Pertanika 9(3), 387 – 392 (1986)

Ionization Coefficients and Breakdown Potential in Krypton

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Key words: Primary ionization coefficient; secondary ionization coefficient; breakdown potential.

ABSTRAK

Arus pengionan dalam kripton kelas penyelidikan di antara elektrod berbentuk satah yang selari bersalut emas, yang berjarak sehingga 3 cm telah pun diukur dalam julat 14 $< E/p <$ *200 volt cm* $^{-1}$ *torr* $^{-1}$ *dan 2* $< p <$ *130 torr, di mana E ialah medan elektrik dan p tekanan gas. Nilai pekali pengionan primer* α/p *yang didapati daripada pengukuran tersebut lebih kecil daripada nilai yang didapati oleh Kruithof (1940), tetapi lebih besar daripada nilai yang didapati oleh Dutton* et al. *(1983), dalam julat* $E/p <$ *200 volt cm* $^{-1}$ *torr* $^{-1}$*. Dalam had ketidakpastian eksperimen* α/p *telah didapati sebagai satu fungsi kepada* E/p *sahaja. Nilai voltan runtuh yang diukur adalah bersetuju dengan nilai yang dikira daripada cirian voltan runtuh dan menunjukkan prinsip keserupaan berlaku.*

ABSTRACT

Ionization currents in research grade krypton between plane parallel gold-plated electrodes at separation up to 3 cm were measured in the range of 14 $< E/p <$ *200 volt cm* $^{-1}$ *torr* $^{-1}$ *and 2* $< p <$ *130 torr where E is the applied electric field and p** is the gas pressure. The values of ionization coefficients* α/p *deduced from these measurements were lower than the values obtained by Kruithof (1940) but higher than the values obtained by Dutton* et al. *(1983), in the range of* $E/p <$ *200 volt cm* $^{-1}$ *torr* $^{-1}$*. Within the limit of experimental error,* $/p$ *was found to be a function of* E/p *only. The measured values of breakdown potentials were in good agreement with the values calculated from the breakdown criterion and satisfied the similarity principle.*

INTRODUCTION

In 1940, Kruithof was the first to measure the Townsend primary (α) and secondary (ω/α) ionization coefficients for krypton. Since then the collision process in krypton has been extensively studied by several workers (Heylen, 1971; Bhattacharya, 1979; Jacques and Bruynooghe, 1981 and Dutton *et al.*, 1983) and it is well known that the values obtained in experimental determinations of ionization coefficient for rare gases depend greatly on the extent to which traces of impurities can be removed from the gas samples (Dutton *et al.*, 1969). Thus their published experimental results of the ionization coefficients in krypton appear to be (10 – 30%) from one to another. Therefore the values of ionization coefficient (α) published recently

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**The pressure p was measured and corrected at temperature 25°C.

(Dutton *et al.*, 1983) were found to be 30% lower than the results obtained by Kruithof (1940), and were regarded as having used a purer gas sample. Similar results in helium and argon have also been obtained by Powell (1970) and Abdulla (1980, 1981) using modern ultra-high vacuum and gas purification techniques.

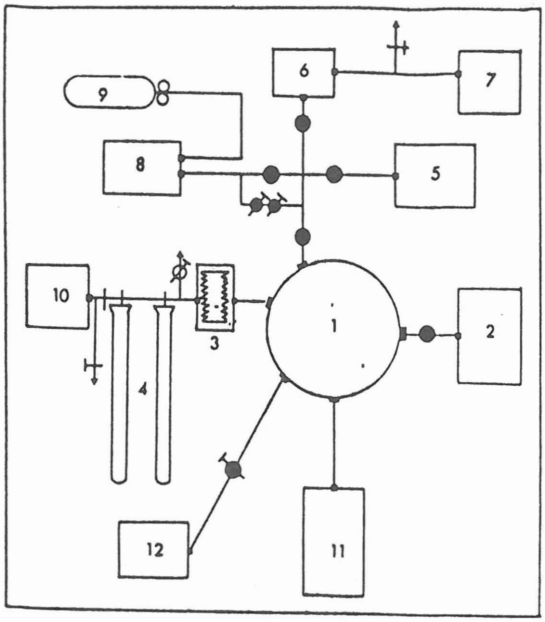
It is the purpose of this paper to describe and discuss the values of ionization coefficient obtained for highly pure krypton in ultra high vacuum chamber for values of E/p up to 200 volt $cm^{-1} torr^{-1}$ corresponding to a pressure range of $3 < p < 200$ torr.

