Letters to the Editor

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Number of Vacancies Created by Heavy Corpuscular Radiation

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KINCHIN and Pease[1] have suggested that a moving atom which collides with and displaces another atom may, in certain cases, take its place. Thus the number of displaced atoms is not the same as the number of vacancies, even when diffusion of interstitial atoms is neglected.

Let E be the energy of the striking atom before a collision and $E-y$ its energy after the collision. Altering the assumptions of Kinchin and Pease, we assume the striking atom replaces the struck atom in the monoatomic case whenever $E-y<\alpha$ and $y>\alpha$. The parameter α is the displacement energy and is often taken as about 25 ev. Thus a vacancy is created only when $y>\alpha$ and $E-y>\alpha$.

If $g(E)$ equals the mean number of vacancies created by the displacement of an atom of the medium by ejecting an atom with energy after ejection of E, then $g(E)=1$ for $0<E<2\alpha$. For $E>2\alpha$, $g(E)$ satisfies the following integral equation:

$$g(E)=\int_0^{E-\alpha} dyK(E,y)g(E-y)+\int_\alpha^E dyK(E,y)g(y-\alpha), \quad (1)$$

where $K(E,y)dy$ is the probability that a striking atom with energy E will lose energy y in dy in its next collision. The derivation of this equation follows closely the similar discussion of Eq. (7) of the authors' paper[2] (hereafter indicated by D), and assumes that ionization can be neglected. In accordance with the theory given in D it should apply only for $E<Me^4/2\hbar^2$.

For low energies "hard sphere" scattering is assumed and $K(E,y)$ is taken as $1/E$. By the methods developed in D it is shown that

$$[(E+\alpha)/3\alpha]<g(E)<1.056[(E+\alpha)/3\alpha] \quad (2)$$

for all monoatomic substances and for $2\alpha<E<\beta$. The value β indicates the energy above which Rutherford scattering is assumed to apply and is given by $\beta=2Z^2e^2/a$ with a the Bohr radius of the atom, (D§3). For Rutherford scattering $K(E,y)=\beta^2/4Ey^2$ for $E\beta^2(4E^2+\beta^2)<y<E$ and $K(E,y)=0$ otherwise. It is established that the inequality (2) is valid for all $Z>10$ for the region of Rutherford scattering, and with minor modifications, for lower Z.

The results for $E>Me^4/2\hbar^2$ are not complete but indicate a less rapid rate of increase for $g(E)$ due to ionization.

Thus the number of vacancies seems to be about $\frac{2}{3}$ the number of displacements as calculated in D.

Harrison and Seitz[3] have calculated the change in resistivity of Cu irradiated by 17-Mev deuterons. Using the number of displaced atoms as equal to the number of vacancies they find the calculated value 5 times the observed value. The calculation of vacancies indicated above reduces this to 3.3 times the observed value.

[1] G. H. Kinchin and R. S. Pease, J. Nuclear Energy **1**, No. 3, 200–202 (1955).
[2] W. S. Snyder and J. Neufeld, Phys. Rev. **97**, 1637–1646 (1955).
[3] W. A. Harrison and F. Seitz, Phys. Rev. **98**, 1530(A) (1955).

Dipole Fields and the Helium Film

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IN measurements of the thickness and the flow rate of liquid helium films the most frequently reproduced characteristic has been lack of reproducibility. The scatter of the values for flow rates obtained in one laboratory is not significantly less than the discrepancies existing between different laboratories.[1,2] An adequate theory of the liquid helium film must account for this salient experimental fact.

The van der Waals theory of the film[3,4] is based on very simple assumptions about the surface and the interaction of helium atoms with surface atoms. According to the theory a film several hundred angstroms in thickness exists both below and above the λ temperature. The essential validity of this theory has been established by the experiments of Ham and Jackson.[5] The theory can be improved by making physically plausible assumptions about the surface. The effect of these assumptions is to introduce into the theory a real surface in place of an idealized and nearly featureless substrate.

On most surfaces liquid will be held in irregularities by surface tension. The volume of this adsorbed capillary liquid will depend on the roughness of the surface and will be increased if impurities are present.[5]