PHYSICS

New Theories in Physics Enter "Practical" Field

Offer New Explanation of Electrical Conductivity; Device Forecasts Results of Atom-Smashing Experiments

THE NEW theories of atomic physics —quantum and wave mechanics— are clarifying knowledge of the structure of solids and thus bringing these seemingly "impractical" playthings of the mathematical physicist into the realm of material objects which one can see and touch; objects which an engineer or layman could class as "practical".

Speaking before a joint meeting of the Optical Society of America and the American Physical Society, Prof. L. A. DuBridge of the University of Rochester described the newest advances of the attack of science on the secrets of matter.

Unifying Theory

The nature of the structure of solids like metal crystals, or glass, or insulators, is only in its beginnings, he emphasized; but already the quantum and wave mechanics has interpreted—from a single starting point—many properties each of which formerly needed its own little separate theory to account for it.

In particular, the old theory of the conduction of electricity through metals has been revised and physicists no longer picture a metal bar as containing myriads of so-called "free" electrons which could move about within the metal and conduct the current.

Central idea of the new picture is that a crystalline solid, like a metal, may be regarded as a single giant molecule. For a crystal of ordinary size this "molecule" will contain in the neighborhood of a hundred thousand million, million, million atoms. Or the figure 1, followed by 23 ciphers.

All these millions upon millions of atoms packed into a regular array in a single crystal produce effects quite different than if they acted individually as they would in a gas. The little energy levels of the atoms between which electrons jump to absorb or release energy are no longer peculiar to the atoms singly. There are energy levels for the whole crystal. And it is the movements of electrons into these energy levels of the crystal which determine many of the properties of crystals.

Crystals like those of sodium, potassium or silver are pictured by the new theory as consisting of electrons occupying the bottom of two broad bands or zones of energy. If the metals are cooled to absolute zero all the electrons are in the bottom compartment of what might be called an energy "basement".

By old theories it was predicted that solids cooled to absolute zero would possess no energy because the energy of motion of the electrons would be stopped. And without motion there was no energy. By the new theory it is predicted that even at absolute zero the electrons have motions and energies from 50 to 100 times greater than it was formerly believed they possessed at temperature of 1,000 degrees.

When an electric field is applied to metals of this group the outer electrons (or those at the top of the energy basement) will move up to the next lowest unoccupied energy levels. They move with the electric field and give rise to current. If vacant energy levels exist, to which the electrons can jump, then the metal is called a good conductor of electricity. Sodium, potassium and silver are notably good electrical conductors.

No Vacant Levels

If the electrons have no vacant levels to which they can go when an electric field is applied because these levels are already occupied, there is no current produced and the solid is known as a poor conductor, or a good insulator. Thus the strange situation may arise where one solid may have twice as many "free" electrons as another and yet be an insulator while the latter is a good conductor; the reason being that the "free" electrons have no place to go.

"The new theories," said Dr. DuBridge, "offer, for the first time, a picture of why one substance is a good insulator or a good conductor. The necessary condition for conduction is that there shall be unfilled but allowed levels immediately adjacent to the occupied levels."

The new theories also offer explanations of heat conduction in solids and predictions of the binding forces in crystals. Moreover, the optical properties of solids—like the photoelectric effect on which all photocell operation is based—are taking on a new understanding through analysis by the new theories. The magnetic properties of crystals are also being studied and, said Dr. DuBridge, "for the first time a satisfactory theory of ferromagnetism is being developed."

FORECASTING DEVICE

Prof. Vladimir Karapetoff of Cornell University, with his newly invented device for forecasting results of atom smashing when applied to any given element.

Compact Device

Prof. Vladimir Karapetoff of Cornell University showed a compact little device which can be set up on a table of elements to show the results of an impact upon any element or isotope by any one of several different kinds of subatomic "bullets" used in experiment. By properly using the scale the operator can read the theoretically possible resulting products of this atom smashing and the ejected particles that should come off.

The work of forecasting disintegrations and transmutations has become increasingly complex, and yet more and more scientists and amateurs are becoming interested in it, said Prof. Karapetoff. Nearly all the stable elements have been made radioactive by bombardment experiments and the number of possible forms of matter now runs into the hundreds instead of the simple 92 forms found in the old tables of the chemical elements. Moreover, the number of pos-

sible kinds of bombarding particles has been increased to nine, in Prof. Karapetoff's scale, so that the varieties of the various impacts which can occur set up a great mass of data.

Prof. Karapetoff's new scale brings order out of this drudgery and forms a convenient tool for the experimental and theoretical physicist in his nuclear research. The scale gives all the theoretically possible transmutations of elements; quantum-mechanical computations and the experiment are necessary to decide on those which can actually take place.

Sun's Expenditure

To maintain the existing radiation pouring out from the sun it is necessary that each one of the trillions upon trillions of protons and neutrons contained in it must give out a photon of light every 20,000 years. Calculations of the sun's energy and estimates of its radiation production were presented by Dr. Arthur E. Haas, mathematical physicist of the University of Notre Dame, before the physicists' meetings.

