Energies, Wavelengths, Transition Probabilities, Radiative Lifetimes and Collision Strengths for Se-Like Mo, Tc, Ru and Rh ions

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Abstract: Energy levels, wavelengths, transition probabilities and oscillator strengths have been calculated for Se-Like Mo, Tc, Ru and Rh ions among the fine-structure levels of terms belonging to the ([Ar] $3d^{10}$) $4s^2 4p^4$, ([Ar] $3d^{10}$) 4s $4p^4$ 4d and ([Ar] $3d^{10}$) $4s^2$ $4p^3$ 4f configurations. The fully relativistic Multiconfiguration Dirac-Fock (MCDF) method, taking both correlations within the n=4 complex and the quantum electrodynamic effects into account, have been used in the calculations. The results are compared with the available experimental and other theoretical results.
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1. Introduction

Research regarding highly ionized atomic systems has been one of the important subjects in atomic physics during the past decades because knowledge of the structure and other properties of these systems are important in many fields of science and technology, such as plasma physics, laser physics, and astrophysics (Gilaspy, 2001). However, experimental data on these systems are not sufficiently complete presently. In general, one has to use reliable theoretical predictions as input in other fields (Gilaspy and Liedahal, 2001). For example, when analyzing astrophysical spectra, accurate wavelengths are necessary for line identification, also transition probabilities are used to derive the stellar abundances.

However, a major task is the identification of the large number of lines, especially from UV to X-ray region for use in sythetic models and calculating opacities. Ab initio relativistic calculations using the Breit-Pauli R-matrix (BPRM) method, developed under the Iron Project (Hummer, Berrington, Eissner, Pradhan and Saraph, 1993), are carried out for extensive and accurate sets of oscillator strengths (f), line strengths (S) and radiative transition probabilities (A) for a number of Li-like ions from carbon to nickel. Results for lithium like Fe XXIV were reported earlier (Nahar and Pradhan, 1999). Compared to the very accurate theoretical methods for oscillator strengths for a relatively small number of transitions, the BPRM method allows consideration of a large number of transitions with comparable accuracy for most of the transitions. Also wavelengths, transition Probabilities and energy levels for the spectra of caesium (Cs L- Cs LV) have been compiled by Sansonetti (Sansonetti, 2009).

2. Calculation

The wavelengths, transition Probabilities and Oscillator strengths for $4s^2$ $4p^4$ - 4s $4p^4$ 4d and $4s^2$ $4p^4$ - $4s^2$ $4p^3$ 4f forbidden transitions (E_2) were calculated for ions belonging to the Selenium isoelectronic sequence. These calculations are performed using the fully relativistic MCDF approach with the Multiconfiguration Dirac-Fock and General Matrix Elements (MCDFGME) (Desclaux and Indelicato, 2005) program.

The orthogonality of the wavefunctions was consistently included in the differential equations by using off-diagonal Lagrange multipliers. Most even configurations within the n=4 layzer complex are included in the calculations. The relevant configurations are ([Ar] $3d^{10}$) $4s^2 4p^4$, ([Ar] $3d^{10}$) 4s $4p^4$ 4d and ([Ar] $3d^{10}$) $4s^2$ $4p^3$ 4f

The LS terms $4s^2 4p^4$ ($^3P_{2,1,0}$, $^1D_2$, $^1S_0$), 4s $4p^4$4d ($^1D_2$, $^1P_1$, $^1G_4$, $^3D_{2,1}$, $^5P_1$, $^3F_{4,3,2}$, $^1F_3$) and $4s^2$ $4p^3$ 4f ($^1D_2$, $^1P_1$, $^3D_{3,2}$, $^3G_3$, $^3P_{2,1,0}$) give rise to 23 fine-structure levels listed in tables, 1-4, of energy levels for our relevant isoelectronic sequence.

3. Results and Discussion.

3.1 Energy levels

The Energy level values obtained using the MCDF method for the $4s^2 4p^4$, 4s $4p^4$4d and $4s^2$ $4p^3$4f configurations in Se-like Mo, Tc, Ru and Rh ions are presented in Tables 1-4. The main component of the computed eigenvectors are also given in these tables in LS- coupling schemes.

3.2 Wavelengths, Transition Probabilities and Oscillator strengths

The wavelengths, transition probabilities and oscillator strengths for $4s^2 4p^4$ - 4s $4p^4$4d and $4s^2 4p^4$ -

$4s^2\ 4p^3 4f$ forbidden transitions (E_2) calculated using the MCDF method are reported in Tables 5-8. the calculated MCDF transition probabilities are presented in both the length and velocity gauges, while the oscillator strengths are only shown in length gauge.

3.3 Radiative Lifetimes

The radiative lifetime of an excited state is calculated from radiative transition probabilities A_{ji} using the relation

$$\tau_j = \frac{1}{\sum_i A_{ji}} \qquad (1)$$

In tables 9-12, we present the calculated MCDF radiative lifetime (in sec) of $4s^2 4p^4$, $4s\,4p^4 4d$ and $4s^2\ 4p^3 4f$ configurations.The calculated MCDF Radiative Lifetimes are presented in both the velocity gauge and length gauge.

3.4 Collision Strengths and Excitation Rate Coefficients

Excitation rate coefficient (in $cm^3\,sec^{-1}$) for a transition from $i \to j$ are calculation using the following formula (Hahn, Pradhan, Tawara, and Zhang, (2001)

$$C(T) = \frac{8.629\times10^{-6}}{g_i\sqrt{kT_e}}\exp\left(-\Delta E_{ij}/kT_e\right)\gamma(T) \qquad (2)$$

where γ is the effective collision strength, T_e is the electron temperature in eV, g_i is the statistical weight of the level i, ΔE_{ij} is the excitation energy, and k is the Boltzmann constant.

Using a Maxwellian velocity distribution, the effective collision strength can de defined as a function of electron temperature.

$$\gamma(i \to j) = \int_0^\infty \Omega_{i\to j}\exp\left(-E/kT_e\right)d\left(E/kT_e\right) \qquad (3)$$

where E is the scattered electron energy, $\Omega_{i\to j}$ is the collision strength.
The unit of temperature is Kelvin.

*Table 1. **MCDF** energy level (in cm^{-1}) of $4s^2 4p^4$, $4s4p^4 4d$ and $4s^2 4p^3 4f$ configurations for **Mo IX** ion.*

	Configuration	J	LS	MCDF (cm^{-1})	Exp (cm^{-1})
1	$4s^2 4p^4$	2	$^3P_2$	0	0
2	$4s^2 4p^4$	1	$^3P_1$	20280	20 576
3	$4s^2 4p^4$	0	$^3P_0$	18910	16 589
4	$4s^2 4p^4$	2	$^1D_2$	38600	35 675
5	$4s^2 4p^4$	0	$^1S_0$	79120	72 885
6	$4s\,4p^4\,4d$	2	$^1D_2$	657440	……
7	$4s\,4p^4\,4d$	1	$^1P_1$	654220	……
8	$4s\,4p^4\,4d$	4	$^1G_4$	657650	……
9	$4s\,4p^4\,4d$	2	$^3D_2$	657440	……
10	$4s\,4p^4\,4d$	3	$^1F_3$	683340	……
11	$4s\,4p^4\,4d$	1	$^5P_1$	564720	……
12	$4s\,4p^4\,4d$	4	$^3F_4$	592720	……
13	$4s\,4p^4\,4d$	3	$^3F_3$	599730	……
14	$4s\,4p^4\,4d$	2	$^3F_2$	611390	……
15	$4s\,4p^4\,4d$	1	$^3D_1$	602290	……
16	$4s^2 4p^3 4f$	1	$^3D_1$	733550	……
17	$4s^2 4p^3 4f$	3	$^3D_3$	719830	……
18	$4s^2 4p^3 4f$	3	$^1D_2$	736670	……
19	$4s^2 4p^3 4f$	3	$^3G_3$	709450	……
20	$4s^2 4p^3 4f$	1	$^1P_1$	721900	……
21	$4s^2 4p^3 4f$	0	$^3P_0$	740520	……
22	$4s^2 4p^3 4f$	1	$^3P_1$	738160	….
23	$4s^2 4p^3\ 4f$	2	$^3P_2$	735320	……

*Table 2. **MCDF** energy level (in cm^{-1}) of $4s^2 4p^4$, $4s4p^4 4d$ and $4s^2 4p^3 4f$ configurations for **Tc X** ion.*

