Energy Required to Produce One Ion Pair in Several Noble Gases*

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The absolute values of W, the energy to produce one ion pair, for electrons have been determined for purified noble gases. A parallel plate extrapolation ionization chamber, which could be evacuated, was used. The gases investigated were H_2, He, Ne, A, Kr, and Xe; and the absolute values of W were 36.3; 40.3; 35.3; 25.8; 24.7; 22.0 ev respectively based on W for air being 33.9 ev.

IN a previous publication,[1] we described the measurement of W, the energy required to produce one ion pair, for several gases, when these gases were ionized by fast electrons. However, with the exception of argon, this investigation was limited to diatomic and polyatomic gases, and no purification was attempted. The energy absorbed in the walls of a parallel plate ionization chamber, which met the requirements of the Bragg-Gray principle, was determined by the use of a ferrous sulfate dosimeter. Within the accuracy of the selected value of G, the oxidation yield of the ferrous sulfate reaction, absolute W values were obtained.

Although the agreement between our W values and those of Jesse and Sadauskis[2] was excellent, it was suggested by Jesse that it would be desirable to extend our measurements to include all of the noble gases for which they had obtained absolute alpha-particle values. Their electron values are all taken relative to argon and it is assumed that in the noble gases the W's are the same for alpha particles and electrons.

Consequently, a new sealed ionization chamber was designed through which purified gases could be circulated by means of a sylphon pump. The purification method was similar to that used by Jesse and Sadauskis and comparable gas purity was probably achieved. In the case of helium and neon, the gases were purified by circulation through a charcoal trap at liquid nitrogen temperature; a liquid oxygen trap without charcoal was used for argon. Spectroscopically pure xenon and krypton were used without circulation or further purification. X-rays from the 2-Mv Chemistry Department Van de Graaff generator were used as a radiation source.

TABLE I. Summary of experimental data and results.

Gas	i (arb. units)	$I(v)$	S_{air}^{g}	W_a^g	W this work	W Jesse and Sadauskis
Air	60.7	83.2	1.00		(33.9)	34.1
H_2	9.51	15.6	0.26	1.07	36.3±0.7	36.3
He	7.75	35.0	0.15	1.19	40.3±0.8	42.3
Ne	38.6	115.0	0.66	1.04	35.3±0.7	36.7
A	89.3	195.0	1.11	0.76	25.8±0.5	26.4
Kr	171	317[a]	2.05	0.73	24.7±0.5	24.2
Xe	268	486[a]	2.90	0.65	22.0±0.4	22.2
O_2	71.9	92.0	1.10	0.92	31.2±0.6	30.9
N_2	57.9	80.5	0.97	1.02	34.6±0.7	34.7
C_2H_4	91.8	51.4	1.18	0.78	26.4±0.5	26.3

[a] Calculated from $I=8.8Z$.

In view of the fact that an absolute W value had previously been determined for air, only the ratio W_g/W_{air} was obtained in these measurements. In order to verify the reproducibility of the experiments, several gases, previously determined, were again measured. In the case of xenon and krypton, measurements were made at reduced pressures of approximately 5 cm to reduce the contribution to the ionization by the absorption of x-rays in the gas itself; air and oxygen readings were taken at about the same pressure. The other gases and also air were run at approximately atmospheric pressure. Extrapolation curves were obtained for the high-Z gases and ethylene.

The experimental results are tabulated in Table I. The vibrating reed readings are all normalized to the same pressure, temperature, and resistor value. The ratio W_{gas}/W_{air} is given by the following equation:

$$\frac{W_{gas}}{W_{air}}=\frac{i_{air}}{i_{gas}}S_a^g,$$

where i_{air} and i_{gas} are the ionization currents in arbitrary units and S_a^g is the ratio of the stopping powers of gas to air and includes the number of electrons/cc and the stopping power per electron. These were calculated as described in reference 1: the values of I, the average ionization potential, are listed in column 3. The W values for the different gases were obtained using 33.9 ev for air.

These values are again in excellent agreement with those of Jesse and Sadauskis. The slight discrepancies are probably within the experimental error, estimated to be approximately ±2%. Certainly systematic errors which cannot be accurately evaluated are present. For example, in the case of He, the value of S_a^g is markedly dependent on the value selected for the average ionization potential for which a variety of values exist in the literature. In the case of Ne, ordinary tank gas was used and it is perhaps uncertain whether purification was complete. Perhaps the most significant point is that Jesse's assumption that the alpha and electron W's for the noble gases are the same is valid to within 3%.

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[1] J. Weiss and W. Bernstein, Phys. Rev. **98**, 1828 (1955).
[2] W. P. Jesse and J. Sadauskis, Phys. Rev. **97**, 1668 (1955).