Reference X-Ray Spectra

of

Metal Foils

Exafs

Materials

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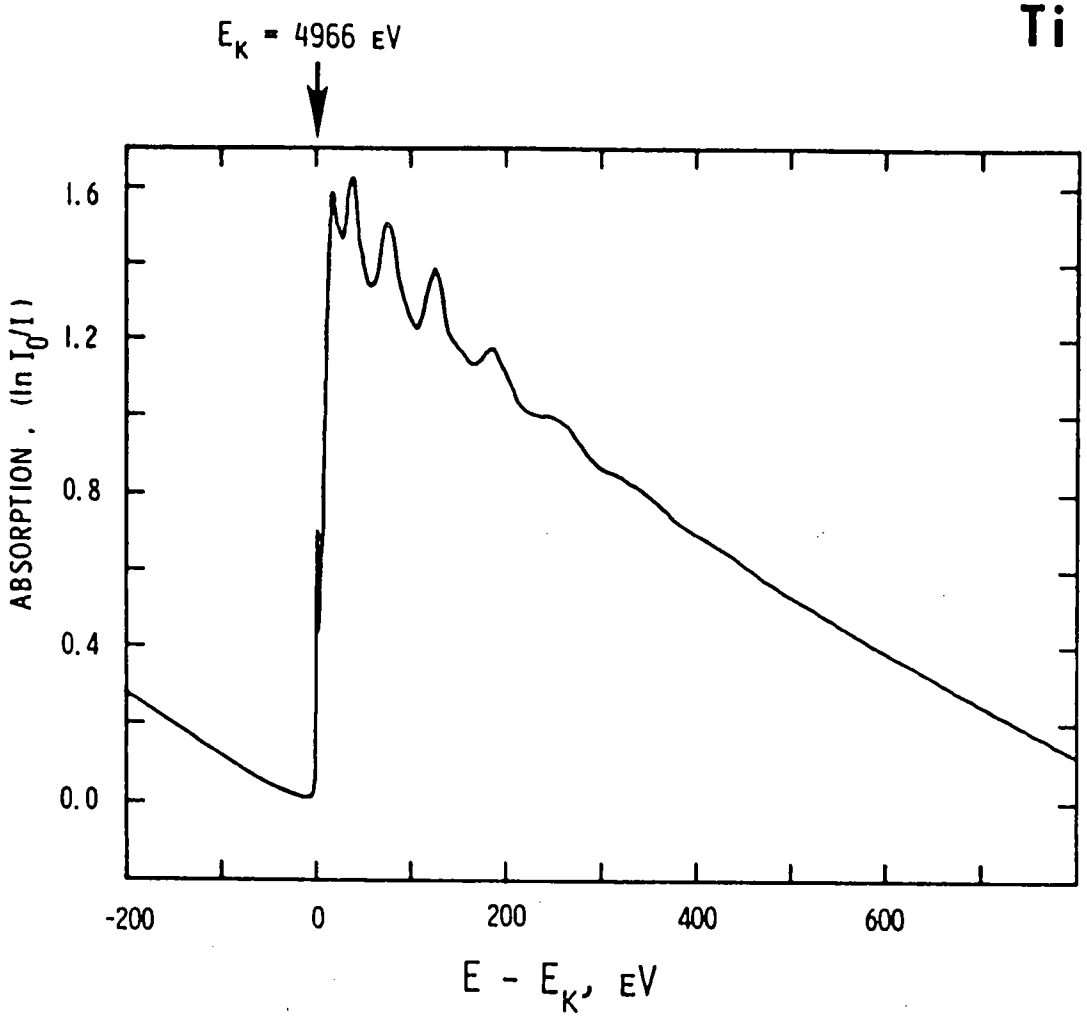
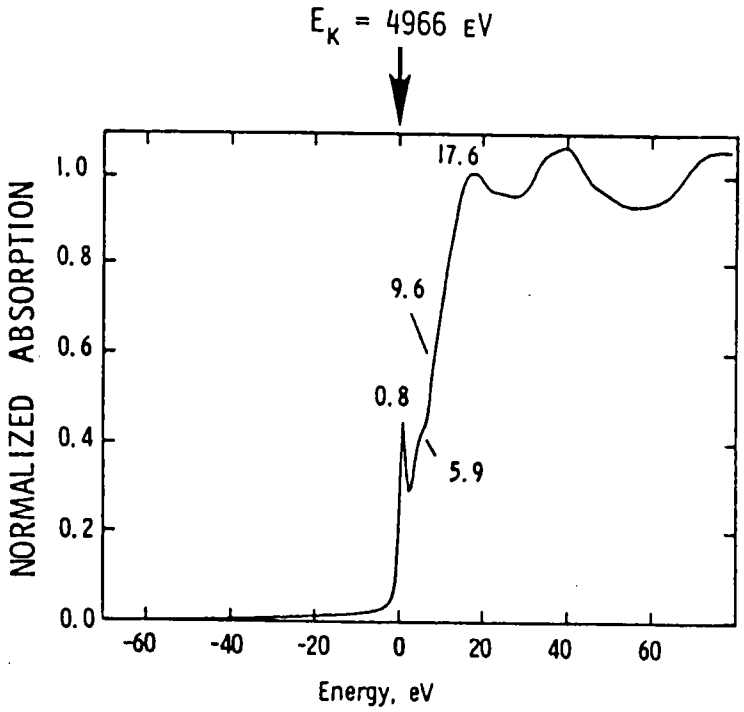
Reference X-ray Spectra of Metal Foils

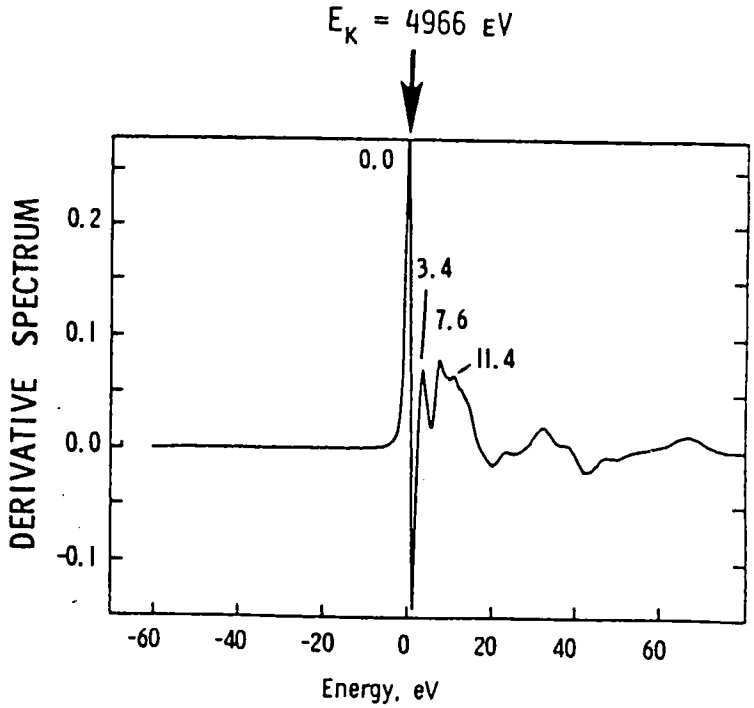
The x-ray spectra compiled herein for the following metal foils were recorded at synchrotron beamlines 1-5, 4-2, 7-3 and 10-2 at Stanford Synchrotron Radiation Laboratory (SSRL) using double crystal Si(220) monochromators. The spectra for Ag, Pt and Au were recorded with a double crystal Si(111) monochromator 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.

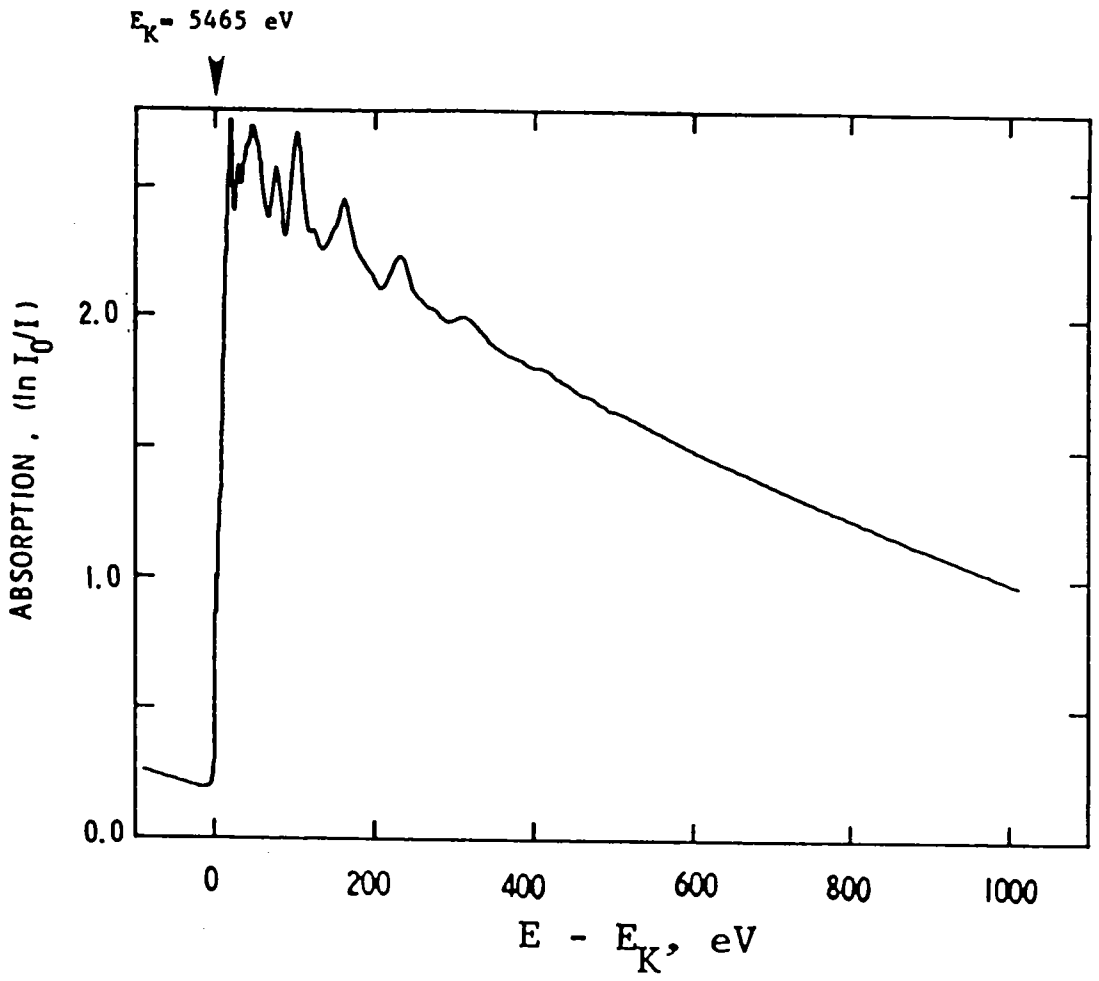
3d Metals:	Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se,
4d Metals:	Zr, Nb, Mo, Pd, Ag, Sn, Sb
5d Metals:	Ta, Pt , Au, Pb.

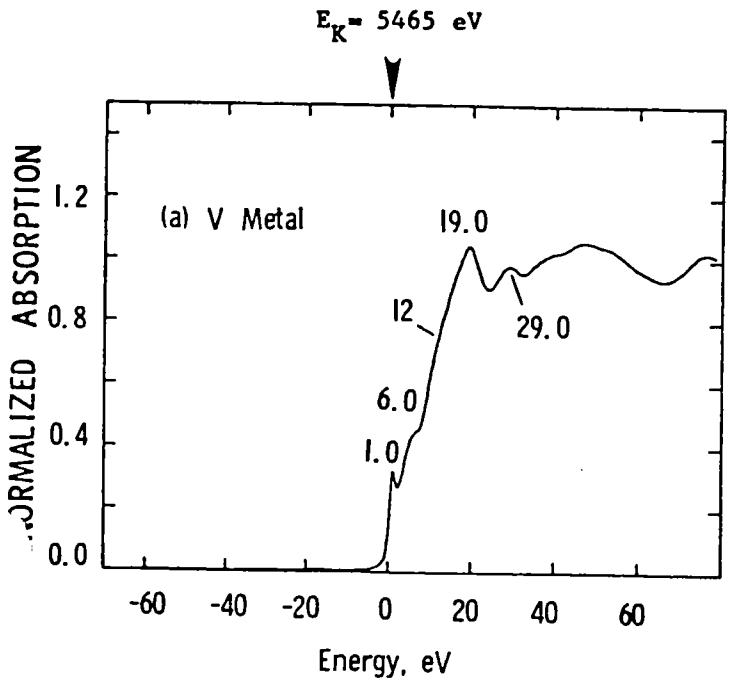
Ti

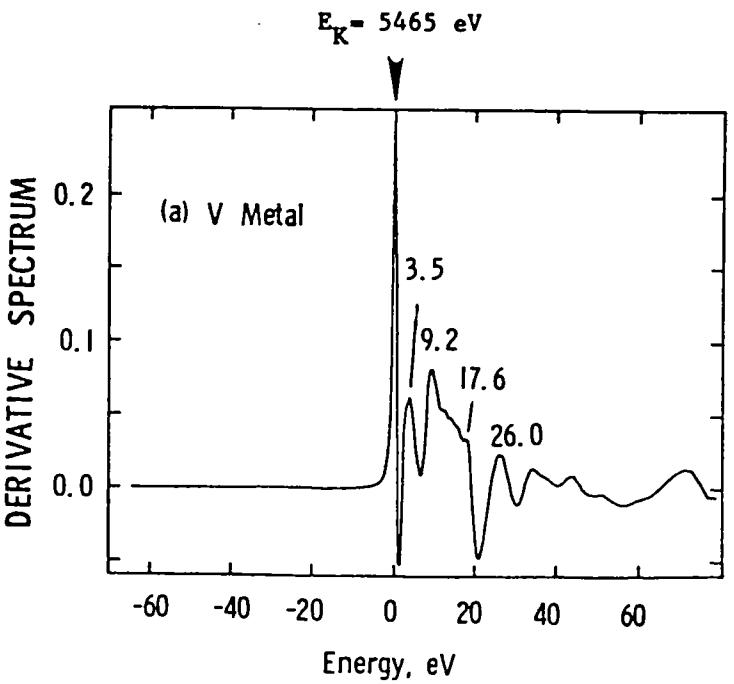

E_K = 4966 eV
ABSORPTION , (ln I_0/I)
1.6
1.2
0.8
0.4
0.0
-200
0
200
400
600
E - E_K, eV

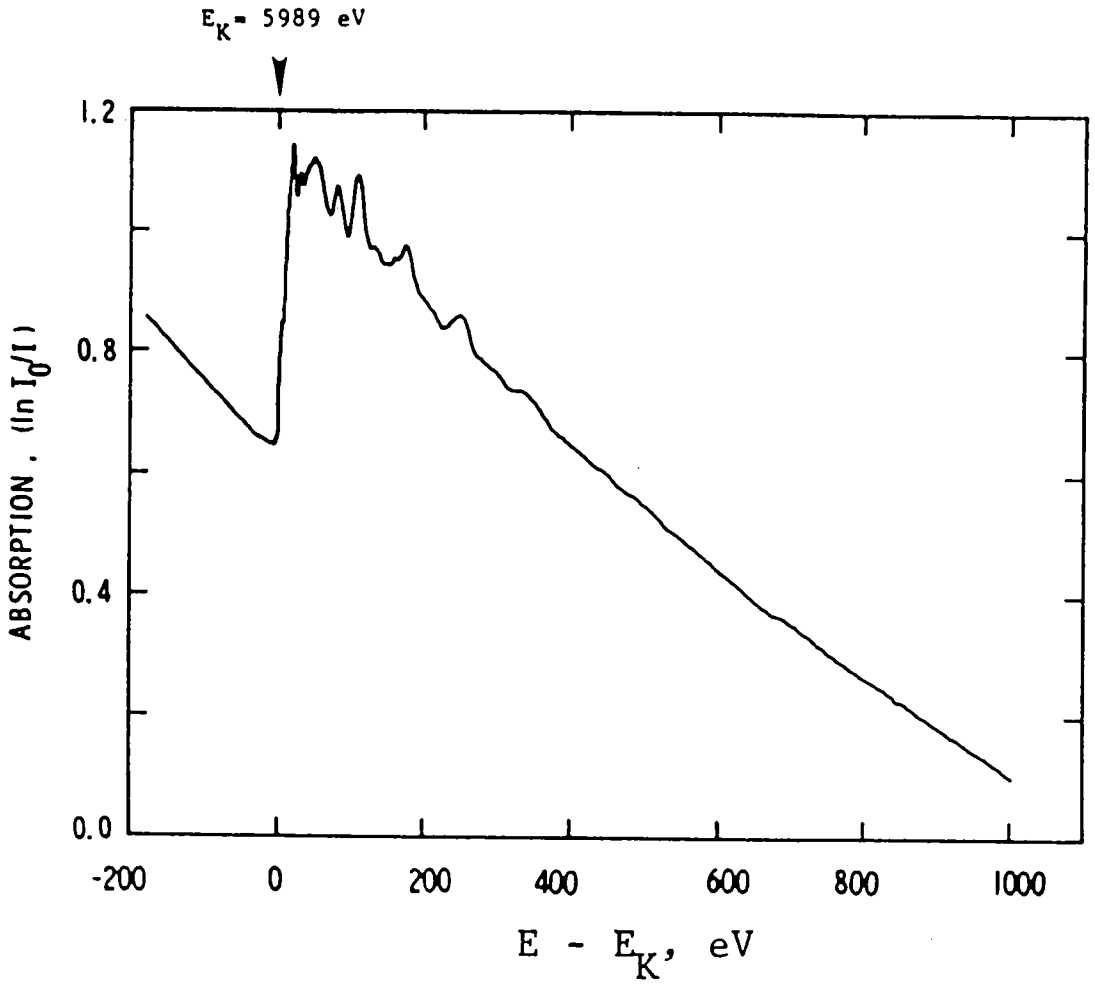

E_K = 4966 eV
NORMALIZED ABSORPTION
1.0
0.8
0.6
0.4
0.2
0.0
17.6
9.6
0.8
5.9
-60
-40
-20
0
20
40
60
Energy, eV

