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HARTREE–SLATER SUBSHELL PHOTOIONIZATION CROSS-SECTIONS AT 1254 AND 1487 eV

J. H. SCOFIELD

Lawrence Livermore Laboratory, University of California, Livermore, California 94550 (U.S.A.)

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ABSTRACT

The results of calculations of photoelectric cross-sections for the Kα lines of magnesium at 1254 eV and of aluminum at 1487 eV are presented. All of the subshell cross-sections are given for Z values up to 96. The calculations were carried out relativistically using the single-potential Hartree–Slater atomic model.

This paper presents calculated subshell photoionization cross-sections for all Z values up to 96 for the energies of the Kα emission lines of magnesium at 1254 eV and of aluminum at 1487 eV. The cross-sections were calculated using transition matrix elements with the electrons in the initial and final states treated as moving in the same Hartree–Slater potential. The potential was determined self consistantly for the neutral-atom occupations of the subshells with the potential introduced by Slater[1] used to approximate the effect of exchange. The relativistic formulation of the calculation was used with the calculated binding energies used for the ionization energies and the coefficient of the exchange potential given by Slater[1]. With the necessary modifications to treat the continuum states, the treatment follows that used previously for the calculation of the characteristic X-ray emission rates[2].

The total and subshell cross-sections are presented in Tables 1 and 2 relative to the calculated values for the ionization of the 1s state of carbon of 22,200 barns at 1254 eV and 13,600 barns at 1487 eV. The 1487 eV data have previously been presented in graphical form by Carter et al.[3] and that at 1254 eV by Swingle[4]. The model uses single particle states in a central potential to represent the atomic states. Within the model the only accessible final states are those with a single vacancy out of the initial configuration. In general the single particle states will be split into a number of components and multiple excitations can also occur. If the multiplet splittings are not too great, the calculated cross-sections should give the sum over all the multiplets from a given vacancy state and all excitations in the outer orbitals. If j–j coupling is not valid, i.e. the splittings are large enough to mix the different

Table 1. Photoionization cross sections at 1254 eV in units of the C 1s cross section of 22,200 barns.

	Z	Total	1s1/2	2s1/2	2p1/2	2p3/2	3s1/2	3p1/2	3p3/2	3d3/2	3d5/2	4s1/2	4p1/2	4p3/2
H	1	0.0002	0.0002											
He	2	0.0087	0.0087											
Li	3	0.0602	0.0593	0.0008										
Be	4	0.207	0.1997	0.0074										
B	5	0.515	0.492	0.0220	0.0001	0.0002								
C	6	1.05	1.00	0.0470	0.0006	0.0012								
N	7	1.87	1.77	0.0841	0.0025	0.0049								
O	8	3.01	2.85	0.1345	0.0073	0.0145								
F	9	4.51	4.26	0.1988	0.0178	0.0352								
Ne	10	6.34	5.95	0.277	0.0381	0.0751								
Na	11	8.60	7.99	0.390	0.0714	0.1406	0.0059							
Mg	12	0.912		0.525	0.1214	0.239	0.0261							
Al	13	1.31		0.681	0.1935	0.380	0.0485	0.0012	0.0023					
Si	14	1.81		0.855	0.292	0.573	0.0726	0.0050	0.0097					
P	15	2.43		1.05	0.422	0.828	0.0998	0.0129	0.0253					
S	16	3.21		1.25	0.590	1.15	0.1302	0.0269	0.0527					
Cl	17	4.15		1.48	0.800	1.56	0.1632	0.0493	0.0964					
Ar	18	5.28		1.71	1.06	2.07	0.1989	0.0823	0.1605					
K	19	6.61		1.95	1.37	2.67	0.249	0.1221	0.238			0.0061		
Ca	20	8.17		2.21	1.74	3.39	0.305	0.1693	0.330			0.0233		
Sc	21	9.90		2.46	2.18	4.24	0.356	0.216	0.420	0.0020	0.0030	0.0273		
Ti	22	11.87		2.72	2.68	5.22	0.408	0.268	0.521	0.0064	0.0095	0.0308		
V	23	14.06		2.98	3.26	6.33	0.462	0.326	0.633	0.0145	0.0213	0.0339		
Cr	24	16.47		3.23	3.92	7.60	0.511	0.382	0.740	0.0303	0.0445	0.0139		
Mn	25	19.18		3.48	4.63	8.99	0.575	0.460	0.892	0.0484	0.0711	0.0398		
Fe	26	22.11		3.70	5.43	10.54	0.634	0.535	1.04	0.0788	0.1156	0.0425		
Co	27	25.25		3.92	6.28	12.20	0.693	0.616	1.19	0.1220	0.1787	0.0451		
Ni	28	28.56		4.16	7.18	13.92	0.753	0.701	1.36	0.1814	0.265	0.0476		
Cu	29	32.18		4.38	8.18	15.87	0.805	0.779	1.50	0.268	0.390	0.0188		
Zn	30	36.25		4.55	9.29	18.01	0.873	0.882	1.70	0.365	0.532	0.0520		
Ga	31	36.17			10.56	20.47	0.945	0.993	1.92	0.485	0.708	0.0742	0.0056	0.0106
Ge	32	27.20				21.22	1.02	1.11	2.15	0.631	0.920	0.0939	0.0179	0.0340
As	33	6.92					1.10	1.24	2.40	0.802	1.17	0.1137	0.0372	0.0710
Se	34	7.99					1.18	1.37	2.65	1.00	1.46	0.1343	0.0642	0.1228
Br	35	9.17					1.26	1.50	2.92	1.24	1.80	0.1557	0.0996	0.1906

