National Academy of Sciences

Abstracts[1] of Papers Presented at the Autumn Meeting, October 9–12, 1950

General Electric Company Research Laboratory, Schenectady, New York

Measurement of the Intensities of X-Ray Reflections from Single Crystals Using a Geiger Counter X-Ray Spectrometer; Application to Beryllium Oxide

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A beam of x-ray incident on a crystal produces a diffraction pattern that is characteristic of the atomic arrangement in the crystal. Conversely, by measuring the intensities of the diffracted radiation, it is possible to compute the distribution of electron density, i.e., the atomic structure. The usual experimental arrangement for observing these data is to rotate or oscillate a single crystal in a monochromatic beam of x-rays, and to observe the diffraction pattern on photographic film. One of the principal limitations of the method is the difficulty of obtaining sufficiently precise intensity data over a wide range of intensity.

In the apparatus to be described here, the diffracted radiation is measured with a Geiger-Müller type counter, using a GE x-ray spectrometer in conjunction with a precision apparatus for tilting and rotating the crystal as desired. By this means, the diffracted intensities can be determined with greater accuracy and convenience, and consequently the method shows promise of elucidating many fine details of the atomic and electron structure of crystals.

Some preliminary results on the diffraction patterns obtained from beryllium oxide are discussed.

Ordering Reaction as a Phase Transition

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A survey of the literature on the ordering reaction in alloy solid solutions, combined with new data on several alloy systems, serves in the present research to show that the ordering reaction is truly a phase transformation of the conventional type. The mechanism of the reaction was studied by metallographic and crystallographic analyses, and the kinetics by electrical resistance measurements. Sufficient evidence was found to permit the following rationalization of the process in terms of features analogous to those of a conventional phase transformation:

1. The disorder → order transition is a heterogeneous reaction which involves nucleation of the ordered phase and growth by migration of a phase boundary.
2. Under certain conditions of temperature and composition the ordered phase may coexist in equilibrium with the disordered phase; i.e., a two-phase field separates the fields of order and disorder in the phase diagram as required by the phase rule.
3. The degree of order in intermetallic compounds, as well as in superlattice, is a function of temperature. Thus the only distinguishing feature of these two types of structures is that at temperatures below the melting point the superlattice transforms into a phase with random atomic distribution.

A Comparison of Light Microscope and Electron Microscope Images of Identical Surface Areas

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A serious difficulty encountered in the use of the electron microscope is the interpretation of the image produced by it in relation to the more familiar light microscopical image. Basically this is caused by the difference in the mechanism of image formation. In addition the difficulty is augmented, in the examination of surface at least, by the necessity of using very thin replicas. The electron image can be formed only by the transmission of electrons through the object, in this case the replica.

To minimize the difficulty of image interpretation, particularly of metals, it is desirable to compare identical areas at the same magnification in both the light and electron microscopes. The principal difficulty involved is in locating the identical area of the sample in each instrument.

A relatively simple technique is proposed whereby an acute angle is scribed, with a sharpened needle in a micromanipulator, on the surface of a polished and etched metal sample. This angle, enclosing or adjacent to the desired surface structure, is readily observed directly in the light microscope. By the use of a modified double-replication procedure and marked specimen

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[1] Contiued from SCIENCE, **112**, 419 (1950).

screens, it also may be readily located in the electron microscope. Using the apex of the angle as a common reference point, many areas adjacent to it may be easily recognized in both instruments, even though the surface has no distinctive natural structure that may be readily identified.

By this method image interpretation is greatly facilitated through the direct comparison of the micrographs from both microscopes of the same surface structures.

Isothermal Rate of Solidification of Mercury Droplets

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The variation with temperature of the rate of solidification of an aggregate of mercury droplets may be described by the following equation that assumes nucleation of crystals to be the rate-determining step:

$$I = A \text{ exp. } [-K\sigma^3/(\Delta F_v)^2 kT],$$

where I = solidification frequency of droplets (cm^{-2} or $^{-3}$ sec^{-1})

K = shape factor

σ = interfacial energy/cm^2 between crystal nucleus and liquid

ΔF_v = free energy difference/cm^3 between phases of infinite volume

A = constant (cm^{-2} or $^{-3}$ sec^{-1})

An aggregate of mercury droplets (2–6 μ diameter) dispersed in hydrocarbon media and prevented from coalescing by a stearic acid film has been found to solidify with a measurable frequency in the temperature range −98° to −102° with $\sigma = 24.0$ ergs/cm^2 (for spherically shaped nucleus) and $A = 10^{31}$ cm^{-3} sec^{-1} in good agreement with the value 10^{33} predicted from reaction rate theory.

Mercury droplets (10–50 μ diameter) coated with a film of mercuric iodide solidify in the temperature range −86.5° to −87.5° with $\sigma = 29$ ergs/cm^2 and $A = 10^{38}$ cm^{-3} sec^{-1} in apparent disagreement with rate theory. I changes by a factor of 100/degree in the temperature range of the measurements. The isotherms can best be described on the hypothesis that I is proportional to the volume of the droplets, but the agreement is almost as good when it is assumed that I is proportional to their surface area.

