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1 January 1954 — No. 8 - 1

CONTENTS:

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MEASUREMENT OF ENERGY IN K-CAPTURE

Dr. O. Kofoed- Hansen of the Institute for Theoretical Physics, Copenhagen, has succeeded in making an accurate measurement of the energy involved in the K capture of A^{37} by measuring the energy of the recoil Cl^{37} nuclei. The theory of his method has been described (O. Kofoed-Hansen, Dan. Mat. Fys. Medd. 26, No. 8 (1951)). The method is particularly applicable to the noble gases and uses a simple geometry in crossed electric and magnetic fields or in either field alone. For this particular experiment the electric field was zero.

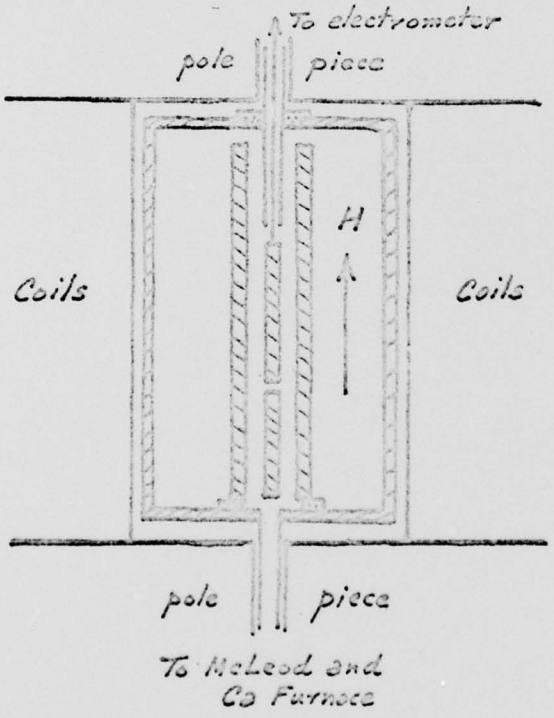


Fig. 1. Apparatus for measuring energy of nuclear recoils.

The inert radioactive gas fills the space between the plates of a double plane-parallel condenser in which the

center plate is divided into a collector electrode and guard ring (see Fig. 1). The plates of the condenser are oriented so that they are parallel to the lines of force of a magnetic field (H). The collector electrode is maintained at the same potential as the guard ring and is connected to a vibrating reed electrometer in a circuit for measuring the current collected. The contaminant gases are pumped by means of a calcium furnace operating at 400°C. Correct alignment of the condenser with respect to the magnetic field corresponds to a symmetrical peak of the collected current and can be determined to an angle of 0.5 minutes. The reason for the peak is that when the collector is at an angle to the magnetic field; secondary electrons hit the collector and reduce the positive currents ($\sim 5 \times 10^{-14}$ amp) due to the recoil nuclei. With correct alignment, the collected current is measured as a function of the magnetic field and the pressure in the condenser.

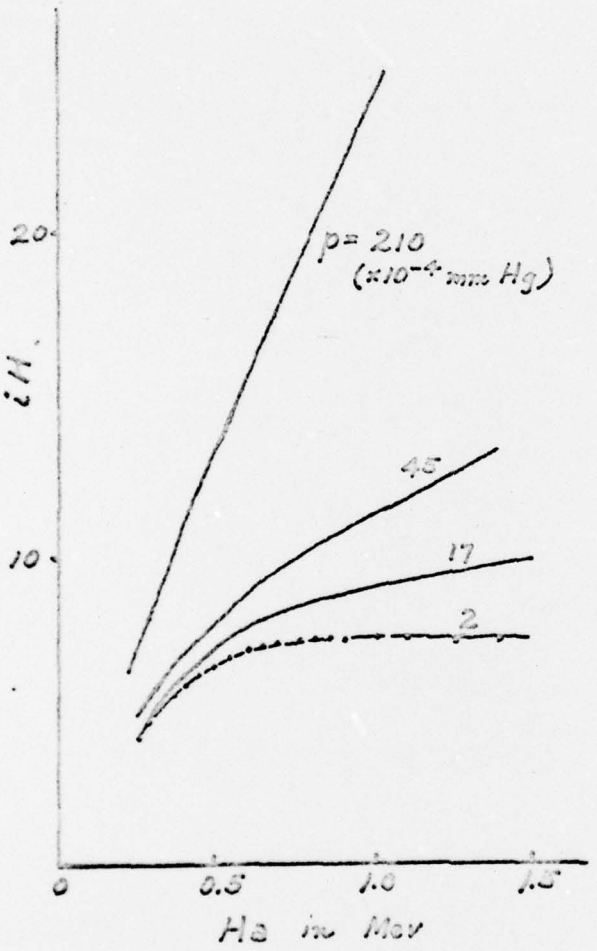


Fig. 2. Plot of magnetic field times current versus magnetic field times one-half condenser plate spacing for various Argon gas pressures.

