REFERENCE SPECTRA

The reference spectra were provided by the Exafs Materials website
http://exafsmaterials.com/ReferenceSpectra.html

There is one error in the document for lead.
The lead absorption edge is 13035, not 13055eV.

A copy of the unedited version is shown below.

Reference X-Ray Spectra

of

Metal Foils

Exafs

Materials

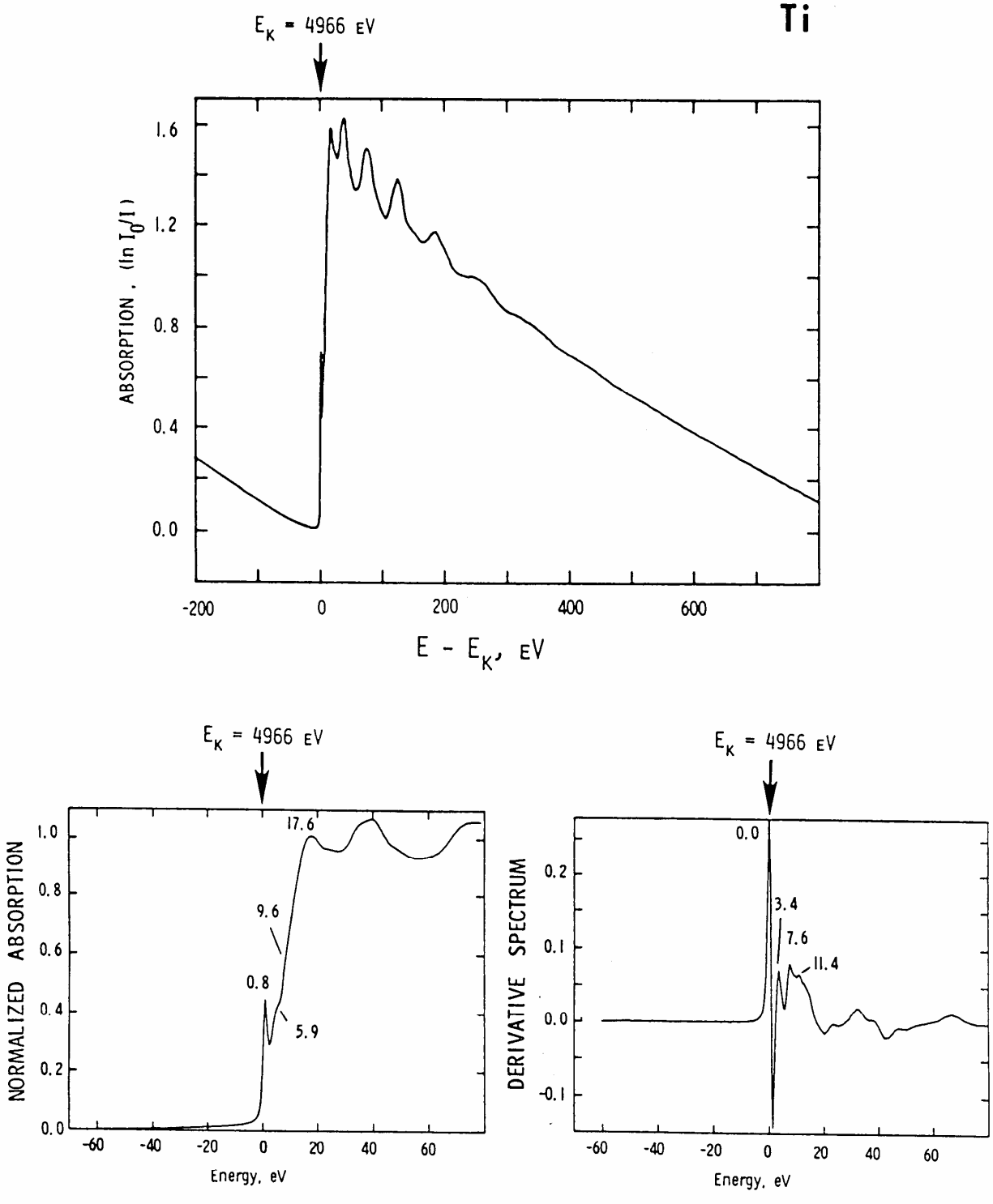
871 El Cerro Blvd., Danville, CA 94526 USA

phone: (925) 838-7162
fax: (925) 838-4630
email: exafs_materials@sbcglobal.net

Reference X-ray Spectra of Metal Foils

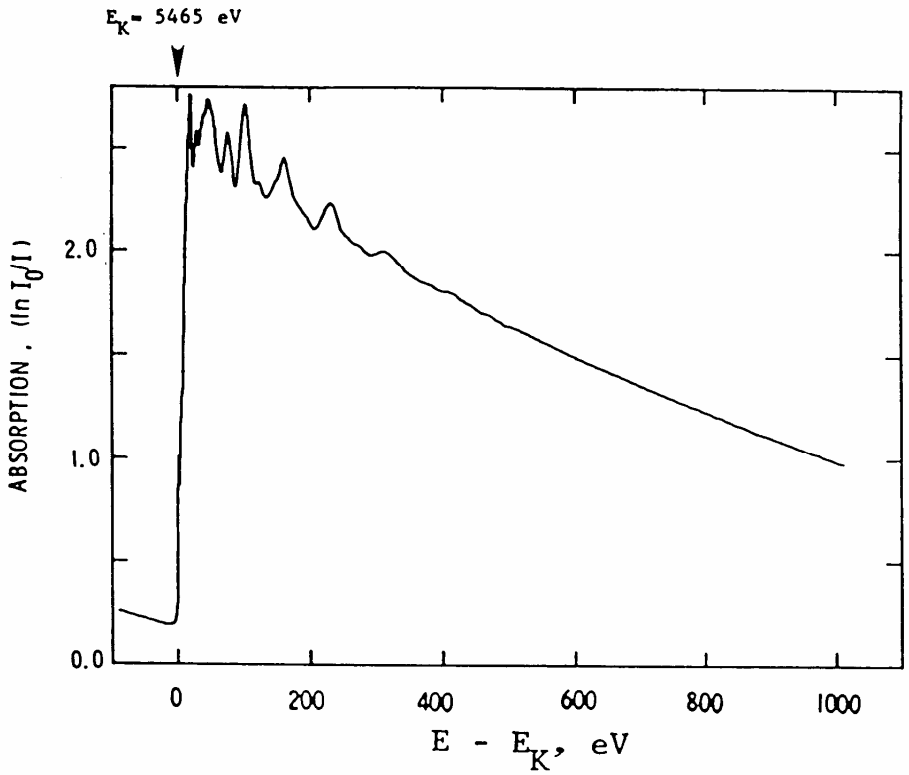
The x-ray spectra compiled herein for the following metal foils were recorded at synchrotron beamlines 1-5, 4-2, 7-3 and 10-2 at Stanford Synchrotron Radiation Laboratory (SSRL) using double crystal Si(220) monochromators. The spectra for Ag, Pt and Au were recorded with a double crystal Si(111) monochromator on beamline X-11A at the National Synchrotron Light Source (NSLS) at Brookhaven. All spectra were taken at room temperature in the transmission geometry. In the region ±50 eV about the absorption edge, each spectrum was scanned in step sizes 0.5 eV. An entrance slit with vertical opening of 1 mm and 0.5 mm was used for Si(220) and Si(111), respectively. The spectrometer resolution in each case was estimated to be 0.5 eV at the K-edge of Ti, and ~1.5 eV at the K-edge of Cu. For each element, the tabulated edge energy (Bearden & Burr, *Rev. Mod. Phys.* 39, *125 (1967)*) is defined operationally as the first inflection point in the derivative spectrum.

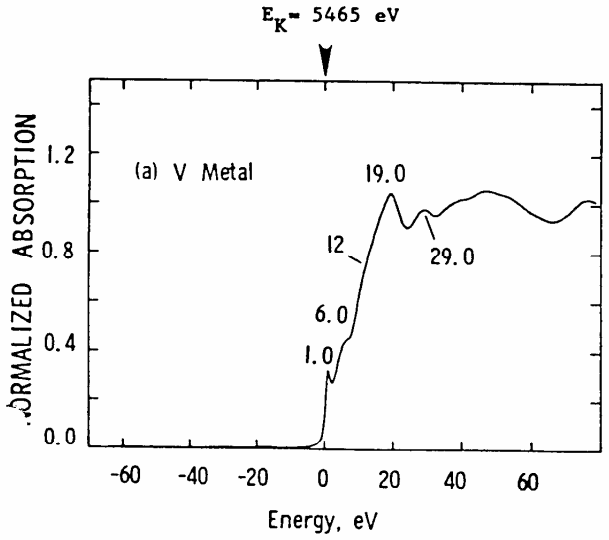
3d Metals:	Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se,
4d Metals:	Zr, Nb, Mo, Ru, Pd, Ag, Sn, Sb
5d Metals:	Ta, Pt, Au, Pb.

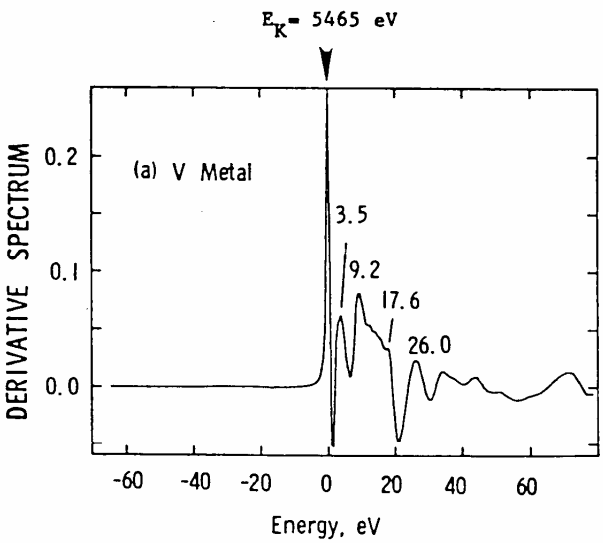

Ti
E_K = 4966 eV
ABSORPTION , (ln I_0/I)
1.6
1.2
0.8
0.4
0.0
-200
0
200
400
600
E - E_K, eV
E_K = 4966 eV
NORMALIZED ABSORPTION
1.0
0.8
0.6
0.4
0.2
0.0
17.6
9.6
0.8
5.9
-60
-40
-20
0
20
40
60
Energy, eV
E_K = 4966 eV
DERIVATIVE SPECTRUM
0.2
0.1
0.0
-0.1
0.0
3.4
7.6
11.4
-60
-40
-20
0
20
40
60
Energy, eV

1

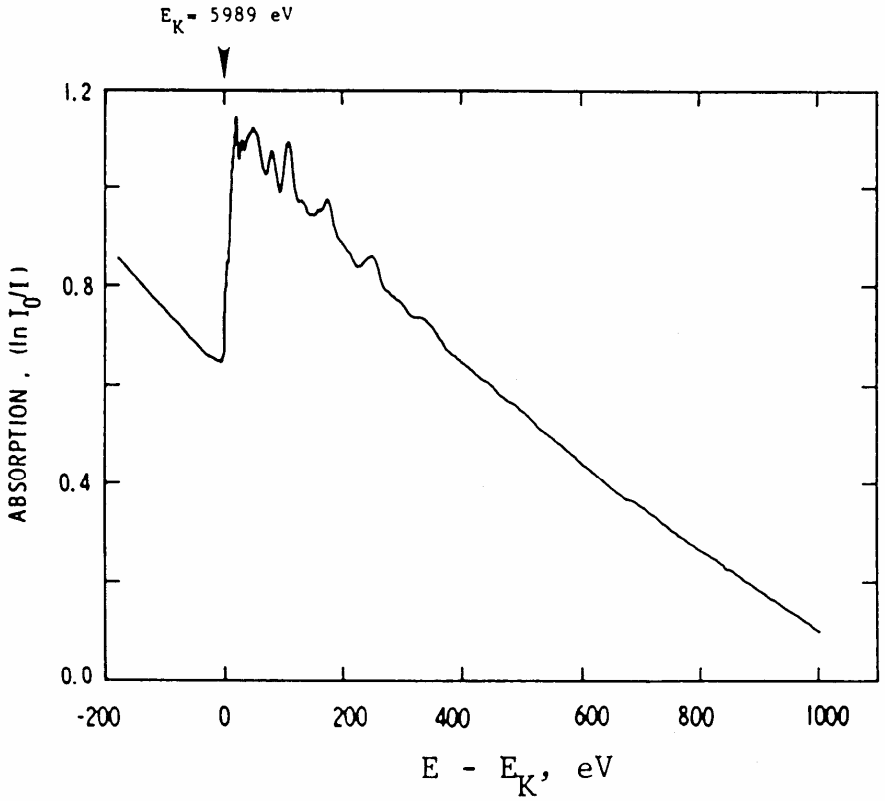
V

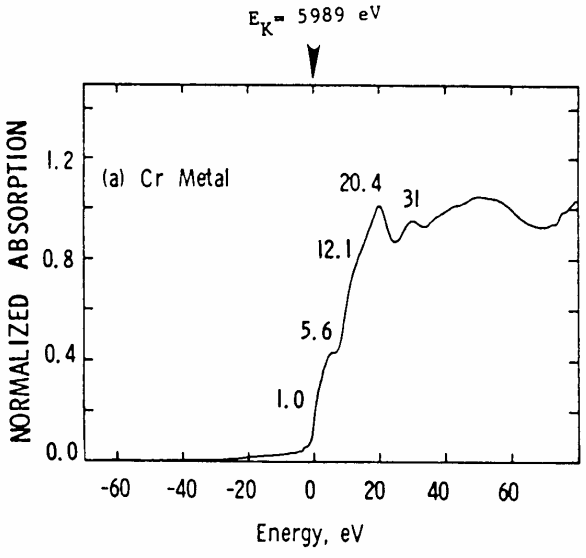

E_K = 5465 eV
ABSORPTION , (ln I_0/I)
2.0
1.0
0.0
0
200
400
600
800
1000
E - E_K, eV

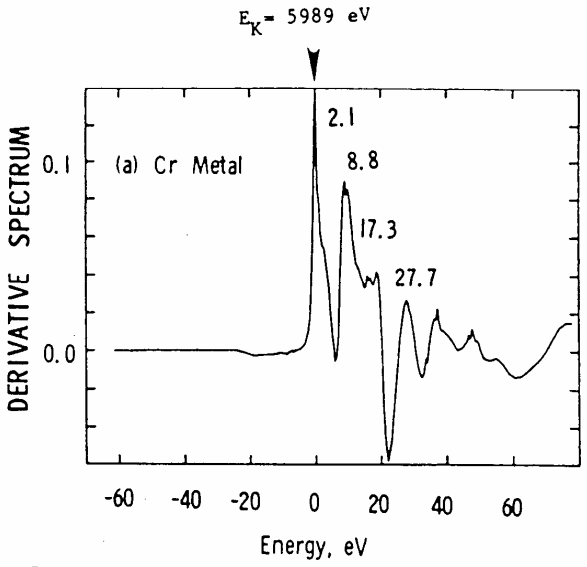

E_K = 5465 eV
ORMALIZED ABSORPTION
1.2
0.8
0.4
0.0
(a) V Metal
19.0
12
29.0
6.0
1.0
-60
-40
-20
0
20
40
60
Energy, eV