	4d3/2	4d5/2	5s1/2											
Kr	36	10.48					1.35	1.64	3.20	1.50	2.19	0.1779	0.1441	0.276
Rb	37	11.91			0.0058		1.43	1.79	3.48	1.81	2.63	0.209	0.1868	0.361
Sr	38	13.47			0.0209		1.52	1.93	3.78	2.15	3.14	0.242	0.230	0.445
Y	39	15.14		0.0128	0.0185	0.0255	1.61	2.08	4.09	2.54	3.70	0.273	0.268	0.521
Zr	40	16.96		0.0353	0.0510	0.0290	1.70	2.24	4.40	2.97	4.33	0.305	0.307	0.596
Nb	41	18.90		0.0816	0.1176	0.0131	1.79	2.39	4.71	3.45	5.01	0.333	0.340	0.661
Mo	42	21.01		0.1296	0.1865	0.0141	1.89	2.54	5.03	3.97	5.77	0.364	0.379	0.739
Tc	43	23.28		0.1915	0.276	0.0149	1.98	2.69	5.36	4.54	6.60	0.397	0.419	0.818
Ru	44	25.71		0.269	0.387	0.0157	2.07	2.84	5.68	5.17	7.51	0.429	0.460	0.899
Rh	45	28.32		0.365	0.524	0.0164	2.15	2.98	6.00	5.84	8.48	0.463	0.501	0.981
Pd	46	31.10		0.495	0.707		2.24	3.12	6.33	6.58	9.54	0.494	0.538	1.06
Ag	47	34.06		0.616	0.884	0.0176	2.33	3.25	6.64	7.36	10.68	0.531	0.586	1.15
Cd	48	37.20		0.747	1.07	0.0464	2.40	3.39	6.96	8.22	11.91	0.571	0.636	1.26

Table 1 (continued). Cross sections at 1254 eV in units of 22,200 barns.

