$+ \log (NH_4^+) (I^-)/(NH_4OH) - 0.5/\sqrt{\mu}$, $K = 1.75 \times 10^{-5}$ was obtained for ammonium hydroxide at 25°. Since this result depends upon a single series of measurements, and a preliminary determination of E^0, it can only be regarded as tentative, but it is sufficiently close to the accepted value, 1.81×10^{-5} ["Int. Crit. Tables," Vol. VI], to demonstrate the potential usefulness of the indirect procedure herein outlined. Further work on this problem is in progress.

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RECEIVED OCTOBER 3, 1934

THE EMISSION OF γ-RAYS IN NUCLEAR REACTIONS

Sir:

It has been shown recently[1] that all known nuclear reactions which result in actual disintegration, and which are induced by a nuclear projectile of ordinary energy (up to 8 to 15 mev) are of the type of a chemical double decomposition or metathesis. Thus: $A + B \longrightarrow AB^* \longrightarrow C^* + D$. Here C is starred to indicate the probability that at least one of the products is activated and shows either γ-ray activity or the emission of an electron or positron, which, since it is commonly delayed, is considered as an artificial radioactivity.

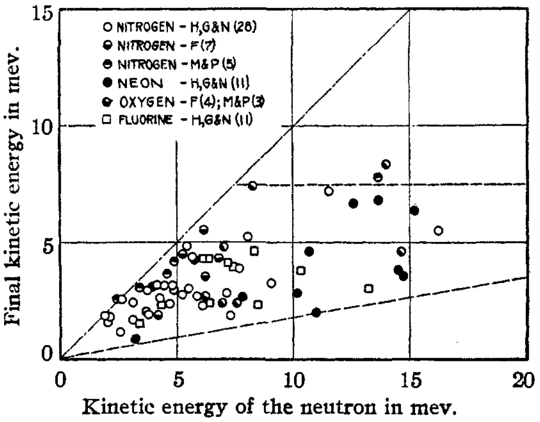

Fig. 1.—H,G & N, Harkins, Gans and Newson; F, Feather; M & P, Meitner and Philipp.

It is now possible to collect complete data where the projectile is a neutron for 71 such reactions, many of which were obtained in this Laboratory, and the others by Feather [*Proc. Roy. Soc.* (London), **A136** (1932); **142,** 689 (1933); *Nature,* **130,** 237 (1932)] and Meitner and Philipp [*Z. Physik,* **87,** 484 (1934); *Naturwissenschaften,* **20,** 929 (1932)]. One such event, obtained by Kurie [*Phys. Rev.,* **43,** 672 and 771 (1933)], was not included since the nature of the reaction involved is supposed by him to be uncertain.

These reveal relations of considerable interest (Fig. 1).

1. Kinetic energy disappears in every reaction, or is rarely conserved.

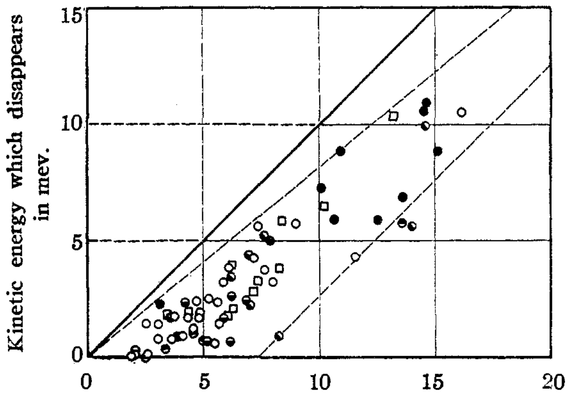

Fig. 2.

2. Though the kinetic energy of the neutron rises as high as 15 mev or slightly more, the maximum kinetic energy retained by the products of the reaction (C and D) is 8.5 mev.

3. The kinetic energy which disappears ($-\Delta KE$) in the reaction rises rapidly with the kinetic energy of the neutron, which is the initial kinetic energy of the system, since the velocity of the atom of A is relatively very small

4. The minimum kinetic energy which remains in the system (ordinates Fig. 1) increases with the kinetic energy of the neutron.

It may be assumed that some or all (depending on the mass change in the reaction) of the kinetic energy decrement is emitted as γ-rays, which are given off either by the atom AB^*, which has an excessively short life, or by the atom C^*. In experiments with fluorine, Harkins, Gans and Newson [*Phys. Rev.,* **44,** 945 (1933)] considered that if C^* is nitrogen 16, a new isotope found by them, it would be likely to be unstable and emit an electron to form oxygen 16. This has been verified by Fermi [Fermi, Amaldi, D'Agostino, Rasetti and Segrè, *Proc. Roy. Soc.* (London), **146,** 483 (1934)], who finds nitrogen 16 to be radioactive.