	Configuration	J	LS	MCDF (cm^{-1})
1	$4s^2 4p^4$	2	$^3P_2$	0
2	$4s^2 4p^4$	1	$^3P_1$	24530
3	$4s^2 4p^4$	0	$^3P_0$	21200
4	$4s^2 4p^4$	2	$^1D_2$	43590
5	$4s^2 4p^4$	0	$^1S_0$	81500
6	$4s\,4p^4\,4d$	2	$^1D_2$	734180
7	$4s\,4p^4\,4d$	1	$^1P_1$	710370
8	$4s\,4p^4\,4d$	4	$^1G_4$	715970
9	$4s\,4p^4\,4d$	2	$^3D_2$	714180
10	$4s\,4p^4\,4d$	3	$^1F_3$	743480
11	$4s\,4p^4\,4d$	1	$^5P_1$	631770
12	$4s\,4p^4\,4d$	4	$^3F_4$	645820
13	$4s\,4p^4\,4d$	3	$^3F_3$	653660
14	$4s\,4p^4\,4d$	2	$^3F_2$	667390
15	$4s\,4p^4\,4d$	1	$^3D_1$	655730
16	$4s^2 4p^3 4f$	1	$^3D_1$	812320
17	$4s^2 4p^3 4f$	3	$^3D_3$	796590
18	$4s^2 4p^3 4f$	2	$^1D_2$	815890
19	$4s^2 4p^3 4f$	3	$^3G_3$	784840
20	$4s^2 4p^3 4f$	1	$^1P_1$	798470
21	$4s^2\ 4p^3 4f$	0	$^3P_0$	820400
22	$4s^2\ 4p^3 4f$	1	$^3P_1$	817450
23	$4s^2\ 4p^3 4f$	2	$^3P_2$	814290

Table 3. **MCDF** energy level (in cm^{-1}) of $4s^24p^4$, $4s\,4p^44d$ and $4s^24p^34f$ configurations for **Ru XI** ion.

	Configuration	J	LS	MCDF (cm^{-1})
1	$4s^24p^4$	2	$^3P_2$	0
2	$4s^24p^4$	1	$3P_1$	29350
3	$4s^24p^4$	0	$^3P_0$	22330
4	$4s^24p^4$	2	$^1D_2$	49130
5	$4s^24p^4$	0	$^1S_0$	98890
6	$4s\,4p^4\,4d$	2	$^1D_2$	795050
7	$4s\,4p^4\,4d$	1	$^1P_1$	767010
8	$4s\,4p^4\,4d$	4	$^1G_4$	775150
9	$4s\,4p^4\,4d$	2	$^3D_2$	708610
10	$4s\,4p^4\,4d$	3	$^1F_3$	804500
11	$4s\,4p^4\,4d$	1	$^5P_1$	667490
12	$4s\,4p^4\,4d$	4	$^3F_4$	699520
13	$4s\,4p^4\,4d$	3	$^3F_3$	708110
14	$4s\,4p^4\,4d$	2	$^3F_2$	724220
15	$4s\,4p^4\,4d$	1	$^3D_1$	709800
16	$4s^24p^34f$	1	$^3D_1$	890290
17	$4s^24p^34f$	3	$^3D_3$	872680
18	$4s^24p^34f$	2	$^1D_2$	894400
19	$4s^24p^34f$	3	$^3G_3$	859610
20	$4s^24p^34f$	1	$^1P_1$	874230
21	$4s^24p^34f$	0	$^3P_0$	899390
22	$4s^24p^34f$	1	$^3P_1$	895890
23	$4s^24p^34f$	2	$^3P_2$	892260

Table 4. **MCDF** energy level (in cm^{-1}) of $4s^24p^4$,$4s\,4p^44d$ and $4s^2\,4p^34f$ configurations for **Rh IV** ion.

	Configuration	J	LS	MCDF (cm^{-1})
1	$4s^24p^4$	2	$^3P_2$	0
2	$4s^24p^4$	1	$^3P_1$	34800
3	$4s^24p^4$	0	$^3P_0$	24600
4	$4s^24p^4$	2	$^1D_2$	55400
5	$4s^24p^4$	0	$^1S_0$	102200
6	$4s\,4p^4\,4d$	2	$^1D_2$	848100
7	$4s\,4p^4\,4d$	1	$^1P_1$	824300
8	$4s\,4p^4\,4d$	4	$^1G_4$	835400
9	$4s\,4p^4\,4d$	2	$^3D_2$	764100
10	$4s\,4p^4\,4d$	3	$^1F_3$	866500
11	$4s\,4p^4\,4d$	1	$^5P_1$	71992
12	$4s\,4p^4\,4d$	4	$^3F_4$	753982
13	$4s\,4p^4\,4d$	3	$^3F_3$	753800
14	$4s\,4p^4\,4d$	2	$^3F_2$	782000
15	$4s\,4p^4\,4d$	1	$^3D_1$	764700
16	$4s^24p^34f$	1	$^3D_1$	967700
17	$4s^24p^34f$	3	$^3D_3$	948400
18	$4s^24p^34f$	2	$^1D_2$	972400
19	$4s^24p^34f$	3	$^3G_3$	934000
20	$4s^24p^34f$	1	$^1P_1$	949400
21	$4s^24p^34f$	0	$^3P_0$	977700
22	$4s^24p^34f$	1	$^3P_1$	973800
23	$4s^24p^34f$	2	$^3P_2$	969600

Table 5**. MCDF** Transition wavelengths **λ** (in Å), Transition probabilities velocity $\mathbf{A_V}$ (in sec^{-1}), Transition probabilities length $\mathbf{A_L}$ (in sec^{-1}) and oscillator strength $\boldsymbol{f_L}$ for lines of **Mo IX** forbidden transitions (E2).

Lower	Upper	λ	A_V	A_L	f_L
$4s^24p^4$ ($^3P_0$)	$4s\,4p^44d$ ($^1D_2$)	156.777	5.6109193E+05	6.7909242E+05	1.0337864E-05
	$4s\,4p^44d$ ($^3D_2$)	156.493	5.6601901E+05	6.8755778E+05	1.0390830E-05
	$4s\,4p^44d$ ($^3F_2$)	168.641	2.2763987E+06	2.3642595E+06	4.8529631E-05
	$4s^24p^34f$ ($^3P_2$)	139.353	1.1653713E+06	1.2883583E+06	1.6963767E-05
$4s^24p^4$ ($^3P_1$)	$4s\,4p^44d$ ($^1D_2$)	157.117	1.0310509E+05	1.2362101E+05	6.3596701E-07
	$4s\,4p^44d$ ($^1P_1$)	157.918	5.0043824E+05	5.9159536E+05	1.8709825E-06
	$4s\,4p^44d$ ($^1F_3$)	150.971	4.5089458E+03	5.6591813E+03	3.5949547E-08.
	$4s\,4p^44d$ ($^3F_2$)	169.366	5.4931093E+05	5.6185282E+05	3.9371421E-06
	$4s\,4p^44d$ ($^3F_3$)	172.782	7.8169061E+05	7.7156508E+05	8.1633271E-06
	$4s^24p^34f$ ($^3D_1$)	140.193	8.8399827E+06	9.5804468E+06	2.6047378E-05
	$4s^24p^34f$ ($^3D_3$)	142.942	6.6735459E+06	7.1884123E+06	4.7699646E-05
	$4s^24p^34f$ ($^3P_2$)	139.847	1.1118760E+07	1.2465306E+07	5.4333839E-05
	$4s^24p^34f$ ($^3G_3$)	145.095	2.3573084E+04	2.4606923E+04	1.7360433E-07
$4s^24p^4$ ($^1D_2$)	$4s\,4p^44d$ ($^1D_2$)	161.773	1.0810158E+06	1.2076842E+06	4.2413381E-06
	$4s\,4p^44d$ ($^1G_4$)	161.715	5.4045535E+06	6.0982196E+06	3.8140999E-05
	$4s\,4p^44d$ ($^1F_3$)	155.264	4.6406429E+06	5.6959695E+06	2.3480454E-05
	$4s\,4p^44d$ ($^1P_1$)	162.621	2.3830495E+06	2.6691910E+06	5.6689127E-06
	$4s\,4p^44d$ ($^3D_2$)	161.773	1.0810158E+06	1.2076842E+06	4.2413381E-06
	$4s^24p^34f$ ($^3D_1$)	143.888	5.3106859E+05	5.7688083E+05	9.8903457E-07
$4s^24p^4$ ($^3P_2$)	$4s\,4p^44d$ ($^1D_2$)	152.261	2.4224196E+06	3.1043588E+06	8.4195065E-06
	$4s\,4p^44d$ ($^1P_1$)	153.013	1.9936925E+06	2.5325615E+06	4.1987832E-06
	$4s\,4p^44d$ ($^1F_3$)	146.482	4.4704495E+05	6.1782105E+05	2.0132757E-06
	$4s\,4p^44d$ ($^1G_4$)	152.210	2.9493258E+05	3.7493658E+05	1.8439100E-06
	$4s\,4p^44d$ ($^3D_1$)	166.219	1.6607202E+05	1.7444120E+05	4.1273353E-07
	$4s\,4p^44d$ ($^3F_2$)	163.737	1.0648408E+03	1.0909581E+03	4.2799618E-09
	$4s\,4p^44d$ ($^3F_3$)	166.927	2.3451024E+06	2.4815546E+06	1.3715275E-05
	$4s\,4p^44d$ ($^3F_4$)	168.907	3.3070855E+06	3.4295460E+06	2.5460591E-05
	$4s^24p^34f$ ($^3D_1$)	136.314	3.4870011E+06	3.8364619E+06	5.8283266E-06
	$4s^24p^34f$ ($^3G_3$)	140.944	1.8634846E+06	2.0287596E+06	7.7697877E-06
	$4s^24p^34f$ ($^3P_2$)	135.987	5.3784642E+05	6.6758419E+05	1.4911139E-06
	$4s^24p^34f$ ($^3D_3$)	138.912	8.4278052E+06	9.2994413E+06	3.4133514E-05
$4s^24p^4$ ($^1S_0$)	$4s\,4p^44d$ ($^1D_2$)	188.750	1.5410529E+05	1.5436863E+05	4.1154986E-06
	$4s\,4p^44d$ ($^3D_2$)	189.305	1.5435978E+05	1.5371520E+05	4.1465583E-06

