

Energy Levels, Oscillator Strengths, and Transition Probabilities of Ni XIX and Cu XX

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Abstract

Energy levels, oscillator strengths, and transition probabilities, for the $1s^2 2s^2 2p^6$, $2p^5 3l$ ($l = 0, 1, 2$), $2p^5 4l$ ($l = 0, 1, 2, 3$) states in Ni XIX and Cu XX are calculated using COWAN code. The Correlation and relativistic effects are considered. The calculations are compared with other results in the literature. A good agreement is found. We also report on some unpublished energy values.

Keywords

Energy Levels; Oscillator Strengths; Transition Probabilities

1. Introduction

Almost coincident with the first observations of laser action in the IR and visible spectral regions in the 1960s, the search started for lasers operating at much shorter wavelengths. Measurements of definitive high output las- ing at wavelength shorter than the ultra-violet were elusive, until the mid 1980s when conclusive evidence for “X-ray laser” operating at 209 Å was produced from neon-like selenium [1].

In recent years, due to their peculiar structure of closed shells, Ne-like ions have been widely applied in the laboratory and in astronomical plasmas. The laboratory application is shown by the successful X-ray laser in the energy level of $2p^5 3p - 2p^5 3s$ of Ne-like ions based on the mechanism of collisional excitation of electros [2]. Since the 1990s, much progress in experimental techniques has been achieved, but experimental data of atomic parameters are still limited, and theoretical calculations are needed.

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Laser produced plasmas are now well-known as suitable lasant media for amplification of soft X-ray energy range of electromagnetic spectrum. There are several schemes proposed and examined for producing laser plasma condition for X-ray lasing at shorter wavelengths with increasing efficiency. Plasma based recombination lasers [3] collisionally pumped [2] [3] are examples of such schemes. The dynamics of laser-produced plasma parameters such as the electron and ion temperatures and the density can be modeled by fluid hydrodynamic codes. Some examples of hydrodynamic codes include MEDUSA [4], and LASNEX [5]. Plasma transient collisionally pumped, using picosecond Chirped pulse amplification (CPA), X-ray lasers [6], using a capillary discharge [7], a free electron laser [8], optical field ionization of a gas cell [9] are also examples of such schemes. Among various pumping techniques for the X-ray lasers, the collisional pumping of different materials in the Ne-like ionization state between the 3p-3s energy levels has shown a more stable and higher output.

The purpose of this work is to present the results of our calculations of energy levels, oscillator strengths, and transition probabilities of Ni XIX and Cu XX ions, and to compare the results with other in literature data.

2. Computation of Atomic Structures

2.1. Model of Central Force Field

In quantum mechanics, various physical processes can be summed by Schrödinger equation, *i.e.*

$$H\Psi_i = E_i\Psi_i. \quad (1)$$

In the non-relativistic case (the influence of relativistic effect will be discussed later), the Hamiltonian of an atomic system with N electrons is:

$$H = H_{kin} + H_{e-nuc} + H_{e-e} = \sum_i \frac{\hbar^2}{2m_e} \nabla_i^2 - \sum_i \frac{Ze^2}{r_i} + \sum_{i>j} \frac{e^2}{r_{ij}}. \quad (2)$$

Here H_{kin} , H_{e-nuc} and H_{e-e} refer, respectively, to the kinetic energy of electrons, the Coulomb potential and the energy of electrostatic interaction of electrons, r_i is the distance between the i -th electron and nucleus, and $r_{ij} = |r_i - r_j|$.

By substituting the Hamiltonian into Schrödinger equation and solving the equation in the case of multiple electrons and multiple energy levels, the wave function is obtained. Now, due to the appearance of the term of interaction of electrons, an exact solution cannot be obtained. On the other hand, the interaction term is comparable with the Coulomb potential term, so it can by no means be ignored. An approximate solution is to adopt the method of central force field. If it is assumed that every electron moves in the central force field of the nucleus and also in the mean force field produced by other electrons, then we have the following effective Hamiltonian:

$$H^{eff} = \sum_i^N H_i^{eff} = -\sum_{i=1}^N \left[\frac{1}{2} \frac{p_i^2}{m_e} + \frac{Ze^2}{r_i} - V_i^{eff}(r_i) \right]. \quad (3)$$

2.2. Method of Calculation

The key problem in the application of central field is to find an adequate potential function V^{eff} . For this, in recent decades many effective method of calculation have been developed. Among them the more important ones are the potential model, Hartree-Fock theory, and the semi-empirical methods. In the following we present a brief introduction of semi-empirical methods.

Semi-empirical methods try to calculate atomic structures via solving the simplified form of the Hartree-Fock equation. The most typical is the Hartree-Fock-Slater method. Afterwards, Cowan *et al.* revised this method and developed the RCN/RCG program used in our work [10]. The merit of the program is its extreme effectiveness, and the shortcoming is its inability to estimate the precision.

2.3. Configuration Interaction

In the above-stated model of central force field, every electron can be described with a simple wave function. The overall wave function of atoms may be expressed with the following Slater determinant:

$$\Phi = \frac{1}{\sqrt{N!}} \begin{pmatrix} \varphi_1(\chi_1) & \dots & \varphi_1(\chi_N) \\ \vdots & \ddots & \vdots \\ \varphi_N(\chi_1) & \dots & \varphi_N(\chi_N) \end{pmatrix}. \quad (4)$$

In reality, such a description is not very precise. The best wave function should be a linear combination of wave functions with single configurations, and these wave functions possess the same total angular momentum and spin symmetry. This method is called the interaction of configurations. In the computation of atomic structures, consideration of the configuration interaction is the basis requirement for a program.

2.4. Relativistic Correction

In a non-relativistic system, the oscillator strengths and dipole transitions under LS-coupling can be calculated. In calculating forbidden transitions, jj-coupling must be used, and for this relativistic effects have to be taken into account. Generally speaking, the effects may be treated in two ways. One is inclusion of Breit-Pauli operator in the non-relativistic equation, and other is direct solution of the Dirac equation. For the former, a mass velocity term, the Darwin term caused by the electric moments of electrons and the spin-orbit term are added to the Hamiltonian of the model of central force field [11]. For relativistic correction, the program RCN/RCCG restore to the Breit-Pauli correction.

2.5. Weighted Oscillator Strengths and Lifetimes

The oscillator strength $f(\gamma\gamma')$ is a physical quantity related to line intensity I and transition probability $W(\gamma\gamma')$, by

$$W(\gamma\gamma') = \frac{2w^2 e^2}{mc^3} |f(\gamma\gamma')| \quad (5)$$

with, $I \propto gW(\gamma\gamma') \propto g|f(\gamma\gamma')| = gf$ Sobelman [12].

Here m is electron mass, e is electron charge, γ is initial quantum state, $w = (E(\gamma) - E(\gamma'))/\hbar$, $E(\gamma)$ initial state energy, $g = (2J + 1)$ is the number of degenerate quantum state with angular momentum J (in the formula for initial state).

Quantities with primes refer to the final state.

In the above equation, the weighted oscillator strength, gf , is given by Cowan [10]:

$$gf = \frac{8\pi^2 m c a_0^2 \sigma}{3h} S, \quad (6)$$

where g is the statistical weight of lower level, f is the absorption oscillator strength, $\sigma = (E(\gamma) - E(\gamma'))/hc$, h is planck's constant, c is light velocity, and a_0 is Bohr radius, and the electric dipole line strength is defined by:

$$S = \left| \langle \lambda J \| P^1 \| \gamma' J' \rangle \right|^2. \quad (7)$$

This quantity is a measure of the total strength of the spectral line, including all possible transitions between m, m' , for different J_z Eigen states. The tensor operator P^1 (first order) in the reduced matrix element is the classical dipole moment for the atom in units of ea_0 .

To obtain gf , we need to calculate S first, (or its square root):

$$S_{\gamma\gamma'}^{1/2} = \left| \langle \lambda J \| P^1 \| \gamma' J' \rangle \right|. \quad (8)$$

In a multiconfiguration calculation we have to expand the wave function $|\gamma J\rangle$ for both upper and lower levels $|\beta J\rangle$.

In terms of single configuration wave functions, lower levels:

$$|\gamma J\rangle = \sum_{\beta} y_{\beta J}^{\gamma} |\beta J\rangle. \quad (9)$$

Therefore, we can have the multiconfigurational expression for the square root of line strength:

$$s_{\gamma^J}^{1/2} = \sum_{\beta} \sum_{\beta'} y_{\beta J}^{\gamma} \langle \beta J \parallel P^1 \parallel \beta' J' \rangle. \quad (10)$$

The probability per unit time of an atom in specific state γJ to make a spontaneous transition to any state with lower energy is

$$P(\gamma J) = \sum A(\gamma J, \gamma' J') \quad (11)$$

where $A(\gamma J, \gamma' J')$ is the Einstein spontaneous emission transition state. $\gamma' J'$ to γJ probability rate, for a transition from the

The sum is over all states $\gamma' J'$ with $E(\gamma' J') < E(\gamma J)$.

The Einstein probability rate is related to gf with the following relation [13]:

$$gA = \frac{8\pi^2 e^2 \sigma^2}{mc} gf. \quad (12)$$

Since the natural lifetime $\tau(\gamma J)$ is the inverse of transition probability, then:

$$\tau(\gamma J) = \left(\sum A(\gamma J, \gamma' J') \right)^{-1} \quad (13)$$

This is applicable to an isolated atom.

Interaction with matter or radiation will reduce the lifetime of any state.

3. Results and Discussions

Adopting the program RCN/RCG [10], we have computed the parameters of atomic structures of Ni XIX and Cu XX respectively. The energy levels considered in the calculation have 65 fine structures ranging from ground state $1s^2 2s^2 2p^6$ to $2p^5 3l$ ($l = 0, 1, 2$) and $2p^5 4l$ ($l = 0, 1, 2, 3$) states. Our computation has yielded the energy level intervals of electric dipolar spectral transitions, oscillator strengths and transition probabilities. In our calculations of wave functions, the relativistic correction is taken into consideration. Our results are presented in **Tables 1-6**. Some new and previously unpublished energy levels are given in energy level tables.

Table 1. The Hartree-Fock parameters and fitted parameters for energy levels of Ni XIX.

parameter	HF	LSF	LSF/HF
$E_{av} 2p^6$	2.142	2.1383	0.998273
$E_{av} 2p^5 3p$	7485.004	7482.363	0.999647
$\zeta_{(2p)}$	95.988	94.7867	0.987485
$\zeta_{(3p)}$	21.438	22.2906	1.039771
$F^2(2p 3p)$	94.276	125.4261	1.330414
$G^0(2p 3p)$	37.202	42.9558	1.154664
$G^2(2p 3p)$	40.74	48.8414	1.198856
$E_{av} 2p^5 4p$	9768.31	9768.302	0.999999
$\zeta_{(2p)}$	96.282	96.2777	0.999955
$\zeta_{(4p)}$	8.556	8.5566	1.00007
$F^2(2p 4p)$	34.073	34.0829	1.000291
$G^0(2p 4p)$	11.939	11.933	0.999497
$G^2(2p 4p)$	14.164	14.1784	1.001017
$E_{av} 2p^5 4f$	9988.381	9988.391	1.000001
$\zeta_{(2p)}$	96.451	96.449	0.999979
$\zeta_{(4f)}$	0.289	0.2877	0.995502
$F^2(2p 4f)$	23.94	23.8338	0.995564
$G^2(2p 4f)$	4.747	4.6954	0.98913
$G^4(2p 4f)$	3.079	3.0733	0.998149
$E_{av} 2p^5 3s$	7161.305	7159.783	0.999787
$\zeta_{(2p)}$	95.984	94.8994	0.9887
$G^1(2p 3s)$	36.478	41.7018	1.143204

Continued

$E_{av}2p^5 3d$	7892.665	7889.081	0.999546
$\zeta_{(2p)}$	96.035	95.2727	0.992062
$\zeta_{(3d)}$	2.508	2.3254	0.927193
$F^2(2p\ 3d)$	120.269	142.4402	1.184347
$G^1(2p\ 3d)$	109.368	115.0901	1.05232
$G^3(2p\ 3d)$	63.043	71.8264	1.139324
$E_{av}2p^5 4s$	9638.228	9634.162	0.999578
$\zeta_{(2p)}$	96.289	93.9094	0.975287
$G^1(2p\ 4f)$	12.077	0	0
$E_{av}2p^5 4d$	9920.106	9915.483	0.999534
$\zeta_{(2p)}$	96.306	93.9707	0.975751
$\zeta_{(4d)}$	1.075	0.6049	0.562698
$F^2(2p\ 4d)$	42.438	66.6911	1.571495
$G^1(2p\ 4d)$	39.057	32.991	0.844689
$G^3(2p\ 4d)$	23.303	11.5745	0.496696

Table 2. The Hartree-Fock parameters and fitted parameters for energy levels of Cu XX.

