The Intermediate Ion of the Atmosphere

In addition to the small and the large or Langevin ion in the atmosphere, there was discovered in 1909, by Pollock[1] of the University of Sydney, an ion having a mobility intermediate between that of the small ion and that of the large ion. His investigations disclosed the fact that the mean mobility of this group of ions diminishes with increasing vapor pressure of the atmosphere. He also obtained results which he interpreted as indicating that the intermediate ion consists of water vapor surrounding a solid rigid nucleus and which condenses into a liquid drop forming the large ion when the vapor-pressure reaches a certain critical value (about 15 mm) which is less than that required for saturation at the usual temperatures in summer. Additional information regarding these ions was secured by Schachl,[2] when he found that at times of Böen their number was greatly increased. Schachl interpreted this to mean that the ion was formed through the Lenard effect. Additional information regarding this ion has been secured at the Department of Terrestrial Magnetism, Carnegie Institution of Washington. These results, which will be published in detail in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, may be summarized as follows:

(1) Contrary to the findings of Pollock, intermediate ions do not diminish at any vapor pressure to form large ions through condensation of water vapor and therefore, no critical vapor pressure exists.

(2) The mobility of the intermediate ion is found to decrease with an increase in vapor pressure in strict accord with Blanc's law, just as in the case of the small ion in a gas. The mobility at zero millimeters vapor pressure is 0.5 cm per sec. per volt per cm and at 30 mm pressure is approximately a tenth of this. This result furnishes information concerning the nature of the intermediate ion.

(3) The number of intermediate ions in the atmosphere undergoes a diurnal variation, similar in character to that for the large ions and more or less opposite in character to that for the small ions of the atmosphere. Evidence indicates that the intermediate ion secures its charge from the small ion through combination with it.

(4) A value for the recombination coefficient for the intermediate ion has, for the first time, been determined, following a method which avoids an error that has occurred[3] in some of the determinations of the recombination coefficient for small ions. The value determined for the intermediate ion coefficient is 7.1×10^{-7} (a value roughly one-half that for the small ion).

(5) The intermediate ions are especially numerous during times of thunderstorms, as pointed out by Schachl, but not as a consequence of the Lenard effect. The number increases at the beginning of the storm, this increase shows a close correspondence to the increase in small ion production recently observed.[4] After the close of the storm their number gradually decreases, the decrease also having a close correspondence to the decrease in production of small ions found to occur at such times. Furthermore, the change in number of intermediate ions is associated with a change in number of small ions present rather than with the operation of the Lenard effect.

(6) As indicated under (3) above, the diurnal variation in the number of intermediate ions is opposite in character to that of the small ions, while under (5) above, it was pointed out that the number of intermediate ions increased with an increase in the number of small ions. Considering the large value found for the intermediate ion recombination coefficient, this apparent paradox is explicable with the assumption that the combination coefficient between small ions and intermediate ions is large compared with that between small ions and uncharged intermediate ion particles.

(7) The mobility spectrum for the intermediate ion appears to be a narrow band and under normal conditions, practically no ions having mobilities between that of the intermediate ion and that of the large ion was found.

(8) In small ion work, it is not customary to differentiate between small and intermediate ions, a portion of the latter being included in the count of the former. As a result, this inclusion, judged from the present results, introduces persistent errors ranging from 10 to 30 percent in small ion counts.

It is worthy of mention that the behavior of intermediate ions seems to introduce certain difficulties. According to present theory, the large ion consists of a condensation nucleus with an electric charge. It has been suggested that condensation nuclei are hygroscopic in character. Because of the similarity between the diurnal variation curves for the large and the intermediate ions as well as a similarity in their daily variation, the intermediate ion particle also might be expected to be hygroscopic. In this case the mobility of the intermediate ion would vary with the relative humidity rather than with the vapor pressure. However, the evidence indicates that the variation is in response to a variation in vapor pressure rather than to a variation in the relative humidity.

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[1] Pollock, Phil. Mag. **29**, 636 (1915).
[2] Schachl, Beitr. Geophysik. **38**, 202 (1933).
[3] L. B. Loeb, Trans. Am. Electrochem. Soc. **55**, 131 (1929).
[4] G. R. Wait and A. G. McNish, Mon. Weath. Rev. **62**, 1 (1934).

