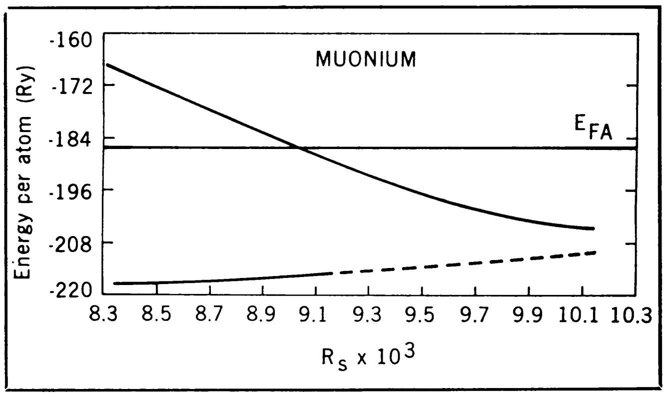
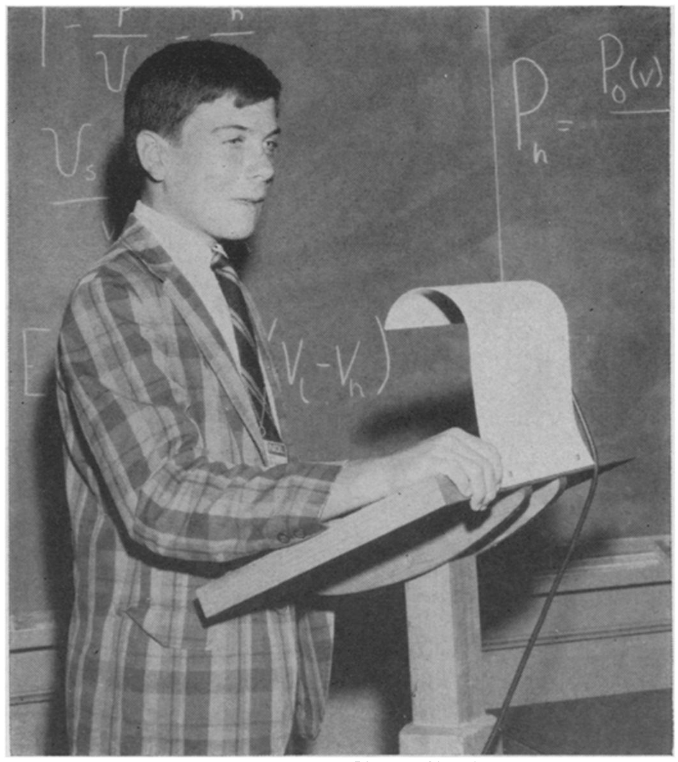
Muonium metal

Young scientist's theory indicates solid and liquid may exist

by Dietrick E. Thomsen



Cohesive energy of muonium versus free atom energy.



Photos: Naval Ordnance Laboratory

McKenna: Solid and liquid muonium metal in the stars.

The characteristics of materials depend on the electrons in their atoms and the forces that bind the electrons to the nucleus. If the electrons could be changed, physical properties—such as boiling point, melting point and density—would change as well.

Two scientists at the Naval Ordnance Laboratory in Silver Spring, Md.,—17-year-old Paul McKenna and Dr. D. John Pastine, with whom McKenna has worked for two summers under a National Science Foundation program—set out to find exactly what other changes would follow change in the electrons.

In the process, McKenna calculated a way in which a substance called muonium could exist in a stable state—either liquid or solid—and developed a theory that, in the words of his mentor, Dr. Pastine, will make "quite a splash" in several fields of science: not only in materials research where it all began, but in astrophysics and cosmology too.

Usually, the nucleus of the atom is surrounded by electrons that orbit around it. But in muonium the single electron of a hydrogen atom is replaced by a mu meson, which is 200 times as heavy as an electron.

Mu mesons are among the strangest inhabitants of the elementary particle menagerie (SN: 3/22, p. 290). Except for their mass they are exactly like electrons, and physicists can see no reason why they should exist at all. They are so ephermeral that, up to now at least, no one thought they had anything to do with stable matter.

Muonium is hard to make because mu mesons are created only in high-energy experiments and they disappear radioactively in two-millionths of a second.

Despite terrestrial muonium's tendency to disappear, the theoretical calculation made by McKenna and Dr. Pastine indicates that muonium could exist either as a solid or a liquid, provided environmental conditions were right and there was a steady source of muons nearby to replace them as fast as they decayed.

The calculation shows that muonium is highly cohesive and that it would form a solid metal with a melting point of 65,000 degrees K. and a boiling point of 250,000 degrees K. Solid muonium does not exist on earth because it also requires density of hydrogen of 10^{23} atoms per cubic centimeter and a pressure of 2 million times the earth's atmosphere. Muonium is also very dense, 28 million times the one-gram-per-cubic-centimeter density of water. "If any existed on earth," says McKenna, "it would sink right through."

But it could exist on a star, and that, suggest McKenna and Dr. Pastine, is where solid or liquid muonium may be found. "I'm convinced it exists," says Dr. Pastine.

If it does, it should emit gamma rays of particular frequencies that will identify it. But a search is not practical now because the equipment used in gamma-ray astronomy is not sensitive enough to pick out the frequencies that are characteristic of it.

"We don't know of any attempts," say the theorists.

The conditions under which solid or liquid muonium could form might have been present early in the history of the universe shortly after the big bang that is supposed to have started it all, suggests one scientist who commented on the work. He feels it would be worthwhile to study the effects that the presence of muonium at such a time would have on current theories of the history of the universe.

Dr. Pastine stresses that, although the present work does not deal with stable atoms, it could have an important effect in materials science since it shows that "by changing the mass of the electrons, you can make fantastic changes in the properties of the material." Ordinary hydrogen for example—with electrons rather than muons—melts at 14 degrees and boils at 21 degrees K.

Young McKenna is already the senior author of a paper (concerning the Gruneisen parameter for aluminum) published in the JOURNAL OF APPLIED PHYSICS. This grew out of the previous summer's work with Dr. Pastine.

The eldest of the eight sons of Mr. and Mrs. Gerald S. McKenna of Bethesda, Md., he is a senior this year at Gonzaga High School in Washington, D.C.

As McKenna described his theory to a group of NOL scientists at a special meeting, Dr. Pastine remarked, "Just listen to him. It's kids like him who will make the significant contributions of the future." ◇