Table 6. **MCDF** Transition wavelengths **λ** (in Å), Transition probabilities velocity $\mathbf{A_V}$ (in sec^{-1}), Transition probabilities length $\mathbf{A_L}$ (in sec^{-1}) and oscillator strength $\boldsymbol{f_L}$ for lines of **Tc X** forbidden transitions (E2).

Lower	Upper	λ	A_V	A_L	f_L
$4s^24p^4$ ($^3P_0$)	$4s4p^44d$ ($^1D_2$)	144.469	7.0081650E+05	8.4207127E+05	1.0964405E-05
	$4s4p^44d$ ($^3D_2$)	144.227	7.0621484E+05	8.5141851E+05	1.1011923E-05
	$4s4p^44d$ ($^3F_2$)	154.661	2.7470696E+06	2.8547012E+06	4.9256135E-05
	$4s^24p^34f$ ($^3P_2$)	125.898	2.3048715E+06	2.5630569E+06	2.7385040E-05
$4s^24p^4$ ($^3P_1$)	$4s4p^44d$ ($^1D_2$)	145.169	1.2228751E+05	1.4478590E+05	6.4393471E-07
	$4s4p^44d$ ($^1P_1$)	145.977	6.3854646E+05	7.4395996E+05	2.0399514E-06
	$4s4p^44d$ ($^1F_3$)	139.243	8.2346345E+02	1.1809287E+03	5.5850231E-09
	$4s4p^44d$ ($^3F_2$)	155.745	8.5819052E+05	8.7383658E+05	5.2013674E-06
	$4s4p^44d$ ($^3F_3$)	159.152	8.3606210E+05	8.1891288E+05	7.4079409E-06
	$4s^24p^34f$ ($^3D_1$)	126.931	1.1713823E+07	1.2663335E+07	2.8293831E-05
	$4s^24p^34f$ ($^3D_3$)	129.518	8.0926100E+06	8.6901049E+06	4.7488676E-05
	$4s^24p^34f$ ($^3P_2$)	126.615	1.4537848E+07	1.6241901E+07	5.8234306E-05
	$4s^24p^34f$ ($^3G_3$)	131.521	1.1120285E+01	6.0825108E+00	6.7288308E-11
$4s^24p^4$ ($^1D_2$)	$4s4p^44d$ ($^1D_2$)	149.302	1.0123005E+06	1.1140133E+06	3.3829571E-06
	$4s4p^44d$ ($^1G_4$)	148.900	6.3145049E+06	7.0801467E+06	3.7779967E-05
	$4s4p^44d$ ($^1F_3$)	143.039	5.9947480E+06	7.3038511E+06	2.5743651E-05
	$4s4p^44d$ ($^1P_1$)	150.156	2.5447181E+06	2.8171153E+06	5.1609753E-06
	$4s4p^44d$ ($^3D_2$)	149.302	1.0123031E+06	1.1140180E+06	3.3829601E-06
	$4s^24p^34f$ ($^3D_1$)	130.078	5.2889812E+05	5.7503605E+05	8.0499288E-07
$4s^24p^4$ ($^3P_2$)	$4s4p^44d$ ($^1D_2$)	140.174	3.0131796E+06	3.8378155E+06	8.8760501E-06
	$4s4p^44d$ ($^1P_1$)	140.927	2.7228954E+06	3.4370475E+06	4.8643755E-06
	$4s4p^44d$ ($^1F_3$)	134.640	4.7865072E+05	6.6026142E+05	1.8211913E-06
	$4s4p^44d$ ($^1G_4$)	139.820	3.7171351E+05	4.7145321E+05	1.9610154E-06
	$4s4p^44d$ ($^3D_1$)	152.683	1.8477458E+05	1.9297046E+05	3.8746959E-07
	$4s4p^44d$ ($^3F_2$)	150.009	1.6082455E+04	1.7328852E+04	5.4255847E-08
	$4s4p^44d$ ($^3F_3$)	153.167	2.9428144E+06	3.1147963E+06	1.4490479E-05
	$4s4p^44d$ ($^3F_4$)	155.028	4.0483732E+06	4.1984853E+06	2.6256295E-05
	$4s^24p^34f$ ($^3D_1$)	123.095	4.1434180E+06	4.5253217E+06	5.6474229E-06
	$4s^24p^34f$ ($^3G_3$)	127.407	2.7271428E+06	2.9717457E+06	9.2914056E-06
	$4s^24p^34f$ ($^3P_2$)	122.798	2.6272234E+05	3.4803373E+05	5.9393583E-07
	$4s^24p^34f$ ($^3D_3$)	125.527	1.0788072E+07	1.1866245E+07	3.5678676E-05
$4s^24p^4$ ($^1S_0$)	$4s4p^44d$ ($^1D_2$)	160.038	1.4498727E+05	1.4138874E+05	2.7835765E-06
	$4s4p^44d$ ($^3D_2$)	160.037	1.4498765E+05	1.4138936E+05	2.7835790E-06

Table 7. **MCDF** Transition wavelengths **λ** (in Å), Transition probabilities velocity $\mathbf{A_V}$ (in sec^{-1}), Transition probabilities length $\mathbf{A_L}$ (in sec^{-1}) and oscillator strength $\boldsymbol{f_L}$ for lines of **Ru XI** forbidden transitions (E2).

Lower	Upper	λ	A_V	A_L	f_L
$4s^24p^4$ ($^3P_0$)	$4s4p^44d$ ($^1D_2$)	129.757	8.3105673E+05	1.0485178E+06	1.0488726E-05
	$4s4p^44d$ ($^3D_2$)	145.905	2.1365404E+04	2.1314630E+04	3.4094293E-07
	$4s4p^44d$ ($^3F_2$)	142.651	3.2860862E+06	3.4204909E+06	5.0125541E-05
	$4s^24p^34f$ ($^3P_2$)	114.945	3.3328307E+06	3.7113986E+06	3.3008350E-05
$4s^24p^4$ ($^3P_1$)	$4s4p^44d$ ($^1D_2$)	130.754	7.0641728E+04	9.0290646E+04	3.0177366E-07
	$4s4p^44d$ ($^1P_1$)	135.734	7.8286681E+05	8.9939247E+05	2.1623331E-06
	$4s4p^44d$ ($^1F_3$)	129.159	2.6427521E+04	3.4590165E+04	1.5421913E-07
	$4s4p^44d$ ($^3F_2$)	144.098	1.1775045E+06	1.1937070E+06	6.1092560E-06
	$4s4p^44d$ ($^3F_3$)	147.527	8.8053425E+05	8.5551853E+05	6.7038198E-06
	$4s^24p^34f$ ($^3D_1$)	116.148	1.4739212E+07	1.5903690E+07	2.9809692E-05
	$4s^24p^34f$ ($^3D_3$)	118.574	9.4672158E+06	1.0140391E+07	4.6562298E-05
	$4s^24p^34f$ ($^3P_2$)	115.883	1.7073121E+07	1.9004991E+07	5.7287445E-05
	$4s^24p^34f$ ($^3G_3$)	120.441	2.3328905E+04	2.4865508E+04	1.1837968E-07