An Approximate Crystal Structure for the Beta Phase of Uranium

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An approximate crystal structure for the beta phase of metallic uranium (stable between 660° and 760°) has been deduced from x-ray diffraction measurements made on single crystals of the phase retained in an alloy containing 1.4 atomic percent chromium and rapidly cooled from approximately 720° C. The diffraction data and other measurements show that the unit cell of the beta phase is tetragonal with $a_0 = b_0 = 10.52$A, $c_0 = 5.57$A, and contains 30 atoms. Of the three possible space groups (D^{14}_{4h}, C^4_{4v}, and D^8_{2d}), D^{14}_{4h} appears definitely excluded; of the remaining two, C^4_{4v} thus far appears to account adequately for the diffraction intensities. Approximate positions of the 30 atoms in the unit cell have been deduced using the Patterson and Patterson-Harker F^2 syntheses and the Fourier electron density synthesis.

The structure of the beta phase is a layer structure, with the layers being parallel to the a_0b_0 plane of the unit cell at ¼ c_0 and ¾ c_0. Approximately midway between the layers are atoms that are linked to the atoms in the adjacent layers but not to each other. The layers are quite closely related to those found in the basal planes of the familiar hexagonal close-packed structure except that atoms at the center of certain hexagons are displaced normal to the layers to form the set of atoms found midway between the layers.

The low symmetry and complexity of the structure account for the hard, brittle nature of the phase. The interrelations between the alpha, beta, and gamma phases of the metal are clear from the beta-phase crystal structure, but the precise mechanism of the transformations has not yet been studied.

Thermodynamics of Coherent Precipitation

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The properties of alloys are greatly influenced by the presence of finely dispersed particles of a second phase, which usually are produced by rapidly cooling the alloy from a high temperature where the single phase is stable to a low temperature where a two-phase mixture is stable. Particles of the second phase then form and grow at rates characteristic of the precipitation mechanism.

There are three important mechanisms whereby particles of a second phase can precipitate: (1) the particle can be strain-free and of equilibrium concentration. Here the volume free energy decrease is a maximum, and large particles are stable up to the usual thermodynamic limit of the two-phase region. (2) The particle can have equilibrium composition and be strained, so that continuity of the lattice (coherency) is maintained across the particle-matrix interface. Although the strain energy lowers the maximum temperature at which such particles can form, a decrease in interfacial free energy resulting from the coherent interface favors their nucleation. (3) The particle can be coherent and of the same composition as the parent solid solution. Here the maximum temperature at which the particle can form is very low, but its nucleation and growth are speeded, for the interfacial energy is small and no long-range diffusion is required.

Coherent precipitates, with equilibrium composition and with the same composition as the parent solid solution, have been observed. It is shown that the upper temperature limit for the existence of either type, the plane of the matrix crystal parallel to which plates of the precipitate form, and the equilibrium composition of coherent precipitates, can be calculated from the crystal structures and lattice parameters of the two phases and the elastic constants of the precipitating phase.

Copper-Copper Interfacial Free Energy

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A small drop of liquid lead resting on the surface of a copper single crystal tends to assume an equilibrium lenslike shape determined by the relative interfacial free energies σ_{1-2}, σ_{1-3} and σ_{2-3}, where the subscripts 1, 2, and 3 refer to Cu(s), Pb(1) and Pb(v) phases, respectively. When this system is heated to 800° C for several hours, the copper atoms become sufficiently mobile that equilibrium is apparently attained.

In the present investigation lead powder was lightly dusted on the polished end of an outgassed cylinder of OFHC copper. The specimen was heated for 8 hr at 800° C in a hydrogen atmosphere. After cooling, the specimen was cross-sectioned and polished normal to the lead-covered surface. The polished section was examined for lead drops at ×500 following a light dichromate etch. Although the equilibrium angles defined by the intersection of the Pb(v)–Pb(1), Pb(1)–Cu(s), and Pb(v)–Cu(s) phase boundaries were found to have been distorted upon solidification of the lead drop, it was possible to calculate the equilibrium angles from measurements on the thickness and length of drops.

Since the absolute value of the surface tension of liquid lead, i.e., σ_{2-3}, is already known, the values σ_{1-2} and σ_{1-3} can be calculated. Smith has measured the ratio $\sigma_{1-1}/\sigma_{1-2}$ and from his data the absolute interfacial free energy of a copper-copper grain boundary can be determined.

Energy Loss of Electrons in Passing Through a Phosphor

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Although the penetration of electrons into thin metal foils has been investigated no experimental data are available on the penetration into phosphors. This is largely because phosphors have not been available in thin films of uniform thickness. Recent developments have made it possible to form very thin uniform layers of ZnS. Studies of the luminesence of these films under electron bombardment give information concerning the penetration and the loss of energy of electrons in the phosphor.

The films used varied in thickness from 0.1 to 0.5 μ. They were excited by electron bombardment in a demountable, post-accelerator cathode-ray tube at voltages up to 30 kv. The data were recorded by photographing the trace on a cathode-ray oscilloscope, with the beam voltage impressed on the horizontal and photocurrent on the vertical plates. In this way, the voltage brightness relation was studied for a number of screens of different thickness.

The voltage brightness curves show a linear increase in brightness with increasing voltage, pass through a maximum, and then fall gradually. From the curves, the voltage at which electrons pass all the way through the phosphor and enter the glass may be determined and the absorption coefficient calculated. The maximum brightness occurs at still higher voltages. This departure of the shape of the curves from the ideal Thompson-Whiddington law is an indication of a significant amount of electron scattering. The relation between scattering and voltage is obtained from the curves.