	Z	Total	3s1/2	3p1/2	3p3/2	3d3/2	3d5/2	4s1/2	4p1/2	4p3/2	4d3/2	4d5/2	4f5/2	4f7/2
In	49	40.54	2.48	3.51	7.27	9.13	13.23	0.611	0.689	1.37	0.893	1.29		
Sn	50	44.02	2.54	3.62	7.58	10.09	14.63	0.653	0.743	1.48	1.05	1.51		
Sb	51	47.69	2.60	3.71	7.86	11.13	16.13	0.696	0.799	1.60	1.22	1.76		
Te	52	51.51	2.67	3.79	8.14	12.21	17.70	0.741	0.856	1.73	1.40	2.01		
I	53	55.43	2.75	3.87	8.37	13.33	19.33	0.785	0.913	1.86	1.58	2.29		
Xe	54	59.64	2.83	3.95	8.64	14.55	21.08	0.831	0.971	1.99	1.78	2.57		
Cs	55	64.02	2.84	4.04	8.94	15.80	22.93	0.877	1.03	2.12	1.99	2.88		
Ba	56	65.53		4.10	9.26	17.04	24.75	0.924	1.09	2.26	2.21	3.20		
La	57	69.64		4.06	9.52	18.25	26.49	0.971	1.15	2.40	2.44	3.53		
Ce	58	69.82			9.67	19.67	28.57	1.00	1.18	2.49	2.58	3.74	0.0689	0.088
Pr	59	74.30			9.75	21.13	30.72	1.04	1.23	2.60	2.77	4.01	0.1256	0.161
Nd	60	69.16				22.66	32.96	1.07	1.27	2.71	2.96	4.28	0.200	0.257
Pm	61	74.06				24.32	35.33	1.11	1.30	2.81	3.14	4.55	0.296	0.379
Sm	62	79.35				26.12	37.90	1.14	1.34	2.91	3.33	4.82	0.416	0.531
Eu	63	85.36				28.20	40.87	1.17	1.37	3.01	3.51	5.09	0.562	0.718
Gd	64	85.24				24.35	43.43	1.20	1.41	3.13	3.73	5.41	0.693	0.887
Tb	65	39.20					20.80	1.22	1.43	3.21	3.88	5.61	0.949	1.21
Dy	66	19.55						1.25	1.45	3.30	4.05	5.87	1.20	1.52
Ho	67	20.78						1.27	1.47	3.39	4.22	6.13	1.49	1.89
Er	68	22.09						1.29	1.49	3.48	4.39	6.37	1.82	2.31
Tm	69	23.48						1.31	1.50	3.56	4.56	6.62	2.20	2.78
Yb	70	24.97						1.32	1.51	3.64	4.72	6.85	2.63	3.33
Lu	71	26.65						1.34	1.52	3.73	4.91	7.13	3.05	3.87
Hf	72	28.45						1.36	1.53	3.83	5.10	7.42	3.50	4.45
Ta	73	30.35						1.38	1.54	3.93	5.29	7.71	3.99	5.08
W	74	32.36						1.39	1.55	4.03	5.48	8.01	4.52	5.75
Re	75	34.48						1.41	1.55	4.13	5.67	8.31	5.08	6.46
Os	76	36.70						1.42	1.55	4.24	5.86	8.60	5.67	7.22
Ir	77	39.08						1.43	1.55	4.34	6.05	8.90	6.30	8.03
Pt	78	41.50						1.44	1.54	4.45	6.24	9.20	6.97	8.89
Au	79	44.03						1.45	1.53	4.55	6.42	9.50	7.68	9.79
Hg	80	46.63						1.45	1.52	4.65	6.60	9.79	8.43	10.75
Tl	81	49.35						1.46	1.50	4.75	6.78	10.08	9.22	11.77
Pb	82	52.15						1.46	1.47	4.86	6.94	10.37	10.05	12.83
Bi	83	55.03						1.45	1.45	4.96	7.11	10.64	10.93	13.95
Po	84	58.01						1.44	1.42	5.06	7.27	10.92	11.84	15.12
At	85	61.08						1.44	1.38	5.15	7.42	11.20	12.80	16.35
Rn	86	64.22						1.44	1.34	5.24	7.56	11.46	13.80	17.63
Fr	87	67.45						1.44	1.30	5.34	7.69	11.70	14.84	18.97
Ra	88	70.74						1.41	1.26	5.42	7.82	11.95	15.92	20.36
Ac	89	74.34						1.58	1.22	5.50	7.95	12.21	17.05	21.80
Th	90	76.27							1.17	5.59	8.05	12.45	18.21	23.30
Pa	91	79.91							1.12	5.68	8.13	12.66	19.38	24.81
U	92	82.57								5.77	8.21	12.84	20.61	26.38
Np	93	86.49								5.87	8.31	13.02	21.87	28.02
Pu	94	90.56								5.95	8.39	13.22	23.14	29.67
Am	95	94.61								6.03	8.43	13.43	24.44	31.35
Cm	96	98.65								6.08	8.45	13.57	25.80	33.09

Table 1 (continued). Cross sections at 1254 eV in units of 22,200 barns.