$4s^24p^4$ ($^1D_2$)	$4s4p^44d$ ($^1D_2$)	134.227	6.9554700E+06	8.2310990E+06	1.8787320E-05
	$4s4p^44d$ ($^1G_4$)	137.910	7.2106622E+06	8.0391222E+06	3.7008038E-05
	$4s4p^44d$ ($^1F_3$)	132.546	7.4159900E+06	8.9766423E+06	2.7345620E-05
	$4s4p^44d$ ($^1P_1$)	139.480	2.6571487E+06	2.9082176E+06	4.6499453E-06
	$4s4p^44d$ ($^3D_2$)	151.849	5.3332425E+04	4.5669329E+04	1.8436225E-07
	$4s^24p^34f$ ($^3D_1$)	118.880	4.2175328E+05	4.6000985E+05	5.3615082E-07
$4s^24p^4$ ($^3P_2$)	$4s4p^44d$ ($^1D_2$)	125.918	5.5079881E+05	7.3914870E+05	1.3092695E-06
	$4s4p^44d$ ($^1P_1$)	130.530	3.5943430E+06	4.5130539E+06	5.5086821E-06
	$4s4p^44d$ ($^1F_3$)	124.437	5.1461939E+05	7.0989056E+05	1.6725388E-06
	$4s4p^44d$ ($^1G_4$)	129.153	4.4358717E+05	5.6197433E+05	1.9967499E-06
	$4s4p^44d$ ($^3D_1$)	141.063	2.0588347E+05	2.1389747E+05	3.6851729E-07
	$4s4p^44d$ ($^3F_2$)	138.247	4.2424800E+04	4.6119078E+04	1.2155958E-07
	$4s4p^44d$ ($^3F_3$)	141.399	3.6069761E+06	3.8194388E+06	1.5136457E-05
	$4s4p^44d$ ($^3F_4$)	143.138	4.8756849E+06	5.0591855E+06	2.6957522E-05
	$4s^24p^34f$ ($^3D_1$)	1.12316	4.5878363E+06	4.9697550E+06	5.2059901E-06
	$4s^24p^34f$ ($^3G_3$)	116.326	3.7225981E+06	4.0579415E+06	1.0572623E-05
	$4s^24p^34f$ ($^3P_2$)	112.068	2.7455085E+04	5.2682293E+04	5.1694811E-08
	$4s^24p^34f$ ($^3D_3$)	114.582	1.3016250E+07	1.4275804E+07	3.5868399E-05
$4s^24p^4$ ($^1S_0$)	$4s4p^44d$ ($^1D_2$)	143.839	3.8284470E+05	3.9053864E+05	5.9374861E-06
	$4s4p^44d$ ($^3D_2$)	164.267	7.9489420E+03	6.6450829E+03	1.6078136E-07

Table 8. **MCDF** Transition wavelengths **λ** (in Å), Transition probabilities velocity$\mathbf{A_V}$ (in sec^{-1}), Transition probabilities length $\mathbf{A_L}$ (in sec^{-1}) and oscillator strength $\boldsymbol{f_L}$ for lines of **Rh XII** Forbidden transitions (E2).

Lower	**Upper**	**λ**	A_V	A_L	f_L
$4s^24p^4$ ($^3P_0$)	$4s4p^44d$ ($^1D_2$)	120.518	1.0535806E+06	1.3257015E+06	1.1470876E-05
	$4s4p^44d$ ($^3D_2$)	135.423	9.5104810E+03	9.4434235E+03	1.3074298E-07
	$4s4p^44d$ ($^3F_2$)	132.209	3.9260333E+06	4.0966063E+06	5.1440243E-05
	$4s^24p^34f$ ($^3P_2$)	105.821	4.1074497E+06	4.5655119E+06	3.4478206E-05
$4s^24p^4$ ($^3P_1$)	$4s4p^44d$ ($^1D_2$)	121.847	8.8863674E+04	1.1109668E+05	3.2965727E-07
	$4s4p^44d$ ($^1P_1$)	126.835	9.2931398E+05	1.0531233E+06	2.2413212E-06
	$4s4p^44d$ ($^1F_3$)	120.384	1.1557036E+05	1.4855426E+05	5.8589373E-07
	$4s4p^44d$ ($^3F_2$)	134.020	1.5012785E+06	1.5150762E+06	6.7376602E-06
	$4s4p^44d$ ($^3F_3$)	137.478	9.1411554E+05	8.8054922E+05	6.0436682E-06
	$4s^24p^34f$ ($^3D_1$)	107.194	1.7787325E+07	1.9165320E+07	3.0641948E-05
	$4s^24p^34f$ ($^3D_3$)	109.458	1.0784919E+07	1.1528805E+07	4.5201080E-05
	$4s^24p^34f$ ($^3P_2$)	106.978	1.9181414E+07	2.1278327E+07	5.4850396E-05
	$4s^24p^34f$ ($^3G_3$)	111.210	9.2926161E+04	9.8432500E+04	4.0203165E-07
$4s^24p^4$ ($^1D_2$)	$4s4p^44d$ ($^1D_2$)	124.979	8.6619620E+06	1.0150875E+07	2.0283615E-05
	$4s4p^44d$ ($^1G_4$)	128.369	8.0862343E+06	8.9672141E+06	3.5958307E-05
	$4s4p^44d$ ($^1F_3$)	123.429	8.8495914E+06	1.0648543E+07	2.8297235E-05
	$4s4p^44d$ ($^1P_1$)	130.232	2.7238251E+06	2.9473329E+06	4.1555247E-06
	$4s4p^44d$ ($^3D_2$)	141.315	5.9285792E+04	5.0067550E+04	1.7749471E-07
	$4s^24p^34f$ ($^3D_1$)	109.611	2.5431024E+05	2.7976684E+05	2.7484016E-07
$4s^24p^4$ ($^3P_2$)	$4s4p^44d$ ($^1D_2$)	116.889	4.5146416E+05	6.0428240E+05	9.2475808E-07
	$4s4p^44d$ ($^1P_1$)	121.472	4.6152293E+06	5.7690663E+06	6.1256970E-06
	$4s4p^44d$ ($^1F_3$)	115.542	5.5507354E+05	7.6698779E+05	1.5552992E-06
	$4s4p^44d$ ($^1G_4$)	119.850	5.0552588E+05	6.4035716E+05	1.9595127E-06
	$4s4p^44d$ ($^3D_1$)	130.956	2.3298451E+05	2.4095497E+05	3.5940530E-07
	$4s4p^44d$ ($^3F_2$)	128.046	7.5172560E+04	8.2137629E+04	1.8477774E-07
	$4s4p^44d$ ($^3F_3$)	131.198	4.3390807E+06	4.5974257E+06	1.5676222E-05
	$4s4p^44d$ ($^3F_4$)	132.810	5.7960195E+06	6.0203515E+06	2.7588128E-05
	$4s^24p^34f$ ($^3D_1$)	103.338	4.8631480E+06	5.2212804E+06	4.6714372E-06
	$4s^24p^34f$ ($^3G_3$)	107.064	4.7993831E+06	5.2307592E+06	1.1546897E-05
	$4s^24p^34f$ ($^3P_2$)	103.137	6.7886389E+04	4.5622080E+04	1.0826105E-07
	$4s^24p^34f$ ($^3D_3$)	105.440	1.5061917E+07	1.6474061E+07	3.5146322E-05
$4s^24p^4$ ($^1S_0$)	$4s4p^44d$ ($^1D_2$)	134.244	4.0051277E+05	4.0448840E+05	5.4104718E-06
	$4s4p^44d$ ($^3D_2$)	153.277	8.6213369E+03	7.1993408E+03	1.5182997E-07

Table 9. **MCDF** Radiative lifetime τ (in sec) of $4s^24p^4$, $4s4p^44d$ and $4s^24p^34f$ configuration for **Mo IX** ion.