E_K = 5465 eV
DERIVATIVE SPECTRUM
0.2
0.1
0.0
(a) V Metal
3.5
9.2
17.6
26.0
-60
-40
-20
0
20
40
60
Energy, eV

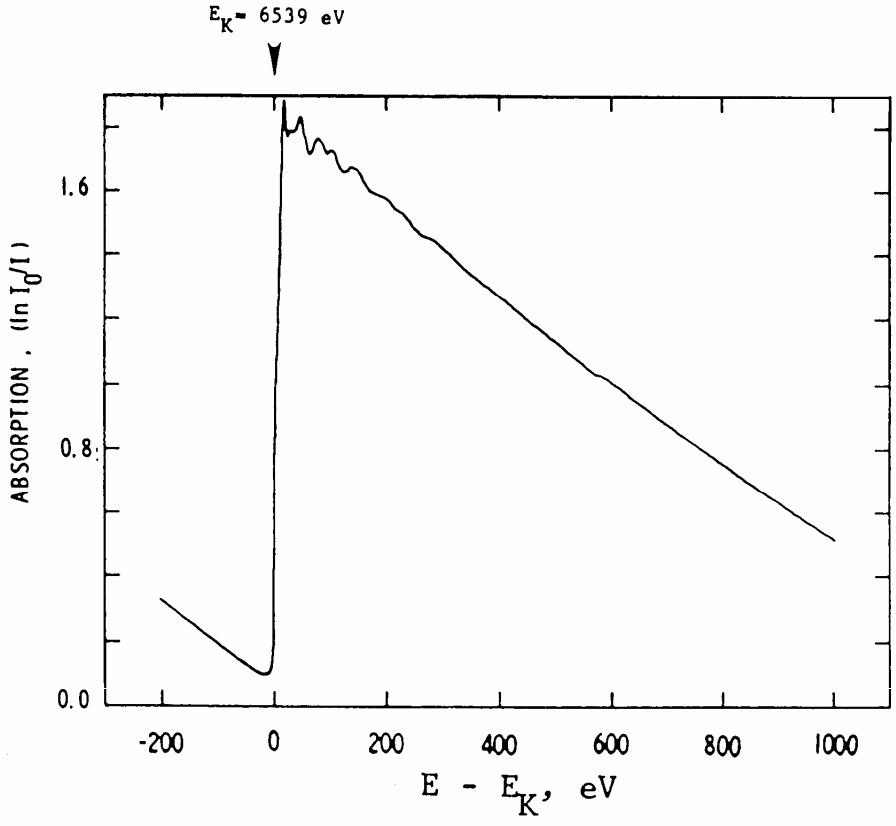
Cr

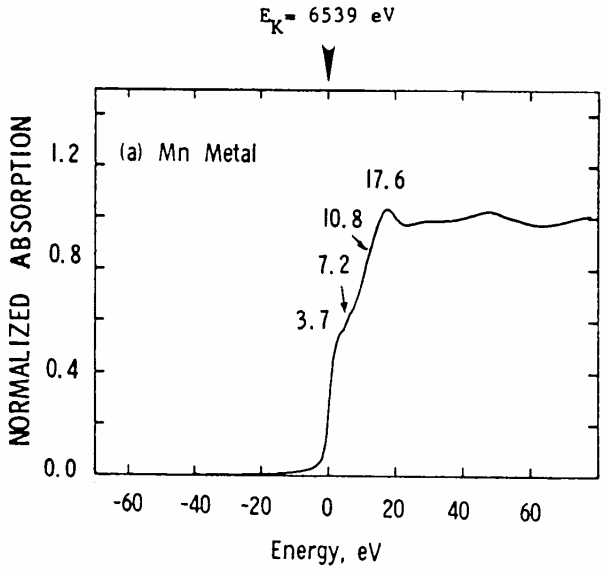

E_K = 5989 eV
1.2
0.8
0.4
0.0
ABSORPTION , (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_K, eV

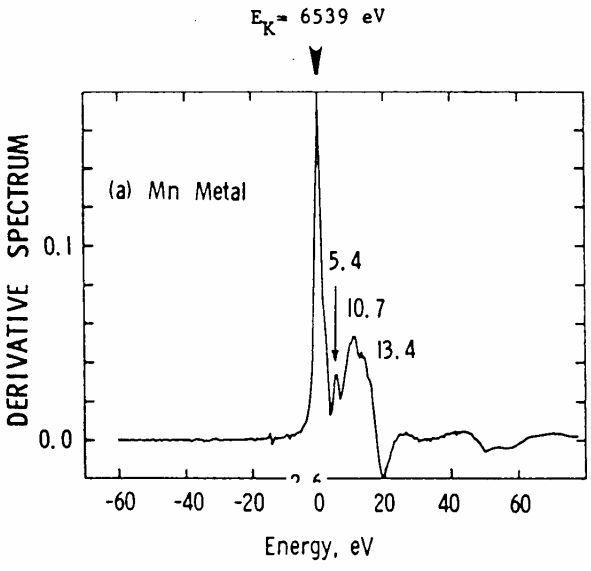

E_K = 5989 eV
NORMALIZED ABSORPTION
(a) Cr Metal
1.0
5.6
12.1
20.4
31
1.2
0.8
0.4
0.0
-60
-40
-20
0
20
40
60
Energy, eV

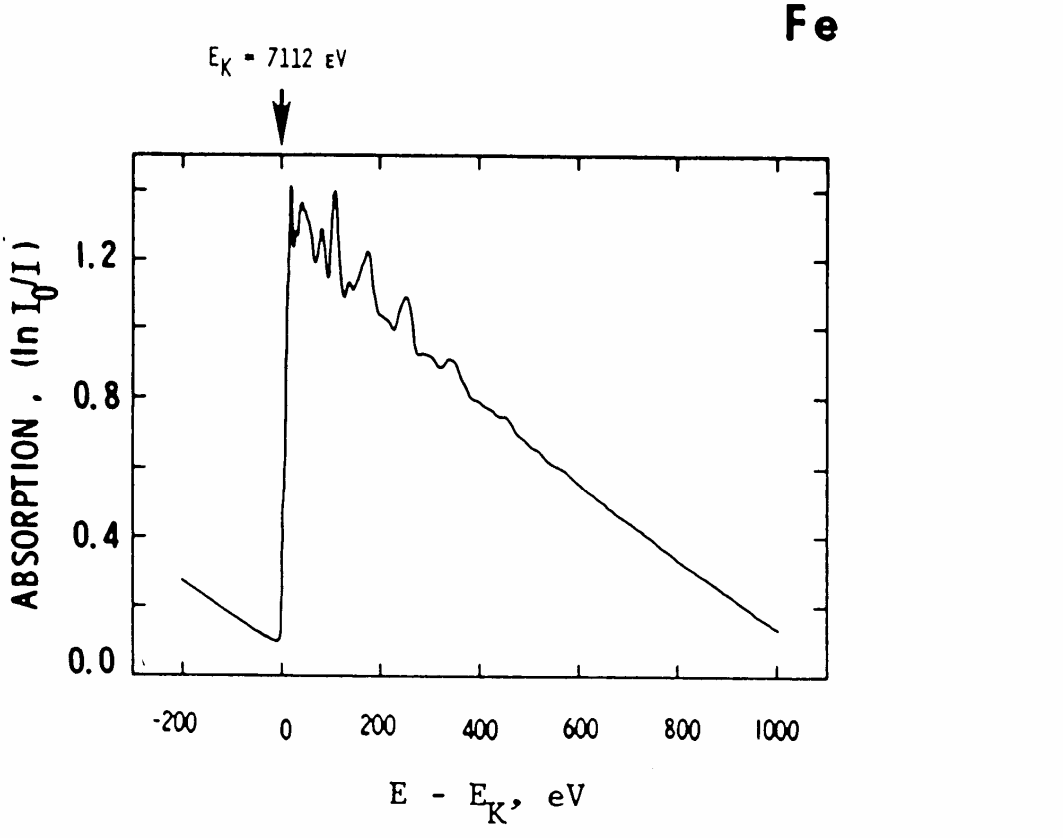

E_K = 5989 eV
DERIVATIVE SPECTRUM
(a) Cr Metal
2.1
8.8
17.3
27.7
0.1
0.0
-60
-40
-20
0
20
40
60
Energy, eV

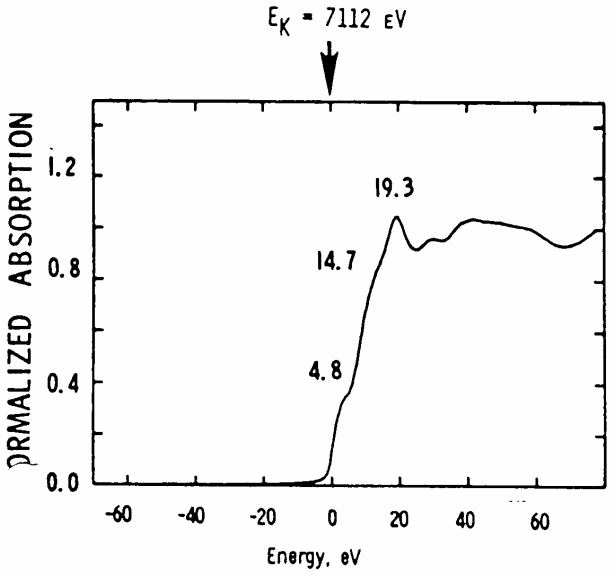
Mn

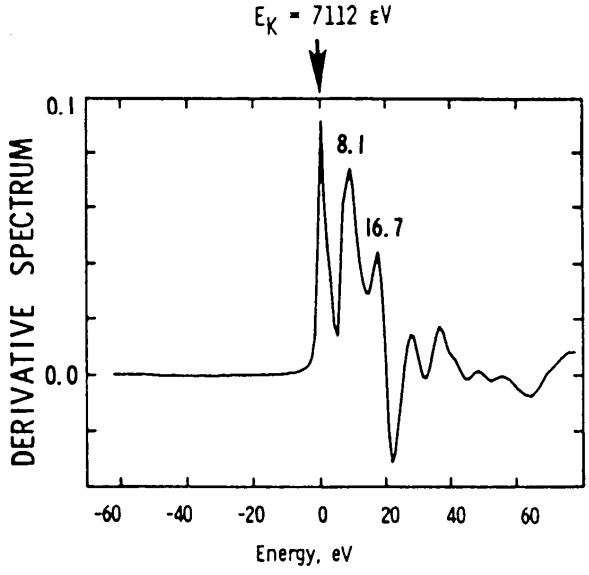

E_K = 6539 eV
ABSORPTION , (ln I_0/I)
1.6
0.8
0.0
-200
0
200
400
600
800
1000
E - E_K, eV


E_K = 6539 eV
NORMALIZED ABSORPTION
(a) Mn Metal
1.2
0.8
0.4
0.0
17.6
10.8
7.2
3.7
-60
-40
-20
0
20
40
60
Energy, eV

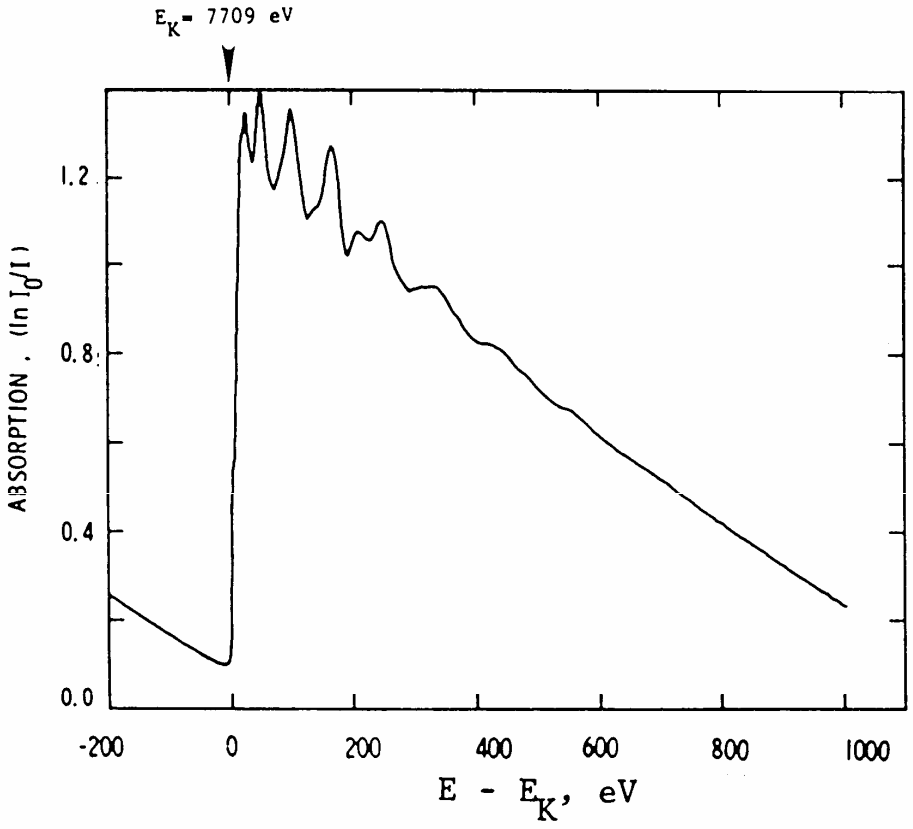

E_K = 6539 eV
DERIVATIVE SPECTRUM
(a) Mn Metal
0.1
0.0
5.4
10.7
13.4
-60
-40
-20
0
20
40
60
Energy, eV

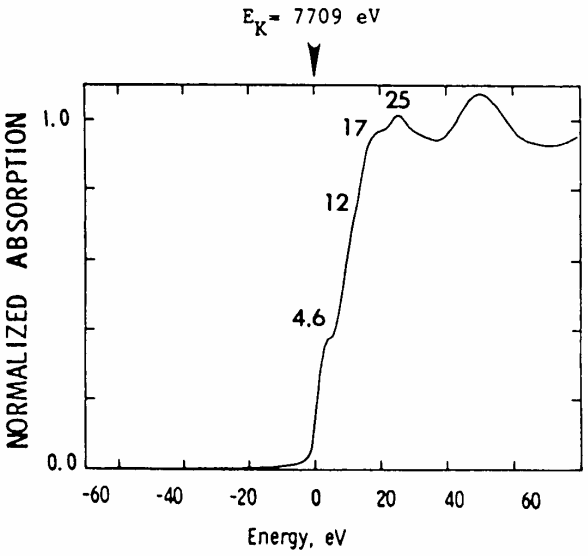

Fe
E_K = 7112 eV
ABSORPTION . (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