	Z	5s1/2	5p1/2	5p3/2	5d3/2	5d5/2	5f5/2	5f7/2	6s1/2	6p1/2	6p3/2	6d3/2	6d5/2	7s1/2
In	49	0.0626	0.0058	0.0107										
Sn	50	0.0765	0.0169	0.0318										
Sb	51	0.0899	0.0331	0.0629										
Te	52	0.1036	0.0542	0.1040										
I	53	0.1175	0.0805	0.1555										
Xe	54	0.1319	0.1123	0.218					0.0049					
Cs	55	0.1523	0.1397	0.278					0.0171					
Ba	56	0.1737	0.1661	0.334					0.0206					
La	57	0.1933	0.1887	0.382	0.0187	0.0267			0.0178					
Ce	58	0.1891	0.1805	0.365					0.0181					
Pr	59	0.1958	0.1864	0.378					0.0183					
Nd	60	0.202	0.1917	0.390										
Pm	61	0.208	0.1964	0.402					0.0184					
Sm	62	0.213	0.201	0.412					0.0186					
Eu	63	0.219	0.205	0.422					0.0187					
Gd	64	0.235	0.223	0.465	0.0219	0.0306			0.0222					
Tb	65	0.228	0.211	0.440					0.0189					
Dy	66	0.232	0.214	0.449					0.0189					
Ho	67	0.237	0.216	0.457					0.0190					
Er	68	0.240	0.219	0.464					0.0190					
Tm	69	0.244	0.220	0.471					0.0191					
Yb	70	0.247	0.222	0.478					0.0191					
Lu	71	0.261	0.237	0.519	0.0212	0.0290			0.0231					
Hf	72	0.276	0.253	0.562	0.0541	0.0747			0.0261					
Ta	73	0.291	0.268	0.606	0.0976	0.1357			0.0287					
W	74	0.306	0.283	0.651	0.1518	0.212			0.0310					
Re	75	0.322	0.299	0.697	0.217	0.303			0.0330					
Os	76	0.337	0.314	0.743	0.293	0.410			0.0349					
Ir	77	0.350	0.324	0.774	0.431	0.593								
Pt	78	0.366	0.340	0.829	0.508	0.709			0.0167					
Au	79	0.381	0.353	0.877	0.619	0.865			0.0173					
Hg	80	0.397	0.368	0.935	0.707	0.997			0.0410					
Tl	81	0.413	0.383	0.996	0.804	1.14			0.0513	0.0042	0.0079			
Pb	82	0.430	0.398	1.06	0.900	1.29			0.0597	0.0115	0.0233			
Bi	83	0.446	0.412	1.13	0.997	1.44			0.0676	0.0210	0.0456			
Po	84	0.462	0.426	1.19	1.09	1.58			0.0753	0.0329	0.0745			
At	85	0.478	0.439	1.26	1.19	1.73			0.0830	0.0469	0.1099			
Rn	86	0.493	0.451	1.33	1.29	1.88			0.0906	0.0631	0.1520			0.0037
Fr	87	0.508	0.462	1.40	1.39	2.04			0.1008	0.0738	0.1928			0.0122
Ra	88	0.523	0.472	1.48	1.49	2.20			0.1109	0.0837	0.230			
Ac	89	0.537	0.480	1.55	1.60	2.36			0.1207	0.0925	0.262	0.0125	0.0174	0.0152
Th	90	0.551	0.488	1.63	1.70	2.52			0.1301	0.1007	0.293	0.0316	0.0446	0.0176
Pa	91	0.561	0.492	1.69	1.77	2.63	0.1907	0.239	0.1304	0.0986	0.290	0.0138	0.0191	0.0159
U	92	0.572	0.495	1.76	1.85	2.76	0.324	0.407	0.1343	0.1006	0.301	0.0142	0.0196	0.0160
Np	93	0.581	0.497	1.82	1.93	2.88	0.482	0.606	0.1379	0.1022	0.312	0.0145	0.0199	0.0161
Pu	94	0.589	0.496	1.88	1.99	2.98	0.747	0.933	0.1370	0.0988	0.304			0.0138
Am	95	0.596	0.494	1.95	2.07	3.10	0.960	1.20	0.1398	0.0995	0.313			0.0138
Cm	96	0.603	0.492	2.02	2.15	3.25	1.11	1.40	0.1463	0.1042	0.340	0.0149	0.0200	0.0163

Table 2. Photoionization cross sections at 1487 eV in units of the C 1s cross section of 13,600 barns.

