

## 1. Introduction

The analysis and interpretation of terrestrial ultraviolet (UV) airglow and auroral emissions require an accurate knowledge of absorption of the emission lines by the dominant atmospheric gases. In the terrestrial thermosphere, the only significant absorbing species at wavelengths longer than 1000 Å is O<sub>2</sub>. The most prominent far ultraviolet (FUV) emission feature in the thermosphere, aside from scattered solar H I Lyman-α emission, is the OI resonance triplet (<sup>3</sup>P - <sup>3</sup>S<sub>0</sub>) near 1304 Å, for which the room-temperature measurements of Stam [1] remain the most commonly used values for the O<sub>2</sub> photoabsorption cross section [2, 3]. However, Link et al. [4] pointed out that in the 100 - 200 km altitude region where absorption by O<sub>2</sub> is significant, the atmospheric temperature increases from 200 K to about 1000 K (the precise value being dependent upon solar activity), suggesting the need for temperature-dependent measurements for the important absorbing gases.

In the present work, we have measured the photoabsorption cross section of O<sub>2</sub> at the OI triplet lines (1302.17, 1301.8, 1306.03 Å) at temperatures of 295, 373, 473, and 573 K. While this does not reach the highest temperature encountered in the thermosphere, absorption by O<sub>2</sub> is most important at the lower altitudes and temperatures [4], and the measured range should suffice for aeronomic applications.

The first quantitative measurement of photoabsorption cross sections of O<sub>2</sub> in the UV region was carried out in 1933 by Ladenberg and von Voorlis [5]. A comprehensive review on photoabsorption measurements of O<sub>2</sub> in the 100-2000 Å spectral region prior to 1958 was given by Watanabe [6]. In 1960's, quite a few results on the photoabsorption cross sections for the O<sub>2</sub> S-R continuum, at room temperature, were published [7-9]. Blake et al. [10] made a detailed study of S-R continuum with an instrumental resolution of 1 Å, and reported a single value for absorption cross section of O<sub>2</sub> at 1302, 1304 and 1306 Å. Hudson [11] published a comprehensive review article on

photoabsorption cross sections of several molecules, including O<sub>2</sub>, and emphasized the significance of instrumental resolution to the measured width of the absorbing feature. Ogawa and Ogawa [12] studied the S R continuum from 1087 to 1700 Å. They concentrated their high resolution photoabsorption cross section measurements on the O<sub>2</sub> (X <sup>3</sup>Σ<sub>g</sub><sup>-</sup>) and O<sub>2</sub> ( a <sup>1</sup>Λ<sub>g</sub>) states. Later, Starr [11] reported the O<sub>2</sub> room-temperature photabsorption cross sections at the OI 1304 Å triplet emission lines. Chan et al. [13] obtained absolute optical oscillator strengths (photoabsorption cross sections) of molecular oxygen at room temperature in the 6-30 eV energy range (from 416-2058 Å) using photoelectron energy-loss spectroscopy. Recently, Lewis [14] measured photoabsorption cross sections of O<sub>2</sub> at 1302, 1304 and 1306 Å, again at room temperature.

Temperature-dependent photoabsorption cross section studies of O<sub>2</sub>, however, are scarce. The first reported temperature-dependent study on photoabsorption cross sections of O<sub>2</sub> was carried out by Hudson et al. [15] in the FUV spectral region between 1580-1950 Å for the temperature range of 300-900 K. Later, Gibson et al. [16] reported measurements at 295 and 575 K in the spectral range from 1400 to 1740 Å. Black et al. [17] reported results at a higher temperature (930 K) and in the 1150-1300 Å spectral region. Wang et al. [18] measured photoabsorption cross sections of O<sub>2</sub> at temperatures of 295 and 575 K in the 1300-1600 Å spectral region emphasizing their theoretical fit to the experimental data. Most recently, Cheung et al. [19] measured absorption cross sections of O<sub>2</sub> at 670 K in the wavelength region 1790 to 2120 Å.

The present studies are aimed at an accurate measurement of O<sub>2</sub> photoabsorption cross sections at the astronomically-important OI 1304 Å triplet emission lines as a function of temperature. To our knowledge, these represent the first temperature-dependent measurements of the O<sub>2</sub> photoabsorption cross sections at the OI 1304 Å triplet lines.

## 2. Experimental Procedure

Photoabsorption cross section measurements of  $O_2$  were carried out by gas phase attenuation of a light source. Attenuation of light through a static gas ( $O_2$ ) target was measured at the OI-1304 Å triplet emission lines (1302, 1304 and 1306 Å) as a function of gas pressure at a given temperature. It should be pointed out that the cross section measurements were carried out by setting the spectrometer at the peak of each OI-1304 Å triplet emission line rather than by scanning the wavelength region. The absorption cross sections are then deduced from these measurements by applying the Beer-Lambert law. A spectrometer system, consisting of a medium-resolution 1.0-meter normal-incident UV spectrometer in tandem with a variable temperature absorption cell and an Ar mini-arc light source, was employed for the measurements. The measurements were carried out at a spectral resolution of 0.5 Å at full-width-at-half-maximum (FWHM). With equal entrance and exit slits the instrument response function was triangular. Fig. 1 shows our experimental arrangement. An intense, high current (40 A), low-voltage (36 V) argon mini-arc lamp, which provides UV continuum in the wavelength range from 1100 to 3600 Å, was used as a light source. The source was supplied continuously with high purity Ar gas at a pressure of about one atmosphere. High gas purity was required to maintain arc stability and reproducibility of the continuum emission. The OI-1304 Å triplet emission lines were present in the UV continuum, along with many other atomic lines of oxygen, nitrogen and carbon due to air and water impurities in the arc chamber and gas handling system. The details of the Ar mini-arc source have been described elsewhere [20]. A special Al-MgF<sub>2</sub> coated custom-made *pick-off* mirror, procured from Acton Research Corporation, was incorporated at the exit slit of spectrometer to monitor drift or fluctuation in the intensity of the OI 1304 Å triplet emission lines during the measurements. Typically, the drift in the light intensity was a few percent during the measurements and was corrected for.

