atom.

Over many years, says Skell, the chemistry of atoms has been largely ignored. This has been for want of a technique. To get free atoms of metals, for example, one can melt and boil them. But then their temperatures are in the thousands of degrees C., and the question is how to react them with organic molecules, for instance, that characteristically decompose at temperatures in the hundreds of degrees.

Skell and his collaborators have found a way—a quick chill process that they describe as a kind of chemical sauna bath. Atoms that have been vaporized are sent in a stream through a vacuum to a surface cooled to liquid-nitrogen temperature (minus 196 degrees C.). Traveling through the vacuum without collisions, the metal atoms retain their independence, and the researchers find that they will react with organic substances previously introduced to the cold surface—substances that in the crystalline solid state the metal in question shows no disposition to combine with.

An example, cited by Skell and J. J. Havel in the Dec. 1 JOURNAL OF THE AMERICAN CHEMICAL SOCIETY, is platinum. Platinum is regarded as the noblest of the noble metals. Its value in jewelry and other practical uses depends on its high resistance to corrosion. It will react with only the strongest of oxidizing agents, such as the so-called universal solvent, aqua regia.

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Skell: In a chemical "sauna bath" vaporized metals produce new compounds.

Skell and Havel boiled platinum at temperatures above 3,800 degrees C. and led the free atoms in a collision-free path to the cold wall. At the wall the free atoms reacted with propylene. This indicates, says Skell, a surprising high reactivity for platinum in the single-atom state. "If it will react with something as innocuous as propylene," says Skell, it is likely to react with a lot of other organic substances.

Some 40 metals with high boiling points have so far been tested, and unexpected reactivities have been found for several. Some 60 or 70 metals are available for the technique and thousands of organic compounds are possible as reaction substrates. "Interactions take place on the cold wall that we have never before seen," says Skell. A whole new basic chemistry of free atoms is likely to develop, he says, and a large new class of organo-metallic compounds will be produced by it. (Inorganic substances can also be used as reactants, but they are less numerous and less interesting. "It's a question of going where the greatest interest is," says Skell.)

Studies of this sort may have connections to astrochemistry. Large collections of free atoms are known in interstellar space. There are also large clouds of nearly two dozen different compounds (SN: 12/4/71, p. 378). Many observers suppose that interstellar compounds are made by combining free atoms. So far there are no metallic compounds on the interstellar list (unless hydrogen be considered a metal—usually it is not), but none of the astronomers who look for such things supposes that the list is closed. Carbon appears in the majority of the interstellar compounds, and free carbon atoms can be extracted from graphite or diamond and reacted by Skell's technique.

Among the new substances that could be produced by the method, Skell foresees some that would find technological uses that are quite unexpected now. He cites the development of plastics and semiconductors as historical analogies. But what such new substances might be or what their detailed properties and uses could be, he refuses to speculate. "We are a long way from that stage yet," he says. □

Residential radioactivity: Sharing of responsibility

Atomic Energy Commission Chairman James R. Schlesinger and Colorado Gov. John A. Love met this week in Denver to work out some preliminary details on studies of houses in western Colorado that may be contaminated with radioactive radon gas from uranium mine tailings.

Schlesinger clearly conceded in a statement that using the tailings as a house construction material was a mistake. But he added that a number of agencies were involved, and he conceded no legal responsibility on the part of AEC—although he said the Federal agency might share the cost of rectifying the problem.

Just how the problem might be corrected is still speculative, said an AEC spokesman. First, it will be necessary to sample radon levels in a large number of houses to determine how widespread the problem is. Then two possible courses might be followed: removal of the materials or improvements in house ventilation systems. Because of the difficulty in measuring radon levels directly, it may be necessary to find some indirect basic for determining them, such as correlations between radon and gamma-ray emissions. □