PHOTOIONIZATION YIELD AND ABSORPTION COEFFICIENT OF XENON IN THE REGION 860-1022 Å*

F. M. MATSUNAGA, R. S. JACKSON+ AND K. WATANABE

Department of Physics, University of Hawaii

Honolulu, Hawaii

Abstract

Absorption coefficient and absolute photoionization yield of xenon gas have been measured by photoelectric methods with 0.2 Å bandwidth in the 860-1022 Å region. Ionization yields were obtained with a platinum detector calibrated against a calibrated thermocouple. A yield value of unity was obtained throughout this region which includes preionized Rydberg lines. The absorption coefficient at most wavelengths fell between the spread of previous values.

author

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+ Present address: Stanford Research Institute, Menlo Park, California.

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INTRODUCTION

Recently, several investigators[1]-[5] have measured the absorption coefficient of xenon in the spectral region below 1022 Å by means of photoelectric techniques. Furthermore, Samson[6] reported that the rare gases have the same relative photoionization yield at many wavelengths and concluded that "the most probable value for the ionization yield of rare gases is unity even in the regions of auto-ionization." This conclusion is consistent with our earlier ionization measurement[7] of xenon. However, in view of the importance of the photoionization of rare gases for absolute intensity measurements as proposed by Samson,[6] further support seems desirable.

In the present study, we have remeasured the absolute photoionization yield of xenon with the aid of a calibrated thermocouple at about two hundred wavelengths in the region 860-1022 Å. In view of the wide spread in the reported values, we also present the absorption coefficient of xenon in this region.

The absorption coefficient k in cm^{-1} is defined by the equation, $I = I_o \exp(-kx)$ where I_o and I are the incident and transmitted intensities, and x in cm is the layer thickness of gas reduced to 0 °C and 1 atm pressure.

EXPERIMENTAL

Absorption coefficients were measured by a method described previously[7] with some improvements. Experimental conditions were as follows: a McPherson one-meter monochromator provided a resolution of 0.2 Å; the light source was a hydrogen discharge tube operated at 0.35 A dc and about 800 V; the absorption chamber was located between the exit slit and a glass plate coated with sodium salicylate; a EMI 9514B photomultiplier was placed behind the glass plate; cell lengths of 13.6 cm and 27.1 cm were used.

Ion currents were measured via two parallel plate electrodes extending over the length of the absorption chamber. The exit slit jaws were electrically insulated from the slit mount and wired to the positive plate; a similar arrangement was described by Samson.[6] The voltage-current curve showed a saturation plateau above 10 V, and usually 15 V was applied across the plates.

Pressures of xenon gas (Airco reagent grade) were measured continuously with a Consolidated micromanometer connected directly to the absorption chamber. The manometer was calibrated against a McLeod gauge with static gas and then by the absorption method[7] with gas flowing in the absorption chamber. The results were the same; therefore, with a 0.017 mm slit, the pressure differential in the chamber appeared to be negligible for pressures in the range 0.01-0.3 mm Hg which were used.

A windowless Reeder compensated thermocouple with a

detector area of 1 mm x 3 mm was used for measurement of absolute intensity. A slit of area 0.519 mm x 2.60 mm was placed over the detector so that only the sensitive area would be illuminated during measurements. The thermocouple was calibrated[8][9] in air against a standard lamp from the National Bureau of Standards according to the recommended procedure. Our calibration method was checked by measuring the sensitivity of an Eppley thermopile to within 1 % of the specified value. The vacuum-to-air ratio was obtained in a manner similar to those described previously.[8][9] The thermocouple sensitivity in vacuum under operating conditions was 6.73 μV/μW.

The thermocouple was too insensitive for use with a 0.017 mm slit; therefore, a platinum photocell was selected as a secondary detector after obtaining reproducible photoelectric yield in the region 900-1300 Å. The photocell which was placed in the ion chamber could be moved in and out of the light beam and also be calibrated readily.

There are at least two possible sources of systematic error in our thermocouple calibration: (a) assumption of spectral "blackness" of the thermocouple and (b) loss of energy to photoelectrons from the gold black deposit. Smith[10] determined a reflectance of 0.3 % for gold black in the photon energy range 7-14 eV. Furthermore, Lee and Seliger[11] have reported that deposits of gold black can be highly non-selective in the visible and infrared as shown by Harris et al,[12]

but the same may not be the case for thin films used in "fast" thermocouples. We have used the former type of thermocouple; therefore, assumption (a) appeared to be a reasonable one.