parameter	HF	LSF	LSF/HF
$E_{av}2p^6$	2.138	2.1348	0.998503
$E_{av}2p^5 3p$	8186.271	8183.26	0.999632
$\zeta_{(2p)}$	112.683	111.043	0.985446
$\zeta_{(3p)}$	25.51	25.9186	1.016017
$F^2(2p\ 3p)$	99.216	138.302	1.393949
$G^0(2p\ 3p)$	39.1	45.3771	1.16054
$G^2(2p\ 3p)$	42.91	45.7448	1.066064
$E_{av}2p^5 4p$	10699.49	10699.48	0.999999
$\zeta_{(2p)}$	113.019	113.013	0.999947
$\zeta_{(4p)}$	10.204	10.2041	1.00001
$F^2(2p\ 4p)$	35.938	35.9537	1.000437
$G^0(2p\ 4p)$	12.541	12.5361	0.999609
$G^2(2p\ 4p)$	14.926	14.938	1.000804
$E_{av}2p^5 4f$	10933.57	10933.58	1.000001
$\zeta_{(2p)}$	113.213	113.2098	0.999972
$\zeta_{(4f)}$	0.354	0.3533	0.998023
$F^2(2p\ 4f)$	25.631	25.5072	0.99517
$G^2(2p\ 4f)$	5.185	5.1263	0.988679
$G^4(2p\ 4f)$	3.364	3.3573	0.998008
$E_{av}2p^5 3s$	7842.324	7840.28	0.999739
$\zeta_{(2p)}$	112.68	111.1721	0.986618
$G^1(2p\ 3s)$	38.31	44.2347	1.154652
$E_{av}2p^5 3d$	8616.991	8613.123	0.999551
$\zeta_{(2p)}$	112.733	111.6444	0.990344
$\zeta_{(3d)}$	3.052	2.5801	0.84538
$F^2(2p\ 3d)$	127.306	160.6774	1.262135
$G^1(2p\ 3d)$	116.36	126.6669	1.088578
$G^3(2p\ 3d)$	67.105	66.6409	0.993084
$E_{av}2p^5 4s$	10560.94	10558.6	0.999778
$\zeta_{(2p)}$	113.028	110.7571	0.979909
$G^1(2p\ 4f)$	12.704	0	0
$E_{av}2p^5 4d$	10860.24	10859.29	0.999912
$\zeta_{(2p)}$	113.046	113.2196	1.001536
$\zeta_{(4d)}$	1.307	1.7952	1.373527
$F^2(2p\ 4d)$	44.878	48.0615	1.070937
$G^1(2p\ 4d)$	41.346	37.5198	0.907459
$G^3(2p\ 4d)$	24.697	27.0868	1.096765

Table 3. The energy levels values in electron volt, the comparison of our data and NIST data (Ref.13), and level composition for Ni XIX.

index	level	J	E(eV)our data	$E_{ref,3}$	Purity	level composition	$E(nist)JKK$	$E(KKour$
1	1S_0	0	0	0	100%		0	0
2	$2p_{3/2}3s_{1/2}$	2	880.92	880.91	100%		7105.26	7105.31
3	$2p_{3/2}3s_{1/2}$	1	883.05	883.06	99%	2P5 3S (2P 1/2) 1/2	7122.6	7122.549
4	$2p_{1/2}3s_{1/2}$	0	898.56	898.57	100%		7247.7	7247.633
5	$2p_{1/2}3s_{1/2}$	1	899.87	899.859	99%	2P5 3S (2P 3/2) 1/2	7258.1	7258.168
6	$2p_{3/2}3p_{1/2}$	1	915.22	915.219	71%	2P5 3P (2P 3/2) 3/2	7381.99	7382.006
7	$2p_{3/2}3p_{1/2}$	2	918.67	918.681	99%		7409.915	7409.863
8	$2p_{3/2}3p_{3/2}$	3	921.39	921.387	100%		7431.735	7431.733
9	$2p_{3/2}3p_{3/2}$	1	922.42	922.417	71%	2P5 3P (2P 3/2) 1/2	7440.05	7440.061
10	$2p_{3/2}3p_{3/2}$	2	924.68	924.675	100%		7458.26	7458.261
11	$2p_{3/2}3p_{3/2}$	0	931.8	931.793	64%	2P5 3P (2P 1/2) 1/2	7515.675	7515.723
12	$2p_{1/2}3p_{1/2}$	1	935.65	935.647	98%	2P5 3P (2P 3/2) 3/2	7546.76	7546.785
13	$2p_{1/2}3p_{3/2}$	1	940.12	940.125	97%	2P5 3P (2P 3/2) 3/2	7582.88	7582.797
14	$2p_{1/2}3p_{3/2}$	2	940.67	940.669	99%		7587.265	7587.307
15	$2p_{1/2}3p_{1/2}$	0	953.5	953.505	64%	2P5 3P (2P 3/2) 3/2	7690.8	7690.795
16	$2p_{3/2}3d_{3/2}$	0	966.78	966.792	100%		7797.965	7797.862
17	$2p_{3/2}3d_{3/2}$	1	968	967.999	76%	2P5 3D (2P 3/2) 5/2	7807.7	7807.748
18	$2p_{3/2}3d_{5/2}$	4	970.18	970.178	100%		7825.28	7825.269
19	$2p_{3/2}3d_{5/2}$	2	970.24	970.239	73%	2P5 3D (2P 3/2) 3/2	7825.77	7825.802
20	$2p_{3/2}3d_{3/2}$	3	970.9	970.879	99%	2P5 3D (2P 1/2) 5/2	7830.93	7831.068
21	$2p_{3/2}3d_{9/2}$	2	972.88	972.883	75%	2P5 3D (2P 3/2) 5/2	7847.1	7847.053
22	$2p_{3/2}3d_{3/2}$	3	974.19	974.19	99%		7857.64	7857.617
23	$2p_{3/2}3d_{5/2}$	1	979.61	979.616	63%	2P5 3D (2P 3/2) 3/2	7901.4	7901.358
24	$2p_{1/2}3d_{3/2}$	2	988.42	988.427	97%	2P5 3D (2P 3/2) 3/2	7972.475	7972.43
25	$2p_{1/2}3d_{5/2}$	2	989.48	989.461	96%	2P5 3D (2P 3/2) 5/2	7980.81	7980.937
26	$2p_{1/2}3d_{5/2}$	3	990.17	990.184	99%	2P5 3D (2P 3/2) 3/2	7986.64	7986.548
27	$2p_{1/2}3d_{3/2}$	1	997.02	997.022	86%	2P5 3D (2P 3/2) 5/2	8041.8	8041.817
28	$2p_{3/2}4s_{1/2}$	2	1188.6		100%		9587.206	0.864235
29	$2p_{3/2}4s_{1/2}$	1	1188.6	1188.35	100%		9585	9587.233
30	$2p_{3/2}4p_{1/2}$	1	1203.3		83%	2P5 4P (2P 3/2) 3/2	9705.696	-0.001407
31	$2p_{3/2}4p_{1/2}$	2	1204		100%		9710.857	0.002569
32	$2p_{3/2}4p_{3/2}$	3	1205.1		100%		9720.159	0.002717
33	$2p_{3/2}4p_{3/2}$	1	1205.4		83%	2P5 4P (2P 3/2) 1/2	9722.642	0.001248
34	$2p_{3/2}4p_{3/2}$	2	1206.1		100%		9727.886	-0.000857
35	$2p_{1/2}4s_{1/2}$	0	1206.1		100%		9728.051	4.433975

Continued

36	$2p_{1/2}4s_{1/2}$	1	1206.1	1205.71	100%	2P5 4P	(2P 1/2) 1/2	9725	9728.065	-3.065185	1.334	2P5 4S				
37	$2p_{3/2}4p_{3/2}$	0	1210.1	95%	5%	2P5 4P	(2P 1/2) 1/2	9760.092	-0.00469	0	2P5 4P					
38	$2p_{3/2}4d_{3/2}$	0	1221.4	100%				9851.711	6.714511	0	2P5 4D					
39	$2p_{1/2}4p_{1/2}$	1	1221.6	100%				9853.245	-0.005022	0.661	2P5 4P					
40	$2p_{3/2}4d_{3/2}$	1	1222	1220.58	75%	25%	2P5 4D	(2P 3/2) 5/2	9845	9856.492	-11.491894	1.379	2P5 4D			
41	$2p_{3/2}4d_{5/2}$	4	1222.7	1222.81	100%			9863	9861.778	1.221512	1.251	2P5 4D				
42	$2p_{3/2}4d_{3/2}$	3	1222.8	1223.08	97%	3%	2P5 4D	(2P 3/2) 5/2	9865.1	9862.613	2.486681	1.044	2P5 4D			
43	$2p_{3/2}4d_{5/2}$	2	1223.1		67%	32%	2P5 4D	(2P 3/2) 3/2	1%	2P5 4D	(2P 1/2) 5/2	2.961005	1.343	2P5 4D		
44	$2p_{1/2}4p_{3/2}$	1	1223.3		100%			9866.518	0.003316	1.479	2P5 4P					
45	$2p_{1/2}4p_{3/2}$	2	1223.5	100%				9868.288	-0.001699	1.168	2P5 4P					
46	$2p_{3/2}4d_{5/2}$	3	1224.4	97%	3%	2P5 4D	(2P 3/2) 3/2	9875.61	1.451479	1.251	2P5 4D					
47	$2p_{3/2}4d_{5/2}$	2	1224.5	67%	32%	2P5 4D	(2P 3/2) 5/2	1%	2P5 4D	(2P 1/2) 3/2	9876.936	-3.628003	0.954	2P5 4D		
48	$2p_{1/2}4p_{1/2}$	0	1225.5	95%	5%	2P5 4P	(2P 3/2) 3/2		9884.651	0.003823	0	2P5 4P				
49	$2p_{3/2}4d_{5/2}$	1	1226.3	1226.29	74%	25%	2P5 4D	(2P 3/2) 3/2	1%	2P5 4D	(2P 1/2) 3/2	9890.778	0.2217	0.8	2P5 4D	
50	$2p_{3/2}4f_{5/2}$	1	1231.8	100%				9935.504	0.002401	0.499	2P5 4F					
51	$2p_{3/2}4f_{7/2}$	2	1232	64%	36%	2P5 4F	(2P 3/2) 5/2		9937.257	0.001282	1.109	2P5 4F				
52	$2p_{3/2}4f_{5/2}$	4	1232.1	98%	2%	2P5 4F	(2P 3/2) 7/2		9938.2	-0.003031	1.026	2P5 4F				
53	$2p_{3/2}4f_{7/2}$	5	1232.2	100%				9938.692	-0.000984	1.2	2P5 4F					
54	$2p_{3/2}4f_{7/2}$	3	1232.5	79%	21%	2P5 4F	(2P 3/2) 5/2		9941.007	-0.00343	1.185	2P5 4F				
55	$2p_{3/2}4f_{5/2}$	2	1232.6	64%	36%	2P5 4F	(2P 3/2) 7/2		9941.685	0.000367	0.845	2P5 4F				
56	$2p_{3/2}4f_{5/2}$	3	1232.7	79%	21%	2P5 4F	(2P 3/2) 7/2		9942.546	0.001509	0.958	2P5 4F				
57	$2p_{3/2}4f_{7/2}$	4	1232.8	98%	2%	2P5 4F	(2P 3/2) 5/2		9943.521	0.001887	1.188	2P5 4F				
58	$2p_{1/2}4d_{3/2}$	2	1240.6	1240.64	79%	20%	2P5 4D	(2P 1/2) 5/2		10006.8	10006.386	0.413551	0.829	2P5 4D		
59	$2p_{1/2}4d_{5/2}$	3	1240.8	1240.25	100%		2P5 4D	(2P 1/2) 3/2	1%	2P5 4D	(2P 3/2) 5/2	10003.6	10008.405	-4.80475	1.123	2P5 4D
60	$2p_{1/2}4d_{5/2}$	2	1241.1	79%	20%	2P5 4D	(2P 1/2) 3/2	1%	2P5 4D	(2P 3/2) 5/2	10023	10010.194	4.244123	1.209	2P5 4D	
61	$2p_{1/2}4d_{3/2}$	1	1242.6	1242.65	99%	1%	2P5 4D	(2P 3/2) 5/2		10023	10022.79	0.21011	0.822	2P5 4D		
62	$2p_{1/2}4f_{5/2}$	3	1250.2	100%					10084.008	0.000589	0.828	2P5 4F				
63	$2p_{1/2}4f_{7/2}$	3	1250.4	100%					10085.112	-0.003092	1.196	2P5 4F				
64	$2p_{1/2}4f_{5/2}$	2	1250.4	100%					10085.192	-0.001234	0.879	2P5 4F				
65	$2p_{1/2}4f_{7/2}$	4	1250.4	100%					10085.312	0.003737	1.087	2P5 4F				

Table 4. The energy levels values in electron volt, the comparison of our data and NIST data (Ref.13), and level composition for Cu XXX.