Absorption of Slow Neutrons in Silver

Fermi and his collaborators[1] have measured the absorption of slow neutrons in a variety of elements, using as a detector of the neutrons usually rhodium, and sometimes silver. Wide differences in absorption are found among the various elements tested, and the removal of neutrons from the beam by absorbing layers has been shown to be due to the mechanisms of capture (with emission of a gamma-ray or of a heavy particle) and elastic scattering. Of these two mechanisms, the first seems to be predominantly important in those elements exhibiting the largest cross sections for slow neutrons.[2]

It seemed desirable to measure the absorption of neutrons in a single element, using a variety of detectors, and this letter is a preliminary report of investigations of that sort. While this work was in progress, other investigators

TABLE I. *Absorption of slow neutrons in silver as measured by different detectors.*

SOURCE OF NEUTRONS	DETECTOR Element	DETECTOR Thickness (g/cm²)	PERCENT ACTIVITY (TRANSMISSION) WITH ABSORBER OF 0 g/cm² Ag	0.46 g/cm² Ag	0.81 g/cm² Ag	1.72 g/cm² Ag
B-Rn	Silver	1.195	100	60±1	42±3	26±4
Be-Rn	Silver	1.195	100	59±1	44±1	27±1
Be-Rn	Silver	0.094	100	46±4	30±1	17±2
Be-Rn	Copper	0.717	100	42±2	28±3	12±2
Be-Rn	Vanadium (as NH_4VO_3)	0.146	100	47±2	35±1	17±2
Be-Rn	Bromine (as NH_4Br)	0.305	100	62±1	56±1	38±1
Be-Rn	Iodine (as CHI_3)	0.143	100	57±2	48±1	36±2

have noted[3] that the cross section measured for an absorber depends strongly on the reaction whereby the slow neutrons are detected.

The geometrical conditions under which the irradiation of samples was conducted is shown in Fig. 1. The detectors of slow neutrons were disks 5 cm in diameter, the absorbers disks 7 cm in diameter. The Ag and Cu detectors were metal sheets; the I, Br and V detectors consisted of compounds (cf. Table I) held on stiff paper with thin collodion. The source of neutrons was beryllium (or boron) and radon in amounts usually between 100 and 200 millicuries. The activity of the detectors after irradiation was measured with a quartz-fiber electroscope of the Lauritsen type, provided with a window of thin aluminum. The procedure was to irradiate the detector, either bare or between two equal layers of an absorber, for a length of time standard for that detector, then to commence readings one minute after the removal of the detector from the neutron source. The reading was terminated at a time, also standard for for each detector, depending on the half-life of the activity under measurement. In Br, for example, the irradiation lasted for twenty-five minutes, and the measurement for fifteen minutes, so that only the short-lived activity was measured in these experiments. Frequent readings on the background were taken in precisely the way the measurements were made, except that the detector had not been exposed to the neutron source. The activities found were in all cases easily measurable, being from twice to about twenty-five times the background due to cosmic and local radiations.

The results are shown in Table I. The absorber was in all cases silver, and the numbers in the table under the heading Percent Activity are referred in each case to the no-absorber value for that detector as 100 percent, so that they are measures of the transmission through the absorber of neutrons having the proper energy to activate the detector.

It is known that the absorption curves obtained with such an arrangement of paraffin as was used in the present experiment are not exponential, but that the absorption decreases with increasing thickness of absorber;[1] this would seem to be the reason for the quite large difference shown in the table between the absorption measured in silver with a thin and with a thick silver detector. So long as the absorption of neutrons in the thickness of the detector can be neglected, this effect will not complicate the results, and the other detectors are apparently thin enough, relative to the half-value thickness of each for slow neutron absorption,[1] so that the results obtained with them may be intercompared, and compared with those for the thin silver detector. None of the detectors employed in the present experiment has a half-value thickness of silver as large as that (1.2 g/cm²) given by Fermi for a Rh detector, but his value cannot properly be compared with the present ones because of the differences which may have been introduced by detector thickness and the disposition of paraffin about the source and detector.

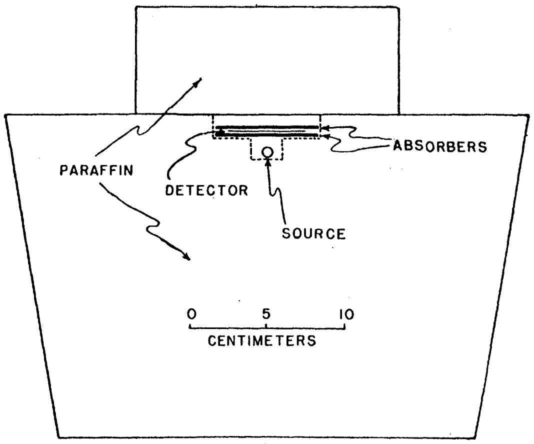

FIG. 1.

The differences between Br, I and the other detectors employed in the present experiment seem necessarily to be due to the fact that neutrons captured by different detectors lie in different ranges of energy. The sense of the differences among the detectors in the energy range of neutrons most likely to be captured by each cannot be determined from these results alone, but the experiment of Moon and Tillman[3] seems to show that the neutrons activating iodine have higher energies than those activating silver, so that presumably Br is activated by faster neutrons still.

Independent experiments showed that the effect of elastic scattering of slow neutrons in the silver was not comparable with neutron capture, so that substantially all the observed absorption is due to the latter phenomenon.

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