Average Matrix Relative Sensitivity Factors (AMRSFs) for X-ray Photoelectron Spectroscopy (XPS)

These tables and plots contain AMRSFs for XPS calculated for the total peak area for all core levels with greater than 17 eV binding energy for both Mg and Al Kα X-rays for instruments operated at the magic angle where, classically the effect of the dipole anisotropy parameter, β, is removed. At the magic angle, the angle between the incident photon beam and the detected photoelectrons is 54.7º. The background to, and use of, AMRSFs, I_i^{Av}, is discussed by Seah, Gilmore and Spencer [1] and also in ISO 18118 [2]. For homogeneous solids, the atomic fraction of element A, X_{A}, is given by

$$X_{\mathrm{A}} = \frac{I_{\mathrm{Am}} / I_{\mathrm{A}}^{\mathrm{Av}}}{\sum_i I_{i\mathrm{m}} / I_i^{\mathrm{Av}}} \qquad (1)$$

where the I_{im} are the measured peak area intensities for the element i in the sample m.

These AMRSFs are based on theory and are thus for use with spectrometers for which the intensity/energy response function is calibrated [3] or otherwise known [4]. They are unlikely to be as accurate, for quantification, as properly determined experimental sensitivity factors, measured on the instrument with the correct settings for which they are intended to be used [2].

It should be noted that these AMRSFs are thought to be valid for all systems, irrespective of the chemical state, but are only valid for a correct measure of the peak areas. The most correct general background to remove for homogeneous solids is Tougaard's background [5]. It is very common to use Shirley's background [6] but this does not give intensities that either agree with Tougaard's background or with theory [7] These AMRSFs are not for use with Shirley's background.

The calculations of the AMRSFs use the procedure of Seah, Gilmore and Spencer [1] in which the AMRSFs, for the core level X in the element A, are given by:

$$I_{\mathrm{AX}}^{\mathrm{Av}} = n_{\mathrm{AX_i}} \sigma_{\mathrm{AX}_i}(h\nu)\, N_{\mathrm{Av}}\; Q_{\mathrm{Av}}\, \lambda_{\mathrm{Av}}(E_{\mathrm{AX}_i}) \qquad (2)$$

where $n_{\mathrm{AX}i}$ is the population of the level X_i, $\sigma_{\mathrm{AX}_i}(h\nu)$ is photoionisation cross section for each electron in the core level X_i in the element A for X-ray photoelectrons of energy $h\nu$, N_{Av} is the atomic density of the average matrix, Q_{Av} is a term allowing for the reduction in overall escape probability of electrons from the average solid arising from elastic scattering, $\lambda_{\mathrm{Av}}(E_{\mathrm{AX}})$ is the inelastic mean free path (IMFP) for the Auger electrons with average energy $E_{\mathrm{AX}i}$ in the average matrix.

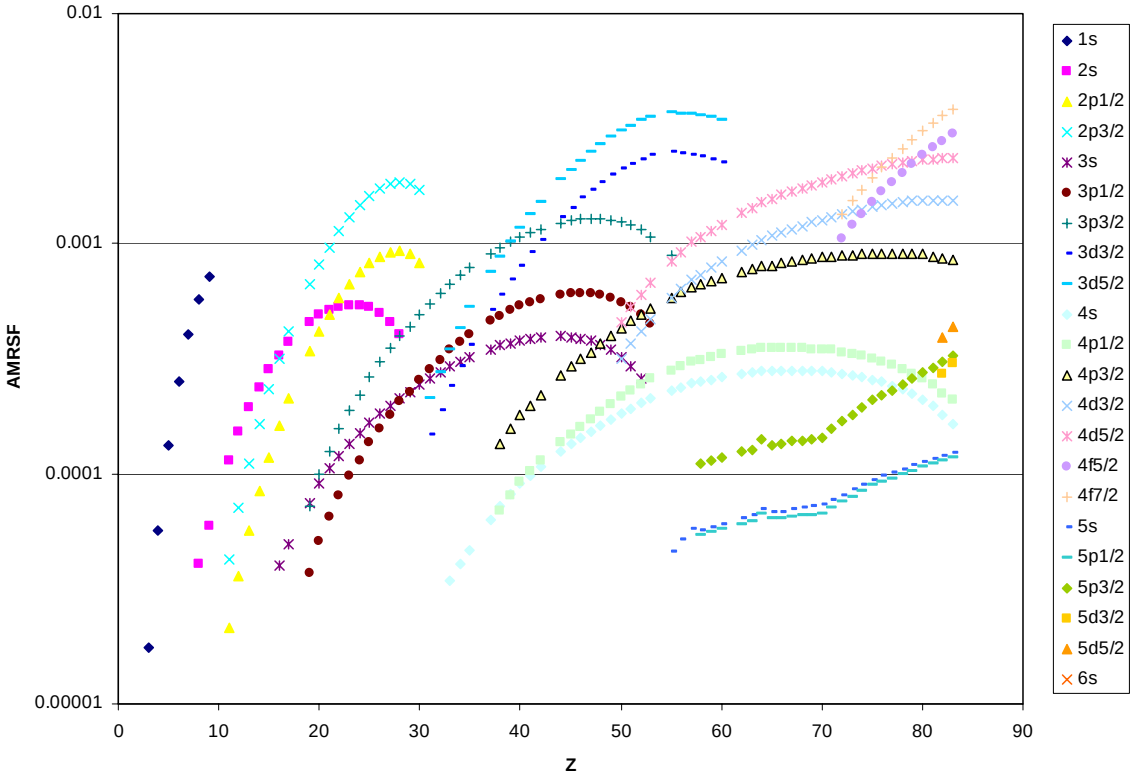
The contributions of N_{Av}, Q_{Av} and $\lambda_{\mathrm{Av}}(E_{\mathrm{AX}})$ are discussed in the document for AES AMRSFs and are the same here. The photoelectron cross sections used here are those of Scofield which have been found to be in good agreement with measurements.

The calculated results are given in Tables I and II for Mg and Al X-rays, respectively, as shown in Figure 1(a) and (b). Tables III and IV show the AMRSFs ratioed to C as unity. These data are slightly different from those published in reference [1] where, for comparison with experiment, a secα term was included in equation (1) and, in the plots there, often adjacent peaks were combined.