index	level	J	E(eV)our data	$E_{\text{ref},13}$	Purity	level composition	$E(\text{nist})\text{KK}$	$E(\text{KK})\text{jour}$
1	$^1\text{S}_0$	0	0	0	100%		0	-0.000001
2	$2\text{p}_{3/2}3\text{s}_{1/2}$	2	964.22	964.226	100%		7777.27	2P5 3S
3	$2\text{p}_{3/2}3\text{s}_{1/2}$	1	966.51	966.505	99%	(2P 1/2) 1/2	7795.65	2P5 3S
4	$2\text{p}_{1/2}3\text{s}_{1/2}$	0	984.89	984.891	100%		7943.95	2P5 3S
5	$2\text{p}_{1/2}3\text{s}_{1/2}$	1	986.26	986.267	99%	(2P 3/2) 1/2	7955.05	2P5 3S
6	$2\text{p}_{3/2}3\text{p}_{1/2}$	1	1000.6	1000.6	73%	(2P 3/2) 3/2	8070.68	2P5 3P
7	$2\text{p}_{3/2}3\text{p}_{1/2}$	2	1004	1004.02	99%		8098.27	2P5 3P
8	$2\text{p}_{3/2}3\text{p}_{3/2}$	3	1007.4	1007.41	100%		8125.59	2P5 3P
9	$2\text{p}_{3/2}3\text{p}_{3/2}$	1	1008.3	1008.38	73%	(2P 3/2) 1/2	8133.41	2P5 3P
10	$2\text{p}_{3/2}3\text{p}_{3/2}$	2	1010.9	1010.88	100%		8154.109	2P5 3P
11	$2\text{p}_{3/2}3\text{p}_{3/2}$	0	1019.2		68%	(2P 1/2) 1/2	8220.378	0
12	$2\text{p}_{1/2}3\text{p}_{1/2}$	1	1024	1023.99	99%	(2P 3/2) 3/2	8259.28	0.668 2P5 3P
13	$2\text{p}_{1/2}3\text{p}_{3/2}$	1	1029.3	1029.18	97%	(2P 3/2) 3/2	8301.829	-0.678573 1.43 2P5 3P
14	$2\text{p}_{1/2}3\text{p}_{3/2}$	2	1029.7		100%		8305.661	1.175 2P5 3P
15	$2\text{p}_{1/2}3\text{p}_{1/2}$	0	1042.3	1042.29	67%	(2P 3/2) 3/2	8406.9	0 2P5 3P
16	$2\text{p}_{3/2}3\text{d}_{3/2}$	0	1055	1055.02	100%		8509.56	0 2P5 3D
17	$2\text{p}_{3/2}3\text{d}_{3/2}$	1	1056.4	1056.41	76%	(2P 3/2) 5/2	8520.82	0.0681 1.404 2P5 3D
18	$2\text{p}_{3/2}3\text{d}_{5/2}$	4	1058.8		100%		8540.1	-0.157757 1.251 2P5 3D
19	$2\text{p}_{3/2}3\text{d}_{5/2}$	2	1058.9	1058.88	77%	(2P 3/2) 3/2	8540.75	0.079763 1.374 2P5 3D
20	$2\text{p}_{3/2}3\text{d}_{3/2}$	3	1059.4	1059.41	99%	(2P 1/2) 5/2	8545.04	-0.203202 1.066 2P5 3D
21	$2\text{p}_{3/2}3\text{d}_{3/2}$	2	1061.6	1061.62	79%	(2P 3/2) 5/2	8562.82	0.161452 0.936 2P5 3D
22	$2\text{p}_{3/2}3\text{d}_{5/2}$	3	1063.1	1063.07	100%		8575.117	-0.607484 1.224 2P5 3D
23	$2\text{p}_{3/2}3\text{d}_{5/2}$	1	1069.4	1069.51	65%	(2P 3/2) 3/2	8626.51	0.775707 0.704 2P5 3D
24	$2\text{p}_{1/2}3\text{d}_{3/2}$	2	1080	1080	99%	(2P 3/2) 5/2	8711.11	0.018367 0.799 2P5 3D
25	$2\text{p}_{1/2}3\text{d}_{5/2}$	2	1081.2	1081.16	97%	(2P 3/2) 5/2	8720.4	-0.527922 1.225 2P5 3D
26	$2\text{p}_{1/2}3\text{d}_{5/2}$	3	1081.9	1082	99%	(2P 3/2) 3/2	8727.22	0.72126 1.127 2P5 3D
27	$2\text{p}_{1/2}3\text{d}_{3/2}$	1	1089.5	1089.41	87%	(2P 3/2) 5/2	8787.01	-0.354893 0.892 2P5 3D
28	$2\text{p}_{3/2}4\text{s}_{1/2}$	2	1302.2		100%		10503.218	-0.906939 1.501 2P5 4S
29	$2\text{p}_{3/2}4\text{s}_{1/2}$	1	1302.2		100%		10504	0.754595 1.167 2P5 4S
30	$2\text{p}_{3/2}4\text{p}_{1/2}$	1	1317.5		86%	(2P 3/2) 3/2	10626.857	-0.001781 1.753 2P5 4P
31	$2\text{p}_{3/2}4\text{p}_{1/2}$	2	1318.2		100%		10631.996	0.003262 1.159 2P5 4P
32	$2\text{p}_{3/2}4\text{p}_{3/2}$	3	1319.6		100%		10643.567	0.003806 1.334 2P5 4P
33	$2\text{p}_{3/2}4\text{p}_{3/2}$	1	1319.9		86%	(2P 3/2) 1/2	10645.937	0.001957 1.107 2P5 4P
34	$2\text{p}_{3/2}4\text{p}_{3/2}$	2	1320.6		100%		10651.717	-0.001548 1.341 2P5 4P
35	$2\text{p}_{1/2}4\text{s}_{1/2}$	0	1322.8		100%		10669.331	2.498869 0 2P5 4S

Continued

36	2p _{1/2} 4s _{1/2}	1	1322.8	1322.49	100%			10667	10669.347	-2.346548	1.334	2P5 4S	
37	2p _{3/2} 4p _{3/2}	0	1324.9	96%	4%	2P5 4P	(2P 1/2) 1/2		10686.069	-0.006146	0	2P5 4P	
38	2p _{3/2} 4d _{3/2}	0	1337.1	100%				10783	10784.963	4.181067	0	2P5 4D	
39	2p _{3/2} 4d _{3/2}	1	1337.7	1336.88	82%	2P5 4D	(2P 3/2) 5/2		10789.691	-6.690891	1.334	2P5 4D	
40	2p _{3/2} 4d _{5/2}	2	1338.7	53%	47%	2P5 4D	(2P 3/2) 3/2		10797.849	2.16177	1.314	2P5 4D	
41	2p _{3/2} 4d _{3/2}	3	1338.9	99%	1%	2P5 4D	(2P 3/2) 5/2		10798.956	0.694294	1.083	2P5 4D	
42	2p _{3/2} 4d _{5/2}	4	1338.9	100%				10798.991	-0.307349	1.251	2P5 4D		
43	2p _{1/2} 4p _{1/2}	1	1338.9	100%				10799.353	-0.007123	0.662	2P5 4P		
44	2p _{3/2} 4d _{3/2}	2	1339.7	53%	47%	2P5 4D	(2P 3/2) 5/2		10805.543	-0.487555	0.979	2P5 4D	
45	2p _{3/2} 4d _{5/2}	3	1340.1	99%	1%	2P5 4D	(2P 3/2) 3/2		10809.286	0.000618	1.222	2P5 4D	
46	2p _{1/2} 4p _{3/2}	1	1340.9	100%				10815.081	0.003754	1.48	2P5 4P		
47	2p _{1/2} 4p _{3/2}	2	1341.1	100%				10816.991	-0.001739	1.168	2P5 4P		
48	2p _{3/2} 4d _{5/2}	1	1342.4	1342.46	81%	18%	2P5 4D	(2P 3/2) 3/2	10828	10827.551	0.44864	0.828	2P5 4D
49	2p _{1/2} 4p _{1/2}	0	1342.9	96%	4%	2P5 4P	(2P 3/2) 3/2		10831.513	0.005582	0	2P5 4P	
50	2p _{3/2} 4f _{5/2}	1	1347.9	100%				10871.889	0.003571	0.499	2P5 4F		
51	2p _{3/2} 4f _{7/2}	2	1348.1	62%	38%	2P5 4F	(2P 3/2) 5/2		10873.881	0.001942	1.108	2P5 4F	
52	2p _{3/2} 4f _{5/2}	4	1348.3	98%	2%	2P5 4F	(2P 3/2) 7/2		10874.786	-0.00437	1.026	2P5 4F	
53	2p _{3/2} 4f _{7/2}	5	1348.3	100%				10875.459	-0.001577	1.2	2P5 4F		
54	2p _{3/2} 4f _{7/2}	3	1348.6	76%	24%	2P5 4F	(2P 3/2) 5/2		10877.914	-0.005404	1.183	2P5 4F	
55	2p _{3/2} 4f _{5/2}	2	1348.7	62%	38%	2P5 4F	(2P 3/2) 7/2		10878.604	0.000611	0.846	2P5 4F	
56	2p _{3/2} 4f _{5/2}	3	1348.8	76%	24%	2P5 4F	(2P 3/2) 7/2		10879.467	0.001777	0.96	2P5 4F	
57	2p _{3/2} 4f _{7/2}	4	1349	98%	2%	2P5 4F	(2P 3/2) 5/2		10880.633	0.00345	1.188	2P5 4F	
58	2p _{1/2} 4d _{3/2}	2	1359.7	99%	1%	2P5 4D	(2P 1/2) 5/2		10967.382	0.315222	0.765	2P5 4D	
59	2p _{1/2} 4d _{5/2}	2	1360.1	99%	1%	2P5 4D	(2P 1/2) 3/2		10970.462	0.846102	1.275	2P5 4D	
60	2p _{1/2} 4d _{5/2}	3	1360.6	100%				10974.638	-0.666388	1.113	2P5 4D		
61	2p _{1/2} 4d _{3/2}	1	1361.9	1361.8	99%	1%	2P5 4D	(2P 3/2) 5/2	10984	10984.495	-0.495437	0.838	2P5 4D
62	2p _{1/2} 4f _{5/2}	3	1369.5	100%				11045.798	0.001413	0.828	2P5 4F		
63	2p _{1/2} 4f _{5/2}	2	1369.6	100%				11047.087	-0.001903	0.88	2P5 4F		
64	2p _{1/2} 4f _{7/2}	3	1369.6	100%				11047.132	-0.004474	1.196	2P5 4F		
65	2p _{1/2} 4f _{7/2}	4	1369.7	100%				11047.359	0.004964	1.087	2P5 4F		

Table 5. The allowed electric dipole transitions for Ni XIX.

i	j	$\lambda(\text{\AA})$	gf	Aji
1	3	14.04	1.02E-01	1.2E+12
1	5	13.778	7.93E-02	9.3E+11
1	17	12.808	1.29E-02	1.7E+11
1	23	12.656	9.40E-01	1.3E+13
1	27	12.435	2.32E+00	3.3E+13
1	29	10.431	2.48E-02	5.1E+11
1	36	10.28	1.34E-02	2.8E+11
1	40	10.146	1.34E-02	2.9E+11
1	49	10.11	5.01E-01	1.1E+13
1	61	9.977	3.77E-01	8.4E+12
2	6	361.41	2.76E-01	4.7E+09
2	7	328.35	2.45E-01	3.0E+09
2	8	306.35	7.91E-01	8.0E+09
2	9	298.73	6.12E-03	1.5E+08
2	10	283.33	3.18E-01	5.3E+09
2	12	226.51	3.85E-04	1.7E+07
2	13	209.43	1.26E-02	6.4E+08
2	14	207.47	2.71E-03	8.4E+07
2	30	38.456	2.59E-01	3.9E+11
2	31	38.38	1.98E-01	1.8E+11
2	32	38.243	6.00E-01	3.9E+11
2	33	38.207	5.61E-05	8.5E+07
2	34	38.13	2.17E-01	2.0E+11
2	39	36.391	1.56E-05	2.6E+07
2	44	36.216	3.28E-04	5.6E+08
2	45	36.193	6.43E-05	6.5E+07
2	50	35.333	6.58E-06	1.2E+07
2	51	35.311	7.59E-05	8.1E+07
2	54	35.265	2.51E-04	1.9E+08
2	55	35.256	2.02E-06	2.2E+06
2	56	35.246	8.20E-06	6.3E+06
2	62	33.572	3.71E-06	3.1E+06
2	63	33.559	2.08E-04	1.8E+08
2	64	33.558	1.49E-05	1.8E+07
3	6	385.42	5.16E-03	7.7E+07
3	7	348.05	2.65E-01	2.9E+09
3	9	314.95	3.21E-01	7.2E+09
3	10	297.88	2.70E-01	4.1E+09
3	11	254.34	9.98E-02	1.0E+10
3	12	235.72	9.08E-04	3.6E+07
3	13	217.27	8.09E-05	3.8E+06
3	14	215.17	2.32E-03	6.7E+07
3	15	175.98	5.65E-02	1.2E+10
3	30	38.712	4.06E-05	6.0E+07
3	31	38.635	2.29E-01	2.0E+11
3	33	38.46	2.60E-01	3.9E+11
3	34	38.383	2.01E-01	1.8E+11