MATERIALS AND METHODS

Krypton has the first ionization energy 14 eV, and all electro-positive impurities have higher ionization cross-section for the same excess energy; thus small traces of impurity have a profound effect upon the measured values of the ionization coefficients. It is therefore necessary to eliminate such impurities from the gas and ionization chamber in order to measure the accurate values of α in pure gas. For this reason, an ultra-high vacuum and a good gas purification system, shown in *Figure 1,* was employed.

The apparatus and experimental method briefly discussed here are necessarily the same as in our earlier paper (W Mahmood and Williams 1985), and Abdulla 1980. The ultra-high vacuum chamber had a volume of about 40 liters and after baking the ultimate pressure in the system was 3×10^{-9} torr with a leak-rate of 1×10^{-6} μl (micron-liter) sec^{-1}. Electrode separations of up to 3 cm could be used and the initial photoelectron current was produced by shinning ultra-violet light through holes in the anode. The gas pressure in the system was measured by manometers isolated from the chamber by a sensitive bellows.

A 6 kV power supply provided a voltage stable to 1 in 10^5 which was measured using a 4 M Ω potentiometer and the ionization currents which were in the range 10^{-13} to 10^{-8} A were measured using an electrometer. The gas



1 - Ionization Chamber.
2 — Ion-Pump.
3 — Bellows.
4 — Manometers.
5 — Ion-Pump.
6 — Sorption Pump.
7 — Rotary Pump.
8 — Gas Purifier.
9 — Gas Tank.
10 — Rotary Pump.
11 — Current Measuring System

Bakeable Valve. Glass Valve.

Leak Needle Valve. Gas Regulator.

Fig. 1: Block diagram of the System

sample supplied by British Oxygen Co was grade X (99.99% purity) and was further refined using B.O.C. MK3 rare gas purifier. In the purifier, the gas passed over titanium granules at 700°C to remove nitrogen and oxygen, through a copper oxide furnance to remove hydrocarbons, hydrogen and carbon monoxide and finally through a moleculer sieve to remove moisture and carbon dioxide. For each value of electrode separation d, a current I_c was measured at a value of E/p at which ionization is negligible; this was followed by measurement of a gas amplified current I for chosen higher values of E/p. The data were analysed using a curve fitting technique (Thomas, 1966) to the Townsend equation.

$$\frac{I}{I_c} = \frac{C \exp(\alpha d)}{1 - \omega/\alpha[\exp(\alpha d) - 1]}$$

where α and ω/α are the primary and generalized secondary ionization coefficients respectively, and C is a constant, related to the initial photoelectric current I_o by $I_o = CI_c$. The sparking potential was calculated by substituting the values of α and ω/α into sparking breakdown criterion. Measurement of sparking potentials were also made for the research grade gas sample in the range of $8 < pd_s 156$ torr-cm.

Two set of experiments were carried out in the range of E/p values $14 < E/p < 200$ volt $cm^{-1} torr^{-1}$ (i.e. the research grade krypton and further purified research grade krypton using B.O.C. purifier). The ionization chamber was initially filled to a low pressure (e.g. 2.09 torr) and the range of E/p values was obtained by admitting more gas into the chamber to increase the pressure p.

RESULTS AND DISCUSSION

Current growth measurements were carried out in the respective gas samples in the following ranges: $14 < E/p < 200$ volt $cm^{-1} torr^{-1}$, $2.09 < p < 130$ torr in research grade krypton; and $15 < E/p < 100$ volt $cm^{-1} torr^{-1}$, $3.43 < p < 86$ torr, in purified research grade krypton. *Figure 2* shows a typical plot of I/I_c as a function of electrode separation d for purified krypton at p = 32.18 torr, at E/p values of; 32, 30, 28, 26, 23, 22 and 19 volt cm^{-1} $torr^{-1}$. The reduced ionization coefficients α/p obtained from the research grade krypton and purified krypton respectively are shown in *Figure 3*. The results obtained from purified krypton are lower than the data of research grade krypton. This may be attributed to the increased purity in the purified krypton used in the experiment. However, the present results are higher than the data obtained by Dutton *et al.* (1983), but were lower than Kruithof's results (1940) in the range of $E/ < 100$ volt $cm^{-1} torr^{-1}$ (see *Figure 4*). At E/p = 75 volt cm^{-1} $torr^{-1}$, the present value is about 5% higher than the value obtained by Dutton *et al.* (1983), but as E/p decreases, the α/p slowly deviated from Dutton's result, until at E/p = 20, the difference is of the order 20% higher. This difference might be due to changes in the efficiency of the purifier itself which has been in use for more than four years.