The photoelectric yield of gold black was measured in the following manner. First, the spectral intensity in the region 850-1300 Å was measured with the thermocouple. Next, a negative voltage was applied to its gold black element via its leads to measure photoemission current in the same region. Saturation current was obtained with 7 V between the gold black and the thermocouple housing. The photoelectric yield at 900 Å was about 5 %, whereas Samson[6] obtained 4.2 %. The difference may be ascribed to the samples. With no applied voltage, the emission current was opposed by a collection current which was apparently due to electrons emitted from the slit jaws, and the net current was less than 5 % of the saturation current. Therefore, no correction was applied to our thermocouple calibration.

RESULTS AND DISCUSSION

A. Absorption Coefficient

The absorption coefficients of xenon in the region 940-1025 Å and 860-940 Å are summarized in Figs. 1 and 2, respectively. The $^2P_{3/2}$ and $^2P_{1/2}$ ionization thresholds and the two Rydberg series identified by Beutler[13] are designated in these figures. Each data point represents a mean k value obtained with four or more xenon pressures. The uncertainty in the mean k value at most wavelengths was estimated to be about 10 %.

The general feature of the absorption spectrum is in good agreement with the results of Huffman et al[2] and Metzger and Cook.[5] These investigators used the helium continuum as light source and were able to resolve members of one Rydberg series up to m = 18. Recently, we have also used the helium continuum and observed members up to m = 20; but we made no attempt to improve Fig. 2.

Some of the k values obtained by several investigators are listed in Table 1 for comparison. The present results in the region 860-1022 Å are consistently lower than the values obtained by Huffman et al[2] by about 20 % but are somewhat higher than those obtained by Metzger and Cook.[5] These differences may be attributed mostly to systematic errors in pressure determination of gas flowing in a windowless cell.

B. Photoionization Yield

The photoionization yield of xenon in the region 860-1022 Å is shown in Fig. 3. Each point represents a mean of three or more yields obtained with different gas pressures. About 85 % of the mean yields lie in the range 100±5 %. Thus, within experimental error, the Rydberg lines are completely preionized as previously inferred from the width of these lines. A curve for the relative photoionization efficiency of xenon obtained by Nicholson[14] also shows that the lower members of the Rydberg series are highly preionized. The low yield values in the region 923-930 Å as shown in Fig. 3 may be ascribed to the incomplete resolution of the higher members of the Rydberg series. However, these Rydberg lines are much sharper than the broad lines at longer wavelength, and ionization efficiency may actually be less than 100 %. The large scatter of value below 880 Å was ascribed to the low intensity of our light source.

With the exception noted above, the present result shows that the photoionization yield of xenon is unity throughout the region 860-1020 Å. By combining this result with the data obtained by Samson,[6] we may conclude that the photoionization yield of xenon, krypton, argon and neon is unity at least down to 450 Å. We are in accord with Samson[6] that photoionization of the rare gases provides a very convenient method to determine absolute intensities. However, for the region 920-1022 Å where only xenon can be used, we found it

necessary to use xenon at two or three pressures because its absorption coefficient varies over a wide range.

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TABLE I. ABSORPTION COEFFICIENT (IN CM^{-1}) OF XENON AT SOME WAVELENGTHS

λ(Å)	Huffman[2]	Metzger[5]	Samson[3]	Present
1020	1500	650		1410
1002	350	350		290
995	5100	3500		4100
970	350	200		290
966	4900	3500		4100
954	400	330		300
920	2100	1800	1680	1800
860	1930	1600	1560	1700

Figure Captions

Fig. 1. Absorption coefficient of xenon in the region 940-1022 Å.

Fig. 2. Absorption coefficient of xenon in the region 860-940 Å.

Fig. 3. Absolute photoionization yield of xenon in the region 860-1022 Å.