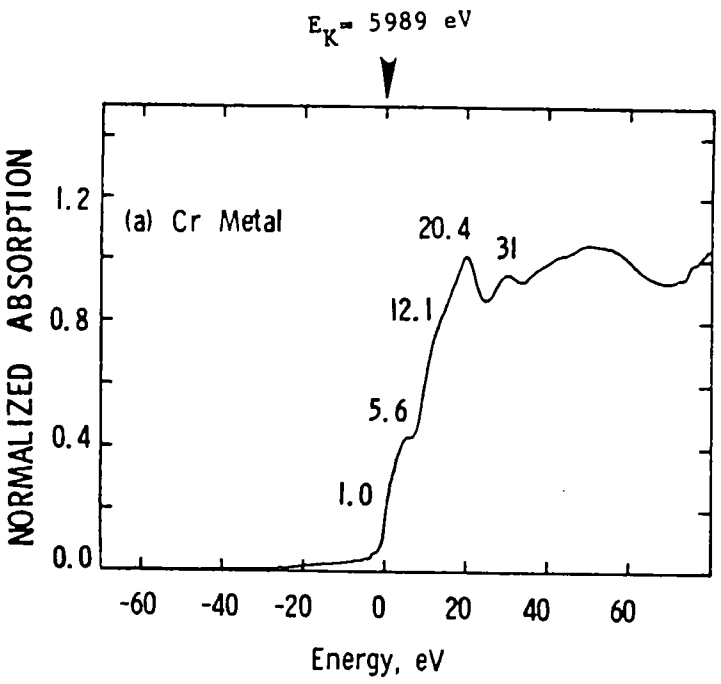

E_K = 4966 eV
DERIVATIVE SPECTRUM
0.2
0.1
0.0
-0.1
0.0
3.4
7.6
11.4
-60
-40
-20
0
20
40
60
Energy, eV

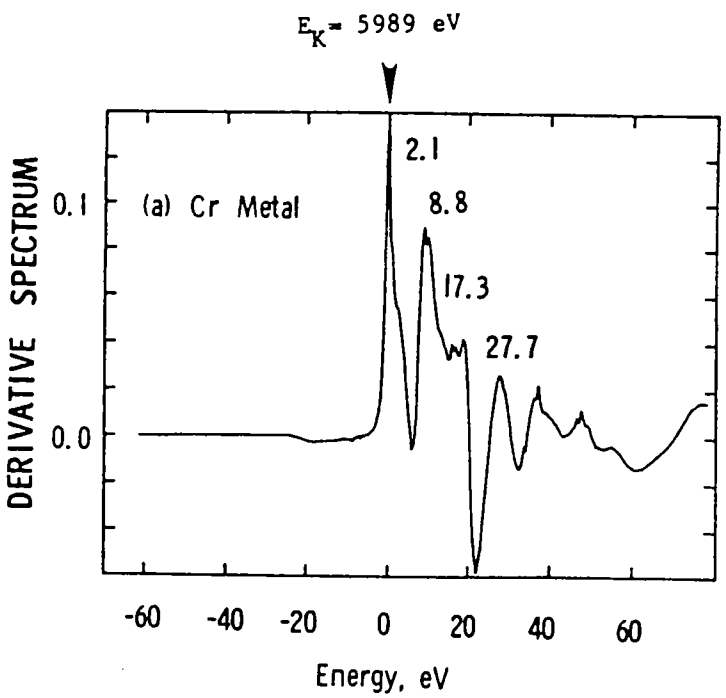

E_K = 5465 eV
ABSORPTION , (ln I_0/I)
2.0
1.0
0.0
0
200
400
600
800
1000
E - E_K, eV

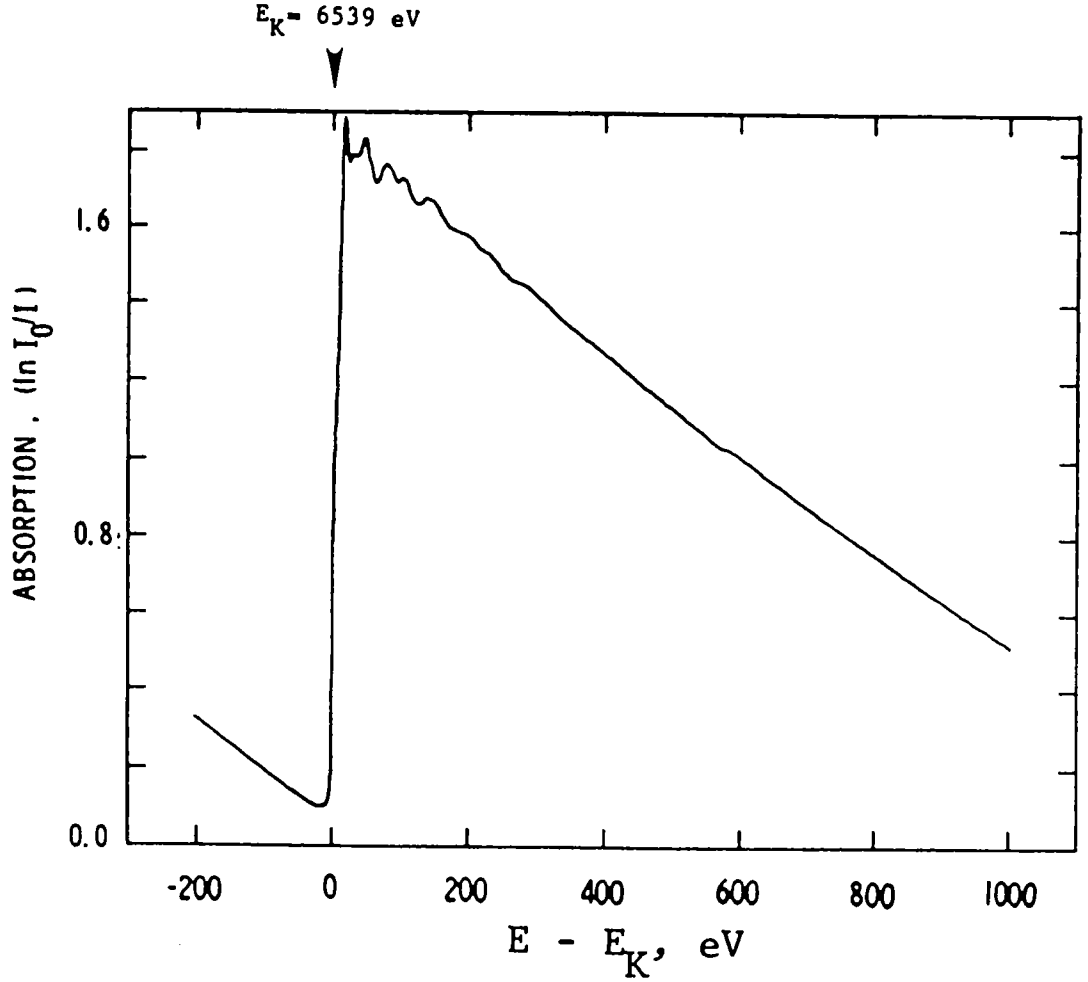

E_K = 5465 eV
NORMALIZED ABSORPTION
1.2
0.8
0.4
0.0
(a) V Metal
19.0
12
29.0
6.0
1.0
-60
-40
-20
0
20
40
60
Energy, eV

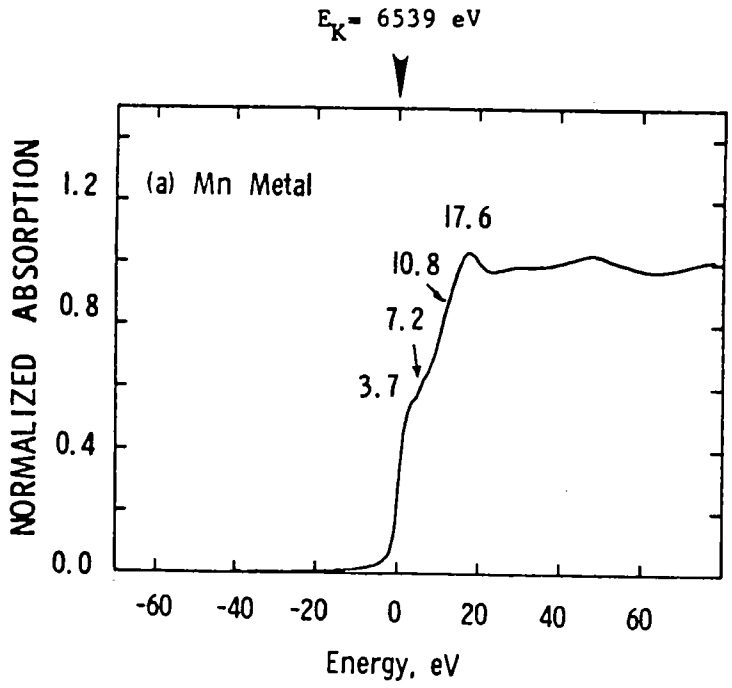

E_K = 5465 eV
DERIVATIVE SPECTRUM
0.2
0.1
0.0
(a) V Metal
3.5
9.2
17.6
26.0
-60
-40
-20
0
20
40
60
Energy, eV

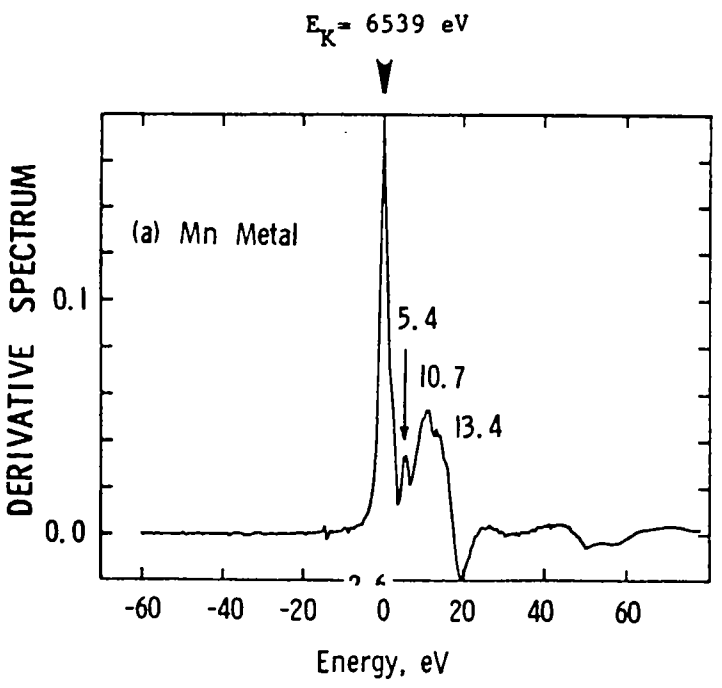

E_K = 5989 eV
1.2
0.8
0.4
0.0
ABSORPTION , (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_K, eV


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

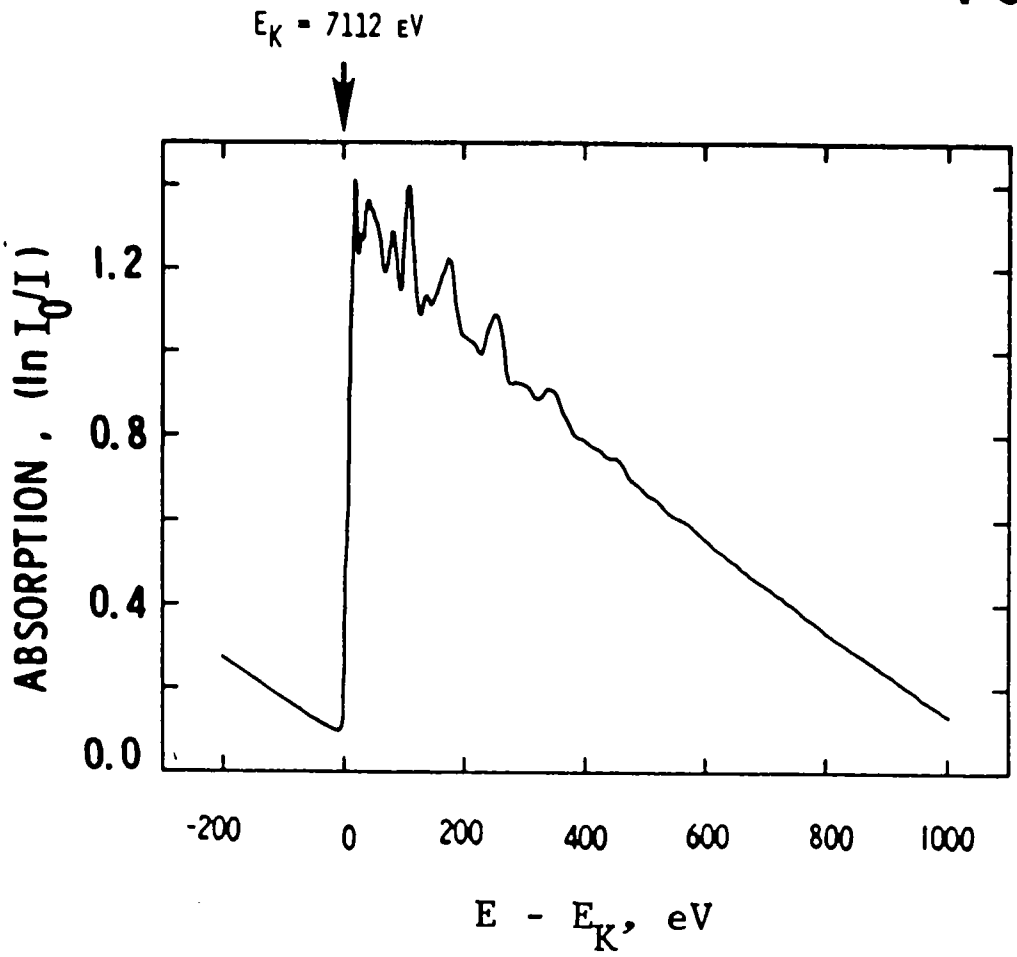

E_K = 5989 eV
DERIVATIVE SPECTRUM
(a) Cr Metal
2.1
8.8
17.3
27.7
0.1
0.0
-60
-40
-20
0
20
40
60
Energy, eV

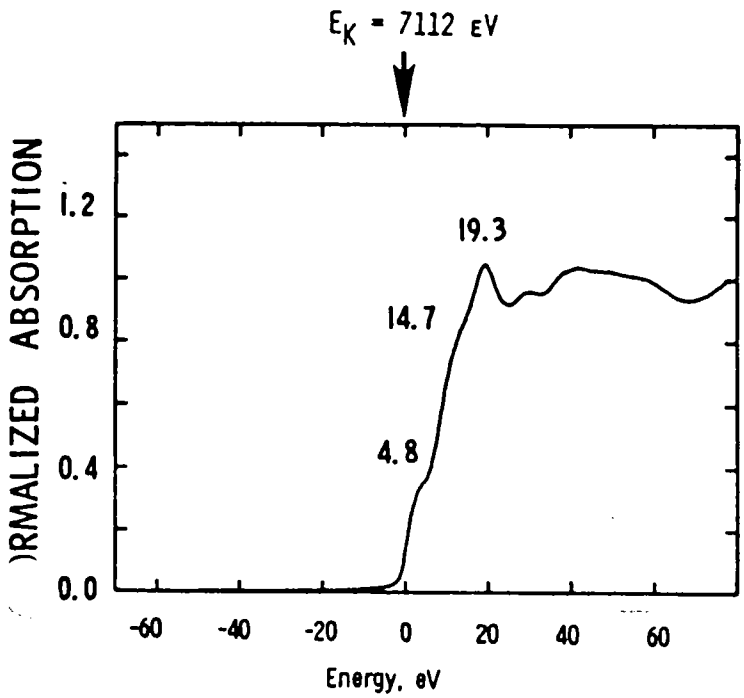

E_K= 6539 eV
ABSORPTION , (ln I_0/I)
1.6
0.8
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

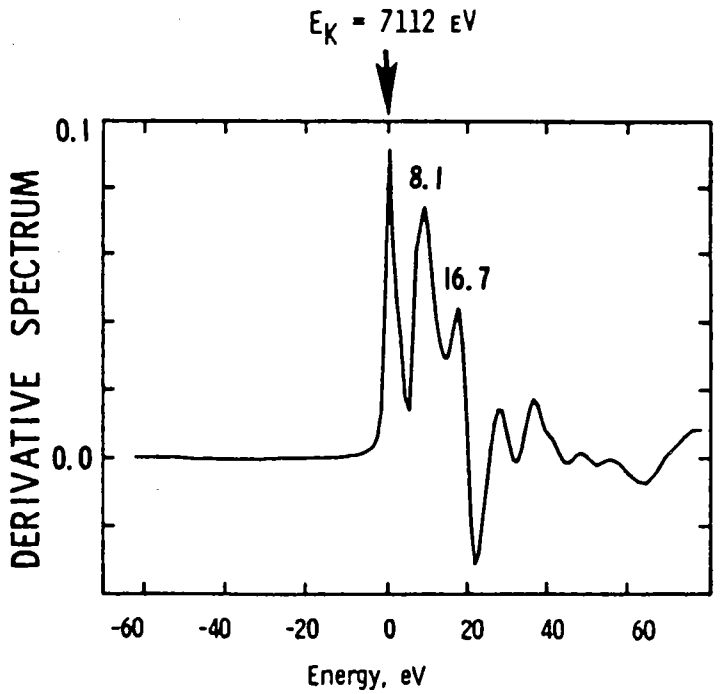

E_K= 6539 eV
NORMALIZED ABSORPTION
(a) Mn Metal
1.2
0.8
0.4
0.0
17.6
10.8
7.2
3.7
-60
-40
-20
0
20
40
60
Energy, eV

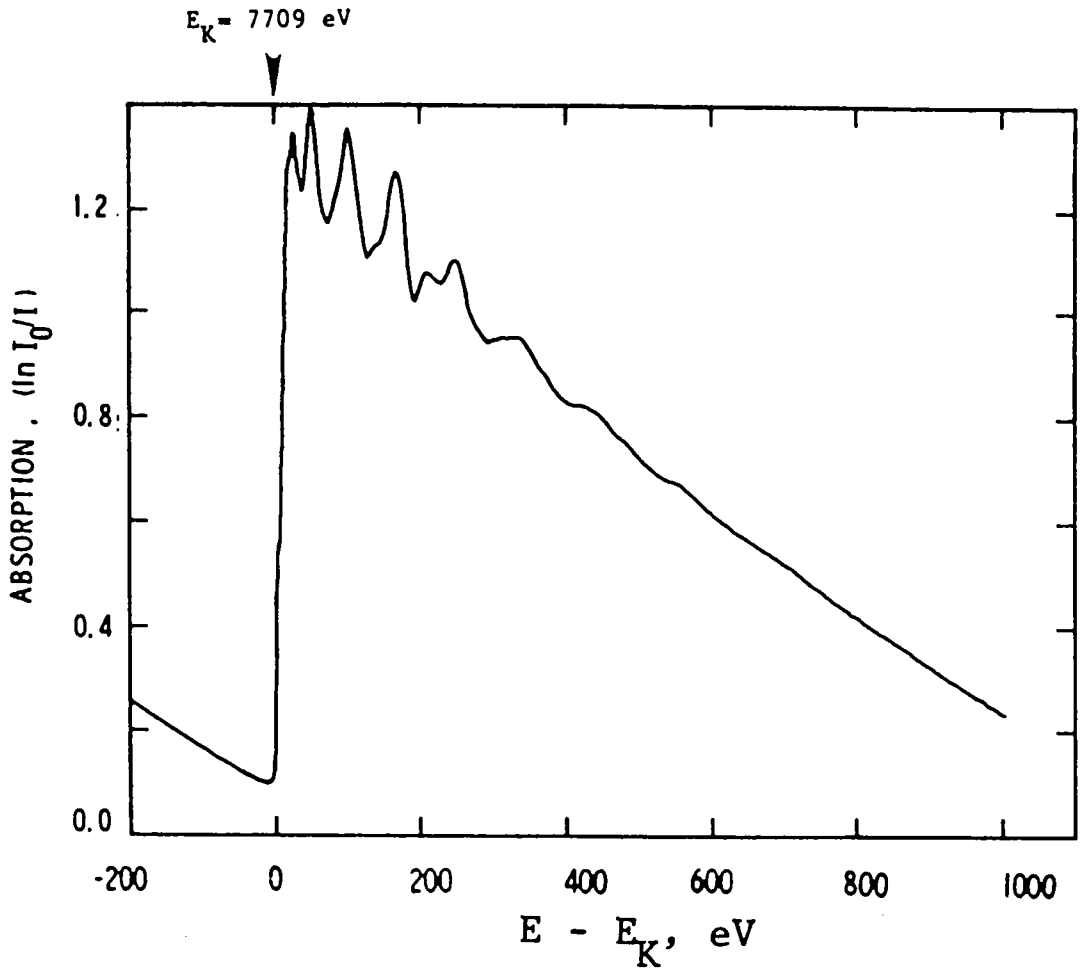

E_K= 6539 eV
DERIVATIVE SPECTRUM
(a) Mn Metal
0.1
0.0
5.4
10.7
13.4
-60
-40
-20
0
20
40
60
Energy, eV

