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Atomic structure, radiative lifetime and oscillator strength calculations in doubly ionized molybdenum (Mo III)

Pascal Quinet

Astrophysique et Spectroscopie, Université de Mons, B-7000 Mons, Belgium
IPNAS, Université de Liège, B15 Sart Tilman, B-4000 Liège, Belgium

E-mail: quinet@umons.ac.be

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Abstract

Radiative lifetimes, transition probabilities and oscillator strengths in doubly ionized molybdenum (Mo III) are reported for the first time in the present paper. This new set of atomic data has been obtained by using a semi-empirical computational technique based on the pseudo-relativistic Hartree–Fock approach in which a large amount of intravalence and core–valence electron correlations were included. In view of the lack of theoretical and experimental data available in the literature for this ion, the reliability of the results obtained in our work is discussed on the basis of comparisons with the isoelectronic ion Nb II for which an investigation was recently performed using a similar method (Nilsson *et al* 2010 *Astron. Astrophys.* **511** A16).

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1. Introduction

Molybdenum, the forty-second chemical element of the periodic table ($Z = 42$) has many applications in different scientific fields. For example, in astrophysics, the abundance of molybdenum in some metal-poor stars was found to be extremely enhanced, as high or higher than the neighboring even-Z elements ruthenium and zirconium (Peterson 2011, 2013) constraining the possible nucleosynthesis scenarios envisioned for the production of nuclei in this mass range. In fusion research, molybdenum is used as component of plasma-facing material in different devices such as Alcator C-Mod reactor (Lipschultz *et al* 2006) or the experimental advanced superconducting tokamak, EAST (Liu *et al* 2013). These applications require a large number of spectroscopic parameters characterizing the different ionization degrees of molybdenum but so far, unfortunately, for lowly charged states, radiative data were only published for the first two spectra.

More precisely, in Mo I, relative transition probabilities for some lines were measured by Dickerman and Deuel (1964) using a high current argon arc plasma mixed with molybdenum in dust form. The lifetimes of some levels of the $4d^5 5p$ and $4d^4 5s5p$ configurations were determined by zero-field level-crossing technique by Baumann *et al* (1978). These measurements were then extended to additional levels by Duquette *et al* (1981) and Kwiatkowski *et al* (1981) with selective laser excitation and time-resolved observation of the reemitted fluorescence. Oscillator strengths of 174 Mo I lines in the range 2470–5570 Å were obtained by Schnehage *et al* (1983) from wall-stabilized arc and hollow cathode measurements. The radiative lifetimes of 56 and 14 excited levels were respectively measured by Whaling (1984, 1986) using time-resolved laser fluorescence spectroscopy. Emission branching ratios for the decay of these levels were measured to determine absolute transition probabilities for a total of about 700 lines in the wavelength range 2600–9767 Å. Decay rates for 2835 Mo I lines between 2548 and 10565 Å were also published by Whaling and Brault (1988) who combined level lifetimes, excited level populations measured in an inductively coupled plasma (ICP) source, and emission branching ratios measured with the ICP source and with a hollow cathode discharge source. Later, the fine structure and transition probabilities were studied by Palmeri and Wyart

(1998) in the semi-empirical Racah–Slater framework by means of the relativistic Hartree–Fock (HFR) and fitting methods developed by Cowan (1981). Finally, radiative lifetimes for 14 odd-parity levels with the energy range between 31654.79 and 47184.52 cm^{-1} of Mo I were measured by Jiang *et al* (2013) using the time-resolved laser-induced fluorescence technique. Branching fraction measurements of these levels were performed based on the emission spectrum of a hollow cathode lamp. By combining the measured lifetimes and branching fractions, new absolute transition probabilities and oscillator strengths for 130 transitions in the wavelength range extending from 2754 to 6005 Å were derived.

In the case of Mo II, Hannaford and Lowe (1983) measured lifetimes for 15 levels using the laser induced fluorescence technique applied to a sputtered metal vapour. Later on, Sikström *et al* (2001) reported experimental radiative lifetimes for 10 levels by the same method. With the HFR approach including core-polarization effects, theoretical lifetimes for 37 levels of Mo II and the oscillator strengths of the depopulating transitions were calculated by Quinet (2002). More recently, Lundberg *et al* (2010) measured new radiative lifetimes for 14 odd levels in the energy range 48000–61000 cm^{-1} while Jiang *et al* (2012) reported experimental values for 13 odd levels between 48022 and 63497 cm^{-1}. In these two latter works, new transition probabilities were also obtained using the HFR method.

To our best knowledge, no experimental neither theoretical radiative parameters have been published so far for Mo III. In order to fill in this gap, in the present paper, we report on calculations of oscillator strengths and transition probabilities in this ion performed using the HFR approach including core-polarization effects. This work is an extension of our recent investigations of the fifth row elements Rb III (Zhang *et al* 2014), Y II, Y III (Biémont *et al* 2011), Zr II (Malcheva *et al* 2006), Nb I (Malcheva *et al* 2011), Nb II, Nb III (Nilsson *et al* 2010), Mo II (Quinet 2002, Lundberg *et al* 2010, Jiang *et al* 2012), Tc II (Palmeri *et al* 2007), Ru I (Fivet *et al* 2009), Ru II, Ru III (Palmeri *et al* 2009), Rh II (Quinet *et al* 2011, 2012), Rh III (Zhang *et al* 2013a), Pd I (Xu *et al* 2006), Pd III (Zhang *et al* 2013a), Ag II (Biémont *et al* 2005, Campos *et al* 2005), Ag III (Zhang *et al* 2013a), Sn I (Zhang *et al* 2008, 2009, 2010), Sb I (Hartman *et al* 2010), Te II and Te III (Zhang *et al* 2013b).

2. The Mo III spectrum

The most recent and complete analysis of the Mo III spectrum was published by Iglesias *et al* (1990) who classified approximately 3100 lines in the range 800–2100 Å, extending in this way their previous data of 679 lines covering the range 1100–3250 Å (Iglesias *et al* 1988). These observations were performed under similar conditions using molybdenum spectra produced in a sliding spark discharge and recorded photographically on the NIST (National Institute of Standards and Technology) 10.7 m normal-incidence vacuum spectrograph equipped with a 1200 l mm^{-1} grating blazed at 1200 Å. The wavelength uncertainty of the observed lines was estimated to be ±0.005 Å. Altogether both investigations led to the establishment of 149 energy levels in the 4d^{4}, 4d^{3}5s, 4d^{2}5s^{2}, 4d^{3}5d and 4d^{3}6s even configurations and 181 energy levels in the 4d^{3}5p and 4d^{2}5s5p odd configurations. According to Iglesias *et al* (1990), the uncertainties of the energy level values listed in their tables are generally less than ±0.10 cm^{-1} and no greater than ±0.20 cm^{-1}. Semi-empirical HFR calculations were also carried out by the same authors for each of the following rather limited interacting configuration groups : (1) 4d^{4} + 4d^{3}5s + 4d^{2}5s^{2}, (2) 4d^{3}5d + 4d^{3}6s, and (3) 4d^{3}5p + 4d^{2}5s5p. This allowed them to give LS designations to the experimental levels with average purities of 83%, 59% and 63% for the three groups of configurations mentioned above, respectively.