Upper	Lower	Lifetime velocity gauge	Lifetime length gauge
$4s^24p^4$ ($^3P_0$)	$4s4p^44d(^1D_2)$	1.782E-06	1.472E-06
	$4s4p^44d(^3D_2)$	1.766E-06	1.454E-06
	$4s4p^44d(^3F_2)$	4.392E-07	4.229E-07
	$4s^24p^34f(^3P_2)$	8.580E-07	7.761E-07
$4s^24p^4$ ($^3P_1$)	$4s4p^44d(^1D_2)$	9.698E-06	8.089E-06
	$4s4p^44d(^1P_1)$	1.998E-06	1.690E-06
	$4s4p^44d(^1F_3)$	2.217E-04	1.767E-04
	$4s4p^44d(^3F_2)$	1.820E-06	1.779E-06
	$4s4p^44d(^3F_3)$	1.279E-06	1.296E-06
	$4s^24p^34f(^3D_1)$	1.131E-07	1.043E-07
	$4s^24p^34f(^3P_2)$	8.993E-08	8.022E-08
	$4s^24p^34f(^3G_3)$	4.242E-05	4.063E-05
	$4s^24p^34f(^3D_3)$	1.498E-07	1.391E-07
$4s^24p^4$ ($^1S_0$)	$4s4p^44d(^1D_2)$	6.549E-06	6.624E-06
	$4s4p^44d(^3D_2)$	6.549E-06	6.624E-06
$4s^24p^4$ ($^3P_2$)	$4s4p^44d(^1D_2)$	4.128E-07	3.221E-07
	$4s4p^44d(^1P_1)$	5.015E-07	3.948E-07
	$4s4p^44d(^1F_3)$	2.236E-06	1.618E-06
	$4s4p^44d(^1G_4)$	3.390E-06	2.667E-06
	$4s4p^44d(^3D_1)$	6.021E-06	5.732E-06
	$4s4p^44d(^3F_2)$	9.391E-04	9.166E-04
	$4s4p^44d(^3F_3)$	4.264E-07	4.029E-07
	$4s4p^44d(^3F_4)$	3.023E-07	2.915E-07
	$4s^24p^34f(^3G_3)$	5.366E-07	4.929E-07
	$4s^24p^34f(^3P_1)$	8.786E-08	7.671E-08
	$4s^24p^34f(^3P_2)$	1.859E-06	1.497E-06
	$4s^24p^34f(^3D_1)$	2.867E-07	2.606E-07
	$4s^24p^34f(^3D_3)$	1.186E-07	1.075E-07
$4s^24p^4$ ($^1D_2$)	$4s4p^44d(^1D_2)$	9.250E-07	8.280E-07
	$4s4p^44d(^1G_4)$	1.850E-07	1.639E-07
	$4s4p^44d(^1F_3)$	2.154E-07	1.755E-07
	$4s4p^44d(^1P_1)$	4.196E-07	3.746E-07
	$4s4p^44d(^3D_2)$	9.250E-07	8.280E-07
	$4s^24p^34f(^3D_1)$	1.882E-06	1.733E-06

Table 10. **MCDF** Radiative lifetime τ (in sec) of $4s^24p^4$, $4s4p^44d$ and $4s^24p^34f$ configuration for **Tc X** ion.

Upper	Lower	Lifetime velocity gauge	Lifetime length gauge
$4s^24p^4$ ($^3P_0$)	$4s4p^44d(^1D_2)$	1.426E-06	1.187E-06
	$4s4p^44d(^3D_2)$	1.415E-06	1.175E-06
	$4s4p^44d(^3F_2)$	3.640E-07	3.503E-07
	$4s^24p^34f(^3P_2)$	4.338E-07	3.901E-07
$4s^24p^4$ ($^3P_1$)	$4s4p^44d(^1D_2)$	8.177E-06	6.907E-06
	$4s4p^44d(^1P_1)$	1.566E-06	1.344E-06
	$4s4p^44d(^1F_3)$	1.214E-03	8.468E-04
	$4s4p^44d(^3F_2)$	1.166E-06	1.144E-06
	$4s4p^44d(^3F_3)$	1.196E-06	1.221E-06
	$4s^24p^34f(^3D_1)$	8.536E-08	7.897E-08
	$4s^24p^34f(^3P_2)$	6.878E-08	6.157E-08
	$4s^24p^34f(^3G_3)$	8.992E-02	1.644E-01
	$4s^24p^34f(^3D_3)$	1.236E-07	1.151E-07
$4s^24p^4$ ($^1S_0$)	$4s4p^44d(^1D_2)$	6.897E-06	7.072E-06
	$4s4p^44d(^3D_2)$	6.897E-06	7.072E-06
$4s^24p^4$ ($^3P_2$)	$4s4p^44d(^1D_2)$	3.319E-07	2.606E-07
	$4s4p^44d(^1P_1)$	3.672E-07	2.909E-07
	$4s4p^44d(^1F_3)$	2.089E-06	1.515E-06
	$4s4p^44d(^1G_4)$	2.690E-06	2.121E-06
	$4s4p^44d(^3D_1)$	5.412E-06	5.182E-06
	$4s4p^44d(^3F_2)$	6.218E-05	5.771E-05
	$4s4p^44d(^3F_3)$	3.398E-07	3.210E-07
	$4s4p^44d(^3F_4)$	2.470E-07	2.381E-07
	$4s^24p^34f(^3G_3)$	3.666E-07	3.365E-07
	$4s^24p^34f(^3P_1)$	6.678E-08	5.850E-08
	$4s^24p^34f(^3P_2)$	3.806E-06	2.873E-06
	$4s^24p^34f(^3D_1)$	2.413E-07	2.209E-07
	$4s^24p^34f(^3D_3)$	9.269E-08	8.427E-08
$4s^24p^4$ ($^1D_2$)	$4s4p^44d(^1D_2)$	9.878E-07	8.976E-07
	$4s4p^44d(^1G_4)$	1.583E-07	1.412E-07
	$4s4p^44d(^1F_3)$	1.668E-07	1.369E-07
	$4s4p^44d(^1P_1)$	3.929E-07	3.549E-07
	$4s4p^44d(^3D_2)$	9.878E-07	8.976E-07
	$4s^24p^34f(^3D_1)$	1.890E-06	1.739E-06

Table 11. **MCDF** Radiative lifetime τ (in sec) of $4s^24p^4$, $4s4p^44d$ and $4s^24p^34f$ configuration for **Ru XI** ion.

Upper	Lower	Lifetime velocity gauge	Lifetime length gauge
$4s^24p^4$ ($^3P_0$)	$4s4p^44d(^1D_2)$	4.680E-05	9.537E-07
	$4s4p^44d(^3D_2)$	1.203E-06	9.537E-07
	$4s4p^44d(^3F_2)$	3.043E-07	2.923E-07
	$4s^24p^34f(^3P_2)$	3.000E-07	2.694E-07
$4s^24p^4$ ($^3P_1$)	$4s4p^44d(^1D_2)$	1.415E-05	1.107E-05
	$4s4p^44d(^1P_1)$	1.277E-06	1.112E-06
	$4s4p^44d(^1F_3)$	3.784E-05	2.891E-05
	$4s4p^44d(^3F_2)$	8.492E-07	8.377E-07
	$4s4p^44d(^3F_3)$	1.135E-06	1.169E-06
	$4s^24p^34f(^3D_1)$	6.784E-08	6.288E-08
	$4s^24p^34f(^3P_2)$	5.857E-08	5.262E-08
	$4s^24p^34f(^3G_3)$	4.286E-05	4.022E-05
	$4s^24p^34f(^3D_3)$	1.056E-07	9.862E-08
$4s^24p^4$ ($^1S_0$)	$4s4p^44d(^1D_2)$	2.612E-06	2.561E-06
	$4s4p^44d(^3D_2)$	1.258E-04	1.505E-04

Table 12. **MCDF** Radiative lifetime τ (in sec) of $4s^24p^4$, $4s4p^44d$ and $4s^24p^34f$ configuration for **Rh XII** ion.