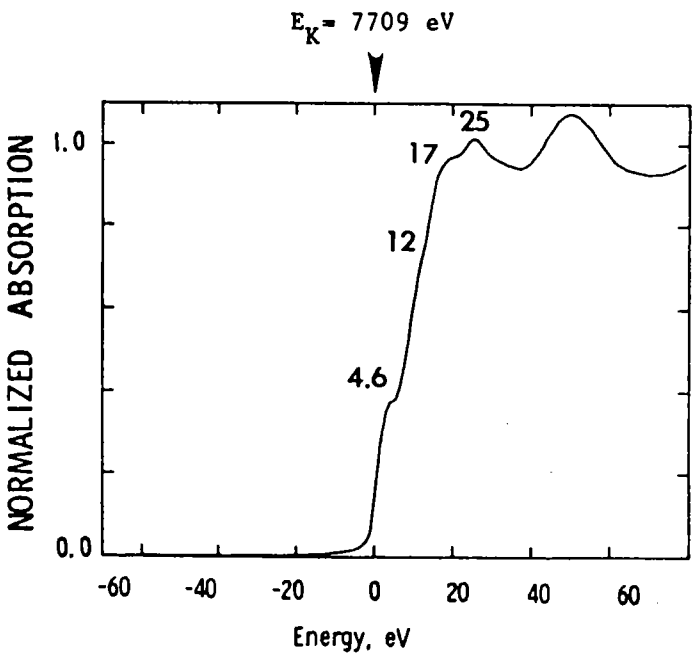
Fe

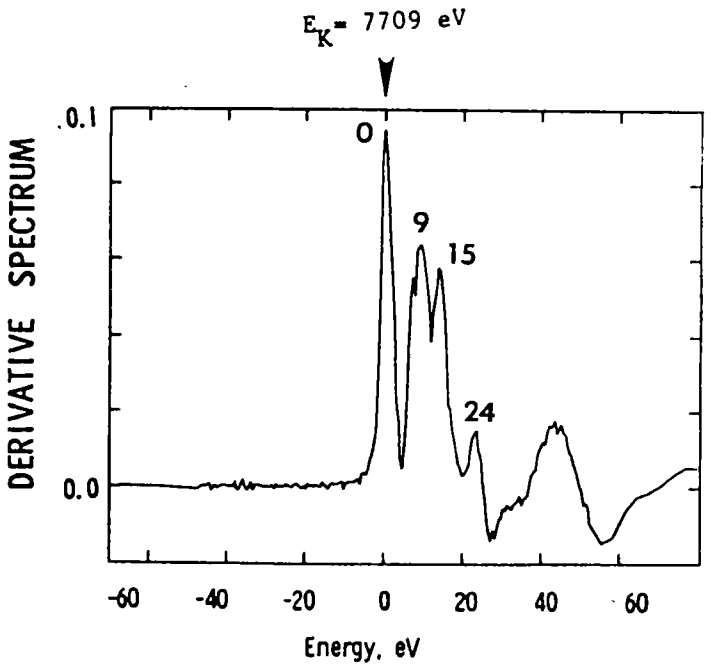

E_K = 7112 eV
ABSORPTION , (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

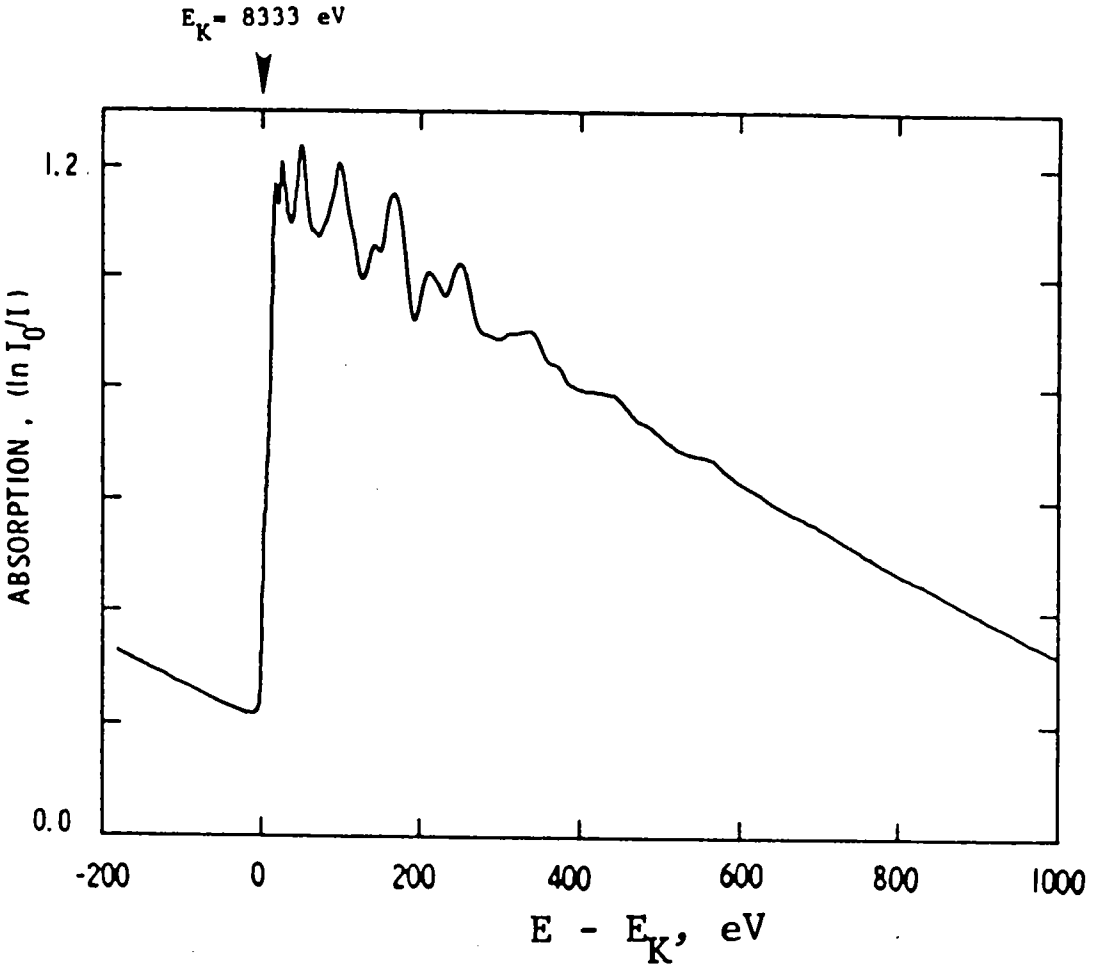

E_K = 7112 eV
)RMALIZED ABSORPTION
1.2
0.8
0.4
0.0
19.3
14.7
4.8
-60
-40
-20
0
20
40
60
Energy, eV

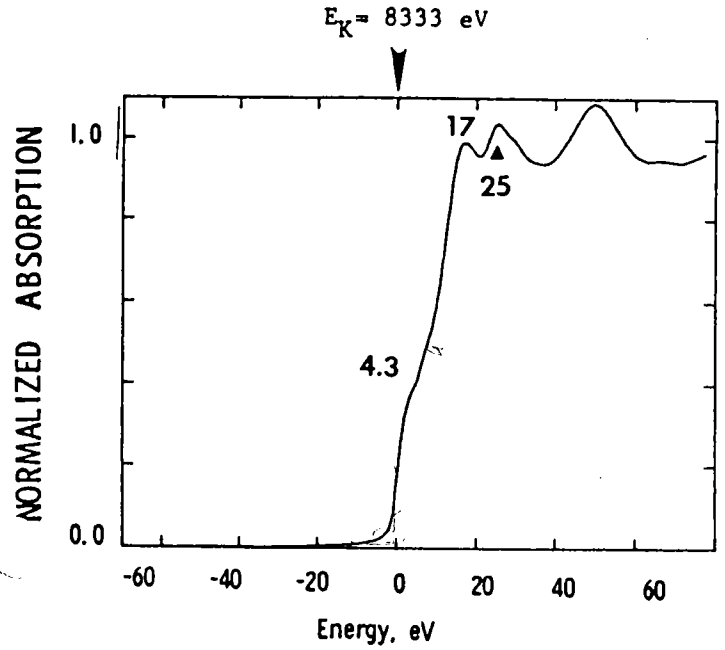

E_K = 7112 eV
DERIVATIVE SPECTRUM
0.1
0.0
8.1
16.7
-60
-40
-20
0
20
40
60
Energy, eV

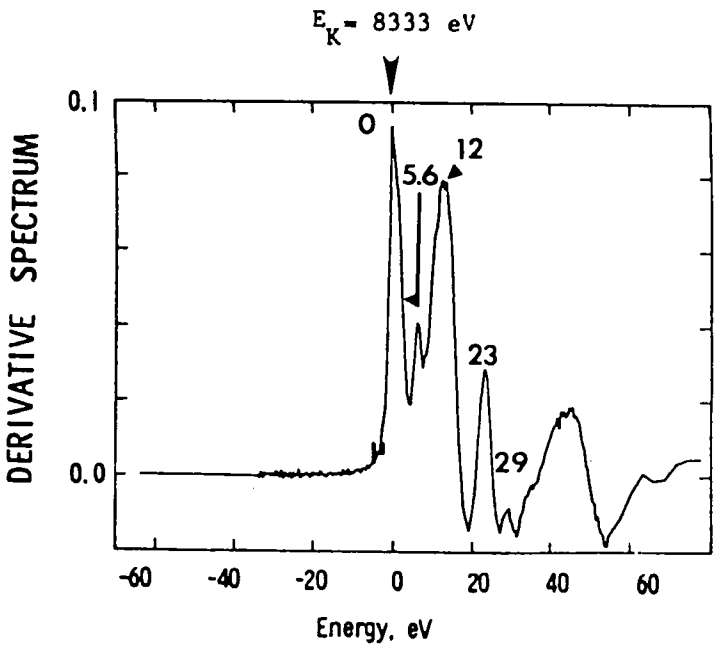

E_K = 7709 eV
ABSORPTION , (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

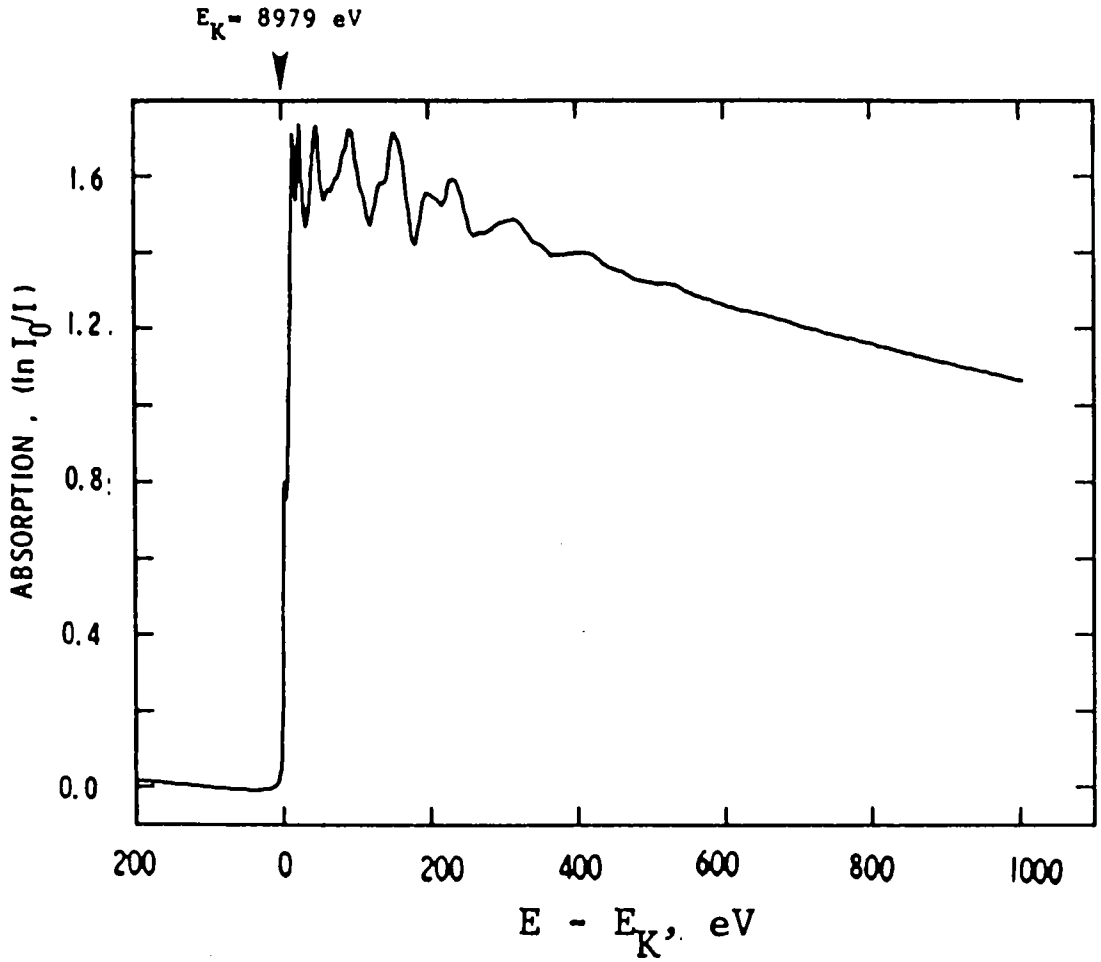

E_K = 7709 eV
NORMALIZED ABSORPTION
1.0
0.0
25
17
12
4.6
-60
-40
-20
0
20
40
60
Energy, eV

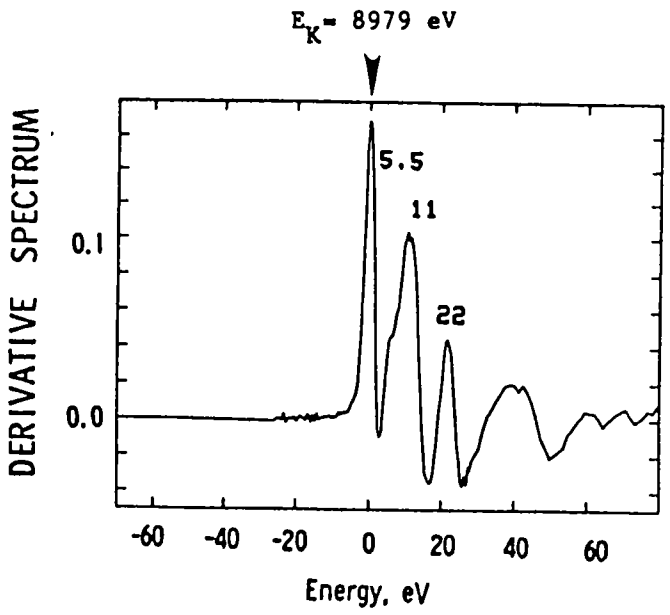

E_K = 7709 eV
DERIVATIVE SPECTRUM
0.1
0.0
0
9
15
24
-60
-40
-20
0
20
40
60
Energy, eV

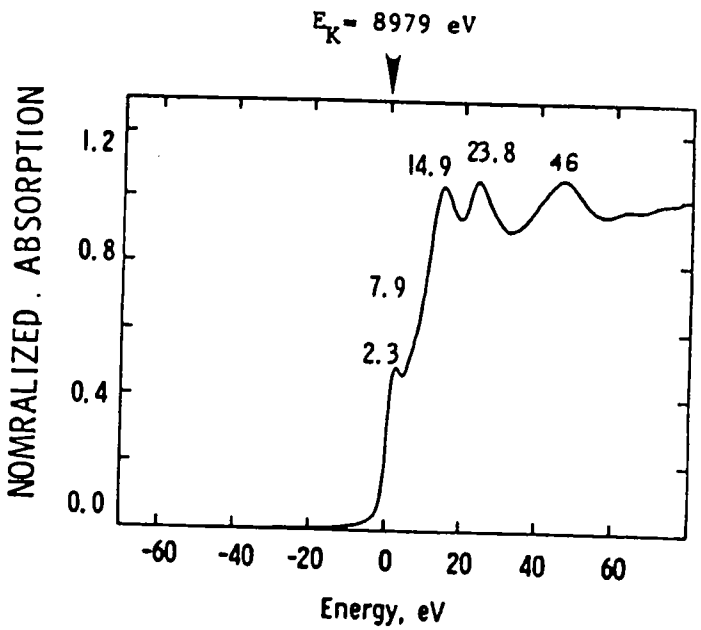

E_K = 8333 eV
1.2
0.0
ABSORPTION , (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_K, eV