3. Atomic structure calculations

3.1. Pseudo-HFR model

The pseudo-HFR approach described by Cowan (1981) was used for modeling the atomic structure and calculating the radiative parameters in Mo III. The interacting configurations explicitly included in the physical model were exactly the same as those considered in our recent study related to the isoelectronic ion Nb II (Nilsson *et al* 2010), i.e. 4d^{4} + 4d^{3}5s + 4d^{3}6s + 4d^{3}5d + 4d^{2}5s^{2} + 4d^{2}5p^{2} + 4d^{2}5d^{2} + 4d^{2}6s^{2} + 4d^{2}5s6s + 4d^{2}5s5d + 4d^{2}4f5p + 4d^{2}5p5f + 4d^{2}5d6s + 4d^{2}5p6p for the even parity and 4d^{3}5p + 4d^{3}6p + 4d^{3}4f + 4d^{3}5f + 4d^{2}5s5p + 4d^{2}5s6p + 4d^{2}4f5s + 4d^{2}4f5d + 4d^{2}5s5f + 4d^{2}5p6s + 4d^{2}5p5d + 4d^{2}6s6p for the odd parity. The relativistic corrections were the mass–velocity and the one-body Darwin terms, as well as the Blume–Watson spin–orbit interaction. The latter contribution includes the part of the Breit interaction that can be reduced to a one-body operator.

3.2. Core-polarization effects

Core–valence interactions were taken into account using a polarization model potential and a correction to the dipole operator following a well-established procedure giving rise to the HFR + CPOL method (see e.g. Quinet *et al* 1999, 2002). In the present work, similarly to our previous work on Nb II ion (Nilsson *et al* 2010), the polarization model adopted for Mo III was based on a Mo^{4+} ionic core surrounded by two valence electrons. In this model, the CPOL effects were thus included using the dipole polarizability of Mo V given by Fraga *et al* (1976), i.e. $\alpha_d = 3.71\ a_0^3$ while the cut-off radius was chosen to be equal to $r_c = 1.60\ a_0$ which corresponds to the mean value $<r>$ of the outermost 4d core orbital computed with the HFR Cowan's code.

3.3. Semi-empirical optimization of radial parameters

The HFR + CPOL method was then combined with a least-squares optimization routine that minimize the discrepancies between calculated and experimental energy levels published by Iglesias *et al* (1990). In the even parity, all the 149 experimentally known levels were fitted using, as adjustable parameters, the average energies, the electrostatic interaction integrals, and the spin–orbit parameters corresponding to the $4d^4$, $4d^35s$, $4d^36s$, $4d^35d$ and $4d^25s^2$ configurations. In the case of odd-parity levels, the 159 experimental values below 143000 cm^{-1} were included in the fitting procedure using the radial parameters of the $4d^35p$ and $4d^25s5p$ configurations as variable parameters. The levels situated above 143000 cm^{-1} were excluded from the semi-empirical adjustment because it was found that many of those might be expected to overlap unknown levels belonging to higher configurations such as $4d^36p$ and $4d^34f$, these two latter configurations being predicted to start around 144000 and 149000 cm^{-1}, respectively, in our calculations. The mean deviations, ΔE, obtained when fitting the levels were found to be equal to 65 and 81 cm^{-1} for even and odd parities, respectively. It was also found that LS-coupling was quite satisfactory for characterizing most of the levels considered in the present work, the average LS purities being calculated equal to 75% for the 149 levels of even parity and to 60% for the 159 levels of the odd parity. This confirms the results obtained previously by Iglesias *et al* (1990) using very limited theoretical models. The full lists of energy levels are given as supplementary files in table S 1 and S 2 for even and odd parities, respectively (available from …).

4. Results and discussion

4.1. Radiative lifetimes

Radiative lifetimes obtained in the present work are reported in table 1 for energy levels belonging to the $4d^35d$, $4d^36s$ even-parity configurations and in table 2 for energy levels of the $4d^35p$, $4d^25s5p$ odd-parity configurations. Unfortunately, no experimental neither theoretical values in Mo III were previously published in the literature for comparison. However, an argument for assessing the reliability of the present results can be obtained from isoelectronic comparisons, particularly from results obtained recently in Nb II (Nilsson *et al* 2010), the HFR + CPOL model adopted in this work being the same as that chosen for this isoelectronic ion. More precisely, in this latter work, radiative lifetimes of 17 states belonging to the $4d^35p$ configuration in Nb II were measured using the time-resolved laser-induced fluorescence technique. The comparison of these accurate laboratory measurements with the HFR + CPOL calculations showed that the computed values were in excellent agreement (within 10%) with experimental lifetimes. An excellent agreement (within a few %) was also found when comparing the calculations with the experimental laser spectroscopy measurements obtained by Salih and Lawler (1983) for seven $4d^35p$ levels of Nb II. Consequently, a similar accuracy can also be expected for most of the radiative lifetimes obtained in the present work for Mo III.

Table 1. Calculated radiative lifetimes for levels belonging to the even-parity configurations of Mo III.

