Photographic Effects Produced by Cadmium and Other Elements Under Neutron Bombardment

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It has been found that when a duplitized x-ray film has Cd placed next to it and is then surrounded by paraffin and exposed to a neutron source, the film shows blackening under the cadmium. Under these conditions the film also shows some general blackening which is rather weak. The neutrons used in these experiments were obtained by bombarding either Li or Be with about 10 microamperes of 1.2 Mev deuterons furnished by a cyclotron. There are, of course, also γ-rays incident on the Cd and the photographic film, and it was necessary to establish the blackening under the cadmium as due to slow neutrons and not to these radiations.

The photographic film was wrapped in heavy black paper to avoid exposure to light and a piece of Cd sheet was bent around the edge of the film so that the film was partially covered by Cd on both sides. It has been found that the Cd can be placed either outside or inside the black paper. Somewhat sharper images are produced with the Cd inside. Half of the film was then covered on both sides with paraffin and it was found that the blackening produced by the Cd was more intense under the paraffin. It is well known that the slow neutrons which are strongly absorbed in Cd are much more numerous in the paraffin. This is one indication that the photographic effect is due to slow neutrons. Several experiments have been carried out to test this point further. It has been found that appreciable photographic blackening can be obtained with thin Cd foils of thickness 0.0013 cm (0.011 g/cm^2). This indicates that the blackening is due to some action which has a large cross section in Cd. This fact also points to the slow neutron absorption. Furthermore, to test a neighboring element in the periodic table, the experiment was carried out with Sn, which gave little blackening compared to Cd. In order to test the origin of the photographic effect still further, the experiment was carried out in a cadmium box and under these conditions the blackening was greatly reduced.

Cd has been compared to various other elements, C, Al, Ni, Mo, Sn, W and Pb. The foils of these elements were compared in thicknesses which contained the same number of atoms per cm^2. These preliminary results indicate that there is some blackening produced by every element when so irradiated. This blackening increases with atomic number (elements which show strong artificial radioactivity are excluded) and is practically negligible for light elements and quite appreciable for Pb, though not nearly as strong as that produced by Cd. This blackening produced by other elements appears not to be a slow neutron effect since it is also produced in a cadmium box. In this connection it was observed that in the cadmium box, tin and cadmium behave in approximately the same way. It seems then, that the photographic effect produced by cadmium is due in part to some process which is not much different for neighboring elements but is mainly due to some action under slow neutron bombardment.

It has been found possible also to produce photographic blackening by the β-particles emitted by radioactive elements. Ag has been investigated in this respect and blackening produced by placing the Ag on the photographic film after the irradiation. Photographic blackening produced in this way by placing activated Ir next to a film, has been described by Groven, Govaerts and Guében.[1] In our experiments it was sufficient to leave the Ag next to the photographic plate for a few minutes only. Under these circumstances Ag naturally produces a considerable blackening when placed next to the plate and irradiated with neutrons. It is perhaps interesting to note that the blackening produced by thicknesses of Cd and Ag which contain the same number of atoms, produce comparable blackening if the

[1] Ch. Groven, J. Govaerts, G. Guében, Nature **141**, 916 (1938).

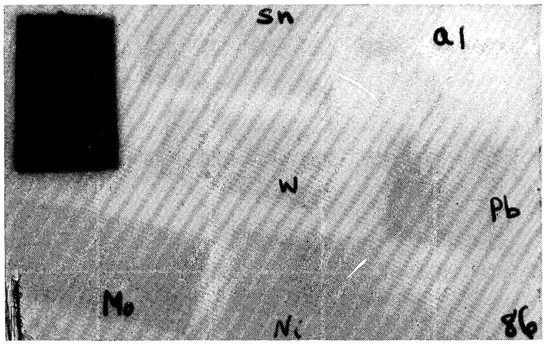


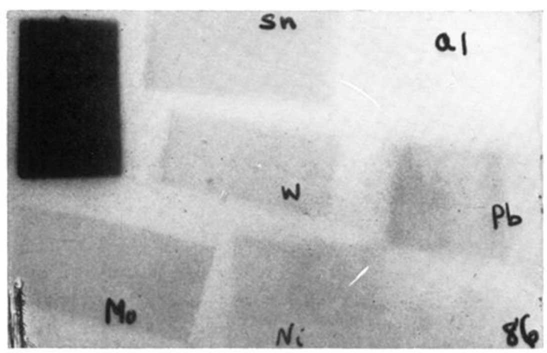
FIG. 1. Photograph taken with various thicknesses of Al, Ni, Mo, Cd, Sn, W and Pb containing the same number of atoms per cm^2. The sheets were placed on one side only of the photographic film and the film was then covered with paraffin on both sides. Exposure, 225 microampere minutes at 60 cm from Be target with 1.2 Mev deuterons. Cd thickness 0.028 cm.

radiators are removed at the end of a five-minute exposure. In the case of Cd, the radioactivity produced under short bombardment by neutrons is negligible, if any, and the effects produced cannot be explained in this way.

In order to determine the nature of the "radiation" from cadmium, which blackens the film, various absorption experiments have been carried out. With the Cd radiator a fixed distance from the film absorbers of C, Al and Ni which contain the same number of atoms per cm^2, have been used. Of these absorbers it is known that Al becomes artificially radioactive under slow neutron bombardment with a period of 2.36 minutes. This artificial radioactivity is apparently of no importance in this photographic work since it was continually observed that the blackening produced directly by the absorbers was negligible. Preliminary estimates indicate that there is little increase in the atomic absorption coefficient with atomic number. If the blackening were produced by electromagnetic radiation its atomic absorption coefficient would be expected to increase as Z^4. The small increase of the atomic absorption coefficient indicates that the blackening is produced by electrons. Furthermore, rough estimates of the absorption coefficient in aluminum indicate that the Cd "radiation" would have to be less than 20 kev and the "radiation" from lead less than 5 kev if electromagnetic in nature.

It seems unlikely that these electrons can come from any direct interaction with the neutrons. If they are produced as a result of nuclear neutron absorption, they may come either directly from a radioactive disintegration or from the internal conversion of the γ-rays emitted by the Cd nucleus or possibly by ejection of electrons from other atoms by these γ-rays. The large absorption of Cd for slow neutrons is not, however, known to be connected with any radioactivity. This point was examined briefly with cadmium in a cloud chamber, making the expansion just after the cyclotron beam had been cut off. No indication of a strong short period activity was found. This does not preclude the possibility of an extremely short period. For the other possibilities, it is well known that Cd sends off hard γ-rays under slow neutron bombardment and the possibility of electron ejection seems likely. From the increase and later decrease in blackening as the thickness of cadmium is increased, as well as from similar experiments in which part of the cadmium thickness was replaced by tin, it seems unlikely that the electrons are ejected from atoms other than the ones in which the γ-rays are produced. The possibility of internal conversion seems most likely since it is probable that some of the γ-rays produced when a Cd nucleus radiates energy upon neutron capture, are multipole radiation and the probability of internal conversion may thus be large.

In the case of the blackening produced by Pb and other elements it is likely that the mechanism is much the same, since, at least in the case of Pb, the "radiation" is probably electron in nature. In this case there is no strong absorption of slow neutrons and possibly the nuclear excitation is produced by the inelastic scattering of fast neutrons.



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