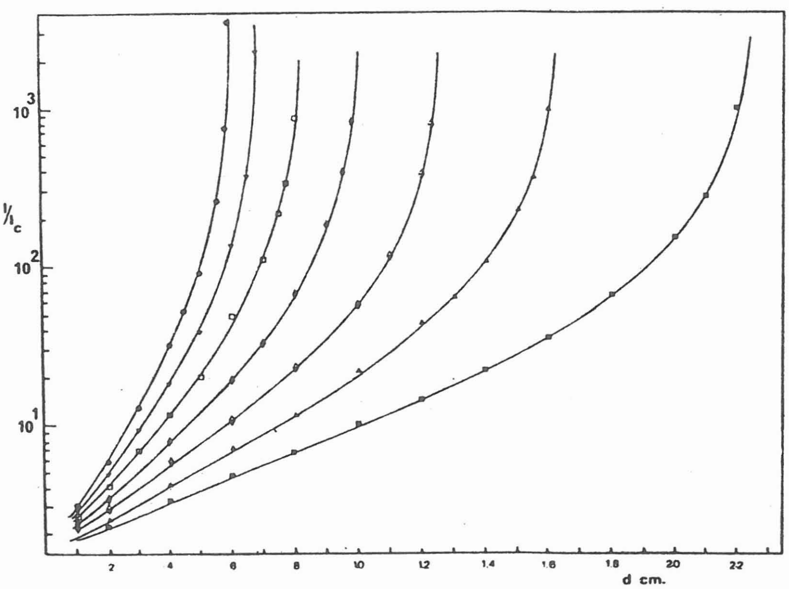


Fig. 2: Experimental log I/I_c versus d curves, Purified Krypton at P = 32.18 torr, at E/P values of:
● 32; ▼ 30; ⧫ 26; ⧫ 23; ▲ 22; □ 28
■ 19 volt/cm torr^{-1}.

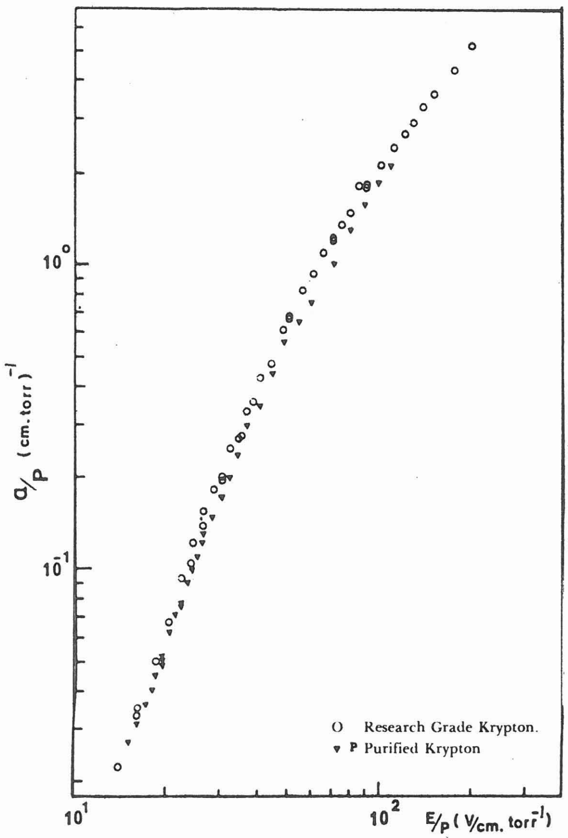


Fig. 3: Present values of α/P as a function of E/P for krypton.