Marcasite Fauna in the Ludlowville Formation of Western New York

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A remarkable faunal assemblage with an unusual mode of preservation occurs in the Ludlowville formation of western New York. The fossils are found preserved within marcasite concretions, the fossils themselves being either wholly or partly replaced by marcasite. These concretions form a clearly defined horizon marker within the upper part of the Ledyard shale member, traceable from Lake Erie to east of East Bethany, New York, a distance of 50 miles. This paper is concerned with the fauna occurring within the concretions, and an explanation is offered as to the conditions that brought about this unusual feature.

Direct Probability Sequential Analysis; Unified Foundation for Finite or Infinite Universes and the Poisson Binomial Limit

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The writer broached the subjects of sequential analysis and of objective (cybernetic) experiment-steering systems that gave fundamental relations for statistical inferences not requiring knowledge of original distribution form of the sampled universe U. Appropriate interpretation of these relations yields a broad base providing direct-probability sequential analysis systems as exact solutions for stipulated conditions that are about the commonest practically met. Conditions may be considered as equivalent to those where ϕ is the unknown relative frequency of *unsatisfactory* individuals in a *lot* or universe U: (I) finite of aggregate number N, or (II) infinite; and, after n random observations, we wish to reject U if possible, with a tolerable risk α that p' exceed ϕ, or to accept U if possible, with a tolerable risk β that ϕ exceed p'', or otherwise to take another observation, etc. Values of α, β, p', and $p'' \geqq p'$ are prescribed; (p', p'') is the *indifference interval.* Case II has already been given in abstract, with criteria in terms of the incomplete beta function; Case I analogously employs the four-argument psi function. Case III is derived from II as the Poisson binomial limit as $n \longrightarrow \infty$ with constants: $w = n \cdot \varphi, m' = n \cdot p'$, and $m'' = n \cdot p''$, respectively, used analogously to φ, p', and p'', such sampling being replicated in ν stages, analogous to n observations in Case II. In any case with the nonzero interval of indifference $(p' < p'')$, a decision (to accept or reject U) will be reached accordingly within a predeterminable amount of sampling ($n - n_o$ in I or II, $\nu \leqq \nu_o$ in Case III). In contrast, the probability-ratio sequential systems that have been widely used in such situations lack such a feature; indeed, arbitrary truncation has been used as a crude cure. This and other objectionable features result from their failure to meet the stipulated conditions completely as they are met by direct probability sequential analysis. An experiment-steering application has been suggested elsewhere.

Null Polygons

Edward Kasner, *Columbia University*

By a null polygon we mean a plane polygon each of whose sides is of length zero. So we have n corners, $P_1, P_2, \ldots P_n$ and n sides $P_1P_2 = 0$, $P_2P_3 = 0, \ldots P_nP_1 = 0$. We study the set of all diagonals. They are not zero. What is the theory of the diagonals? This is the problem of this paper.

Naturally, all our polygons are imaginary. The first interesting case is the quadrilateral, $n = 4$. Here we have 2 diagonals. Theorem: the sum of the squares of the diagonals equals zero. The next interesting case is the hexagon, $n = 6$. Here we have 9 diagonals, 3 major and 6 minor.

All our theorems are most conveniently stated in terms of the square of distance. The span (13) will mean the square of distance P_1P_3.

Theorem I: $(13) + (24) = (14)$. Thus the major diagonals are expressed in terms of the minor. The next question is what are the interrelations of the minor diagonals. Theorem II: in any null hexagon the differences of the spans of opposite minor diagonals are equal.

Our theory can be extended to polygons of more sides and to polygons in space of 3 or more dimensions. Applications can be made to restricted relativity.

Stalk Formation in *Dictyostelium*

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Species of *Dictyostelium,* a genus of pseudoplasmodium-forming slime molds, afford exceptionally favorable material for observing the emergence and elaboration of morphogenetic patterns. The pattern of the fruiting structure, or sorocarp, arises through the whole community of closely coordinated individual cells, or myxamoebae, functioning as a unit. During differentiation, individual cells assume whatever form is necessary to produce a sorocarp of characteristic form and of dimensions proportional to the mass of myxamoebae comprising the organization.

The formation of stalks, or supporting structures, is most important to the consummation of developmental patterns, and this is accomplished by a process that is unique to the Dictyosteliaceae. In the higher plants, tissues generally assume rigidity and definitive form by an orderly sequence of cell divisions followed by intracellular deposition of cellulose. In these microorganisms, cellulose (or a celluloselike material) is apparently first produced extracellularly, perhaps in a manner analogous to that reported for species of *Acetobacter* or the tunicates. This material then condenses to form a centrally placed continuous tubular sheath of a diameter proportional to the mass of cooperating myxamoebae. As this sheath is extended in length, the myxamoebae entrapped within it become vacuolate and fitted together into a compact parenchymalike tissue constituting the stalk, or sorophore. The walls of individual stalk cells subsequently become thickened and comparatively rigid by localized cellulose deposition. Whereas, species of *Dictyostelium* are not believed to bear direct phylogenetic relationship to higher plants or animals, they represent easily propagated primitive forms wherein the transition from a unicellular to a multicellular level of organization is effectively bridged.

Demonstration of New Processes of Blood Collection and Separation of Red Blood Cells, White Blood Cells, and Platelets; Protein, Glycoprotein, Lipoprotein, and other Components of Plasma

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Separation from each other of the formed elements of blood, as well as the diverse protein and other complexes of plasma, was undertaken in order more completely to understand the nature and function of each, the equilibria in which each is a component, both within the blood and with the tissues, the optimum environment of stabilizing each, the optimum method of sterilizing each, and of preserving and utilizing each in the interest of national health and security.