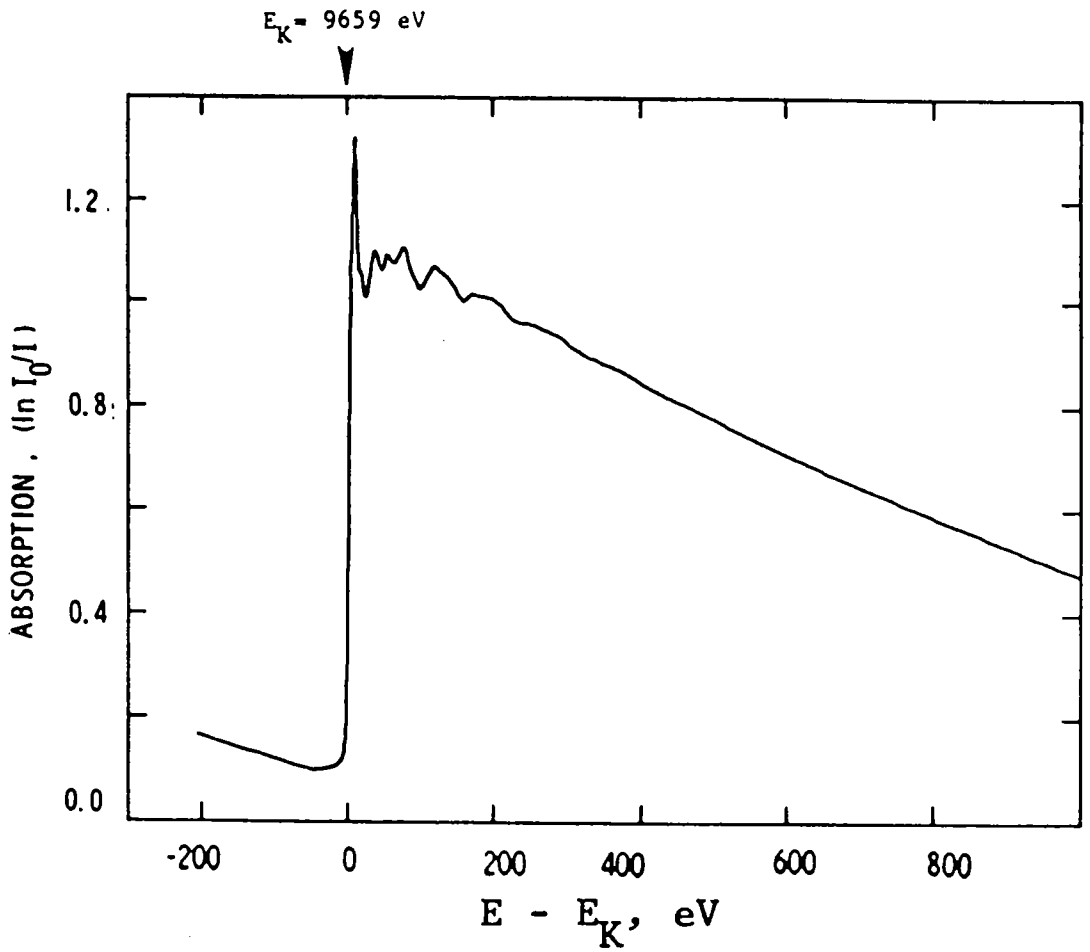

E_K = 8333 eV
1.0
0.0
NORMALIZED ABSORPTION
17
25
4.3
-60
-40
-20
0
20
40
60
Energy, eV

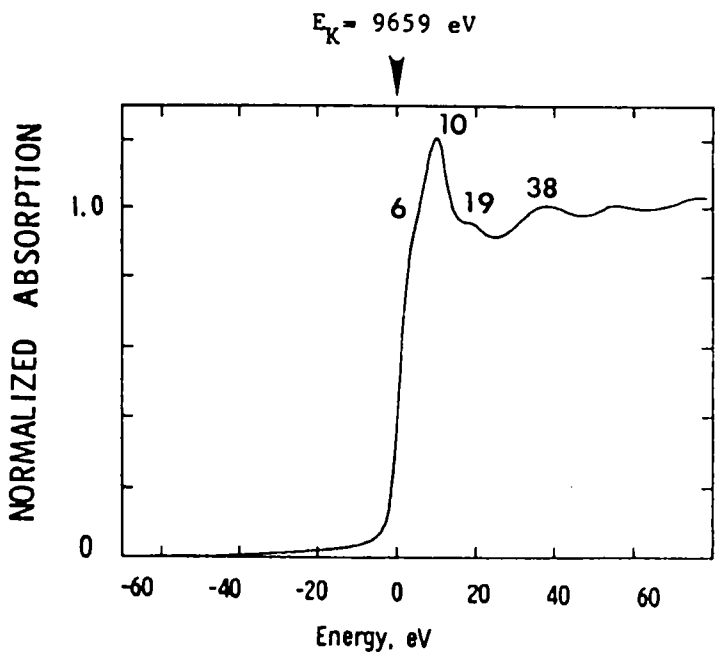

E_K = 8333 eV
0.1
0.0
DERIVATIVE SPECTRUM
0
5.6
12
23
29
-60
-40
-20
0
20
40
60
Energy, eV

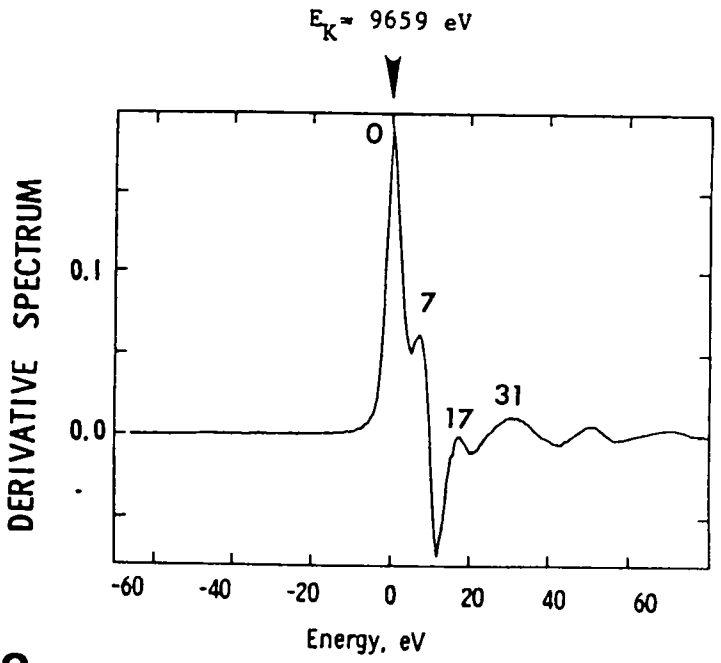

E_K = 8979 eV
ABSORPTION . (ln I_0/I)
1.6
1.2
0.8
0.4
0.0
200
0
200
400
600
800
1000
E - E_K, eV


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

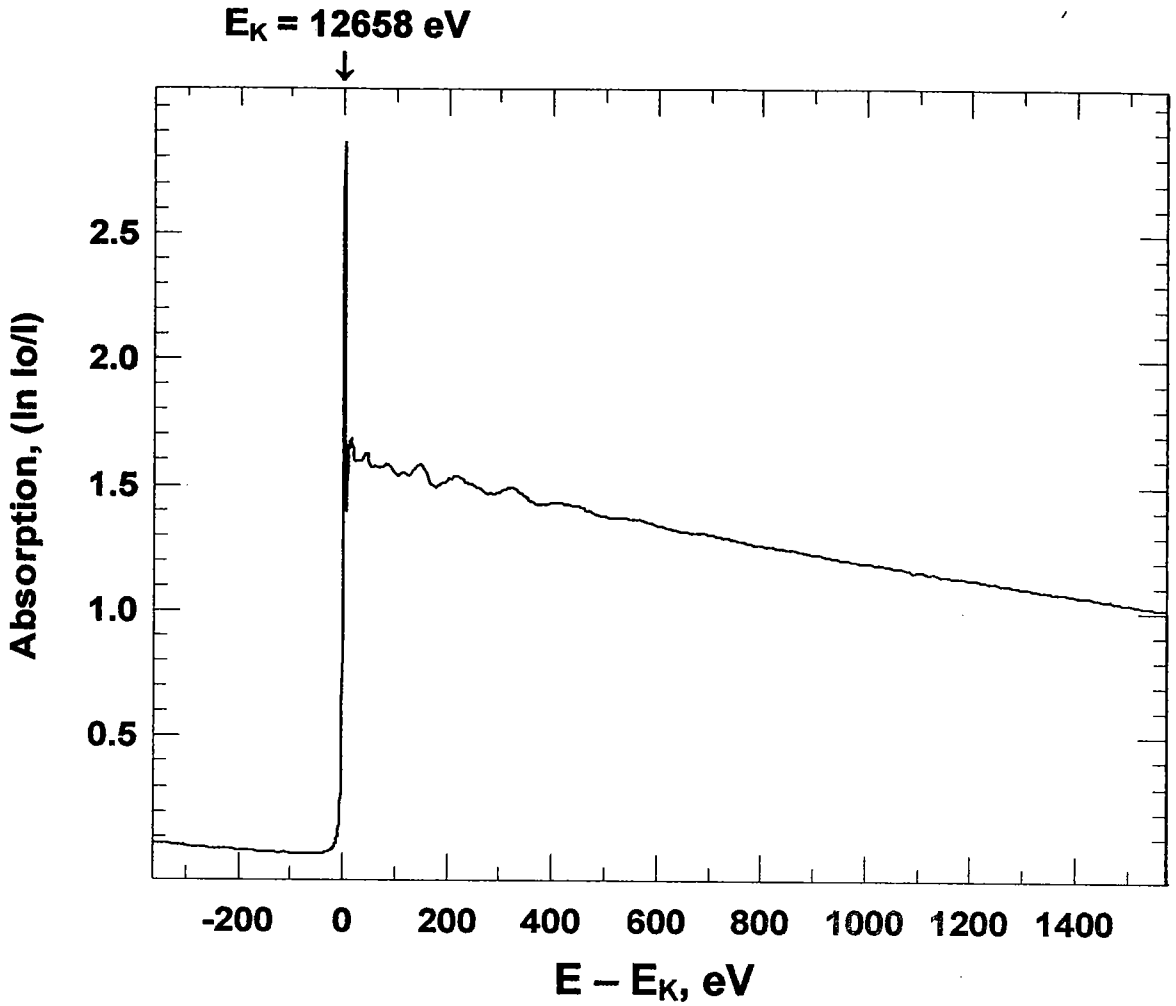

E_K = 8979 eV
NOMRALIZED . ABSORPTION
1.2
0.8
0.4
0.0
14.9
23.8
46
7.9
2.3
-60
-40
-20
0
20
40
60
Energy, eV

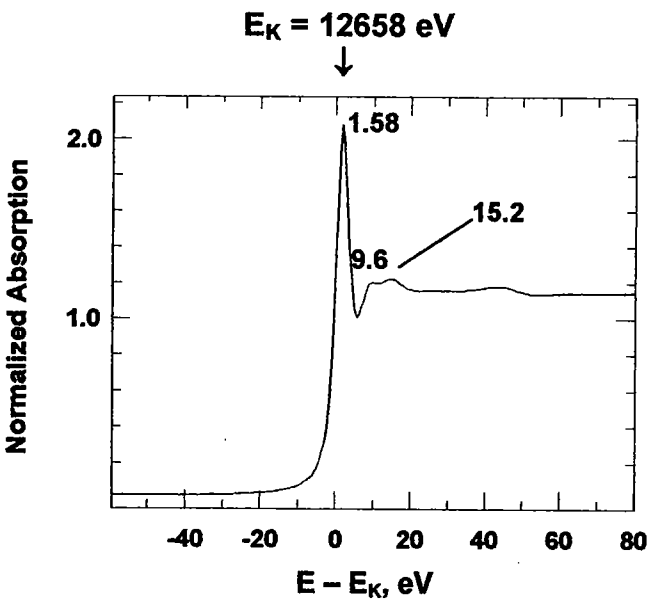

E_K = 9659 eV
1.2
0.8
0.4
0.0
ABSORPTION , (ln I_0/I)
-200
0
200
400
600
800
E - E_K, eV

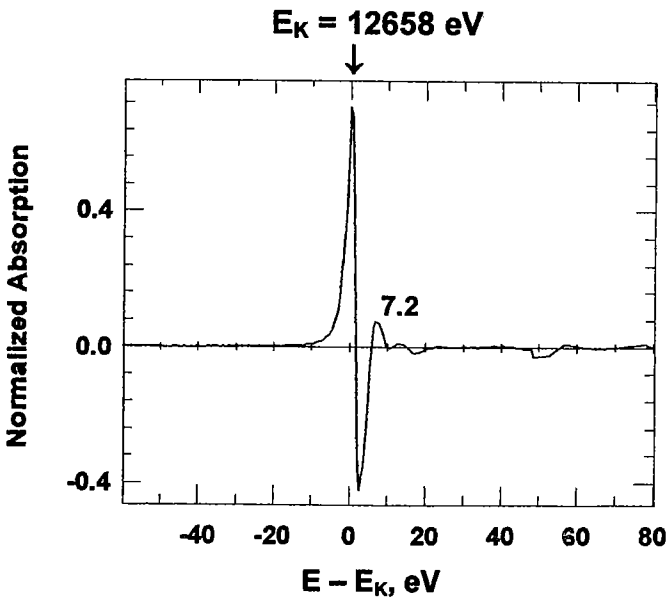

E_K = 9659 eV
NORMALIZED ABSORPTION
1.0
0
10
6
19
38
-60
-40
-20
0
20
40
60
Energy, eV


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

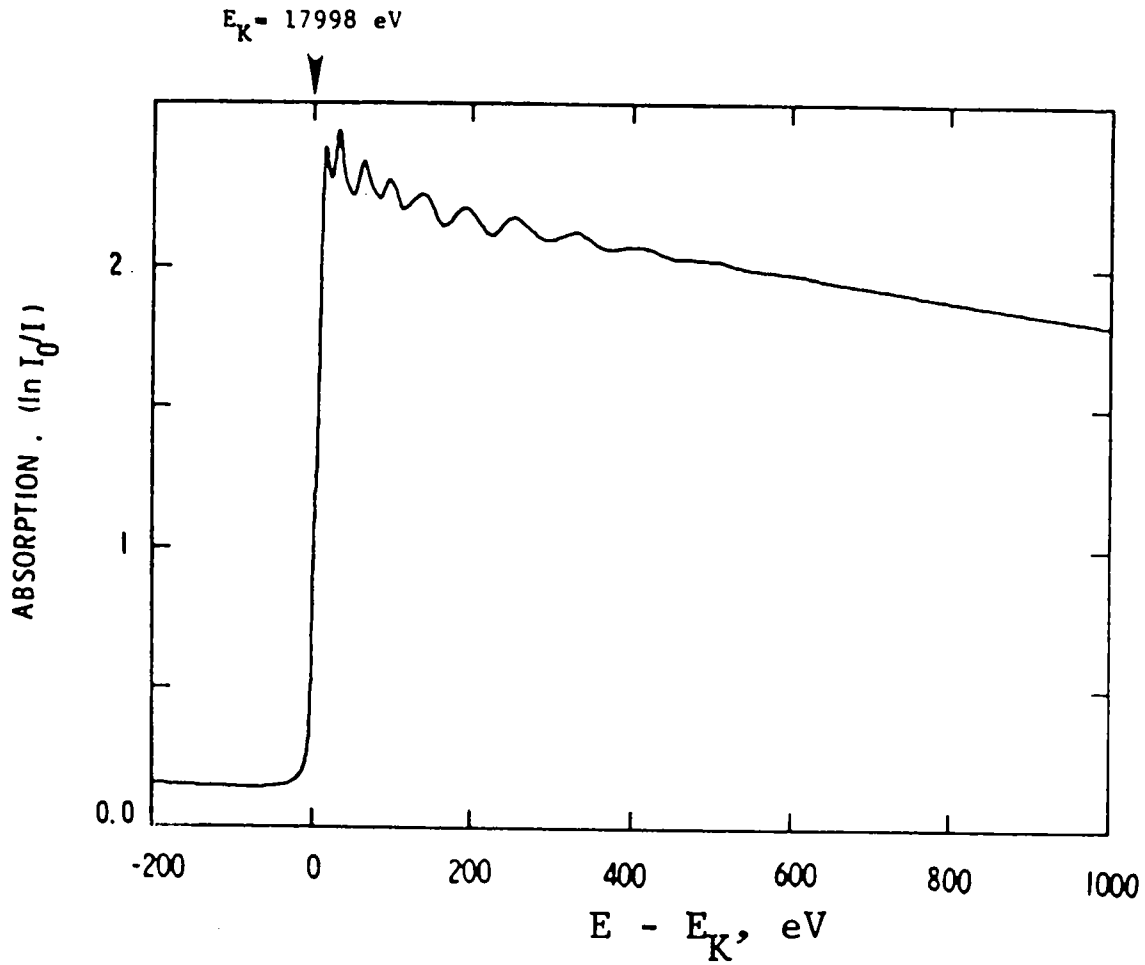
Se

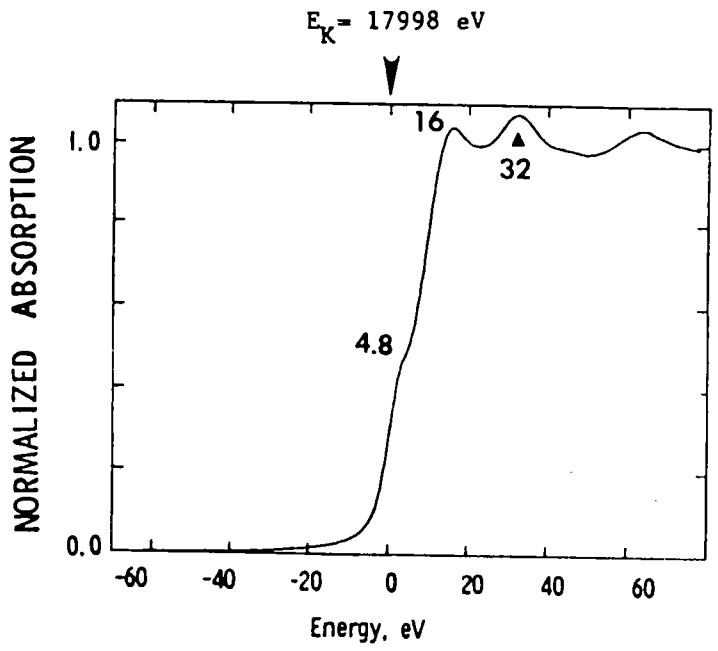

E_K = 12658 eV
Absorption, (ln Io/I)
2.5
2.0
1.5
1.0
0.5
-200
0
200
400
600
800
1000
1200
1400
E – E_K, eV

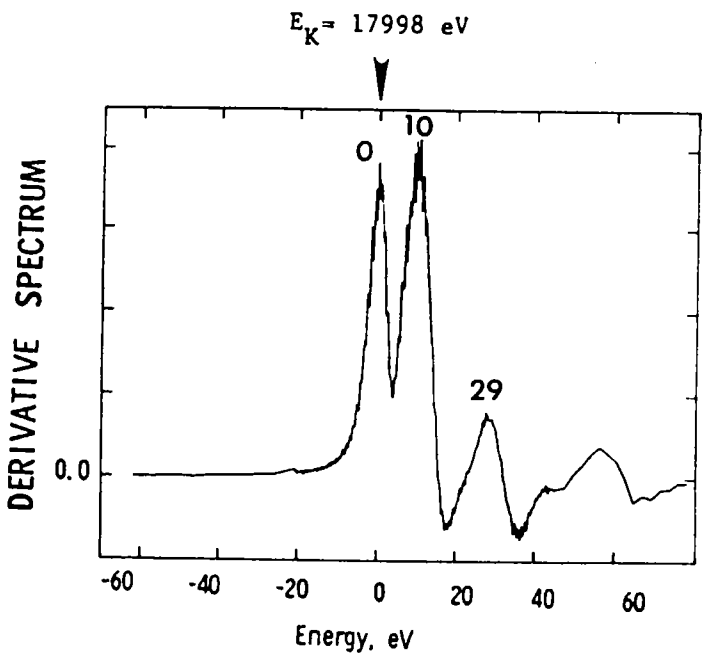

E_K = 12658 eV
Normalized Absorption
2.0
1.0
1.58
15.2
9.6
-40
-20
0
20
40
60
80
E – E_K, eV

