Letters to the Editor

PROMPT publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. Because of the late closing dates for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

Thermal Conductivity of Liquids

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AT present it may be said that there is no satisfactory theory of the mechanism of thermal conduction in liquids, although it is recognized[1] that the mechanism of thermal conduction in liquids must be different from that in a gas. The mechanism of thermal conduction outlined here refers to the melting point and leads us to an expression for the thermal conductivity of a liquid near the freezing point in terms of the melting point, molecular weight and molecular volume of the liquid.

A liquid near its freezing point is here considered as an assemblage of a number of linear harmonic oscillators, each vibrating with a frequency ν about a slowly displaced equilibrium position with an amplitude which is comparable with the mean molecular distance σ. This simple picture of a liquid has yielded interesting results[2] about the properties of the liquid state of matter. In dealing with the problem of heat conduction we are concerned with the transport of thermal energy. Let us consider a thermal energy gradient dE/dz along the z axis and layers of molecules parallel to the direction of thermal energy gradient and the molecules vibrating in random directions. Then, on an average, $\frac{1}{3}$ of the molecules will be vibrating along each of three directions normal to one another. The difference of energy between two layers separated by a distance σ is $\sigma(dE/dz)$. Since the amplitude of vibration is large, molecules of one layer come into contact with the molecules of a neighboring layer at each extreme libration, the contact being of a short duration. When there is contact between molecules we shall assume that there is transfer of the excess thermal energy. If we consider a plane normal to the direction of drift, a molecule of a given layer conveying thermal energy crosses this plane twice in every oscillation. A molecule of the adjacent layer also crosses this plane twice in every oscillation. The number of molecules in unit area is $1/\sigma^2$ and, hence, on the basis of the assumptions, it follows that the transfer of thermal energy per unit area per unit time is given by

$$\tfrac{1}{3}4\nu\frac{1}{\sigma^2}\frac{dE}{dz}\sigma.$$

This, by definition of the coefficient of thermal conduction, is equal to $K(d\theta/dz)$ where $d\theta/dz$ is the temperature gradient. Hence we have

$$K\frac{d\theta}{dz}=\frac{4}{3}\frac{\nu}{\sigma}\frac{dE}{dz}.$$

It follows that

$$K=\frac{4}{3}\frac{\nu}{\sigma}\frac{dE}{d\theta}.$$

Since the average energy (both kinetic and potential) of a vibrating molecule is $3k\theta$ where k is Boltzmann constant, we have

$$K=4k\nu/\sigma.$$

For ν we substitute the Lindemann expression

$$2.8\times10^{12}(\theta_s/MV_s^{\frac{2}{3}})^{\frac{1}{2}}$$

where θ_s is the melting point and V_s the molecular volume and M the molecular weight. For σ we substitute, $(3V_s/4\pi N)^{\frac{1}{3}}$ where N is Avogadro number. It then follows that

$$K=2.05\times10^{5}(\theta_s/MV_s^{4/3})^{\frac{1}{2}}.$$

Calculated values of K from the above expression agree fairly well with the observed values. Details will be published very soon.

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[1] P. Bridgman, Proc. Am. Acad. Arts Sci. **59**, 141 (1923).

[2] L. Sibaiya and M. Rama Rao, Nature **143**, 723 (1939).

Fission Products of Uranium and Thorium Produced by High Energy Neutrons

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IN the uranium and thorium fission by neutrons of energy up to ~10 Mev no fission products with atomic numbers between 43 and 51 have been reported.[1] This fact, together with the experiments on the energy of the fragments,[2] points to unsymmetrical fission for neutrons of such energies, and recent work may show that this has a theoretical explanation.[3]

Recently Nishina, Yasaki, Ezoe, Kimura and Ikawa[4] have reported the production by fission of some radioactive isotopes of palladium, silver, cadmium and indium by bombardment of uranium with ~17-Mev neutrons (3-Mev D^2 on lithium). This is evidence for more symmetrical types of fission produced by higher energy neutrons.

We have investigated the production of radioactive silver and palladium from uranium and thorium fission. With the ~17-Mev neutrons (16-Mev D^2 on beryllium) from the 60-inch cyclotron we have observed both the following chains from uranium and thorium:

$$\mathrm{Pd}^{112}\ (17\ \mathrm{hr.})\rightarrow\mathrm{Ag}^{112}\ (3.4\ \mathrm{hr.})\rightarrow\mathrm{Cd}^{112}\ (\mathrm{stable})$$
$$\mathrm{Pd}^{111}\ (26\ \mathrm{min.})\rightarrow\mathrm{Ag}^{111}\ (7.5\ \mathrm{d.})\rightarrow\mathrm{Cd}^{111}\ (\mathrm{stable}).$$

The first chain is in agreement with the results of Nishina and co-workers.[4] The products in the second chain were also reported by Nishina, but the assignment of the 26-minute palladium as the parent of the 7.5-day silver was not made. We have established this genetic relationship by means of successive extractions of the silver from the palladium.