The transmitted photon beam entered the single-pass temperature-variable absorption cell (Fig. 1) through a vacuum sealed  $MgF_2$  window. The cell was evacuated to a base pressure of  $10^{-6}$  torr by an oil-free turbomolecular pump and was vacuum sealed at the other end by using another  $MgF_2$  Window. These windows were recessed into the absorption cell so that only the heated absorbing gas column (47.2 cm) accounted for the high temperature absorption cross section measurements. The absorption cell, which was 50-cm in total length and 2.5-cm in diameter, was made of an oxygen free copper tube (with wall thickness  $0.125$  in (0.5 cm) to achieve excellent thermal conductivity, and was coated with nickel for chemical inertness. The absorption cell was thermally separated from the rest of the components in the system by ceramic insulators at each port and at both ends of the cell. These insulators are rated to  $725^\circ$  K as stated by the manufacturer. The heating of the cell was achieved by wrapping the absorption cell with a commercially available heating tape. The temperature of the absorption cell was monitored constantly at three locations (at both ends and at the middle) by Chromel-Alumel thermocouples. A temperature gradient (if not more than  $\pm 2^\circ$  C (usually less) was observed during the measurements.

A research grade oxygen gas was fed without further purification to the absorption cell through a leak valve. Pressure in the cell was continuously monitored by two MKS Baratron capacitance manometers with 1 and 10 torr range heads to cover the pressure range (typically, 0.1- 1.2 torr) used during the measurements. It should be pointed out that care was taken in our experimental design to avoid possible damage from the hot gas directly contacting the pressure monitoring diaphragm in the Baratron gauge. The gas was collisionally cooled to the room temperature before it reached to the Baratron gauge. This was achieved by installing the Baratron gauge on an elbow-shaped tube (with a  $45^\circ$  angle with respect to the flow) attached to the port so that the hot gas molecules could make at least one collision with the wall of the tube. For high temperature measurements, one should expect that the pressure in the absorption cell

would be somewhat higher than the pressure indicated by the manometer due to thermal transpiration effects. Due to the high-pressure range used in the measurements (0.1 - 2 Torr), the mean free path of  $O_2$  was much less than the tube diameter and intermolecular collisions were dominant. The thermal transpiration effect correction is therefore expected to be very small but, nonetheless, corrected for. An empirical model of Takatsuki and Sensui [21], which provides a simple method for calculating the thermal transpiration effect for a given gas, was employed to estimate the amount of pressure correction due to the thermal transpiration effect. Fig. 2 shows the percentage pressure correction versus the measured pressure over a range of 0.1 - 1.0 Torr at different temperatures varying from 373 to 573 K. As pointed out earlier, most of the photoabsorption cross section measurements have been carried out in this pressure range. These corrections have been incorporated in the pressures measured by the capacitance manometer during the experiment.

The transmitted intensity was measured at the end of the absorption chamber by using a photomultiplier tube (PMT 1; EMI Photoelectric, model 5542). It should be pointed out that the diameter of the light beam, coming out of the exit slit of the spectrometer, was collimated so that it did not cause any multiple scattering in the absorption cell. An aperture of 2.5 mm in diameter was placed at the entrance window of the absorption cell for this purpose. Monitoring the fluctuations in the incoming beam intensity was achieved by a pick-off mirror which served as a beam splitter) placed in the spectrometer (Fig. 1) and a photomultiplier tube (PMT 2), identical to PMT 1, installed at the other exit port to collect the signal. Both PMT's were solar blind so as not to respond to the radiation coming from the excited photofragments formed by the incident light and also had very low dark count rates (typically 2 counts/sec). Both PMT's were operated in photon-counting mode and the signals were stored first in a multi-channel analyzer and then in a computer for further analysis. Wavelength scans

were made by using a Compumotor indexer. Wavelength calibration was done by using the OI-1304 triplet emission lines before each experimental run.

