Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR (September 24–25 1980)

Usp. Fiz. Nauk 133, 543–547 (March 1981)

PACS numbers: 01.10.Fv

A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR was held on September 24 and 25, 1980 at the Academy's P. N. Lebedev Physics Institute. The following papers were presented:

1. *S. M. Stishov*, The present status of the physics of high pressures.

2. *E. N. Yakovlev*, The problem of metallic hydrogen. advances and prospects.

3. *S. I. Anisimov*, The thermodynamic properties of molecular hydrogen.

4. *Yu. M. Kagan*. The problem of metallic hydrogen.

September 25

5. *V. S. Berenzinskiĭ*, The neutrino astronomy of high energies: sources and fluxes.

6. *G. T. Zatsepin*, Observational high-energy neutrino astronomy.

7. *B. A. Dolgoshein*, Possibility of acoustic detection of neutrinos in the ocean.

Below we publish three of the papers in condensed form.

E. N. Yakovlev. *The problem of metallic hydrogen advances and prospects.* It was nearly ten years ago that L. F. Vereschchagin and I. M. Khalatnikov published in a journal of general interest their paper "Metal from Hydrogen: Fantasy or Reality?"[1] This article and publications by American scientists[2] took note of the enormous technical difficulty of creating the static pressures needed to produce metallic hydrogen. What has happened during the past decade?

First of all, it must be said that the problem has emerged from the realm of fantasy and is a solid reality. The results that have been obtained testify to major advances in this area, both in the USSR and abroad.[3]

In this note we touch upon problems that have a bearing only on static-pressure experiments.

The equation of state of molecular hydrogen has been determined at pressures up to 30 kbar,[4] and the structure of solid hydrogen has been studied by neutron diffraction at pressures up to 5 kbar.[5] It was confirmed in investigations of the Raman scattering spectrum of hydrogen at pressures up to 150 kbar[6] that molecular hydrogen crystallizes only into an h.c.p. structure. Sharma *et al.*[7] reported attaining a pressure of 630 kbar in hydrogen and studying the Raman spectra of molecular hydrogen. These studies are of great importance for derivation of a theoretical model for molecular hydrogen, and ultimately for determination of the pressure at which hydrogen is transformed into a metal.

The metallic-hydrogen probelm has been a stimulus to appreciable broadening of the available range of static pressures. The pressure limit has been raised during the past decade from ~200 to ~2000 kbar, i.e., by an order of magnitude.[8-10] For comparison, we might recall that diamond is synthesized at 50–60 kbar. Polycrystalline diamonds of the "carbonado" type, which were first produced by the USSR Academy of Sciences Institute of the Physics of High Pressures,[11] played a special role in the production of pressures around 1 Mbar. "Carbonado" and single-crystal diamonds are basic materials for the creation of such pressures. Diamond instruments are capable of producing ~1 Mbar pressures only in volumes smaller than 10^{-6} cm^3. Microscopic volumes are one of the hallmarks of the contemporary physics of megabar static pressures. It was necessary to develop special procedures for experiments with microscopic amounts of matter.

Dielectric-to-metal transformations have been studied in several substances with various types of bonding in the megabar pressure range. This series of experiments was undertaken by way of preparation for experiments with hydrogen. But their results are of interest in themselves. For example, it was possible to determine a sequence of dielectric-to-metal transitions in order of increasing pressure:

$$P_{GaP} \approx 200\,\text{kbar} < P_{NaCl} < P_{Al_2O_3} \ldots < P_{SiO_2} < P_{MgO}.$$

Transitions were also detected in water. Water (ice) served as a model substance before the experiments with hydrogen were designed.

As a result of the studies of hydrogen, it has been established that: 1) a conductive modification of hydrogen exists and can be prepared by compressing solid molecular hydrogen between carbonado anvils; 2) there exists a metastable conductive phase that vanishes on heating; 3) the metastable conductive phase does not exist at ordinary pressures[12] (see Ref. 13).

Advances in experimental technique have made it possible to investigate the superconductivity of metals in the megabar pressure range. The new superconductors GaP, S, Xe, and NaCl were discovered.[14-17]

High-pressure experimental techniques are now being prepared for study of the superconductivity of hydrogen.

In conclusion: the results already obtained under the "banner" of metallic hydrogen are of importance for solid-state physics, geophysics, and technology, and have lived up to the widespread publicity that began ten years ago.

[1]L. F. Vereshchagin and I. M. Khalatnikov, Nedelya No. 21 (1971).

[2]E. Gross, Science News **97**, June 27, 1970.

[3]M. Ross and C. Shishkevich, Molecular and Metallic Hydrogen, Rand, Santa Monica, R-2056-ARPA.

[4]V. V. Kechin, Yu. M. Pavlyuchenko, A. I. Likhter, and A. N. Utyuzh, Zh. Eksp. Teor. Fiz. **76**, 2194 (1979) [Sov. Phys. JETP **49**, 1108 (1979)].

[5]B. A. Vindryaevskyi, S. N. Ishmaev, I. P. Sadikov, A. A. Chernyshov, V. A. Sukhoparov, and A. S. Telepnev, Phys. Lett. A **76**, 353 (1980).

[6]R. I. Wiyngaarden and I. F. Silvera, Phys. Rev. Lett. **44**, 456 (1980).

[7]S. K. Sharma, H. K. Mao, and P. M. Bell, in: Proc. VII AIRAPT Conf., Le Creusot, France (to be published).

[8]N. Kawai, Techn. Japan **3**, 68 (1971).

[9]L. F. Vereshchagin, E. N. Yakovlev, G. N. Stepanov, K. Kh. Bibaev, and B. V. Vinogradov, Pis'ma Zh. Eksp. Teor. Fiz. **16**, 240 (1972) [JETP Lett. **16**, 169 (1972)].

[10]H. K. Mao and P. M. Bell, Science **191**, No. 4229 (1976).

[11]L. F. Vereshchagin, E. N. Yakovlev, T. D. Varfolomeeva, V. N. Slesarev, and L. E. Shterenberg, Dokl. Akad. Nauk SSSR **185**, 555 (1969) [Sov. Phys. Dokl. **14**, 248 (1969)].

[12]L. F. Vereshchagin, E. N. Yakovlev, and Yu. A. Timofeev, Pis'ma Zh. Eksp. Teor. Fiz. **21**, 190 (1975) [JETP Lett. **21**, 85 (1975)].

[13]N. Kawai, M. Togaya, and O. Mishima, Proc. Japan Academy **185**, 555 (1969).

[14]L. F. Vereshchagin, E. N. Yakovlev, Yu. A. Timofeev, and B. V. Vinogradov, Pis'ma Zh. Eksp. Teor. Fiz. **26**, 61 (1977) [JETP Lett. **26**, 55 (1977)].

[15]E. N. Yakovlev, G. N. Stepanov, Yu. A. Timofeev, and B. V. Vinogradov, *ibid*. **28**, 369 (1978) [**28**, 340 (1978)].

[16]E. N. Yakovlev, Yu. A. Timofeev, and B. V. Vinogradov, *ibid*. **29**, 400 (1979) [**29**, 362 (1979)].

[17]G. N. Stepanov, E. N. Yakovlev, and T. V. Valyanskaya, *ibid*. **29**, 460 (1979) [**29**, 418 (1979)].