The results are shown in Fig. 2 where the current (i) times H

in relative units is plotted vs Ha expressed in Mev for different values of the pressure (units 10^{-4} mm Hg). The plates of the condenser are separated by a distance, 2a. At high pressures the secondary electrons in turn produce positive ions which give a current to the collector largely independent of H (and therefore linear in the figure).

At the lower pressures ($\sim 2 \times 10^{-4}$ mm Hg), however, this effect is negligible and the idealized case can be considered where the mean free path for collision is large compared with the radius of curvature (ρ) of the recoil nuclei in the magnetic field. In the range of H where $\rho > a$ the quantity iH will clearly increase as the magnetic field increases. However, for $\rho \leq a$ the fraction of recoils which escape axially instead of hitting the collector will increase as H increases, in fact, $i \sim \rho \sim 1/H$ or iH = constant. Thus if the value of H for which the condition $\rho = a$ holds can be determined from the experimental curves, then the nuclear recoil momentum ($He\rho = Hea$) can be determined. Since the neutrino and recoil momenta are equal for this two-body disintegration, the total disintegration energy is readily computed. Corrections due to the momenta of thermal motion of the recoils and the impulse from Auger electrons amount to about seven per cent and must be subtracted from this value. A more accurate result is obtained by plotting the difference between the saturation value of iH and particular values of iH as a function of Ha, and then comparing these experimental points with theoretical curves obtained from the exact expression for iH integrated over the momentum distribution obtained from thermal motion, Auger effect, and assumed neutrino momenta. The result which Kofoed-Hansen obtains from this method for the total disintegration energy is 806 $\pm$ 8 kev. This energy can also be inferred from the threshold energy for the reaction $Cl^{37}(p,n)A^{37}$. The result obtained by Richards, Smith, and Brown (Phys. Rev. 80, 524 (1950)) was 816 $\pm$ 4 kev.

The present method, using both electric and magnetic fields is applicable to a determination of the angular correlation between neutrino and β particle (Kofoed-Hansen and Kristensen, Dan. Mat. Fys. Medd. 26, No. 6 (1951)), which should give good results with a suitable isotope. Also information about the charge distribution after Auger processes and electron-capture cross sections can be obtained.

THE CERN COLLOQUIUM ON THE STRONG FOCUSING PROTON SYNCHROTRON

A colloquium, held in Geneva, 26 - 28 October, was organized to discuss and evaluate strong focusing in general and, in particular, the current design for the CERN proton synchrotron. Some reports were also given by other groups, including several from the United States.

Progress on the strong focusing principle in the past year has consisted primarily of an increased appreciation of the difficulties inherent in the method. In particular, the effects of azimuthal inhomogeneities and the possible resonances they produce in the free betatron oscillations have been investigated. For example, simple misalignment of a sector can produce a resonance resulting in loss of the beam if the number, Q, of betatron wavelengths contained in a complete revolution is integral. In addition, field-free sectors will produce resonances or, more precisely, "stop bands" at either integral or half integral values of Q. On the other hand, coupling resonances are excited by a "twist" of the median plane. These are serious when the sum of the phase shifts per turn for oscillations in the axial and radial directions is 0, 2π, 4π, etc. Investigations have been made using magnetic fields which are non-linear as a function of radius in the hope of controlling these resonances by amplitude-dependence of the wavelength. Results so far, however, are discouraging for the hope that a non-linear system could allow one to ignore resonances; in fact in many cases the instability near stop bands seems to be worse than in the linear system. Calculations at the transition energy of phase instability indicated that although the amplitudes of radial oscillations increased here, they would not, in general, be larger than those at injection, provided the radial linearity of the field is maintained to rather rigid specifications as to the non-existence of its quadratic and cubic terms. The design parameters of the presently proposed 30 Bev CERN proton synchrotron were presented, together with estimates of costs totalling 70 million Swiss francs ($16,000,000) and a scheduled completion time of six years. The n-value, $-(r/H)\partial H/\partial r$, chosen was 392, with 57 pairs of focusing and defocusing sectors, and the length of the members of the pair

chosen so that Q_V for the vertical oscillations is 7.78 while Q_r for the radial oscillations is 6.78.