Blood is collected in nonwettable equipment; calcium is removed by exchange resin; dextrose is made available continuously for all cells, red cells separated from white cells and platelets by sedimentation in the presence of reversible rouleaux-forming fibrinogen substitutes; white cells and plateletes by new and especially devised long traverse and falling film centrifugation. Prothrombin and prothrombin conversion accelerator are adsorbed by $BaSo_4$ and separated from each other by fractional elution in an ethanol-water mixture at −5° C. Fibrinogen, plasminogen, and antihemophilic globulin are precipitated near the pH 7, as in previous methods, at low ethanol concentration as sodium salts; α and β lipoproteins, steroid, and certain hormones, Seegers accelerator globulin, isoagglutinins, γ-globulins, and amylase are precipitated under the same conditions as zinc salts. Lipoproteins are fractionally extracted from remaining components of this fraction in glycine-ethanol-water mixture, γ-globulins from remaining components as previously. Albumins and glycoproteins, iodoprotein, β metal-combining protein, phosphatase and esterase enzymes, certain hormones, and all but small proteins are precipitated from ethanol-water mixture near pH 7 as zinc salts, the acid glycoprotein as a barium or cadmium salt.

New methods of subfractionation by extraction in ethanol-water mixtures in the presence of bivalent metals and metal buffers are supplanting earlier procedures and rendering possible separation of all proteins without increase of ethanol above mole fraction .09 at – 8° C near pH 7. Metals are removed by exchange resin before proteins are concentrated. Lipoproteins are separated from each other and preserved as concentrates; all other proteins are dried from the frozen state.

The formed elements, all proteins, amino acids, peptides, and related substances, the colloidal polysaccharides related to isoagglutinogens, and all other nitrogenous components of plasma, are separated and concentrated, it is believed, more nearly in their natural state than has heretofore been possible.

A Multiple Pressure Gage of the Resistance Type

S. P. Schlesinger (*formerly of Union College*)

Recently there has been a great deal of interest shown in the testing of small models in supersonic and hypersonic wind tunnels. Although there has been improvement in the methods used in measuring model forces, little has been done in the development of new methods of measuring quickly and accurately the many pressures of interest to the aerodynamicist. This paper describes a pressure-measuring device that gives electrical responses to several pressure impulses, and is small enough to fit inside the model tested. The device makes use of the change in circumference of a series of concentrically arranged extremely thin copper tubes when exposed to given pressure differentials, this change being transmitted to bonded resistance wire, which in turn gives recordable electric signals. An equation showing theoretical signal is given, and the development is outlined. The nine units built by the author are described, as are the results of testing. Suggestions for further tests and several methods of improving performance are discussed.

The State of the Primitive Earth

Harold C. Urey, *University of Chicago*

(1) The face of the moon records the terminal phase of its formation from planetesimals which contained both iron-nickel and silicate phases. Presumably the earth collected similar material at the same time. (2) The generally quoted radius of Mars must include a rather thick atmosphere, according to Wright and Trumpler. Using Trumpler's radius the ratio, ε/Φ, is found to be 1.21 as compared to a calculated value of 1.22 for a compressible Mars of uniform composition, and of 1.02 for a Mars with approximately the present earth structure. (ε is the oblateness and Φ the ratio of centrifugal to gravitational force at the equator.) Thus Mars is nearly uniform in composition and contains about 30 percent of iron phase. The earth probably had a similar structure initially. (3) The marked increased density of the earth between 400 and 1,000 km is most plausible by assuming the presence of iron phase below this level. (4) The secular accelerations of the sun and moon do not agree with the tidal friction theory. However, if iron phase is now sinking to the core at the rate of 7×10^{-10} g sec^{-1}, the discrepancy is removed. This rate would produce the present core in 8×10^{8} years. This time is too short, but the core probably was not formed at a constant rate. (5) The heat balance of the earth indicates too much heat generation if gravitational energy due to formation of the core as well as radioactive heat, is included, unless the earth has expanded its radius by 2×10^{2} km, because of the more compressible silicate moving from higher to lower pressure regions, and the less compressible iron moving in the reverse sense. It is concluded that the evidence favors a primitive earth of grossly uniform composition and that the core has been formed during geological time, and in fact that it is still growing.

The High Temperature Stage in the Evolution of the Terrestrial Planets

Harold C. Urey, *University of Chicago*

The evolution of the terrestrial planets proceeded from a gaseous cold nebula containing dust through a higher temperature stage to one at low temperature. Iron sulfide is unstable with respect to reduction above 1,200° K in the presence of cosmic proportions of hydrogen and sulfur and yet is a prominent constituent of iron meteorites; hence, these meteorites could not have been deposited from a completely volatilized state. The sulfide must have been formed at low temperatures, and the high-temperature stage must not have existed long enough to establish equilibrium. This means that substantial bodies up to about 100 km in radius (estimated size of the Imbrium planetesimal) were accumulated during the low-temperature stage.

Silicates would be reduced to silicon hydride and metals at 2,000° K and at hydrogen pressures of ~ 1 atmosphere or greater. Since silicates are regular constituents of pallasite meteorites, whose structures show that the iron was once molten, the temperature, pressure, duration of the high-temperature stage, and size of the objects were such that all the silicate was not volatized. If the conditions had been such that iron was volatilized and condensed in an iron rain, no silicate could be present mixed with the condensed iron. Hence, again, temperatures between 1,500° C and ~ 2,800° C are indicated. The silicon hydride provides a volatile substance for removing silicon from the nebulae, thus producing the different densities of the planets.