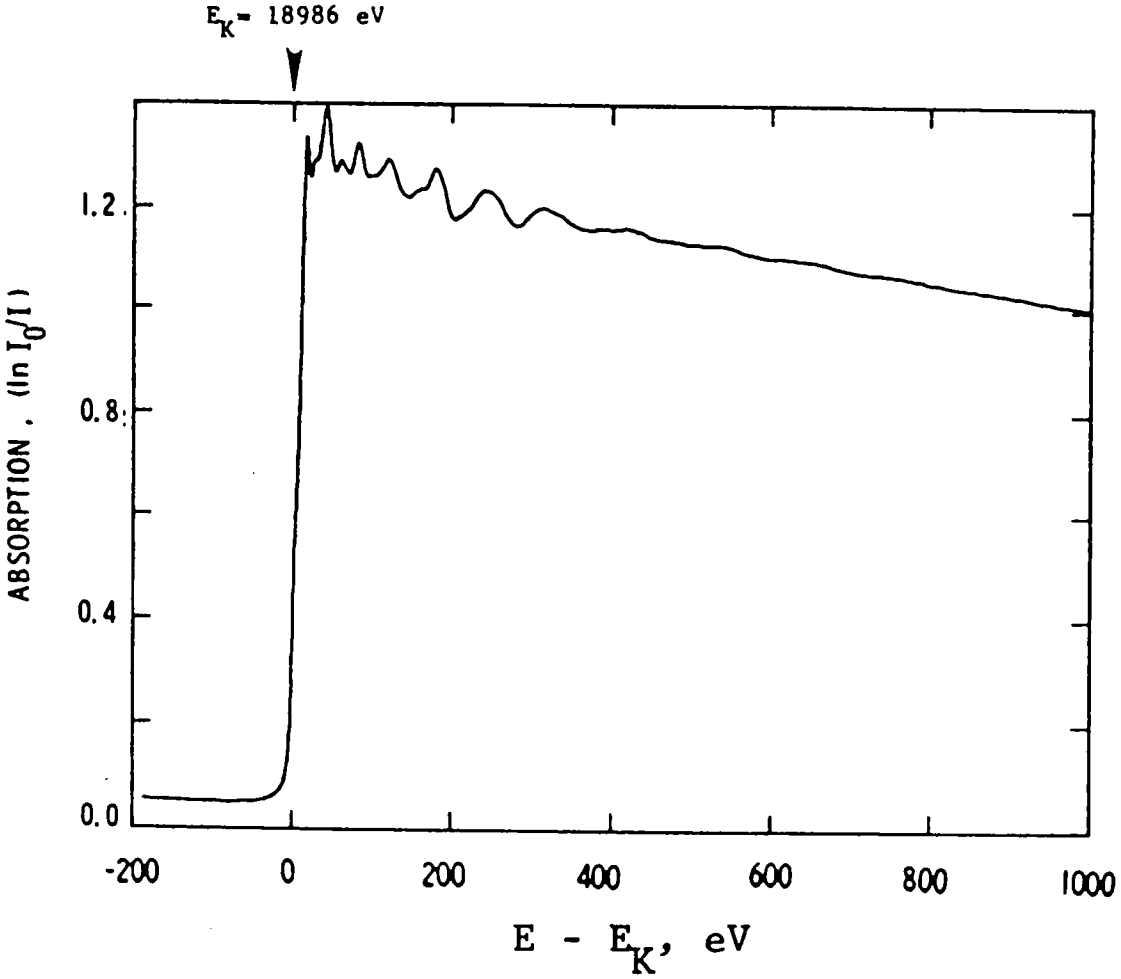

E_K = 12658 eV
Normalized Absorption
0.4
0.0
-0.4
7.2
-40
-20
0
20
40
60
80
E – E_K, eV

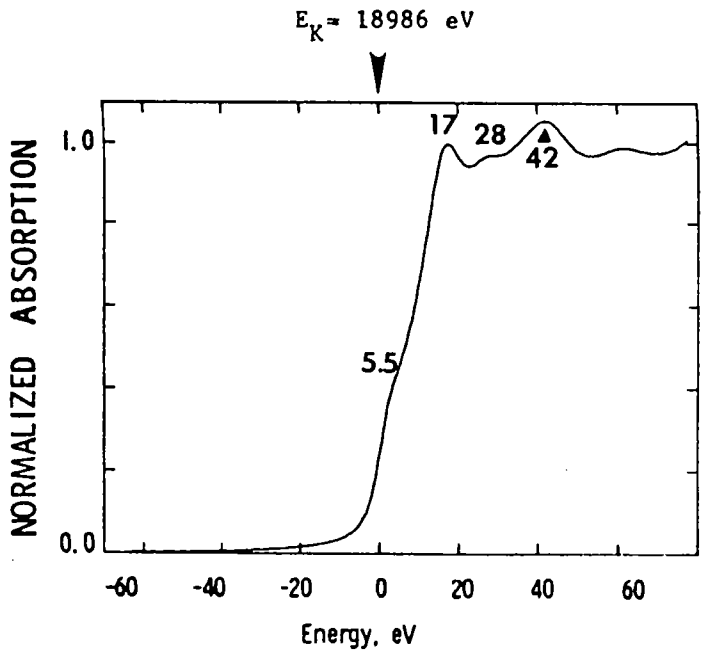
Zr

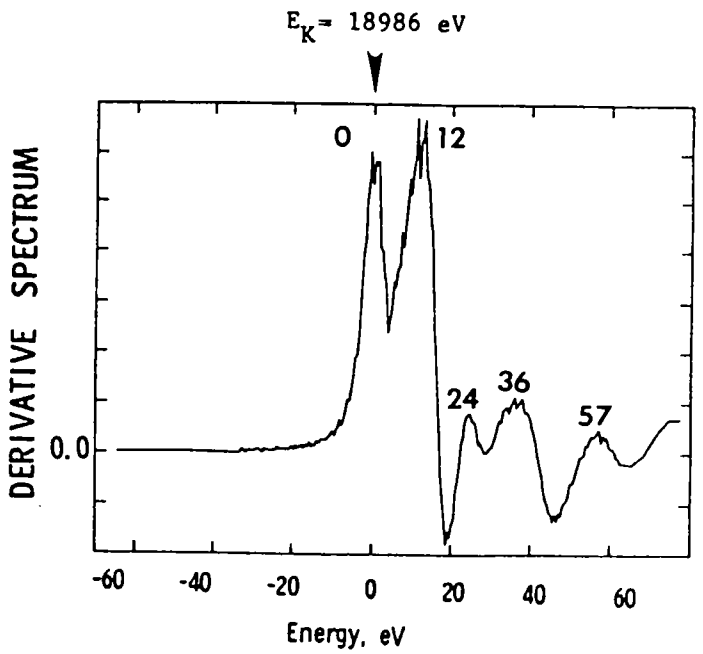

E_K = 17998 eV
ABSORPTION . (ln I_0/I)
2
1
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

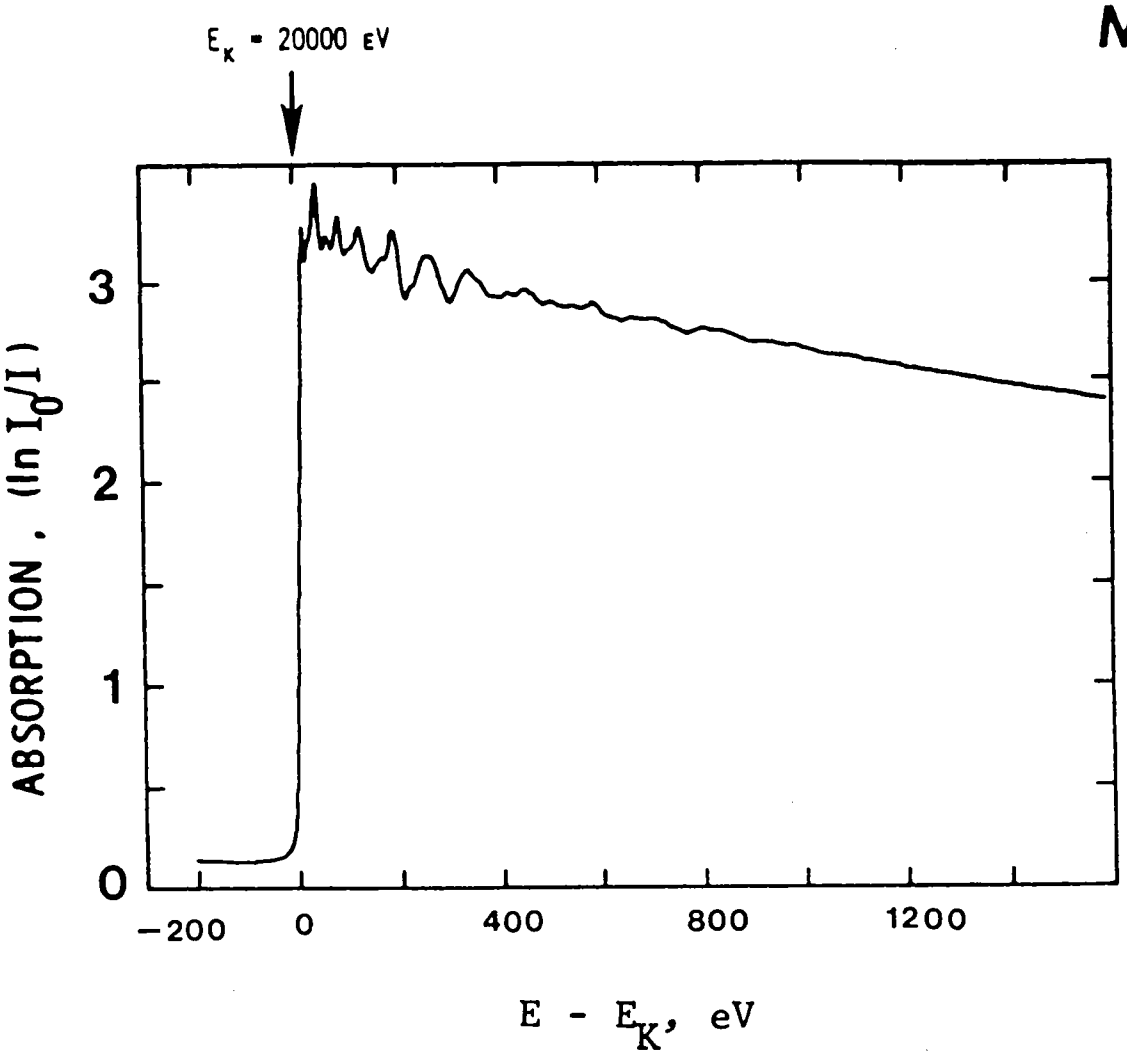

E_K = 17998 eV
NORMALIZED ABSORPTION
1.0
0.0
16
32
4.8
-60
-40
-20
0
20
40
60
Energy, eV

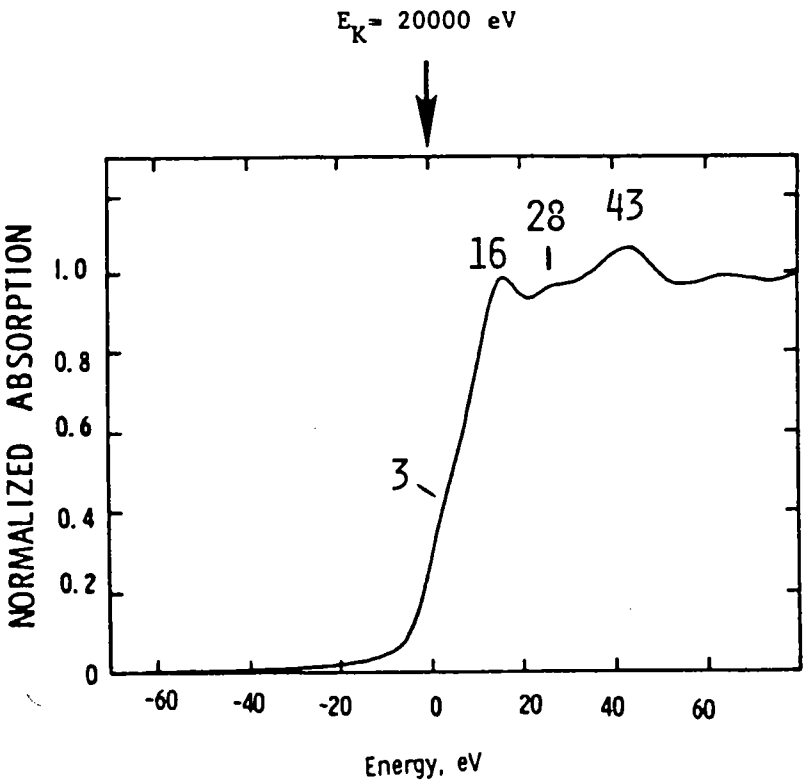

E_K = 17998 eV
DERIVATIVE SPECTRUM
0.0
0
10
29
-60
-40
-20
0
20
40
60
Energy, eV

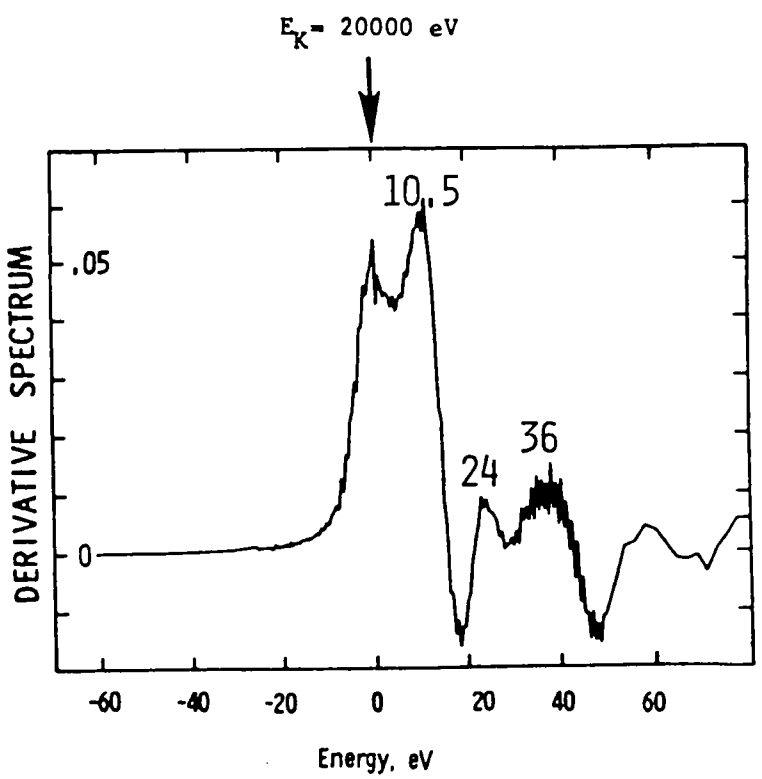

E_K = 18986 eV
ABSORPTION . (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
1000
E - E_K, eV

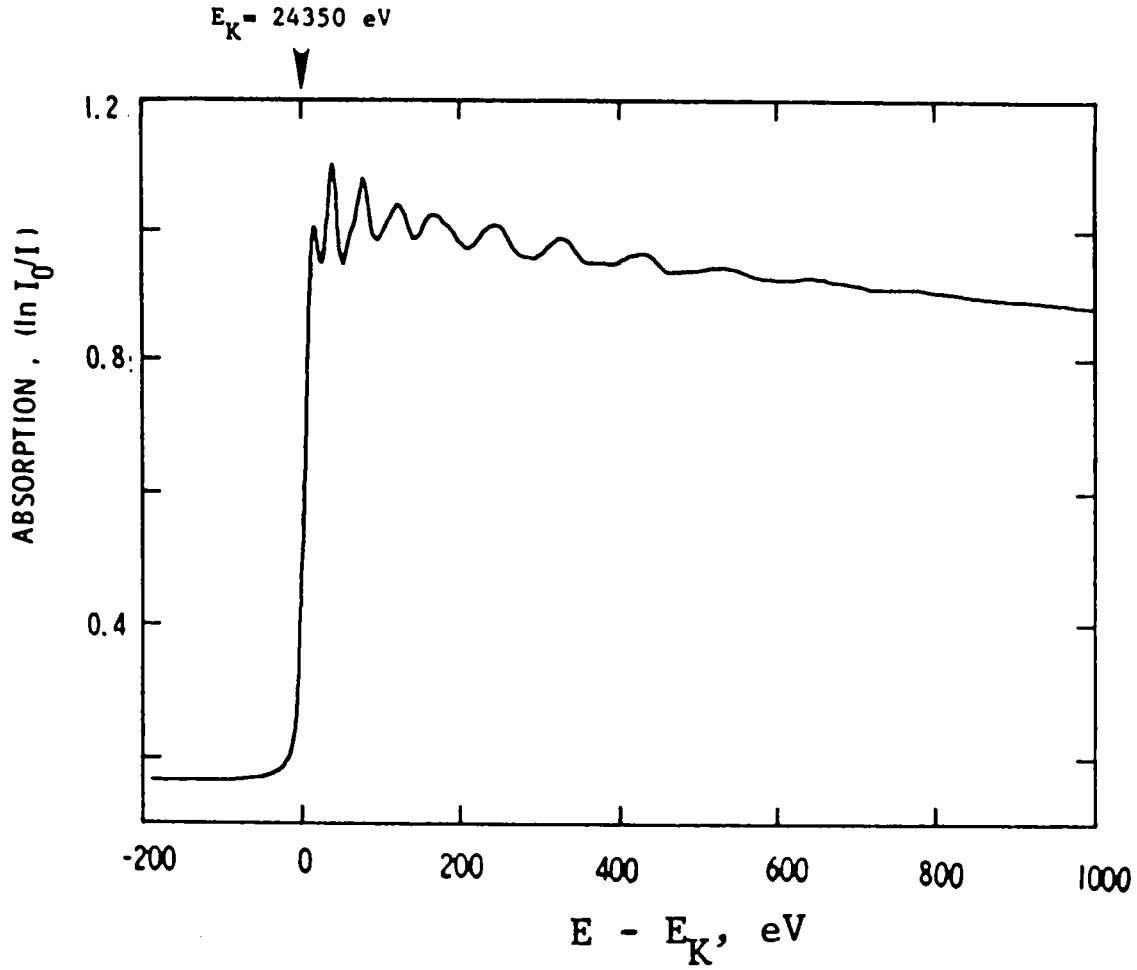

E_K = 18986 eV
NORMALIZED ABSORPTION
1.0
0.0
17
28
42
5.5
-60
-40
-20
0
20
40
60
Energy, eV