The photoabsorption cross section of a molecule at a given wavelength ( $\lambda$ ) and temperature ( $T$ ) is given by Beer-Lambert's Law:

$$I(\lambda, T) = I_0(\lambda) \exp[-n \sigma(\lambda, T) L] \quad (1)$$

where  $\sigma(\lambda, T)$  is the total photoabsorption cross section of a gas (at wavelength  $\lambda$  and temperature  $T$ ),  $I(\lambda, T)$  and  $I_0(\lambda)$  are the transmitted (through the gas) and incident intensities respectively,  $n$  is the number density, and  $L$  is the path length. When there is no gas in the absorption cell,  $I_0(\lambda)$ , measured by using the *pick-off* mirror, and  $I(\lambda, T)$  should be the same. In practice, there is a difference in the two values since the  $MgF_2$  windows located at both ends of the absorption cell intercepted the photon beam and the photomultiplier tubes (PMT 1 and PMT 2) were not exactly identical in terms of their quantum efficiencies. This gave a calibration scale. The absorption cross section,  $\sigma(\lambda, T)$ , was, therefore, measured by using the ratio of  $I_0(\lambda)$  to  $I(\lambda, T)$ , as a function of pressure in the absorption cell for a selected temperature  $T$ . The gas density in the absorption cell was determined by using the ideal gas law  $P = nkT$ , where  $k$  is the Boltzman constant. A plot of the pressure against the logarithm of intensity ratio [ $I_0(\lambda) / I(\lambda, T)$ ] yielded a straight line with a positive slope whose magnitude was directly proportional to  $\sigma L$ . A least-squares fitting routine was employed in order to obtain the best fit to the data. A plot of absorbance vs gas concentration (*curve of growth*) for  $O_2$  was made for each experimental wavelength to ensure the Beer-Lambert law was obeyed for the range of pressures used in the measurements (Fig. 3). This type of testing for deviations from the Beer-Lambert law is of critical importance if meaningful cross section data are to be obtained.

### 3. Experimental Results and Discussion of Errors

Table 1 summarizes previously measured room-temperature O<sub>2</sub> photoabsorption cross sections [1, 12-14, 18] at the OI 1304 Å triplet emission lines, together with the present measurements. We digitized and interpolated Ogawa and Ogawa [12] and Chan et al. [13] data for the purpose of a direct comparison with our results. The present measurements at room temperature are, in general, found to be in good agreement with those of other investigators. A comparison of present data with those of Starr [1] and Ogawa and Ogawa [12] shows a good agreement. The present values at 1302 and 1304 Å are about 2.0 % and 3.6 % higher, respectively than those of Starr [1] whereas at 1306 Å the present value is about 0. X % smaller than Starr's data [1]. Our values are 3.2 % and 3.6 % higher than the results of Ogawa and Ogawa [12] at 1302 and 1304 Å respectively, and match within 1.1 % at 1306 Å with their result. The photoabsorption cross-section values, obtained indirectly from the energy-loss technique by Chan et al. [13], also agree well with our results at 1302 and 1304 Å (about 2.0 % lower and 2.6 % higher, respectively); however, at 1306 Å, their value of  $4.36 \times 10^{-19} \text{ cm}^2$  is about 22% higher than our result. Their value [13] is also much higher in comparison with other measurements. This is probably due to their low instrumental-resolution (6.54 Å). [Their energy-resolution is 0.048 eV (FWHM) which is equivalent to 6.54 Å (FWHM)]. Our measurement at 1302 Å agrees remarkably well with that of Lewis [14] where disagreement is only about 0.9 %. The present measurements and those of Lewis [14], at 1304 and 1306 Å, are also in good agreement within the combined error limits of 3.5% and 3.8%, respectively (the disagreement is found to be 2.3 % at 1304 Å and 2.2 % at 1306 Å).

Table 2 summarizes the results of our photoabsorption cross section measurements, together with the statistical and total errors, in the 295-573 K temperature range with a step size of 100 K. Each entry given in Table 2 is the average of several

independent experimental runs taken over a period of several weeks. The temperature dependency of the present measurements was found to be linear within the error limits, increasing by about 0% above the room-temperature values for the measured temperature range as shown in Fig. 4. Unfortunately, there are no experimental data available for high-temperature photoabsorption cross sections for  $O_2$  measured at the OI 1304 Å triplet emission lines to which the present results can be compared directly. However, in Table 2, we give the theoretical values of Lewis [14] and his estimated errors (in parenthesis) associated with their calculation. Lewis used his measured room-temperature cross sections as the basis to calculate high-temperature cross section values. His calculation, based on the same basic theoretical approach used in the Wang et al. calculation [8], employed improved fitting parameters. The discrepancy between the present high-temperature measurements and the calculation by Lewis is found to be quite substantial, especially a 573 K ( $\sim 2\%$ ), and exceeds the combined error limits. The calculated cross sections of Lewis follow a different trend; i.e., their cross sections decrease with increasing temperature when compared with the present measurements. It should be pointed out that the  $O_2$  photoabsorption cross sections as a function of temperature vary very rapidly in the 1300-1306 Å wavelength region and the variation could amount to 10 % based on Wang et al. [8] theoretical formalism. This rapid variation (from -5% to +5%) in the temperature coefficient (i.e. the percentage change in absorption cross section with respect to temperature) within 6 Å may be a major factor contributing to the large discrepancy found between the present measurements and calculated cross sections.

It is worth mentioning that as a means for checking the performance of the experimental apparatus at high temperatures, the 65 Å photoabsorption cross section of  $O_2$  was measured at 373, 473, and 573 K (prior to the cross section measurements of  $O_2$  at the OI 1304 Å triplet emission lines) and was compared with the Gibson et al. [6] measurements. They reported absorption cross section as a function of temperature, along



with a theoretical fit to observed behavior. The present cross section values at 373, 473, and 573 K not only follow the same trend, in terms of temperature dependency of the cross section, but also agree well in value within the combined error limits. Table 3 compares the present photoabsorption cross section with the Gibson et al. data.