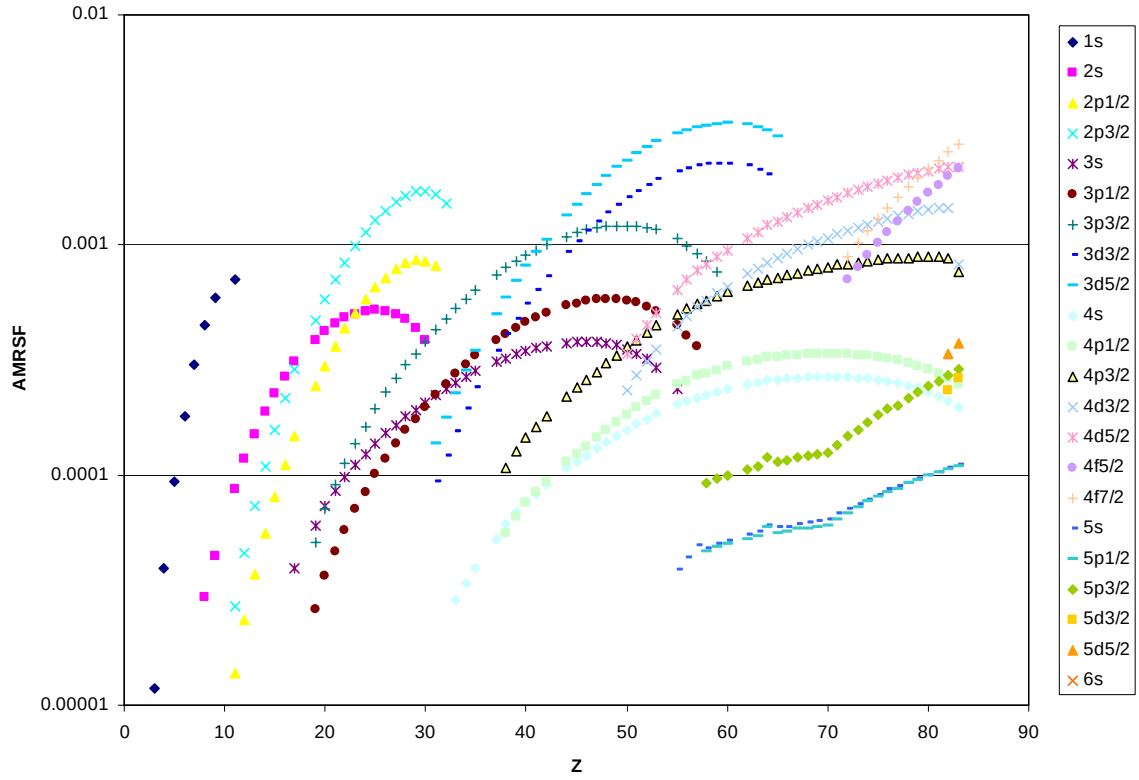
For work at angles, γ, between the incident X-rays and the detected photo-emitted electrons, other than the magic angle, an angular anisotropy needs to be considered. For homogeneous solids within the dipole approximation, the angular distribution is given by an added factor, G(γ), on the right of Eq. (2) where, for angles of emission less than 60º from the surface normal [8],

$$G_{\mathrm{A}}(\gamma) = 1+\tfrac{1}{2}(0.69\beta_{\mathrm{AX}_i})(\tfrac{3}{2}\sin^2\gamma-1) \qquad (3)$$

where β_{AX_i} is the angular anisotropy parameter for the level X_i in the element A. Equation (3) includes the effects of elastic scattering in the 0.69 appropriate for the average matrix. Figure 2 shows how this term affects the intensities for scattering angles, g, in the range 45º to 90º. For scattering angles in the range 90º to 180º, use 180º – γ. In Fig 2, the β values are from 0.5 to 2. For all s levels, $\beta = 2$. For the other angles, the values are taken from Reilman *et al* [9]. These are given at intervals of 5 in *Z* and so a simple linear interpolation has been used for the plots of b for relevant levels for Mg and Al Kα X-rays in Figs. 3 (a) and (b), respectively. For angles other than the magic angle, the effects of Figs 2 and 3 need to be included.



(a) Mg Kα X-rays



(b) Al Kα X-rays

Figure 1 - The AMRSFs for all core levels with binding energies greater than 17 eV for Mg and Al Kα X-rays.

