

We compared the absorption of the hard γ -rays with that of annihilation radiation from the 3.5-hr. Cu^{63} , under enough lead to reduce the ionization to less than eight percent. The Cd γ -ray is more penetrating. An experiment with coincidence counters also showed it to be for the most part a nuclear γ -ray. We found evidence for the expected Auger electrons from a sample of pure radioactive Cd, distilled in vacuum, from bombarded silver. This distillation technique should find many uses in the field of artificial radioactivity.

From the ratio of the numbers of K and L conversions, a theory proposed by one of us⁵ requires a multipole order of 4 ± 0.1 for the transition between the two silver states. The measured internal conversion coefficient of 98 percent demands a similar, but not quite so precise value of this multipole order, from the theory of Dancoff and Morrison.⁶ If we assume the value 4 to be correct, and calculate the lifetime of a 93.5 keV level in Ag by means of Weizsäcker's formulae corrected by Hebb and Uhlenbeck⁷ to include decay by internal conversion, we obtain an expected value of 30 sec. On this theory, multipole orders of 3 and 5 would give lifetimes of about 10^{-3} and 10^6 sec., respectively. The agreement between these three methods of computing the order indicates further that the transition is an electric rather than a magnetic 2^4 pole, so that the spin difference between the two states in silver is 4 units. In view of the approximations made in the theory, the agreement with respect to lifetime is a most encouraging check.

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Elementary Derivation of Thermal Diffusion

Thermal diffusion is usually thought not amenable to elementary derivation.¹ It may, then, be of value to point out a method of showing its existence and sign from elementary considerations. Thermal diffusion shows itself if a mixture of two gases is kept at a non-uniform temperature. It causes a gradient of the partial pressure of either gas which is observed as a partial separation of the gases. To support this partial pressure gradient the "partial gas" must experience a constant force due to collisions with molecules of the other gas. Hence there must be a continual net transfer of momentum from one gas to the other. To evaluate this one can find the momentum change suffered by a molecule of type "1" in a collision with a "2" molecule and sum over all collisions.

The result of this may be most easily understood by the following very rough treatment. Consider the heavier

molecules as stationary, the light gas as composed of two streams of uniform velocities moving toward the cold and hot sides, respectively. The velocity of the stream coming from the hot side is somewhat greater than the velocity of the other stream. Each light molecule with velocity V loses its momentum to the heavy molecules at a rate $V\sigma$ where σ is the cross section for complete dissipation of momentum. Since each stream must carry the same momentum per cm^3 (to make the net particle flux zero) the momentum transfer per second of the streams is proportional to $V\sigma$. The dependence of $V\sigma$ on the velocity can be found by a dimensional argument. Let the molecules interact by an inverse s th power repulsion, $F = -K/r^s$. Then σ may depend on K , on the mass of the light molecule (strictly the reduced mass), on V , and on s . From the dimensions of these quantities it is seen that σ must be proportional to $(K/mV^2)^{2/(s-1)}$ or to $V^{-4/(s-1)}$. Thus $V\sigma$ varies as $V^{(s-5)/(s-1)}$. This gives a force supporting an excess of light component at the hot side for molecules "harder" than Maxwellian molecules ($s=5$) or at the cold side for $s < 5$ and no thermal diffusion for Maxwellian molecules.

A more rigorous treatment would take account of the motion of the heavy molecules and of the distribution in velocities of both types. Denote by $f_1(\mathbf{c}_1)$ and $f_2(\mathbf{c}_2)$ the velocity distributions of the light and heavy gases, respectively, normalized to their respective particle densities. Define a cross section for momentum transfer as follows: If a uniform stream of particles of mass μ , the reduced mass of the collisions, impinges on a scattering center $F = -K/r^s$, then the total momentum transferred to the scattering center is the product of the cross section, σ , and the momentum per cm^2 of the stream. Then as before this cross section must vary with the relative velocity as $V^{-4/(s-1)}$. The momentum gained per second by the light gas is then given by the expression

$$\begin{aligned} \int \int \frac{1}{2}(\mathbf{p}_2 - \mathbf{p}_1) f_1(\mathbf{c}_1) f_2(\mathbf{c}_2) \sigma V d\mathbf{c}_1 d\mathbf{c}_2 \\ = C \int \int (\mathbf{p}_2 - \mathbf{p}_1) f_1(\mathbf{c}_1) f_2(\mathbf{c}_2) V^{(s-5)/(s-1)} d\mathbf{c}_1 d\mathbf{c}_2, \end{aligned}$$

where \mathbf{p}_1 and \mathbf{p}_2 are the momenta of the light and heavy molecules, respectively. C is positive and does not depend on the velocities. $f_1(\mathbf{c}_1)$ and $f_2(\mathbf{c}_2)$ while not Maxwellian still must obey the relationship $\int f(\mathbf{c}) \mathbf{p} d\mathbf{c} = 0$ since this expression divided by m is the rate of flux of molecules. Hence for $s=5$ the term in V drops out and the integral vanishes. For harder molecules the collisions of high relative velocity are more effective. The collisions of highest relative velocity are predominantly those in which the lighter molecule is coming from the hotter region and the heavier from the colder region. Thus the resulting force is such as to support a greater partial pressure of light molecules in the hot part of the gas, and conversely as before for molecules softer than $s=5$. It may also be seen from this argument that the effect must be proportional to the product of the two fractional concentrations and to the relative mass difference.

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