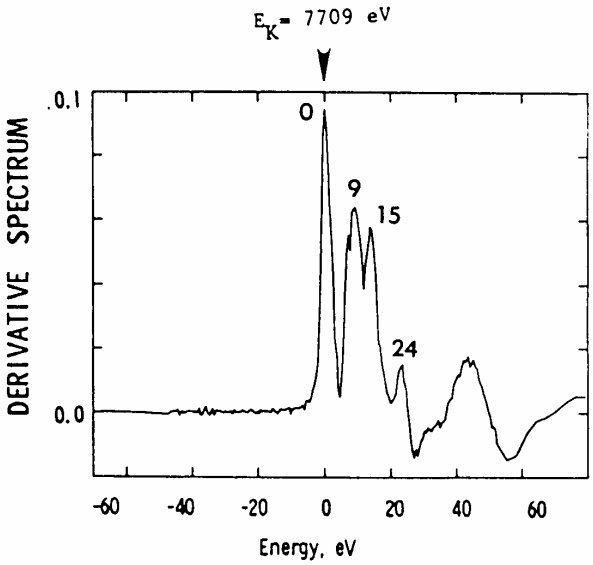

E_K = 7112 eV
ORMALIZED ABSORPTION
1.2
0.8
0.4
0.0
19.3
14.7
4.8
-60
-40
-20
0
20
40
60
Energy, eV


E_K = 7112 eV
DERIVATIVE SPECTRUM
0.1
0.0
8.1
16.7
-60
-40
-20
0
20
40
60
Energy, eV

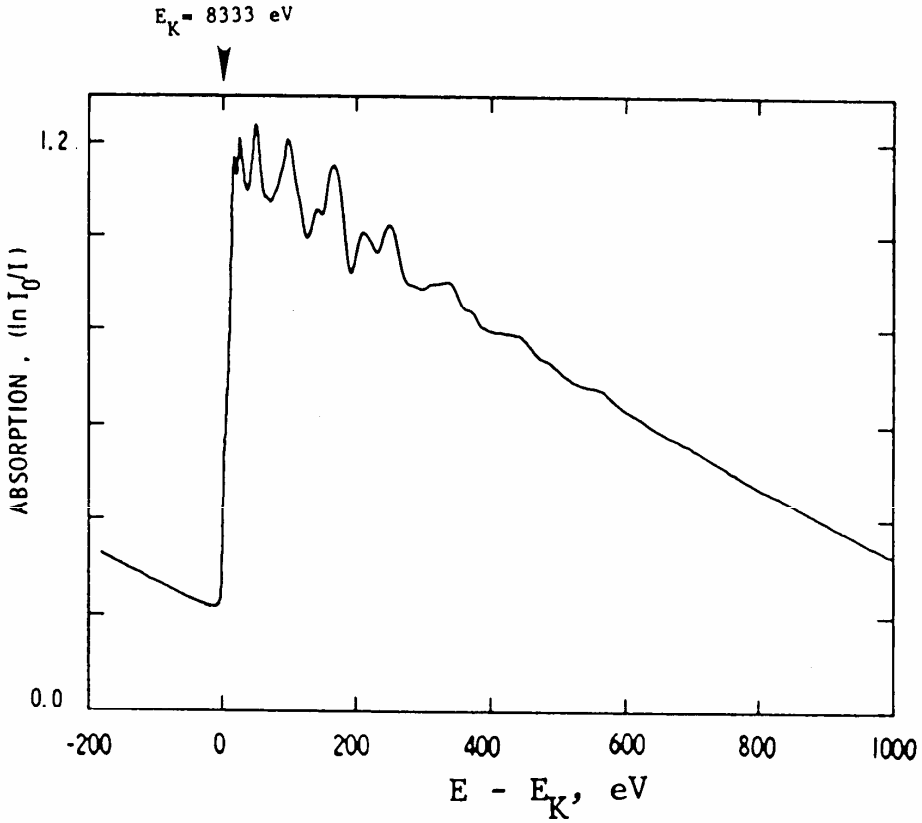
Co

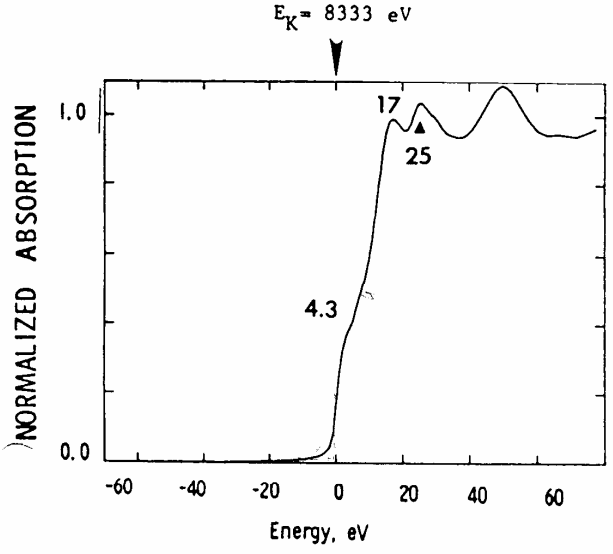

E_K = 7709 eV
ABSORPTION , (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

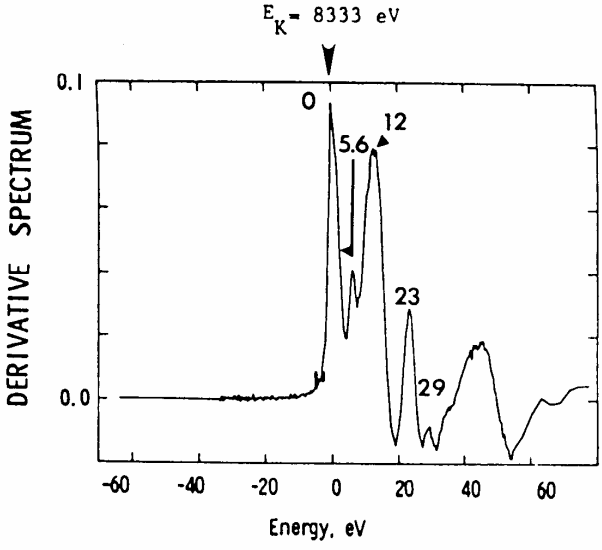

E_K = 7709 eV
NORMALIZED ABSORPTION
1.0
0.0
25
17
12
4.6
-60
-40
-20
0
20
40
60
Energy, eV


E_K = 7709 eV
DERIVATIVE SPECTRUM
.0.1
0.0
0
9
15
24
-60
-40
-20
0
20
40
60
Energy, eV

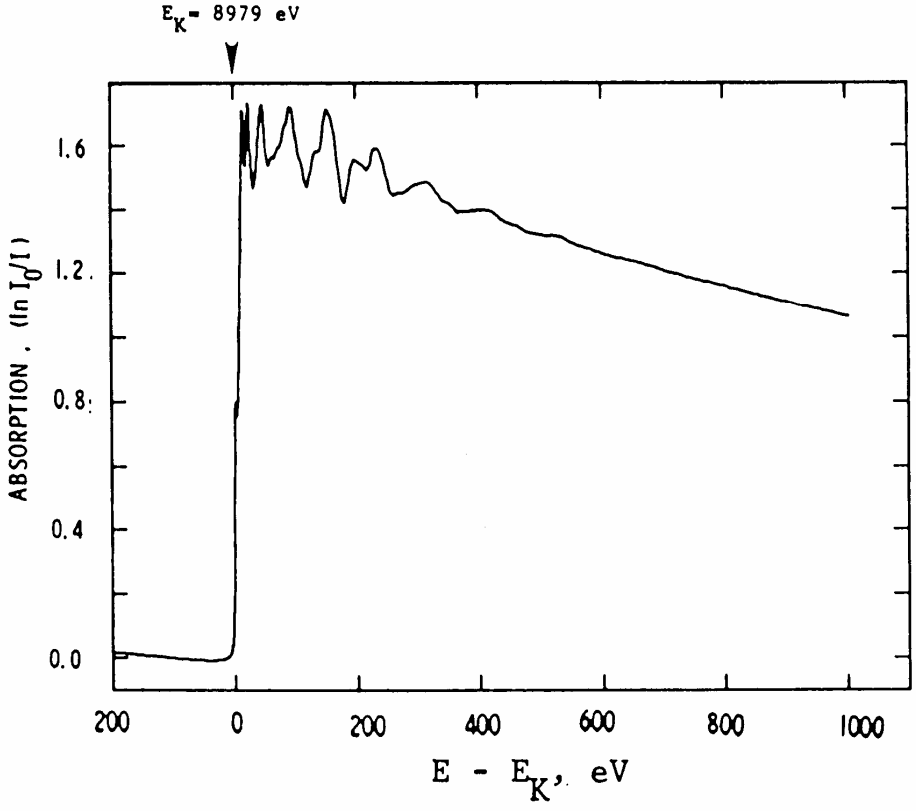
Ni

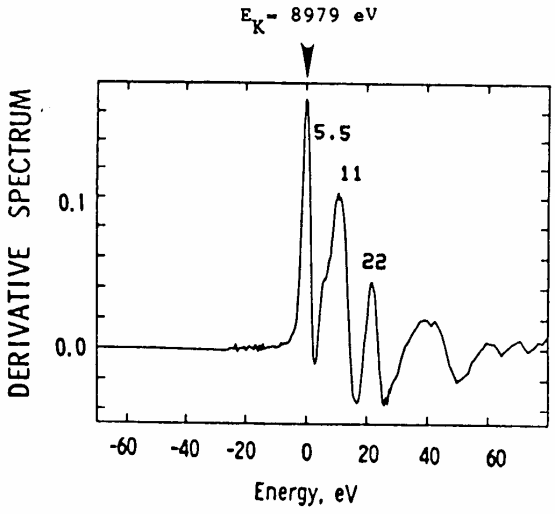

E_K = 8333 eV
1.2
0.0
ABSORPTION , (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_K, eV

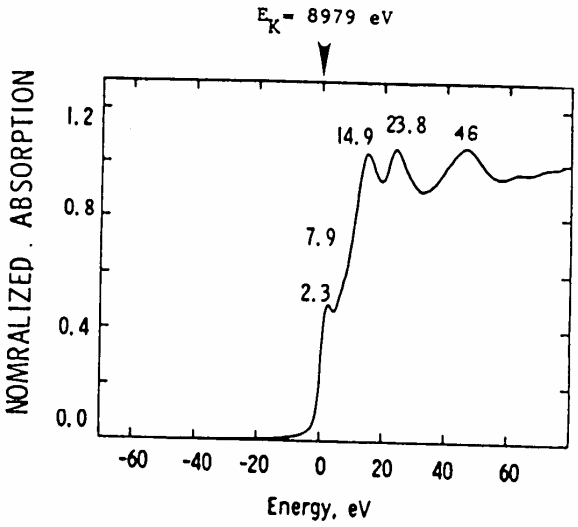

E_K = 8333 eV
NORMALIZED ABSORPTION
1.0
0.0
17
25
4.3
-60
-40
-20
0
20
40
60
Energy, eV


E_K = 8333 eV
DERIVATIVE SPECTRUM
0.1
0.0
0
5.6
12
23
29
-60
-40
-20
0
20
40
60
Energy, eV

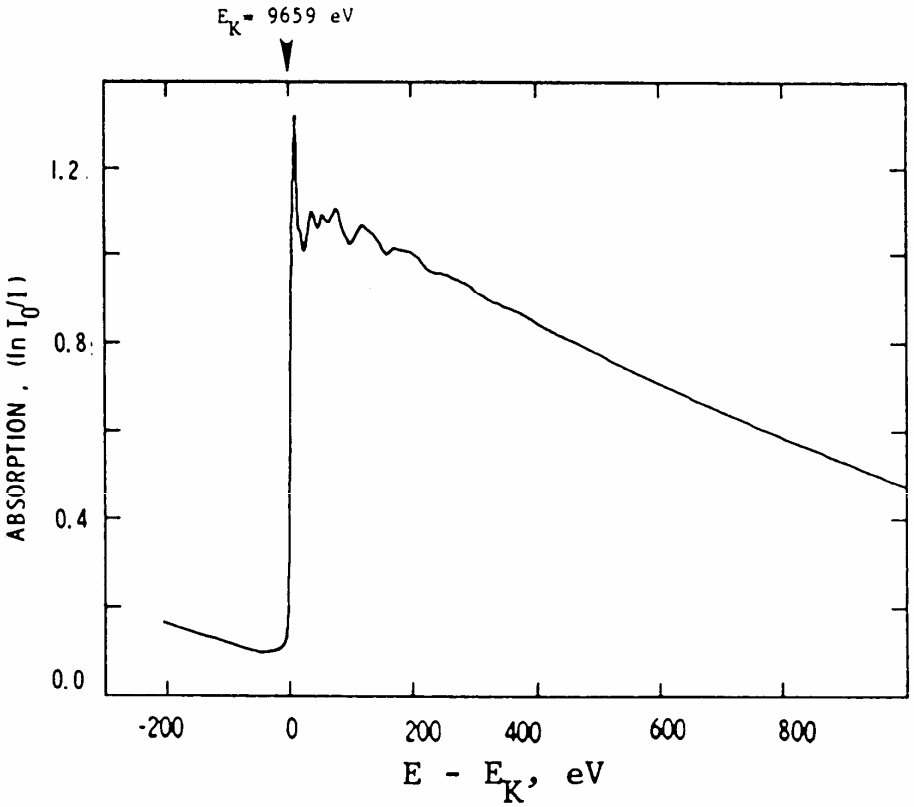
Cu

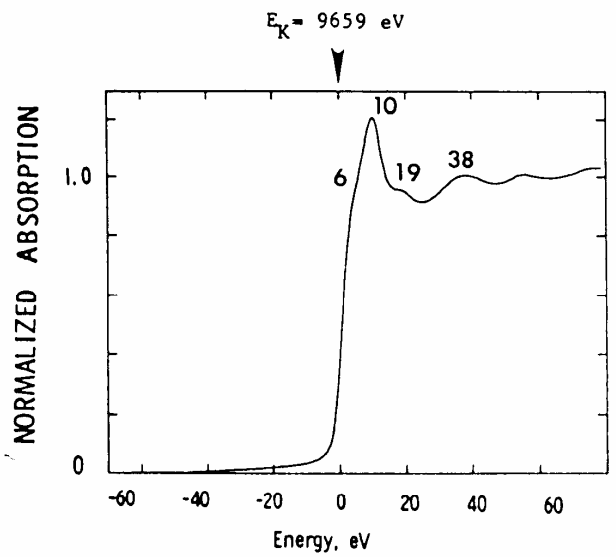

E_K = 8979 eV
ABSORPTION . (ln I_0/I)
1.6
1.2
0.8
0.4
0.0
200
0
200
400
600
800
1000
E - E_K, eV

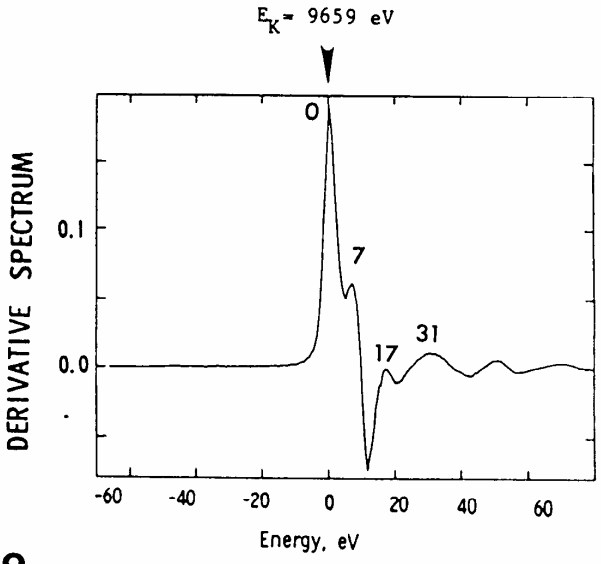

E_K = 8979 eV
DERIVATIVE SPECTRUM
0.1
0.0
5.5
11
22
-60
-40
-20
0
20
40
60
Energy, eV