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3	37	37.914	7.33E-02	3.4E+11
3	38	36.621	5.57E-04	9.2E+08
3	39	36.444	3.26E-04	5.4E+08
3	44	36.42	2.37E-03	2.4E+09
3	48	36.204	4.06E-04	2.1E+09
3	50	35.55	4.47E-05	7.9E+07
3	51	35.528	2.14E-05	2.3E+07
3	55	35.472	1.25E-04	1.3E+08
3	64	33.754	1.23E-04	1.4E+08
4	6	744.197	1.82E-03	7.3E+06
4	9	519.673	2.30E-04	1.9E+06
4	12	334.278	1.17E-01	2.3E+09
4	13	298.361	2.11E-01	5.3E+09
4	30	40.682	7.08E-04	9.5E+08
4	33	40.404	5.55E-07	7.6E+05
4	39	38.379	8.85E-02	1.3E+11
4	44	38.184	1.66E-01	2.5E+11
4	50	37.204	2.02E-04	3.2E+08
5	6	807.511	2.34E-03	8.0E+06
5	7	659.218	2.17E-08	6.7E+01
5	9	549.774	1.78E-04	1.3E+06
5	10	499.769	2.49E-03	1.3E+07
5	11	388.268	2.31E-02	1.0E+09
5	12	346.481	1.85E-01	3.4E+09
5	13	308.044	1.22E-01	2.8E+09
5	14	303.823	5.66E-01	8.2E+09
5	15	231.146	1.13E-01	1.4E+10
5	30	40.858	8.05E-04	1.1E+09
5	31	40.772	1.06E-03	8.5E+08
5	33	40.577	1.05E-03	1.4E+09
5	34	40.49	2.93E-03	2.4E+09
5	37	39.969	2.25E-03	9.4E+09
5	38	38.535	1.68E-01	2.5E+11
5	39	38.338	8.95E-02	1.4E+11
5	44	38.312	4.28E-01	3.9E+11
5	48	38.074	7.35E-02	3.4E+11
5	50	37.351	8.91E-05	1.4E+08
5	51	37.326	3.94E-04	3.8E+08
5	55	37.265	5.09E-05	4.9E+07
5	64	35.373	8.26E-08	8.8E+04
6	16	240.468	1.25E-01	1.4E+10
6	17	234.884	2.92E-01	1.2E+10
6	19	225.329	2.34E-01	6.1E+09
6	21	215.032	2.11E-02	6.1E+08
6	23	192.547	2.96E-03	1.8E+08
6	24	169.37	5.86E-04	2.7E+07
6	25	166.964	2.37E-03	1.1E+08
6	27	151.559	3.85E-07	3.7E+04
6	28	45.347	1.66E-01	1.1E+11

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6	29	45.347	2.22E-03	2.4E+09
6	35	42.625	2.13E-03	7.8E+09
6	36	42.625	3.63E-03	4.4E+09
6	38	40.491	2.12E-01	8.6E+11
6	40	40.412	4.76E-01	6.5E+11
6	43	40.267	3.74E-01	3.1E+11
6	47	40.081	1.59E-02	1.3E+10
6	49	39.86	5.89E-03	8.2E+09
6	58	38.104	5.28E-04	4.9E+08
6	60	38.049	1.14E-02	1.0E+10
6	61	37.868	9.27E-04	1.4E+09
7	17	251.329	3.53E-02	1.2E+09
7	19	240.42	5.82E-02	1.3E+09
7	20	237.41	7.91E-01	1.3E+10
7	21	228.73	2.20E-01	5.6E+09
7	22	223.34	5.66E-03	1.1E+08
7	23	203.46	1.63E-02	8.7E+08
7	24	177.76	1.64E-03	6.9E+07
7	25	175.11	4.55E-03	2.0E+08
7	26	173.41	2.39E-04	7.6E+06
7	27	158.24	4.06E-05	3.6E+06
7	28	45.928	1.39E-01	8.8E+10
7	29	45.927	1.56E-01	1.6E+11
7	36	43.137	1.37E-03	1.6E+09
7	40	40.873	6.47E-02	8.6E+10
7	42	40.771	1.29E+00	7.4E+11
7	43	40.724	1.36E-01	1.1E+11
7	46	40.556	3.23E-02	1.9E+10
7	47	40.534	3.18E-01	2.6E+11
7	49	40.308	2.24E-02	3.1E+10
7	58	38.513	7.19E-04	6.5E+08
7	59	38.483	3.22E-03	2.1E+09
7	60	38.457	1.05E-03	9.5E+08
7	61	38.271	2.99E-04	4.5E+08
8	18	254.11	1.13E+00	1.3E+10
8	19	253.76	2.90E-02	6.0E+08
8	20	250.42	1.33E-01	2.0E+09
8	21	240.78	9.38E-03	2.2E+08
8	22	234.81	1.73E-01	3.0E+09
8	24	184.95	1.16E-04	4.5E+06
8	25	182.08	2.06E-03	8.3E+07
8	26	180.24	3.85E-03	1.1E+08
8	28	46.394	4.06E-01	2.5E+11
8	41	41.151	1.99E+00	8.7E+11
8	42	41.137	1.20E-01	6.7E+10
8	43	41.09	6.08E-02	4.8E+10
8	46	40.919	3.89E-01	2.2E+11
8	47	40.896	1.03E-02	8.2E+09
8	58	38.84	1.70E-04	1.5E+08

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8	59	38.81	1.11E-03	7.0E+08
8	60	38.783	3.24E-04	2.9E+08
9	16	279.49	2.10E-03	1.8E+08
9	17	271.97	7.38E-07	2.2E+04
9	19	259.24	6.35E-02	1.3E+09
9	21	245.71	4.17E-01	9.2E+09
9	23	216.78	1.81E-01	8.5E+09
9	24	187.84	1.65E-05	6.2E+05
9	25	184.89	3.38E-04	1.3E+07
9	27	166.18	1.69E-02	1.4E+09
9	28	46.573	3.71E-03	2.3E+09
9	29	46.573	1.66E-01	1.7E+11
9	35	43.706	2.01E-04	7.0E+08
9	36	43.706	3.03E-03	3.5E+09
9	38	41.465	4.75E-03	1.8E+10
9	40	41.383	2.04E-05	2.6E+07
9	43	41.231	6.70E-02	5.3E+10
9	47	41.036	7.60E-01	6.0E+11
9	49	40.804	2.64E-01	3.5E+11
9	58	38.966	1.23E-03	1.1E+09
9	60	38.909	4.23E-04	3.7E+08
9	61	38.719	1.07E-03	1.6E+09
10	17	286.133	4.79E-02	1.3E+09
10	19	272.079	2.44E-01	4.4E+09
10	20	268.235	9.77E-03	1.3E+08
10	21	257.206	1.55E-03	3.1E+07
10	22	250.403	7.29E-01	1.1E+10
10	23	225.684	2.45E-04	1.1E+07
10	24	194.488	2.82E-04	9.9E+06
10	25	191.323	1.34E-02	4.9E+08
10	26	189.291	2.73E-04	7.3E+06
10	27	171.363	2.24E-03	1.7E+08
10	28	46.972	1.56E-01	9.4E+10
10	29	46.971	1.39E-01	1.4E+11
10	36	44.057	9.33E-05	1.1E+08
10	40	41.697	9.82E-02	1.3E+11
10	42	41.591	1.55E-01	8.5E+10
10	43	41.543	4.67E-01	3.6E+11
10	46	41.368	1.13E+00	6.3E+11
10	47	41.345	1.36E-02	1.1E+10
10	49	41.11	6.68E-04	8.8E+08
10	58	39.245	8.53E-05	7.4E+07
10	59	39.213	6.50E-04	4.0E+08
10	60	39.186	4.84E-03	4.2E+09
10	61	38.994	4.33E-04	6.3E+08
11	17	342.436	8.02E-03	1.5E+08
11	23	259.312	1.85E-01	6.1E+09
11	27	190.08	1.79E-02	1.1E+09
11	29	48.274	4.48E-02	4.3E+10

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11	36	45.201	1.77E-02	1.9E+10
11	40	42.721	1.75E-02	2.1E+10
11	49	42.104	2.68E-01	3.4E+11
11	61	39.887	9.73E-02	1.4E+11
12	16	398.283	1.64E-05	6.9E+05
12	17	383.195	1.02E-04	1.5E+06
12	19	358.401	9.23E-04	9.6E+06
12	21	333.035	2.92E-04	3.5E+06
12	23	282.029	3.61E-03	1.0E+08
12	24	234.937	5.70E-01	1.4E+10
12	25	230.334	1.77E-03	4.4E+07
12	27	202.007	1.22E-01	6.6E+09
12	28	49.009	1.60E-04	8.9E+07
12	29	49.009	2.55E-03	2.4E+09
12	35	45.845	6.67E-02	2.1E+11
12	36	45.845	1.06E-01	1.1E+11
12	38	43.385	1.01E-04	3.6E+08
12	40	43.296	2.52E-05	3.0E+07
12	43	43.129	2.78E-03	2.0E+09
12	47	42.916	7.33E-04	5.3E+08
12	49	42.662	3.24E-04	4.0E+08
12	58	40.657	7.83E-01	6.3E+11
12	60	40.594	1.60E-01	1.3E+11
12	61	40.388	1.64E-01	2.2E+11
13	16	464.98	2.31E-03	7.1E+07
13	17	444.54	2.25E-03	2.5E+07
13	19	411.52	1.25E-03	9.9E+06
13	21	378.42	1.86E-04	1.7E+06
13	23	313.91	4.33E-03	9.8E+07
13	24	256.65	2.01E-02	4.1E+08
13	25	251.17	5.46E-01	1.2E+10
13	27	217.86	6.70E-02	3.1E+09
13	28	49.89	5.55E-03	3.0E+09
13	29	49.889	8.32E-04	7.4E+08
13	35	46.615	1.06E-01	3.3E+11
13	36	46.614	6.15E-02	6.3E+10
13	38	44.074	7.85E-03	2.7E+10
13	40	43.981	1.16E-02	1.3E+10
13	43	43.809	7.36E-04	5.1E+08
13	47	43.589	8.65E-05	6.1E+07
13	49	43.328	3.95E-04	4.7E+08
13	58	41.261	2.83E-01	2.2E+11
13	60	41.196	7.06E-01	5.6E+11
13	61	40.984	9.86E-02	1.3E+11
14	17	453.64	8.65E-04	9.3E+06
14	19	419.3	3.81E-03	2.9E+07
14	20	410.24	4.24E-04	2.4E+06
14	21	384.99	3.05E-05	2.7E+05
14	22	369.95	7.78E-04	5.4E+06

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14	23	318.42	8.63E-04	1.9E+07
14	24	259.66	7.76E-02	1.5E+09
14	25	254.05	7.23E-02	1.5E+09
14	26	250.48	8.91E-01	1.4E+10
14	27	220.02	1.00E-02	4.6E+08
14	28	50.003	1.22E-03	6.5E+08
14	29	50.002	5.53E-04	4.9E+08
14	36	46.712	2.90E-01	3.0E+11
14	40	44.069	1.78E-03	2.0E+09
14	42	43.95	2.86E-03	1.4E+09
14	43	43.896	6.14E-03	4.3E+09
14	46	43.701	1.04E-03	5.2E+08
14	47	43.675	1.01E-05	7.1E+06
14	49	43.413	4.70E-05	5.6E+07
14	58	41.338	4.69E-02	3.7E+10
14	59	41.304	1.55E+00	8.6E+11
14	60	41.273	2.29E-01	1.8E+11
14	61	41.06	1.70E-02	2.2E+10
15	17	855.04	2.96E-06	9.0E+03
15	23	474.92	7.94E-03	7.8E+07
15	27	284.88	1.78E-01	4.9E+09
15	29	52.73	3.90E-02	3.1E+10
15	36	49.085	5.47E-02	5.0E+10
15	40	46.175	1.72E-03	1.8E+09
15	49	45.455	1.25E-01	1.3E+11
15	61	42.882	3.08E-01	3.7E+11
16	30	52.415	2.84E-02	2.3E+10
16	33	51.954	6.67E-06	5.5E+06
16	39	48.653	2.21E-05	2.1E+07
16	44	48.341	1.96E-04	1.9E+08
16	50	46.781	9.33E-01	9.5E+11
17	30	52.688	6.32E-02	5.1E+10
17	31	52.546	7.59E-03	3.7E+09
17	33	52.222	1.10E-03	8.9E+08
17	34	52.08	1.26E-02	6.2E+09
17	37	51.22	1.91E-03	4.9E+09
17	38	48.888	4.29E-05	4.0E+07
17	39	48.573	6.21E-06	5.9E+06
17	44	48.531	2.94E-04	1.7E+08
17	48	48.149	3.51E-04	1.0E+09
17	50	46.998	8.89E-01	9.0E+11
17	51	46.959	1.68E+00	1.0E+12
17	55	46.862	1.94E-01	1.2E+11
17	64	43.909	3.77E-02	2.6E+10
18	32	52.773	2.70E-01	9.2E+10
18	52	47.328	2.35E-01	7.8E+10
18	53	47.317	7.36E+00	2.0E+12
18	54	47.265	5.38E-02	2.3E+10
18	56	47.23	1.31E-02	5.6E+09