Upper	Lower	Lifetime velocity gauge	Lifetime length gauge
$4s^24p^4$ ($^3P_0$)	$4s4p^44d(^1D_2)$	9.491E-07	7.543E-07
	$4s4p^44d(^3D_2)$	1.051E-04	1.058E-04
	$4s4p^44d(^3F_2)$	2.547E-07	2.441E-07
	$4s^24p^34f(^3P_2)$	2.434E-07	2.190E-07
$4s^24p^4$ ($^3P_1$)	$4s4p^44d(^1D_2)$	1.125E-05	9.001E-06
	$4s4p^44d(^1P_1)$	1.076E-06	9.495E-07
	$4s4p^44d(^1F_3)$	8.652E-06	6.732E-06
	$4s4p^44d(^3F_2)$	6.661E-07	6.600E-07
	$4s4p^44d(^3F_3)$	1.094E-06	1.136E-06
	$4s^24p^34f(^3D_1)$	5.622E-08	5.218E-08
	$4s^24p^34f(^3P_2)$	5.213E-08	4.699E-08
	$4s^24p^34f(^3G_3)$	1.076E-05	1.016E-05
	$4s^24p^34f(^3D_3)$	9.272E-08	8.674E-08
$4s^24p^4$ ($^1S_0$)	$4s4p^44d(^1D_2)$	2.496E-06	2.472E-06
	$4s4p^44d(^3D_2)$	1.159E-04	1.389E-04

4s²4p⁴ (³P₂)	**4s 4p⁴4d(¹D₂)**	1.816E-06	1.353E-06
	4s 4p⁴4d (¹P₁)	2.782E-07	2.216E-07
	4s 4p⁴4d (¹F₃)	1.943E-06	1.409E-06
	4s 4p⁴4d(¹G₄)	2.254E-06	1.779E-06
	4s 4p⁴4d(³D₁)	4.857E-06	4.675E-06
	4s 4p⁴4d (³F₂)	2.357E-05	2.168E-05
	4s 4p⁴4d (³F₃)	2.772E-07	2.618E-07
	4s 4p⁴4d (³F₄)	2.051E-07	1.977E-07
	4s²4p³4f(³G₃)	2.686E-07	2.464E-07
	4s²4p³4f(³P₁)	5.284E-08	4.643E-08
	4s²4p³4f(³P₂)	3.642E-05	1.898E-05
	4s²4p³4f(³D₁)	2.179E-07	2.012E-07
	4s²4p³4f(³D₃)	7.682E-08	7.005E-08
4s²4p⁴ (¹D₂)	**4s 4p⁴4d(¹D₂)**	1.437E-07	1.215E-07
	4s 4p⁴4d(¹G₄)	1.386E-07	1.244E-07
	4s 4p⁴4d (¹F₃)	1.348E-07	1.114E-07
	4s 4p⁴4d (¹P₁)	3.763E-07	3.438E-07
	4s 4p⁴4d(³D₂)	1.875E-05	2.189E-05
	4s²4p³4f(³D₁)	2.371E-06	2.174E-06

4s²4p⁴ (³P₂)	**4s 4p⁴4d(¹D₂)**	2.215E-06	1.654E-06
	4s 4p⁴4d (¹P₁)	2.166E-07	1.733E-07
	4s 4p⁴4d (¹F₃)	1.802E-06	1.303E-06
	4s 4p⁴4d(¹G₄)	1.978E-06	1.562E-06
	4s 4p⁴4d(³D₁)	4.292E-06	4.150E-06
	4s 4p⁴4d (³F₂)	1.330E-05	1.217E-05
	4s 4p⁴4d (³F₃)	2.304E-07	2.175E-07
	4s 4p⁴4d (³F₄)	1.725E-07	1.661E-07
	4s²4p³4f(³G₃)	2.083E-07	1.911E-07
	4s²4p³4f(³P₁)	4.312E-08	3.800E-08
	4s²4p³4f(³P₂)	1.473E-05	2.192E-05
	4s²4p³4f(³D₁)	2.056E-07	1.915E-07
	4s²4p³4f(³D₃)	6.639E-08	6.070E-08
4s²4p⁴ (¹D₂)	**4s 4p⁴4d(¹D₂)**	1.154E-07	9.851E-08
	4s 4p⁴4d(¹G₄)	1.237E-07	1.115E-07
	4s 4p⁴4d (¹F₃)	1.130E-07	9.391E-08
	4s 4p⁴4d (¹P₁)	3.671E-07	3.393E-07
	4s 4p⁴4d(³D₂)	1.686E-05	1.997E-05
	4s²4p³4f(³D₁)	3.932E-06	3.574E-06

Table 13. Collision Strengths of transitions of **Mo IX ion**.

Lower	Upper	Incident Energy (eV)							
		50	100	200	300	500	1000	5000	10000
4s²4p⁴ (³P₀)	**4s 4p⁴4d (¹D₂)**	0	4.382E-02	6.845E-02	7.450E-02	7.895E-02	8.209E-02	8.450 E-02	8.480E-02
	4s 4p⁴4d (³D₂)	0	4.379E-02	6.861E-02	7.471E-02	7.919E-02	8.235E-02	8.488E-02	8.508E-02
	4s 4p⁴4d (³F₂)	0	2.490E-01	3.517E-01	3.777E-01	3.969E-01	4.105E-01	4.209E-01	4.222E-01
	4s4p³4f (³P₂)	0	1.815E-02	4.586E-02	5.333E-02	5.899E-02	6.307E-02	6.625E-02	6.664E-02
4s²4p⁴ (³P₁)	**4s 4p⁴4d (¹D₂)**	0	8.048E-03	1.254E-02	1.365E-02	1.446E-02	1.504E-02	1.548E-02	1.554E-02
	4s 4p⁴4d (¹P₁)	0	2.391E-02	3.697E-02	4.020E-02	4.257E-02	4.425E-02	4.554E-02	4.570E-02
	4s 4p⁴4d (¹F₃)	0	3.781E-04	6.378E-04	7.009E-04	7.473E-04	7.800E-04	8.052E-04	8.083E-04
	4s 4p⁴4d (³F₂)	0	6.048E-02	8.510E-02	9.136E-02	9.598E-02	9.925E-02	1.017E-01	1.020E-01
	4s 4p⁴4d (³F₃)	0	1.328E-01	1.827E-01	1.955E-01	2.049E-01	2.116E-01	2.167E-01	2.173E-01
	4s²4p³4f (³D₁)	0	8.856E-03	2.157E-01	2.498E-01	2.756E-01	2.942E-01	3.086E-01	3.104E-01
	4s²4p³4f (³P₂)	0	1.797E-01	4.491E-01	5.221E-01	5.773E-01	6.173E-01	6.484E-01	6.522E-01
	4s²4p³4f (³G₃)	0	3.412E-02	5.014E-02	5.079E-02	5.110E-02	5.128E-02	5.139E-02	5.141E-02
	4s²4p³4f (³D₃)	0	2.515E-01	5.165E-01	5.822E-01	6.311E-01	6.660E-01	6.930E-01	6.963E-01
4s²4p⁴ (¹D₂)	**4s 4p⁴4d (¹D₂)**	0	9.494E-02	1.419E-01	1.536E-01	1.623E-01	1.684E-01	1.731E-01	1.737E-01
	4s 4p⁴4d (³D₂)	0	9.494E-02	1.419E-01	1.536E-01	1.623E-01	1.684E-01	1.731E-01	1.737E-01
	4s 4p⁴4d (¹P₁)	0	1.327E-01	1.962E-01	2.121E-01	2.238E-01	2.321E-01	2.384E-01	2.392E-01
	4s 4p⁴4d (¹F₃)	0	4.750E-01	7.562E-01	8.252E-01	8.759E-01	9.118E-01	9.393E-01	9.426E-01
	4s 4p⁴4d (¹G₄)	0	8.684E-01	1.296E+0	1.403E+0	1.481E+0	1.537E+0	1.580E+0	1.585E+0
	4s²4p³4f (³D₁)	0	6.633E-03	1.478E-02	1.700E-02	1.867E-02	1.988E-02	2.082E-02	2.094E-02
4s²4p⁴ (³P₂)	**4s4p⁴4d (¹D₂)**	0	1.611E-01	2.658E-01	2.911E-01	3.098E-01	3.230E-01	3.331E-01	3.343E-01
	4s4p⁴4d (³D₂)	0	9.814E-03	1.416E-02	1.526E-02	1.608E-02	1.665E-02	1.710E-02	1.715E-02
	4s4p⁴4d (¹P₁)	0	8.167E-02	1.334E-01	1.460E-01	1.553E-01	1.618E-01	1.668E-01	1.675E-01
	4s4p⁴4d (¹F₃)	0	3.289E-02	5.938E-02	6.569E-02	7.031E-02	7.358E-02	7.608E-02	7.639E-02
	4s4p⁴4d (³F₂)	0	8.674E-05	1.294E-04	1.403E-04	1.484E-04	1.542E-04	1.586E-04	1.592E-04
	4s4p⁴4d (³F₃)	0	3.407E-01	4.876E-01	5.247E-01	5.521E-01	5.715E-01	5.863E-01	5.882E-01
4s²4p⁴ (¹S₀)	**4s 4p⁴4d (¹D₂)**	0	1.899E-02	2.602E-02	2.782E-02	2.914E-02	3.008E-02	3.080E-02	3.089E-02
	4s 4p⁴4d (³D₂)	0	1.899E-02	2.602E-02	2.782E-02	2.914E-02	3.008E-02	3.080E-02	3.089E-02

Table 14. Collision Strengths of transitions of **Tc X** ion.