The ordinate of Fig. 2 ($-\Delta KE$) plus a con-

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(1) Harkins and Gans, *Phys. Rev.,* **46,** 397 (1934).

stant $(-\Delta E_m)$ for the reaction gives the total energy which disappears in the reaction.

If it is assumed that the energy escapes largely as γ-ray energy, then it follows that:

5. The total γ-ray energy emitted increases rapidly as the energy of the projectile, the neutron, increases.

6. A remarkable feature of Fig. 2 is the absence of points in the lower right-hand section. Thus the γ-ray energy is always high if the energy of the neutron is high.

Let it be supposed that the γ-ray levels are discrete. Then since all possible neutron energies are involved, the points for each level in Fig. 2 should lie on or close to a horizontal line. This would give a scattering along the x-axis, while the different levels would give a scattering along the y-axis. While the points in Figs. 1 and 2 have the general type of distribution suggested by this hypothesis, the accuracy of the values is not sufficient to resolve the levels which may exist. It is possible that the type of plot found may, on account of the existence of some unknown relation, be associated with a continuous rather than a line spectrum. On the whole it does not seem improbable that both types of spectra may be represented.

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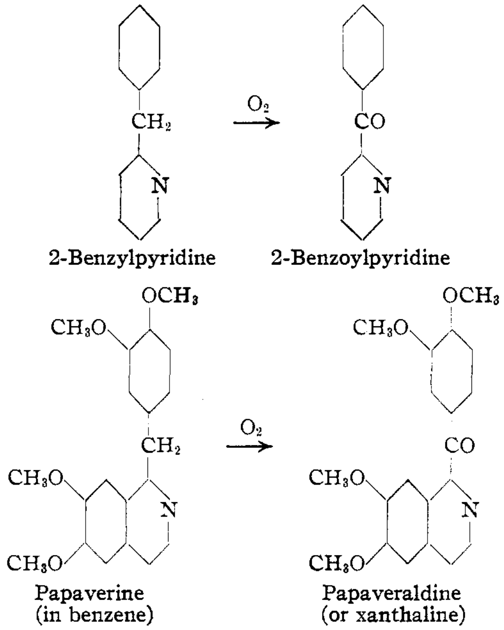
CHICAGO, ILL. DAVID M. GANS

RECEIVED OCTOBER 15, 1934

THE PHOTO-OXIDATION OF 2-BENZYLPYRIDINE AND PAPAVERINE

Sir:

It has been established that the following reactions take place photochemically in air.



2-Benzylpyridine 2-Benzoylpyridine

Papaverine (in benzene)

Papaveraldine (or xanthaline)

The second reaction is of plant physiological interest since these alkaloids occur together in nature.

2-Benzylpyridine in a glass bulb was exposed to a quartz mercury lamp (the liquid becomes brown[1]) and fractionally distilled *in vacuo* whereby a small quantity of the ketone, which is the chief product, was obtained and identified by isolating the semicarbazone and phenylhydrazone. A benzene solution of papaverine[2] in a quartz flask after three days in sunlight (the color becomes brown with the formation of a slight precipitate) yielded approximately 10% papaveraldine which was identified by analysis and mixed melting points with synthetic papaveraldine and by those of the hydrochlorides. In the solid state, papaverine and papaveraldine became brown after several hours in mercury light.

Using glass bulbs sealed to mercury manometers, papaveraldine in benzene, 2-benzylpyridine and 2-benzoylpyridine in dry oxygen showed no absorption in the dark at 115°, but at lower temperatures in mercury light a strong absorption occurred and the practically colorless liquids became deep brown as in air. In the dark at 115°, papaverine in benzene absorbed oxygen but in air at 60° (20° higher than reached by the solution exposed in sunlight) no color appeared and evaporation (without crystallization) yielded unchanged papaverine. Similarly it was found that papaverine solutions in glass bulbs sealed off in high vacuum or with water remained unchanged after forty hours in mercury light. However, such bulbs containing papaveraldine solution or 2-benzoylpyridine so exposed soon became brown and later in the case of papaveraldine precipitates resulted. 2-Benzylpyridine in vacuum remained colorless but with water became pale yellow after exposure.

The effect of various spectral lines of the mercury lamp in so far as they produced color was studied. Filter paper strips impregnated with alcoholic solutions were exposed in place of a

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[1] This color change in light was first observed by H. Freytag and A. Müller, *Naturwiss.*, **21**, 720 (1933).

[2] E. Paternò, *Gazz. chim. ital.*, **44**, II, 104 (1914), simply reports that from a solution of papaverine in acetone contained in glass, after seven months in daylight, only the starting materials and traces of reaction products could be obtained. Although not mentioned, undoubtedly little or no air had access.