The errors in the present measurements fall into two categories, statistical and systematic:

a) *Statistical.* The counting statistics for the incident and transmitted intensities measured by the pick-off mirror (beam splitter) and absorption cell photomultiplier detectors have introduced errors in the photoabsorption cross sections varying from 0.7 to 2.5%. Table 2 lists the assigned statistical errors to the present measurements. The statistical error associated with the cross sections is given by:

$$\% \text{ error} = \frac{100}{\langle \sigma \rangle} \left[ \frac{\sum_{i=1}^N (\sigma_i - \langle \sigma \rangle)^2}{N-1} \right]^{1/2} \quad (2)$$

where  $\langle \sigma \rangle$  is the average cross section,  $\sigma_i$  is the  $i$ th measured cross section and  $N$  is the number of measurements. It should be pointed out that the cross sections reported here are an average of several independent runs for a given temperature.

b) *Systematic.* There are several sources of systematic errors.

A systematic error of  $\pm 0.3\%$  resulting from pressure measurements is assigned to the cross sections since the MKS manometer as specified by the manufacturer would have a maximum error of  $\pm 0.3\%$  in the measured pressure range. Another type of the systematic error is due to the absorption path length. The absorption path length in the present measurements was 47.2 cm. The accuracy of this length would include the extent of the movement of the  $\text{MgF}_2$  windows in the absorption cell, the compression of the O-

rings in the flanges at both ends of the cell, misalignment of the photon beam with respect to the central axis of the cell, etc. Our estimation for the accuracy, in the worst case scenario, would be  $\pm 0.3$  cm, giving an error of  $\pm 0.64$  %. So the combined maximum systematic error in room temperature measurements is about  $\pm 1$  %. Thermal transpiration effects can be another source of systematic error at high temperature measurements. The corrections due to thermal transpiration effect was found to be only a few percent at 573 K (usually much less). Corrections due to the thermal transpiration effects have been calculated at various gas temperatures and incorporated in our pressure measurements, and absorption cross sections have been calculated accordingly. Another source of error was due to inaccuracy in the measurement of temperatures. This could be as large as  $\pm 2$  C. This would introduce an error of about  $\pm 1$  % at worst case. As a result, the combined systematic error in the present data is of the order of  $\pm 2$  % for elevated temperature measurements.

*c) Total.* The overall error (unrelated sum of all errors) represents the most probable estimate of the accuracy in the present photoabsorption cross section measurements and was obtained by adding the squares of all the errors and taking the square root of the total sum. Table 2 gives the total errors (in %) associated with the present measurements.

## CONCLUSIONS

We have measured the temperature dependency of the  $O_2$  photoabsorption cross section at the 1304 Å triplet emission lines over the range 295 - 573 K. The cross sections increase apparently linearly, by about 10%, over this temperature range. A substantial discrepancy was found between the present high-temperature measurements and the calculation by Lewis. In addition, the present values and the calculated cross

sections of Lewis follow different trends in terms of temperature dependency as discussed in the manuscript.

Our room temperature values, however, are found to be, in general, within 3% of previous measurements, except for the (interpolated) 1306 Å result of Chan et al. which lies 22% above the mean of the other measurements. This is probably due to their lower resolution (6.5 Å).

#### ACKNOWLEDGMENTS

This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, and was supported by the National Aeronautics and Space Administration, Space Physics Program Office. One of us (S. M. A.) gratefully acknowledges the receipt of the National Research Council Resident Research Associateship. The authors are thankful to Dr. B. R. Lewis for generously providing us with the unpublished results of his latest photoabsorption cross sections of  $\text{Fe}^2+$  at 302, 1304 and 306 Å. We benefited greatly from discussions with Drs. S. Trajman, J. M. Ajello and G. K. James. The authors also wish to acknowledge R. Cowe and M. Young for their invaluable assistance in the design of the experimental apparatus.

#### REFERENCES

- [1] W. L. Starr *J. Geophys. Res.* **81** (1976) 3363
- [2] R. Link, S. Chakrabarti, G. R. Gladstone, and J. C. McConnell, *J. Geophys. Res.* **93** (1988) 2693.
- [3] R. Link, R. Gladstone, S. Chakrabarti and J. C. McConnell, *J. Geophys. Res.* **93**