Lower	Upper	Incident Energy (eV)							
		50	100	200	300	500	1000	5000	10000
4s²4p⁴ (³P₀)	**4s 4p⁴4d (¹D₂)**	0	3.507E-02	6.252E-02	6.857E-02	7.296E-02	7.604E-02	7.838E-02	7.867E-02
	4s 4p⁴4d (³D₂)	0	3.497E-02	6.262E-02	6.871E-02	7.313E-02	7.623E-02	7.859E-02	7.888E-02
	4s 4p⁴4d (³F₂)	0	1.980E-01	3.055E-01	3.304E-01	3.486E-01	3.614E-01	3.711E-01	3.723E-01
	4s4p³4f (³P₂)	0	3.507E-02	6.252E-02	6.857E-02	7.296E-02	7.604E-02	7.838E-02	7.867E-02
4s²4p⁴ (³P₁)	**4s 4p⁴4d (¹D₂)**	0	6.239E-03	1.099E-02	1.204E-02	1.281E-02	1.335E-02	1.375E-02	1.381E-02
	4s 4p⁴4d (¹P₁)	0	2.004E-02	3.485E-02	3.815E-02	4.055E-02	4.223E-02	4.352E-02	4.367E-02
	4s 4p⁴4d (¹F₃)	0	5.188E-05	1.030E-04	1.137E-04	1.214E-04	1.268E-04	1.310E-04	1.315E-04

	$4s4p^44d\ (^3F_2)$	0	6.337E-02	9.674E-02	1.045E-01	1.102E-01	1.142E-01	1.172E-01	1.176E-01
	$4s4p^44d\ (^3F_3)$	0	9.712E-02	1.432E-01	1.541E-01	1.620E-01	1.676E-01	1.719E-01	1.724E-01
	$4s^24p^34f\ (^3D_1)$	0	3.904E-02	1.958E-01	2.306E-01	2.564E-01	2.748E-01	2.891E-01	2.908E-01
	$4s^24p^34f\ (^3P_2)$	0	7.417E-02	4.026E-01	4.759E-01	5.305E-01	5.695E-01	5.997E-01	6.035E-01
	$4s^24p^34f\ (^3G_3)$	0	1.382E-02	3.270E-02	3.300E-02	3.303E-02	3.304E-02	3.304E-02	3.305E-02
	$4s^24p^34f\ (^3D_3)$	0	1.340E-01	4.419E-01	5.036E-01	5.487E-01	5.805E-01	6.048E-01	6.078E-01
$4s^24p^4\ (^1D_2)$	$4s4p^44d\ (^1D_2)$	0	5.873E-02	9.725E-02	1.060E-01	1.124E-01	1.169E-01	1.203E-01	1.207E-01
	$4s4p^44d\ (^3D_2)$	0	5.873E-02	9.725E-02	1.060E-01	1.124E-01	1.169E-01	1.203E-01	1.207E-01
	$4s4p^44d\ (^1P_1)$	0	9.484E-02	1.545E-01	1.681E-01	1.779E-01	1.849E-01	1.901E-01	1.908E-01
	$4s4p^44d\ (^1F_3)$	0	3.880E-01	7.131E-01	7.844E-01	8.361E-01	8.724E-01	9.001E-01	9.034E-01
	$4s4p^44d\ (^1G_4)$	0	6.659E-01	1.106E+0	1.206E+0	1.278E+0	1.329E+0	1.368E+0	1.373E+0
	$4s^24p^34f\ (^3D_1)$	0	2.831E-03	1.005E-02	1.174E-02	1.300E-02	1.390E-02	1.459E-02	1.468E-02
$4s^24p^4\ (^3P_2)$	$4s4p^44d\ (^1D_2)$	0	1.227E-01	2.403E-01	2.656E-01	2.839E-01	2.967E-01	3.064E-01	3.076E-01
	$4s4p^44d\ (^3D_2)$	0	7.174E-03	1.137E-02	1.234E-02	1.305E-02	1.355E-02	1.393E-02	1.398E-02
	$4s4p^44d\ (^1P_1)$	0	6.909E-02	1.329E-01	1.466E-01	1.566E-01	1.636E-01	1.690E-01	1.696E-01
	$4s4p^44d\ (^1F_3)$	0	1.962E-02	4.595E-02	5.136E-02	5.527E-02	5.801E-02	6.009E-02	6.035E-02
	$4s4p^44d\ (^3F_2)$	0	9.366E-04	1.539E-03	1.677E-03	1.778E-03	1.848E-03	1.902E-03	1.909E-03
	$4s4p^44d\ (^3F_3)$	0	2.815E-01	4.420E-01	4.791E-01	5.061E-01	5.250E-01	5.395E-01	5.413E-01
$4s^24p^4\ (^1S_0)$	$4s4p^44d\ (^1D_2)$	0	1.255E-02	1.834E-02	1.970E-02	2.071E-02	2.140E-02	2.194E-02	2.204E-02
	$4s4p^44d\ (^3D_2)$	0	1.258E-02	1.835E-02	1.973E-02	2.070E-02	2.141E-02	2.193E-02	2.200E-02

Table 15. Collision Strengths of transitions of **Ru XI ion**

Lower	Upper	Incident Energy (eV)							
		50	100	200	300	500	1000	5000	10000
$4s^24p^4\ (^3P_0)$	$4s4p^44d\ (^1D_2)$	0	1.654E-02	4.872E-02	5.438E-02	5.841E-02	6.122E-02	6.334E-02	6.360E-02
	$4s4p^44d\ (^3D_2)$	0	1.129E-03	1.900E-03	2.061E-03	2.177E-03	2.258E-03	2.319E-03	2.326E-03
	$4s4p^44d\ (^3F_2)$	0	1.501E-01	2.685E-01	2.926E-01	3.100E-01	3.221E-01	3.313E-01	3.325E-01
	$4s4p^34f\ (^3P_2)$	0	1.815E-02	4.586E-02	5.333E-02	5.899E-02	6.307E-02	6.625E-02	6.665E-02
$4s^24p^4\ (^3P_1)$	$4s4p^44d\ (^1D_2)$	0	1.647E-03	4.480E-03	4.979E-03	5.335E-03	5.583E-03	5.770E-03	5.793E-03
	$4s4p^44d\ (^1P_1)$	0	1.497E-02	3.223E-02	3.554E-02	3.791E-02	3.956E-02	4.081E-02	4.097E-02
	$4s4p^44d\ (^1F_3)$	0	7.165E-04	2.212E-03	2.470E-03	2.654E-03	2.782E-03	2.878E-03	2.890E-03
	$4s4p^44d\ (^3F_2)$	0	4.434E-02	9.561E-02	1.054E-02	1.125E-02	1.174E-02	1.212E-02	1.216E-02
	$4s4p^44d\ (^3F_3)$	0	6.886E-02	1.130E-01	1.223E-01	1.290E-01	1.337E-01	1.373E-01	1.377E-01
	$4s^24p^34f\ (^3D_1)$	0	0.000E+00	1.754E-01	2.102E-01	2.356E-01	2.536E-01	2.673E-01	2.690E-01
	$4s^24p^34f\ (^3P_2)$	0	0.000E+00	3.372E-01	4.057E-01	4.559E-01	4.913E-01	5.185E-01	5.218E-01
	$4s^24p^34f\ (^3G_3)$	0	0.000E+00	2.177E-02	2.223E-02	2.227E-02	2.232E-02	2.237E-02	2.238E-02
	$4s^24p^34f\ (^3D_3)$	0	0.000E+00	3.786E-01	4.365E-01	4.779E-01	5.068E-01	5.287E-01	5.314E-01
$4s^24p^4\ (^1D_2)$	$4s4p^44d\ (^1D_2)$	0	2.036E-01	4.641E-01	5.131E-01	5.481E-01	5.724E-01	5.909E-01	5.931E-01
	$4s4p^44d\ (^3D_2)$	0	3.081E-03	4.807E-03	5.189E-03	5.466E-03	5.659E-03	5.807E-03	5.825E-03
	$4s4p^44d\ (^1P_1)$	0	6.327E-02	1.215E-01	1.331E-01	1.414E-01	1.472E-01	1.515E-01	1.521E-01
	$4s4p^44d\ (^1F_3)$	0	2.665E-01	6.574E-01	7.294E-01	7.809E-01	8.167E-01	8.438E-01	8.471E-01
	$4s4p^44d\ (^1G_4)$	0	4.691E-01	9.420E-01	1.034E+0	1.101E+0	1.147E+00	1.182E+00	1.187E+00
	$4s^24p^34f\ (^3D_1)$	0	0.000E+00	5.694E-03	6.769 E-03	7.555E-03	8.110E-03	8.536E-03	8.589E-03
$4s^24p^4\ (^3P_2)$	$4s4p^44d\ (^1D_2)$	0	5.020E-03	9.328E-03	1.020E-02	1.083E-02	1.127E-02	1.160E-02	1.164E-02
	$4s4p^44d\ (^3D_2)$	0	4.695E-02	1.304E-01	1.453E-01	1.559E-01	1.632E-01	1.688E-01	1.695E-01
	$4s4p^44d\ (^1P_1)$	0	1.506E-03	3.005E-03	3.303E-03	3.516E-03	3.665E-03	3.778E-03	3.792E-03
	$4s4p^44d\ (^1F_3)$	0	2.176E-01	3.998E-01	4.366E-01	4.631E-01	4.816E-01	4.956E-01	4.973E-01
	$4s4p^44d\ (^3F_2)$	0	4.108E-01	7.278E-01	7.927E-01	8.394E-01	8.720E-01	8.968E-01	8.998E-01
	$4s4p^44d\ (^3F_3)$	0	1.469E-02	4.558E-02	5.096E-02	5.480E-02	5.747E-02	5.949E-02	5.974E-02
$4s^24p^4\ (^1S_0)$	$4s4p^44d\ (^1D_2)$	0	1.835E-02	3.207E-02	3.490E-02	3.693E-02	3.835E-02	3.942E-02	3.956E-02
	$4s4p^44d\ (^3D_2)$	0	8.555E-04	1.172E-03	1.243E-03	1.294E-03	1.330E-03	1.357E-03	1.360E-03