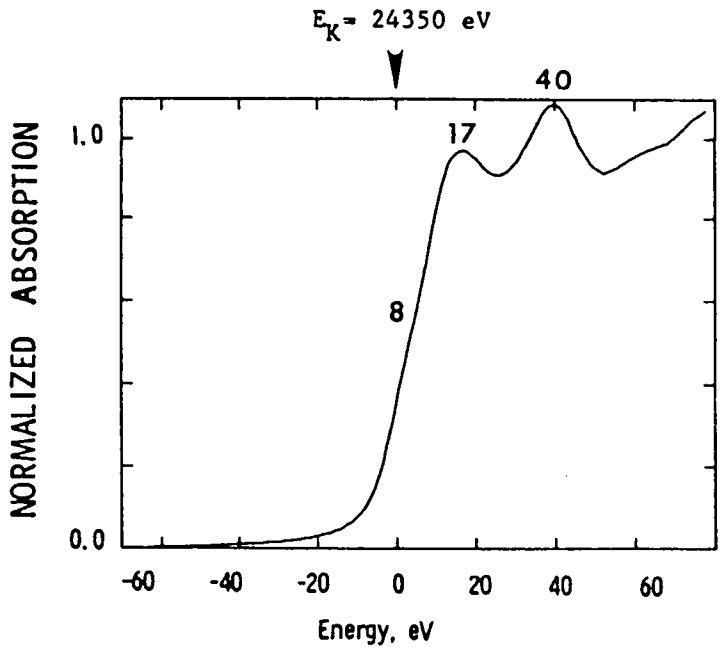

E_K = 18986 eV
DERIVATIVE SPECTRUM
0.0
0
12
24
36
57
-60
-40
-20
0
20
40
60
Energy, eV

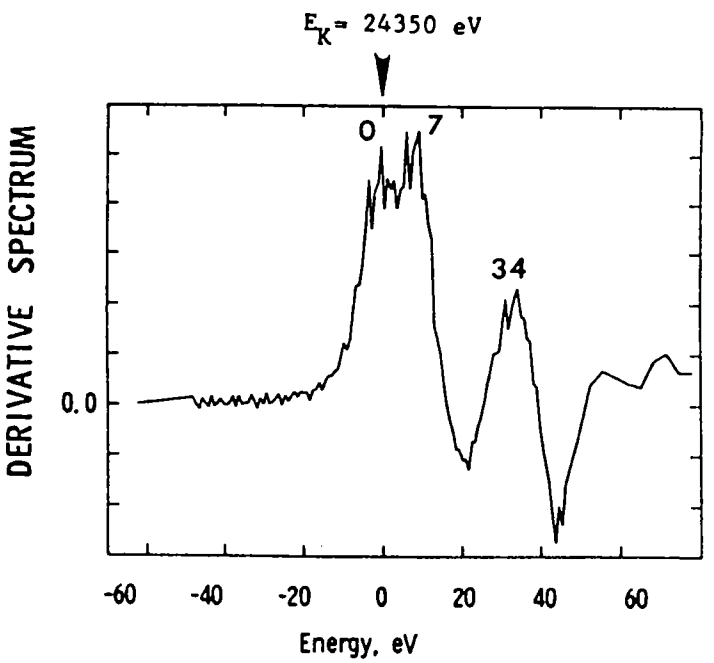

E_K = 20000 eV
ABSORPTION . (ln I_0/I)
0
1
2
3
−200
0
400
800
1200
E - E_K, eV

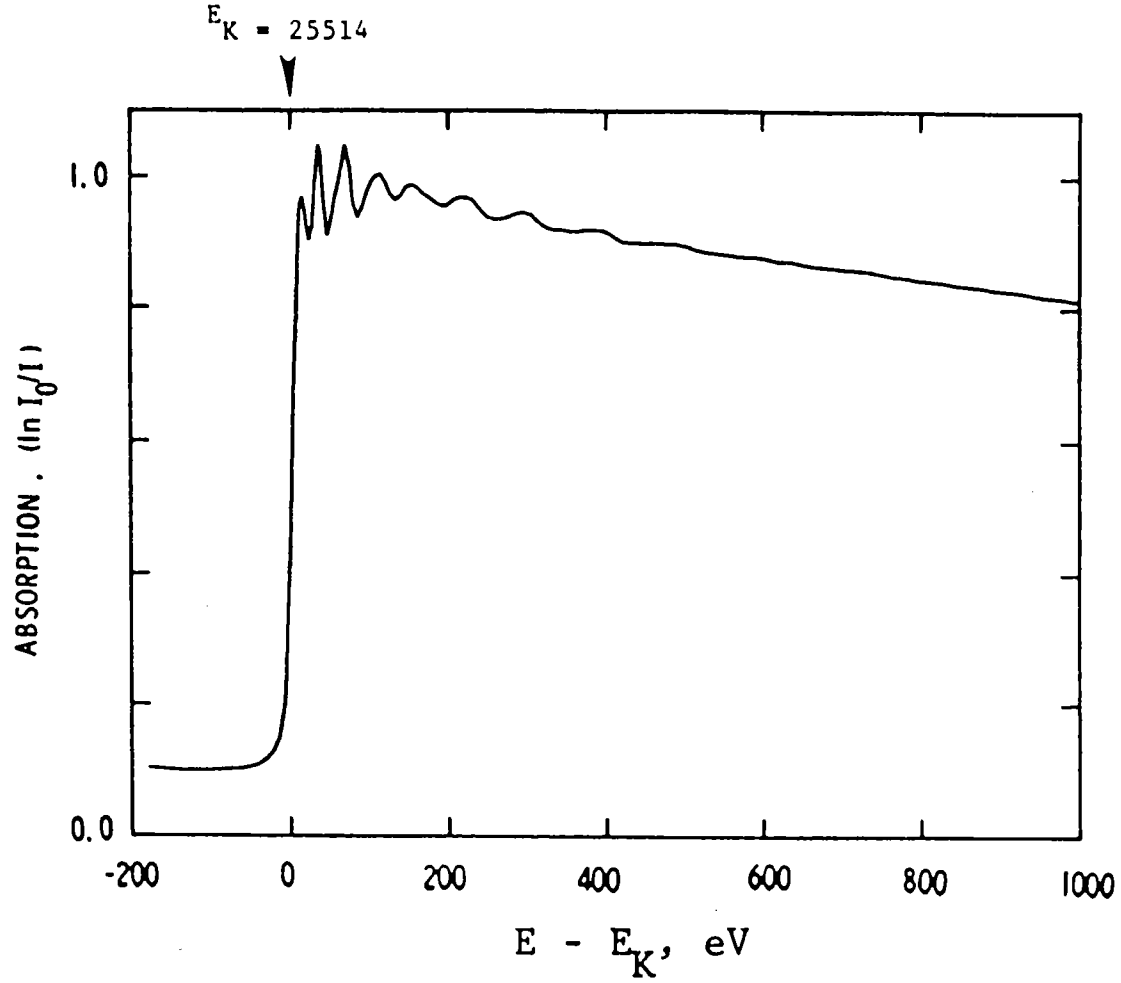

E_K= 20000 eV
NORMALIZED ABSORPTION
0
0.2
0.4
0.6
0.8
1.0
3
16
28
43
-60
-40
-20
0
20
40
60
Energy, eV

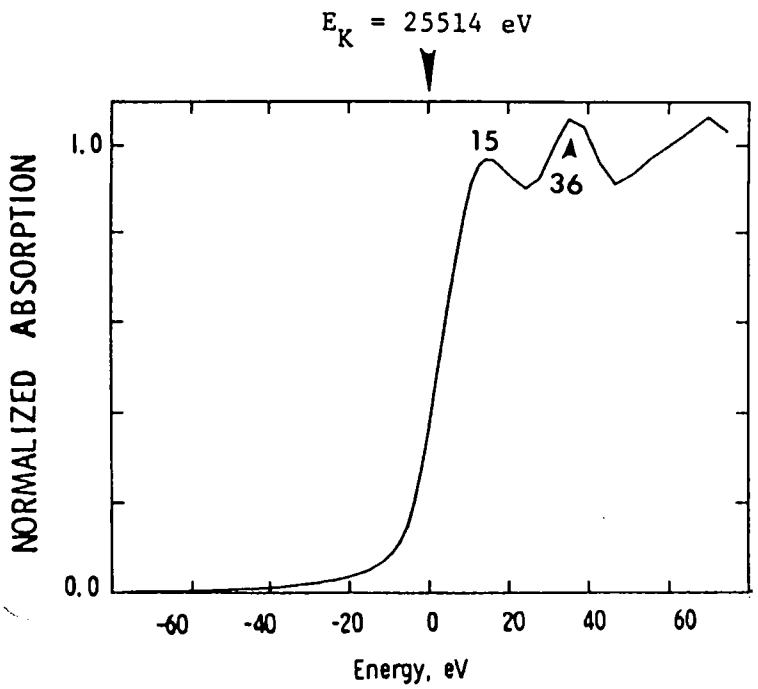

E_K= 20000 eV
DERIVATIVE SPECTRUM
.05
0
10.5
24
36
-60
-40
-20
0
20
40
60
Energy, eV

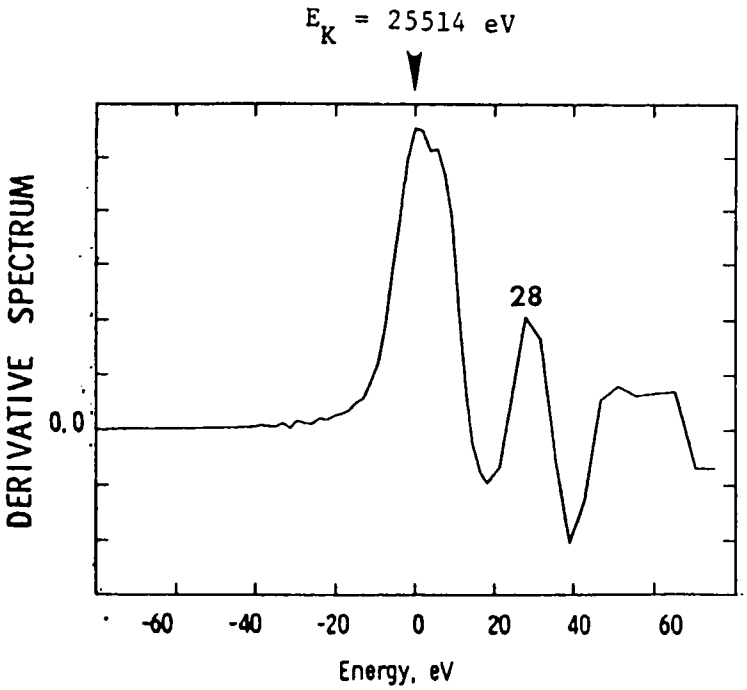

E_K = 24350 eV
1.2
0.8
0.4
ABSORPTION , (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_K, eV


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

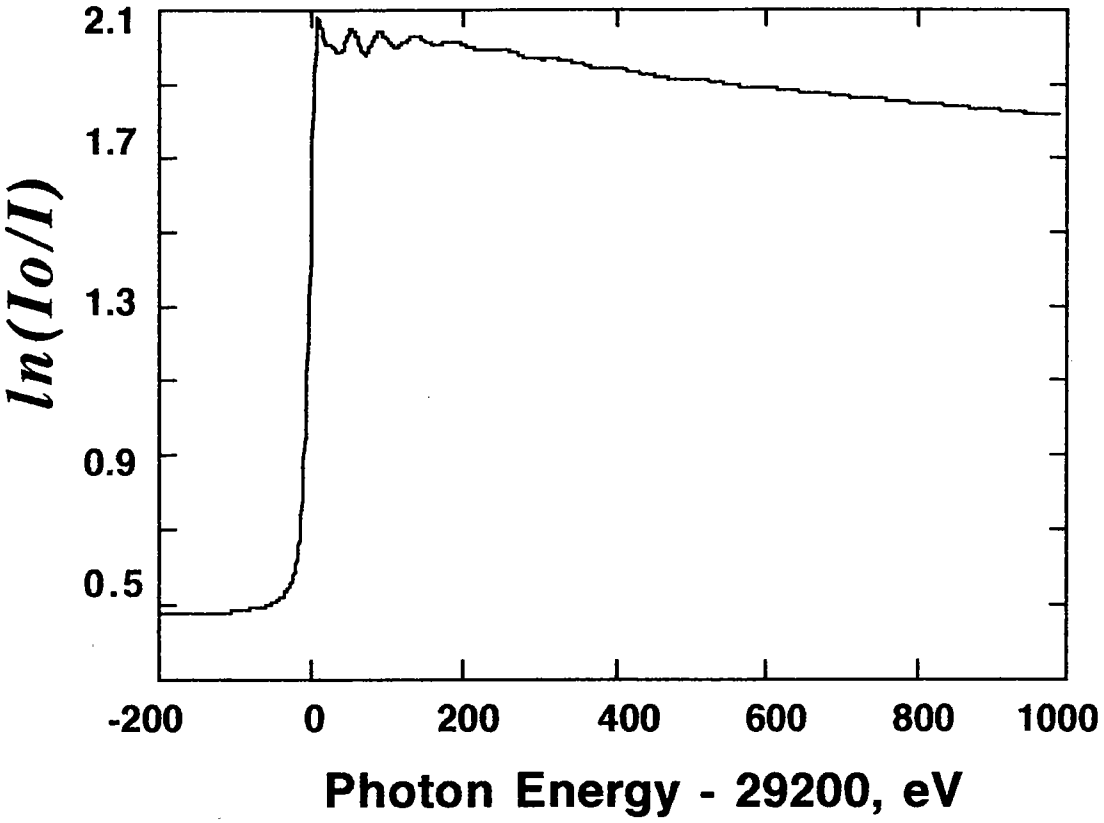

E_K = 24350 eV
0
7
34
0.0
DERIVATIVE SPECTRUM
-60
-40
-20
0
20
40
60
Energy, eV

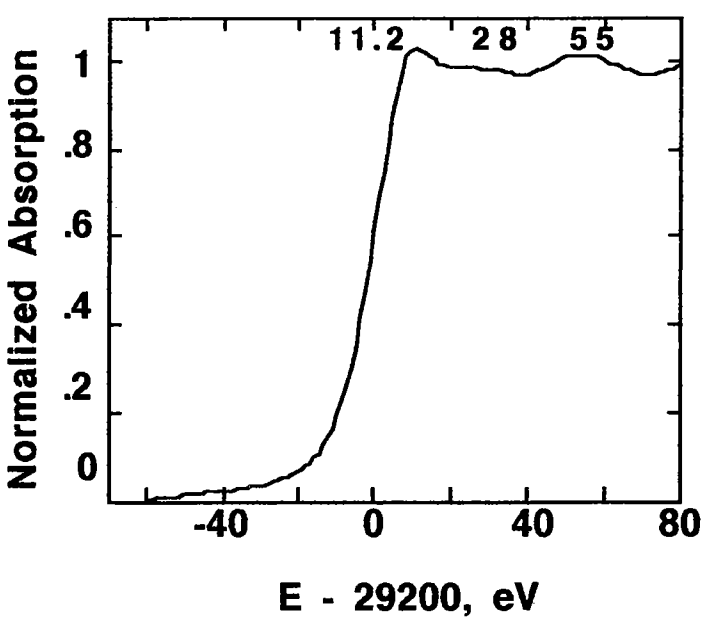

E_K = 25514
1.0
0.0
ABSORPTION . (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_K, eV

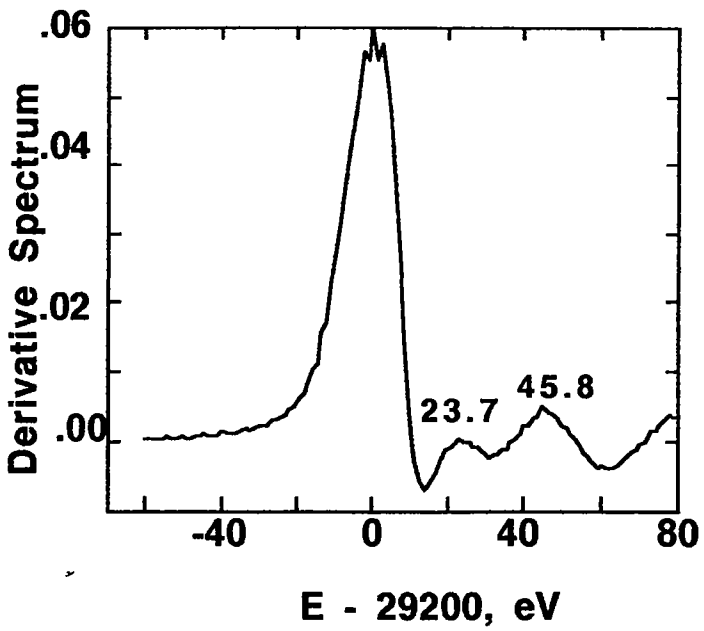

E_K = 25514 eV
1.0
0.0
NORMALIZED ABSORPTION
15
36
-60
-40
-20
0
20
40
60
Energy, eV


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

Sn

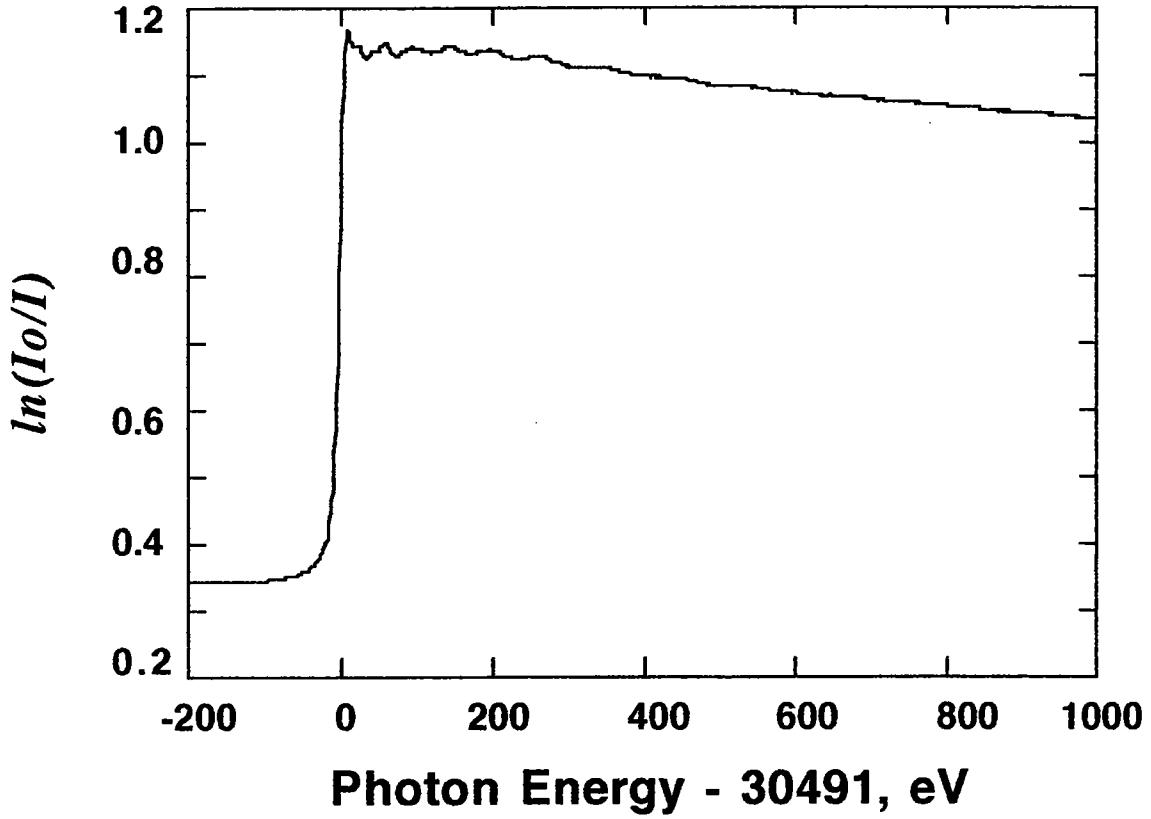

2.1
1.7
1.3
0.9
0.5
ln(Io/I)
-200
0
200
400
600
800
1000
Photon Energy - 29200, eV

