determine the fundamental crystal-chemical laws governing the formation of dense high-pressure phases. Particular attention on the part of both experimenters and theoreticians should be paid to the problem of the transition of dielectrics into the metallic state. Of large scientific and practical significance is the study of the mechanisms of phase transformations and chemical reactions in strong shock waves, and the investigation of the electrical, optical, and magnetic phenomena accompanying the shock compression. One should expect interesting results to be obtained from a study of the expansion of bodies compressed by strong shock waves.

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V. B. Braginskiĭ, Detectors of Gravitational Radiation.

The article discusses the present status of searches for gravitational radiation of extraterrestrial origin. A review is presented of the results obtained in the experiments of J. Weber, and the difficulties in the interpretation of his experimental data are considered. The prospect of increasing the sensitivity of gravitational-radiation detectors are considered, especially detectors of the heterodyne type.

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A. G. Masevich, A. M. Lozinskiĭ, and V. E. Chertoprud, Special Astronomical Observations of Artificial Celestial Bodies for Problems of Geophysics and Geodesy and in the New Large Soviet Telescope for these purposes

Accurate photographic observations of artificial earth satellites, carried out from many stations in accordance with special programs, are used sucessfully to investigate the density of the upper layers of the atmosphere and its variation as a function of the activity of the sun, to solve problems in cosmic geodesy on the basis of simultaneous observations from several stations, and to determine more accurately the earth's figure by determining the higher-order terms in the expansion of the earth's potential. This work has been carried out by the Astronomic Council of the USSR Academy of Sciences since 1957 on the basis of a specially created network of observation stations, which recently have been greatly expanded by adding stations in the African continent.

A new high-accuracy astronomical installation, specially intended for the observation of satellites, has been created in the USSR and comprises at present the largest telescope capable of following a satellite and registering the instant of observation accurate to 1 msec. This telescope is located at the Zvenigorod station of the Astronomic Council and is presently being readied for operation.

The Astronomic Council is performing statistical studies of the fluctuations of the parameters of the upper atmosphere and of the structure of the absorption bands of the variable radiation from the sun.

A. I. Nikishov and V. I. Ritus, Interaction of Electrons and Photons with a Very Strong Electromagnetic Field.

A characteristic value of the intensity of the electromagnetic field in quantum electrodynamics is

$$B_0 = m^2c^3/e\hbar = 4{,}4\cdot 10^{13}\,\text{э}.$$

At the Compton wavelength, such a field performs work equal to mc^2 (we use $\hbar = c = 1$). The parameter B_0 is characteristic of nonlinear quantum-electrodynamic effects (for example, the passage of an electron through a potential barrier, pair production by an electric field in vacuum), which reach their optimal values in fields of the order of B_0. Unfortunately, the intensities of the existing fields are weaker than B_0 by many orders of magnitude, and therefore the probabilities of many effects are exponentially small and incapable of being observed. It is possible, however, to observe certain nonlinear quantum effects also at fields of intensity $B \ll B_0$, by using an ultrarelativistic particle with momentum $p \sim m(B_0/B)$. Then, in the particle rest system, the intensity of the field will be of the order of B_0 and the probability of the process becomes optimal. Regardless of the type of the field in the laboratory system, in the particle rest system it will be very close to the field of a plane wave, for which $E \perp H$ and $E = H$. As a result, the probabilities for an ultrarelativistic particle in a constant field will depend on a single invariant parameter

$$\chi = [(F_{\mu\nu}p_\nu)^2]^{1/2}/B_0 m,$$

equal in order of magnitude to the field in the proper system, and referred to B_0 or Bp_0/B_0m; the dependence on purely-field invariants that are small compared with 1 and χ can be neglected. The probabilities $W(\chi)$ describe exactly the processes in a constant crossed field ($E \perp H$, $E = H$) and approximately those in an arbitrary constant field; the degree of approximation is determined by the smallness of the purely-field invariants compared with χ. The processes in a magnetic field were considered by Klepikov[1] (see also Erber's review[2]). In a constant field, the process evolves over a length m/eB. The alternating field acts like a constant field if its characteristic wavelength and period are large compared with the length and time of evolution of m/eB. On the other hand, if the wavelength is comparable with or smaller than m/eB, i.e., if the parameter

$$x = eB\bar{\lambda}/m = Bm/B_0\omega$$

is of the order of or smaller than unity, then the process evolves over a length $\sim\lambda$ and the probabilities will depend essentially on the field frequency or on the parameter x, which is the characteristic of the nonlinearity of the interaction: at small values of x the probabilities go over into the corresponding expressions of perturbation theory, and at large x the theory is essentially nonlinear in the field. The largest intensities have been attained in alternating fields of monochromatic plane waves (lasers). The processes in such fields were considered in[3-5]. Among the most interesting is the emission of the proton by an electron, $e \to e\gamma$, and pair production by a photon, $\gamma \to e^+e^-$.