E_K = 8979 eV
NOMRALIZED . ABSORPTION
1.2
0.8
0.4
0.0
14.9
23.8
46
7.9
2.3
-60
-40
-20
0
20
40
60
Energy, eV

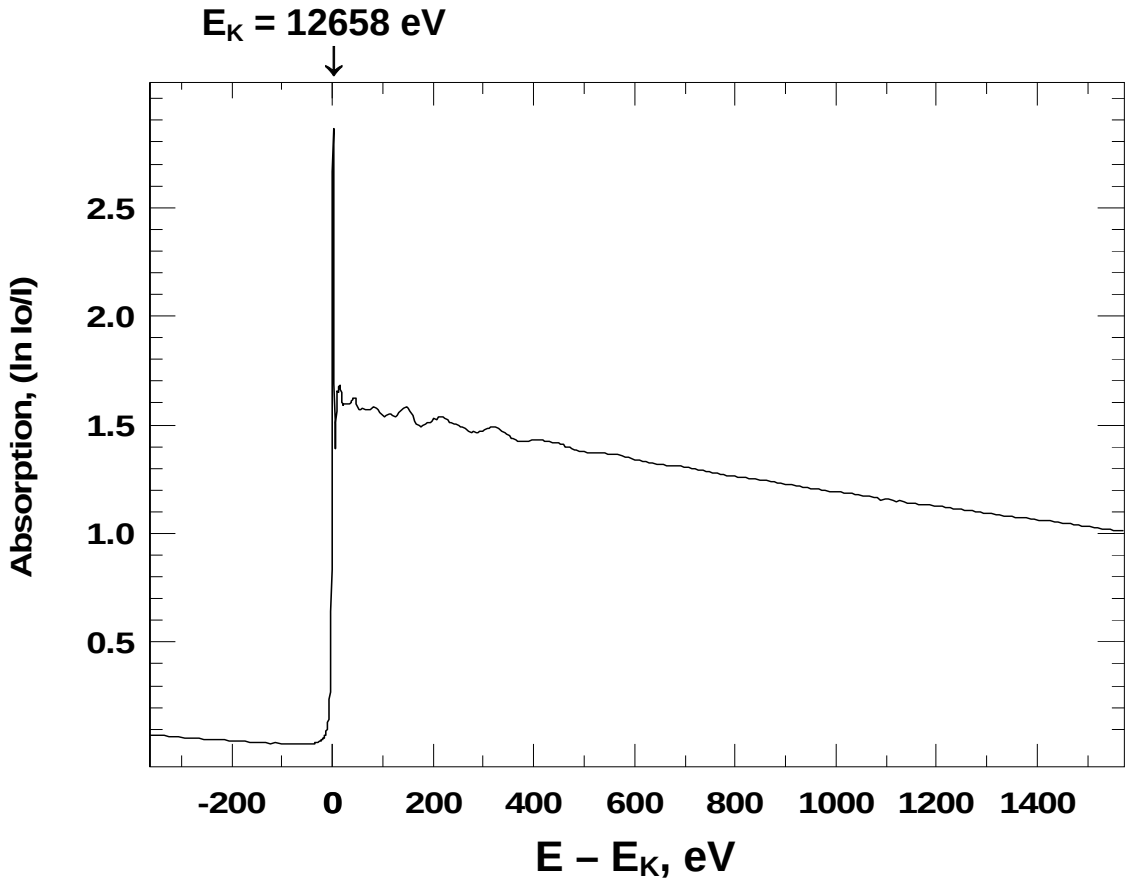
Zn

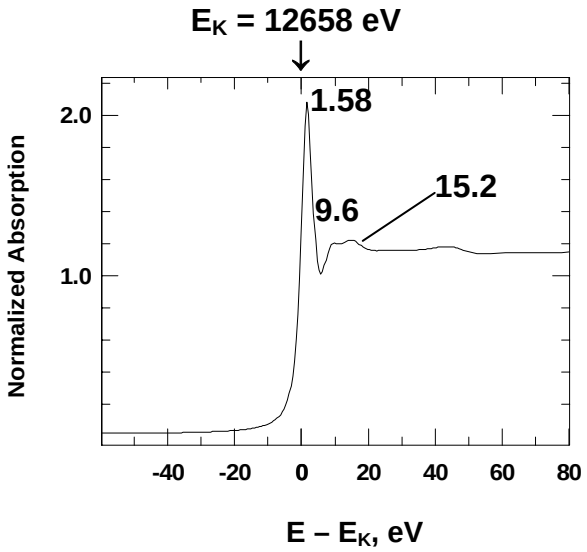

E_K = 9659 eV
ABSORPTION , (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
E - E_K, eV

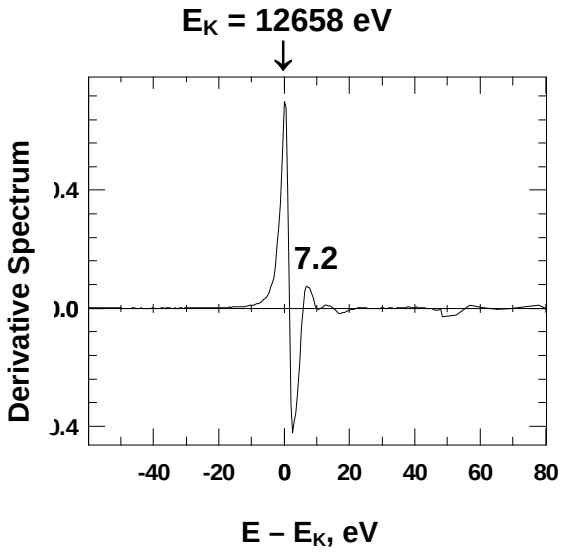

E_K = 9659 eV
NORMALIZED ABSORPTION
1.0
0
10
6
19
38
-60
-40
-20
0
20
40
60
Energy, eV


E_K = 9659 eV
DERIVATIVE SPECTRUM
0.1
0.0
0
7
17
31
-60
-40
-20
0
20
40
60
Energy, eV

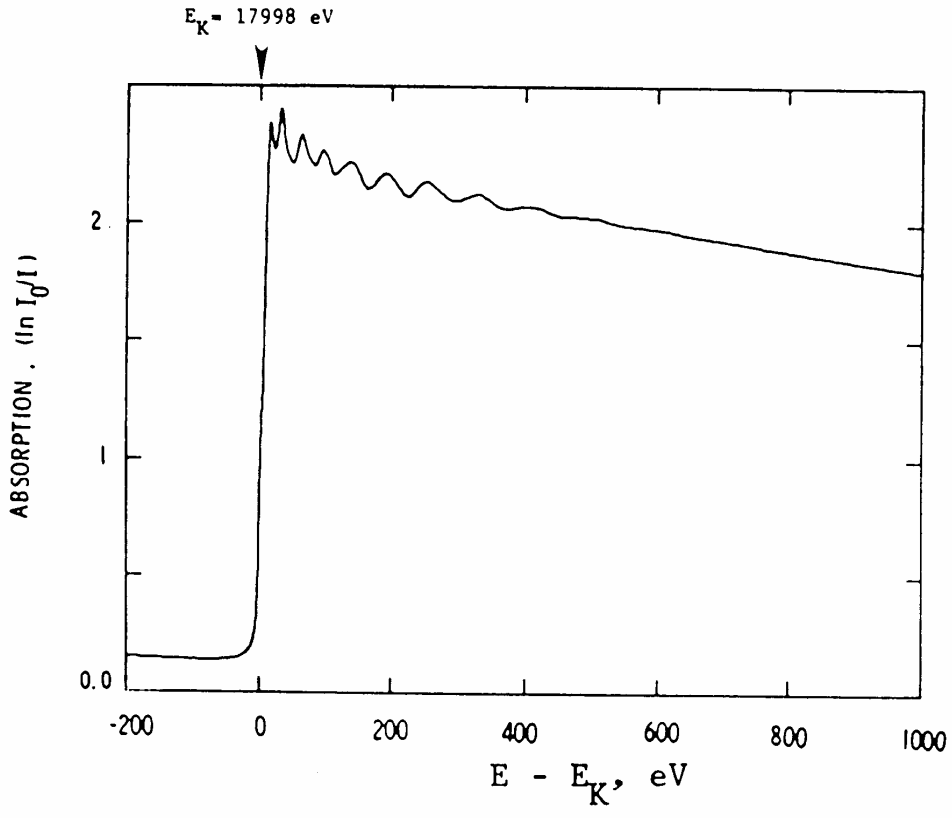
Se

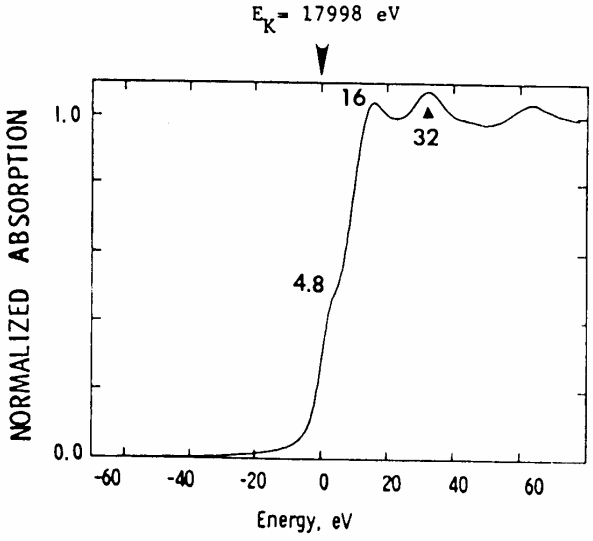

E_K = 12658 eV
Absorption, (ln Io/I)
2.5
2.0
1.5
1.0
0.5
-200
0
200
400
600
800
1000
1200
1400
E – E_K, eV

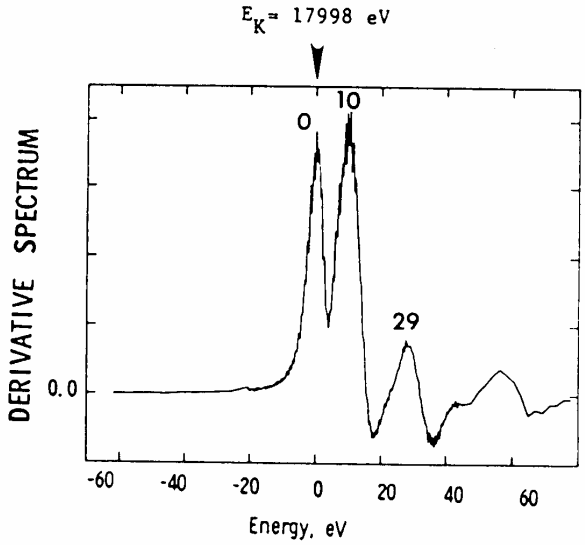

E_K = 12658 eV
Normalized Absorption
2.0
1.0
1.58
9.6
15.2
-40
-20
0
20
40
60
80
E – E_K, eV


E_K = 12658 eV
Derivative Spectrum
7.2
-40
-20
0
20
40
60
80
E – E_K, eV

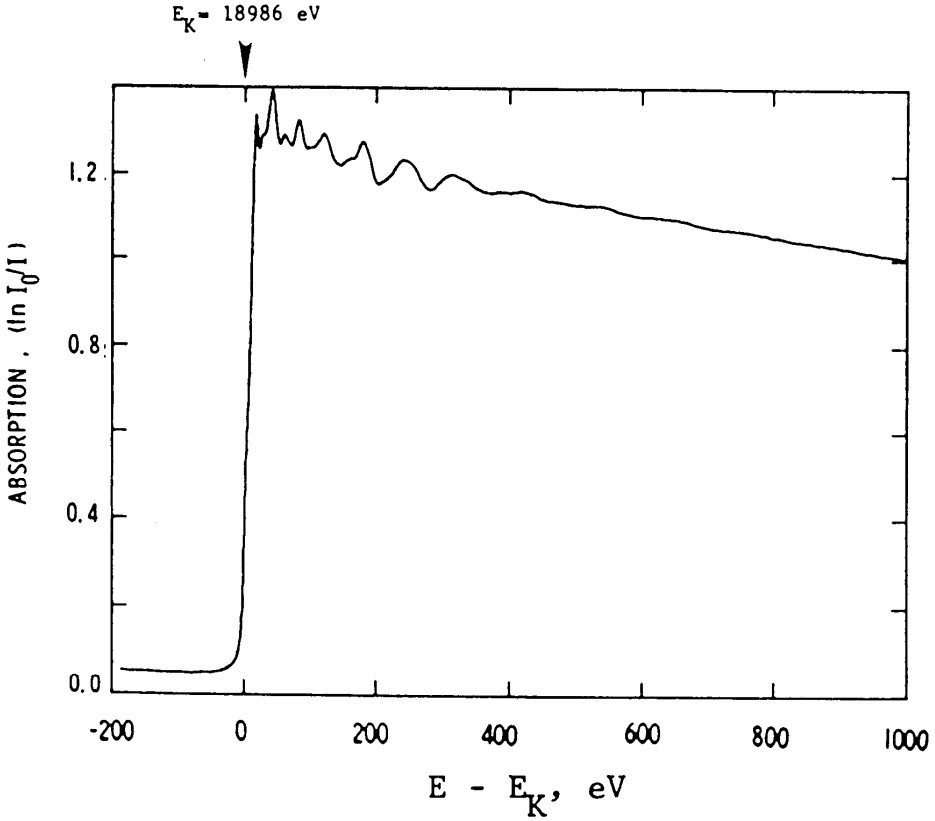
Zr

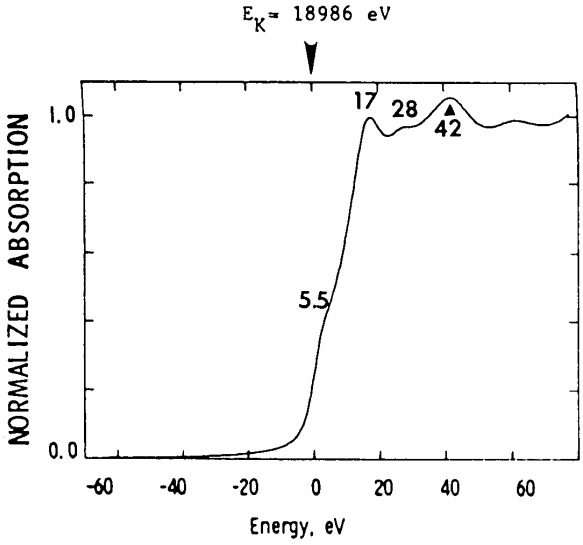

E_K= 17998 eV
ABSORPTION . (ln I_0/I)
2
1
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