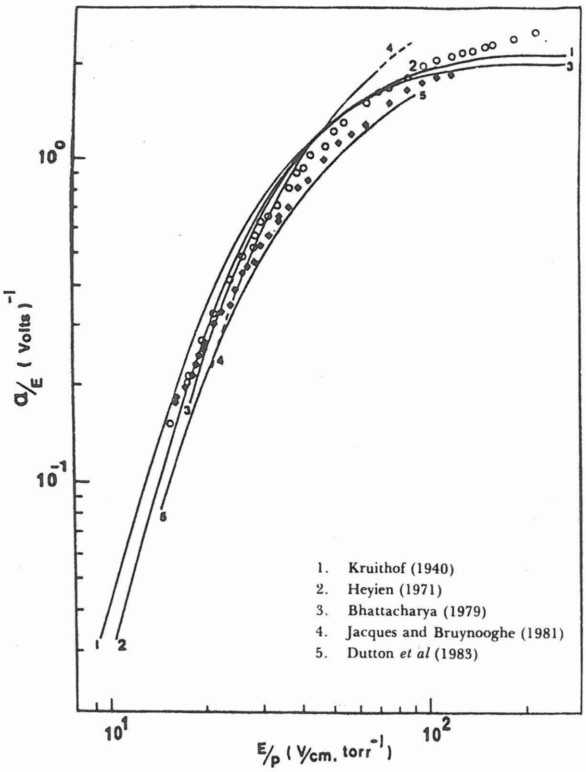


Fig. 4: Present values of α/E as a function of E/P$_o$ compared with the previous experimental results. O research grade krypton.

The measured values of sparking potential shown by a solid line in *Figure 5* are in good agreement with the values calculated from Townsend breakdown criterion formula. However, the breakdown potential obtained for purified krypton *(Figure 6)* deviated slowly from Paschen's law as pd_s decreased from 30 torr-cm. Consequently, it seems likely that this deviation might due to the dependence of the secondary ionization coefficient on gas pressure. These are similar to those results reported by Jacques and Bruynooghe (1981). However, within the experimental error no firm conclusion can be drawn from the deviation of sparking potentials obtained in the present investigation. Considering that the action of positive ions at the cathode is the dominant secondary process, secondary ionization will greatly depend on gas pressure. If such a pressure dependence of the coefficient, ω/α does exist, then it would mean that the sparking potential is not accurately a function of parameter pd only. For this reason, a more extensive investigation of this effect should be made in krypton.

CONCLUSION

The present values of α/p for krypton are between the values obtained by Kruithof (1940) and Dutton *et al.* (1983). The present study also shows that in the case of research grade krypton, the values of α/p obtained are higher than in the purifid krypton.
krypton.

ACKNOWLEDGEMENT

The author wishes to thank Dr A.W. Williams, a lecturer in the Department of Physics, University College of Swansea for his encouragement and helpful discussion at all stages of the work.

