

losing its excess energy it will settle down in the lowest energy state it can reach in the crystal. Which compound will be formed during this process will depend on the chemical composition of the lattice. This makes it possible to compare the fate of the same activated monatomic ion in different crystals. In general, we may expect to find the products of  $(n,p)$  and of  $(n,\alpha)$  reactions in a highly oxidized state. Apart from this, a large concentration of oxygen in the lattice will favor the formation of oxygen-rich anions. On the whole, the results of the measurements in Table I are in agreement with these conclusions.

TABLE I. Valency of radiophosphorus from sulfur and chlorine with fast neutrons. Fraction of total radiophosphorus (in phosphate+phosphite+hypophosphite) found in phosphite+hypophosphite in different crystals.

Crystals irradiated	Fraction of $P^{32}$ found in phosphite+hypophosphite
$K_2SO_4$	0.09; 0.10; 0.10
$K_2SO_4$ , dissolved in sulfite solution	0.09; 0.10
$Na_2SO_4 \cdot 10$ aq.	0.02; 0.02
$Na_2SO_3 \cdot 7$ aq.	0.50; 0.56
$Na_2S$ hydrate	0.64; 0.78; 0.93; 0.93
$KClO_4$	0.01; 0.01
$KClO_3$	-0.01; 0.01
$MgCl_2$ hydrate	0.07
$MgCl_2$ hydrate dissolved in sulfite solution	0.02
$NaCl$	0.62; 0.68; 0.69

A radium-beryllium neutron source was used, and the irradiated products were dissolved in water containing phosphate, phosphite, and hypophosphite ions, and, in the case of potassium chlorate, ammonia. Separations were carried out as described by Libby, hypophosphite following the phosphite fraction. Although it remains to be investigated in how far the results depend on the time elapsed between the irradiation and the separation and on the temperature of the experiment, the good agreement between duplicates is sufficient proof of the reliability of the figures for comparative purpose (the value  $-0.01$  found for  $KClO_3$  was included in the table to give an idea of the degree of experimental accuracy). It is at present an open question whether the phosphate and phosphite ions are formed inside the lattice or whether they adopt their final state at the moment the crystal is dissolved. In this connection it is of interest that the presence of reducing sulfite ions does not influence the result.

In the  $NaCl$  crystal the primary product will consist of chlorine-phosphorus complexes, which hydrolyze when dissolved in water. Evidently the presence of oxygen in the  $MgCl_2$  hydrate crystal favors the phosphate formation. In the  $Na_2S$  hydrate crystal many different types of thiophosphates will be formed which do not hydrolyze as easily as the chloro compounds. Their fate during the chemical separations will depend on absorption processes and will be quite irreproducible, as is seen clearly in the table. These figures for  $Na_2S$  hydrate are, of course, without meaning.

<sup>1</sup> W. F. Libby, *J. Am. Chem. Soc.* **62**, 1930 (1940).

<sup>2</sup> A. H. W. Aten, Jr., *Rec. Trav. Chim. Pays-Bas.* **61**, 467 (1942). Analogous considerations concerning organic compounds have been published by Yankwich, Rollefson, and Norwick, *J. Chem. Phys.* **14**, 131 (1946).

## A Note Concerning the Motion of Arc Cathode Spots in Magnetic Fields\*

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A NUMBER of observers<sup>1-3</sup> have reported that low pressure arc cathode spots, when in a magnetic field, move in a direction opposite from what one might expect by an application of Ampere's law to the interaction of the magnetic field and arc current. The following explanation is consistent with the field emission theory of cathode spots<sup>4</sup> which requires a strong electric field at the cathode. This field is due to an excess of ions over electrons in the space between the plasma and the cathode. Electrons carry most of the current but, because of their relatively great velocity, have low density in this transition space<sup>5</sup> and therefore make only a secondary contribution to the electric field at the cathode. As the field emission increases very sharply with field strength, the cathode-spot position will be that of the peak field. It will be shown that the electron space charge has a significant effect on the position of the field's peak, and therefore influences the cathode spot position.