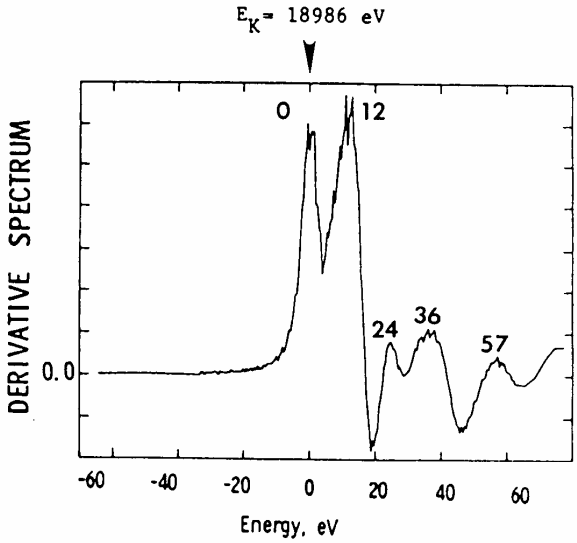

E_K= 17998 eV
NORMALIZED ABSORPTION
1.0
0.0
16
32
4.8
-60
-40
-20
0
20
40
60
Energy, eV

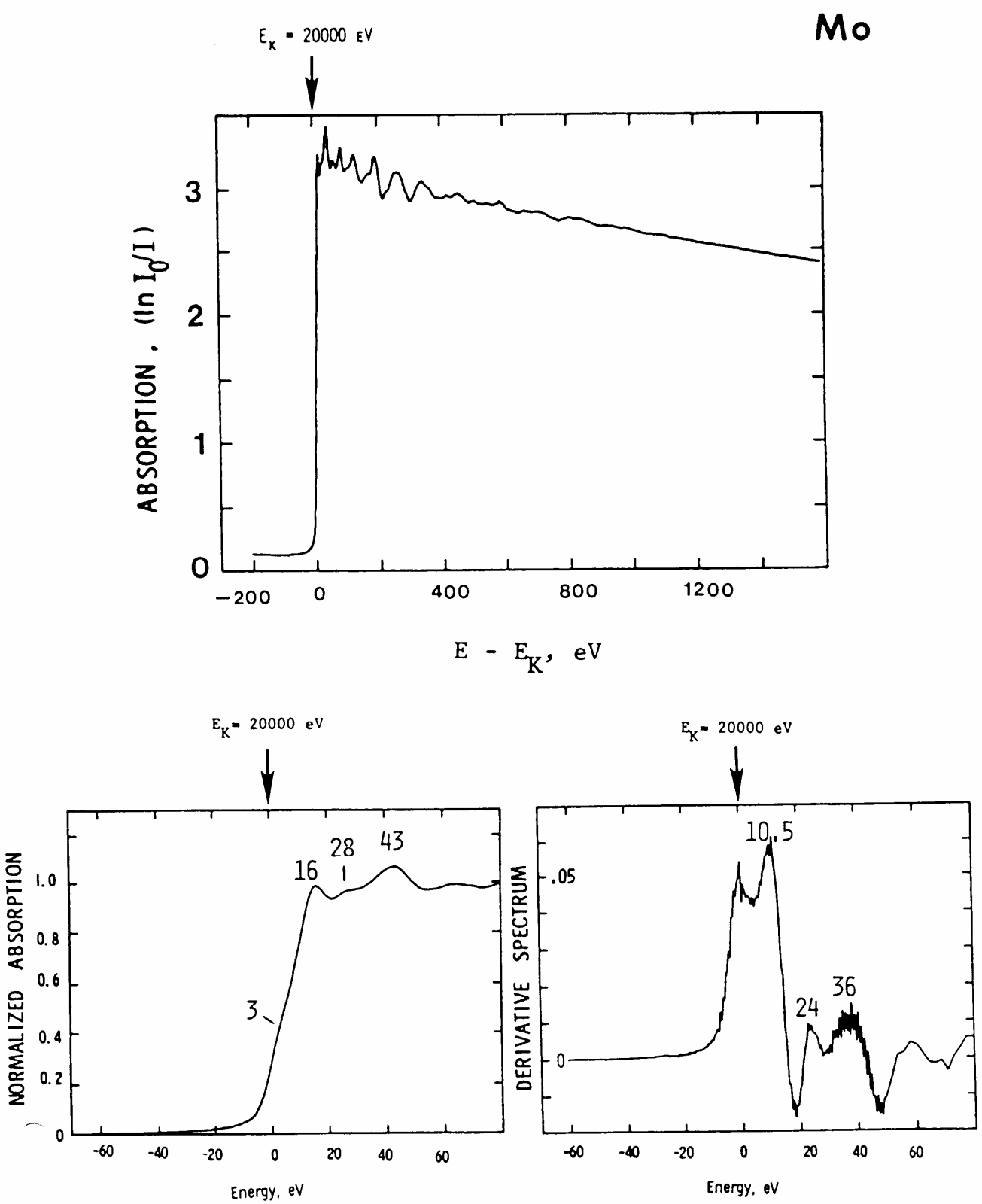

E_K= 17998 eV
DERIVATIVE SPECTRUM
0.0
0
10
29
-60
-40
-20
0
20
40
60
Energy, eV

Nb

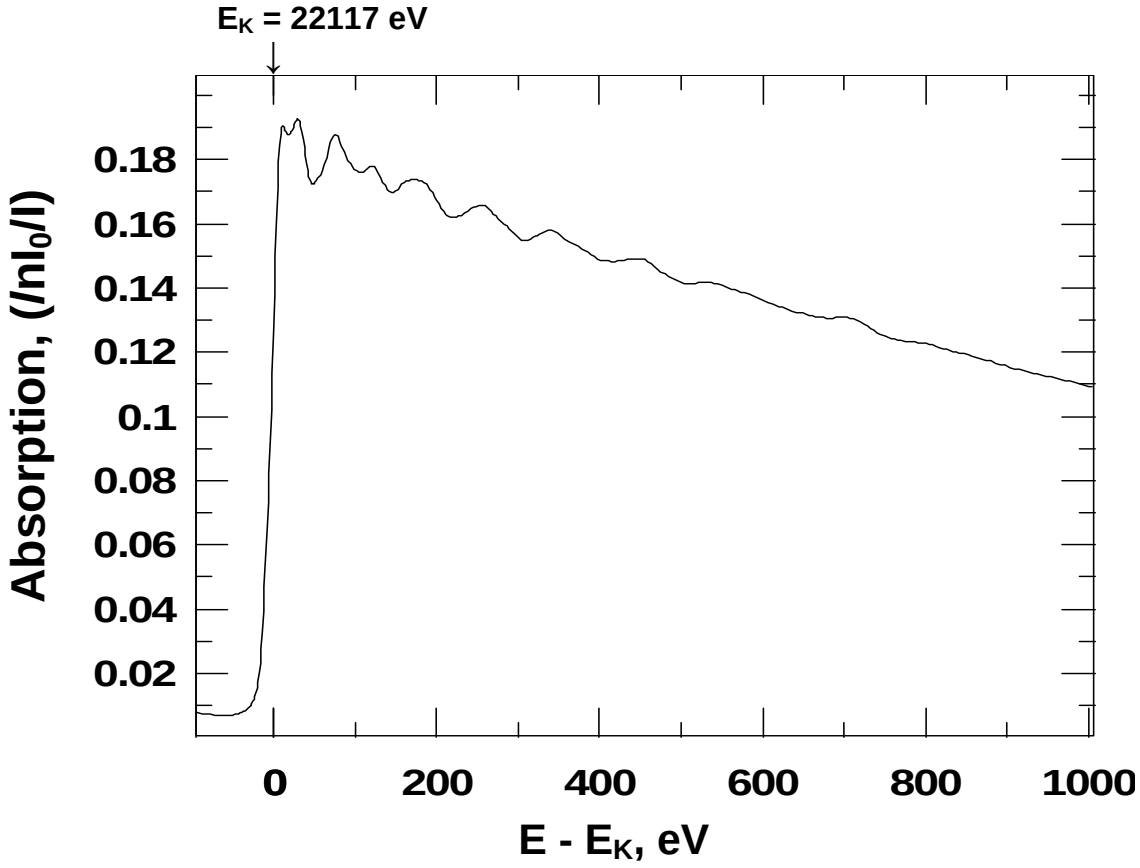

E_K = 18986 eV
ABSORPTION , (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

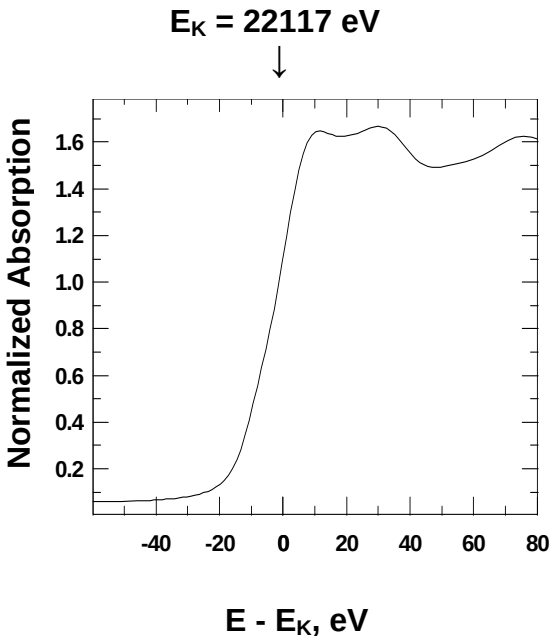

E_K = 18986 eV
NORMALIZED ABSORPTION
1.0
0.0
17
28
42
5.5
-60
-40
-20
0
20
40
60
Energy, eV

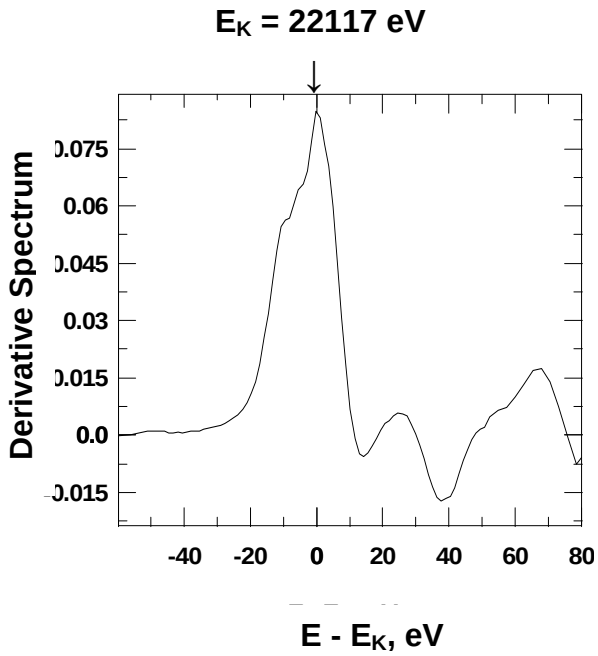

E_K = 18986 eV
DERIVATIVE SPECTRUM
0.0
0
12
24
36
57
-60
-40
-20
0
20
40
60
Energy, eV


Mo
E_K = 20000 eV
ABSORPTION . ($\ln I_0/I$)
0
1
2
3
−200
0
400
800
1200
E - E_K, eV
E_K= 20000 eV
NORMALIZED ABSORPTION
0
0.2
0.4
0.6
0.8
1.0
3
16
28
43
-60
-40
-20
0
20
40
60
Energy, eV
E_K= 20000 eV
DERIVATIVE SPECTRUM
.05
0
10.5
24
36
-60
-40
-20
0
20
40
60
Energy, eV