The Brookhaven plans for a 25 - 35 Bev strong focusing synchrotron were also presented. The parameters turned out to have values very closely the same as those in the CERN design and the estimated cost was $20,000,000. Brookhaven, however, plans to build a 10 Mev electron model first. The current status of various other groups interested in or building strong focusing synchrotrons was reported including Harvard - M.I.T. (15 Bev protons), Princeton (15 Bev protons), Cornell (1.5 Bev electrons), Mid-West (20 Bev protons), and Stockholm (1 Bev electrons). The Cornell experience indicates that the tune-up of a strong-focusing synchrotron is considerably more difficult than that of an ordinary synchrotron. This is associated with the shortness of the wavelength of free betatron oscillations in the strong focusing case. Probably techniques can be worked out, however, which will simplify the process.

The general conclusion of the conference was that the strong focusing synchrotron for energies up to 30 or 40 Bev was a feasible machine with the only reservations being expressed by those who were concerned by the apparently rigid requirements on the linearity of the variation of magnetic field with radius. Some of the papers given at the colloquium will be published. Technical Report CNRL-135-53 has been written summarizing parts of the colloquium.

ZONE REFINING OF SILICON FOR USE AS A TRANSISTOR MATERIAL

At the Radar Research Establishment (formerly T.R.E.), Great Malvern, the group under Dr. A.F. Gibson is devoting considerable effort to the development of silicon transistors. Bulk silicon, obtained from Johnson Matthey and Company Limited, Wembley, Middlesex, is N-type of about 0.5 ohm-cm with antimony as the most probable impurity. Zone refining is especially effective for this material, since the ratio of solubilities of antimony in solid and liquid silicon at the melting point is approximately 0.01; in contrast, P-type silicon, with boron as the principal impurity, is poorly

adapted to this method since the solubility ratio is about 0.9. By avoiding boron in the base material of a silicon transistor, the difficulties associated with the fairly high diffusion coefficient of this element are largely avoided. This means that such a transistor will be able to stand higher temperatures without deterioration.

At. R.R.E., a Vitrosil (artificial quartz) lining in a graphite container has been used to hold the sample when it is passed through the induction heating coils during the zone-refining process. In order to ensure that the lining does not crack and expose the graphite to the molten silicon, argon gas at a temperature of about 1000°C is passed around the material as it is moved through the induction coils. The lining generally cracks during the cooling process, however, due to the differential expansion of graphite and Vitrosil, and thus the lining can only be used once. Recently, a layer of silicon carbide has been successfully formed on the container surface by exposing the heated graphite to silicon vapor, and this development should provide containers that can be used a number of times.

THE CELL MODEL OF BINARY LIQUID MIXTURES

The cell model of binary liquid mixtures, developed by Prigogine and his collaborators in Brussels during the past few years, is strongly supported by some measurements currently in progress at Oxford University. Dr. V. Mathot and Dr. L.A.K. Staveley are planning to make a complete study of the thermodynamic properties of the carbon monoxide-methane system.

Preliminary results have been obtained for the volume change upon mixing and for the vapor-pressure curve of this system. The volume change is determined in a small calibrated volume which can be stirred from the outside electromagnetically and which is kept at a constant temperature by means of a double cryostat using melting methane as the thermostatic agent. It is found that a volume contraction of about one per cent occurs upon mixing, for mixtures in the range of 50-50 mole per cent. The Raoult's law

deviations of the system are positive, and it thus resembles closely the behavior reported for the neopentane-carbon tetrachloride mixture (cf. Prigogine, Bull. Soc. Chim. Belg., 62, 125 (1953)). The results suggest that the cell model is the best simple treatment available so far for an understanding of the behavior of binary mixtures of relatively simple, nearly spherical molecules of closely similar size.

PROTON MAGNETIC RESONANCE SPECTRA OF INORGANIC COMPOUNDS

In a study dealing with a series of simple inorganic hydrides, Dr. R.E. Richards (Oxford) has extended his proton magnetic resonance investigations to liquid hydrogen temperatures; ions such as PH_4^+, BH_4^-, NH_2^-, etc., all of which rotate in the solid state down to very low temperatures, are being studied at present.

The results of an investigation dealing with a series of hydrazine salts have already been published (Trans. Farad. Soc. 49, 744 (1953)). It is hoped that the results obtained on $N_2H_6F_2$, in which both proton and fluorine nuclear resonance can be measured, will enable a complete analysis to be made, including the localization of hydrogen atoms.