- (1988) 4,631.
- [4] R. Link, J. S. Evans, G. R. Gladstone, *J. Geophys. Res.* **99** (1994) 212
- [5] R. Radenburg and C.C. von Voithin, *Phys.Rev.* **43** (1933) 3-5.
- [6] K. Watanabe, *Advances in Geophysics*. Vol. 5. (Academic Press Inc., New York, 1958) p. 57
- [7] R. E. Huffman, Y. T. Chan and J. C. G. Mitchell, *Discussions Faraday Soc.* **37**, (1964) 154.
- [8] P. Metzger and G. R. Cook, *J. Quant. Spectrosc. Radiat. Transfer* **4** (1964) 17
- [9] R. Goldstein and E. N. Maslup, *J. Opt. Soc. Am.* **56** (1966) 765
- [0] A.J. Blake, J.H. Carver, and G.N. Hadjilad, *J. Quant. Spectrosc. Radiat. Transfer* **6** (1966) 45
- [1] R. J. Hudson, *Rev. Geophys. Space Phys.* **9** (1971) 305
- [2] S. Ogawa and S. Ogawa, *Can. J. of Phys.* **53** (1975) 845.
- [3] W. F. Chan, G. Cooper and C. E. Brion *Chem. Phys.* **170** (1993) 99.
- [4] B. R. Lewis, private communication (1996).
- [15] R.J.D. Hudson, V.L. Carter, and J.A. Stein, *J. Geophys. Res.* **71** (1966) 2295.
- [16] S.T. Gibson, I. F. Gies, A.J. Blake, D.G. McCoy, and P.J. Rogers, *J. Quant. Spectrosc. Radiat. Transfer* **30** (1983) 385.
- [17] J.G. Black, R.L. Sharpless, T.G. Slanger and M.R. Tabetan, *Chem. Phys.Lett.* **113**, (1985) 3
- [18] J. Wang, D. G. McCoy, A. J. Blake and S. Torop, *J. Quant. Spectrosc. Radiat. Transfer* **38** (1987) 9.
- [9] A. S. -C. Cheung, K. Yoshino, J. E. Lismond and W. J. Parkinson, private communication (1996), submitted.
- [2] J.M. Bridges and W.R. Ott, *Appl. Opt.* **16** (1977) 367
- [2] T. Takaishi and Y. Sensui, *Trans. Faraday Soc.* **59** (1963) 2053.

**Table 1.** Summary of previous measurements of  $O_2$  photoabsorption cross sections ( $\times 10^{-19} \text{ cm}^2$ ) at room temperature. Experimental resolutions are indicated in paranthesis under each reference.

<u>Wavelength (<math>\text{\AA}</math>)</u>	<u>OI Transition</u>	<u>Mean Value</u>	<u>Starr [1]</u> (0.3 $\text{\AA}$ )	<u>Ogawa and Ogawa [12]</u> (0.14 $\text{\AA}$ )	<u>Chan et al. [13]</u> (6.5 $\text{\AA}$ )	<u>Lewis [14]</u> (0.03 $\text{\AA}$ )	<u>Present</u> (0.5 $\text{\AA}$ )
1302.17	$3^1P_2 - 3^1S_0$	3.26	4.24	4.19	4.24	4.29	4.33
1304.86	$3^1P_1 - 3^1S_0$	3.82	3.73	3.73	3.97	3.78	3.87
1306.02	$3^1P_0 - 3^1S_0$	3.60 <sup>(*)</sup>	3.60	3.59	4.36	3.64	3.56

## REFERENCES

<sup>(\*)</sup> Chan et al. (1993) value ignored.

Table 2. Present measurements of photoabsorption cross sections (in units of  $10^{-19} \text{ cm}^2$ ) for  $\text{O}_2$  at  $1304\text{\AA}$  triplet emission lines as a function of temperature. Also shown are the theoretical values of Lewis [14]. Numbers in paranthesis refer to estimated errors.

Wavelength ( $\text{\AA}$ )	Temperature (K)	Present	Statistical Error (%)	Total Error (%)	Lewis [14]
1302.17	295	4.33	0.9	1.3	
	373	4.53	0.7	2.1	4.22 (5%)
	473	4.58	1.4	2.4	4.15 (5%)
	573	4.65	2.9	2.8	4.09 (5%)
1304.86	295	3.87	1.7	2.0	
	373	3.89	1.3	2.4	3.74 (5%)
	473	4.00	1.2	2.3	3.70 (5%)
	573	4.10	2.1	3.0	3.68 (5%)
1306.03	295	3.56	1.3	1.6	
	373	3.69	1.1	2.3	3.61 (5%)
	473	3.95	1.9	2.8	3.69 (5%)
	573	3.92	2.5	3.2	3.60 (5%)

**Table 3.** Comparison of the present photoabsorption cross section measurements (in units of  $10^{-18} \text{ cm}^2$ ) of  $\text{O}_2$  at 1651 Å as a function of temperature with those of Gibson et al. [16]. The numbers in parenthesis refer to total errors.

Wavelength (Å)	Temperature (K)	Present	Gibson et al. [16]
1651.0	373	<b>2.17</b> (2.2%)	2.11 (5.2%)
1651.0	473	2.34 (4.9%)	2.16 (5.2%)
1651.0	573	<b>2.36</b> (2.27.)	<b>2.27</b> (5.2%)

## Figure Captions

**Figure 1.** Schematic diagram of the experimental arrangement for the present measurements. **VS** - Ultraviolet Spectrometer; **G** - Grating; **ABS. CELL** - Ten Variable Absorption Cell; **PM** - Photomultiplier tube; **TM** - Thermomolecular Pump; **A** - Light Aperture; **W** - Recessed MgF<sub>2</sub> Window; **LS** - Ar Ni Arc Light Source; **1** - Pick-off Mirror.

**Figure 2.** Thermal transpiration correction to be applied at different temperatures to the pressures of molecular oxygen measured by MKS capacitance manometer.

**Figure 3.** A typical plot of absorption versus pressure (curve of growth). Beer-Lambert's law was obeyed for the range of pressures and spectral resolution used in the present measurements.