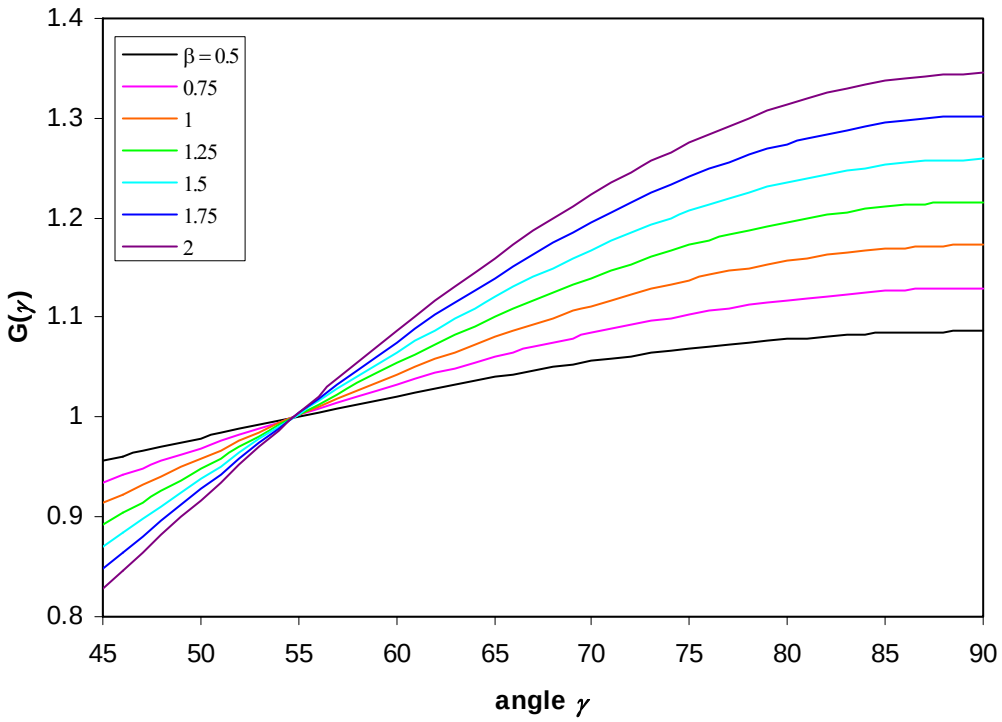
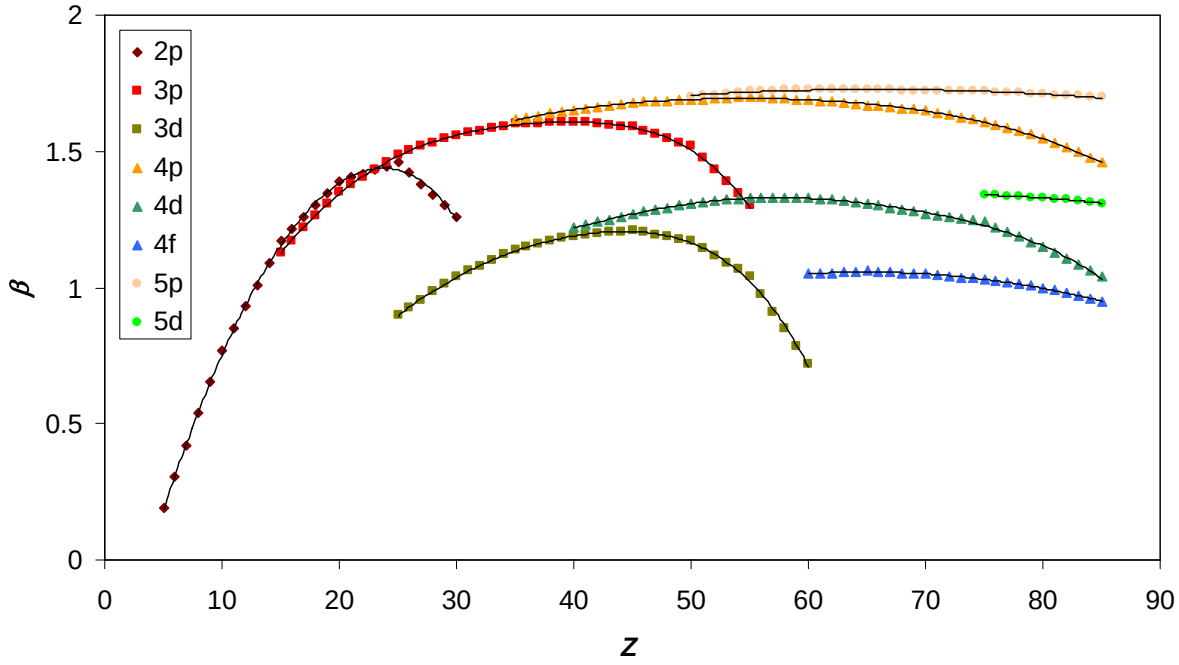
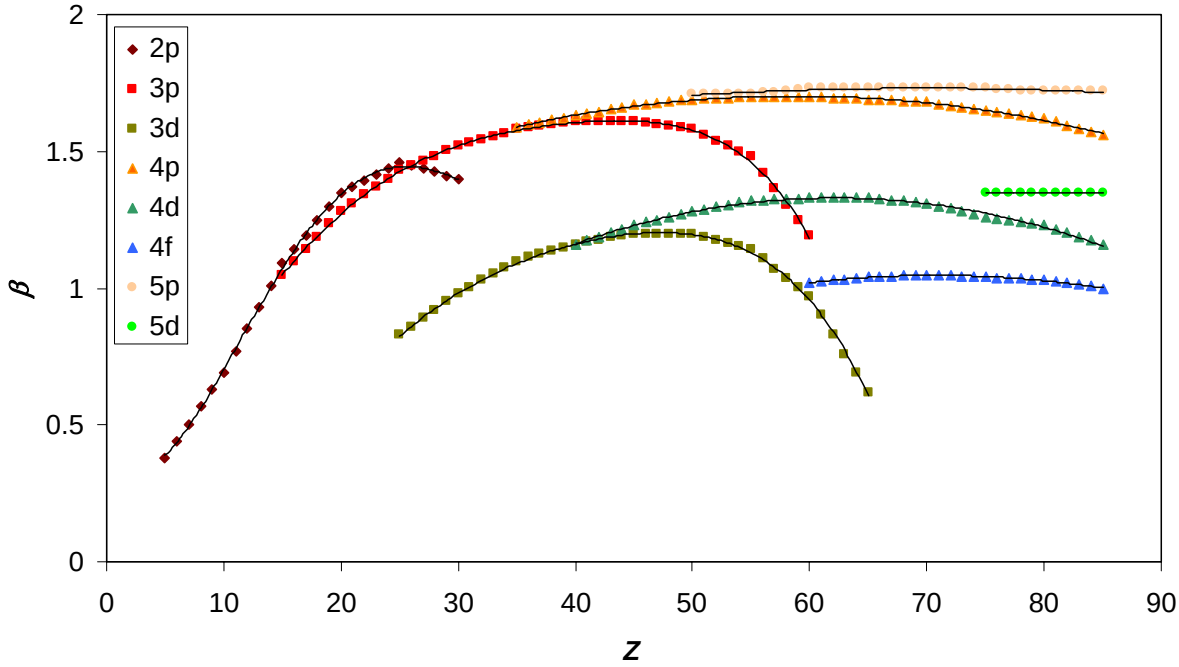


Figure 2 – Dependence of G(γ) on γ for $0.5 \leq \beta \leq 2$.



(a) Mg Kα X-rays



(b) Al Kα X-rays

Figure 3 – Values of β as a function of Z for relevant core levels for (a) Mg and (b) Al, Kα X-rays.