Level	$E_{exp}{}^a$ (cm^{-1})	$E_{calc}{}^b$ (cm^{-1})	Lifetime^b (ns)
$4d^3(^4F)5d\ ^5H_3$	130365.61	130354	0.78
$4d^3(^4F)5d\ ^3D_1$	130629.3	130610	0.87
$4d^3(^4F)5d\ ^5P_1$	130886.95	130859	0.87
$4d^3(^4F)5d\ ^5H_4$	130918.16	130898	0.80
$4d^3(^4F)5d\ ^5G_2$	131072.5	131061	0.85
$4d^3(^4F)5d\ ^5P_2$	131379.2	131359	0.88
$4d^3(^4F)6s\ ^5F_1$	131396.0	131435	0.90
$4d^3(^4F)5d\ ^5G_3$	131592.6	131566	0.87
$4d^3(^4F)5d\ ^5H_5$	131607.85	131582	0.82
$4d^3(^4F)6s\ ^5F_2$	131647.45	131639	0.85
$4d^3(^4F)5d\ ^5F_1$	131900.8	131901	0.91
$4d^3(^4F)5d\ ^3D_2$	131913.3	131928	0.91
$4d^3(^4F)5d\ ^5G_4$	132173.9	132145	0.89
$4d^3(^4F)5d\ ^5F_2$	132228.4	132225	0.91
$4d^3(^4F)6s\ ^5F_3$	132279.6	132252	0.86
$4d^3(^4F)5d\ ^5P_3$	132337.96	132342	0.86
$4d^3(^4F)5d\ ^5H_6$	132424.4	132396	0.84
$4d^3(^4F)5d\ ^5F_3$	132666.7	132661	0.88
$4d^3(^4F)5d\ ^5G_5$	132951.3	132920	0.89
$4d^3(^4F)5d^5F_4$	133034.7	132974	0.86
$4d^3(^4F)5d\ ^3D_3$	133151.83	133137	0.93
$4d^3(^4F)5d\ ^5H_7$	133337.7	133307	0.85
$4d^3(^4F)6s\ ^5F_4$	133446.5	133381	0.89
$4d^3(^4F)5d\ ^3P_0$	133508.9	133511	0.86
$4d^3(^4F)6s\ ^3F_2$	133563.4	133636	0.89
$4d^3(^4F)5d\ ^3H_4$	133739.17	133703	0.92
$4d^3(^4F)5d\ ^5F_5$	133782.3	133722	0.85
$4d^3(^4F)5d\ ^5G_6$	134010.4	133979	0.90
$4d^3(^4F)5d\ ^3P_1$	134185.0	134172	0.88
$4d^3(^4F)5d\ ^3G_3$	134295.5	134298	0.93
$4d^3(^4F)6s\ ^5F_5$	134371.48	134205	0.91
$4d^3(^4F)6s\ ^3F_3$	134665.06	134631	0.90
$4d^3(^4F)5d\ ^3H_5$	134799.5	134775	0.91
$4d^3(^4F)5d\ ^3F_2$	135112.06	135128	0.95
$4d^3(^4F)5d\ ^3G_4$	135261.56	135276	0.91
$4d^3(^4F)5d\ ^3P_2$	135441.05	135443	0.92
$4d^3(^4F)6s\ ^3F_4$	135857.46	135715	0.90
$4d^3(^4F)5d\ ^3F_3$	135882.9	135897	0.96
$4d^3(^4F)5d\ ^3H_6$	135979.5	135965	0.90
$4d^3(^4F)5d\ ^3G_5$	136391.56	136422	0.92
$4d^3(^4F)5d\ ^3F_4$	136574.54	136599	0.95
$4d^3(^2G)5d\ ^1F_3$	141993.9	142033	0.87
$4d^3(^2G)5d\ ^3H_4$	142696.6	142707	0.81
$4d^3(^2G)5d\ ^1H_5$	142712.95	142735	0.89
$4d^3(^2G)5d\ ^3I_6$	142822.32	142876	0.84
$4d^3(^2G)5d\ ^3H_5$	142946.75	142950	0.85
$4d^3(^4P)5d\ ^5F_5$	142950.65	142975	0.90
$4d^3(^2G)5d\ ^3G_4$	143198.04	143219	0.88
$4d^3(^2G)6s\ ^3G_3$	143396.8	143051	0.90
$4d^3(^2G)5d\ ^3I_7$	143528.65	143537	0.88
$4d^3(^2G)6s\ ^3G_4$	143568.8	143450	0.88
$4d^3(^2G)5d\ ^3G_5$	143653.5	143705	0.87
$4d^3(^2G)5d\ ^3H_6$	143829.4	143830	0.86
$4d^3(^2G)6s\ ^3G_5$	144121.65	143907	0.91
$4d^3(^2G)6s\ ^1G_4$	144656.26	144495	0.91
$4d^3(^2G)5d\ ^1I_6$	144783.96	144741	0.87
$4d^3(^4P)5d\ ^3F_4$	145096.74	145098	0.91

Table 1. (Continued.)

Level	E_{exp}[a] (cm^{-1})	E_{calc}[b] (cm^{-1})	Lifetime[b] (ns)
4d^3(^{2}H)5d ^{1}H$_5$	145904.28	145927	0.89
4d^3(^{2}H)5d ^{3}I$_7$	146257.14	146257	0.87
4d^3(^{2}H)5d ^{3}I$_6$	146277.52	146260	0.86
4d^3(^{2}H)5d ^{3}I$_5$	146342.74	146317	0.86
4d^3(^{2}D)5d ^{3}G$_4$	147431.23	147379	0.88
4d^3(^{2}H)6s ^{3}H$_4$	147703.6	147730	0.90
4d^3(^{2}H)6s ^{3}H$_5$	147752.1	147814	0.90
4d^3(^{2}H)5d ^{3}K$_6$	147758.2	147753	0.83
4d^3(^{2}H)5d ^{3}K$_7$	147963.3	147947	0.87
4d^3(^{2}H)6s ^{3}H$_6$	147984.1	148082	0.90
4d^3(^{2}H)5d ^{1}K$_7$	148595.3	148584	0.92
4d^3(^{2}H)6s ^{1}H$_5$	148816.1	148818	0.89
4d^3(^{2}H)5d ^{3}H$_5$	151580.2	151588	0.84
4d^3(^{2}F)6s ^{3}F$_4$	156378.82	156256	0.88
4d^3(^{2}F)6s ^{3}F$_3$	156587.8	156362	0.87
4d^3(^{2}F)6s ^{1}F$_3$	157546.6	157385	0.92

[a] From Iglesias *et al* (1990).

[b] This work.

4.2. Transition rates

Oscillator strengths and transition probabilities were computed for Mo III spectral lines using our HFR + CPOL model. Due to space limitations, only a small sample of results corresponding to the strongest gf-values, i.e. log $gf > 0$, is presented in table 3. This corresponds to 172 lines in the ultraviolet region from 1081 to 2634 Å. The full set of data containing transition rates for 7555 lines in the wavelength range from extreme ultraviolet to mid-infrared (724 Å–9.32 μm) is reported in table S 3 given as supplementary file (available from …). Note that, in those two tables, the wavelengths (given in vacuum below 2000 Å and in air above that limit) were deduced from experimental energy level values published by Iglesias *et al* (1990). Laboratory measurements of accurate radiative lifetimes and branching fractions in Mo III would now be welcome to definitely assess the accuracy of the new theoretical results obtained in the present work. However, in view of the very good agreement observed when comparing available experimental data with our previous calculations performed in many other similar ions using the same HFR + CPOL approach (see reference quoted in the last paragraph of introduction), one can expect uncertainties of the order of 10–20% for the computed transition rates listed in the present paper, at least for the most intense lines.