In a monochromatic wave, the total probability of the process is determined by two parameters, x and χ, and is an infinite sum $W = \sum_{s > s_0}^{\infty} W_s$, the s-th term of which is the probability of the process with absorption of s photons from the wave. For the emission $e \to e\gamma$, the threshold number is $s_0 = 1$, and the probability W_s corresponds to the conservation law $sk + q = q' + k'$, containing the quasimomenta of the particles. The quasimomenta describe the average translational motion of an electron that oscillates in the wave, and depend on the intensity of the wave, the electron having an effective mass $m_* = [1 + (x^2/2)]^{1/2}$. Therefore the connection between the frequency of the emitted photon with the frequency of the wave (the analog of the Compton formula) also depends on the intensity of the wave.

At small x, the probability can be expanded in powers of x^2, from which it is seen that $W_s \sim x^{2s}$, i.e., the principal term will be W_1. The first term of the expansion of W_1, proportional to x^2, will be the well known Klein-Nishina formula. When $x \gg 1$ the probability is determined by the absorption of a large number (on the order of x^3) of quanta from the wave, and assumes the form of the probability in a constant cross field, averaged over the phase of the region of formation of the process. The probability of the emission in a constant crossed field has an order of magnitude

$$W \sim \frac{\alpha m^2 n}{q_0}\begin{cases}\chi, & \chi \ll 1,\\ \chi^{2/3}, & \chi \gg 1,\end{cases}$$

where n is the average density of the incoming particles. In the region of the parameters x, $\chi \sim 1$, the probability depends nonlinearly on x^2 and χ and is of the order of $\alpha(mc^2/\hbar)(mc^2/q)n$, corresponding to a reciprocal lifetime of the electron $\sim 5.6 \times 10^{18}$ $(mc^2/q_0)\,\text{sec}^{-1}$ relative to emission. The values $\chi \sim 1$ and $x \gtrsim 1$ are reached, for example, for electrons with energy 20 GeV (the energy of the Stanford accelerator) in a field $B \sim 4 \times 10^8$ Oe and frequency $\omega \lesssim 1$ eV. In this case the evolution range is $m/eB \sim 4 \times 10^{-6}$ cm, and the mean free path is $\sim 3 \times 10^{-4}$ cm. We note that fields $B \sim 2 \times 10^7$ Oe, i.e., only smaller than those given above by a factor of only 20, are presently attainable in lasers.

Unlike emission, the process of pair production has no classical limit, so that spin effects are always significant. In addition, the process has a threshold s_0 with respect to the number of photons absorbed from the field; this threshold depends on the parameters x and χ. As a result, with increasing x the terms W_1, W_2, etc. drop out in sequence from the total probability, and this leads to a nonmonotonic dependence of the total probability on x at fixed χ. In the case of sufficiently small x, the principal term in the total probability will again be W_1, and its first term in the expansion in x^2 will be the well known Breit-Wheeler formula for the production of a pair by two photons. At $x \gg 1$, the probability reduces to an expression in a constant field, equal in order of magnitude to

$$W \sim \frac{\alpha m^2 n}{k_0'}\begin{cases}\chi e^{-8/3\chi}, & \chi \ll 1,\\ \chi^{2/3}, & \chi \gg 1.\end{cases}$$

Inasmuch as the dependence on the polarization of the wave enters into the probability amplitude in a nonlinear manner, the probabilities of the same process in linearly and circularly polarized waves are essentially different. This difference is particularly striking for pair production at a high threshold $s_0 \gg 1$. For linear polarization, the distribution with respect to s reaches a maximum near the threshold, and then drops off exponentially. For circular polarization, the maximum of the distribution lies between s_0 and $2s_0$, and comes closer to $2s_0$ with increasing x. The decrease on the left side becomes steeper and steeper, and on the right side less and less steep. This difference is connected with the large momentum of the pair in the circular wave, equal to the number of absorbed photons.

Interest attaches also to the effects of second order in the interaction with the radiation field (for example, $e \to ee^+e^-$), and radiation effects such as the appearance of the photon mass, the change of the electron mass, and the anomalous magnetic moment of the electron. Radiation effects in a constant field[6] are optimal at $\chi \sim 1$ (for example, a field of 4×10^8 Oe and an energy 20 GeV). At higher energies, the square of the photon mass and the change of the electron mass increase like $\chi^{2/3}$, and the anomalous magnetic moment decreases like $\chi^{-2/3}$. At $\alpha\chi^{2/3} \gtrsim 1$ it is necessary to have an exact theory of the interaction with the radiation field, with account taken of all the radiative corrections—the electrodynamic interaction becomes strong. This energy region is more accessible than the corresponding region of logarithmically large energies for radiation effects in vacuum.