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18	57	47.209	7.69E-01	2.6E+11
18	62	44.272	5.07E-06	2.5E+06
18	63	44.251	4.46E-05	2.2E+07
18	65	44.247	3.37E-04	1.3E+08
19	30	53.194	4.04E-02	3.2E+10
19	31	53.049	1.46E-02	6.9E+09
19	32	52.788	5.93E-03	2.0E+09
19	33	52.719	2.32E-02	1.9E+10
19	34	52.574	6.27E-02	3.0E+10
19	39	49.323	8.11E-06	7.4E+06
19	44	49.002	1.95E-03	1.8E+09
19	45	48.96	5.82E-04	3.2E+08
19	50	47.4	1.02E-01	1.0E+11
19	51	47.361	1.07E+00	6.4E+11
19	54	47.277	3.32E+00	1.4E+12
19	55	47.262	6.04E-02	3.6E+10
19	56	47.242	1.55E-02	6.6E+09
19	62	44.283	8.99E-04	4.4E+08
19	63	44.261	1.12E-01	5.5E+10
19	64	44.26	6.30E-03	4.3E+09
20	31	53.197	1.79E-01	8.5E+10
20	32	52.935	3.26E-02	1.1E+10
20	34	52.72	2.79E-03	1.3E+09
20	45	49.087	6.59E-04	3.7E+08
20	51	47.479	2.69E-02	1.6E+10
20	52	47.458	5.37E+00	1.8E+12
20	54	47.395	2.26E-01	9.6E+10
20	55	47.38	4.14E-02	2.5E+10
20	56	47.36	6.93E-01	2.9E+11
20	57	47.338	1.94E-01	6.4E+10
20	62	44.386	1.04E-03	5.0E+08
20	63	44.365	3.07E-03	1.5E+09
20	64	44.363	3.07E-04	2.1E+08
20	65	44.361	4.19E-02	1.6E+10
21	30	53.803	1.17E-02	9.0E+09
21	31	53.654	4.98E-02	2.3E+10
21	32	53.387	2.41E-03	8.0E+08
21	33	53.317	9.23E-02	7.2E+10
21	34	53.168	3.81E-04	1.8E+08
21	39	49.846	9.27E-04	8.3E+08
21	44	49.518	1.92E-05	1.7E+07
21	45	49.475	1.54E-04	8.4E+07
21	50	47.882	2.80E-02	2.7E+10
21	51	47.842	1.56E-02	9.1E+09
21	54	47.757	4.04E-03	1.7E+09
21	55	47.741	6.70E-01	3.9E+11
21	56	47.721	3.94E+00	1.7E+12
21	62	44.704	4.66E-02	2.2E+10
21	63	44.682	5.77E-06	2.8E+06

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21	64	44.68	7.50E-03	5.0E+09
22	31	53.96	1.40E-03	6.4E+08
22	32	53.69	4.20E-02	1.4E+10
22	34	53.468	1.83E-01	8.6E+10
22	45	49.735	3.05E-04	1.6E+08
22	51	48.085	7.52E-02	4.3E+10
22	52	48.063	4.29E-01	1.4E+11
22	54	47.999	1.00E+00	4.2E+11
22	55	47.983	4.62E-03	2.7E+09
22	56	47.963	2.51E-03	1.0E+09
22	57	47.941	5.11E+00	1.6E+12
22	62	44.916	6.43E-04	3.0E+08
22	63	44.893	2.67E-03	1.3E+09
22	64	44.892	1.22E-04	8.1E+07
22	65	44.889	4.88E-03	1.8E+09
23	30	55.422	3.44E-03	2.5E+09
23	31	55.264	3.75E-03	1.6E+09
23	33	54.906	4.42E-02	3.3E+10
23	34	54.749	6.35E-05	2.8E+07
23	37	53.8	5.30E-02	1.2E+11
23	38	51.232	1.34E-03	1.1E+09
23	39	50.886	8.47E-04	7.3E+08
23	44	50.841	3.74E-04	1.9E+08
23	48	50.421	7.00E-04	1.8E+09
23	50	49.161	4.28E-02	3.9E+10
23	51	49.118	3.10E-01	1.7E+11
23	55	49.012	2.17E+00	1.2E+12
23	64	45.791	3.62E-01	2.3E+11
24	30	57.695	1.40E-04	9.4E+07
24	31	57.523	7.45E-04	3.0E+08
24	32	57.217	2.67E-05	7.8E+06
24	33	57.136	1.25E-03	8.5E+08
24	34	56.965	3.96E-05	1.6E+07
24	39	53.168	1.26E-01	9.9E+10
24	44	52.796	6.52E-03	5.2E+09
24	45	52.747	1.90E-02	9.1E+09
24	50	50.941	2.99E-04	2.6E+08
24	51	50.895	1.29E-04	6.6E+07
24	54	50.798	1.11E-03	4.1E+08
24	55	50.781	1.19E-02	6.2E+09
24	56	50.758	4.47E-02	1.7E+10
24	62	47.358	4.37E+00	1.9E+12
24	63	47.333	3.20E-02	1.4E+10
24	64	47.331	2.57E-01	1.5E+11
25	30	57.979	5.87E-04	3.9E+08
25	31	57.806	6.01E-04	2.4E+08
25	32	57.497	7.40E-04	2.1E+08
25	33	57.415	9.10E-04	6.1E+08
25	34	57.243	3.03E-03	1.2E+09

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25	39	53.41	8.47E-04	6.6E+08
25	44	53.034	1.32E-01	1.0E+11
25	45	52.984	1.81E-02	8.6E+09
25	50	51.162	3.62E-03	3.1E+09
25	51	51.116	3.71E-02	1.9E+10
25	54	51.019	8.73E-02	3.2E+10
25	55	51.001	7.69E-04	3.9E+08
25	56	50.979	1.93E-03	7.1E+08
25	62	47.55	2.58E-03	1.1E+09
25	63	47.525	4.33E+00	1.8E+12
25	64	47.523	2.52E-01	1.5E+11
26	31	57.994	1.17E-03	4.6E+08
26	32	57.683	1.02E-03	2.9E+08
26	34	57.427	1.60E-04	6.5E+07
26	45	53.142	2.19E-01	1.0E+11
26	51	51.263	8.73E-04	4.4E+08
26	52	51.239	3.37E-02	9.5E+09
26	54	51.165	1.07E-02	3.9E+09
26	55	51.147	6.08E-04	3.1E+08
26	56	51.125	4.35E-03	1.6E+09
26	57	51.099	9.68E-03	2.7E+09
26	62	47.677	2.91E-01	1.2E+11
26	63	47.652	2.26E-01	9.5E+10
26	64	47.65	1.46E-02	8.6E+09
26	65	47.647	6.01E+00	2.0E+12
27	30	60.1	1.11E-04	6.8E+07
27	31	59.915	2.55E-05	9.5E+06
27	33	59.495	1.22E-02	7.7E+09
27	34	59.31	5.43E-04	2.1E+08
27	37	58.198	2.52E-03	5.0E+09
27	38	55.205	3.10E-02	2.3E+10
27	39	54.803	1.67E-02	1.2E+10
27	44	54.75	2.61E-03	1.2E+09
27	48	54.264	5.73E-02	1.3E+11
27	50	52.807	3.69E-03	2.9E+09
27	51	52.758	1.55E-01	7.4E+10
27	55	52.635	3.10E-01	1.5E+11
27	64	48.939	2.49E+00	1.4E+12
28	30	843.948	4.43E-01	1.4E+09
28	31	808.723	3.61E-01	7.4E+08
28	32	752.142	1.15E+00	1.9E+09
28	33	738.356	2.29E-05	9.3E+04
28	34	710.83	4.54E-01	1.2E+09
28	39	375.88	1.01E-04	1.6E+06
28	44	358.02	2.51E-03	4.3E+07
28	45	355.77	5.01E-04	5.3E+06
28	50	287.11	1.49E-06	4.0E+04
28	51	285.67	1.72E-05	2.8E+05
28	54	282.64	5.70E-05	6.8E+05

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28	55	282.1	4.59E-07	7.7E+03
28	56	281.42	1.86E-06	2.2E+04
28	62	201.29	8.49E-07	2.0E+04
28	63	200.84	4.79E-05	1.1E+06
28	64	200.81	3.42E-06	1.1E+05
29	30	844.14	1.01E-07	3.1E+02
29	31	808.9	4.04E-01	8.2E+08
29	33	738.51	4.99E-01	2.0E+09
29	34	710.97	4.10E-01	1.1E+09
29	37	578.51	2.03E-01	4.0E+09
29	38	375.92	7.21E-04	1.1E+07
29	39	358.06	3.27E-04	5.7E+06
29	44	355.8	3.21E-04	3.4E+06
29	48	336.23	1.76E-02	1.0E+09
29	50	287.13	7.52E-06	2.0E+05
29	51	285.7	1.30E-06	2.1E+04
29	55	282.13	3.48E-05	5.8E+05
29	64	200.82	2.99E-05	9.9E+05
30	35	4473.3	1.85E-04	6.2E+04
30	36	4470.5	2.16E-04	2.4E+04
30	38	684.86	2.01E-01	2.9E+09
30	40	663.15	4.48E-01	2.3E+09
30	43	626.03	3.28E-01	1.1E+09
30	47	583.98	5.93E-02	2.3E+08
30	49	540.3	2.44E-02	1.9E+08
30	58	332.57	1.99E-04	2.4E+06
30	60	328.41	1.44E-04	1.8E+06
30	61	315.36	4.49E-04	1.0E+07
31	36	5811.3	7.03E-05	4.6E+03
31	40	686.65	5.74E-02	2.7E+08
31	42	658.95	1.20E+00	2.6E+09
31	43	646.93	1.33E-01	4.2E+08
31	46	606.97	3.24E-02	8.4E+07
31	47	602.13	3.24E-01	1.2E+09
31	49	555.8	2.56E-02	1.8E+08
31	58	338.38	2.59E-03	3.0E+07
31	59	336.08	2.99E-06	2.5E+04
31	60	334.07	3.52E-04	4.2E+06
31	61	320.58	2.52E-04	5.5E+06
32	41	706.12	1.76E+00	2.6E+09
32	42	701.98	1.07E-01	2.1E+08
32	43	688.35	5.42E-02	1.5E+08
32	46	643.29	3.83E-01	8.8E+08
32	47	637.85	1.04E-02	3.4E+07
32	58	349.37	3.70E-04	4.0E+06
32	59	346.93	2.32E-03	1.8E+07
32	60	344.79	7.71E-04	8.7E+06
33	35	18486.8	4.93E-08	9.6E-01
33	36	18438.6	3.67E-05	2.4E+02

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33	38	774.775	2.41E-06	2.7E+04
33	40	747.104	9.44E-03	3.8E+07
33	43	700.319	1.05E-01	2.8E+08
33	47	648.112	6.81E-01	2.2E+09
33	49	594.755	2.77E-01	1.7E+09
33	58	352.43	8.89E-04	9.5E+06
33	60	347.763	3.61E-03	4.0E+07
33	61	333.169	1.77E-03	3.5E+07
34	40	777.569	7.67E-02	2.8E+08
34	42	742.239	1.30E-01	2.3E+08
34	43	727.019	3.92E-01	9.9E+08
34	46	676.94	1.03E+00	2.1E+09
34	47	670.915	1.25E-02	3.7E+07
34	49	613.902	7.67E-04	4.5E+06
34	58	359.066	2.74E-04	2.8E+06
34	59	356.482	2.58E-03	1.9E+07
34	60	354.223	7.83E-03	8.3E+07
34	61	339.093	8.95E-04	1.7E+07
35	39	798.761	1.62E-01	5.6E+08
35	44	722.196	3.34E-01	1.4E+09
35	50	482.038	7.35E-05	7.0E+05
36	34	3122.43	1.75E-03	1.2E+06
36	37	798.851	3.03E-01	1.1E+09
36	38	722.269	1.77E-01	7.6E+08
36	39	713.152	8.67E-01	2.3E+09
36	44	638.627	1.84E-01	3.0E+09
36	48	482.071	3.61E-05	3.5E+05
36	50	478.031	1.41E-04	8.2E+05
36	51	468.122	1.04E-05	6.3E+04
36	55	280.012	4.05E-07	6.9E+03
37	40	1037.34	1.01E-02	2.1E+07
37	49	765.189	2.75E-01	1.0E+09
37	61	380.665	1.15E-02	1.8E+08
38	39	65210.5	3.80E-08	2.0E-02
38	44	6753.94	1.09E-04	5.3E+03
38	50	1193.43	1.11E-01	1.7E+08
38	40	30798.8	2.92E-06	6.8E+00
38	49	2664.3	6.64E-05	2.1E+04
38	61	589.814	1.90E-01	1.2E+09
39	43	8204.16	1.49E-06	2.9E+01
39	49	4121.91	5.96E-05	7.8E+03
39	58	652.991	7.13E-01	2.2E+09
39	60	637.15	1.74E-01	5.7E+08
39	61	639.909	9.38E-02	5.1E+08
40	39	9974.27	3.03E-05	6.8E+02
40	44	8477.57	6.15E-05	1.1E+03
40	48	3551.25	7.96E-05	4.2E+04
40	50	1265.64	9.98E-02	1.4E+08
40	51	1238.16	1.99E-01	1.7E+08