	Z	Total	1s1/2	2s1/2	2p1/2	2p3/2	3s1/2	3p1/2	3p3/2	3d3/2	3d5/2	4s1/2	4p1/2	4p3/2
H	1	0.0002	0.0002											
He	2	0.0082	0.0082											
Li	3	0.0576	0.0568	0.0008										
Be	4	0.202	0.1947	0.0072										
B	5	0.508	0.486	0.0220	0.0001	0.0001								
C	6	1.05	1.000	0.0477	0.0005	0.0010								
N	7	1.89	1.80	0.0867	0.0022	0.0043								
O	8	3.09	2.93	0.1405	0.0065	0.0128								
F	9	4.68	4.43	0.210	0.0161	0.0317								
Ne	10	6.70	6.30	0.296	0.0347	0.0683								
Na	11	9.14	8.52	0.422	0.0654	0.1287	0.0064							
Mg	12	12.11	11.18	0.575	0.1125	0.221	0.0285							
Al	13	1.35		0.753	0.1811	0.356	0.0535	0.0011	0.0022					
Si	14	1.87		0.955	0.276	0.541	0.0808	0.0047	0.0093					
P	15	2.52		1.18	0.403	0.789	0.1116	0.0124	0.0244					
S	16	3.33		1.43	0.567	1.11	0.1465	0.0262	0.0512					
Cl	17	4.31		1.69	0.775	1.51	0.1852	0.0486	0.0947					
Ar	18	5.49		1.97	1.03	2.01	0.227	0.0821	0.1597					
K	19	6.90		2.27	1.35	2.62	0.286	0.1229	0.239			0.0069		
Ca	20	8.55		2.59	1.72	3.35	0.351	0.1720	0.335			0.0268		
Sc	21	10.39		2.91	2.17	4.21	0.411	0.221	0.429	0.0017	0.0025	0.0314		
Ti	22	12.48		3.24	2.69	5.22	0.473	0.276	0.537	0.0055	0.0081	0.0355		
V	23	14.84		3.57	3.29	6.37	0.538	0.339	0.657	0.0125	0.0184	0.0394		
Cr	24	17.43		3.91	3.98	7.69	0.596	0.400	0.773	0.0264	0.0387	0.0161		
Mn	25	20.39		4.23	4.74	9.17	0.674	0.485	0.938	0.0424	0.0622	0.0464		
Fe	26	23.61		4.57	5.60	10.82	0.745	0.569	1.10	0.0694	0.1017	0.0497		
Co	27	27.10		4.88	6.54	12.62	0.818	0.660	1.27	0.1082	0.1582	0.0529		
Ni	28	30.90		5.16	7.57	14.61	0.892	0.757	1.46	0.1619	0.236	0.0560		
Cu	29	34.90		5.46	8.66	16.73	0.957	0.848	1.63	0.240	0.349	0.0221		
Zn	30	39.22		5.76	9.80	18.92	1.04	0.968	1.86	0.330	0.480	0.0618		
Ga	31	44.09		6.07	11.09	21.40	1.13	1.10	2.11	0.442	0.643	0.0882	0.0062	0.0116
Ge	32	49.42		6.31	12.52	24.15	1.23	1.24	2.39	0.578	0.842	0.1119	0.0199	0.0377
As	33	48.73			14.07	27.19	1.32	1.39	2.68	0.741	1.08	0.1357	0.0417	0.0792
Se	34	51.18			13.66	28.90	1.43	1.55	2.98	0.934	1.36	0.1605	0.0724	0.1376
Br	35	9.91					1.53	1.72	3.31	1.16	1.68	0.1863	0.1129	0.215

	Z	4d3/2	4d5/2	5s1/2									
Kr	36				1.64	1.89	3.65	1.42	2.06	0.213	0.1643	0.312	
Rb	37			0.0070	1.75	2.07	4.00	1.72	2.49	0.251	0.214	0.411	
Sr	38			0.0251	1.86	2.25	4.37	2.06	2.99	0.291	0.265	0.510	
Y	39	0.0126	0.0181	0.0306	1.98	2.44	4.75	2.44	3.54	0.329	0.311	0.599	
Zr	40	0.0348	0.0502	0.0348	2.10	2.64	5.14	2.87	4.17	0.367	0.357	0.689	
Nb	41	0.0812	0.1166	0.0157	2.22	2.84	5.53	3.35	4.86	0.402	0.398	0.767	
Mo	42	0.1298	0.1864	0.0169	2.34	3.04	5.94	3.88	5.62	0.440	0.445	0.860	
Tc	43	0.1934	0.277	0.0179	2.45	3.23	6.36	4.46	6.47	0.479	0.494	0.955	
Ru	44	0.274	0.393	0.0188	2.57	3.44	6.78	5.10	7.39	0.519	0.544	1.05	
Rh	45	0.373	0.535	0.0197	2.70	3.64	7.21	5.80	8.39	0.560	0.595	1.15	
Pd	46	0.510	0.725		2.81	3.83	7.63	6.56	9.48	0.598	0.641	1.24	
Ag	47	0.638	0.911	0.0212	2.93	4.03	8.06	7.38	10.66	0.644	0.700	1.36	
Cd	48	0.778	1.11	0.0558	3.04	4.22	8.50	8.27	11.95	0.692	0.762	1.49	

Table 2 (continued). Cross sections at 1487 eV in units of 13,600 barns.