[1] M P Seah, I S Gilmore and S J Spencer, *J. Electron Spectrosc.* **120** 93-111 (2001).

[2] ISO 18118:2004 - Surface chemical analysis - Auger electron spectroscopy and X-ray photoelectron spectroscopy - Guide to the use of experimentally determined relative

sensitivity factors for the quantitative analysis of homogeneous materials, ISO, Geneva (see also S Tanuma, *Surface and Interface Analysis* **38** 178-180 (2006)).
[3] http://www.npl.co.uk/nanoanalysis/a1calib.html.
[4] M P Seah, *J. Electron Spectrosc*. **71** 191-204 (1995).
[5] S Tougaard, *Surface and Interface Analysis* **11**, 453-472 (1988).
[6] D A Shirley, *Phys. Rev*. B **5**, 4709 (1972).
[7] M P Seah and I S Gilmore, *Phys. Rev*. B **73** 174113 (2006)
[8] M P Seah, *Surface Analysis by Auger and X-Ray Photoelectron Spectroscopy*, Eds D Briggs and J T Grant, SurfaceSpectra Ltd/I M Publications 2003, pp 345-375, Chapter 13, Quantification in AES and XPS.
[9] R F Reilman, A Msezane and S T Manson, *J. Electron Spectrosc*. **8** 389-394 (1976).

Table I – Calculated AMRSFs for Mg X-rays

Level	1s	2s	$2p_{1/2}$	$2p_{3/2}$	3s	$3p_{1/2}$	$3p_{3/2}$	$3d_{3/2}$	$3d_{5/2}$	4s	$4p_{1/2}$	$4p_{3/2}$	$4d_{3/2}$	$4d_{5/2}$	$4f_{5/2}$	$4f_{7/2}$	5s	$5p_{1/2}$	$5p_{3/2}$	$5d_{1/2}$	$5d_{3/2}$
Z = 1																					
2																					
3	0.0000175																				
4	0.0000569																				
5	0.000133																				
6	0.000251																				
7	0.000404																				
8	0.000575	0.0000405																			
9	0.000723	0.0000596																			
10																					
11		0.000115	0.0000214	0.0000422																	
12		0.000152	0.0000359	0.0000708																	
13		0.000193	0.0000565	0.000111																	
14		0.000237	0.0000838	0.000164																	
15		0.000283	0.000118	0.000232																	
16		0.000328	0.000162	0.000316	0.0000397																
17		0.000376	0.000214	0.000418	0.0000494																
18																					
19		0.000454	0.000341	0.000666	0.0000746	0.0000369	0.0000720														
20		0.000488	0.000415	0.000810	0.0000908	0.0000510	0.0000993														
21		0.000512	0.000495	0.000966	0.000105	0.0000647	0.000126														
22		0.000531	0.000581	0.00113	0.000120	0.0000802	0.000156														
23		0.000541	0.000665	0.00130	0.000135	0.0000974	0.000189														
24		0.000542	0.000749	0.00147	0.000149	0.000114	0.000220														
25		0.000528	0.000819	0.00161	0.000167	0.000136	0.000265														
26		0.000498	0.000880	0.00174	0.000183	0.000158	0.000307														
27		0.000457	0.000918	0.00182	0.000199	0.000181	0.000351														
28		0.000405	0.000925	0.00185	0.000214	0.000205	0.000398														
29			0.000905	0.00183	0.000228	0.000227	0.000438														
30			0.000826	0.00170	0.000244	0.000255	0.000492														
31					0.000261	0.000284	0.000550	0.000147	0.000214												
32					0.000277	0.000313	0.000608	0.000190	0.000276												
33					0.000294	0.000345	0.000670	0.000239	0.000349	0.0000344											
34					0.000309	0.000375	0.000729	0.000295	0.000431	0.0000404											
35					0.000323	0.000405	0.000792	0.000363	0.000527	0.0000468											
36																					
37					0.000349	0.000463	0.000905	0.000515	0.000749	0.0000628											
38					0.000360	0.000487	0.000961	0.000602	0.000881	0.0000723	0.0000695	0.000134									
39					0.000370	0.000511	0.00101	0.000700	0.00102	0.0000811	0.0000807	0.000157									
40					0.000378	0.000536	0.00107	0.000805	0.00118	0.0000903	0.0000922	0.000179									
41					0.000384	0.000556	0.00111	0.000918	0.00134	0.0000982	0.000102	0.000198									
42					0.000392	0.000575	0.00116	0.00104	0.00151	0.000107	0.000113	0.000221									