Table 16. Collision Strengths of transitions of **Rh XII ion**

Lower	Upper	Incident Energy (eV)							
		50	100	200	300	500	1000	5000	10000
$4s^24p^4\ (^3P_0)$	$4s4p^44d\ (^1D_2)$	0	4.382E-02	6.845E-02	7.450E-02	7.895E-02	8.210E-02	8.450E-02	8.480E-02
	$4s4p^44d\ (^3D_2)$	0	4.379E-02	6.861E-02	7.471E-02	7.919E-02	8.235E-02	8.478E-02	8.508E-02
	$4s4p^44d\ (^3F_2)$	0	2.940 E-01	3.517E-01	3.777E-01	3.969E-01	4.105E-01	4.210E-01	4.223E-01
	$4s4p^34f\ (^3P_2)$	0	5.622E-02	6.933E-02	7.530E-02	8.529E-02	8.844E-02	9.029E-02	9.090E-02
$4s^24p^4\ (^3P_1)$	$4s4p^44d\ (^1D_2)$	0	8.048E-03	1.254E-02	1.365E-02	1.446E-02	1.504E-02	1.548E-02	1.553E-02
	$4s4p^44d\ (^1P_1)$	0	2.392E-02	3.697E-02	4.020E-02	4.258E-02	4.425E-02	4.554E-02	4.570E-02
	$4s4p^44d\ (^1F_3)$	0	3.781E-04	6.378E-04	7.009E-04	7.473E-04	7.800E-04	8.052E-04	8.083E-04
	$4s4p^44d\ (^3F_2)$	0	6.048E-02	8.510E-02	9.136E-02	9.598E-02	9.925E-02	1.017E-02	1.021E-02
	$4s4p^44d\ (^3F_3)$	0	1.328E-01	1.827E-01	1.955E-01	2.049E-01	2.116E-01	2.167E-01	2.173E-01

	$4s^24p^34f\,(^3D_1)$	0	0.000E+00	1.553E-01	1.897E-01	2.144E-01	2.316E-01	2.447E-01	2.463E-01
	$4s^24p^34f\,(^3P_2)$	0	0.000E+00	2.784E-01	3.415E-01	3.867E-01	4.183E-01	4.424E-01	4.453E-01
	$4s^24p^34f\,(^3G_3)$	0	0.000E+00	1.495E-02	1.590E-02	1.612E-02	1.630E-02	1.646E-02	1.647E-02
	$4s^24p^34f\,(^3D_3)$	0	0.000E+00	3.251E-01	3.797E-01	4.177E-01	4.438E-01	4.635E-01	4.659E-01
$4s^24p^4$ ($^1D_2$)	$4s\,4p^44d\,(^1D_2)$	0	2.036E-01	4.641E-01	5.131E-01	5.353E-01	5.481E-01	5.724E-01	5.840E-01
	$4s\,4p^44d\,(^3D_2)$	0	2.222E-03	4.025E-03	4.374E-03	4.623E-03	4.796E-03	4.927E-03	4.943E-03
	$4s\,4p^44d\,(^1P_1)$	0	3.477E-02	9.556E-02	1.054E-01	1.123E-01	1.172E-01	1.208E-01	1.212E-01
	$4s\,4p^44d\,(^1F_3)$	0	0.000E+00	5.947E-01	6.661E-01	7.163E-01	7.509E-01	7.770E-01	7.802E-01
	$4s\,4p^44d\,(^1G_4)$	0	2.477E-01	8.014E-01	8.876E-01	9.485E-01	9.907E-01	1.022E+00	1.026E+00
	$4s^24p^34f\,(^3D_1)$	0	0.000E+00	2.522E-03	3.056E-03	3.439E-03	3.706E-03	3.910E-03	3.936E-03
$4s^24p^4$ ($^3P_2$)	$4s4p^44d\,(^1D_2)$	0	1.611E-01	2.658E-01	2.911E-01	3.098E-01	3.230E-01	3.331E-01	3.343E-01
	$4s4p^44d\,(^3D_2)$	0	3.005E-03	7.899E-03	8.715E-03	9.293E-03	9.693E-03	9.99E-03	1.003E-02
	$4s4p^44d\,(^1P_1)$	0	3.289E-02	5.938E-02	6.569E-02	7.031E-02	7.358E-02	7.608E-02	7.639E-02
	$4s4p^44d\,(^1F_3)$	0	1.183E-03	3.978E-03	4.413E-03	4.721E-03	4.933E-03	5.094E-03	5.113E-03
	$4s4p^44d\,(^3F_2)$	0	1.339E-01	3.610E-01	3.976E-01	4.235E-01	4.414E-01	4.550E-01	4.566E-01
	$4s4p^44d\,(^3F_3)$	0	2.752E-01	6.501E-01	7.138E-01	7.590E-01	7.902E-01	8.138E-01	8.167E-01
$4s^24p^4$ ($^1S_0$)	$4s\,4p^44d\,(^1D_2)$	0	1.164E-02	2.579E-02	2.824E-02	2.998E-02	3.118E-02	3.209E-02	3.220E-02
	$4s\,4p^44d\,(^3D_2)$	0	1.899E-02	2.602E-02	2.782E-02	2.915E-02	3.008E-02	3.080E-02	3.089E-02

4. Conclusions

Accurate and large-scale calculations have been carried out for the set of fine structure energy levels and transition probabilities for Se-Like Mo, Tc, Ru and Rh ions. The set of results for energy levels are comparable with the a available experimental measurements. We report energy levels and radiative rates for forbidden transitions with the fully relativistic mutliconfiguration Dirac-Fock method. In this paper we report the first set of theoretical energies**,** wavelengths, transition probabilities, radiative lifetimes and collision strengths for Se-Like Mo, Tc, Ru and Rh ions for forbidden transitions. Hopefully, they will help in line identification in future experimental work.

Our results from the present work should be particularly useful in the analysis of X-ray and Extreme Ultraviolet spectra from astrophysical and laboratory sources where non-local thermodynamic equilibrium (NLTE) atomic models with many excited levels are needed.

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