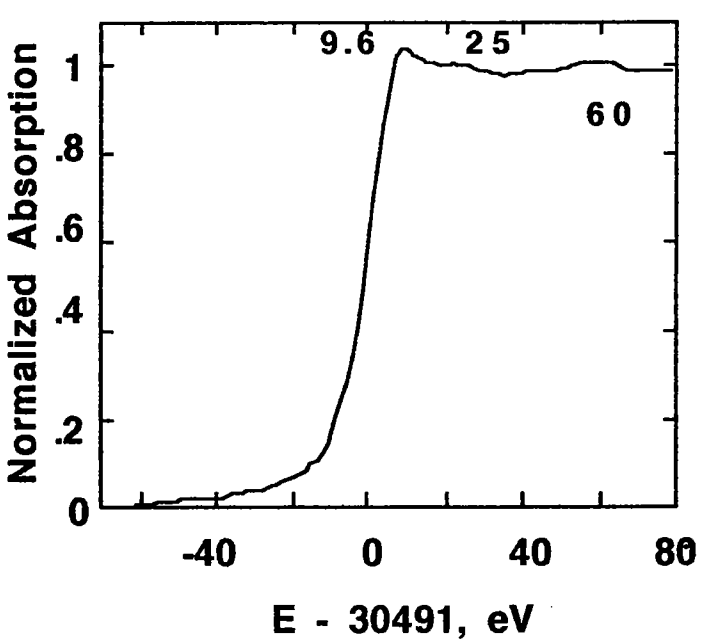

11.2
28
55
1
.8
.6
.4
.2
0
Normalized Absorption
-40
0
40
80
E - 29200, eV

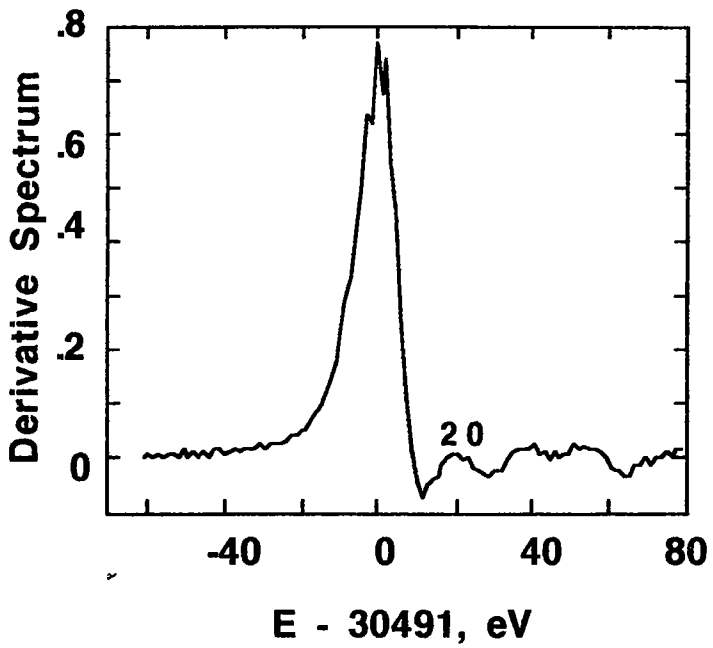

.06
.04
.02
.00
Derivative Spectrum
23.7
45.8
-40
0
40
80
E - 29200, eV

15a

Sb

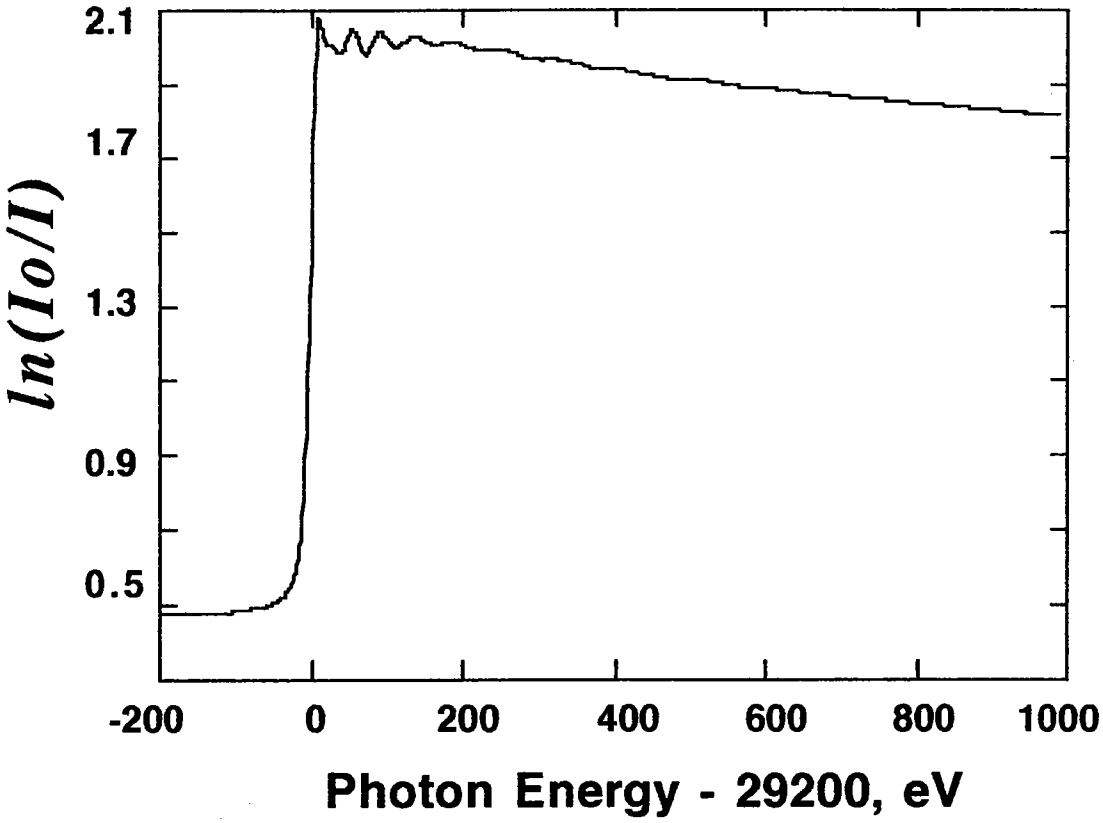

1.2
1.0
0.8
0.6
0.4
0.2
ln(Io/I)
-200
0
200
400
600
800
1000
Photon Energy - 30491, eV

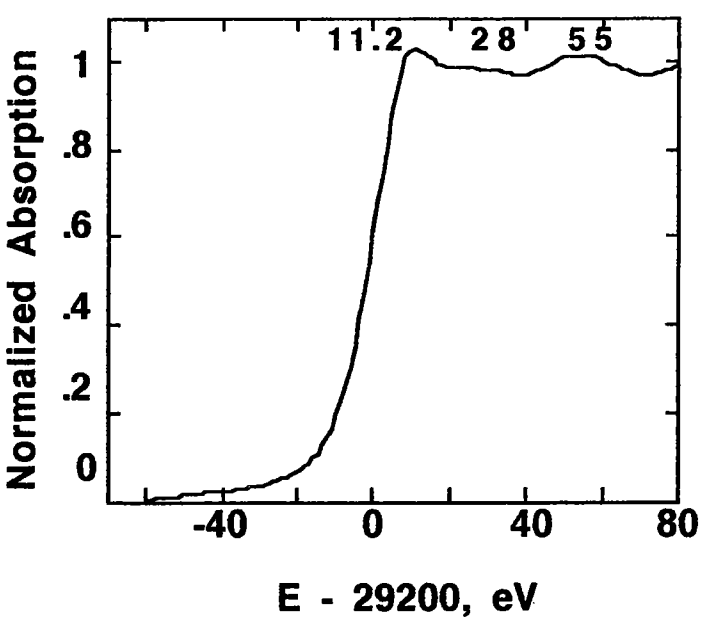

Normalized Absorption
1
.8
.6
.4
.2
0
9.6
25
60
-40
0
40
80
E - 30491, eV

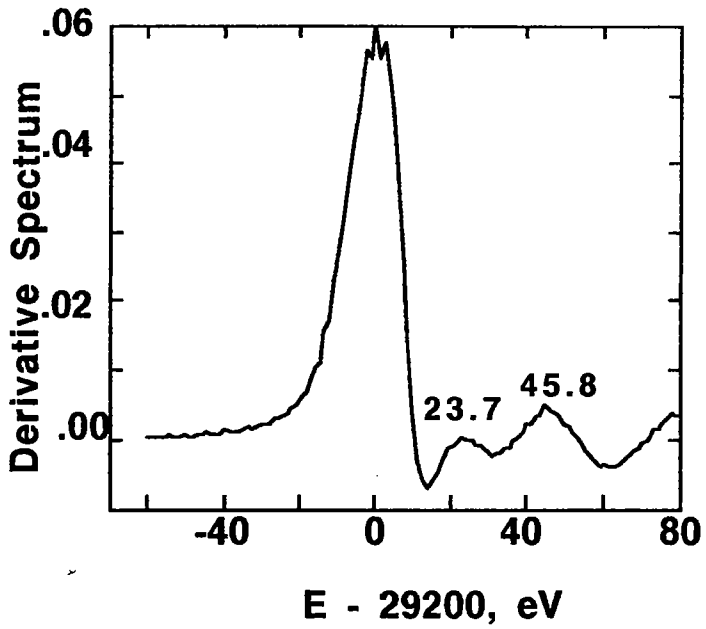

Derivative Spectrum
.8
.6
.4
.2
0
20
-40
0
40
80
E - 30491, eV

15b

Sn

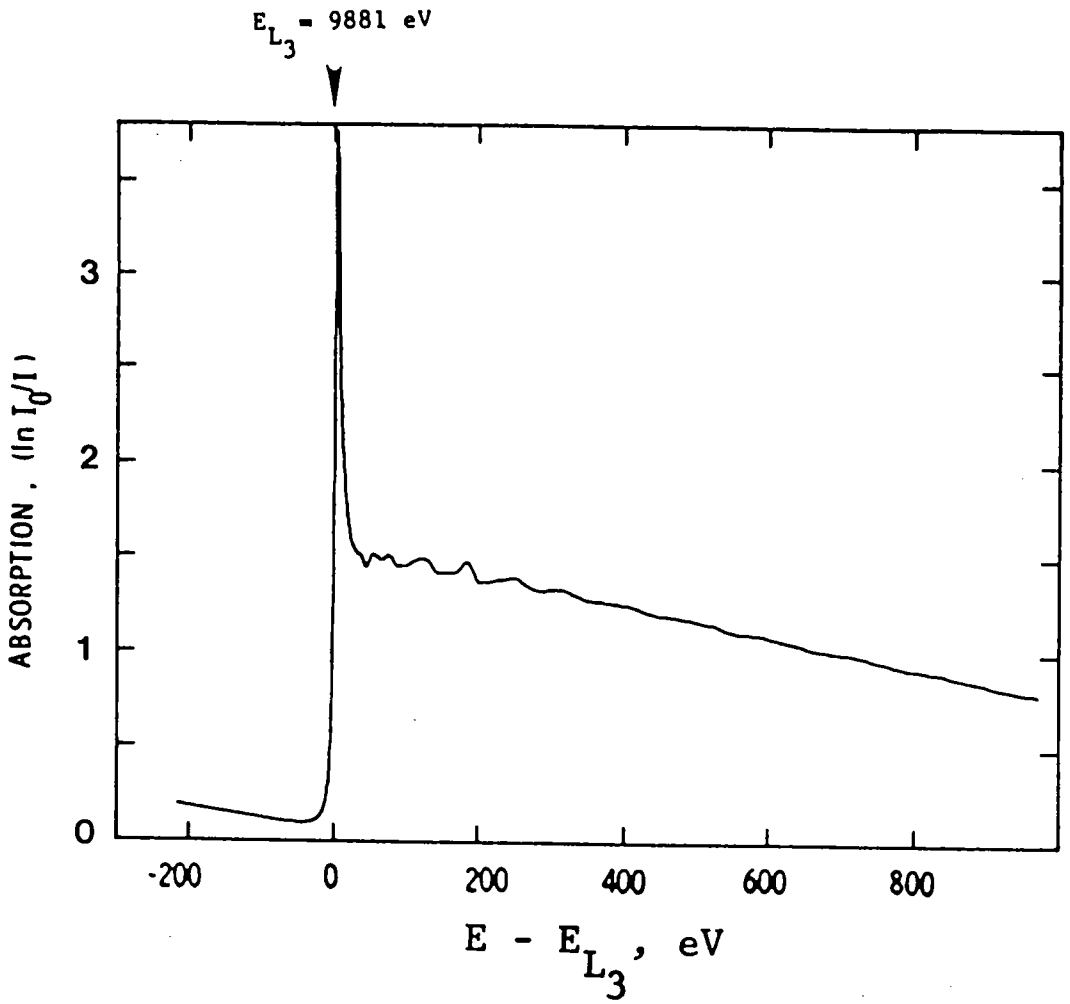

2.1
1.7
1.3
0.9
0.5
ln(Io/I)
-200
0
200
400
600
800
1000
Photon Energy - 29200, eV