43																					
44					0.000395	0.000601	0.00123	0.00130	0.00189	0.000125	0.000137	0.000268									
45					0.000391	0.000608	0.00125	0.00144	0.00209	0.000134	0.000149	0.000291									
46					0.000387	0.000612	0.00128	0.00158	0.00230	0.000143	0.000159	0.000314									
47					0.000379	0.000608	0.00129	0.00172	0.00251	0.000153	0.000172	0.000337									
48					0.000363	0.000600	0.00128	0.00186	0.00271	0.000163	0.000186	0.000369									
49					0.000345	0.000583	0.00127	0.00199	0.00291	0.000173	0.000201	0.000399									
50					0.000320	0.000559	0.00124	0.00211	0.00309	0.000183	0.000215	0.000428	0.000316	0.000455							
51					0.000292	0.000528	0.00120	0.00223	0.00327	0.000193	0.000229	0.000459	0.000366	0.000528							
52					0.000261	0.000490	0.00115	0.00233	0.00342	0.000203	0.000244	0.000493	0.000418	0.000600							
53						0.000447	0.00107	0.00241	0.00355	0.000212	0.000258	0.000526	0.000468	0.000679							
54																					
55							0.000892	0.00250	0.00369	0.000230	0.000281	0.000583	0.000579	0.000839			0.0000459				
56								0.00248	0.00369	0.000238	0.000293	0.000614	0.000637	0.000924			0.0000518				
57								0.00245	0.00365	0.000247	0.000307	0.000647	0.000700	0.00101			0.0000579				
58								0.00240	0.00361	0.000250	0.000311	0.000663	0.000735	0.00107			0.0000565	0.0000545	0.000110		
59								0.00234	0.00354	0.000257	0.000321	0.000687	0.000788	0.00114			0.0000585	0.0000562	0.000114		
60								0.00225	0.00344	0.000262	0.000329	0.000713	0.000840	0.00121			0.0000603	0.0000579	0.000118		
61																					
62										0.000273	0.000342	0.000752	0.000937	0.00136			0.0000636	0.0000607	0.000124		
63										0.000276	0.000344	0.000773	0.000985	0.00143			0.0000657	0.0000618	0.000127		
64										0.000280	0.000353	0.000795	0.00104	0.00151			0.0000703	0.0000673	0.000140		
65										0.000279	0.000352	0.000806	0.00108	0.00156			0.0000680	0.0000635	0.000132		
66										0.000281	0.000351	0.000824	0.00112	0.00162			0.0000682	0.0000644	0.000135		
67										0.000281	0.000352	0.000837	0.00116	0.00169			0.0000702	0.0000652	0.000138		
68										0.000282	0.000350	0.000850	0.00120	0.00175			0.0000707	0.0000658	0.000139		
69										0.000280	0.000347	0.000858	0.00124	0.00180			0.0000722	0.0000659	0.000141		
70										0.000278	0.000346	0.000872	0.00127	0.00185			0.0000730	0.0000669	0.000144		
71										0.000277	0.000344	0.000882	0.00131	0.00192			0.0000770	0.0000712	0.000156		
72										0.000273	0.000338	0.000890	0.00134	0.00197	0.00106	0.00135	0.0000810	0.0000756	0.000169		
73										0.000269	0.000332	0.000894	0.00137	0.00202	0.00120	0.00153	0.0000851	0.0000797	0.000181		
74										0.000262	0.000325	0.000900	0.00141	0.00207	0.00135	0.00172	0.0000891	0.0000840	0.000195		
75										0.000257	0.000317	0.000907	0.00144	0.00213	0.00151	0.00193	0.0000934	0.0000889	0.000209		
76										0.000250	0.000308	0.000910	0.00147	0.00218	0.00168	0.00214	0.0000977	0.0000926	0.000221		
77										0.000241	0.000298	0.000909	0.00149	0.00222	0.00185	0.00236	0.000101	0.0000952	0.000229		
78										0.000233	0.000286	0.000909	0.00151	0.00226	0.00203	0.00260	0.000105	0.0000998	0.000245		
79										0.000223	0.000273	0.000905	0.00153	0.00230	0.00222	0.00284	0.000109	0.000103	0.000259		
80										0.000210	0.000261	0.000900	0.00154	0.00232	0.00242	0.00309	0.000112	0.000107	0.000276		
81										0.000197	0.000243	0.000882	0.00154	0.00233	0.00261	0.00333	0.000116	0.000110	0.000291		
82										0.000181	0.000224	0.000867	0.00154	0.00234	0.00280	0.00359	0.000119	0.000114	0.000307	0.000272	0.000389
83										0.000165	0.000208	0.000849	0.00153	0.00234	0.00301	0.00385	0.000123	0.000117	0.000326	0.000300	0.000434