The isotopic assignments in the first chain are based upon the identification[5] of Ag^{112}. The isotopic assignments in the second chain are based upon the identification[6] of Ag^{111}. By deuteron bombardment of palladium, Kraus and Cork[6] have found a period of 17 minutes which they assign to Pd^{111}. We have found a 26-minute palladium in the palladium fraction of the fission products of uranium and thorium, and repeated extractions of silver from neutron irradiated thorium shows that the 7.5-day period grows from a 26-minute parent. Our neutron irradiation of palladium (no chemical separation) also shows an activity of about 26 minutes half-life. The reason for the discrepancy between these results and those of Kraus and Cork is not yet clear.

The cross sections for the production from thorium of these two chains are comparable and are of the order of one-tenth of the cross section for the formation of the 77-hour tellurium under identical conditions. The comparatively low intensity of these activities makes it imperative to purify the products very carefully in the chemical separations.

We have also looked for radioactive ruthenium among the fission products of uranium and thorium and have found an activity of $\sim$4 hours half-life. An investigation of this region is being continued.

Worth mentioning here is the observation, made during our neutron bombardments of palladium, that a 40 second Ag$^{107*,\ 109*}$, which may be the same as the 40-second silver formed as the product[7] of the decay of the 6.7-hour Cd$^{107,\ 109}$ also grows from the 13-hour[6] Pd$^{107,\ 109}$.

We wish to express our gratitude to the Rockefeller Foundation and the Research Corporation, whose financial support made this work possible.

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[1] See, e.g., O. Hahn and F. Strassmann, Naturwiss. **28**, 543 (1940).

[2] See, e.g., L. A. Turner, Rev. Mod. Phys. **12**, 21–23 (1940).

[3] This point is under investigation by R. D. Present and J. K. Knipp. See Phys. Rev. **57**, 751, 1188 (1940).

[4] Y. Nishina, T. Yasaki, H. Ezoe, K. Kimura and M. Ikawa, Nature **146**, 24 (1940); Phys. Rev. **58**, 660 (1940). Also T. Yasaki, Sci. Papers Inst. Phys. Chem. Research (Tokyo) **37**, 457 (1940).

[5] M. L. Pool, Phys. Rev. **53**, 116 (1938).

[6] J. D. Kraus and J. M. Cook, Phys. Rev. **52**, 763 (1937).

[7] L. W. Alvarez, A. C. Helmholz and E. Nelson, Phys. Rev. **57**, 660 (1940).

Anode Spots in Oxygen

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It has been shown[1] that anode spots appear in N_2 glow discharges when a certain minimum anode current density is exceeded. Anode spots have never been observed in O_2, and various reasons[2,3] have been proposed for their absence. In these explanations, however, the authors neglect the possibility that in their experiments a sufficiently high anode current density to permit the appearance of the spots might not have been established. Since a method[1] was developed for attaining considerable anode current densities in N_2, it appeared that an application of this same procedure to O_2 might provide the conditions under which anode spots would appear. Should this be the case, it would provide an excellent opportunity to test the conditions proposed as essential for the formation of anode spots.

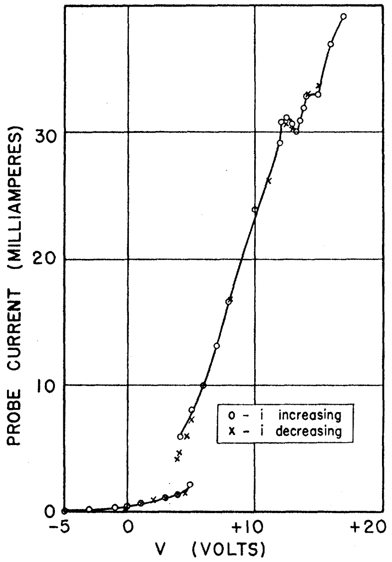

Fig. 1. Current-voltage characteristic for the growth of anode spots in O_2.

The experiment was performed in an oxygen glow discharge maintained in the same apparatus previously described. For O_2 in the same pressure range under which anode spots appeared spontaneously in N_2, neither anode spots nor even a well-defined anode glow could be observed for drift currents up to 500 ma so long as the flat probe auxiliary electrode was maintained at the anode potential. However, when the probe was 5 volts or more positive with respect to the anode, a bright, pale green glow covered the surface of the flat probe, and the probe current rose discontinuously. Holding the drift current constant at 300 ma the current-voltage characteristic curve shown in Fig. 1 was obtained.

It is seen that the current rises discontinuously at 5.0 volts and then increases to a sharp maximum. When the minimum at 13.2 volts was attained, the uniform glow on the auxiliary electrode changed to four brilliant hemispherical spots equally spaced around the probe edge. When the probe potential was further increased, the spots rotated. From these observations, which are similar to those in N_2, we conclude that anode spots might form spontaneously in an oxygen glow discharge at sufficiently great current densities. By dividing the probe current, when the spots appeared, by the probe area, a lower limit for the current density should result. This was found to be of the order of 100 ma/cm^2, a value which would be difficult to obtain in conventional discharge tubes.

The probe potential at which the current maximum occurs, 12.7 volts, is nearly the same as the value found by Guntherschultze and Keller[4] for the anode fall in O_2,