

with twenty times its own weight of water and filtering off the extract. This operation is repeated another three times and the combined four filtrates are evaporated to dryness on the water-bath, the residue being weighed and calculated as the water-soluble content of the cellulose.

My own experiments show, however, that when this method of extraction is continued on the same sample, after the above determination of water soluble content, approximately constant weights of residue may be recovered from subsequent extracts in a long series of extractions.

Hydrolysis was suspected at this temperature of extraction (95–100° C.), and a further series of experiments were conducted with very pure distilled water at ordinary temperatures (15–18° C.) in carefully selected apparatus, when it was found that the extracts again gave a lower but still approximately constant residue after repeated extractions.

In one case a sample of cellulose, weighing 10 gm., after removal of water-soluble impurities, was digested and washed in the cold with 20 litres of distilled water, corresponding to fifty extractions, without diminution of the residue obtained from the last extract. Micro-biological attack of the cellulose was considered as a possible explanation, but after consideration of microscopical and other evidence, was discarded. The following are typical of the results obtained when using 20 gm. samples stirred in 800 c.c. water for 2 hours at 15-18° C. :

Cellulose	Average Water-soluble Residue in Extracts
A. Bleached spruce wood	18·6 mgm. per litre
(sulphite process)	
B.	21·0 "
C. Alpha-Cellulose from B ..	13·6 "
D. Bleached cotton wool ..	20·6 "

The residue obtained from the extracts after evaporation, when final drying is done in a desiccator over phosphoric acid, appears as a white film, having a uniform granular appearance. Under the microscope, it is largely colloidal and isotropic but contains some scattered crystallites. The residue, if not charred during drying, is soluble in water and the solution shows a reducing action equivalent to about 15 per cent calculated as glucose. Whether this hydrolysis has taken place during extraction or evaporation of the extracts remains to be determined. Evaporation of a concentrated solution of the residue yielded a transparent brittle gum-like substance giving negative reactions for the presence of crystalline cellulose or of dextrin.

One fact appears certain, namely, that pure cellulose is slightly soluble in pure water at ordinary temperatures to the extent of 1·4 to 2·1 parts per 100,000, forming a perfectly clear sol. This dispersion of cellulose in water is probably accompanied by some breakdown in the cellulose molecule, but the nature of the reaction will take some time to determine.

This slight solubility of cellulose in water obviously sheds light on numerous scientific and technical problems involving the physical and chemical reactions of cellulose, from its origin in the cell-wall to its resolution by bacteria.

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'Convergent' Sunbeams

THE phenomenon of 'divergent' beams of sunlight is known to everyone. The illusion of divergence of the beams is so good that one has forcibly to remind himself that they are really parallel.

One day last summer, I observed 'convergent' beams and this observation was corroborated by others with me. It was late afternoon in a flat country. Clouds hid the sun, which, perhaps, was nearly eclipsed by the horizon. It had been raining in the surrounding country and cumulus clouds were still prominent in the west. The rays of the setting sun gave the familiar fan-like pattern in the west, passed almost invisibly overhead and then 'converged' in the east as if they emanated from a sun on the eastern horizon. These rays were of lower intensity than those in the west but were plainly visible.

The explanation of the phenomenon is obvious ; one is under the parallel beams, and looking along them in opposite directions. The spectacle was new to me.

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Origin of Stellar Energy

It is well known that matter consists of nuclei and electrons. Nevertheless it can be shown that in bodies of very large mass, this usual 'electronic' state of matter can become unstable. The reason for this lies in the fact that the 'electronic' state of matter does not lead to extremely great densities, because at such densities electrons form a Fermi gas having an immense pressure. On the other hand, it is easy to see that matter can go into another state which is much more compressible—the state where all the nuclei and electrons have combined to form neutrons.¹ Even if we assume that neutrons repel each other, this repulsion can become appreciable only at densities of the order of magnitude of nuclear densities, that is, 10^{14} gm./cm.³, and the pressure of a Fermi gas consisting of neutrons is much less than that of an electronic gas of the same density, because of the greater mass of the neutrons.

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Therefore, in spite of the fact that the 'neutronic' state of matter is, in usual conditions, energetically less favourable, since the reaction of neutron formation is strongly endothermic, this state must nevertheless become stable when the mass of the body is large enough. In this case, the gravitational energy gained in going over to the neutronic state with its greater density, compensates for the losses of internal energy.

It is easy to compute the critical mass of the body for which the 'neutronic' state begins to be more stable than the 'electronic' state. First of all we must calculate the energy necessary to form one neutron. For example, in the reaction $^{16}_8\text{O} + 8c = ^{16}_0n$, we find from the mass defects that to form one neutron the energy required is 0.008 mass units or $1 \cdot 210^{-5}$ ergs (7.5 Mv.). To transform one gram of matter into neutrons we thus need 7×10^{18} erg/cm³

Now we must calculate the gain in gravitational energy. The gravitational energy of the much less dense 'electronic' state can, of course, be neglected. Let us assume first of all that the neutronic state has a constant density, 10^{14} gm./cm.³. The gravitational energy of a homogeneous sphere

of mass M is then $3 \times 10^{-3} M^{5/3}$ ergs. For the stability of the neutronic phase we must then have $3 \times 10^{-3} M^{5/3} > 7 \times 10^{18} M$, or, $M > 10^{32}$ gm. = $0.05 \odot$, where \odot is the mass of the sun. On the other hand, if we assume that the neutrons behave like a Fermi gas, we find for the energy $7 \times 10^{-22} M^{7/3}$ ergs and hence

$$M > 1.5 \times 10^{30} = 10^{-3} \odot$$

which critical value is even less than on the first assumption.