It is assumed that the meteorites are fragments from a planetary nebula which did not quite produce a planet and also, perhaps, from the planetary nebulae of the earth and Mars. Gravitational energy could not have heated them to high temperatures, and hence they were heated from the exterior by the contracting gases of the nebula. These conclusions are the same as those required to preserve water, nitrogen, mercury, and carbon on the earth while the inert gases were lost.

On the Origin of the Solar System

Gerard P. Kuiper, *University of Chicago*

The origin of the planets and the smaller bodies in the solar system can be attributed to the interaction of two processes in the preplanetary gas cloud: large-scale turbulence and gravitational instability. The cloud may be assumed to be of cosmic composition: 98 percent hydrogen and helium and the rest heavier elements. Regardless of the original nature of the cloud, it will contract because of internal collisions and energy losses by radiation, and will develop into a flat disk in near-hydrostatic equilibrium, with the parts rotating around the sun in nearly free Kepler orbits. However, on this broad picture a finer density pattern will be superimposed, caused by turbulence. The scale of the eddies increases proportionally with the distance to the sun.

The eddy pattern in itself will not lead to the formation of planets. If the density of the cloud remains below a certain critical value, in spite of the contraction process referred to, the eddy pattern will change ceaselessly until the cloud will finally dissipate by turbulent dissipation, caused by internal viscosity operating in a cloud having different angular speed at different distances to the sun. But, if the density of the cloud exceeds the critical value, gravitational instability will become operative. The large-scale density fluctuations will be amplified indefinitely until gravitationally stable subclouds (protoplanets) have formed, which together sweep up the entire volume previously occupied by the preplanetary cloud. The outer fringe of this cloud, however, will not attain the critical density and, in this region numerous small bodies are expected to form. This region (outside Neptune and Pluto) will have produced the comets. It is found that some 10^{12} condensations will form, each having a diameter of about 1 km and less. This number and this size are just what is required to account for the present-day comets. The expected composition (mostly ices of H_2O, CO_2, NH_3, and CH_4) is precisely what is found empirically to be the comet composition. The dynamics of lifting the comets out of their ring of formation is discussed; Pluto appears to play a decisive role in this process.

The density requirements valid for the formation of stable protoplanets, together with the present planetary distances, lead at once to the determination of the masses of the protoplanets. Proto-Earth appears to have been about 1,200 times the Earth mass; proto-Jupiter about 12 times Jupiter. The condensation products formed from these protoplanets are in general accord with expectation. It appears that the distance to the sun is less important to the ultimate composition of a planet than the precise mass of the protoplanet. The Earth differs greatly in composition and mass from Jupiter, not because it was closer to the sun but because proto-Earth was about 4 times less massive. It is shown that solar tidal friction is responsible for the present direct rotations of the planets; and also for the occasional high obliquities. The theory of the secular change of planetary obliquities has been developed. The origin of the asteroid ring and of meteorites is briefly reviewed.

Seismic Measurements in the Atlantic Ocean

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Seismic refraction measurements made in the western North Atlantic have given information about the nature of the rocks beneath the ocean basin and the thickness of sediment covering them.

Coherent Seismic Wave Patterns

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Our first series of seismic measurements from explosions showed phases corresponding to several discrete velocities; this apparently confirmed the existence of subcrustal layers between the surface and the Mohorovicic discontinuity. Increasing the regional density of our measurements decreased the plausibility of this interpretation; furthermore, overlapping systems of regional travel-time curves were different. The growing body of evidence after three years thus did not support the familiar hypothesis that the crust has uniform horizontal layers.

If there are uniform horizontal layers within the crust, they should be observable on explosion-wave records chiefly as second arrivals. These arrivals would be in the form of coherent waves which would cause some systematic pattern of earth motion over a given surface area around a receiving location, possibly recognizable amidst a background of random scattered radiation. Our first experiments seeking evidence of this coherent pattern utilized seismometers either perpendicular to, or along, the ray path from the shot point. The arrays extended over one km, and the results were not encouraging. In our latest experiments we have employed 48 seismometers uniformly spaced along 2 km of ray path. Two 24-trace oscillographs recorded the ground motion. This technique duplicates oil prospecting procedures on a greatly enlarged scale. We observed at positions 52 and 106 km from 7 one-ton explosions, shot for us by the Navy.

At 106 kilometers we can recognize a phase seen as a moving pattern of related impulses lasting for about one second, which we consider to be a P30P reflection. Previously, a series of single observations in this particular region had failed to identify this reflection. The characteristics of the multiple seismogram are consistent with a previous hypothesis that the Mohorovicic discontinuity at some 30 km of depth has marked topographic features making it both sloping and rough to the seismic waves (roughly, 300 m wavelength). In some regions it is fairly flat, acting seismically like a plane mirror. At 52 km we do not as yet identify any phases; there is evidence, however, for the existence of a pattern of inhomogeneities at a depth range of 8–15 km.

