SCIENTIFIC SESSION OF THE DIVISION OF GENERAL PHYSICS AND ASTRONOMY OF THE USSR ACADEMY OF SCIENCES (26–27 November 1969)

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A scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences was held on 26 and 27 November 1969 in the conference hall of the P. N. Lebedev Physics Institute. The following papers were delivered:

1. V. I. Gol'danskiĭ, Some New Applications of Physical Methods in Chemistry.
2. L. V. Al'tshuler, Progress in High-pressure Physics.
3. V. B. Braginskiĭ, Detectors of Gravitational Radiation.
4. A. G. Masevich, A. M. Lozinskiĭ, and V. E. Chertoprud, Special Astronomical Observations of Artificial Celestial Bodies for Problems of Geophysics and Geodesy, and the New Large Soviet Telescope for these Purposes.
5. A. I. Nikishov and V. I. Ritus, Interaction of Electrons and Photons with a Very Strong Electromagnetic Field.
6. B. V. Deryagin, New Data on Superdense Water.

We publish below a brief contents of the delivered papers.

V. I. Gol'danskiĭ, Some New Applications of Physical Methods in Chemistry.

More and more new examples of the influence of the chemical (atomic-molecular and crystalline) environment on transformations of nuclei and elementary particles, and also on different transitions in which electrons of the internal shells take part, have been observed and investigated in detail in recent years. As a rule, the first step was the gathering of examples of such an influence, due to specially produced and already-known changes of the properties of the chemical environment. Then, on the basis of observation of several differences in the characteristics of the transformations of nuclei and elementary particles, as revealed by x-ray and photoelectronic spectra, new methods are being developed in modern chemistry[1] and yield comprehensive and sometimes quite unique and hitherto unavailable information. Different variants of the influence of the chemical environment on physical processes are illustrated in the table.

The paper considers in greatest detail the results obtained on positron annihilation[5] in the author's laboratory at the Institute of Chemical Physics of the USSR Academy of Sciences, and the work of Professor K. Siegbahn and co-workers (Uppsala, Sweden) on the development and various applications of the method of precision photoelectronic spectroscopy[14].

Sufficiently complete information on the character of annihilation of positrons is obtained by combining observations of temporal positron spectra (i.e., the distribution of the positrons by their lifetime in matter) and the curves of angular correlation of two annihilation γ quanta (i.e., small deviations of the angle between them from 180°).

Physical process	Character of chemical influence
Capture of orbital electrons by nuclei [2]	Change of capture rate
Isomeric nuclear transition [2,3]	Change of rate of transitions, of internal conversion coefficients, of γ-quantum energy
Cascade nuclear transition [4]	Change of angular correlation of cascade particles and quanta
Positron annihilation [5]	Change of lifetime of positrons and of the number and angular correlation of the annihilation γ-quanta
μ^+-meson decay [6,7]	Change of residual μ^+ polarization
μ^--meson decay [8]	Change of lifetime of μ^- and of the type of the mesic-x-ray spectra
π^--meson decay [8]	Change of probability of charge exchange $\pi^- + p \to \pi^0 + n$
Deceleration of neutrons	Change of scattering cross sections and of deceleration rate
Deceleration and scattering of charged particles [9-11]	Channeling of particles by the lattice and appearance of the "shadow effect"
Emission of x-rays [12,13]	Change of the energy of the emitted x-ray quanta
Absorption of x-rays	Occurrence of a fine structure of the edges of the absorption spectra
Emission of photoelectrons from the internal shells and of Auger electrons	Change of electron energy (as a result of the change in the ionization potentials)