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Table 2. Calculated radiative lifetimes for levels belonging to the odd-parity configurations of Mo III.

Level	E_{exp}[a] (cm^{-1})	E_{calc}[b] (cm^{-1})	Lifetime[b] (ns)
4d^3(^{4}F)5p ^{5}G$_2$	73853.18	73867	3.17
4d^3(^{4}F)5p ^{5}G$_3$	74724.72	74731	3.07
4d^3(^{4}F)5p ^{5}G$_4$	75816.51	75811	2.95
4d^3(^{4}F)5p ^{3}D$_1$	75972.36	76006	1.65
4d^3(^{4}F)5p ^{3}D$_2$	76836.82	76871	1.51
4d^3(^{4}F)5p ^{5}G$_5$	77113.28	77087	2.82
4d^3(^{4}F)5p ^{5}F$_3$	78158.42	78162	1.26
4d^3(^{4}F)5p ^{5}D$_0$	78568.37	78545	0.73
4d^3(^{4}F)5p ^{5}F$_1$	78677.94	78618	1.09
4d^3(^{4}F)5p ^{5}G$_6$	78689.51	78622	2.70
4d^3(^{4}F)5p ^{5}D$_1$	78947.76	78952	0.92
4d^3(^{4}F)5p ^{5}F$_2$	79013.98	78952	1.15
4d^3(^{4}F)5p ^{5}D$_2$	79467.93	79503	0.94
4d^3(^{4}F)5p ^{5}F$_4$	79497.10	79462	1.16
4d^3(^{4}F)5p ^{5}D$_3$	79508.33	79454	1.07
4d^3(^{4}F)5p ^{5}D$_4$	80095.61	80061	0.89
4d^3(^{4}F)5p ^{5}F$_5$	80343.19	80287	1.50
4d^3(^{4}F)5p ^{3}D$_3$	80354.49	80423	1.12
4d^3(^{4}F)5p ^{3}G$_3$	81040.69	81047	1.49
4d^3(^{4}F)5p ^{3}G$_4$	82009.90	82017	1.45
4d^3(^{4}F)5p ^{3}F$_2$	82540.14	82570	1.83
4d^3(^{4}F)5p ^{3}G$_5$	83147.76	83164	1.43
4d^3(^{4}F)5p ^{3}F$_3$	83584.53	83610	1.69
4d^3(^{2}P)5p ^{1}S$_0$	84216.41	84307	3.92
4d^3(^{4}F)5p ^{3}F$_4$	84544.52	84542	1.57
4d^3(^{4}P)5p ^{5}P$_1$	85308.94	85354	1.42
4d^3(^{4}P)5p ^{3}P$_2$	85329.99	85406	2.44
4d^3(^{4}P)5p ^{5}D$_1$	85683.11	85566	1.06
4d^3(^{2}G)5p ^{3}H$_4$	85896.20	86029	2.29
4d^3(^{4}P)5p ^{5}D$_0$	86322.66	86395	3.18
4d^3(^{4}P)5p ^{5}P$_2$	86426.81	86318	0.83
4d^3(^{2}G)5p ^{3}H$_5$	86892.62	86989	2.04
4d^3(^{4}P)5p ^{5}P$_3$	87391.79	87252	0.80
4d^3(^{4}P)5p ^{5}D$_2$	87473.30	87521	2.05
4d^3(^{4}P)5p ^{5}D$_3$	87810.66	87822	1.88
4d^3(^{4}P)5p ^{3}P$_1$	87831.20	87945	1.91
4d^3(^{2}G)5p ^{3}H$_6$	88441.64	88523	2.26
4d^3(^{2}G)5p ^{1}F$_3$	88499.21	88597	1.00
4d^3(^{2}P)5p ^{1}D$_2$	88592.07	88603	1.70
4d^3(^{2}P)5p ^{3}P$_0$	88669.74	88638	0.99
4d^3(^{4}P)5p ^{5}D$_4$	89100.17	89160	2.31
4d^3(^{2}P)5p ^{3}P$_1$	89139.81	89049	1.09
4d^3(^{2}G)5p ^{3}F$_4$	89503.85	89523	1.01
4d^3(^{2}G)5p ^{1}H$_5$	89689.91	89663	2.08
4d^3(^{4}P)5p ^{3}P$_0$	89775.81	89671	1.94
4d^3(^{2}G)5p ^{3}G$_4$	90255.05	90292	0.80
4d^3(^{2}P)5p ^{3}D$_1$	90301.83	90045	1.25
4d^3(^{2}G)5p ^{3}F$_2$	90586.00	90688	1.26
4d^3(^{2}G)5p ^{3}G$_3$	90588.46	90697	0.95
4d^3(^{2}P)5p ^{3}P$_2$	90982.60	90984	1.10
4d^3(^{2}G)5p ^{3}G$_5$	91006.90	90990	0.91
4d^3(^{2}G)5p ^{3}F$_3$	91050.30	91159	1.20
4d^3(^{2}H)5p ^{3}H$_4$	91387.50	91389	0.90
4d^3(^{2}P)5p ^{3}D$_2$	91674.55	91562	1.20
4d^3(^{4}P)5p ^{5}S$_2$	92099.55	92222	1.78
4d^3(^{2}H)5p ^{3}H$_5$	92254.52	92162	1.02
4d^3(^{2}H)5p ^{3}H$_6$	92728.95	92619	1.00

Table 2. (Continued.)