Table II – Calculated AMRSFs for Al X-rays

Level	1s	2s	$2p_{1/2}$	$2p_{3/2}$	3s	$3p_{1/2}$	$3p_{3/2}$	$3d_{3/2}$	$3d_{5/2}$	4s	$4p_{1/2}$	$4p_{3/2}$	$4d_{3/2}$	$4d_{5/2}$	$4f_{5/2}$	$4f_{7/2}$	5s	$5p_{1/2}$	$5p_{3/2}$	$5d_{1/2}$	$5d_{3/2}$
Z = 1																					
2																					
3	0.0000118																				
4	0.0000392																				
5	0.0000936																				
6	0.000181																				
7	0.000302																				
8	0.000446	0.0000297																			
9	0.000591	0.0000442																			
10																					
11	0.000711	0.0000872	0.0000138	0.0000271																	
12		0.000117	0.0000234	0.0000460																	
13		0.000151	0.0000372	0.0000732																	
14		0.000188	0.0000559	0.000110																	
15		0.000227	0.0000802	0.000157																	
16		0.000269	0.000111	0.000217																	
17		0.000309	0.000148	0.000289	0.0000392																
18																					
19		0.000387	0.000243	0.000472	0.0000601	0.0000260	0.0000506														
20		0.000423	0.000299	0.000583	0.0000733	0.0000363	0.0000707														
21		0.000454	0.000363	0.000706	0.0000854	0.0000465	0.0000902														
22		0.000481	0.000432	0.000842	0.0000979	0.0000580	0.000113														
23		0.000502	0.000505	0.000984	0.000111	0.0000711	0.000138														
24		0.000517	0.000581	0.00113	0.000122	0.0000836	0.000162														
25		0.000520	0.000652	0.00127	0.000138	0.000101	0.000195														
26		0.000518	0.000723	0.00141	0.000152	0.000118	0.000229														
27		0.000502	0.000784	0.00154	0.000166	0.000137	0.000263														
28		0.000475	0.000832	0.00164	0.000179	0.000156	0.000301														
29		0.000437	0.000863	0.00171	0.000192	0.000174	0.000335														
30		0.000383	0.000856	0.00171	0.000206	0.000198	0.000380														
31			0.000817	0.00166	0.000221	0.000222	0.000427	0.0000937	0.000136												
32				0.00152	0.000238	0.000247	0.000478	0.000122	0.000177												
33					0.000252	0.000274	0.000531	0.000155	0.000226	0.0000287											
34					0.000268	0.000302	0.000583	0.000194	0.000282	0.0000339											
35					0.000282	0.000331	0.000640	0.000239	0.000346	0.0000393											
36																					
37					0.000310	0.000384	0.000747	0.000346	0.000502	0.0000529											
38					0.000322	0.000409	0.000800	0.000409	0.000594	0.0000610	0.0000561	0.000108									
39					0.000334	0.000435	0.000853	0.000478	0.000694	0.0000687	0.0000656	0.000126									
40					0.000345	0.000460	0.000905	0.000554	0.000807	0.0000764	0.0000752	0.000145									
41					0.000355	0.000484	0.000952	0.000637	0.000927	0.0000833	0.0000836	0.000161									
42					0.000364	0.000507	0.00100	0.000728	0.00106	0.0000910	0.0000934	0.000181									
43																					
44					0.000375	0.000544	0.00109	0.000926	0.00135	0.000107	0.000114	0.000219									
45					0.000380	0.000559	0.00113	0.00103	0.00150	0.000115	0.000124	0.000240									
46					0.000380	0.000570	0.00116	0.00115	0.00166	0.000122	0.000133	0.000258									
47					0.000379	0.000579	0.00119	0.00126	0.00183	0.000131	0.000145	0.000281									
48					0.000374	0.000581	0.00121	0.00138	0.00200	0.000140	0.000157	0.000307									
49					0.000366	0.000578	0.00121	0.00149	0.00217	0.000148	0.000170	0.000332									
50					0.000353	0.000571	0.00121	0.00161	0.00234	0.000158	0.000183	0.000361	0.000234	0.000336							
51					0.000338	0.000560	0.00121	0.00172	0.00250	0.000167	0.000196	0.000387	0.000271	0.000389							
52					0.000319	0.000542	0.00119	0.00183	0.00266	0.000176	0.000209	0.000417	0.000312	0.000448							
53					0.000294	0.000518	0.00116	0.00193	0.00281	0.000185	0.000222	0.000446	0.000352	0.000508							
54																					
55					0.000235	0.000446	0.00106	0.00209	0.00305	0.000203	0.000247	0.000501	0.000441	0.000636			0.0000389				
56						0.000404	0.000992	0.00214	0.00314	0.000209	0.000257	0.000528	0.000488	0.000705			0.0000440				
57						0.000360	0.000924	0.00220	0.00324	0.000218	0.000270	0.000559	0.000541	0.000780			0.0000492				
58							0.000847	0.00224	0.00331	0.000224	0.000277	0.000577	0.000572	0.000824			0.0000482	0.0000468	0.0000929		
59							0.000769	0.00226	0.00336	0.000229	0.000286	0.000600	0.000617	0.000887			0.0000499	0.0000484	0.0000964		
60								0.00226	0.00339	0.000236	0.000296	0.000624	0.000660	0.000951			0.0000518	0.0000499	0.0000998		
61																					
62								0.00220	0.00332	0.000247	0.000312	0.000667	0.000749	0.00108			0.0000547	0.0000527	0.000106		
63								0.00213	0.00326	0.000252	0.000318	0.000687	0.000793	0.00114			0.0000564	0.0000539	0.000109		
64								0.00202	0.00313	0.000258	0.000326	0.000710	0.000844	0.00122			0.0000604	0.0000590	0.000120		
65									0.00294	0.000259	0.000328	0.000723	0.000880	0.00126			0.0000589	0.0000559	0.000114		
66										0.000262	0.000331	0.000744	0.000921	0.00132			0.0000593	0.0000569	0.000116		
67										0.000263	0.000333	0.000758	0.000962	0.00138			0.0000610	0.0000580	0.000119		
68										0.000266	0.000335	0.000775	0.000999	0.00144			0.0000617	0.0000583	0.000120		
69										0.000266	0.000336	0.000786	0.00104	0.00150			0.0000630	0.0000591	0.000123		
70										0.000268	0.000337	0.000803	0.00107	0.00156			0.0000640	0.0000600	0.000125		
71										0.000269	0.000338	0.000819	0.00112	0.00162			0.0000676	0.0000641	0.000136		
72										0.000266	0.000337	0.000831	0.00116	0.00168	0.000704	0.000890	0.0000711	0.0000681	0.000147		
73										0.000265	0.000333	0.000840	0.00119	0.00174	0.000802	0.00102	0.0000747	0.0000722	0.000158		
74										0.000262	0.000330	0.000851	0.00123	0.00179	0.000906	0.00115	0.0000786	0.0000766	0.000170		
75										0.000259	0.000326	0.000862	0.00127	0.00185	0.00102	0.00130	0.0000822	0.0000808	0.000182		
76										0.000255	0.000320	0.000871	0.00131	0.00192	0.00114	0.00145	0.0000863	0.0000846	0.000194		
77										0.000250	0.000314	0.000876	0.00134	0.00197	0.00127	0.00161	0.0000890	0.0000873	0.000201		
78										0.000245	0.000306	0.000882	0.00137	0.00202	0.00140	0.00178	0.0000929	0.0000917	0.000216		
79										0.000239	0.000297	0.000887	0.00140	0.00206	0.00154	0.00196	0.0000966	0.0000953	0.000229		
80										0.000231	0.000288	0.000891	0.00142	0.00210	0.00168	0.00214	0.000100	0.0000989	0.000243		
81										0.000221	0.000275	0.000884	0.00144	0.00214	0.00183	0.00233	0.000103	0.000102	0.000257		
82										0.000210	0.000262	0.000877	0.00145	0.00217	0.00198	0.00252	0.000107	0.000106	0.000272	0.000235	0.000334
83										0.000199	0.000249	0.000765	0.000822	0.00219	0.00214	0.00272	0.000110	0.000110	0.000287	0.000261	0.000372