When the mass of the body is greater than the critical mass, then in the formation of the 'neutronic' phase an enormous amount of energy is liberated, and we see that the conception of a 'neutronic' state of matter gives an immediate answer to the question of the sources of stellar energy. The sun during its probable time of radiation (about 2×10^9 years according to general relativity theory) must have emitted something of the order of magnitude of 3×10^{30} ergs. The liberation of this amount of energy requires the transition of only about 2 per cent of the mass of the sun (with the assumption of constant density) or even only $3 \times 10^{-3} \odot$ (with the Fermi

gas model) to the 'neutronic' phase. Even for such a bright star as β Orionis, we find for the mass of the neutronic core only about $0.1 \odot$ (with the Fermi gas model).

Thus we can regard a star as a body which has a neutronic core the steady growth of which liberates the energy which maintains the star at its high temperature; the condition at the boundary between the two phases is as usual the equality of chemical potentials. The detailed investigation of such a model should make possible the construction of a consistent theory of stars.

As regards the question of how the initial core is formed, I have already shown² that the formation of a core must certainly take place in a body with a mass greater than $1.5 \odot$. In stars with smaller mass the conditions which make the formation of the initial core possible have yet to be made clear.

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¹ Cf. Hund, F., *Erg. d. exakten Naturw.* 15, 189 (1936).

² Landau, L., *Sov. Phys.*, 1, 285 (1932).

Points from Foregoing Letters

CONTRARY to expectations, γ -rays of 17 million volts energy eject neutrons from the nuclei of some of the heavier elements only. Prof. Niels Bohr suggests that this selective behaviour is conditioned by "certain special vibratory motions with singular radiation properties" and these, together with other possible modes of vibration, lead to an energy distribution analogous to that of the heat motions in a solid body at a low temperature. The radiative properties of the nucleus in this state will resemble that of a black body with a temperature of several million volts. Based on this analogy Prof. Bohr gives a formula of selective absorption, relating the cross-section for nuclear photo-effects with the frequency of the incident γ -rays and the probabilities for the re-emission of a quantum.

Prof. Max Born proposes a 'principle of reciprocity' according to which each general law in x -space (space-time dimensions) has an 'inverse image' in the p -space (of momenta and energy). He indicates some of the consequences and numerical results: An energetically closed system would correspond to a closed momentum-space, with a radius c representing the maximum possible momentum. A number of quantities which are infinite in accepted theories become finite. Coulomb's law is modified, which implies a change in Rutherford's law of scattering so that for head-on collisions there is an absolute limit for the distance of closest approach. Plank's and Stephan-Boltzmann's laws and the laws of the kinetic theory of gases are altered. Applied to the theory of nuclear structure, the new principle yields, for the mean kinetic energy per nuclear particle and for the ratio between the nuclear and electronic radii, values in excellent agreement with Bethe's estimates.

Wilson chamber photographs showing the emission of the electron from atoms when they interact with neutrons are submitted by S. Kikuchi and H. Aoki. The authors assume the expulsion of an orbital electron or an electron in a negative state, due to some unknown interaction between the electron and heavy particle.

According to Dr. J. W. Weissenhoff, from the simple classical theory it follows that, in particular cases, the superimposed action of a magnetic dipole can annihilate the radiation of an electric charge in motion. This may remove the difficulty in connexion with Mathisson's theory of the spinning electron since the moving electron charge will be compensated so that there is no radiation.

In a paramagnetic salt it should be possible, according to Prof. K. S. Krishnan and A. Bose, from measurements on the magnetic anisotropy of the crystal at different temperatures, to calculate the coupling between the orbital and the spin angular momenta of the paramagnetic ion. The value of the coupling in Ni^{++} calculated in this manner agrees well with the spectroscopic value.

Photographs of electron-emission patterns of α -zirconium (at $600^\circ C.$, cathode temperature) and of β -zirconium (at $1100^\circ C.$) submitted by Dr. W. G. Burgers and J. J. A. Ploos van Amstel show that, as in the case of martensite, a Widmannstätten texture is exhibited by α -crystallites formed from the β -phase. On retransformation into the β -state, the original crystallites reappear, showing phenomena of growth.

The difficulties associated with the application of the Gibbs Phase Rule equation arise from the special significance which is attached to the term component. A modified equation proposed by Dr. S. T. Bowden avoids the use of this term and leads to a clear differentiation between the phase transformations of compounds and solid solutions.

Pure cellulose is generally regarded as being perfectly insoluble in water, but from investigations described by James Strachan, it appears that high-grade cellulose from wood and from cotton is slightly soluble in pure water at $15-18^\circ C.$ to the extent of 1.4 to 2.1 parts per 100,000, and that this dispersion of cellulose in water is probably accompanied by some breakdown in the cellulose molecule.