Elasticity and Composition of the Earth's Interior

Francis Birch, *Harvard University*

The variation of seismic velocities with depth is compared with the predictions of a theoretical equation of state which is in good agreement with available experimental data. The observed variation of $K/\rho (= V_P^2 - 4/3\, V_S^2)$ between depths of 900 and 2,800 km is given within 1–2% by this equation; this fact suggests that a homogeneous phase occupies this region, while the numerical values are such as to exclude known phases of plausible materials. Between about 200 and 900 km lies a region in which the variation of K/ρ cannot be accounted for in terms of compression of a homogeneous phase; this is interpreted as a region either of changing composition, changing phases, or, more probably, both.

Consideration of these results in terms of the theory that the earth is of meteoritic composition suggests that the elements Na, K, Ca, and Al have been concentrated in the uppermost 800–900 km, where, below the thin crust, they exist as silicates of high elasticity and density, such as jadeites or garnets. A high-pressure modification of a ferro-magnesian silicate is probably required for the uniform layer between 900 and 2,800 km.

The core (below 2,900 km) is also examined, and the large uncertainty of extrapolated zero-pressure densities emphasized. Though present data are considered inadequate for a positive identification of the material of the core, the "iron core" hypothesis still appears to be acceptable.

Radiocarbon Dates

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An attempt has been made during the past year and a half to check the radiocarbon dating technique by selection of a wide variety of problems and the measurement of a considerable number of samples in each of these problems. The results are presented briefly.

The dates include the following: historic and predynastic Egypt; Mesopotamia and Western Asia; Scandinavia and Western Europe; pollen dates, principally the boreal period throughout North America and Western Europe; the last ice sheet in both North America and Western Europe; early man in North America, in particular the ancient Westerners; the valley of Mexico; South America and Peru; and certain miscellaneous materials, such as tree-ring samples used as checks on the method.

A brief discussion of the significance of the results as far as the validity of the radiocarbon-dating technique is concerned is given.

Progress Report on Geologic Time Measurement

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Current practices in geologic age measurement by lead, helium, and strontium ratios are briefly outlined. A compilation is presented of the age measurements made on the basement rocks of the North American continent. The measurements suggest that the continent grew as a result of a succession of peripheral orogenies that added stable land masses continuously throughout geologic history at least as far back as 2.4×10^9 years.

Petrologic-Cosmogonic Dilemma

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Analyses of meteorites afford an increasing knowledge of their average composition, and comparison with the composition of heavenly bodies, as determined in various ways, suggests that meteorites represent a sample of cosmic matter. Moreover, the detailed studies of meteorite phases by Brown and Patterson tend to confirm the old belief that meteorites came into existence through the disruption of a planet, and the distribution of elements between the phases appears to give some indication of the temperatures and pressures prevailing and therefore of the size of the planet, which, it is suggested, was comparable with that of the earth.

It is tempting, therefore, to regard our earth as probably made up of material corresponding with meteoritic matter, but if the earth as a whole really had as high a content of alkalis and aluminum as the meteorite average we would probably have a universal granitic shell on the earth of very considerable thickness.

The model of the earth suggested by petrologic-seismologic considerations is one having a localized granitic shell of moderate thickness with basaltic and dunitic material coming in at moderate depth. Moreover, seismologists lean toward the opinion that the dunitic layer has a nearly uniform composition all the way to the iron core. This results in an earth composition departing rather widely from that of average meteorites. The difficulty of disposing of the heat of the several kinds of atomic disintegration for such an earth is very much less than that for an earth of meteoritic composition.

We need a great deal more information on all aspects of these questions before we can make a first approximation to a solution of the problem of the composition of the whole earth and its shells.

On the Origin of Planets and Comets

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The evidence is strong though not absolutely conclusive that comets must have originated concomitantly with the planets or prior to them. An understanding of the comets should, therefore, aid in the development of a theory for the origin of the planets.

The writer has developed a theory of the nature of comets which accounts in some cases quantitatively and in others qualitatively for the major observable characteristics of comet nuclei, including their observed deviation from Newton's law of motion. This theory indicates that a comet nucleus consists of a true conglomerate of the most probable interstellar compounds including ices, with high vapor pressures at temperatures of 300° K or below, and meteoritic materials, with low vapor pressures at 600° K.

The nature of the ices present in cometary nuclei sets limits to the gas temperatures and pressures at the time when comets developed, and hence limits on the conditions under which the planets developed, if we accept a concomitant origin. If solid methane actually exists in comets, the sun must not have been more luminous at the time of the origin of comets and planets than it is now.

A postulate that the sun has lost a large fraction of its mass since the formation of the planets can be eliminated on the ground that the comet family would also have been lost. A theory involving this postulate has been suggested to account for loss of angular momentum by the sun.

Some Laplacian-type theory for the origin of the planets can possibly account for the concomitant origin of comets if the above restrictions on the sun's mass and luminosity at the time of planet and comet formation are satisfied. In case the comets developed prior to the planets, the restrictions on the mass, but not on the luminosity, of the sun still apply.

Geologic Evidence Regarding the Source of the Earth's Hydrosphere and Atmosphere

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Many of the minerals and fossils in sedimentary rocks suggest that the composition of sea water and atmosphere has varied only slightly throughout much of the geologic past. Some materials, such as Na, have accumulated progressively in the sea water; others, such as CO_2, have remained about constant, having been added from some source and subtracted by sedimentation almost continuously throughout geologic time. The relatively volatile constituents—water, carbon, chlorine, nitrogen, and sulfur—are much too abundant in the atmosphere, hydrosphere, and ancient sediments to be explained simply by rock-weathering. The relative amounts of these "excess" volatiles correspond closely enough to those of the gases occluded in igneous rocks and escaping from volcanoes and hot springs to suggest that the ocean and atmosphere may have come from such gases.