Table III – Calculated AMRSFs ratioed to C as unity for Mg X-rays

Level	1s	2s	$2p_{1/2}$	$2p_{3/2}$	3s	$3p_{1/2}$	$3p_{3/2}$	$3d_{3/2}$	$3d_{5/2}$	4s	$4p_{1/2}$	$4p_{3/2}$	$4d_{3/2}$	$4d_{5/2}$	$4f_{5/2}$	$4f_{7/2}$	5s	$5p_{1/2}$	$5p_{3/2}$	$5d_{1/2}$	$5d_{3/2}$
Z = 1																					
2																					
3	0.0697																				
4	0.226																				
5	0.528																				
6	1.00																				
7	1.61																				
8	2.29	0.161																			
9	2.87	0.237																			
10																					
11		0.456	0.0852	0.168																	
12		0.603	0.143	0.282																	
13		0.768	0.225	0.441																	
14		0.944	0.333	0.654																	
15		1.13	0.471	0.925																	
16		1.30	0.644	1.26	0.158																
17		1.50	0.851	1.66	0.196																
18																					
19		1.81	1.36	2.65	0.297	0.147	0.286														
20		1.94	1.65	3.22	0.361	0.203	0.395														
21		2.04	1.97	3.84	0.419	0.258	0.501														
22		2.11	2.31	4.51	0.478	0.319	0.620														
23		2.15	2.65	5.18	0.539	0.387	0.752														
24		2.15	2.98	5.83	0.593	0.453	0.877														
25		2.10	3.26	6.41	0.663	0.543	1.05														
26		1.98	3.50	6.91	0.727	0.629	1.22														
27		1.82	3.65	7.26	0.791	0.722	1.39														
28		1.61	3.68	7.35	0.853	0.817	1.58														
29			3.60	7.28	0.907	0.905	1.74														
30			3.29	6.77	0.973	1.02	1.96														
31					1.04	1.13	2.19	0.584	0.852												
32					1.10	1.24	2.42	0.754	1.10												
33					1.17	1.37	2.67	0.951	1.39	0.137											
34					1.23	1.49	2.90	1.17	1.71	0.161											
35					1.29	1.61	3.15	1.44	2.10	0.186											
36																					
37					1.39	1.84	3.60	2.05	2.98	0.250											
38					1.43	1.94	3.82	2.40	3.50	0.288	0.276	0.535									
39					1.47	2.03	4.04	2.78	4.06	0.323	0.321	0.624									
40					1.50	2.13	4.24	3.20	4.68	0.359	0.367	0.712									
41					1.53	2.21	4.42	3.65	5.32	0.391	0.405	0.787									
42					1.56	2.29	4.60	4.13	6.02	0.426	0.451	0.880									
43																					
44					1.57	2.39	4.89	5.17	7.54	0.498	0.545	1.06									
45					1.56	2.42	4.99	5.71	8.33	0.535	0.592	1.16									
46					1.54	2.43	5.08	6.29	9.16	0.569	0.634	1.25									
47					1.51	2.42	5.11	6.85	9.99	0.608	0.685	1.34									
48					1.45	2.39	5.10	7.40	10.8	0.648	0.742	1.47									
49					1.37	2.32	5.04	7.92	11.6	0.687	0.798	1.59									
50					1.27	2.22	4.93	8.41	12.3	0.727	0.854	1.70	1.26	1.81							
51					1.16	2.10	4.76	8.88	13.0	0.767	0.913	1.83	1.46	2.10							
52					1.04	1.95	4.56	9.29	13.6	0.807	0.970	1.96	1.66	2.39							
53						1.78	4.27	9.60	14.1	0.844	1.03	2.09	1.86	2.70							
54																					
55							3.55	9.93	14.7	0.913	1.12	2.32	2.30	3.34			0.183				
56								9.88	14.7	0.946	1.17	2.44	2.53	3.68			0.206				
57								9.73	14.5	0.981	1.22	2.57	2.79	4.03			0.230				
58								9.56	14.3	0.995	1.24	2.64	2.92	4.24			0.225	0.217	0.439		
59								9.30	14.1	1.02	1.28	2.73	3.13	4.54			0.233	0.224	0.454		
60								8.94	13.7	1.04	1.31	2.84	3.34	4.83			0.240	0.230	0.468		
61																					
62										1.08	1.36	2.99	3.73	5.39			0.253	0.241	0.495		
63										1.10	1.37	3.08	3.92	5.68			0.261	0.246	0.506		
64										1.11	1.40	3.16	4.14	6.01			0.280	0.268	0.559		
65										1.11	1.40	3.21	4.29	6.20			0.271	0.253	0.527		
66										1.12	1.40	3.28	4.46	6.46			0.271	0.256	0.537		
67										1.12	1.40	3.33	4.62	6.71			0.279	0.260	0.549		
68										1.12	1.39	3.38	4.76	6.94			0.281	0.262	0.554		
69										1.12	1.38	3.41	4.93	7.16			0.287	0.262	0.562		
70										1.11	1.38	3.47	5.03	7.38			0.290	0.266	0.573		
71										1.10	1.37	3.51	5.21	7.62			0.306	0.283	0.621		
72										1.08	1.34	3.54	5.34	7.83	4.21	5.36	0.322	0.301	0.671		
73										1.07	1.32	3.56	5.47	8.04	4.78	6.09	0.338	0.317	0.721		
74										1.04	1.29	3.58	5.59	8.25	5.38	6.85	0.355	0.334	0.775		
75										1.02	1.26	3.61	5.72	8.46	6.03	7.66	0.372	0.354	0.830		
76										0.995	1.23	3.62	5.84	8.68	6.70	8.53	0.389	0.368	0.879		
77										0.959	1.19	3.62	5.92	8.83	7.36	9.40	0.401	0.379	0.912		
78										0.927	1.14	3.62	6.01	8.99	8.09	10.3	0.417	0.397	0.976		
79										0.887	1.09	3.60	6.08	9.13	8.84	11.3	0.433	0.410	1.03		
80										0.835	1.04	3.58	6.11	9.21	9.61	12.3	0.447	0.425	1.10		
81										0.783	0.966	3.51	6.13	9.27	10.4	13.3	0.460	0.437	1.16		
82										0.719	0.893	3.45	6.11	9.32	11.1	14.3	0.475	0.453	1.22	1.08	1.55
83										0.656	0.829	3.38	6.10	9.33	12.0	15.3	0.489	0.465	1.30	1.19	1.73