Ru



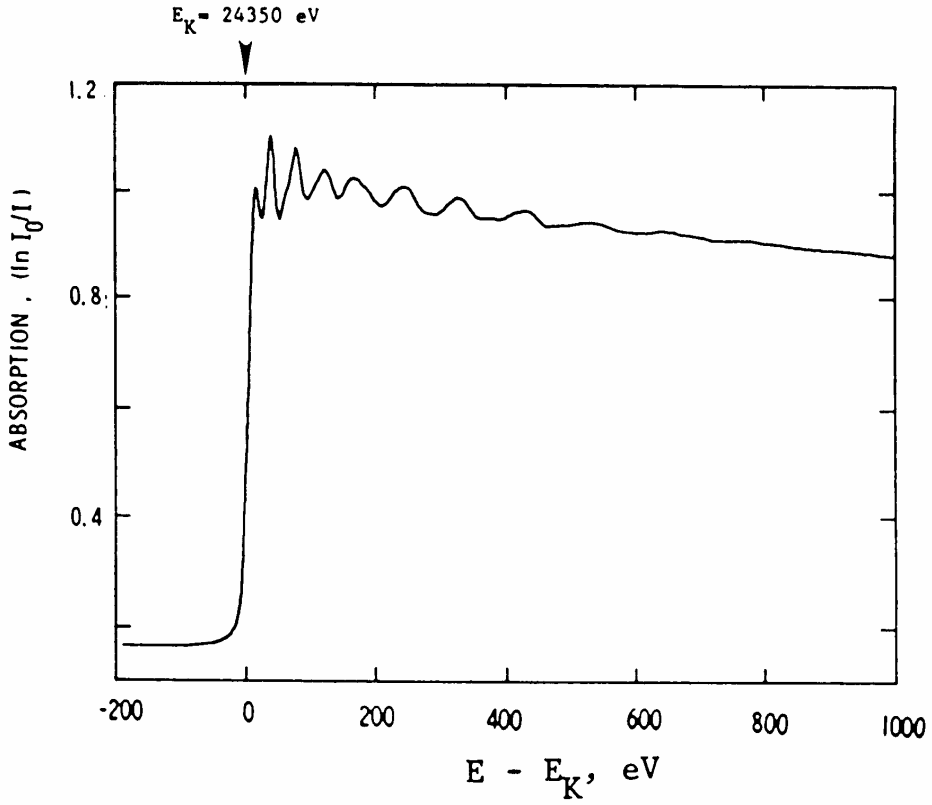


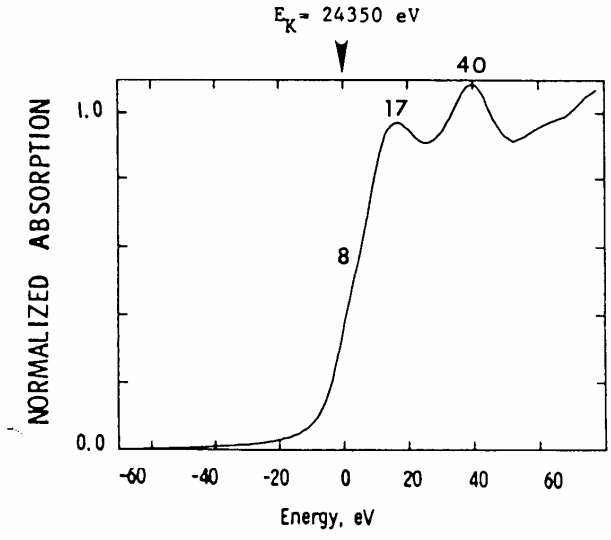


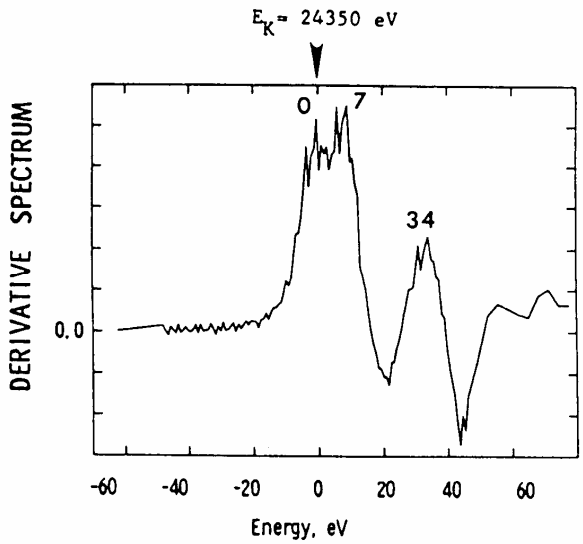
13a

Spectrum at 100K – Courtesy of Farrel Lytle

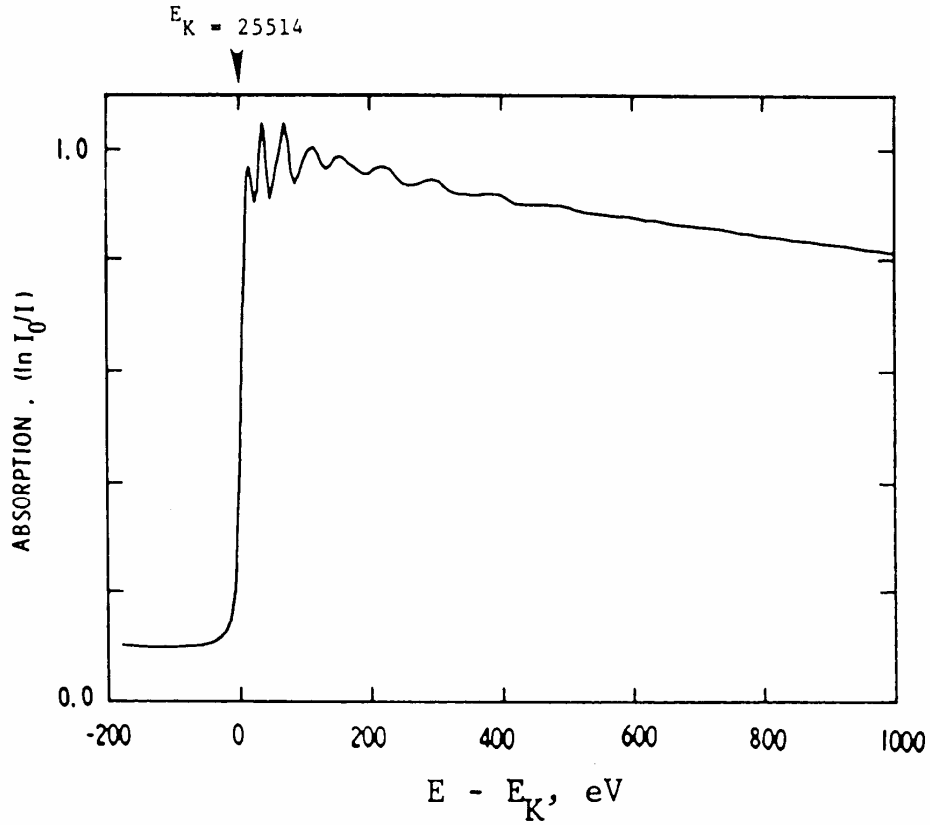
Pd

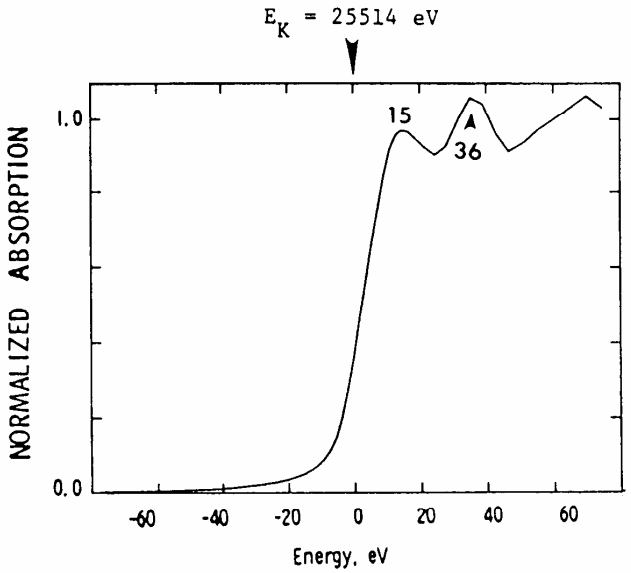

E_K = 24350 eV
1.2
0.8
0.4
ABSORPTION , (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_K, eV

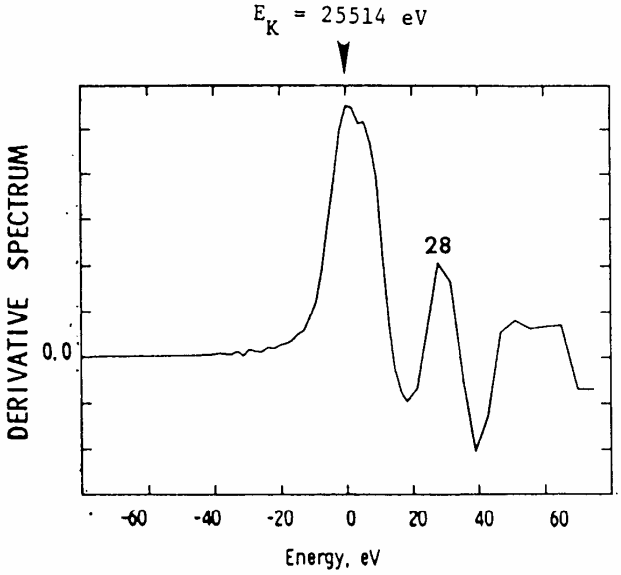

E_K = 24350 eV
40
17
8
1.0
0.0
NORMALIZED ABSORPTION
-60
-40
-20
0
20
40
60
Energy, eV


E_K = 24350 eV
0
7
34
0.0
DERIVATIVE SPECTRUM
-60
-40
-20
0
20
40
60
Energy, eV

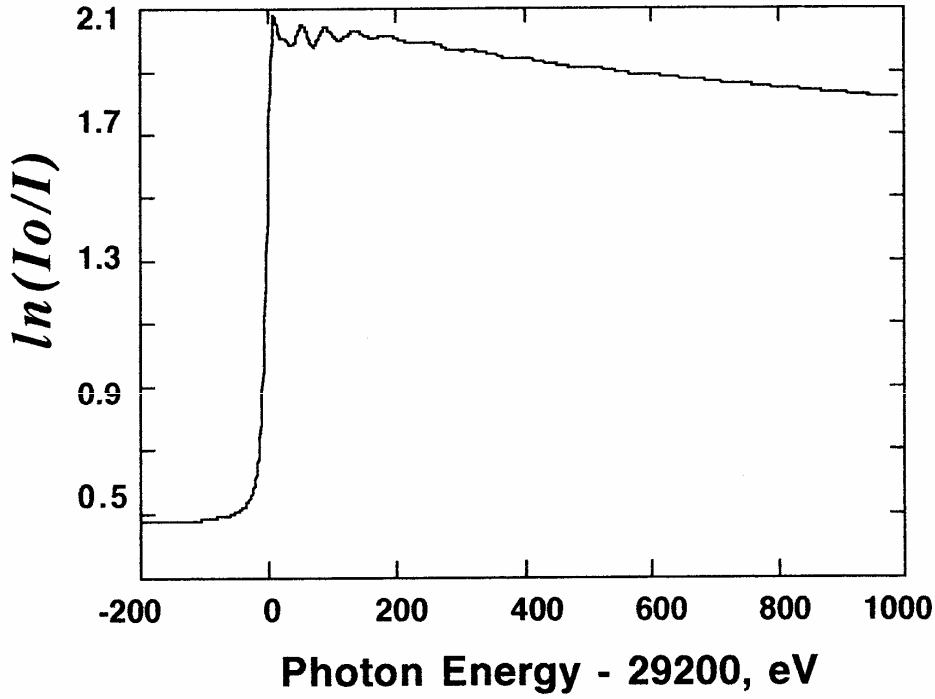
Ag

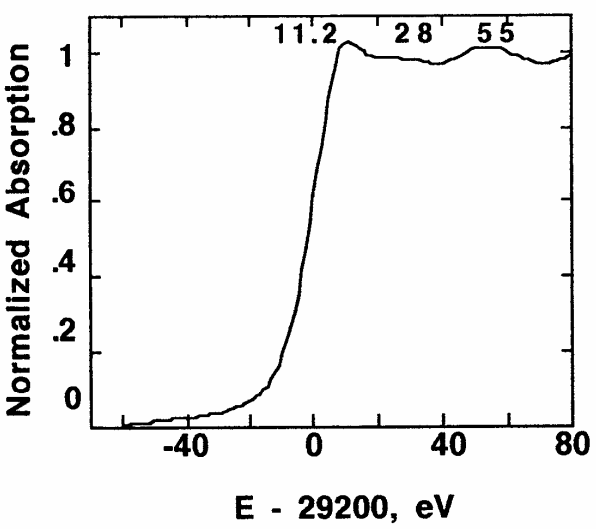

E_K = 25514
1.0
0.0
ABSORPTION . (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_K, eV

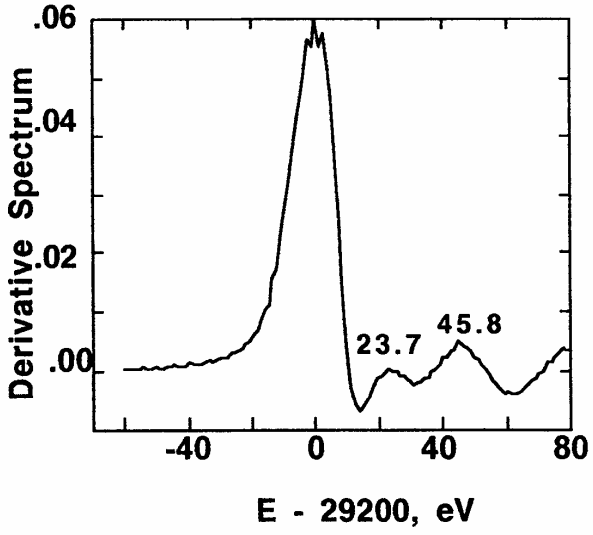

E_K = 25514 eV
1.0
0.0
NORMALIZED ABSORPTION
15
A
36
-60
-40
-20
0
20
40
60
Energy, eV


E_K = 25514 eV
DERIVATIVE SPECTRUM
0.0
28
-60
-40
-20
0
20
40
60
Energy, eV

Sn

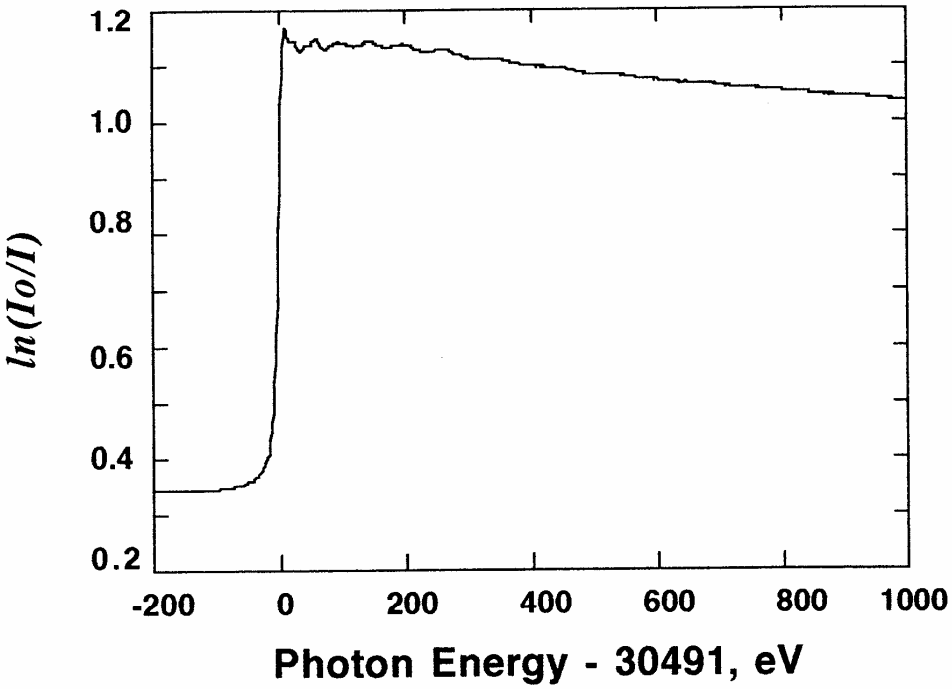

2.1
1.7
1.3
0.9
0.5
ln(Io/I)
-200
0
200
400
600
800
1000
Photon Energy - 29200, eV