Quantitative calculations of the effect of magnetic fields on cathode electric field intensity would require a thorough knowledge of space charge distribution. Since this is unknown, only a qualitative discussion will be given here. For simplicity of description, we shall assume independent electric fields at the cathode, one caused by ion space charge (ion field) and one caused by electron space charge (electron field) (ignoring interactions between these). Figure

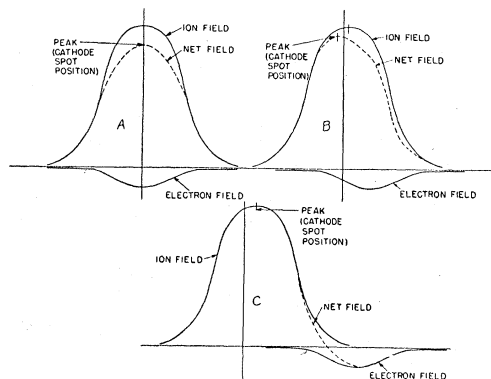


FIG. 1. Qualitative electric fields at the cathode surface. (Magnetic field into Paper.) Figure A—Zero magnetic field. Figure B—Small magnetic field. Shows retrograde motion of the peak field or cathode spot. Figure C—Large magnetic field. Shows the spot moving in the direction of the elementary particles.

1 shows the two fields and their sum, the net field, the peak of which determines the cathode-spot position.

Ions and electrons, having both opposite charges and directions of motion, will be deflected in the same direction by the magnetic field with the electrons being deflected hundreds of times farther than the ions because of their small mass. Thus when a small tangential magnetic field is applied, the average instantaneous position of the ions

and electrons (the space charge) will be displaced in the direction of their deflection. The electron field at the cathode will no longer partially neutralize the ion field symmetrically as in Fig. 1A but will have a greater neutralizing effect in the direction of their displacement, because of the larger electron displacement, as shown in Fig. 1B. Thus, surprisingly enough, while each of the component fields is shifted to the right, the peak of the net field is shifted to the left, thus accounting for the observed motion of the spot.

If the magnetic field intensity is increased greatly in magnitude, the electron and ion fields will be separated to the point of resolution, and then further displacement of the electron space charge would not influence the position of the net field maximum which would then be solely a function of the ion space charge. The displacement of the latter, small though it is, now solely determines the motion of the cathode spot (see Fig. 1C). This theory thus demands that the spot motion should reverse its direction as the magnetic field is greatly increased. This reversal has, indeed, been observed.<sup>2</sup>

Random motion will be superimposed on those described above because of irregularities in the cathode shape which will cause variations in the net field.

\* Taken in part from Master's thesis submitted to the University of Pittsburgh.

<sup>1</sup> M. N. Minorsky, *J. de phys. et rad.* **9**, 127 (1928).

<sup>2</sup> C. G. Smith, *Phys. Rev.* **62**, 48 (1942); **64**, 40 (1943); **69**, 96 (1946).

<sup>3</sup> C. J. Gallagher and J. D. Cobine, *Bull. Am. Phys. Soc.* **22**, 28 (1947).

<sup>4</sup> I. Langmuir, *Gen. Elec. Rev.* **26**, 731 (1923); *Zeits. f. Physik* **46**, 282 (1927).

<sup>5</sup> S. S. Mackeown, *Phys. Rev.* **34**, 611 (1929).

### Activities Induced by Pile Neutron Bombardment of Samarium\*

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A SAMPLE of  $\text{Sm}_2\text{O}_3$  was given a long neutron bombardment in the Hanford pile. By mass spectrographic analysis<sup>1</sup> active masses were observed at mass numbers 145, 151, 152, 154, 155, 156, 161, 167, 169, and 176. The interpretation of these active masses is given in Table I. Parentheses are placed about those half-lives which are tentative.

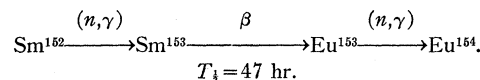
The assignment of samarium to certain of these active masses was made because samarium emits ions of form  $\text{Sm}^+$  and  $\text{SmO}^+$  from the heated oxide. The assignment of europium to other active masses was made because europium emits only as the metal. The 169 activity could conceivably have been caused by samarium, gadolinium, erbium, or ytterbium. Since no line was observed as mass 153 the possibility of samarium was ruled out. Gadolinium, which emits mostly as  $\text{GdO}^+$ , could have caused the line as could erbium or ytterbium emitting as  $\text{Er}^+$  and  $\text{Yb}^+$ . However, since gadolinium was a known impurity in the samarium sample and no erbium or ytterbium impurities could be detected, it was concluded that the 169 mass line

TABLE I.