The hindered rotation of the trifluoromethyl group attached to a benzene ring, with different substituents in the ortho and ortho' positions, was studied by means of nuclear resonance. While the results indicated that the hindrance increases with increasing size of these o,o' substituents, they are only qualitative and do not lend themselves readily to a quantitative evaluation of the potential barriers involved.

SPECTROSCOPIC STUDIES OF MOLECULAR INTERACTIONS IN THE LIQUID PHASE

Dr. H.W. Thompson (Oxford) has found that details of the infrared spectrum become more accessible when molecular interactions are studied in an

"inert" solvent. The best known of these interactions is, of course, that between iodine with a wide range of organic molecules. The most interesting recent extension of this work is the use of cyanogen iodide, ICN, instead of iodine itself, as the acceptor molecule. This triatomic species has characteristic infrared absorption bands of its own, and thus their changes and in extreme cases their disappearance, provide valuable information in addition to the conventionally studied changes in the spectrum of the donor molecules. In particular, the postulated complete charge transfer resulting in the formation of ionic molecules (cf. J. Chem. Phys. 21, 1407 (1953)) can be confirmed in this case by observing the disappearance of the I - CN stretching band in the infrared spectrum.

One of the new donor molecules recently studied is 2,6-dimethyl-γ-pyrone. The interaction with ICN was spectroscopically shown to occur between the carbonyl oxygen and the iodine of ICN.

SELF DIFFUSION IN THE COPPER-ZINC SYSTEM

Dr. R. Shuttleworth (University of Leeds) is engaged in a fairly long-range program on self diffusion in the Cu-Zn system, one of the purposes of which is to obtain information regarding the mechanism of diffusion and the activation energy for the creation and movement of vacancies. Experiments are being conducted in a dilute solid solution (99Cu/1 Zn), alpha brass (70 Cu/30Zn), and beta brass (50 Cu/50Zn). In the case of the dilute solid solution a vacancy would most likely be created in a region where the atomic nearest neighbors are copper, whereas in beta brass a vacancy would in all probability be surrounded by both copper and zinc atoms. Thus with regard to vacancy creation the environment is markedly different in the two cases. With regard to vacancy movement it is quite possible, particularly in dilute solution, that the zinc atoms and vacancies move together as "molecules" as has been previously proposed.

The work on beta brass has been completed, that on alpha brass is in progress, while the study of diffusion in the dilute solid solution is just beginning and should be completed in about a year. The

following results in the diffusion formula ($D = D_o e^{-Q/RT}$) were obtained for the 50 Cu/50Zn:

$$D_{oCu} = 0.16 \text{ cm}^2/\text{sec} \qquad Q_{Cu} \cong 24 \text{ Kcal/mole}$$

$$D_{oZn} = 0.11 \text{ cm}^2/\text{sec} \qquad Q_{Zn} \cong 21 \text{ Kcal/mole.}$$

These results give an approximate value for the ratio of D_{Zn}/D_{Cu} of 2 at the usual diffusion temperatures. The lack of appreciable difference in the activation energies and the mere two-fold difference in diffusion coefficients is somewhat unexpected. Further it is seen that diffusion in this alloy is about as rapid as that for carbon in iron, as was also shown recently by Landergren and Mehl who determined the chemical-diffusion coefficients as contrasted with these self-diffusion coefficients.

The experimental technique used in Shuttleworth's experiments was to irradiate a sample of the beta brass in a pile and then sandwich it between metal of the same composition. After appropriate time and temperature treatment to produce diffusion, layers were machined from the sample, dissolved in acid, and a count made of the emitted gamma radiation. The half lives of the copper and zinc isotopes produced differ markedly (Cu ~12 hours, Zn ~250 hours) and the activities contributed by each species were readily separated.

An interesting point worthy of investigation is the possible change in the activation energy for diffusion upon change in temperature of an alloy which undergoes an order-disorder reaction. In most systems such a study is difficult because the rate of diffusion is too low at temperatures below the critical temperature of order. Beta brass, however, appears to be a very suitable alloy since the diffusion rates are high. Shuttleworth proposes to investigate the point in a preliminary qualitative experiment by heating a strip of beta brass in a temperature-gradient furnace such that one end of the specimen is in the ordered state while the other is disordered. By observing the

degree of penetration of a copper plate into the brass strip, it may be possible to detect a discontinuity in the amount of diffusion in the region on the brass specimen corresponding to the critical temperature of order. If the preliminary work indicates an effect, subsequent quantitative experiments will be made.