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40	55	1173.81	1.95E-02	1.9E+07
40	64	437.254	3.01E-03	2.1E+07
41	52	1308.53	2.53E-02	1.1E+07
41	53	1300.2	7.98E-01	2.9E+08
41	54	1262.2	6.00E-03	3.6E+06
41	56	1238.1	1.49E-03	9.3E+05
41	57	1223.4	8.85E-02	4.4E+07
41	62	449.98	1.49E-06	7.0E+03
41	63	447.76	1.31E-05	6.2E+04
41	65	447.36	9.91E-05	3.7E+05
42	45	17623	4.10E-08	1.8E-01
42	51	1339.7	9.75E-04	7.2E+05
42	52	1323	6.12E-01	2.6E+08
42	54	1275.6	5.97E-03	3.5E+06
42	55	1264.7	3.68E-03	3.1E+06
42	56	1251	7.53E-02	4.6E+07
42	57	1236	9.71E-04	4.7E+05
42	62	451.68	9.16E-06	4.3E+04
42	63	449.44	6.08E-05	2.9E+05
42	64	449.28	1.64E-05	1.1E+05
42	65	449.04	5.06E-04	1.9E+06
43	44	92272	2.16E-05	5.7E+00
43	45	35041	4.13E-05	4.5E+01
43	50	1427.2	1.12E-02	1.2E+07
43	51	1392.3	1.12E-01	7.7E+07
43	54	1323.2	3.54E-01	1.9E+08
43	55	1311.5	1.09E-02	8.5E+06
43	56	1296.8	2.77E-04	1.6E+05
43	62	457.51	6.71E-05	3.1E+05
43	63	455.21	7.31E-03	3.4E+07
43	64	455.05	2.86E-04	1.8E+06
44	49	4446.3	2.93E-05	3.3E+03
44	58	714.96	2.72E-01	7.1E+08
44	60	696.01	6.21E-01	1.7E+09
44	61	647.24	1.72E-02	9.1E+07
45	46	13658	1.20E-04	6.1E+02
45	58	724.12	3.92E-02	1.0E+08
45	59	713.69	1.35E+00	2.5E+09
45	60	704.69	2.02E-01	5.4E+08
46	51	1622.1	8.00E-03	4.1E+06
46	52	1597.7	6.37E-04	1.9E+05
46	54	1529.1	1.07E-01	4.4E+07
46	55	1513.4	1.20E-03	7.0E+05
46	56	1493.9	2.06E-03	8.8E+05
46	57	1472.5	4.98E-01	1.7E+08
46	62	479.85	1.63E-04	6.8E+05
46	63	477.32	8.71E-04	3.6E+06
46	64	477.14	4.71E-05	2.8E+05
46	65	476.87	1.81E-03	5.9E+06

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47	39	4221	3.61E-04	2.7E+04
47	44	9598.5	3.62E-06	5.2E+01
47	45	11563	3.40E-05	3.4E+02
47	50	1707.4	1.54E-03	1.2E+06
47	51	1657.8	6.76E-05	3.3E+04
47	54	1560.8	4.90E-03	1.9E+06
47	55	1544.4	5.70E-02	3.2E+07
47	56	1524.1	3.64E-01	1.5E+08
47	62	482.923	3.98E-03	1.6E+07
47	63	480.362	3.20E-04	1.3E+06
47	64	480.178	1.32E-03	7.6E+06
48	49	16320.5	2.06E-04	1.7E+03
48	61	723.909	3.05E-01	1.3E+09
49	50	2235.87	2.47E-03	1.1E+06
49	51	2151.54	2.28E-02	6.6E+06
49	55	1964.39	1.66E-01	5.7E+07
49	64	514.367	7.67E-03	3.9E+07
50	58	1410.78	3.11E-05	2.1E+04
50	60	1338.86	5.47E-05	4.1E+04
50	61	1145.65	2.96E-04	5.0E+05
51	58	1446.56	1.36E-04	8.7E+04
51	59	1405.52	3.13E-05	1.5E+04
51	60	1371.04	6.81E-04	4.8E+05
51	61	1169.14	1.31E-03	2.1E+06
52	59	1424.41	5.92E-05	2.8E+04
54	58	1529.54	1.96E-05	1.1E+04
54	59	1483.74	4.47E-04	1.9E+05
54	60	1445.37	1.33E-03	8.5E+05
55	58	1545.55	3.17E-04	1.8E+05
55	59	1498.8	1.04E-05	4.4E+03
55	60	1459.66	5.74E-05	3.6E+04
55	61	1232.96	1.41E-03	2.1E+06
56	58	1566.42	5.28E-04	2.9E+05
56	59	1518.41	6.08E-06	2.5E+03
56	60	1478.25	5.41E-04	3.3E+05
57	59	1541.22	3.46E-04	1.4E+05
58	62	1288.3	4.06E-01	2.3E+08
58	63	1270.23	9.57E-02	5.7E+07
58	64	1268.94	9.31E-03	7.7E+06
59	62	1322.69	3.08E-02	1.7E+07
59	63	1303.65	2.44E-02	1.4E+07
59	64	1302.3	1.58E-03	1.2E+06
59	65	1300.26	6.49E-01	2.8E+08
60	62	1354.75	6.81E-02	3.5E+07
60	63	1334.79	3.75E-01	2.0E+08
60	64	1333.36	4.55E-02	3.4E+07
61	64	1602.51	2.39E-01	1.2E+08

Table 6. The allowed electric dipole transitions for Cu XX.

i	j	$\lambda(\text{\AA})$	gf	A _{ji}
1	3	12.828	1.00E+00	0.00E+00
1	5	12.571	1.00E+00	0.00E+00
1	17	11.736	1.00E+00	0.00E+00
1	23	11.593	1.00E+00	0.00E+00
1	27	11.38	1.00E+00	0.00E+00
1	29	9.521	1.00E+00	0.00E+00
1	36	9.373	1.00E+00	0.00E+00
1	39	9.268	1.00E+00	0.00E+00
1	48	9.236	1.00E+00	0.00E+00
1	61	9.104	1.00E+00	0.00E+00
2	6	340.94	1.00E+00	0.00E+00
2	7	311.332	1.00E+00	0.00E+00
2	8	287.005	1.00E+00	0.00E+00
2	9	280.976	1.00E+00	0.00E+00
2	10	265.351	1.00E+00	0.00E+00
2	12	207.397	1.00E+00	0.00E+00
2	13	190.629	1.00E+00	0.00E+00
2	14	189.246	1.00E+00	0.00E+00
2	30	35.093	1.00E+00	0.00E+00
2	31	35.029	1.00E+00	0.00E+00
2	32	34.888	1.00E+00	0.00E+00
2	33	34.859	1.00E+00	0.00E+00
2	34	34.789	1.00E+00	0.00E+00
2	43	33.09	1.00E+00	0.00E+00
2	46	32.918	1.00E+00	0.00E+00
2	47	32.898	1.00E+00	0.00E+00
2	50	32.314	1.00E+00	0.00E+00
2	51	32.293	1.00E+00	0.00E+00
2	54	32.251	1.00E+00	0.00E+00
2	55	32.244	1.00E+00	0.00E+00
2	56	32.235	1.00E+00	0.00E+00
2	62	30.595	1.00E+00	0.00E+00
2	63	30.583	1.00E+00	0.00E+00
2	64	30.582	1.00E+00	0.00E+00
3	6	363.787	1.00E+00	0.00E+00
3	7	330.274	1.00E+00	0.00E+00
3	9	296.313	1.00E+00	0.00E+00
3	10	278.988	1.00E+00	0.00E+00
3	11	235.456	1.00E+00	0.00E+00
3	12	215.636	1.00E+00	
3	13	197.567	1.00E+00	0.00E+00
3	14	196.082	1.00E+00	0.00E+00
3	15	163.58	1.00E+00	0.00E+00
3	30	35.321	1.00E+00	0.00E+00
3	31	35.257	1.00E+00	0.00E+00
3	33	35.084	1.00E+00	0.00E+00
3	34	35.013	1.00E+00	0.00E+00

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3	55	32.437	1.14E-04	1.44E+08
3	63	30.756	1.11E-04	1.57E+08
4	6	790.026	1.43E-03	5.10E+06
4	9	528.615	1.49E-04	1.19E+06
4	12	317.02	1.07E-01	2.38E+09
4	13	279.447	2.12E-01	6.04E+09
4	30	37.273	6.08E-04	9.74E+08
4	33	37.01	6.78E-08	1.10E+05
4	43	35.022	8.99E-02	1.63E+11
4	46	34.83	1.71E-01	3.14E+11
4	50	34.154	1.99E-04	3.80E+08
5	6	865.536	1.82E-03	5.41E+06
5	7	697.211	6.04E-06	1.66E+04
5	9	561.385	1.01E-04	7.15E+05
5	10	502.29	2.41E-03	1.28E+07
5	11	376.851	1.96E-02	9.22E+08
5	12	328.521	1.83E-01	3.78E+09
5	13	288.344	1.14E-01	3.03E+09
5	14	285.193	5.50E-01	9.01E+09
5	15	221.253	1.11E-01	1.51E+10
5	30	37.427	7.53E-04	1.20E+09
5	31	37.356	8.83E-04	8.45E+08
5	33	37.162	8.20E-04	1.32E+09
5	34	37.082	2.48E-03	2.41E+09
5	37	36.616	1.86E-03	9.24E+09
5	43	35.158	1.73E-01	3.12E+11
5	46	34.964	9.12E-02	1.66E+11
5	47	34.941	4.39E-01	4.79E+11
5	49	34.765	7.66E-02	4.22E+11
5	50	34.283	8.93E-05	1.69E+08
5	51	34.26	3.80E-04	4.33E+08
5	55	34.205	5.15E-05	5.88E+07
5	63	32.341	2.90E-09	3.71E+03
6	16	227.802	1.20E-01	5.15E+09
6	17	222.126	2.80E-01	1.26E+10
6	19	212.714	2.12E-01	1.04E+10
6	21	203.21	3.14E-02	1.69E+09
6	23	180.122	3.76E-03	2.57E+08
6	24	156.119	8.39E-04	7.66E+07
6	25	153.758	1.73E-03	1.62E+08
6	27	139.507	2.20E-07	2.51E+04
6	28	41.107	1.65E-01	2.17E+11
6	29	41.107	1.62E-03	2.13E+09
6	35	38.48	2.02E-03	3.03E+09
6	36	38.479	3.27E-03	4.91E+09
6	38	36.84	2.19E-01	3.59E+11
6	39	36.776	4.97E-01	8.17E+11
7	19	226.132	1.00E+00	0.00E+00

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7	20	223.817	1.00E+00	0.00E+00
7	21	215.42	1.00E+00	0.00E+00
7	22	209.79	1.00E+00	0.00E+00
7	23	189.651	1.00E+00	0.00E+00
7	24	163.228	1.00E+00	0.00E+00
7	25	160.648	1.00E+00	0.00E+00
7	26	159.223	1.00E+00	0.00E+00
7	27	145.156	1.00E+00	0.00E+00
7	28	41.584	1.00E+00	0.00E+00
7	29	41.584	1.00E+00	0.00E+00
7	36	38.897	1.00E+00	0.00E+00
7	39	37.158	1.00E+00	0.00E+00
7	40	37.045	1.00E+00	0.00E+00
7	41	37.03	1.00E+00	0.00E+00
7	44	36.94	1.00E+00	0.00E+00
7	45	36.889	1.00E+00	0.00E+00
7	48	36.642	1.00E+00	0.00E+00
7	58	34.856	1.00E+00	0.00E+00
7	59	34.819	1.00E+00	0.00E+00
7	60	34.768	1.00E+00	0.00E+00
7	61	34.649	1.00E+00	0.00E+00
8	18	241.207	1.00E+00	0.00E+00
8	19	240.967	1.00E+00	0.00E+00
8	20	238.341	1.00E+00	0.00E+00
8	21	228.842	1.00E+00	0.00E+00
8	22	222.498	1.00E+00	0.00E+00
8	24	170.819	1.00E+00	0.00E+00
8	25	167.996	1.00E+00	0.00E+00
8	26	166.438	1.00E+00	0.00E+00
8	28	42.06	1.00E+00	0.00E+00
8	40	37.423	1.00E+00	0.00E+00
8	41	37.407	1.00E+00	0.00E+00
8	42	37.407	1.00E+00	0.00E+00
8	44	37.315	1.00E+00	0.00E+00
8	45	37.263	1.00E+00	0.00E+00
8	58	35.19	1.00E+00	0.00E+00
8	59	35.152	1.00E+00	0.00E+00
8	60	35.1	1.00E+00	0.00E+00
9	16	265.688	1.00E+00	0.00E+00
9	17	257.998	1.00E+00	0.00E+00
9	19	245.388	1.00E+00	0.00E+00
9	21	232.825	1.00E+00	0.00E+00
9	23	203.012	1.00E+00	0.00E+00
9	24	173.028	1.00E+00	0.00E+00
9	25	170.133	1.00E+00	0.00E+00
9	27	152.855	1.00E+00	0.00E+00
9	28	42.193	1.00E+00	0.00E+00
9	29	42.192	1.00E+00	0.00E+00