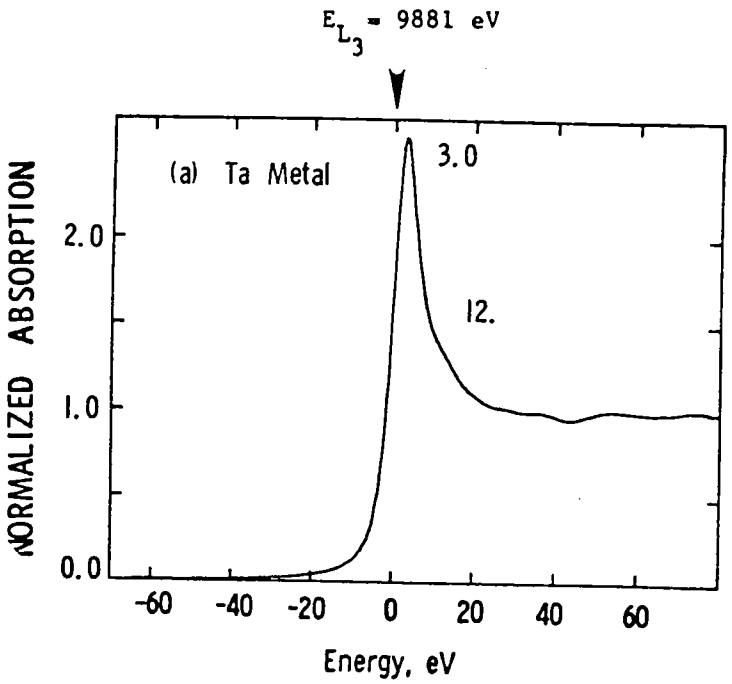

11.2
28
55
1
.8
.6
.4
.2
0
Normalized Absorption
-40
0
40
80
E - 29200, eV

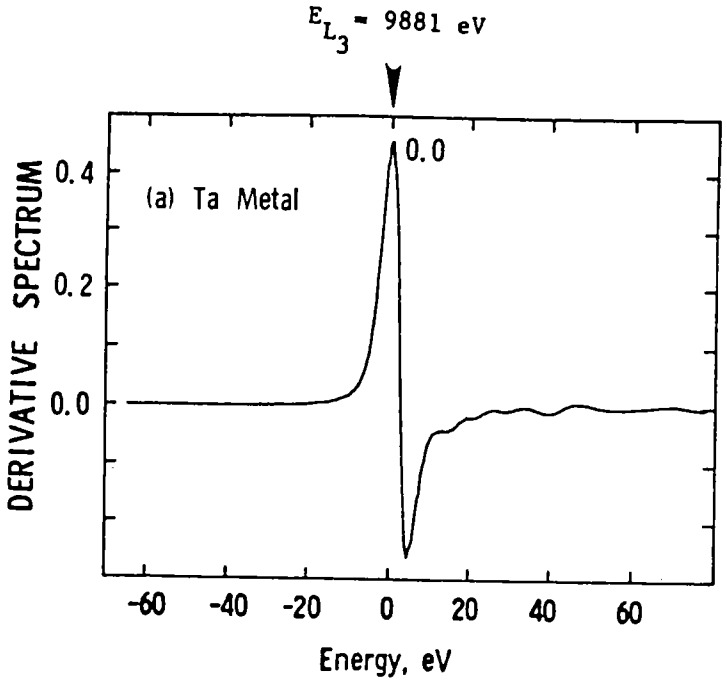

.06
.04
.02
.00
Derivative Spectrum
23.7
45.8
-40
0
40
80
E - 29200, eV

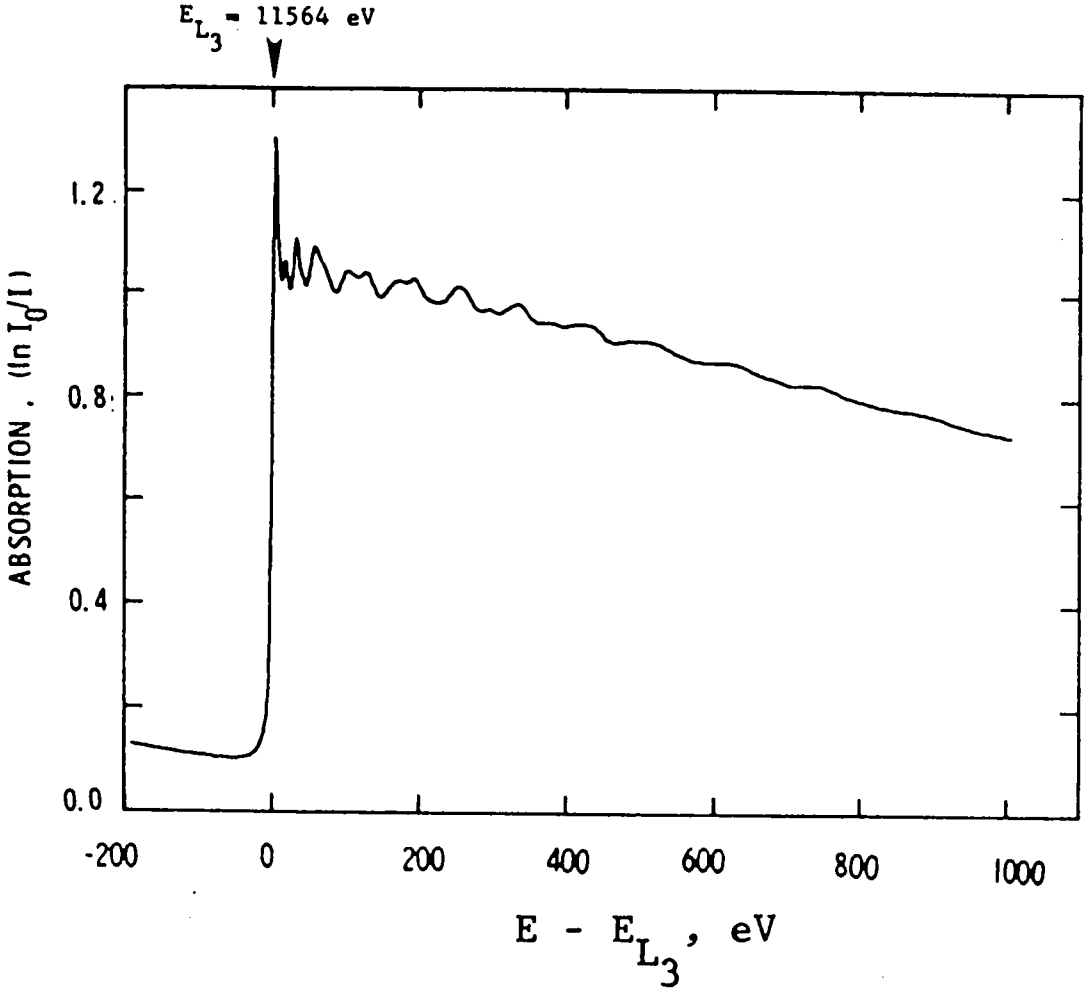
15a

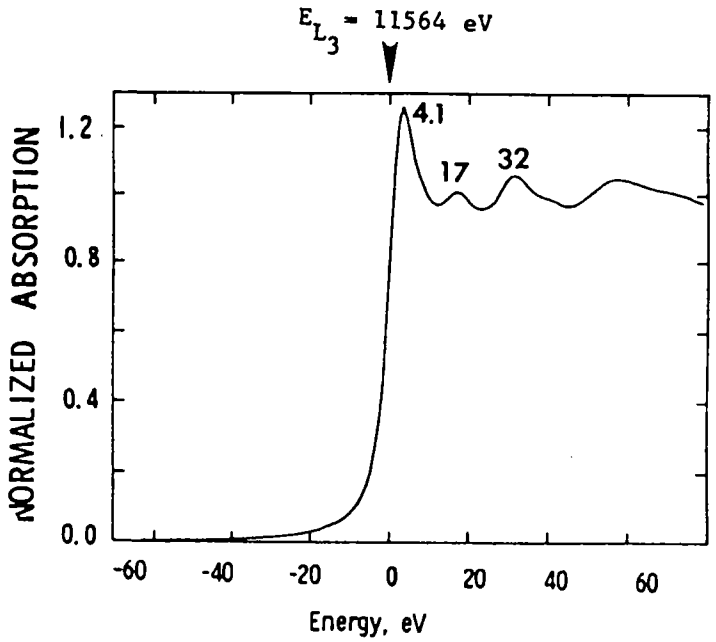
Ta

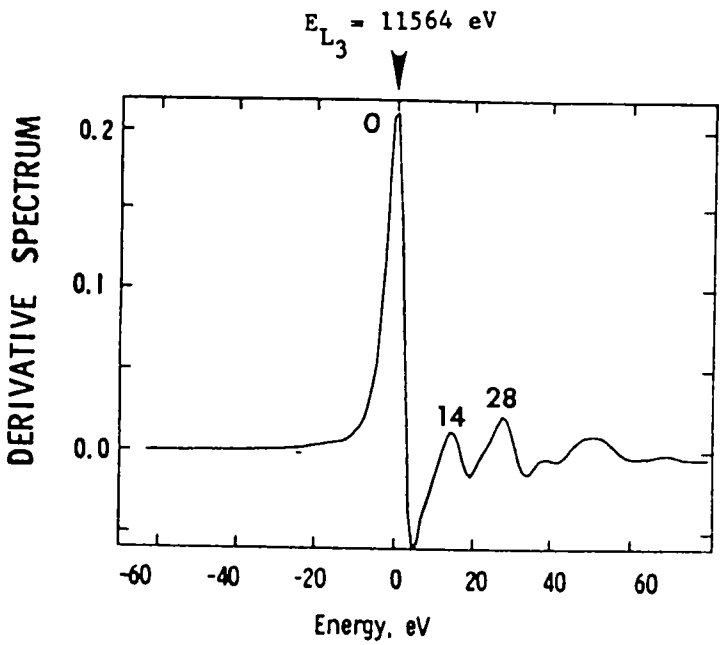

E_{L_3} = 9881 eV
ABSORPTION, ($\ln I_0/I$)
0
1
2
3
-200
0
200
400
600
800
$E - E_{L_3}$, eV


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

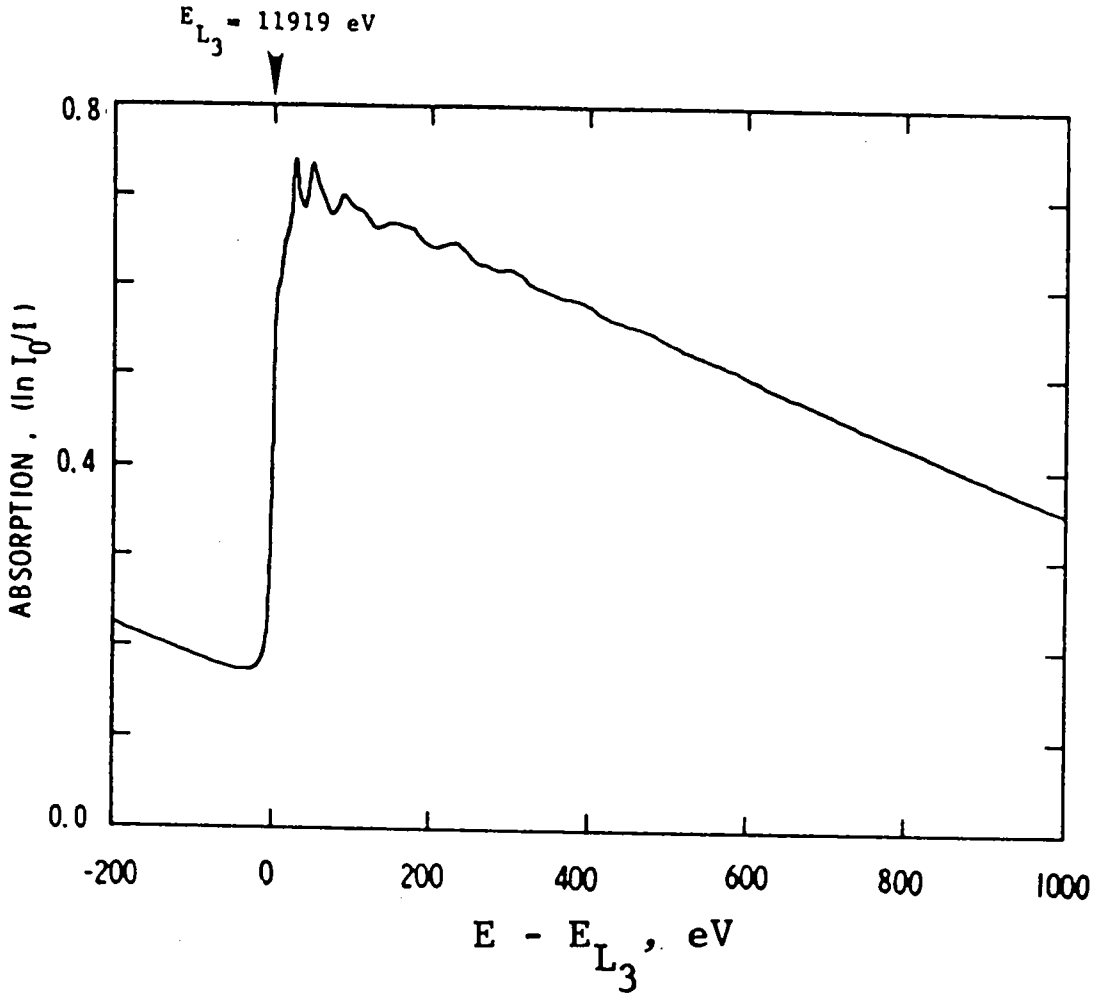

E_{L_3} = 9881 eV
(a) Ta Metal
0.0
DERIVATIVE SPECTRUM
0.0
0.2
0.4
-60
-40
-20
0
20
40
60
Energy, eV

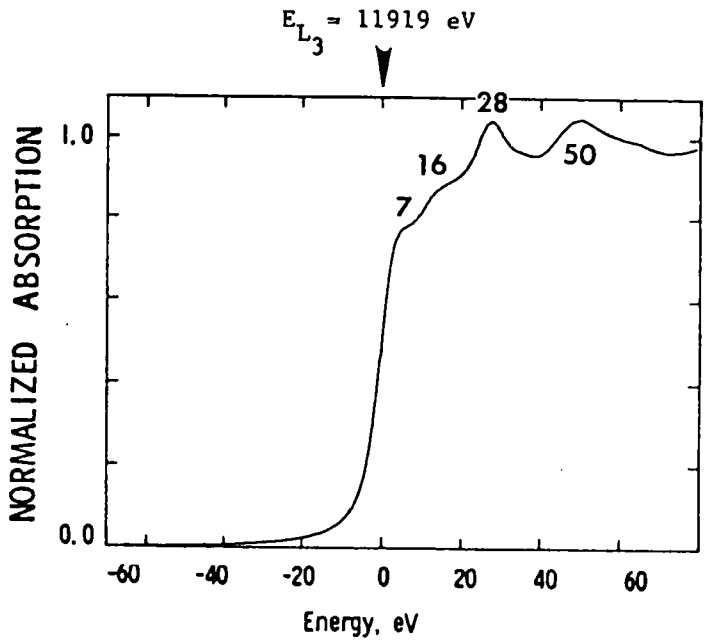

E_{L_3} = 11564 eV
ABSORPTION . (ln I_0/I)
1.2
0.8
0.4
0.0
-200
0
200
400
600
800
1000
E - E_{L_3}, eV

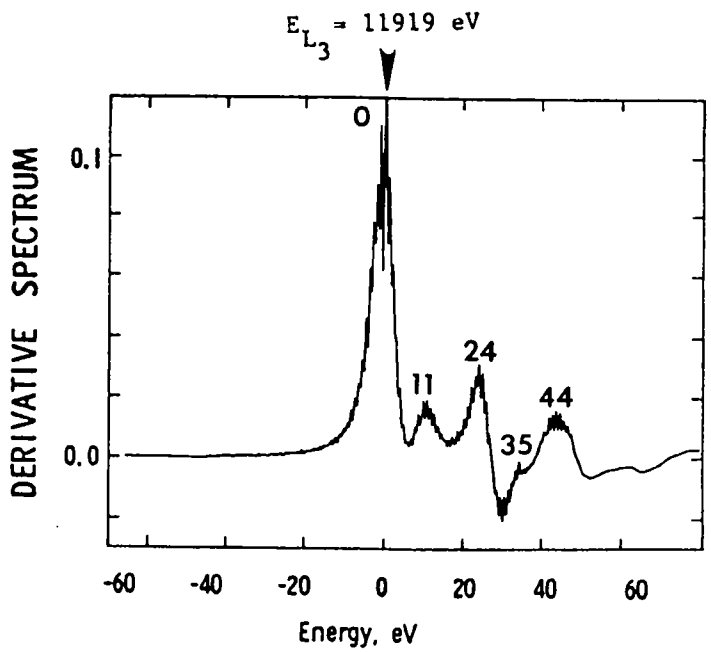

E_{L_3} = 11564 eV
NORMALIZED ABSORPTION
1.2
0.8
0.4
0.0
4.1
17
32
-60
-40
-20
0
20
40
60
Energy, eV

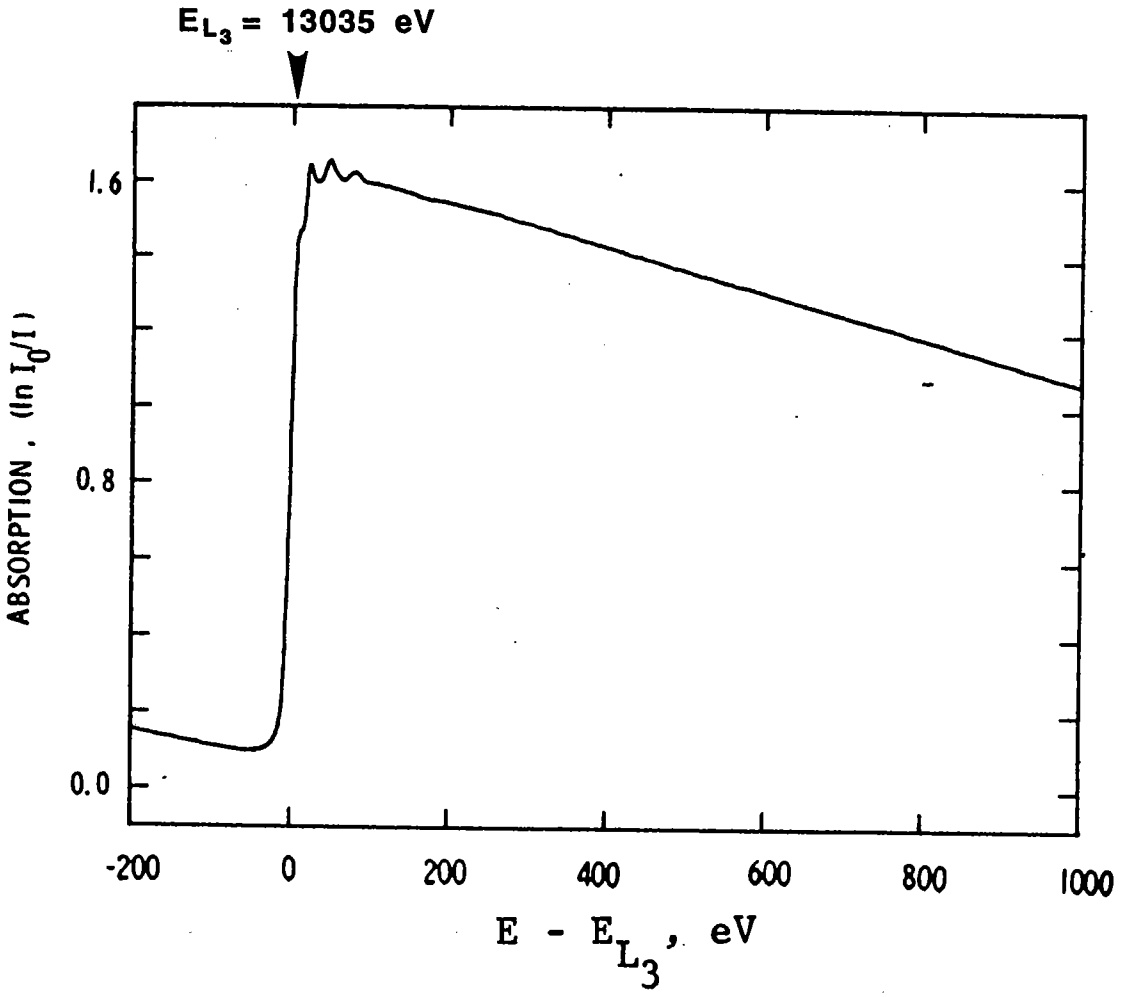

E_{L_3} = 11564 eV
DERIVATIVE SPECTRUM
0.2
0.1
0.0
0
14
28
-60
-40
-20
0
20
40
60
Energy, eV

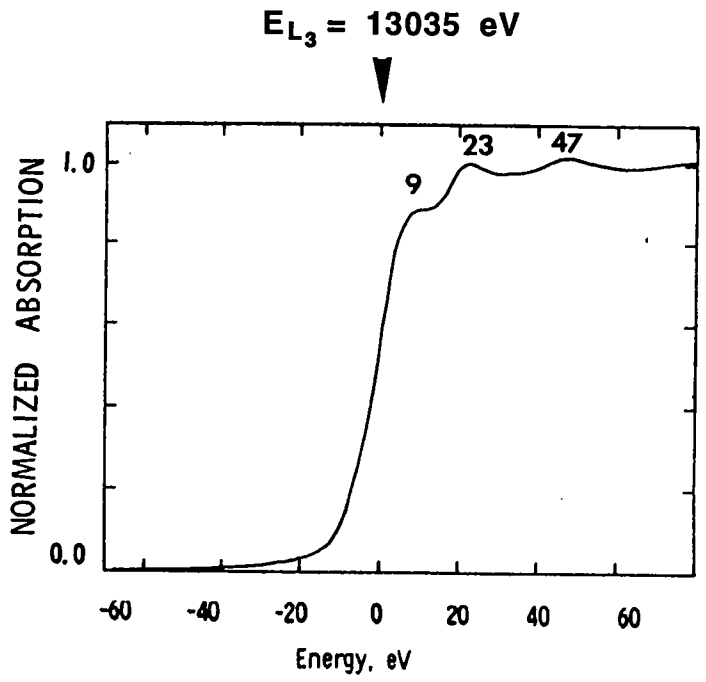
Au

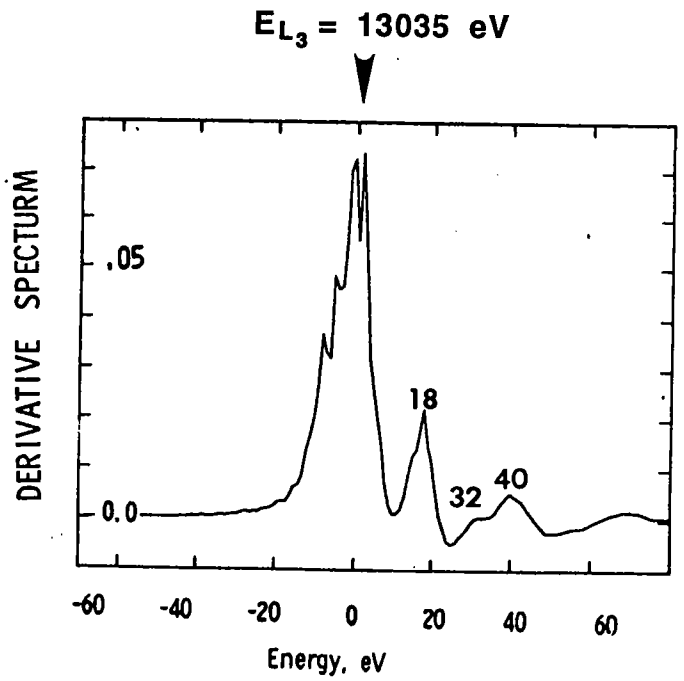

E_{L_3} = 11919 eV
0.8
0.4
0.0
ABSORPTION , (ln I_0/I)
-200
0
200
400
600
800
1000
E - E_{L_3}, eV


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


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, eV

Element	Z	K-Edge	L1	L2	L3
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	1305.0	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
I	53	33169.4	5188.1	4852.1	4557.1

X-Ray K- and L-Edge Energies, eV

Element	Z	K-Edge	L1	L2	L3
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	57485.5	9751.3	9264.3	8357.9
Tm	69	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