Table IV – Calculated AMRSFs ratioed to C as unity for Al X-rays

Level	1s	2s	$2p_{1/2}$	$2p_{3/2}$	3s	$3p_{1/2}$	$3p_{3/2}$	$3d_{3/2}$	$3d_{5/2}$	4s	$4p_{1/2}$	$4p_{3/2}$	$4d_{3/2}$	$4d_{5/2}$	$4f_{5/2}$	$4f_{7/2}$	5s	$5p_{1/2}$	$5p_{3/2}$	$5d_{1/2}$	$5d_{3/2}$
Z = 1																					
2																					
3	0.0650																				
4	0.216																				
5	0.516																				
6	1.00																				
7	1.66																				
8	2.46	0.164																			
9	3.26	0.243																			
10																					
11	3.92	0.481	0.0758	0.149																	
12		0.646	0.129	0.253																	
13		0.832	0.205	0.403																	
14		1.04	0.308	0.604																	
15		1.25	0.442	0.865																	
16		1.48	0.610	1.19																	
17		1.70	0.816	1.59	0.216																
18																					
19		2.13	1.34	2.60	0.331	0.143	0.279														
20		2.33	1.65	3.22	0.404	0.200	0.390														
21		2.50	2.00	3.89	0.471	0.256	0.497														
22		2.65	2.38	4.64	0.540	0.319	0.621														
23		2.76	2.78	5.42	0.612	0.392	0.759														
24		2.85	3.20	6.23	0.675	0.461	0.891														
25		2.87	3.60	7.02	0.759	0.557	1.08														
26		2.85	3.98	7.79	0.835	0.651	1.26														
27		2.77	4.32	8.47	0.913	0.753	1.45														
28		2.62	4.59	9.03	0.989	0.860	1.66														
29		2.41	4.75	9.43	1.06	0.961	1.85														
30		2.11	4.72	9.44	1.14	1.09	2.09														
31			4.50	9.13	1.22	1.22	2.35	0.516	0.751												
32				8.40	1.31	1.36	2.64	0.671	0.977												
33					1.39	1.51	2.92	0.854	1.25	0.158											
34					1.48	1.66	3.21	1.07	1.55	0.187											
35					1.56	1.82	3.53	1.32	1.91	0.216											
36																					
37					1.71	2.12	4.12	1.91	2.76	0.291											
38					1.77	2.26	4.41	2.25	3.28	0.336	0.309	0.595									
39					1.84	2.40	4.70	2.63	3.82	0.378	0.362	0.696									
40					1.90	2.54	4.99	3.05	4.45	0.421	0.414	0.800									
41					1.95	2.67	5.25	3.51	5.11	0.459	0.461	0.888									
42					2.00	2.79	5.52	4.01	5.82	0.502	0.515	0.995									
43																					
44					2.06	3.00	6.00	5.10	7.41	0.587	0.627	1.21									
45					2.09	3.08	6.22	5.70	8.27	0.632	0.684	1.32									
46					2.10	3.14	6.40	6.32	9.17	0.673	0.735	1.42									
47					2.09	3.19	6.55	6.96	10.1	0.721	0.798	1.55									
48					2.06	3.20	6.65	7.59	11.0	0.769	0.866	1.69									
49					2.02	3.19	6.70	8.22	11.9	0.818	0.936	1.83									
50					1.95	3.15	6.69	8.86	12.9	0.868	1.01	1.99	1.29	1.85							
51					1.86	3.08	6.65	9.48	13.8	0.919	1.08	2.13	1.50	2.14							
52					1.76	2.99	6.57	10.1	14.7	0.969	1.15	2.30	1.72	2.47							
53					1.62	2.85	6.41	10.6	15.5	1.02	1.22	2.46	1.94	2.80							
54																					
55					1.30	2.46	5.86	11.5	16.8	1.12	1.36	2.76	2.43	3.51			0.215				
56						2.22	5.47	11.8	17.3	1.15	1.42	2.91	2.69	3.88			0.242				
57						1.98	5.09	12.1	17.8	1.20	1.49	3.08	2.98	4.30			0.271				
58							4.67	12.4	18.2	1.24	1.53	3.18	3.15	4.54			0.266	0.258	0.512		
59							4.24	12.5	18.5	1.26	1.58	3.30	3.40	4.89			0.275	0.267	0.531		
60								12.5	18.7	1.30	1.63	3.44	3.64	5.24			0.285	0.275	0.550		
61																					
62								12.1	18.3	1.36	1.72	3.67	4.13	5.93			0.302	0.290	0.584		
63								11.7	17.9	1.39	1.75	3.79	4.37	6.29			0.311	0.297	0.600		
64								11.1	17.2	1.42	1.79	3.91	4.65	6.70			0.333	0.325	0.662		
65									16.2	1.43	1.81	3.99	4.85	6.97			0.324	0.308	0.627		
66										1.44	1.82	4.10	5.08	7.30			0.327	0.314	0.640		
67										1.45	1.84	4.18	5.30	7.63			0.336	0.319	0.655		
68										1.46	1.85	4.27	5.50	7.96			0.340	0.321	0.664		
69										1.47	1.85	4.33	5.74	8.26			0.347	0.326	0.675		
70										1.48	1.85	4.43	5.92	8.58			0.353	0.331	0.689		
71										1.48	1.86	4.51	6.17	8.93			0.373	0.353	0.749		
72										1.47	1.86	4.58	6.37	9.24	3.88	4.91	0.392	0.375	0.811		
73										1.46	1.84	4.63	6.57	9.56	4.42	5.61	0.412	0.398	0.872		
74										1.44	1.82	4.69	6.79	9.89	4.99	6.34	0.433	0.422	0.938		
75										1.43	1.80	4.75	7.00	10.2	5.63	7.15	0.453	0.445	1.01		
76										1.41	1.77	4.80	7.21	10.6	6.30	8.00	0.475	0.466	1.07		
77										1.38	1.73	4.83	7.38	10.8	6.97	8.88	0.490	0.481	1.11		
78										1.35	1.68	4.86	7.55	11.1	7.71	9.81	0.512	0.505	1.19		
79										1.32	1.63	4.89	7.71	11.4	8.48	10.8	0.532	0.525	1.26		
80										1.27	1.59	4.91	7.82	11.6	9.28	11.8	0.552	0.545	1.34		
81										1.22	1.51	4.87	7.92	11.8	10.1	12.8	0.569	0.564	1.42		
82										1.16	1.44	4.83	8.00	11.9	10.9	13.9	0.589	0.586	1.50	1.29	1.84
83										1.09	1.37	4.21	4.53	12.1	11.8	15.0	0.607	0.604	1.58	1.44	2.05