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9	35	39.429	1.00E+00	0.00E+00
9	36	39.429	1.00E+00	0.00E+00
9	38	37.71	1.00E+00	0.00E+00
9	39	37.643	1.00E+00	0.00E+00
9	40	37.528	1.00E+00	0.00E+00
9	44	37.42	8.28E-01	1.31E+12
9	48	37.114	2.71E-01	4.37E+11
9	58	35.283	3.86E-03	6.90E+09
9	59	35.245	3.79E-04	6.79E+08
9	61	35.071	1.37E-04	2.47E+08
10	17	272.745	4.71E-02	8.45E+08
10	19	258.691	2.38E-01	4.74E+09
10	20	255.667	1.49E-02	3.03E+08
10	21	244.768	2.19E-05	4.88E+05
10	22	237.525	6.84E-01	1.62E+10
10	23	212.033	1.79E-04	5.31E+06
10	24	179.539	8.63E-04	3.57E+07
10	25	176.423	1.21E-02	5.17E+08
10	26	174.706	3.28E-04	1.43E+07
10	27	157.914	2.16E-03	1.16E+08
10	28	42.569	1.61E-01	1.18E+11
10	29	42.569	1.30E-01	9.57E+10
10	36	39.758	2.55E-04	2.15E+08
10	39	37.942	1.02E-01	9.47E+10
10	40	37.825	4.59E-01	4.28E+11
10	41	37.809	4.09E-03	3.81E+09
10	44	37.715	4.33E-02	4.06E+10
10	45	37.662	1.30E+00	1.22E+12
10	48	37.405	2.62E-03	2.50E+09
10	58	35.546	2.52E-04	2.66E+08
10	59	35.507	2.21E-03	2.33E+09
10	60	35.454	8.81E-04	9.35E+08
10	61	35.331	3.66E-04	3.92E+08
11	17	332.918	7.31E-03	4.40E+08
11	23	246.696	1.77E-01	1.94E+10
11	27	176.371	1.57E-02	3.37E+09
11	29	43.805	4.69E-02	1.63E+11
11	36	40.834	1.52E-02	6.10E+10
11	39	38.921	6.79E-03	2.99E+10
11	48	38.356	3.05E-01	1.39E+12
11	61	36.178	8.11E-02	4.13E+11
12	16	399.812	2.20E-05	3.06E+05
12	17	382.649	7.62E-05	1.16E+06
12	19	355.55	7.16E-04	1.26E+07
12	21	329.769	2.25E-04	4.61E+06
12	23	272.986	3.40E-03	1.01E+08
12	24	221.398	5.45E-01	2.47E+10
12	25	216.679	1.74E-03	8.25E+07

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12	27	189.412	1.20E-01	7.46E+09
12	28	44.567	1.93E-04	2.16E+08
12	29	44.567	1.95E-03	2.18E+09
12	35	41.495	6.28E-02	8.12E+10
12	36	41.495	1.08E-01	1.40E+11
12	38	39.595	1.32E-04	1.88E+08
12	39	39.521	1.24E-04	1.76E+08
12	40	39.394	1.85E-03	2.65E+09
12	44	39.275	3.40E-03	4.90E+09
12	48	38.939	4.54E-06	6.65E+06
12	58	36.928	9.59E-01	1.57E+12
12	59	36.886	1.00E+00	0.00E+00
12	61	36.696	1.00E+00	0.00E+00
13	16	481.452	1.00E+00	0.00E+00
13	17	456.781	1.00E+00	0.00E+00
13	19	418.687	1.00E+00	0.00E+00
13	21	383.391	1.00E+00	0.00E+00
13	23	308.732	1.00E+00	0.00E+00
13	24	244.342	1.00E+00	0.00E+00
13	25	238.607	1.00E+00	0.00E+00
13	27	205.958	1.00E+00	0.00E+00
13	28	45.426	1.00E+00	0.00E+00
13	29	45.425	1.00E+00	0.00E+00
13	35	42.239	1.00E+00	0.00E+00
13	36	42.238	1.00E+00	0.00E+00
13	38	40.272	1.00E+00	0.00E+00
13	39	40.195	1.00E+00	0.00E+00
13	40	40.064	1.00E+00	0.00E+00
13	44	39.941	1.00E+00	0.00E+00
13	48	39.593	1.00E+00	0.00E+00
13	58	37.516	1.00E+00	0.00E+00
13	59	37.472	1.00E+00	0.00E+00
13	61	37.276	1.00E+00	0.00E+00
14	17	464.92	1.00E+00	0.00E+00
14	19	425.515	1.00E+00	0.00E+00
14	20	417.393	1.00E+00	0.00E+00
14	21	389.109	1.00E+00	0.00E+00
14	22	371.118	1.00E+00	0.00E+00
14	23	312.428	1.00E+00	0.00E+00
14	24	246.651	1.00E+00	0.00E+00
14	25	240.809	1.00E+00	0.00E+00
14	26	237.621	1.00E+00	0.00E+00
14	27	207.596	1.00E+00	0.00E+00
14	28	45.505	1.00E+00	0.00E+00
14	29	45.505	1.00E+00	0.00E+00
14	36	42.307	1.00E+00	0.00E+00
14	39	40.257	1.00E+00	0.00E+00
14	40	40.125	1.00E+00	0.00E+00

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14	41	40.108	1.00E+00	0.00E+00
14	44	40.002	1.00E+00	0.00E+00
14	45	39.942	1.00E+00	0.00E+00
14	48	39.653	1.00E+00	0.00E+00
14	58	37.57	1.00E+00	0.00E+00
14	59	37.526	1.00E+00	0.00E+00
14	60	37.468	1.00E+00	0.00E+00
14	61	37.33	1.00E+00	0.00E+00
15	17	879.043	1.00E+00	0.00E+00
15	23	457.159	1.00E+00	0.00E+00
15	27	262.9	1.00E+00	0.00E+00
15	29	47.704	1.00E+00	0.00E+00
15	36	44.202	1.00E+00	0.00E+00
15	39	41.969	1.00E+00	0.00E+00
15	48	41.313	1.00E+00	0.00E+00
15	61	38.797	1.00E+00	0.00E+00
16	30	47.229	1.00E+00	0.00E+00
16	33	46.808	7.00E-05	7.11E+07
16	43	43.672	2.23E-05	2.60E+07
16	46	43.374	1.69E-04	2.00E+08
16	50	42.331	9.38E-01	1.16E+12
17	30	47.481	6.07E-02	5.98E+10
17	31	47.365	7.41E-03	4.41E+09
17	33	47.055	1.73E-03	1.73E+09
17	34	46.927	1.21E-02	7.35E+09
17	37	46.183	1.82E-03	5.68E+09
17	43	43.887	3.91E-05	4.51E+07
17	46	43.586	2.55E-06	2.98E+06
17	47	43.549	2.72E-04	1.91E+08
17	49	43.276	3.52E-04	1.26E+09
17	50	42.533	8.93E-01	1.10E+12
17	51	42.497	1.71E+00	1.27E+12
17	55	42.411	1.71E-01	1.27E+11
17	63	39.583	3.65E-02	3.10E+10
18	32	47.544	2.61E-01	1.10E+11
18	52	42.835	2.39E-01	9.66E+10
18	53	42.823	7.38E+00	2.44E+12
18	54	42.778	5.61E-02	2.92E+10
18	56	42.749	1.10E-02	5.72E+09
18	57	42.728	7.67E-01	3.12E+11
18	62	39.912	4.18E-06	2.50E+06
18	64	39.89	3.73E-05	2.23E+07
18	65	39.887	2.81E-04	1.31E+08
19	30	47.934	3.47E-02	3.36E+10
19	31	47.817	1.18E-02	6.89E+09
19	32	47.553	5.45E-03	2.30E+09
19	33	47.5	2.94E-02	2.89E+10
19	34	47.37	6.11E-02	3.63E+10

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19	43	44.274	7.21E-06	8.18E+06
19	46	43.967	1.71E-03	1.97E+09
19	47	43.931	4.81E-04	3.32E+08
19	50	42.896	9.75E-02	1.18E+11
19	51	42.859	1.07E+00	7.78E+11
19	54	42.785	3.30E+00	1.72E+12
19	55	42.773	3.42E-02	2.49E+10
19	56	42.757	9.02E-02	4.70E+10
19	62	39.918	8.24E-04	4.93E+08
19	63	39.898	5.92E-03	4.96E+09
19	64	39.897	1.02E-01	6.08E+10
20	31	47.921	1.75E-01	1.02E+11
20	32	47.657	2.75E-02	1.15E+10
20	34	47.473	5.92E-03	3.50E+09
20	47	44.019	3.69E-04	2.54E+08
20	51	42.944	2.32E-02	1.68E+10
20	52	42.927	5.56E+00	2.24E+12
20	54	42.869	2.06E-01	1.07E+11
20	55	42.857	3.87E-02	2.81E+10
20	56	42.841	6.68E-01	3.47E+11
20	57	42.819	8.97E-02	3.63E+10
20	62	39.991	6.28E-04	3.74E+08
20	63	39.971	2.17E-04	1.81E+08
20	64	39.97	1.00E+00	0.00E+00
20	65	39.966	1.00E+00	0.00E+00
21	30	48.445	1.00E+00	0.00E+00
21	31	48.325	1.00E+00	0.00E+00
21	32	48.056	1.00E+00	0.00E+00
21	33	48.001	1.00E+00	0.00E+00
21	34	47.868	1.00E+00	0.00E+00
21	43	44.709	1.00E+00	0.00E+00
21	46	44.397	1.00E+00	0.00E+00
21	47	44.359	1.00E+00	0.00E+00
21	50	43.304	1.00E+00	0.00E+00
21	51	43.267	1.00E+00	0.00E+00
21	54	43.192	1.00E+00	0.00E+00
21	55	43.179	1.00E+00	0.00E+00
21	56	43.163	1.00E+00	0.00E+00
21	62	40.272	1.00E+00	0.00E+00
21	63	40.251	1.00E+00	0.00E+00
21	64	40.25	1.00E+00	0.00E+00
22	31	48.617	1.00E+00	0.00E+00
22	32	48.345	1.00E+00	0.00E+00
22	34	48.156	1.00E+00	0.00E+00
22	47	44.606	1.00E+00	0.00E+00
22	51	43.502	1.00E+00	0.00E+00
22	52	43.485	1.00E+00	0.00E+00
22	54	43.425	1.00E+00	0.00E+00

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22	55	43.412	1.00E+00	0.00E+00
22	56	43.396	1.00E+00	0.00E+00
22	57	43.374	1.00E+00	0.00E+00
22	62	40.475	1.00E+00	0.00E+00
22	63	40.454	1.00E+00	0.00E+00
22	64	40.453	1.00E+00	0.00E+00
22	65	40.449	1.00E+00	0.00E+00
23	30	49.972	1.00E+00	0.00E+00
23	31	49.844	1.00E+00	0.00E+00
23	33	49.5	1.00E+00	0.00E+00
23	34	49.359	1.00E+00	0.00E+00
23	37	48.536	1.00E+00	0.00E+00
23	43	46.006	1.00E+00	0.00E+00
23	46	45.676	1.00E+00	0.00E+00
23	47	45.636	1.00E+00	0.00E+00
23	49	45.335	1.00E+00	0.00E+00
23	50	44.521	1.00E+00	0.00E+00
23	51	44.481	1.00E+00	0.00E+00
23	55	44.388	1.00E+00	0.00E+00
23	63	41.299	1.00E+00	0.00E+00
24	30	52.198	1.00E+00	0.00E+00
24	31	52.059	1.00E+00	0.00E+00
24	32	51.747	1.00E+00	0.00E+00
24	33	51.684	1.00E+00	0.00E+00
24	34	51.53	1.00E+00	0.00E+00
24	43	47.887	1.00E+00	0.00E+00
24	46	47.529	1.00E+00	0.00E+00
24	47	47.486	1.00E+00	0.00E+00
24	50	46.279	1.00E+00	0.00E+00
24	51	46.237	7.00E-05	4.37E+07
24	54	46.151	2.64E-03	1.18E+09
24	55	46.136	8.18E-03	5.13E+09
24	56	46.117	3.39E-02	1.52E+10
24	62	42.832	4.35E+00	2.26E+12
24	63	42.808	3.25E-01	2.37E+11
24	64	42.807	7.78E-03	4.05E+09
25	30	52.468	6.22E-04	5.02E+08
25	31	52.327	7.78E-04	3.79E+08
25	32	52.012	7.00E-04	2.47E+08
25	33	51.948	4.94E-04	4.07E+08
25	34	51.792	2.49E-03	1.24E+09
25	43	48.113	2.31E-04	2.21E+08
25	46	47.752	1.33E-01	1.29E+11
25	47	47.708	1.31E-02	7.66E+09
25	50	46.491	3.61E-03	3.72E+09
25	51	46.448	3.40E-02	2.11E+10
25	54	46.361	7.57E-02	3.35E+10
25	55	46.346	1.88E-03	1.17E+09