There are three basic ways of positron annihilation, each of which can be experimentally distinguished and can serve as a source of specific physico-chemical information. Thus, annihilation of positrons in quasi-free collisions makes it possible to investigate, by the method of angular correlations, the momentum distribution of the conduction electrons and of the valence electrons. Annihilation via formation of bound states of the type e^+M or e^+A^- (M—molecule, A^-—anion) can be used to investigate new types of chemical bonds (for example He-e^+-He) and to determine the effective charges of the atoms in molecules and crystals. Particularly exhaustive information is offered to chemists by the observation of the production and annihilation of the lightest hydrogenlike atom, positronium, which consists of a positron and an electron. Like any other radioactive tracer atom, positronium reveals its presence in matter by characteristic radiation. However, unlike ordinary tracer atoms, the signal sent by the positronium during the instant of its annihilation is not always the same. The lifetime and the mechanism of the annihilation of the positronium depend themselves on the properties of the surrounding medium and serve as characteristics of the latter. This is one of the most remarkable properties of the positronium method. Another advantage of this method is that, owing to the very small proper lifetime of the positronium atoms, this time can serve as a comparison standard for the determination of the rates of even the fastest reactions in which the positronium takes part, lasting billionths of a second.

Positronium turned out to be a sensitive detector of the presence of free atoms and radicals in gases, and also of the structure of the coordination sphere around paramagnetic complex-formers (for example Co^{2+}) in solutions ("smearing" of unpaired electrons over this sphere). A comparison of the reaction rates of hydrogen and positronium (for example, their interaction with Fe^{3+} and Fe^{2+}) makes it possible to reveal the role of diffusion and quantum factors (tunnel effect) in chemical kinetics. By observing the change in the character of the annihilation of the positrons with the composition and with pressure of the gas, it is possible to measure the lifetimes of the intermediate active complexes of gas reactions on the order of 10^{-2} sec and less. Finally, measurements of the positronium-production probability make it possible to describe important elementary processes wherein atomic vibrations in crystal lattices and the energy levels of molecules are excited by positron (and electron) impact.

Very highly promising for chemistry is the ESCA (electron spectroscopy for chemical analysis) method developed by Swedish scientists. The highest level of accuracy of the determination of the energy of photoelectrons with the aid of magnetic or electrostatic spectrometers makes it possible to separate, when complex compounds or mixtures are irradiated by x-ray quanta, the groups of electrons corresponding to each species of atoms and to ensure on this basis a very sensitive elemental analysis (up to 10^{-9} g). Moreover, it becomes possible to establish in how many chemically different positions the various atoms are situated in the investigated system, and in what ratio these atoms are distributed over the different positions. For example, the ionization potentials of the K electrons of the carbon atoms in the benzene ring and in the carboxyl group differ by almost 5 eV, while the accuracy of determination of the kinetic energy of the photoelectrons knocked out when carbon is irradiated by the K_α lines of Mg or Al reaches hundredths of 1%, i.e., tenths of an electron volt.

The paper describes in less detail the results of mesochemical experiments performed with the synchrocyclotron of the Nuclear Problems Laboratory of the Joint Institute for Nuclear Research in Dubna[6,8], and the prospects of their chemical applications. The main features and the chemical significance of precision observations of x-ray absorption and of emission spectra are described just as briefly.

Finally, the author proposes and describes ways of future investigations of spatial and temporal delocalization of electrons in molecular systems[15]. These involve the use of the Mossbauer effect and measurements of giant magnetic fields produced at the nuclei by a hole in the K shell[16], and are based on a comparison of the angular correlations of the cascade γ quanta with the γ quanta or K-conversion electrons preceding them.

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L. V. Al'tshuler, Progress in High-pressure Physics

The use of strong shock waves as a tool of modern physics has made pressures of hundreds of thousands and millions atmospheres the subject of laboratory investigations. During the last two decades this method has filled to a considerable extent the gap between the experimental region and the region of high-temperature and high-density states amenable to quantitative theoretical calculations. The shock-wave procedure makes it possible to compress and to heat the investigated samples within short time intervals, to determine with high accuracy the compression curves, to record first- and second-order phase transitions, to determine melting curves, and to register the electric, optical and magnetic phenomena in extremal states of matter. The experimental phase of the dynamic methods of determining the compressibility consists of accelerating metallic strikers to high velocities and to measure with precision their velocities and the wave velocities in the