DIFFUSION OF ARGON IN SILVER

Among the products of nuclear fission are the noble gases, xenon and krypton, and therefore the diffusion of such gases in metals is a subject of some interest. Dr. A.D. Le Claire (A.E.R.E., Harwell) has investigated the problem by determining the rate of diffusion of argon in silver. The usual technique for studying the diffusion of a gas in a metal is a steady state experiment in which the gas is introduced at one side of the metal sample and its appearance at the other side measured. This method involves adsorption of the gas, solution, diffusion, and the reverse processes. Inert gases do not adsorb or go into solution and therefore Le Claire devised a new experimental method.

Samples of silver in the form of sheet rolled into hollow cylinders were used as the cathode in a discharge tube containing 0.5 mm Hg pressure of argon. Under conditions corresponding to the discharge in a Schuler tube, the argon striking the interior of the cathode was captured and after about 48 hours the major part of the argon had penetrated the cathode surface. Two such silver sheets were placed with their argon-containing surfaces in contact and welded together by rolling, thus producing a specimen with argon at its central plane. This specimen was irradiated in a pile to produce radioactive argon, A^{40}.

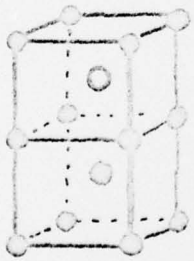
Samples were heated for given times at temperatures between 600° - 800°C in a vacuum. The evolved argon was pumped off, circulated through purifiers, and measured in Geiger counters. At the end of each run the silver was melted and the argon counted to obtain the fraction of gas evolved for a given time and temperature relative to that evolved upon melting. Knowing this fraction the diffusion coefficient could be determined.

The results obtained for the diffusion formula, $D = D_0 e^{-Q/RT}$ were: Q = 33.6 Kcal/mole and $D_0 = 0.12$ cm^2/sec. Rather surprisingly, these values are of the same order as for the diffusion of other elements in silver. Apparently once the inert gas is introduced in the metal its diffusion behavior is not much different from the ordinary elements. Since the argon atom is large, it is very unlikely that it exists or diffuses interstitially; probably it occupies vacant lattice sites in the silver and further, diffuses by a vacancy mechanism.

THE SUPERLATTICE U_3Mo

P.C.L. Pfeil (A.E.R.E., Harwell) has extended his previous research on the constitution of uranium-molybdenum alloys (J. Inst. Metals 77, 553 (1950)) to lower temperatures to investigate the solid state reactions. It has been found that the body-centered-cubic solid solution, γ, becomes unstable with respect to a body-centered-tetragonal phase, γ', at compositions in the neighborhood of U_3Mo. The coexistence in equilibrium of the γ and γ' phases has been shown, and in addition the phase boundaries have been established.

The crystal structure of the ordered U_3Mo is body-centered tetragonal and is like that of two BCC lattices placed together with a Mo atom at one body-center position and U atoms at the other body-center position and the edge and corner locations. This structure is shown below.



○ U atoms

○ Mo atom

Fig. 1. Crystal structure of U_3Mo

On the basis of a simple billiard ball model, Pfeil calculated the lattice parameters of a = 3.47 A and (1/2) c = 3.23 A for the stochiometric composition. X-ray diffraction measurements, however, have shown that the values are a = 3.42 and (1/2) c = 3.27, which represent a slight volume contraction for the ordered state. It was also found that these lattice parameters varied in a peculiar manner with composition. This is thought to be due to electronic effects associated with the valences of Mo and U, and it is believed that these changes in lattice dimensions occur so as to decrease the electron kinetic energy. Pfeil proposes to make specific heat measurements at low temperatures to investigate this point further. It is also intended to study ternary alloys associated with U_3Mo.

ULTRAVIOLET DOSIMETER

Dr. Raymond Latarjet, Radium Institute, 26 Rue d'Ulm, Paris, has devised a dosimeter which is capable of measuring ultraviolet radiations by direct reading. The instrument is calibrated in microwatts/cm^2 for the wavelength 2537 A. The instrument is fully described in a paper by Latarjet, Morenne, and Berger, appearing in the Annales de l'Institut Pasteur, 85, 174 (1953). Dr. Latarjet has indicated that this instrument can be supplied to American scientists at the cost price of approximately $80.

TECHNICAL REPORTS OF ONRL

The following reports have been forwarded to ONR, Washington. Copies may be obtained by addressing requests to the Commanding Officer, Office of Naval Research Branch Office, Navy No. 100, c/o Fleet Post Office, New York, N. Y.

ONRL-132-53 "Sixth International Congress of Microbiology" by J. L. Tullis

ONRL-133-53 "French Work in the Field of Digital Computation" by R. R. Weber

CNRL-134-53 "Tidal Power Studies in France" by W. D. Hayes

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