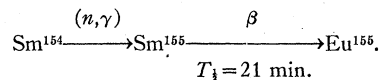
Mass No.	Ion	Active isotope	Half-life
145	$\text{Sm}^{145+}$	$\text{Sm}^{145}$	> 72 days
151	$\text{Sm}^{151+}$	$\text{Sm}^{151}$	(~20 years)
152	$\text{Eu}^{152+}$	$\text{Eu}^{152}$	(~5 years)
154	$\text{Eu}^{154+}$	$\text{Eu}^{154}$	(~5 years)
155	$\text{Eu}^{155+}$	$\text{Eu}^{155}$	2-3 years
156	$\text{Eu}^{156+}$	$\text{Eu}^{156}$	15.4 days
161	$\text{Sm}^{161O+}$	$\text{Sm}^{161}$	> 72 days
167	$\text{Sm}^{167O+}$	$\text{Sm}^{167}$	(~20 years)
169	$\text{Gd}^{169O+}$	$\text{Gd}^{169}$	> 72 days
176	$\text{Tb}^{176O+}$	$\text{Tb}^{176}$	72 days

was caused by a gadolinium isotope of mass 153. The mass observed at 176 was caused by 72-day terbium<sup>2</sup> emitting at  $\text{TbO}^+$ .

The  $\text{Sm}^{145}$  was formed by  $(n,\gamma)$  reaction on  $\text{Sm}^{144}$ . It probably decays by  $K$ -capture or positron emission to  $^{61}\text{La}$ . Since the ratio of blackening at 145 and 161 positions is that characteristic of samarium, the half-life of the  $^{61}\text{La}$  cannot be of the same order of magnitude as the half-life of  $\text{Sm}^{145}$ . The half-lives of  $\text{Sm}^{145}$  and  $\text{Gd}^{153}$  were shown to be greater than 72 days by comparison with the decay of 72-day  $\text{Tb}^{160}$ . The  $\text{Sm}^{161}$  has previously been observed only in fission.<sup>3</sup> It decays with a half-life of roughly 20 years to  $\text{Eu}^{161}$ . The europium activities at masses 152 and 154 were formed by  $(n,\gamma)$  reactions on impurities of europium in the samarium sample. In addition an appreciable part of the 154 observed was formed by the reaction



The 2-3 year  $\text{Eu}^{155}$  was formed by the reaction



It has previously been observed only in fission.<sup>2</sup> The 15.4-day  $\text{Eu}^{156}$  had also been observed only in fission. Here it was formed by  $(n,\gamma)$  reaction on the  $\text{Eu}^{155}$ . The cross section for this reaction was calculated to be roughly  $14,000 \times 10^{-24} \text{ cm}^2$ . This is the first example of the determination of an absorbing cross section for a radioactive isotope by means of the mass spectrometer. The half-life of the europium activity at the 156 position on the plate was shown to be 15.4 days by the following method. The active plate was placed successively against various parts of a larger photographic plate for times calculated to give equal intensity at the 156 position if the half-life were 15.4 days. Four exposures were taken for successive times of 5 days, 6.4 days, 9.2 days, and 15.8 days. The lines at masses 152, 154, and 155 became denser with successive exposure, but the intensity of the 156 lines remained constant thus verifying that the half-life of the  $\text{Eu}^{156}$  was actually 15.4 days. The half-lives of the  $\text{Sm}^{145}$ ,  $\text{Gd}^{153}$ , and  $\text{Tb}^{160}$  were determined by a similar method.

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<sup>1</sup> R. J. Hayden and M. G. Inghram, *Phys. Rev.* **70**, 89 (1946).

<sup>2</sup> Bothe, *Naturwiss.* **31**, 551 (1943).

<sup>3</sup> *Rev. Mod. Phys.* **18**, 513 (1946).