Every second the sun liberates photons represented by an enormous number consisting of the figure 2 followed by 45 ciphers, or 2,000,000,000,000,000,000,000,000,000,000,000,000,000,000,000 photons a second.

The total number of particles in the sun (the protons and neutrons) Dr. Haas estimates as consisting of 1.2×10^{57} particles, or a number represented by 12 followed by 56 ciphers.

It takes the sun about 20,000 years to liberate a number of photons equal to the number of particles it contains.

Once in 20,000 Years

"We must therefore assume," said Dr. Haas, "that each primordial particle contained in the sun experiences, at least in intervals of about 20,000 years, some reaction leading to the emission of a photon, or we must assume that extremely 'hard' primary photons produced in the interior of the sun split into a variety of softer photons on the way to the surface of the sun, or perhaps we must combine both assumptions."

Cosmic rays may be the most piercing and powerful of all radiation but one modern steam generating plant develops about the same amount of energy as do all the cosmic rays incident on the surface of the earth. Dr. Thomas H. Johnson of the Franklin Institute's Bartol Research Foundation estimated that the total cosmic ray energy striking the earth comes out to be about a million kilowatts. This is the same energy rating as the new steam generator plants of the South Philadelphia electric utility company.

The total number of rays striking the earth per second, said Dr. Johnson, is 8×10^{17}, or 800,000,000,000,000,000. This makes the cosmic ray current to the earth .13 amperes.

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Harvard to Have Largest Cyclotron Atom Smasher

A NEW type cyclotron, a 100-ton atom-smasher that promises to yield the most accurate information ever obtained concerning atomic disintegration, will be put into operation at Harvard University this summer. It will be the largest of the twenty-odd such "big guns" now in use throughout the world in man's assault on the atom.

Major development in the Harvard apparatus is a special device that will enable the experimenters to use atomic bullets of only one known energy, a procedure that promises to permit far more precise and reliable quantitative measurements of the forces involved in atom-splitting than have heretofore been possible.

At the outset the Harvard cyclotron is expected to produce atom-smashing projectiles of about eight-million-electron-volt energies. Further development, however, is expected to enable the production of projectiles of much higher energies.

In direct charge of the cyclotron are four of Harvard's outstanding young physicists, Prof. Kenneth T. Bainbridge, Prof. Jabez C. Street, Prof. Harry R. Mimno and Dr. Roger Hickman. They have supervised the construction of the apparatus during the past year.

The new feature of the Harvard cyclotron, energy-control, is obtained by steering the stream of ions through a special magnetic field that attracts, or combs out, all the particles of a single, known energy content. Only these uniform projectiles are used in the bombardment and thus the energy needed to produce disintegration and the characteristic internal energies of the nuclei will presumably be accurately measurable. Other cyclotron experiments have used the entire stream of ions, the energy content of which may vary considerably.

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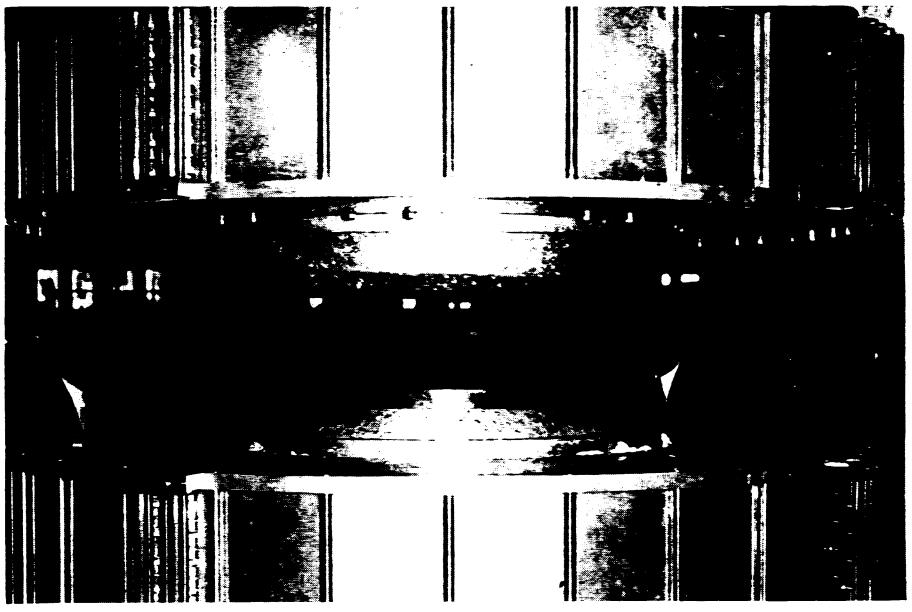

NEWEST ATOM-SMASHER

The Harvard University cyclotron is inspected by Prof. Jabez C. Street (left) and Prof. Kenneth T. Bainbridge.