Level	E$_{exp}$^{a} (cm^{-1})	E$_{calc}$^{b} (cm^{-1})	Lifetime^b (ns)
4d^3(^{2}P)5p ^{3}D$_3$	92758.61	92667	0.98
4d^3(^{2}H)5p ^{3}I$_5$	92884.18	92841	1.76
4d^3(^{2}G)5p ^{1}G$_4$	93102.01	93198	1.05
4d^3(^{2}P)5p ^{3}S$_1$	93222.37	92904	0.94
4d^3(^{2}H)5p ^{3}I$_6$	93306.10	93224	2.20
4d^3(^{2}D)5p ^{3}F$_2$	93642.52	93696	0.82
4d^3(^{2}D)5p ^{1}P$_1$	93709.46	93668	0.81
4d^3(^{2}H)5p ^{1}G$_4$	94098.26	94258	1.35
4d^3(^{2}D)5p ^{3}F$_3$	94117.58	94132	0.80
4d^3(^{2}D)5p ^{3}D$_1$	94292.66	94396	0.88
4d^3(^{4}P)5p ^{3}D$_2$	94387.70	94479	0.93
4d^3(^{2}H)5p ^{3}I$_7$	94424.07	94335	2.47
4d^3(^{4}P)5p ^{3}D$_3$	94676.73	94698	0.95
4d^3(^{2}D)5p ^{3}F$_4$	94955.85	94999	0.88
4d^3(^{4}P)5p ^{3}D$_1$	95016.32	94975	0.88
4d^3(^{2}D)5p^{3}D$_2$	95551.80	95534	0.84
4d^3(^{2}D)5p ^{3}D$_3$	95856.45	95884	1.09
4d^3(^{2}H)5p ^{3}G$_5$	96285.38	96170	0.68
4d^3(^{2}D)5p ^{3}P$_2$	96589.89	96592	0.90
4d^3(^{2}D)5p ^{3}P$_1$	96736.45	96826	0.94
4d^3(^{2}H)5p ^{3}G$_3$	96838.34	96850	0.79
4d^3(^{2}H)5p ^{1}I$_6$	96907.92	96762	1.14
4d^3(^{2}D)5p ^{3}P$_0$	97135.60	97189	0.92
4d^3(^{2}H)5p ^{3}G$_4$	97184.77	97192	0.83
4d^3(^{2}H)5p ^{1}H$_5$	97709.08	97709	0.60
4d^3(^{2}D)5p ^{1}F$_3$	98562.38	98589	0.68
4d^3(^{2}P)5p ^{1}P$_1$	99313.02	99336	0.94
4d^3(^{2}F)5p ^{3}F$_2$	99952.26	99960	0.74
4d^3(^{4}P)5p ^{3}S$_1$	100184.65	100178	1.06
4d^3(^{2}D)5p ^{1}D$_2$	100219.97	100213	1.24
4d^3(^{2}F)5p ^{3}F$_3$	100397.67	100389	1.28
4d^3(^{2}F)5p ^{3}F$_4$	100858.67	100842	1.30
4d^3(^{2}F)5p ^{3}G$_3$	102557.67	102504	1.60
4d^3(^{2}F)5p ^{3}G$_4$	103276.74	103211	1.51
4d^3(^{2}F)5p ^{1}D$_2$	103303.98	103501	1.14
4d^3(^{2}F)5p ^{3}G$_5$	103621.4	103536	1.54
4d^3(^{2}F)5p ^{3}D$_3$	103667.40	103744	1.10
4d^3(^{2}F)5p ^{3}D$_2$	104511.12	104626	1.07
4d^3(^{2}F)5p ^{3}D$_1$	105041.26	105175	1.05
4d^3(^{2}F)5p ^{1}G$_4$	106511.94	106530	1.15
4d^3(^{2}F)5p ^{1}F$_3$	106803.63	106726	0.90
4d^3(^{2}D)5p ^{3}D$_1$	114014.74	114042	0.87
4d^3(^{2}D)5p ^{3}D$_2$	114083.06	114080	0.90
4d^3(^{2}D)5p ^{3}D$_3$	114591.26	114538	0.90
4d^3(^{2}D)5p ^{3}F$_2$	115794.02	115799	1.28
4d^3(^{2}D)5p ^{3}F$_3$	116497.95	116385	1.25
4d^3(^{2}D)5p ^{3}F$_4$	117287.80	117164	1.38
4d^3(^{2}D)5p ^{1}D$_2$	117336.75	117392	0.95
4d^3(^{2}D)5p ^{3}P$_2$	118451.23	118432	1.21
4d^2(^{3}F)5s5p ^{5}G$_2$	119170.3	119106	7.73
4d^3(^{2}D)5p ^{3}P$_1$	119206.22	119230	1.22
4d^3(^{2}D)5p ^{1}F$_3$	119479.53	119402	1.01
4d^3(^{2}D)5p ^{3}P$_0$	119559.55	119602	1.22
4d^2(^{3}F)5s5p ^{5}G$_3$	120064.7	120027	7.27
4d^2(^{3}F)5s5p ^{5}G$_4$	121118.4	121255	6.94
4d^2(^{3}F)5s5p ^{5}F$_1$	121723.8	121620	0.90
4d^2(^{3}F)5s5p ^{5}F$_2$	122229.55	122149	0.90
4d^2(^{3}F)5s5p ^{5}G$_5$	122817.2	122755	6.82

Table 2. (Continued.)