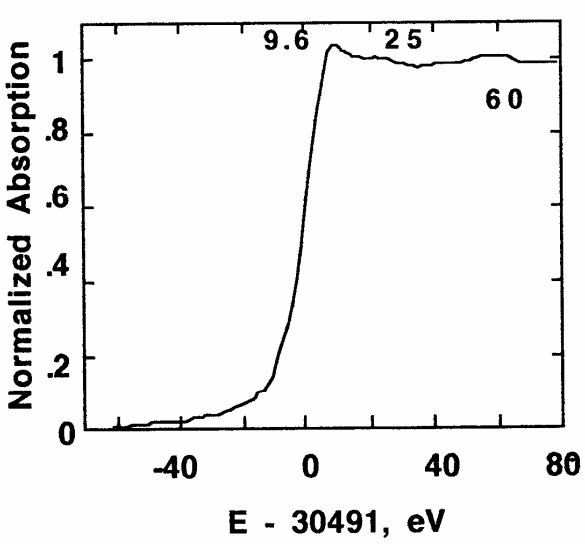

Normalized Absorption
1
.8
.6
.4
.2
0
11.2
28
55
-40
0
40
80
E - 29200, eV

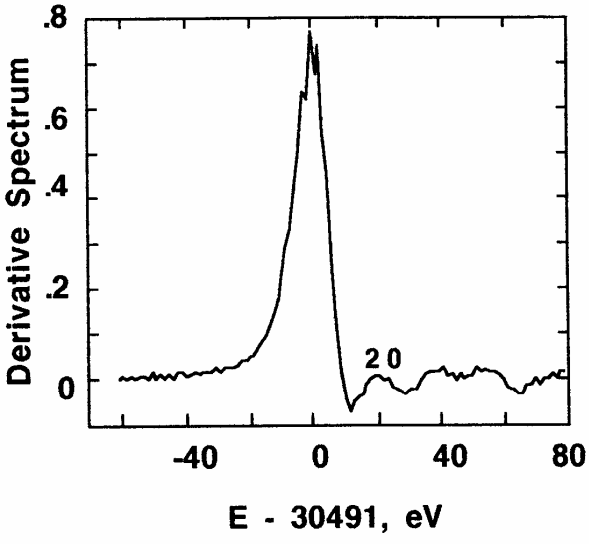

Derivative Spectrum
.06
.04
.02
.00
23.7
45.8
-40
0
40
80
E - 29200, eV

15a

Sb

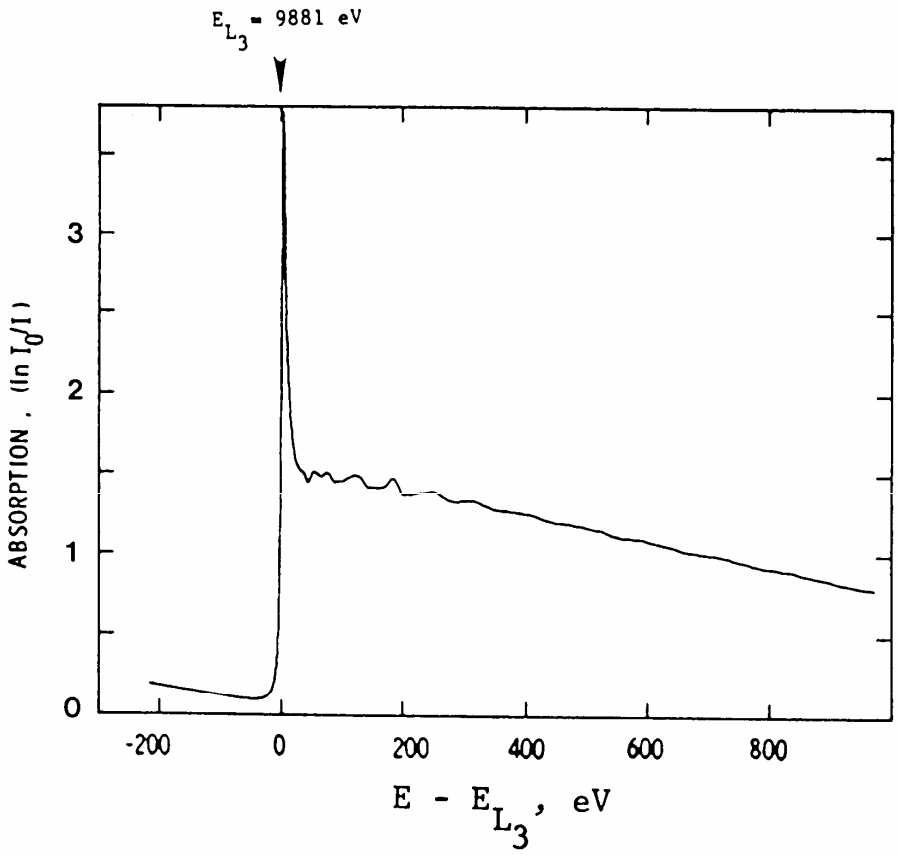

1.2
1.0
0.8
0.6
0.4
0.2
ln(Io/I)
-200
0
200
400
600
800
1000
Photon Energy - 30491, eV

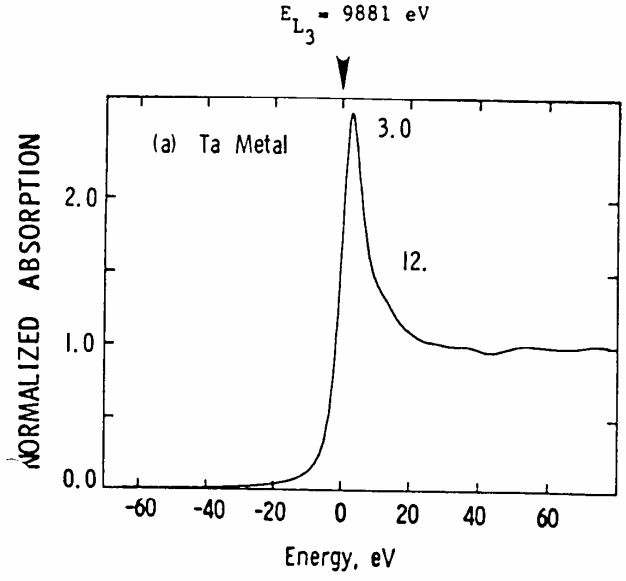

9.6
25
60
1
.8
.6
.4
.2
0
Normalized Absorption
-40
0
40
80
E - 30491, eV

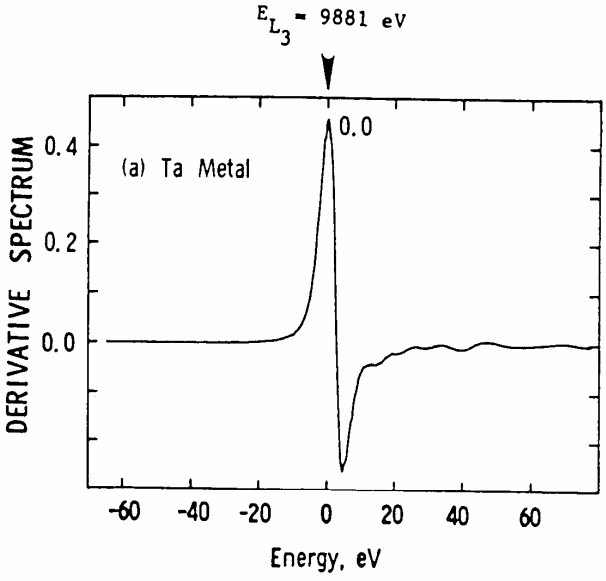

.8
.6
.4
.2
0
Derivative Spectrum
20
-40
0
40
80
E - 30491, eV

15b

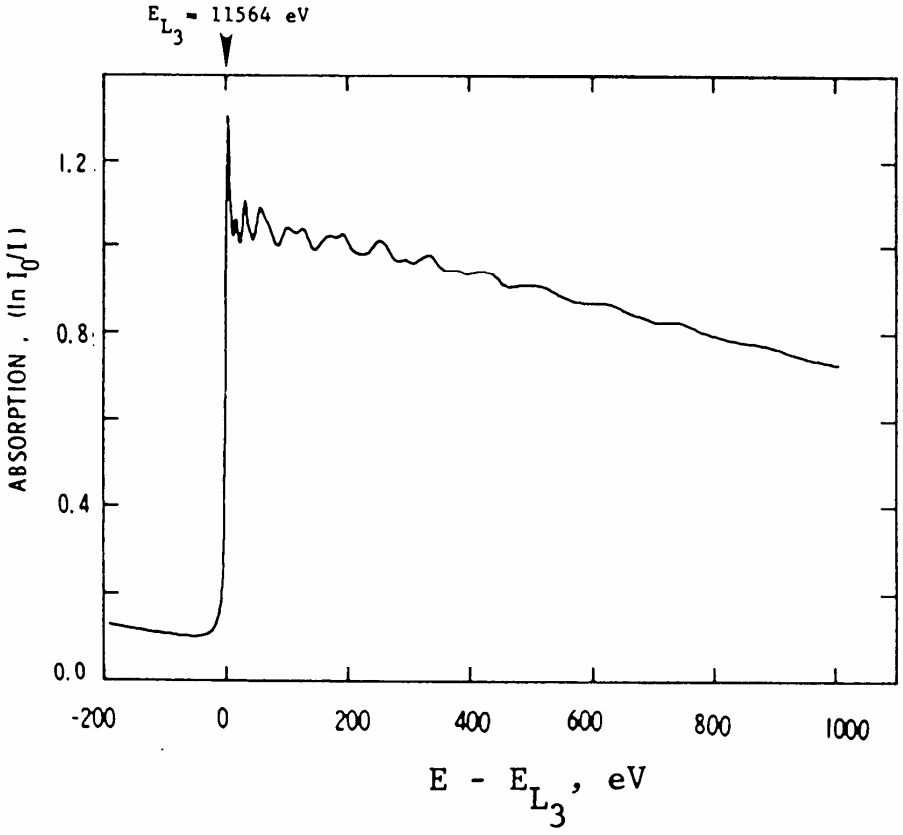
Ta

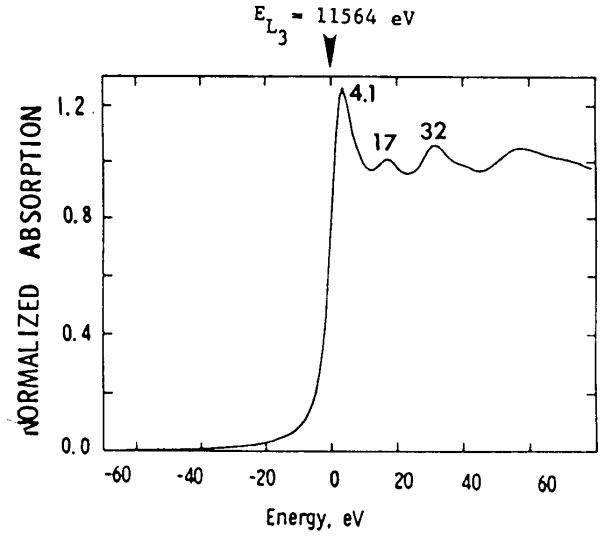

E_{L_3} = 9881 eV
ABSORPTION , ($\ln I_0/I$)
0
1
2
3
-200
0
200
400
600
800
$E - E_{L_3}$, eV

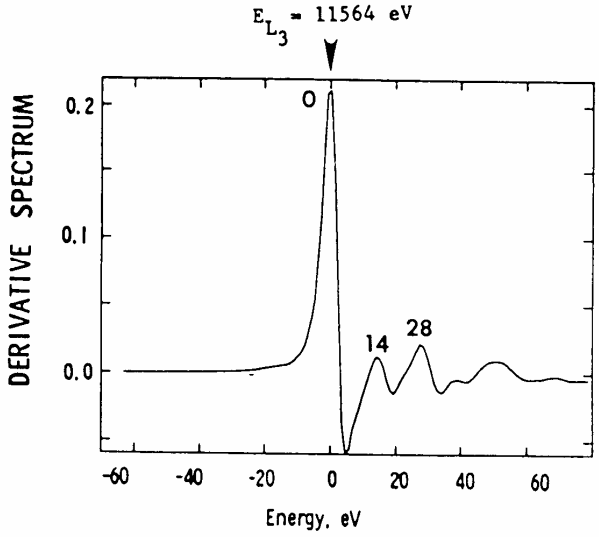

E_{L_3} = 9881 eV
(a) Ta Metal
3.0
12.
NORMALIZED ABSORPTION
0.0
1.0
2.0
-60
-40
-20
0
20
40
60
Energy, eV


E_{L_3} = 9881 eV
(a) Ta Metal
0.0
DERIVATIVE SPECTRUM
0.0
0.2
0.4
-60
-40
-20
0
20
40
60
Energy, eV

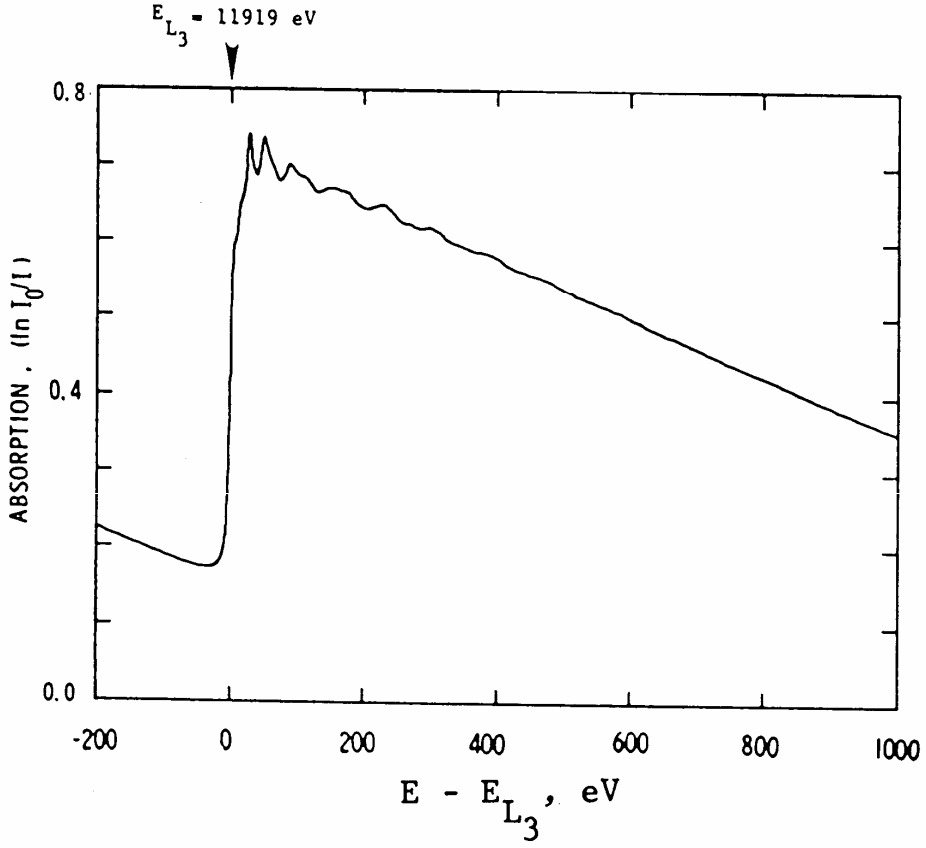
Pt

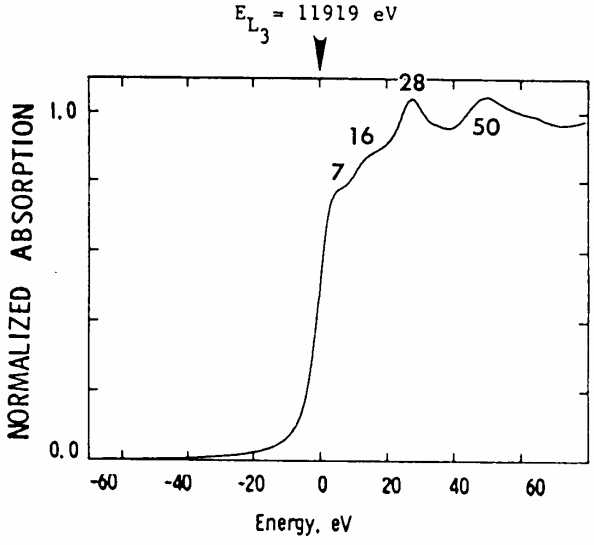

E_{L_3} = 11564 eV
ABSORPTION , (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
1000
E - E_{L_3}, eV