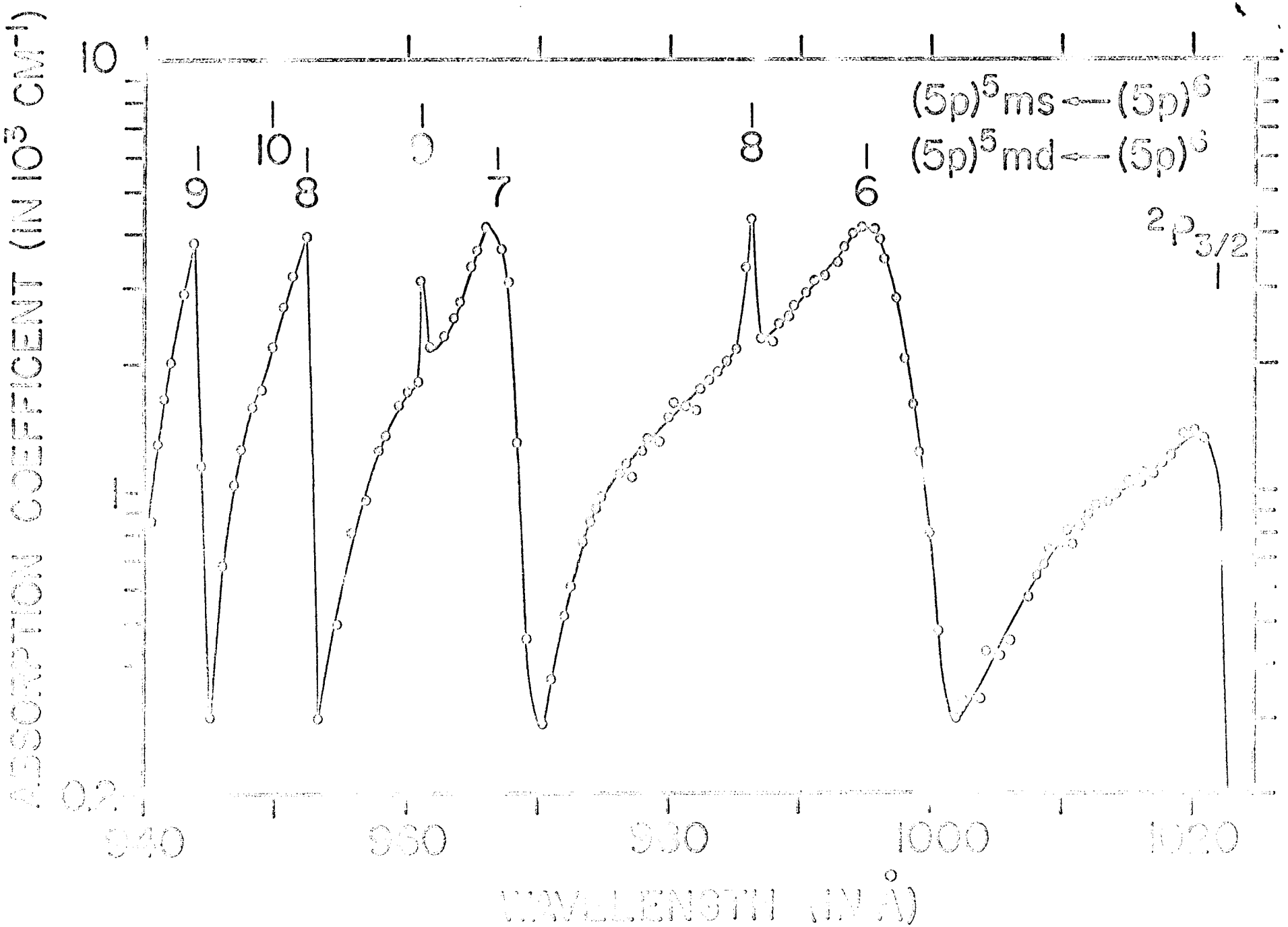
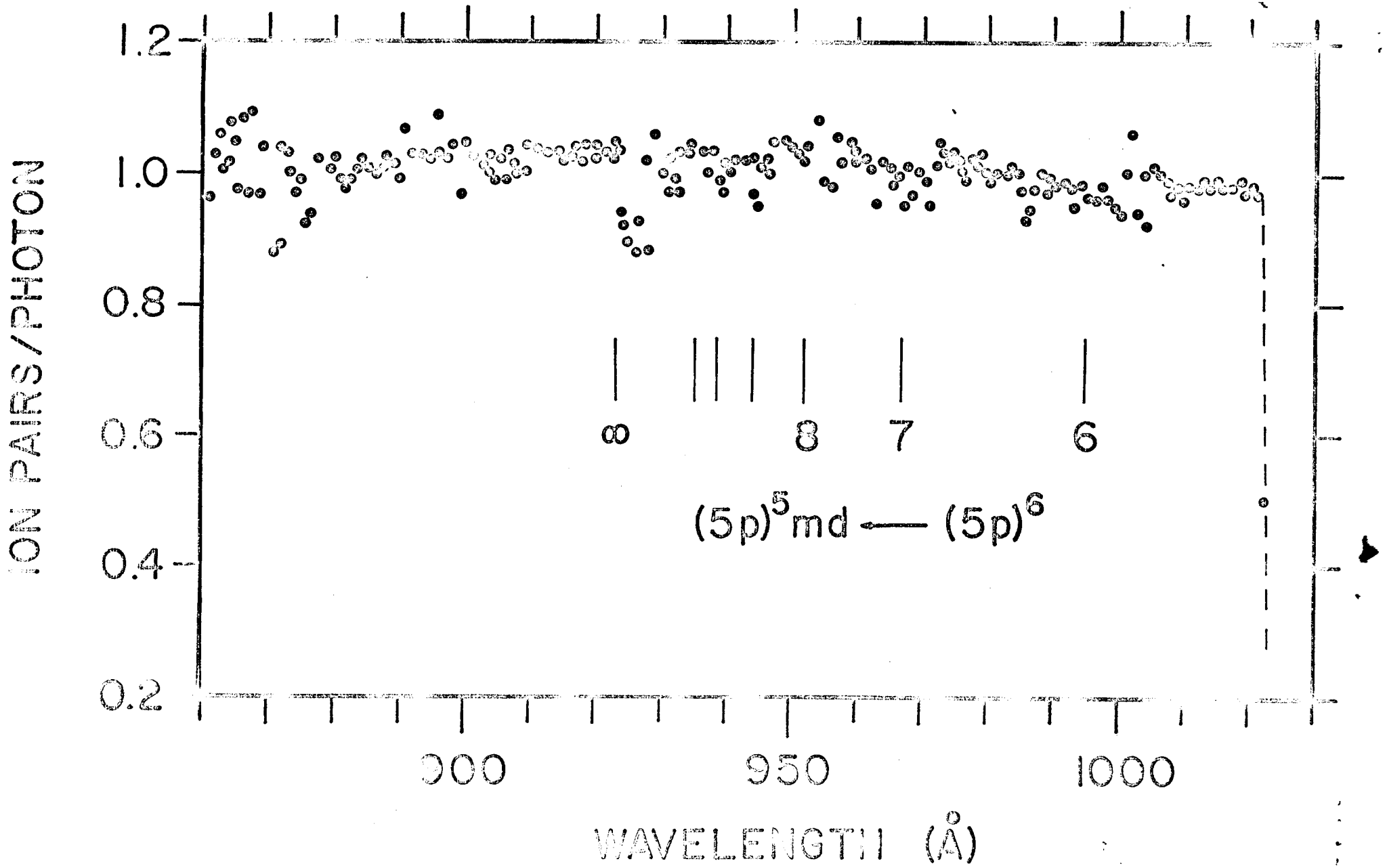

ABSORPTION COEFICENT (IN 10^3 CM^{-1})
10
0.2
9
10
8
5
7
8
6
$(5p)^5ms \leftarrow (5p)^6$
$(5p)^5md \leftarrow (5p)^6$
$^2P_{3/2}$
940
960
980
1000
1020
WAVELENGTH (IN Å)

Fig 1

ABSORPTION COEFFICIENT (M 10^3 CM^{-1})
WAVELENGTH (IN Å)
$2P_{1/2}$


ION PAIRS/PHOTON
1.2
1.0
0.8
0.6
0.4
0.2
∞
8
7
6
(5p)5md — (5p)6
900
950
1000
WAVELENGTH (Å)