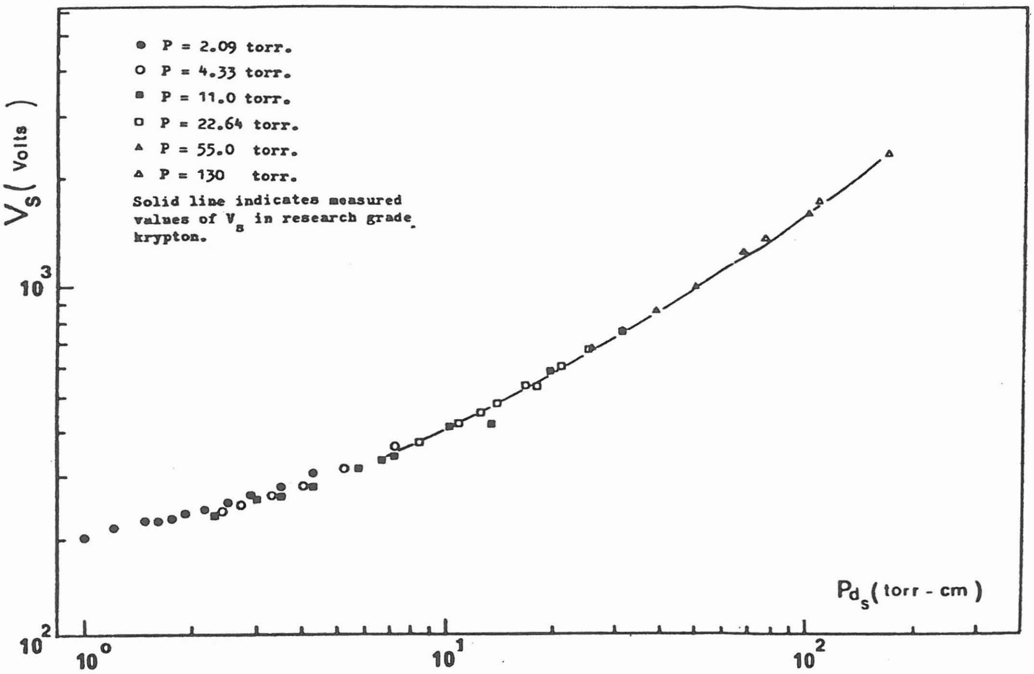


Fig. 5: Present values of V_s as a function of Pd_s for research grade krypton.

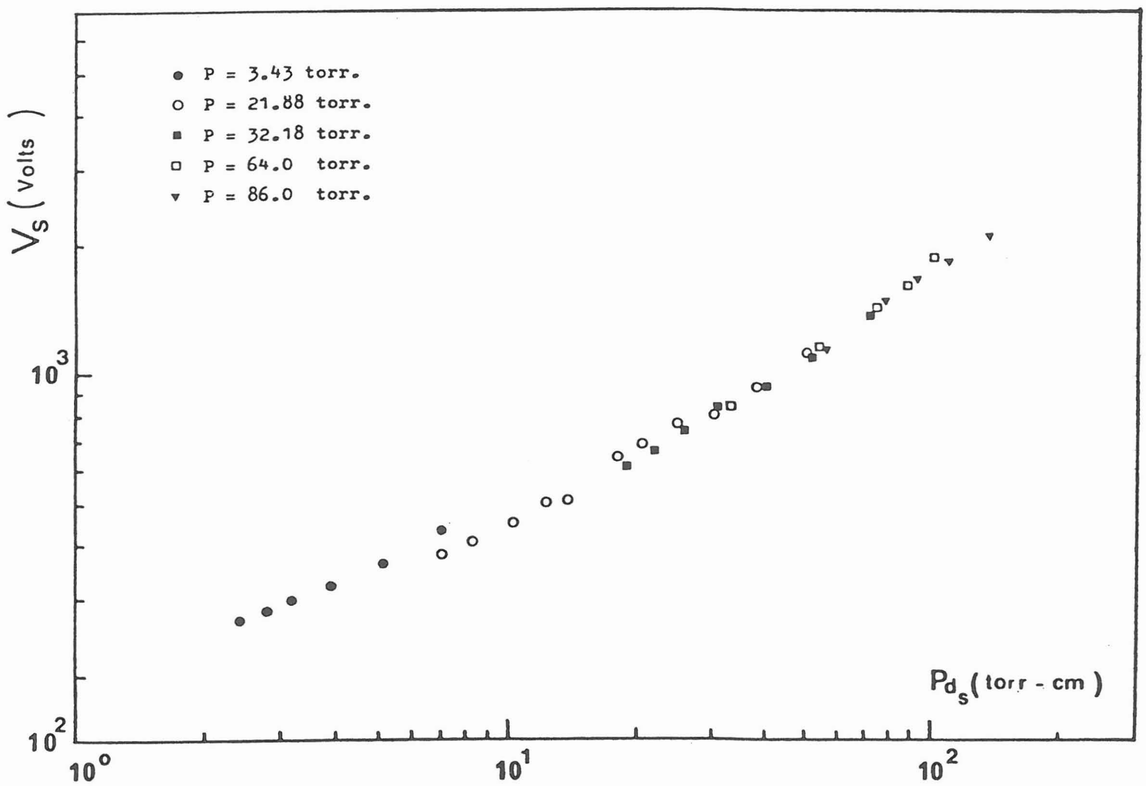


Fig. 6: Present values of V_s as a function of Pd_s for purified krypton.

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(Received 4 March, 1986