**Figure 4.** Photoabsorption cross sections (in units of  $10^{-19}$  cm<sup>2</sup>) of O<sub>2</sub> at different temperatures for three wavelengths - 302, 1304, 306 Å. The points are from experimental measurements. Error bars associated with the data are also shown. The straight line represents the best fit to the data at each wavelength.



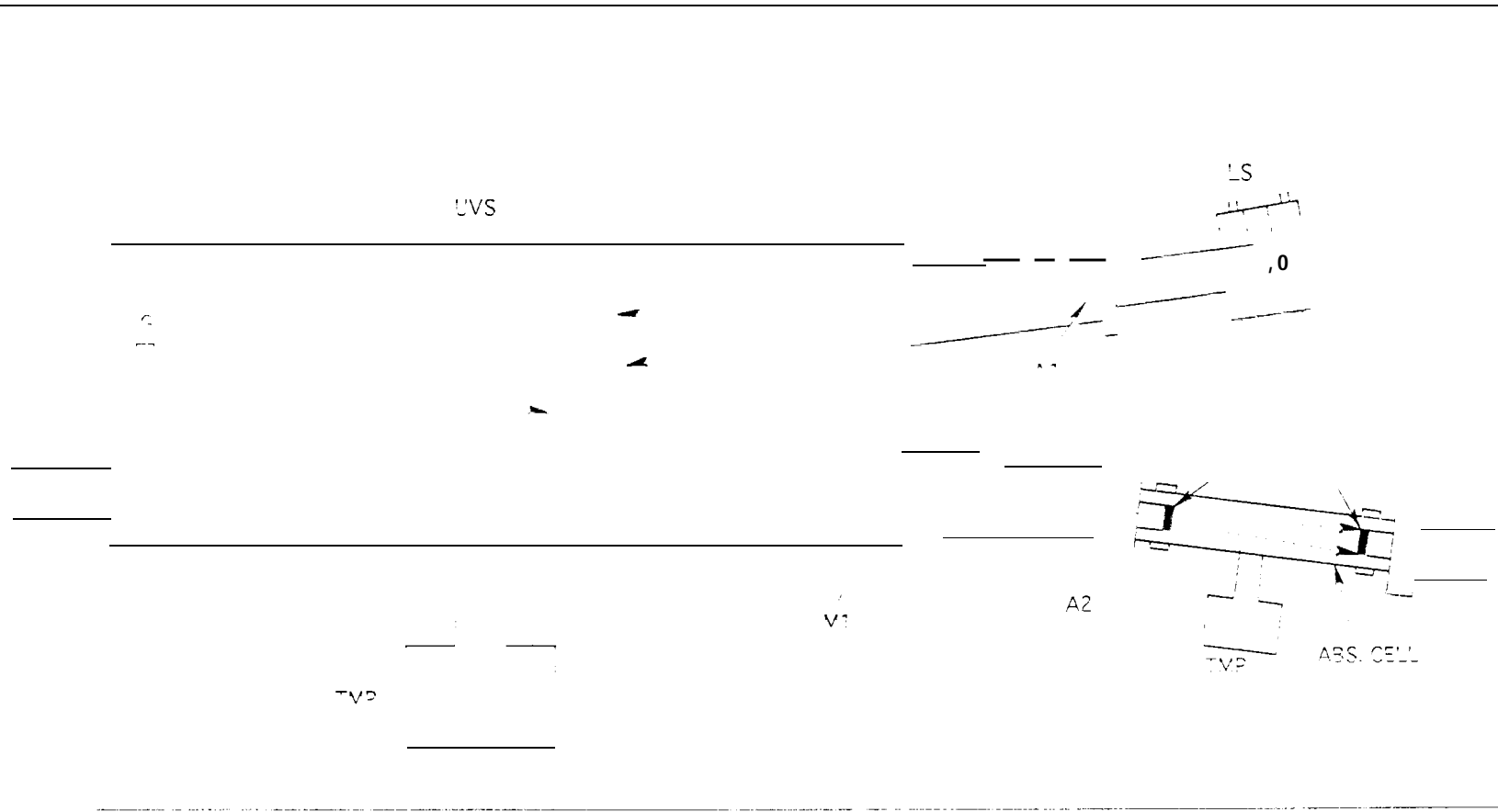