	Z	Total	3s1/2	3p1/2	3p3/2	3d3/2	3d5/2	4s1/2	4p1/2	4p3/2	4d3/2	4d5/2	4f5/2	4f7/2
In	49	44.59	3.16	4.40	8.93	9.22	13.32	0.742	0.828	1.62	0.935	1.34		
Sn	50	48.54	3.26	4.58	9.35	10.25	14.80	0.794	0.897	1.77	1.11	1.59		
Sb	51	52.73	3.36	4.76	9.77	11.35	16.39	0.848	0.968	1.91	1.29	1.85		
Te	52	57.11	3.46	4.92	10.21	12.52	18.06	0.903	1.04	2.07	1.49	2.14		
I	53	61.70	3.53	5.06	10.62	13.77	19.87	0.959	1.11	2.23	1.69	2.44		
Xe	54	66.52	3.62	5.20	10.99	15.10	21.79	1.02	1.19	2.39	1.92	2.76		
Cs	55	71.46	3.73	5.29	11.38	16.46	23.76	1.08	1.27	2.56	2.15	3.10		
Ba	56	76.65	3.84	5.42	11.71	17.92	25.84	1.13	1.34	2.73	2.40	3.46		
La	57	82.21	3.89	5.55	12.11	19.50	28.12	1.19	1.42	2.91	2.67	3.85		
Ce	58	87.45	3.93	5.66	12.53	21.12	30.50	1.24	1.47	3.03	2.84	4.09	0.0609	0.078
Pr	59	92.91	3.98	5.75	12.94	22.72	32.85	1.28	1.53	3.17	3.07	4.41	0.1115	0.143
Nd	60	94.31		5.75	13.35	24.27	35.29	1.33	1.59	3.31	3.29	4.74	0.1788	0.228
Pm	61	99.79		5.72	13.66	26.08	37.65	1.38	1.64	3.45	3.52	5.07	0.265	0.339
Sm	62	99.90			13.84	27.96	40.37	1.42	1.70	3.59	3.76	5.40	0.374	0.477
Eu	63	106.32			14.30	29.91	43.24	1.46	1.75	3.72	3.99	5.74	0.508	0.647
Gd	64	98.46				31.98	46.23	1.51	1.80	3.88	4.26	6.14	0.630	0.804
Tb	65	104.92				34.20	49.42	1.54	1.84	3.99	4.46	6.41	0.867	1.10
Dy	66	112.10				36.65	52.83	1.58	1.88	4.12	4.69	6.74	1.10	1.39
Ho	67	119.88				39.19	56.66	1.61	1.91	4.24	4.92	7.08	1.37	1.73
Er	68	122.63				36.70	60.42	1.64	1.95	4.37	5.15	7.41	1.69	2.13
Tm	69	68.10					41.01	1.67	1.98	4.48	5.38	7.74	2.05	2.59
Yb	70	28.76						1.70	2.00	4.60	5.61	8.07	2.47	3.11
Lu	71	30.68						1.73	2.03	4.74	5.87	8.45	2.87	3.63
Hf	72	32.74						1.76	2.06	4.88	6.13	8.84	3.32	4.20
Ta	73	34.92						1.79	2.08	5.02	6.40	9.24	3.80	4.82
W	74	37.23						1.81	2.10	5.16	6.68	9.65	4.32	5.48
Re	75	39.67						1.84	2.12	5.30	6.95	10.06	4.88	6.20
Os	76	42.24						1.86	2.13	5.45	7.23	10.48	5.48	6.96
Ir	77	44.99						1.88	2.14	5.59	7.51	10.90	6.12	7.78
Pt	78	47.79						1.90	2.14	5.74	7.78	11.32	6.81	8.65
Au	79	50.75						1.92	2.14	5.89	8.06	11.74	7.54	9.58
Hg	80	53.79						1.94	2.14	6.04	8.33	12.17	8.32	10.57
Tl	81	56.97						1.95	2.13	6.19	8.60	12.60	9.14	11.62
Pb	82	60.25						1.96	2.12	6.33	8.87	13.02	10.01	12.73
Bi	83	63.65						1.96	2.10	6.48	9.14	13.44	10.93	13.90
Po	84	67.17						1.97	2.07	6.62	9.40	13.87	11.90	15.14
At	85	70.79						1.96	2.04	6.77	9.65	14.29	12.92	16.44
Rn	86	74.51						1.95	2.00	6.92	9.90	14.70	14.00	17.81
Fr	87	78.37						1.95	1.97	7.07	10.16	15.11	15.12	19.24
Ra	88	82.33						1.95	1.91	7.20	10.40	15.53	16.30	20.74
Ac	89	86.41						1.95	1.86	7.33	10.61	15.93	17.53	22.30
Th	90	90.58						1.95	1.80	7.46	10.82	16.31	18.81	23.94
Pa	91	94.93						1.92	1.74	7.61	11.04	16.67	20.12	25.60
U	92	99.42						1.90	1.68	7.71	11.25	17.05	21.50	27.36
Np	93	104.17						2.00	1.61	7.83	11.44	17.44	22.91	29.18
Pu	94	106.95							1.54	7.95	11.60	17.81	24.36	31.03
Am	95	111.82							1.47	8.08	11.74	18.14	25.87	32.95
Cm	96	115.41								8.21	11.88	18.43	27.45	34.97