Level	E$_{exp}$^{a} (cm^{-1})	E$_{calc}$^{b} (cm^{-1})	Lifetime^b (ns)
4d^2(^{3}F)5s5p ^{5}F$_3$	123007.56	122959	0.90
4d^2(^{3}F)5s5p ^{5}F$_4$	124005.8	123990	0.90
4d^3(^{2}D)5p ^{1}P$_1$	124221.46	124295	0.91
4d^2(^{3}F)5s5p ^{5}G$_6$	124605.7	124526	8.13
4d^2(^{3}F)5s5p ^{5}D$_0$	124982.8	125009	0.59
4d^2(^{3}F)5s5p ^{5}D$_1$	125107.68	125145	0.61
4d^2(^{3}F)5s5p ^{5}F$_5$	125143.67	125160	0.90
4d^2(^{3}F)5s5p ^{5}D$_2$	125359.42	125422	0.63
4d^2(^{3}F)5s5p ^{5}D$_3$	125786.8	125890	0.66
4d^2(^{3}F)5s5p^{5}D$_4$	126533.5	126667	0.64
4d^2(^{3}F)5s5p ^{3}F$_2$	127336.03	127442	1.79
4d^2(^{3}F)5s5p ^{3}F$_3$	127795.88	127844	1.52
4d^2(^{3}F)5s5p ^{3}D$_2$	129055.2	129157	1.05
4d^2(^{3}F)5s5p ^{3}D$_1$	129065.63	129235	1.11
4d^2(^{3}F)5s5p ^{3}F$_4$	129383.82	129439	1.54
4d^2(^{3}F)5s5p ^{3}D$_3$	129964.64	130072	1.10
4d^2(^{3}P)5s5p ^{5}S$_2$	130073.7	130105	0.61
4d^2(^{3}F)5s5p ^{3}G$_3$	130453.9	130373	1.22
4d^2(^{3}F)5s5p ^{3}G$_4$	131570.80	131567	1.14
4d^2(^{3}P)5s5p ^{5}D$_1$	131782.5	131744	2.35
4d^2(^{3}P)5s5p ^{3}S$_1$	132164.6	132104	0.86
4d^2(^{3}P)5s5p ^{5}D$_2$	132439.5	132402	2.08
4d^2(^{3}F)5s5p ^{3}G$_5$	132792.84	132832	1.13
4d^2(^{3}P)5s5p ^{5}D$_3$	133255.4	133143	1.48
4d^2(^{3}F)5s5p ^{1}D$_2$	133422.2	133372	1.20
4d^2(^{3}F)5s5p ^{1}F$_3$	133818.4	133760	1.44
4d^2(^{3}P)5s5p ^{5}D$_4$	134502.10	134420	1.61
4d^2(^{3}P)5s5p ^{5}P$_2$	134695.4	134824	0.89
4d^2(^{3}P)5s5p ^{5}P$_1$	134844.9	134869	1.15
4d^2(^{1}D)5s5p ^{3}F$_2$	135721.81	135589	0.68
4d^2(^{1}D)5s5p ^{3}P$_2$	135963.7	135956	1.14
4d^2(^{3}P)5s5p ^{5}P$_3$	136281.5	136182	0.68
4d^2(^{1}D)5s5p ^{3}P$_1$	136300.2	136373	0.97
4d^2(^{1}D)5s5p ^{3}F$_3$	136402.5	136321	1.53
4d^2(^{3}F)5s5p ^{1}G$_4$	136575.7	136451	0.78
4d^2(^{1}G)5s5p ^{3}G$_4$	137605.1	137524	0.70
4d^2(^{1}G)5s5p ^{3}G$_3$	137796.5	137777	0.72
4d^2(^{1}G)5s5p ^{3}G$_5$	138344.9	138162	0.64
4d^2(^{1}D)5s5p ^{3}F$_4$	138688.1	138672	0.70
4d^2(^{1}D)5s5p ^{3}D$_3$	139243.0	139257	1.35
4d^2(^{1}G)5s5p ^{3}H$_4$	141176.2	141222	1.68
4d^2(^{1}G)5s5p ^{3}H$_5$	141967.4	142045	1.86
4d^2(^{3}P)5s5p ^{3}D$_1$	142845.9	142974	0.93
4d^2(^{1}G)5s5p ^{3}H$_6$	142940.8	143056	1.90

[a] From Iglesias *et al* (1990).
[b] This work.

Table 3. Oscillator strengths and transition probabilities for strong Mo III lines (log $gf > 0.0$).

Wavelength[a]	Lower level[b]			Upper level[b]				gA[c]
(Å)	E (cm^{-1})	Parity	J	E (cm^{-1})	Parity	J	log gf[c]	(s^{-1})
1081.558	50482	(e)	6.0	142941	(o)	6.0	0.05	6.44E+09
1092.163	34225	(e)	4.0	125787	(o)	3.0	0.08	6.70E+09
1094.044	35129	(e)	5.0	126534	(o)	4.0	0.24	9.77E+09
1110.936	35129	(e)	5.0	125144	(o)	5.0	0.32	1.13E+10
1113.829	34225	(e)	4.0	124006	(o)	4.0	0.17	7.97E+09
1115.077	46602	(e)	4.0	136282	(o)	3.0	0.09	6.63E+09
1118.290	46300	(e)	3.0	135722	(o)	2.0	0.04	5.86E+09
1133.082	49542	(e)	4.0	137797	(o)	3.0	0.01	5.30E+09
1138.132	50482	(e)	6.0	138345	(o)	5.0	0.39	1.27E+10
1165.084	46962	(e)	5.0	132793	(o)	5.0	0.05	5.53E+09
1266.159	13276	(e)	5.0	92255	(o)	5.0	0.15	5.88E+09
1267.142	13811	(e)	6.0	92729	(o)	6.0	0.28	8.00E+09
1278.095	16714	(e)	5.0	94956	(o)	4.0	0.12	5.40E+09
1278.394	1872	(e)	4.0	80096	(o)	4.0	0.19	6.31E+09
1282.865	20612	(e)	4.0	98562	(o)	3.0	0.17	6.02E+09
1286.413	19974	(e)	6.0	97709	(o)	5.0	0.43	1.08E+10
1295.409	13811	(e)	6.0	91007	(o)	5.0	0.18	6.08E+09
1299.046	13276	(e)	5.0	90255	(o)	4.0	0.05	4.47E+09
1299.809	19974	(e)	6.0	96908	(o)	6.0	0.25	6.97E+09
1310.413	19974	(e)	6.0	96285	(o)	5.0	0.23	6.64E+09
1370.884	27007	(e)	3.0	99952	(o)	2.0	0.11	4.54E+09
1421.506	36164	(e)	4.0	106512	(o)	4.0	0.11	4.23E+09
1685.611	92255	(o)	5.0	151580	(e)	5.0	0.20	3.76E+09
1739.112	85896	(o)	4.0	143397	(e)	3.0	0.01	2.22E+09
1756.767	74725	(o)	3.0	131647	(e)	2.0	0.03	2.32E+09
1758.462	74725	(o)	3.0	131593	(e)	3.0	0.09	2.62E+09
1760.551	85896	(o)	4.0	142697	(e)	4.0	0.39	5.29E+09
1769.522	73853	(o)	2.0	130366	(e)	3.0	0.58	8.17E+09
1771.068	75817	(o)	4.0	132280	(e)	3.0	0.17	3.13E+09
1774.390	75817	(o)	4.0	132174	(e)	4.0	0.17	3.11E+09
1779.567	74725	(o)	3.0	130918	(e)	4.0	0.67	9.78E+09
1779.672	100398	(o)	3.0	156588	(e)	3.0	0.22	3.50E+09
1783.990	86893	(o)	5.0	142947	(e)	5.0	0.22	3.50E+09
1787.959	86893	(o)	5.0	142822	(e)	6.0	0.73	1.12E+10
1788.224	77113	(o)	5.0	133035	(e)	4.0	0.31	4.25E+09
1790.894	77113	(o)	5.0	132951	(e)	5.0	0.22	3.48E+09
1792.393	75817	(o)	4.0	131608	(e)	5.0	0.75	1.15E+10
1795.977	88442	(o)	6.0	144122	(e)	5.0	0.12	2.70E+09
1801.148	100859	(o)	4.0	156379	(e)	4.0	0.36	4.71E+09
1801.682	92255	(o)	5.0	147758	(e)	6.0	0.34	4.50E+09
1801.880	92255	(o)	5.0	147752	(e)	5.0	0.24	3.55E+09
1803.661	76837	(o)	2.0	132280	(e)	3.0	0.03	2.19E+09
1805.453	88442	(o)	6.0	143829	(e)	6.0	0.49	6.31E+09
1807.635	78690	(o)	6.0	134010	(e)	6.0	0.44	5.65E+09
1807.955	77113	(o)	5.0	132424	(e)	6.0	0.83	1.38E+10
1809.786	92729	(o)	6.0	147984	(e)	6.0	0.32	4.29E+09
1810.468	92729	(o)	6.0	147963	(e)	7.0	0.07	2.40E+09
1815.078	89690	(o)	5.0	144784	(e)	6.0	0.58	7.75E+09
1815.120	78690	(o)	6.0	133782	(e)	5.0	0.33	4.33E+09
1815.310	88442	(o)	6.0	143529	(e)	7.0	0.81	1.29E+10
1822.281	78158	(o)	3.0	133035	(e)	4.0	0.24	3.50E+09
1822.356	92884	(o)	5.0	147758	(e)	6.0	0.67	9.34E+09
1824.171	92884	(o)	5.0	147704	(e)	4.0	0.09	2.47E+09
1827.558	94098	(o)	4.0	148816	(e)	5.0	0.08	2.39E+09
1829.585	93306	(o)	6.0	147963	(e)	7.0	0.80	1.26E+10
1829.887	78690	(o)	6.0	133338	(e)	7.0	0.95	1.77E+10
1834.584	78158	(o)	3.0	132667	(e)	3.0	0.01	2.05E+09
1836.682	93306	(o)	6.0	147752	(e)	5.0	0.24	3.41E+09
1838.390	97185	(o)	4.0	151580	(e)	5.0	0.03	2.09E+09