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25	56	46.328	9.12E-05	4.05E+07
25	62	43.013	4.50E-02	2.32E+10
25	63	42.989	1.89E-01	1.37E+11
25	64	42.988	4.38E+00	2.25E+12
26	31	52.48	8.45E-04	4.09E+08
26	32	52.163	9.57E-04	3.35E+08
26	34	51.942	2.99E-04	1.47E+08
26	47	47.836	2.11E-01	1.23E+11
26	51	46.568	9.31E-04	5.72E+08
26	52	46.549	2.22E-02	7.61E+09
26	54	46.481	1.17E-02	5.18E+09
26	55	46.466	4.83E-04	2.98E+08
26	56	46.447	2.64E-03	1.17E+09
26	57	46.422	1.41E-02	4.83E+09
26	62	43.116	2.93E-01	1.50E+11
26	63	43.093	1.47E-02	1.05E+10
26	64	43.092	2.26E-01	1.16E+11
26	65	43.087	6.04E+00	2.41E+12
27	30	54.363	6.12E-05	4.61E+07
27	31	54.211	1.64E-05	7.47E+06
27	33	53.805	1.07E-02	8.24E+09
27	34	53.638	4.95E-04	2.30E+08
27	37	52.667	2.45E-03	5.89E+09
27	43	49.702	3.00E-02	2.70E+10
27	46	49.317	1.60E-02	1.46E+10
27	47	49.27	2.56E-03	1.41E+09
27	49	48.92	5.50E-02	1.53E+11
27	50	47.973	3.83E-03	3.70E+09
27	51	47.927	1.34E-01	7.76E+10
27	55	47.819	2.77E-01	1.62E+11
27	63	44.253	2.54E+00	1.73E+12
28	30	808.807	4.19E-01	1.43E+09
28	31	776.531	3.44E-01	7.60E+08
28	32	712.508	1.11E+00	2.08E+09
28	33	700.677	8.51E-04	3.85E+06
28	34	673.407	1.00E+00	0.00E+00
28	43	337.684	1.00E+00	0.00E+00
28	46	320.653	1.00E+00	0.00E+00
28	47	318.702	1.00E+00	0.00E+00
28	50	271.244	1.00E+00	0.00E+00
28	51	269.787	1.00E+00	0.00E+00
28	54	266.883	1.00E+00	0.00E+00
28	55	266.392	1.00E+00	0.00E+00
28	56	265.781	1.00E+00	0.00E+00
28	62	184.305	1.00E+00	0.00E+00
28	63	183.868	1.00E+00	0.00E+00
28	64	183.852	1.00E+00	0.00E+00
29	30	808.987	1.00E+00	0.00E+00

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29	31	776.697	1.00E+00	0.00E+00
29	33	700.812	1.00E+00	0.00E+00
29	34	673.532	1.00E+00	0.00E+00
29	37	546.975	1.00E+00	0.00E+00
29	43	337.715	1.00E+00	0.00E+00
29	46	320.682	1.00E+00	0.00E+00
29	47	318.73	1.00E+00	0.00E+00
29	49	304.629	1.00E+00	0.00E+00
29	50	271.264	1.00E+00	0.00E+00
29	51	269.807	1.00E+00	0.00E+00
29	55	266.412	1.00E+00	0.00E+00
29	63	183.877	1.00E+00	0.00E+00
30	35	2354.366	1.00E+00	0.00E+00
30	36	2353.512	1.00E+00	0.00E+00
30	38	632.487	1.00E+00	0.00E+00
30	39	614.122	1.00E+00	0.00E+00
30	40	584.821	1.00E+00	0.00E+00
30	44	559.642	1.00E+00	0.00E+00
30	48	498.27	1.00E+00	0.00E+00
30	58	293.664	1.00E+00	0.00E+00
30	59	291.032	1.00E+00	0.00E+00
30	61	279.612	1.00E+00	0.00E+00
31	36	2677.322	1.00E+00	0.00E+00
31	39	634.135	1.00E+00	0.00E+00
31	40	602.942	1.00E+00	0.00E+00
31	41	598.946	1.00E+00	0.00E+00
31	44	576.214	1.00E+00	0.00E+00
31	45	564.046	1.00E+00	0.00E+00
31	48	511.364	1.00E+00	0.00E+00
31	58	298.164	1.00E+00	0.00E+00
31	59	295.451	1.00E+00	0.00E+00
31	60	291.849	1.00E+00	0.00E+00
31	61	283.688	1.00E+00	0.00E+00
32	40	648.164	1.00E+00	0.00E+00
32	41	643.549	1.00E+00	0.00E+00
32	42	643.401	1.00E+00	0.00E+00
32	44	617.378	1.00E+00	0.00E+00
32	45	603.43	1.00E+00	0.00E+00
32	58	308.819	1.00E+00	0.00E+00
32	59	305.909	1.00E+00	0.00E+00
32	60	302.05	1.00E+00	0.00E+00
33	35	4274.59	6.17E-09	7.51E-01
33	36	4271.77	1.33E-04	1.62E+04
33	38	719.291	2.64E-04	1.13E+06
33	39	695.634	5.90E-03	2.71E+07
33	40	658.275	4.79E-02	2.45E+08
33	44	626.545	6.95E-01	3.93E+09
33	48	550.617	2.74E-01	2.01E+09

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33	58	311.096	8.49E-05	1.95E+06
33	59	308.143	2.70E-04	6.32E+06
33	61	295.37	3.48E-03	8.87E+07
34	36	5672.15	5.86E-06	2.43E+02
34	39	724.773	7.24E-02	1.84E+08
34	40	684.31	3.50E-01	9.97E+08
34	41	679.168	7.46E-03	2.16E+07
34	44	650.085	4.09E-02	1.29E+08
34	45	634.639	1.12E+00	3.72E+09
34	48	568.715	3.00E-03	1.24E+07
34	58	316.791	1.07E-04	1.42E+06
34	59	313.73	3.03E-03	4.12E+07
34	60	309.672	4.59E-06	6.39E+04
34	61	300.5	6.49E-04	9.58E+06
35	43	769.1	1.52E-01	5.70E+08
35	46	686.106	3.21E-01	1.52E+09
35	50	493.685	7.50E-05	6.84E+05
36	37	5979.9	6.47E-04	1.21E+05
36	43	769.191	2.87E-01	1.08E+09
36	46	686.178	1.69E-01	7.97E+08
36	47	677.304	8.30E-01	2.41E+09
36	49	616.648	1.75E-01	3.07E+09
36	50	493.723	3.62E-05	3.30E+05
36	51	488.915	1.35E-04	7.52E+05
36	55	477.879	9.42E-06	5.50E+04
36	63	264.732	4.86E-07	9.25E+03
37	39	965.05	3.35E-03	2.40E+07
37	48	706.803	2.81E-01	3.76E+09
37	61	335.091	5.55E-03	3.30E+08
38	43	6949.1	7.18E-07	3.30E+01
38	46	3320.23	1.83E-04	3.70E+04
38	50	1150.4	1.04E-01	1.74E+08
39	43	10349.4	8.63E-07	1.79E+01
39	46	3938.49	9.14E-05	1.31E+04
39	47	3663.02	1.00E-04	9.97E+03
39	49	2391.04	1.00E-04	1.17E+05
39	50	1216.57	9.64E-02	1.45E+08
39	51	1187.79	1.74E-01	1.65E+08
39	55	1124.69	2.94E-02	3.10E+07
39	63	388.506	1.09E-03	9.60E+06
40	43	66489.2	5.98E-07	3.01E-01
40	46	5803.13	5.90E-05	3.90E+03
40	47	5224.24	1.11E-04	5.44E+03
40	50	1350.62	1.18E-02	1.44E+07
40	51	1315.24	1.08E-01	8.32E+07
40	54	1248.98	3.24E-01	1.98E+08
40	55	1238.31	1.74E-02	1.51E+07
40	56	1225.219	1.00E+00	0.00E+00

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40	62	403.31	1.00E+00	0.00E+00
40	63	401.223	1.00E+00	0.00E+00
40	64	401.15	1.00E+00	0.00E+00
41	47	5544.735	1.00E+00	0.00E+00
41	51	1334.66	1.00E+00	0.00E+00
41	52	1318.726	1.00E+00	0.00E+00
41	54	1266.483	1.00E+00	0.00E+00
41	55	1255.512	1.00E+00	0.00E+00
41	56	1242.057	1.00E+00	0.00E+00
41	57	1224.336	1.00E+00	0.00E+00
41	62	405.117	1.00E+00	0.00E+00
41	63	403.012	1.00E+00	0.00E+00
41	64	402.938	1.00E+00	0.00E+00
41	65	402.571	1.00E+00	0.00E+00
42	52	1319.348	1.00E+00	0.00E+00
42	53	1307.749	1.00E+00	0.00E+00
42	54	1267.057	1.00E+00	0.00E+00
42	56	1242.608	1.00E+00	0.00E+00
42	57	1224.871	1.00E+00	0.00E+00
42	62	405.176	1.00E+00	0.00E+00
42	64	402.996	1.00E+00	0.00E+00
42	65	402.629	1.00E+00	0.00E+00
43	44	16156.91	1.00E+00	0.00E+00
43	48	3546.327	1.00E+00	0.00E+00
43	58	595.137	1.00E+00	0.00E+00
43	59	584.424	1.00E+00	0.00E+00
43	61	540.125	1.00E+00	0.00E+00
44	46	10483.53	1.00E+00	0.00E+00
44	47	8734.963	1.00E+00	0.00E+00
44	50	1507.229	1.00E+00	0.00E+00
44	51	1463.303	1.00E+00	0.00E+00
44	54	1381.751	1.00E+00	0.00E+00
44	55	1368.702	1.00E+00	0.00E+00
44	56	1352.727	1.00E+00	0.00E+00
44	62	416.224	1.00E+00	0.00E+00
44	63	414.002	1.00E+00	0.00E+00
44	64	413.924	1.00E+00	0.00E+00
45	47	12979.67	1.00E+00	0.00E+00
45	51	1548.115	1.00E+00	0.00E+00
45	52	1526.718	1.00E+00	0.00E+00
45	54	1457.131	1.00E+00	0.00E+00
45	55	1442.626	1.00E+00	0.00E+00
45	56	1424.89	1.00E+00	0.00E+00
45	57	1401.617	1.00E+00	0.00E+00
45	62	422.813	1.00E+00	0.00E+00
45	63	420.52	1.00E+00	0.00E+00
45	64	420.44	1.00E+00	0.00E+00
45	65	420.04	1.00E+00	0.00E+00

Continued

46	48	8019.169	1.00E+00	0.00E+00
46	58	656.597	1.00E+00	0.00E+00
46	59	643.581	1.00E+00	0.00E+00
46	61	590.27	1.00E+00	0.00E+00
47	48	9469.121	1.00E+00	0.00E+00
47	58	664.934	1.21E-01	3.63E+08
47	59	651.588	1.15E-01	3.63E+08
47	60	634.326	1.37E+00	4.56E+09
47	61	596.998	1.69E-02	6.32E+07
48	50	2255.4	7.23E-04	3.16E+05
48	51	2158.44	2.67E-02	7.64E+06
48	55	1958.75	1.44E-01	5.01E+07
48	63	455.507	1.21E-02	7.75E+07
49		25238.4	4.34E-05	4.54E+02
49	61	653.673	3.09E-01	4.82E+09
50	58	1047.21	1.10E-06	2.23E+03
50	59	1014.48	3.79E-05	8.20E+04
50	61	888.052	1.43E-04	4.03E+05
51	58	1069.51	2.46E-06	2.87E+03
51	59	1035.4	3.44E-04	4.28E+05
51	60	992.484	7.78E-06	1.05E+04
51	61	904.042	1.37E-03	2.24E+06
52	60	1001.48	2.97E-04	2.20E+05
54	58	1117.73	3.38E-05	2.58E+04
54	59	1080.53	3.03E-04	2.48E+05
54	60	1033.87	1.24E-04	1.10E+05
55	58	1126.41	1.20E-04	1.26E+05
55	59	1088.64	6.65E-07	7.49E+02
55	60	1041.3	7.16E-06	8.81E+03
55	61	944.368	3.05E-03	4.57E+06
56	58	1137.47	8.13E-05	5.99E+04
56	59	1098.97	5.31E-05	4.19E+04
56	60	1050.74	1.10E-05	9.49E+03
57	60	1063.76	2.92E-05	1.91E+04
58	62	1275.25	4.37E-01	2.56E+08
58	63	1254.62	2.69E-02	2.28E+07
58	64	1253.91	2.64E-03	1.60E+06
59	62	1327.39	1.34E-04	7.25E+04
59	63	1305.06	2.45E-02	1.92E+07
59	64	1304.28	4.30E-01	2.41E+08
60	62	1405.3	2.63E-02	1.27E+07
60	63	1380.29	1.36E-03	9.50E+05
60	64	1379.42	2.08E-02	1.04E+07
60	65	1375.12	5.53E-01	2.17E+08
61	63	1597.66	2.16E-01	1.13E+08

4. Conclusions

This paper presents calculations of fine structure levels, oscillator strengths, and radiative decay rates for Ne-like Ni and Cu ions. We show that there is a good agreement between our results which were obtained by using COWAN code and the other values from NIST.

The analysis that has been presented in this work shows that electron collisional pumping (ECP) is suitable for attaining population inversion and offering the potential for laser emission in the spectral region between 50 and 1000Å from the Ni XIX and Cu XX. This class of lasers can be achieved under the suitable conditions of pumping power as well as electron density. If the positive gains obtained previously for some transitions in the ions under studies (Ni XIX and Cu XX) together with the calculated parameters, it could be achieved experimentally. A successful low-cost electron collisional pumping XUV and soft X-ray lasers can be developed for various applications. The results have suggested the following laser transitions in the Ni XIX and Cu XX plasma ion, as the most promising laser emission lines in the XUV and soft X-ray spectral regions.

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