Table 2 (continued). Cross sections at 1487 eV in units of 13,600 barns.

	Z	5s1/2	5p1/2	5p3/2	5d3/2	5d5/2	5f5/2	5f7/2	6s1/2	6p1/2	6p3/2	6d3/2	6d5/2	7s1/2
In	49	0.0755	0.0069	0.0126										
Sn	50	0.0922	0.0203	0.0377										
Sb	51	0.1085	0.0398	0.0747										
Te	52	0.1251	0.0653	0.1237										
I	53	0.1421	0.0974	0.1854										
Xe	54	0.1596	0.1361	0.260										
Cs	55	0.1843	0.1697	0.332					0.0059					
Ba	56	0.210	0.202	0.400					0.0206					
La	57	0.234	0.230	0.458	0.0205	0.0291			0.0248					
Ce	58	0.230	0.221	0.439					0.0215					
Pr	59	0.238	0.229	0.456					0.0218					
Nd	60	0.247	0.236	0.472					0.0221					
Pm	61	0.254	0.243	0.487					0.0224					
Sm	62	0.261	0.249	0.501					0.0226					
Eu	63	0.268	0.255	0.515					0.0228					
Gd	64	0.288	0.279	0.568	0.0249	0.0347			0.0271					
Tb	65	0.281	0.265	0.539					0.0230					
Dy	66	0.287	0.270	0.551					0.0232					
Ho	67	0.293	0.274	0.562					0.0233					
Er	68	0.298	0.277	0.572					0.0233					
Tm	69	0.303	0.281	0.583					0.0234					
Yb	70	0.308	0.284	0.592					0.0235					
Lu	71	0.326	0.304	0.645	0.0252	0.0341			0.0285					
Hf	72	0.344	0.325	0.699	0.0644	0.0882			0.0322					
Ta	73	0.363	0.346	0.754	0.1168	0.1610			0.0354					
W	74	0.383	0.367	0.811	0.1824	0.252			0.0383					
Re	75	0.402	0.387	0.869	0.261	0.363			0.0408					
Os	76	0.422	0.408	0.928	0.354	0.493			0.0431					
Ir	77	0.438	0.422	0.967	0.524	0.714								
Pt	78	0.459	0.444	1.04	0.620	0.857			0.0207					
Au	79	0.479	0.463	1.10	0.758	1.05			0.0214					
Hg	80	0.500	0.484	1.17	0.869	1.21			0.0508					
Tl	81	0.520	0.505	1.25	0.991	1.39			0.0637	0.0054	0.0098			
Pb	82	0.542	0.526	1.33	1.11	1.58			0.0742	0.0148	0.0291			
Bi	83	0.563	0.546	1.41	1.24	1.76			0.0840	0.0273	0.0568			
Po	84	0.584	0.566	1.50	1.36	1.95			0.0937	0.0428	0.0928			
At	85	0.605	0.584	1.58	1.49	2.14			0.1033	0.0612	0.1370			
Rn	86	0.625	0.602	1.67	1.62	2.33			0.1129	0.0824	0.1895			
Fr	87	0.645	0.618	1.77	1.75	2.53			0.1257	0.0966	0.240			0.0046
Ra	88	0.665	0.633	1.86	1.88	2.73			0.1383	0.1099	0.286			0.0150
Ac	89	0.684	0.647	1.95	2.02	2.94			0.1506	0.1216	0.326	0.0156	0.0215	0.0187
Th	90	0.702	0.660	2.05	2.15	3.15			0.1625	0.1325	0.366	0.0397	0.0552	0.0216
Pa	91	0.718	0.667	2.13	2.25	3.29	0.204	0.255	0.1630	0.1300	0.361	0.0174	0.0237	0.0195
U	92	0.732	0.674	2.22	2.36	3.46	0.389	0.485	0.1682	0.1330	0.376	0.0179	0.0243	0.0197
Np	93	0.746	0.678	2.31	2.46	3.62	0.522	0.652	0.1729	0.1354	0.390	0.0183	0.0248	0.0199
Pu	94	0.758	0.680	2.38	2.56	3.76	0.812	1.01	0.1720	0.1313	0.380			0.0170
Am	95	0.769	0.680	2.47	2.66	3.92	1.05	1.30	0.1758	0.1325	0.391			0.0170
Cm	96	0.780	0.680	2.56	2.78	4.11	1.22	1.52	0.1842	0.1390	0.426	0.0190	0.0251	0.0202