Table 3. (Continued.)

Wavelength[a]	Lower level[b]			Upper level[b]				gA[c]
(Å)	E (cm^{-1})	Parity	J	E (cm^{-1})	Parity	J	log gf[c]	(s^{-1})
1842.123	79497	(o)	4.0	133782	(e)	5.0	0.40	4.90E+09
1845.715	78158	(o)	3.0	132338	(e)	3.0	0.05	2.19E+09
1847.081	89690	(o)	5.0	143829	(e)	6.0	0.20	3.11E+09
1850.882	80343	(o)	5.0	134371	(e)	5.0	0.54	6.76E+09
1851.063	92255	(o)	5.0	146278	(e)	6.0	0.33	4.16E+09
1853.589	79497	(o)	4.0	133447	(e)	4.0	0.31	3.92E+09
1856.994	89100	(o)	4.0	142951	(e)	5.0	0.66	8.87E+09
1857.128	89100	(o)	4.0	142947	(e)	5.0	0.11	2.50E+09
1859.529	91007	(o)	5.0	144784	(e)	6.0	0.32	4.02E+09
1863.335	80343	(o)	5.0	134010	(e)	6.0	0.60	7.69E+09
1867.064	94424	(o)	7.0	147984	(e)	6.0	0.40	4.78E+09
1868.175	92729	(o)	6.0	146257	(e)	7.0	0.49	5.93E+09
1872.893	92884	(o)	5.0	146278	(e)	6.0	0.27	3.58E+09
1874.383	80096	(o)	4.0	133447	(e)	4.0	0.02	1.99E+09
1875.692	94118	(o)	3.0	147431	(e)	4.0	0.21	3.09E+09
1875.783	103277	(o)	4.0	156588	(e)	3.0	0.05	2.10E+09
1877.765	81041	(o)	3.0	134296	(e)	3.0	0.10	2.36E+09
1877.876	82010	(o)	4.0	135262	(e)	4.0	0.19	2.93E+09
1878.153	83148	(o)	5.0	136392	(e)	5.0	0.30	3.74E+09
1878.261	93102	(o)	4.0	146343	(e)	5.0	0.26	3.42E+09
1881.171	79508	(o)	3.0	132667	(e)	3.0	0.13	2.55E+09
1885.973	89690	(o)	5.0	142713	(e)	5.0	0.34	4.11E+09
1886.077	92884	(o)	5.0	145904	(e)	5.0	0.24	3.30E+09
1887.493	90588	(o)	3.0	143569	(e)	4.0	0.09	2.27E+09
1887.810	93306	(o)	6.0	146278	(e)	6.0	0.42	4.93E+09
1888.537	93306	(o)	6.0	146257	(e)	7.0	0.22	3.14E+09
1888.824	90255	(o)	4.0	143198	(e)	4.0	0.38	4.44E+09
1891.944	80096	(o)	4.0	132951	(e)	5.0	0.49	5.75E+09
1892.802	83148	(o)	5.0	135980	(e)	6.0	0.76	1.07E+10
1893.133	91007	(o)	5.0	143829	(e)	6.0	0.30	3.68E+09
1893.640	90588	(o)	3.0	143397	(e)	3.0	0.07	2.13E+09
1894.035	80354	(o)	3.0	133152	(e)	3.0	0.12	2.47E+09
1894.313	82010	(o)	4.0	134800	(e)	5.0	0.71	9.58E+09
1895.468	103621	(o)	5.0	156379	(e)	4.0	0.16	2.69E+09
1896.304	91388	(o)	4.0	144122	(e)	5.0	0.18	2.79E+09
1897.184	83148	(o)	5.0	135857	(e)	4.0	0.19	2.83E+09
1897.588	81041	(o)	3.0	133739	(e)	4.0	0.65	8.27E+09
1898.774	79508	(o)	3.0	132174	(e)	4.0	0.48	5.55E+09
1899.149	82010	(o)	4.0	134665	(e)	3.0	0.13	2.51E+09
1899.458	91007	(o)	5.0	143654	(e)	5.0	0.38	4.46E+09
1901.914	79014	(o)	2.0	131593	(e)	3.0	0.33	3.92E+09
1902.156	82540	(o)	2.0	135112	(e)	2.0	0.18	2.76E+09
1903.938	81041	(o)	3.0	133563	(e)	2.0	0.03	1.97E+09
1906.291	90255	(o)	4.0	142713	(e)	5.0	0.28	3.52E+09
1912.105	83585	(o)	3.0	135883	(e)	3.0	0.37	4.27E+09
1914.156	80096	(o)	4.0	132338	(e)	3.0	0.08	2.21E+09
1921.967	84545	(o)	4.0	136575	(e)	4.0	0.55	6.45E+09
1925.304	91007	(o)	5.0	142947	(e)	5.0	0.06	2.07E+09
1926.479	96908	(o)	6.0	148816	(e)	5.0	0.43	4.81E+09
1928.750	84545	(o)	4.0	136392	(e)	5.0	0.56	6.50E+09
1929.270	94424	(o)	7.0	146257	(e)	7.0	0.56	6.55E+09
1930.278	94098	(o)	4.0	145904	(e)	5.0	0.15	2.49E+09
1932.167	82540	(o)	2.0	134296	(e)	3.0	0.24	3.11E+09
1934.708	96908	(o)	6.0	148595	(e)	7.0	0.89	1.40E+10
1935.096	83585	(o)	3.0	135262	(e)	4.0	0.33	3.79E+09
1945.802	92729	(o)	6.0	144122	(e)	5.0	0.17	2.59E+09
1959.453	106512	(o)	4.0	157547	(e)	3.0	0.15	2.43E+09
1968.516	92729	(o)	6.0	143529	(e)	7.0	0.33	3.69E+09
1970.716	106804	(o)	3.0	157547	(e)	3.0	0.07	1.99E+09

