Induced Radioactivity produced by Neutrons liberated from Heavy Water by Radium Gamma-Rays

WORKING in this laboratory, Szilard and Chalmers[1] have shown that neutrons are liberated from beryllium irradiated by radium gamma-rays, and that they are capable of inducing radioactivity in a number of elements. Previously, Chadwick and Goldhaber[2] had reported that, using an ionisation method, they had observed the liberation of protons from heavy hydrogen which was irradiated by gamma rays from thorium C.

In the light of these observations, and having regard to possible biological applications of heavy water, it is of interest to determine whether the neutrons presumed to be liberated by the gamma-ray disintegration of heavy hydrogen can activate other elements.

We have succeeded in observing the radioactivation of iodine and bromine which had been bombarded by the neutrons liberated from heavy water irradiated by radium gamma-rays. In one series of experiments we used 10 c.c. of heavy water of 30 per cent concentration, and irradiated it with gamma-rays from 150 mgm. of radium filtered by 1 mm. of platinum. The heavy water almost completely filled the space between the double walls of a glass container similar in construction to a diminutive cylindrical Dewar vessel. The radium occupied the central cavity of the container, which was immersed in 400 c.c. of ethyl iodide.

After irradiation, the radio-iodine was precipitated and removed from the ethyl iodide by the method of isotopic separation described by Szilard and Chalmers[3], and its activity measured on a Geiger-Müller β-ray counter. Using the quantities above mentioned, the counter recorded an average of 110 impulses in 5 minutes, whereas the control experiments carried out with 10 c.c. of ordinary water contained in a duplicate vessel gave 55 impulses against a normal 'background' of 30–35 impulses in 5 minutes. We attribute the difference in count between the normal 'background' and the control experiments with ordinary water to primary neutrons emitted by the source.

A similar series of experiments, in which 300 c.c. of bromoform was substituted for the ethyl iodide, gave strictly comparable results with radio-bromine to those obtained with radio-iodine. We conclude that neutrons emitted from heavy water irradiated by radium gamma-rays are capable of inducing radioactivity in iodine.

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[1] NATURE, 134, 494, Sept. 29, 1934.
[2] NATURE, 134, 237, Aug. 18, 1934.
[3] NATURE, 134, 462, Sept. 22, 1934.

Spectrum of Ordinary Hydrogen (H_2)

I HAVE recently found several systems of bands in which the electronic transitions are from new upper states of H_2 down to the singlet state generally denoted by ^1X. These band systems are of importance and interest for a variety of reasons.

I gather that there is no general agreement as to what the electronic configuration of the final state ^1X is, but I have put forward what I believe strong reasons for thinking it to be the $1s\sigma 2s\sigma ^1\Sigma_g$ state which otherwise would, quite unaccountably, be missing. Hitherto, our knowledge of ^1X, derived from the analysis of the $^1X \rightarrow 2p^1\Sigma$ system, has been very meagre except at the vibrational levels $v = 1$ and 2. These levels have a very irregular rotational structure and so also had the $v = 3$ level according to the old analysis.

This has generally been supposed to be due to uncoupling, which is impossible if the state is $1s\sigma 2s\sigma ^1\Sigma$, or to some other type of perturbation. I have recently repeated the former analysis of the $^1X \rightarrow 2p^1\Sigma$ system and have found an error at the $v' = 3$ level and some new lines. These changes make the rotational structure of the $v' = 3$ level quite regular as H_2 levels go. As a result of the analysis of the new systems ending on ^1X, I have found what I believe to be the $v = 0$ level of this state. It has a quite regular rotational structure and is about what one would expect *a priori* for $1s\sigma 2s\sigma ^1\Sigma$, so that the most serious objection to the identification of ^1X with $1s\sigma 2s\sigma ^1\Sigma$ has now disappeared. The cause of the rotational irregularity at the $v = 2$ and 3 levels is still a mystery. The difficulty about attributing it to a perturbation is that there is no known state, and so far as can be foreseen no possible state, which could be in the position and have the other properties theoretically necessary to cause a perturbation.

The strength of the new systems, which are weak, lies mainly along the diagonal axis in each case. So far, three systems seem to have emerged definitely, but there are indications of the existence of others. The upper states of the three I call provisionally ^1D, ^1R and ^1U. The analysis of these has gone far enough to enable some definite, though preliminary, statements to be made about them.

The system $^1D \rightarrow {}^1X$ lies in the infra-red around 8000 A. I believe that the upper state ^1D is the same as the D state of Hopfield, to which he found strong transitions up from the ground state in the absorption spectrum of H_2. At least if my interpretation[1] of Hopfield's data be accepted, they lie close together and have similar properties. An analysis of the $v = 2$ and 3 levels of ^1D (I have not yet found the $v = 0$ level and the $v = 1$ level is not very secure) gives the following approximate electronic constants: ν_e (depth from the ground level of the molecular ion) 11267 wave numbers, Rydberg denominator 3·12, fundamental frequency (ω_0) 2300 wave numbers. The corresponding quantities for Hopfield's D state which I derived from his absorption data are: ν_e 11560, *R.d.* 3·08, ω_0 2257, $x\omega_0$ 59·5. These data also involve an extrapolation from higher but different vibrational levels down to the $v = 0$ level, so that exact agreement is not to be expected. I think that ^1D is $1s\sigma 3p\pi ^1\Pi_u$, but the possibility that it might be $1s\sigma 3p\sigma ^1\Sigma_u$ is not yet absolutely excluded.

The system $^1R \rightarrow {}^1X$ lies around λ5900 A. The ν_e of ^1R is about 6400 giving a denominator of 4·14, ω_0 is about 2230 and $x\omega_0$ about 60. I think ^1R is $1s\sigma 4p\pi ^1\Pi_u$, but here again $1s\sigma 4p\sigma ^1\Sigma_u$ is also possible. $^1U \rightarrow {}^1X$ lies around λ5400 A. The approximate numerical data for ^1U are $\nu_e = 4900$ wave numbers, *R.d.* = 4·74, ω_0 about 2220 and $x\omega_0$ about 45. I think this state is most likely to be $1s\sigma 5p\sigma ^1\Sigma_u$, but there are some lines about which look like Q branches, so it may be