vacancy states, then only the sum of the cross-sections for the production of the mixed single vacancy states will be of relevance.

The Hartree–Slater model has been used for a number of previous photoionization calculations. These include those of Cooper[5], Combet Farnoux[6], Manson and Cooper[8], and of Henry et al.[7] Compilations using the non-relativistic version of the model have been given by McGuire[9] and in conjunction with experimental data by Viegele[10]. Henke and Ebisu[11] have used experimental data and Viegele's calculated results to present the total absorption cross-sections for a large number of characteristic x-ray energies including the two here. The relativistic model has been used by Brysk and Zerby[12] and compilations based on it have been presented by Storm and Israel[13], by Barfield et al.[14] and by Scofield[15]. Barfield et al.[14] present the subshell cross sections for the low Z elements in a form convenient to interpolate to a given energy. The subshell cross-sections are listed from 1 to 1500 keV in the report by Scofield. The subshell cross-sections for the two energies covered here have previously been given by Nefedov et al.[16] for Z values up to 20.

Comparing the total cross-section results of the present calculation with the experimentally derived low Z values listed by Henke and Ebisu[11] and the cross-sections with small experimental uncertainties listed in Section III of the compilations of McMaster et al.[17] shows agreement to within 5% for all except the high Z elements. For the elements for which the N shell is the major contributor, the differences rise to approximately 10%; for the photoabsorption in uranium at these energies recent experiments of Del Grande and Oliver[18] show 16% differences.

The experimental results for the subshell cross-sections have thus far been too fragmentary for a clear picture of the reliability of these theoretical results. Results of the measurements in solids[3, 16, 19, 20] have a large amount of scatter but show a general agreement with the theoretical results within something like 30%. Most of the results of Kemeny et al.[20] for NaF and NaCl agree well with the present values except the 3s result in chlorine which is one-half the theoretical value. The relative cross-sections for the 3s, 3p and 3d shells in krypton[21] agree with the results of the model. Results from the Uppsala group reported by Gelius[22] show systematic discrepancies for the 2s/2p and 3s/3p cross-section ratios presented per electron. For carbon their 2s/2p ratio is one-half the theoretical value and, progressing to neon it is 1.2 times the theoretical. Their experimental value of the 3s/3p ratio is one-third of the theoretical value for sulfur and 0.6 times the theoretical value for argon. Experiments of Wuilleumier and Krause[23] for neon find the cross-sections, with those for multivacancy production included, for the 2s vacancy production 0.7 times the Hartree–Slater value and for 2p 0.8 times this value. In contrast to the Uppsala group's value, their 2s/2p value is 0.8 times the theoretical value.

The inaccuracy in the Hartree–Slater model in the treatment of the photoionization from isolated atoms comes about because of the approximate manner of treating the electron–electron interactions. The problem of more accurately calculating the magnitude and the structure of the photoelectron spectrum is being pursued using a number of different methods. Recent review articles which treat the theoretical approaches include Fano and Cooper[24], Pratt et al.[25], Fadley[26] and Cooper[27].

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