Table 3. (Continued.)

Wavelength[a]	Lower level[b]			Upper level[b]				gA[c]
(Å)	E (cm^{-1})	Parity	J	E (cm^{-1})	Parity	J	log gf[c]	(s^{-1})
1977.561	97185	(o)	4.0	147752	(e)	5.0	0.07	2.01E+09
1983.340	94677	(o)	3.0	145097	(e)	4.0	0.33	3.58E+09
2074.234	97709	(o)	5.0	145904	(e)	5.0	0.09	1.92E+09
2113.644	49542	(e)	4.0	96838	(o)	3.0	0.03	1.62E+09
2133.072	50319	(e)	5.0	97185	(o)	4.0	0.20	2.32E+09
2170.584	33452	(e)	3.0	79508	(o)	3.0	0.06	1.63E+09
2179.381	34225	(e)	4.0	80096	(o)	4.0	0.02	1.48E+09
2182.544	50482	(e)	6.0	96285	(o)	5.0	0.06	1.58E+09
2184.304	46962	(e)	5.0	92729	(o)	6.0	0.09	1.72E+09
2190.445	43462	(e)	3.0	89100	(o)	4.0	0.23	2.35E+09
2211.028	35129	(e)	5.0	80343	(o)	5.0	0.26	2.47E+09
2214.400	42666	(e)	2.0	87811	(o)	3.0	0.10	1.72E+09
2216.611	72188	(e)	3.0	117288	(o)	4.0	0.36	3.11E+09
2224.649	58730	(e)	4.0	103667	(o)	3.0	0.01	1.37E+09
2226.929	58730	(e)	4.0	103621	(o)	5.0	0.43	3.63E+09
2252.421	58894	(e)	3.0	103277	(o)	4.0	0.30	2.63E+09
2253.197	35129	(e)	5.0	79497	(o)	4.0	0.18	1.97E+09
2257.204	46300	(e)	3.0	90588	(o)	3.0	0.05	1.49E+09
2264.742	72356	(e)	2.0	116498	(o)	3.0	0.22	2.14E+09
2269.714	46962	(e)	5.0	91007	(o)	5.0	0.22	2.13E+09
2275.001	50482	(e)	6.0	94424	(o)	7.0	0.62	5.40E+09
2275.488	34225	(e)	4.0	78158	(o)	3.0	0.05	1.44E+09
2275.637	43462	(e)	3.0	87392	(o)	3.0	0.06	1.45E+09
2289.202	49089	(e)	2.0	92759	(o)	3.0	0.03	1.36E+09
2290.062	46602	(e)	4.0	90255	(o)	4.0	0.09	1.55E+09
2294.974	35129	(e)	5.0	78690	(o)	6.0	0.58	4.80E+09
2296.561	51426	(e)	3.0	94956	(o)	4.0	0.27	2.32E+09
2298.245	59060	(e)	2.0	102558	(o)	3.0	0.14	1.74E+09
2306.494	49542	(e)	4.0	92884	(o)	5.0	0.05	1.41E+09
2325.556	50319	(e)	5.0	93306	(o)	6.0	0.51	3.98E+09
2330.945	34225	(e)	4.0	77113	(o)	5.0	0.40	3.09E+09
2332.694	54853	(e)	5.0	97709	(o)	5.0	0.03	1.31E+09
2349.913	46962	(e)	5.0	89504	(o)	4.0	0.02	1.26E+09
2353.747	64331	(e)	3.0	106804	(o)	3.0	0.16	1.72E+09
2357.584	72188	(e)	3.0	114591	(o)	3.0	0.22	2.00E+09
2359.758	33452	(e)	3.0	75817	(o)	4.0	0.26	2.20E+09
2366.290	50482	(e)	6.0	92729	(o)	6.0	0.28	2.28E+09
2370.025	64331	(e)	3.0	106512	(o)	4.0	0.19	1.83E+09
2372.982	58730	(e)	4.0	100859	(o)	4.0	0.29	2.28E+09
2377.137	54853	(e)	5.0	96908	(o)	6.0	0.49	3.63E+09
2383.876	50319	(e)	5.0	92255	(o)	5.0	0.24	2.02E+09
2384.649	77557	(e)	2.0	119480	(o)	3.0	0.18	1.75E+09
2386.965	32843	(e)	2.0	74725	(o)	3.0	0.13	1.57E+09
2408.682	58894	(e)	3.0	100398	(o)	3.0	0.10	1.46E+09
2410.094	46962	(e)	5.0	88442	(o)	6.0	0.33	2.43E+09
2474.252	52698	(e)	4.0	93102	(o)	4.0	0.12	1.44E+09
2481.192	46602	(e)	4.0	86893	(o)	5.0	0.22	1.79E+09
2487.664	52698	(e)	4.0	92884	(o)	5.0	0.00	1.09E+09
2490.018	49542	(e)	4.0	89690	(o)	5.0	0.00	1.08E+09
2506.187	44655	(e)	4.0	84545	(o)	4.0	0.22	1.78E+09
2524.709	46300	(e)	3.0	85896	(o)	4.0	0.19	1.63E+09
2547.336	54853	(e)	5.0	94098	(o)	4.0	0.04	1.14E+09
2597.134	44655	(e)	4.0	83148	(o)	5.0	0.18	1.50E+09
2633.565	50482	(e)	6.0	88442	(o)	6.0	0.11	1.25E+09

[a] Wavelengths deduced from experimental energies reported by Iglesias *et al* (1990).

[b] Iglesias *et al* (1990).

[c] This work.

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