Recent geophysical and geochemical data imply that the earth may never have been completely molten and that the hydrosphere and atmosphere may have accumulated by gradual escape from the interior. Geologic evidence is consistent with a growing contrast between continental masses and ocean basins and a progressive sinking of the ocean basins, which would mean an increasing volume of sea water.

A mechanism that might account for a continuous supply of volatiles to the earth's surface would be a process of selective refusion of rocks beneath the unstable continental margins and mountains, a cooling and recrystallization of these fractional melts to form new granitic rocks, resulting isostatic readjustments, and gradual escape of the volatile materials in volcanoes and hot springs.

The Vapors of Sulfuric Acid-Water Mixtures as Nucleating Sources in Aerosol Formation

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The presence of foreign nuclei of radii greater than 10^{-7} cm is generally assumed to be necessary for the condensation of molecular vapors to form an aerosol whenever the supersaturation is below the limit of self-nucleation (4.2 for water vapor). Puzzling results in the production of monodisperse aerosols by the uniform cooling of vapors upon foreign nuclei (ions and smokes from a spark discharge, NaCl dusts, etc.) have been traced to the presence of vapors of H_2SO_4 created in the drying train for the incoming air. Although the vapors of HCl and NH_3 have been known since the pioneer work of von Helmholtz (1890) to be nucleating sources for the production of water fogs by the expansion of superheated steam, no one has recognized that the vapors arising from moderately concentrated H_2SO_4–H_2O mixtures at room temperatures are excellent sources of nuclei for the production of aerosols of sulfur, stearic acid, nujol, dioctylphthalate (D.O.P.), and similar types of condensing vapors. The nucleating efficiency of H_2SO_4 vapor in respect to both number of particles produced and the degree of supersaturation necessary decreases with the temperature and the water content of the nucleating source.

With sulfur as the condensing vapor, no aerosol formation could be detected in the homogeneous generator, or in a cloud chamber operating by adiabatic expansion, for nucleating sources having a content of H_2SO_4 below 90 percent at 0° C, 75 percent at 12° C, 62 percent at 25° C, and still lower values at 50° C. These results indicate that the ability to nucleate condensable vapors vanishes at a vapor pressure of H_2SO_4 of roughly 10^{-9} mm Hg, and that these vapors may exist as molecular clusters of H_2SO_4 and H_2O of a size that is much larger than is generally believed.

Internal Excitation and Apparent Range of Nuclear Forces in Scattering Experiments

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Scattering of protons by protons and by neutrons is usually explained in terms of a potential energy between particles, and conclusions concerning the magnitude of the potential and the range of force can then be drawn. Explanations in terms of nucleon-meson interaction have been only partially successful and do not lead uniquely to the potential energy view. The possibility that mesons are only connected with nucleonic interactions but are not emitted in the first elementary process appears open either as a strong coupling modification or as a point of departure.

The effect of an internal excitation of nucleons on the scattering of elementary particles is examined by means of a schematic model. It is found that the relation between the integral of the square of the wave function describing the normal nucleonic state and the apparent range of force differs from that expected on the ordinary potential energy description. The effect is of the order of 8 percent if one assumes the excitation to be 275 mc^2. The direction is such as to decrease the apparent range as though the meson mass were increased, somewhat as indicated by a comparison of the mass of a pi meson with experiments on scattering. A possible necessity of corrections for the velocity dependence of nuclear forces considered is briefly discussed in connection with the correlation of data on scattering with that on binding energies.

Studies on *Euglena* and Vitamin B_{12}

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Euglena gracilis var. *bacillaris* was used as a bioassay for vitamin B_{12} or its physiological equivalent. A considerable proportion of the bacteria and actinomycetes in the soil were found able to synthesize B_{12}, and the vitamin appears, at least in part, in an extracellular form. The ability to synthesize substantial amounts of B_{12} seems less common for the yeasts and the filamentous fungi. Extracts prepared by shaking 1 part of fresh soil with 2 parts of water contained amounts of B_{12} of the same order as those present in cow's milk. Vitamin B_{12} was found in the roots of a majority of a variety of higher plants, mostly garden vegetables; the amount ranged from .0002 to .01 μg of B_{12}/g of fresh material. The B_{12} present in the roots may have been absorbed from the soil solution. A few stems gave positive tests; leaves and fruits were generally negative. The water of a pond on which *Euglena* develops regularly contained vitamin B_{12} throughout the year in amounts ranging from .0001 to .001 μg per ml. Bacteria and actinomycetes capable of synthesizing B_{12} were found in the pond mud. On the basis of our present knowledge, vitamin B_{12} seems to occupy a unique position among the vitamins. It appears probable that the synthetic activity of microorganisms, especially bacteria and actinomycetes, and not that of higher plants is the original source of vitamin B_{12} in nature.

Some Electrical Properties of the Ice of Dilute Aqueous Solutions

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The author, with S. E. Reynolds, has reported the existence of relatively large potential differences (5–230 v) between the ice and liquid during the freezing of certain dilute aqueous solutions (10^{-2}–10^{-6} N). A survey of this phenomenon indicates its existence for a great variety of compounds that produce ions in weak aqueous solutions.