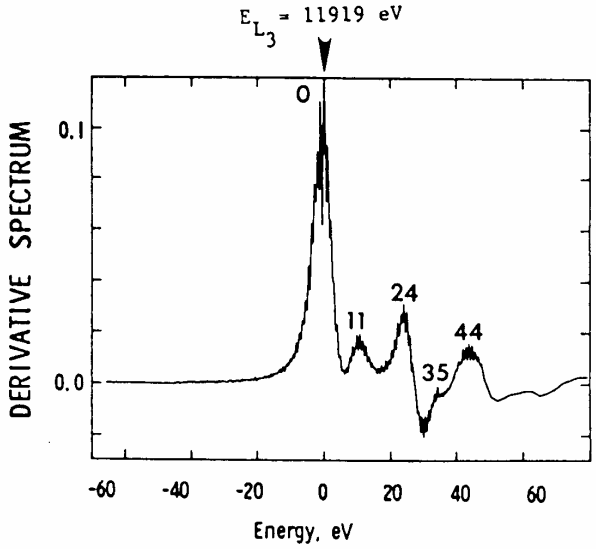

E_{L_3} = 11564 eV
NORMALIZED ABSORPTION
1.2
0.8
0.4
0.0
4.1
17
32
-60
-40
-20
0
20
40
60
Energy, eV


E_{L_3} = 11564 eV
DERIVATIVE SPECTRUM
0.2
0.1
0.0
0
14
28
-60
-40
-20
0
20
40
60
Energy, eV

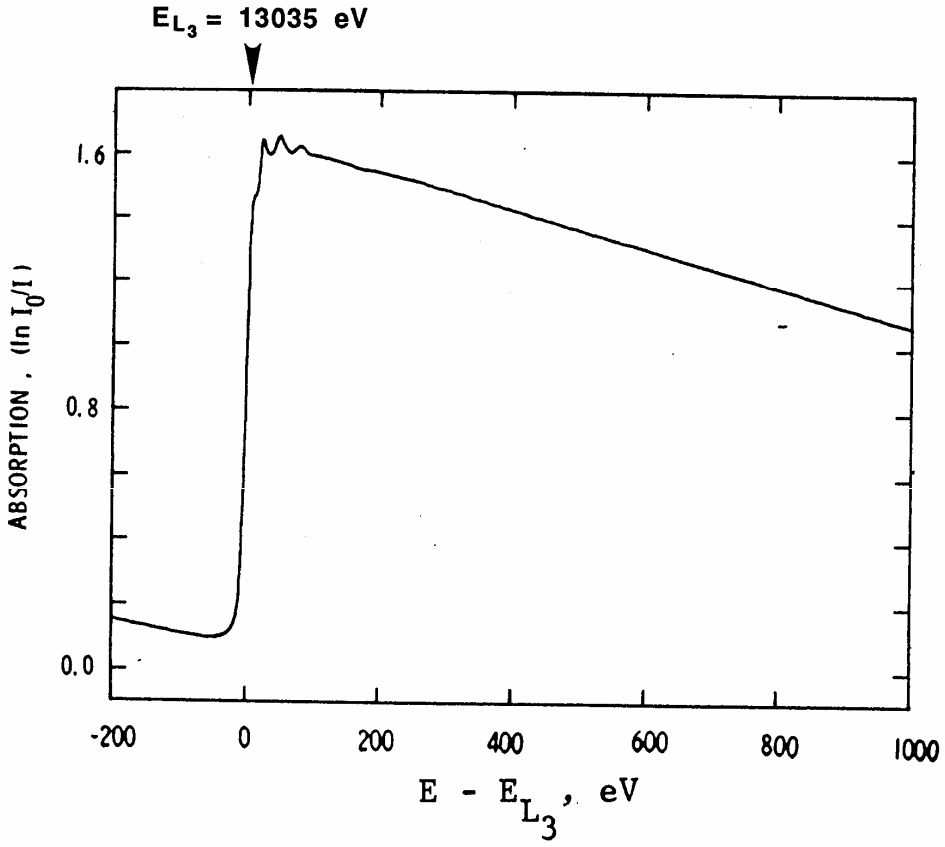
Au

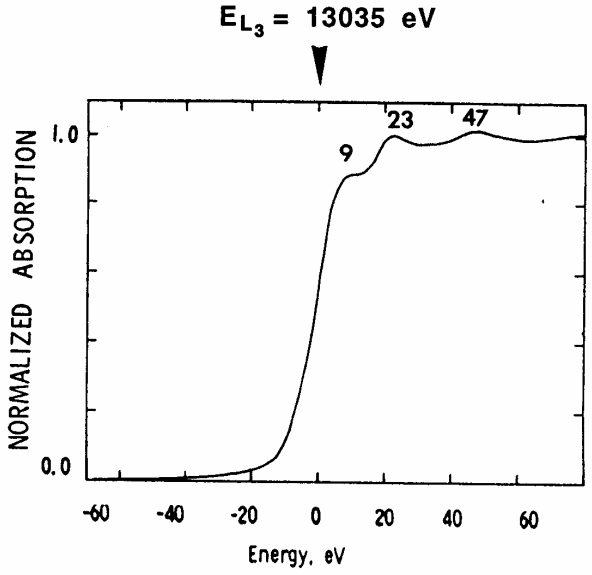

E_{L_3} = 11919 eV
0.8
0.4
0.0
ABSORPTION, (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_{L_3}, eV

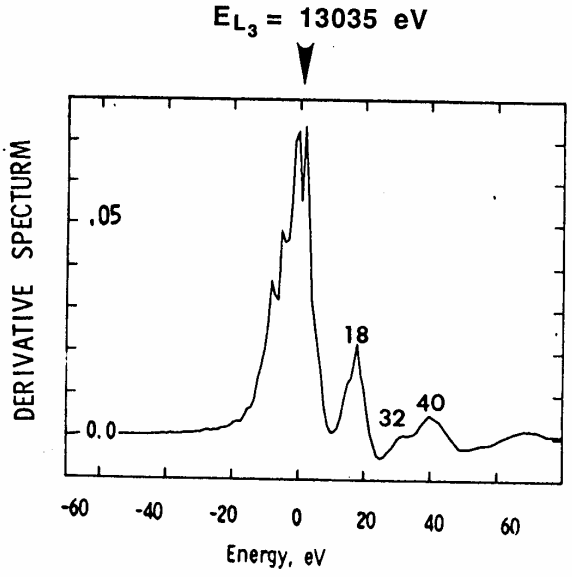

E_{L_3} = 11919 eV
NORMALIZED ABSORPTION
1.0
0.0
28
16
7
50
-60
-40
-20
0
20
40
60
Energy, eV


E_{L_3} = 11919 eV
DERIVATIVE SPECTRUM
0.1
0.0
0
11
24
35
44
-60
-40
-20
0
20
40
60
Energy, eV

Pb


E_{L_3} = 13035 eV
ABSORPTION , (ln I_0/I)
1.6
0.8
0.0
-200
0
200
400
600
800
1000
E - E_{L_3}, eV


E_{L_3} = 13035 eV
NORMALIZED ABSORPTION
1.0
0.0
9
23
47
-60
-40
-20
0
20
40
60
Energy, eV


E_{L_3} = 13035 eV
DERIVATIVE SPECTURM
.05
0.0
18
32
40
-60
-40
-20
0
20
40
60
Energy, eV

X-ray K- and L-edge Energies of the Elements, eV

Element	Z	K-Edge	L_1	L_2	L_3
H	1	13.6	0.0	0.0	0.0
He	2	24.6	0.0	0.0	0.0
Li	3	54.8	0.0	0.0	0.0
Be	4	111.0	0.0	0.0	0.0
B	5	188.0	0.0	4.7	4.7
C	6	283.8	0.0	6.4	6.4
N	7	401.6	0.0	9.2	9.2
O	8	532.0	23.7	7.1	7.1
F	9	685.4	31.0	8.6	8.6
Ne	10	866.9	45.0	18.3	18.3
Na	11	1072.1	63.3	31.1	31.1
Mg	12	1303.0	89.4	51.4	51.4
Al	13	1559.6	117.7	73.1	73.1
Si	14	1838.9	148.7	99.2	99.2
P	15	2145.5	189.3	132.2	132.2
S	16	2472.0	229.2	164.8	164.8
Cl	17	2822.4	270.2	201.6	200.0
Ar	18	3202.9	320.0	247.3	245.2
K	19	3607.4	377.1	296.3	293.6
Ca	20	4038.1	437.8	350.0	346.4
Sc	21	4492.8	500.4	406.7	402.2
Ti	22	4966.4	563.7	461.5	455.5
V	23	5465.1	628.2	520.5	512.9
Cr	24	5989.2	694.6	583.7	574.5
Mn	25	6539.0	769.0	651.4	640.3
Fe	26	7112.0	846.1	721.1	708.1
Co	27	7708.9	925.6	793.8	778.6
Ni	28	8332.8	1008.1	871.9	854.7
Cu	29	8978.9	1096.1	951.0	931.1
Zn	30	9658.6	1193.6	1042.8	1019.7
Ga	31	10367.1	1297.7	1142.3	1115.4
Ge	32	11103.1	1414.3	1247.8	1216.7
As	33	11866.7	1526.5	1358.6	1323.1
Se	34	12657.8	1653.9	1476.2	1435.8
Br	35	13473.7	1782.0	1596.0	1549.9
Kr	36	14325.6	1921.0	1727.2	1674.9
Rb	37	15199.7	2065.1	1863.9	1804.4
Sr	38	16104.6	2216.3	2006.8	1939.6
Y	39	17038.4	2372.5	2155.5	2080.0
Zr	40	17997.6	2531.6	2306.7	2222.3
Nb	41	18985.6	2697.7	2464.7	2370.5
Mo	42	19999.5	2865.6	2625.1	2520.2
Tc	43	21044.0	3042.5	2793.2	2676.9
Ru	44	22117.2	3224.0	2966.9	2837.9
Rh	45	23219.9	3411.9	3146.1	3003.8
Pd	46	24350.3	3604.3	3330.3	3173.3
Ag	47	25514.0	3805.8	3523.7	3351.0
Cd	48	26711.2	4018.0	3727.0	3537.5
In	49	27939.9	4237.5	3938.0	3730.1
Sn	50	29200.1	4464.7	4156.1	3928.8
Sb	51	30491.2	4698.3	4380.4	4132.2
Te	52	31813.8	4939.2	4612.0	4341.4

X-ray K- and L-Edge Energies of the Elements, eV

Element	Z	K-Edge	L_1	L_2	L_3
I	53	33169.4	5188.1	4852.1	4557.1
Xe	54	34561.4	5452.8	5103.7	4782.2
Cs	55	35984.6	5714.3	5359.4	5011.9
Ba	56	37440.6	5988.8	5623.6	5247.0
La	57	38924.6	6266.3	5890.6	5482.7
Ce	58	40443.0	6548.8	6164.2	5723.4
Pr	59	41990.6	6834.8	6440.4	5964.3
Nd	60	43568.9	7126.0	6721.5	6207.9
Pm	61	45184.0	7427.9	7012.8	6459.3
Sm	62	46834.2	7736.8	7311.8	6716.2
Eu	63	48519.0	8052.0	7617.1	6976.9
Gd	64	50239.1	8375.6	7930.3	7242.8
Tb	65	51995.7	8708.0	8251.6	7514.0
Dy	66	53788.5	9045.8	8580.6	7790.1
Ho	67	55617.7	9394.2	8917.8	8071.1
Er	68	59389.6	10115.7	9616.9	8648.0
Yb	70	61332.3	10486.4	9978.2	8943.6
Lu	71	63313.8	10870.4	10348.6	9244.1
Hf	72	65350.8	11270.7	10739.4	9560.7
Ta	73	67416.4	11681.5	11136.1	9881.1
W	74	69525.0	12099.8	11544.0	10206.8
Re	75	71676.4	12526.7	11958.7	10535.3
Os	76	73870.8	12968.0	12385.0	10870.9
Ir	77	76111.0	13418.5	12824.1	11215.2
Pt	78	78394.8	13879.9	13272.6	11563.7
Au	79	80724.9	14352.8	13733.6	11918.7
Hg	80	83102.3	14839.3	14208.7	12283.9
Tl	81	85530.4	15346.7	14697.9	12657.5
Pb	82	88004.5	15860.8	15200.0	13035.2
Bi	83	90525.9	16387.6	15711.1	13418.6
Po	84	93105.0	16939.3	16244.3	13813.8
At	85	95729.9	17493.0	16784.7	14213.5
Rn	86	98404.0	18049.0	17337.1	14619.4
Fr	87	101137.0	18639.0	17906.5	15031.2
Ra	88	103921.9	19236.7	18484.3	15444.4
Ac	89	106755.3	19840.0	19083.2	15871.0
Th	90	109650.9	20472.1	19693.2	16300.3
Pa	91	112601.4	21104.6	20313.7	16733.1
U	92	115606.1	21757.4	20947.6	17166.3
Np	93	118678.0	22426.8	21600.5	17610.0
Pu	94	121818.0	23097.2	22266.2	18056.8
Am	95	125027.0	23772.9	22944.0	18504.1
Cm	96	128200.0	24460.0	23779.0	18930.0
Bk	97	131590.0	25275.0	24385.0	19452.0
Cf	98	135960.0	26110.0	25250.0	19930.0
Es	99	139490.0	26900.0	26020.0	20410.0
Fm	100	143090.0	27700.0	26810.0	20900.0
Md	101	146780.0	28530.0	27610.0	21390.0
No	102	150540.0	29380.0	28440.0	21880.0
Lr	103	154380.0	30240.0	29280.0	22360.0

Source: J.A.Bearden and A.F.Burr, Rev.Mod.Phys.39, 125(1967)

Tabulated by: B. Rupp and Joe Wong