Figure 1

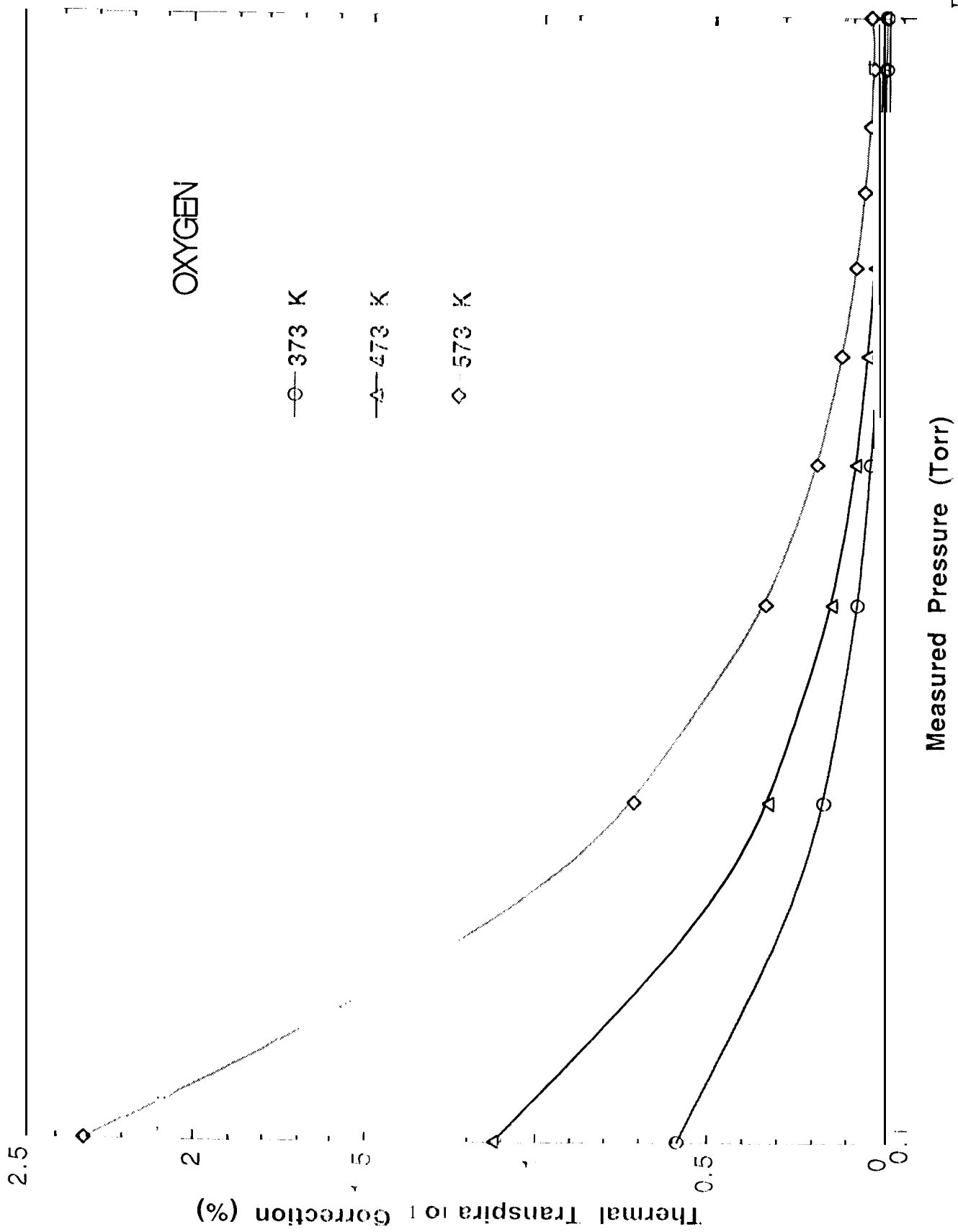


Figure 2

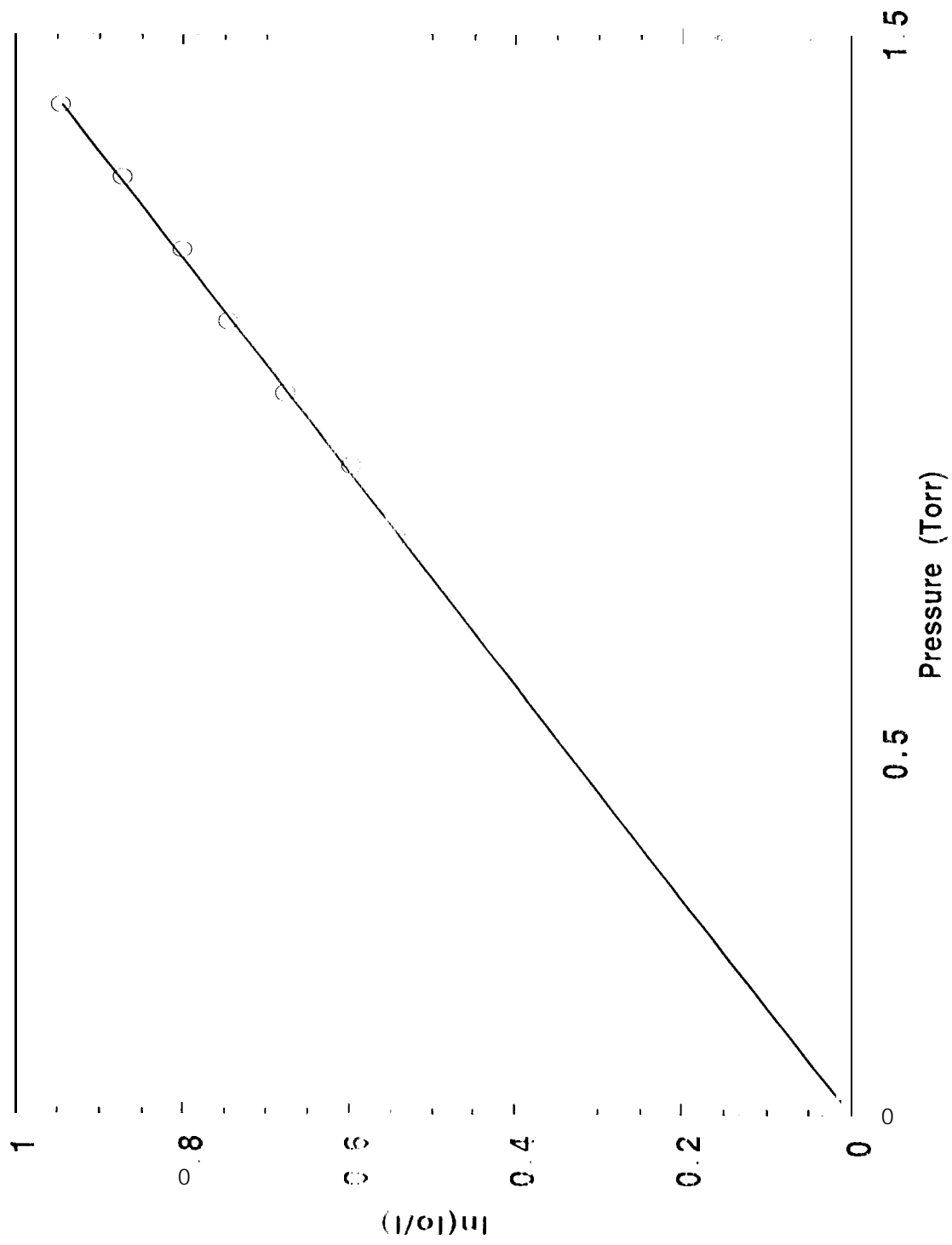


Figure 3

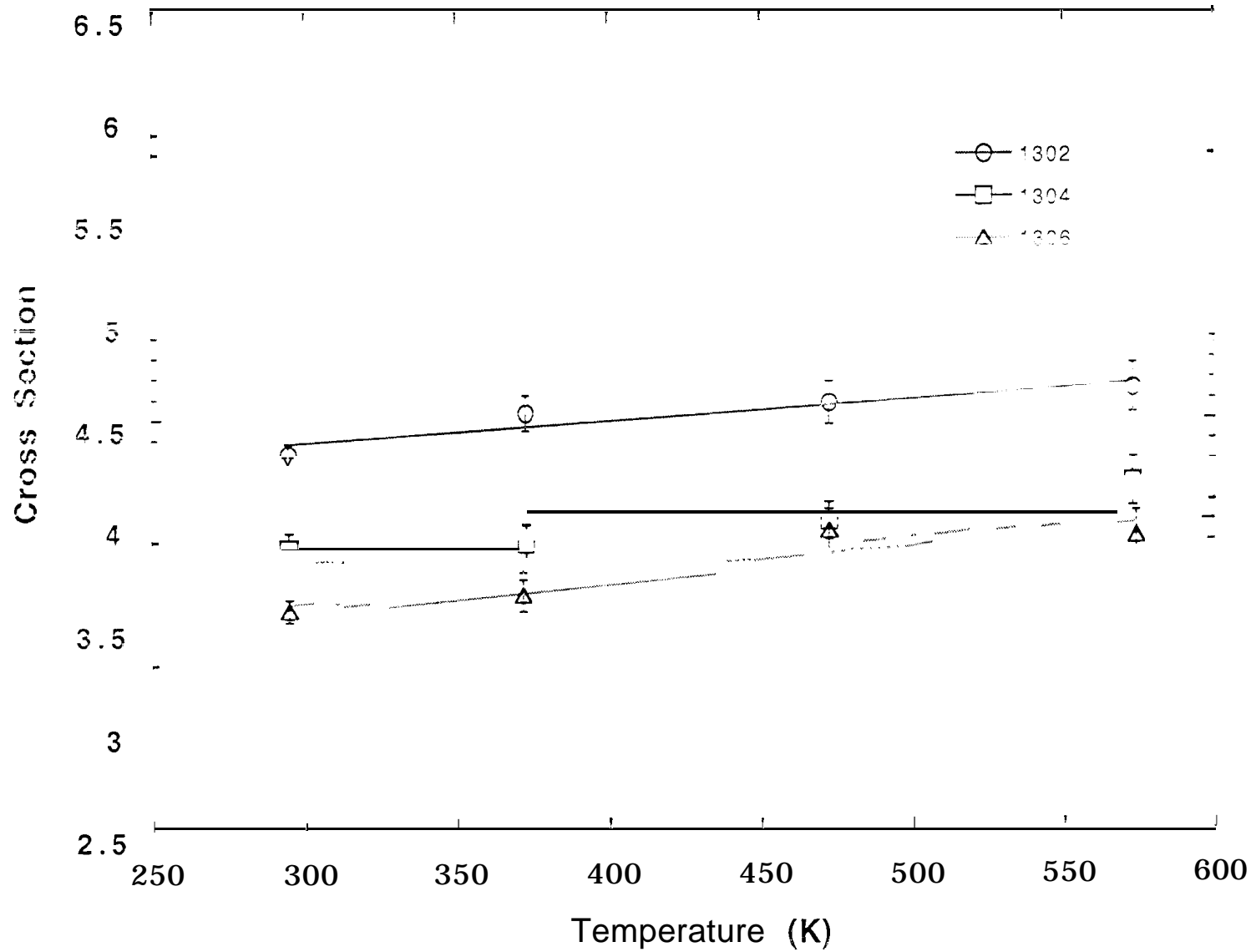


Figure 4