Electrical properties of 8 of these compounds (sodium chloride, cesium chloride, sodium fluoride, ammonium hydroxide, ammonium chloride, lead acetate, calcium hydroxide, and ammonium fluoride) are representative, with respect to sign and magnitude, of the potential difference generated and of the quantity of charge transferred during the freezing process. The ices of these compounds show characteristic plate-to-plate rectifying effects in the direction of the C-axes of the crystal units. For the first 6 compounds listed, the rectified current in the sample is in the same direction as that which flows during freezing. The ammonium fluoride and calcium hydroxide compounds give rectified current contrary to that observed during freezing of the sample. A suggested explanation of the behavior of the exceptional compounds is based on relative compatibility of ions in the ice structure.

Localized Effects Induced by Seeding Supercooled Clouds with Dry Ice and Silver Iodide

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A series of experiments is described showing some of the reactions that occur when particles of solid carbon dioxide or silver iodide aerosols are introduced into supercooled clouds or cold, moist air supersaturated with respect to ice.

The relationship of the seeding operations to radar echoes, visible precipitation, and similar reactions shows that the induced effects depend on such factors as

1) the quantity and nature of the seeding agent used;
2) the structure of the cloud, its temperature profile, and dimensions;
3) the location of the seeding operation with respect to the freezing isotherm; and
4) the concentration of natural ice nuclei in the atmosphere during the operation.

The experimental results show that under certain conditions of the atmosphere the introduction of seeding agents may profoundly alter the normal developmental sequence of a cloud system.

Widespread Modifications of Synoptic Weather Conditions Induced by Localized Silver Iodide Seeding

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In previous papers it was indicated that the introduction of a few hundred g of finely dispersed silver iodide into the atmosphere in New Mexico on July 21, 1949, gave rains averaging more than .1 inch over an area of 33,000 sq mi. The total rain that could be attributed to the seeding amounted to 780,000 acre-feet, corresponding to an average rainfall of .44 inch.

Preliminary studies indicated that the known seedings in Arizona and New Mexico may have led to unusually heavy rains in eastern Kansas a few days later at distances of 700–900 miles from the points of seeding.

Beginning early last winter, more extensive silver iodide seedings have been carried out in California, Arizona, and New Mexico by increasing numbers of experimenters. These seedings have been of two kinds: promiscuous seedings made under favorable synoptic conditions, and systematic seedings, made in accord with prearranged schedules not dependent upon the weather. Studies of rainfall for 6 months at the 160 Weather Bureau stations that report each day the 24-hour precipitation have indicated significantly high correlations between the times of rainfall and the times of the systematic seedings up to 2,000 miles downwind from the point of seeding.

During the winter and spring repeated seedings in the Southwest apparently gave, 5–6 days later, heavy widespread rains over areas of more than 600,000 sq mi extending ENE from the western boundaries of Louisiana, Arkansas, and Missouri. West of this line and south of central Colorado there was at this time unusually low rainfall. As summer approached, the area showing high correlation with the systematic seedings gradually receded nearer to the point of seeding, so that in July the average rainfall in New Mexico greatly exceeded previous records.

During the winter in the Southwest there is insufficient moisture and convection activity for the silver iodide to be carried into clouds where ice crystals could form. The prevailing winds therefore carry it over the Mississippi Valley where it meets moist air from the Gulf. The heat liberated by the condensation in the showers that are set up over wide areas greatly exceeds the heat delivered by the sun. Cyclogenesis leads to the influx of moist Gulf air in the east, with Northwest winds in the rear of the rain area. Thus drought in the Southwest and heavy rains in the Southeast may have resulted from changes in the synoptic weather conditions induced by seeding in the Southwest. During the summer, however, there is enough Gulf air in the Southwest to make both the promiscuous and the systematic seeding effective in giving rain in that region.

Technical Papers

The Hemolytic and Antihemolytic Activities of Various Centrifugally Separated Fractions of Adult and Fetal Liver Cells[1]

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We have recently reported (*16*) that saline extracts of fetal guinea pig livers possess a very high hemolytic activity, which can be demonstrated by incubating such preparations for 2–4 hr with a 1% suspension of washed red blood cells. The agent is not species-specific, since it will lyse not only the red cells from the same fetus but also those from the mother, as well as those from the rat. This hemolytic activity is due, for the most part, to a heat-sensitive factor and, to a lesser extent, to a heat-resistant substance. This observation, together with other considerations such as its sensitivity to certain enzyme poisons, suggests that the hemolytic agent is an enzyme, or may be produced by enzyme action. Adult liver extracts show very little lysis in 2–4 hr and then only with much higher concentrations (*16*).

It has long been known that hemolytic agents can be prepared from normal, as well as from pathological, tissues (*22, 1, 10, 11*). The pertinent literature bearing on the probable nature of the fetal autohemolytic agent has been briefly reviewed elsewhere (*16*). It is also known that the plasma or serum contains substances that possess the capacity to protect red cells from a variety of lytic agents (*12, 8, 21, 11*). There is, however, considerable uncertainty as to the chemical nature of both the hemolytic and inhibitor agents, and as to the mechanism of their actions. Since this paper does not, strictly, deal with these phases of the problem, reference is made to the excellent reviews of Ponder (*11, 12*) for a detailed consideration of these substances.

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[1] Aided in part by grants from the American Cancer Society, recommended by the Committee on Growth of the National Research Council and the Division of Research Grants and Fellowships of the National Institutes of Health, U. S. Public Health Service.