Although pair production by an electric field in vacuum is exponentially small in the presently attained laboratory fields, a study of these processes is of interest both from the purely theoretical aspect and from the point of view of astrophysical applications. It is curious that when scattering is considered in fields that generate pairs[7-8], a connection between the spin and statistics is revealed. An analysis shows that the total scattering probability with allowance for pair production in arbitrarily possible states is equal to unity (as predicted by Feynman), i.e., the Klein paradox actually disappears when the field-theoretical approach is used.

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V. B. Deryagin. New Data on Superdense Water.

In the June 1968 session of the Division of General Physics and Astronomy I already reported on a modification of water, which we shall call for brevity water II, with composition H_2O but physical properties that differ significantly from those of ordinary water, namely, it is much more viscous, has a density 1.4, a refractive index 1.48, it is not volatile at room temperature, has a linear expansion in the interval −40–60°C, and goes over into vitreous form at −40°C because of the increased viscosity.

At the same time, the idea was advanced that the "anomalous" or "modified" water consists of polymer molecules $(H_2O)_n$. Since that time, research continued in our laboratory by the late M. V. Talanev, V. V. Krasev, Ya. I. Rabinovich, Z. M. Zorin, N. N. Zakhavaeva, G. V. Zheleznyĭ, and D. S. Lychnikov under the general direction of N. V. Churaev and myself.

The question was first raised of the possibility of explaining the properties of water II as being due to the presence of organic or inorganic impurities.

Measurements have shown that the surface tension of solutions of water II increases in water I by 2–3%, indicating that the anomalous component, water II, cannot be identified with any known organic compound. A spectrochemical analysis with laser excitation, carried out by Lippincott in the USA, revealed only traces of certain elements, incapable of explaining the sharp difference between water II and water I, in view of the extremely small concentration. For further identification and clarification the structure of the polymer complexes of water II, a number of microscopic methods of physico-chemical analysis were employed. The decrease of the vapor pressure of water I as a function of the concentration of the water II dissolved in it has made it possible to determine the (average) molecular weight: $M = 150 \pm 30$. This value coincides with the value of M obtained from the curve of the composition vs. temperature of the phase lamination of the binary mixture water I—water II at temperatures below zero. It should be noted that the value $M = 150$ is possibly somewhat too high, and furthermore represents an average value if not all the polymer complexes of water II are the same.

This value of M is compatible with the assumption that water II exists when dissolved in water I mainly in the form of hexamers. Important conclusions were obtained by studying the thermal properties of water II. It was shown that below 700°C water II is redistilled via a vapor-like state without noticeable decomposition and without loss of the "anomalous" properties. At higher temperatures, water II becomes depolymerized and is transformed into water I. An analogous transformation was observed by Lippincott on the basis of the IR spectrum. We have measured the saturated vapor density of "pure" water II as a function of the temperature (its boiling point lies near 450°), making it possible to determine the heat of evaporation, $L = 7$ kcal/mole. The low value of L is obviously due to the rather weak interaction of the polymer (hexamer?) complexes of water II with one another. It should be noted that there exists apparently a higher-molecular fraction of water II, which is not redistilled at 350°C, with a refractive index close to the initial value 1.48 and with other attributes of water II.

Recently, water II has been diligently investigated in England and especially in the USA, and all the basic experiments on the production of water II in water I by condensation of vapor of the latter in capillaries of quartz or pyrex have been reproduced. However, Pethica and co-workers obtained, as seen from the depression of the melting point, small amounts of a low-concentration solution, and it was impossible to observe the difference between its IR and NMR spectra and those of water I.

To the contrary, Bellami and Lippincott, using more concentrated solutions, observed differences in the Raman-scattering spectra.

Lippincott, Stromberg, Cessac, and Grant obtained (by evaporation), just as in our case, pure water II, the IR spectrum of which revealed two strong absorption lines at wave numbers 1595 and 1400 cm^{-1}. This IR spectrum differs strongly from the spectrum of any of the 100,000 compounds listed in the corresponding catalogue. These absorption bands have allowed the authors to assume that the polymer molecules of water II are connected by a symmetrical O-H-O bond with a binding energy of approximately 40 kcal.

This estimate agrees with our observations of the thermal stability of water II. However, Allen and Kollman, on the basis of quantum-mechanical calculations, obtained for the O-H-O bond the same distance ~ 2.3 Å between the O atoms as Lippincott, but a much lower binding energy.

The thermal stability of water II is attributed by them to the larger activation barrier required to break a six-element ring with O-H-O bonds.

As noted by the same authors, the discovery of water II becomes less surprising if it is recalled that, for example, acetaldehyde and carbon disulfide can exist also in a stable polymer modificiation ("black carbon disulfide").

It should be added that it was demonstrated in our laboratory that it is possible to obtain modified methyl alcohol, acetone, and acetic acid by vapor condensation, as was recently confirmed also by Lippincott.