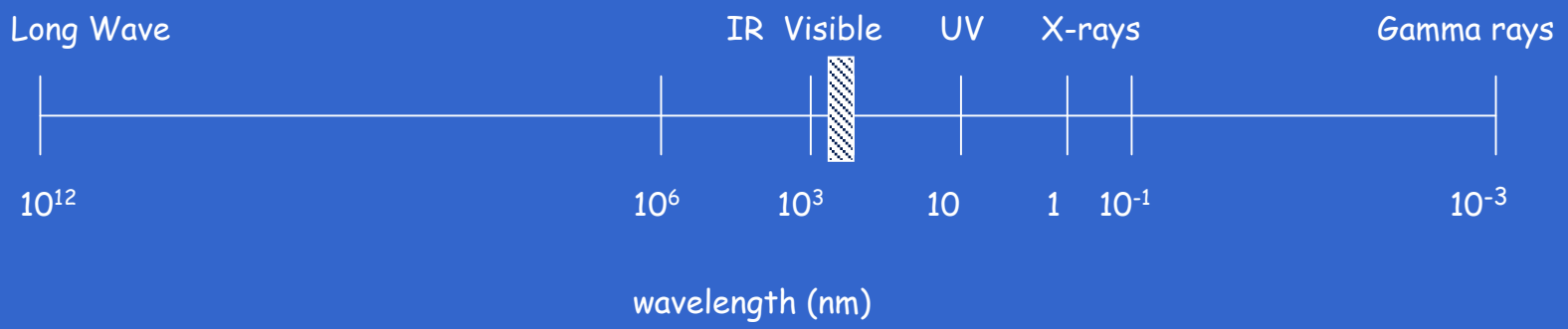
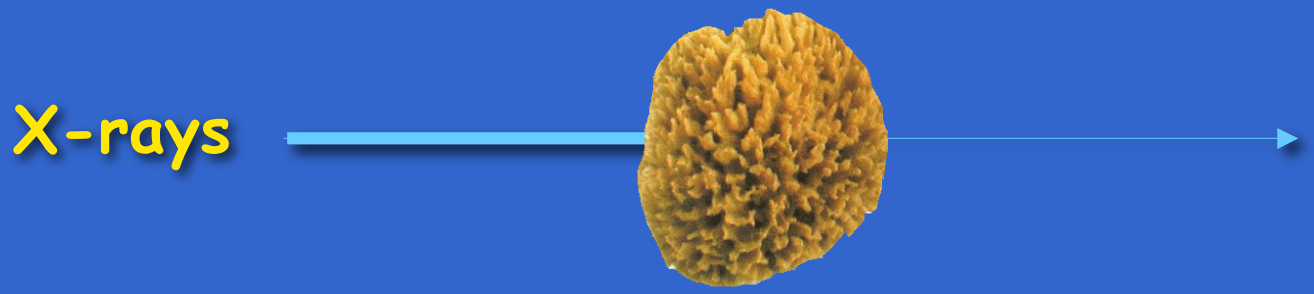
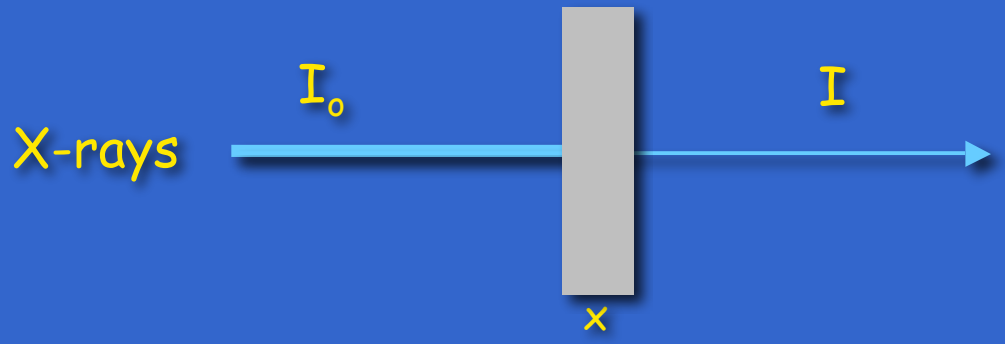

Long Wave
IR
Visible
UV
X-rays
Gamma rays
10^{12}
10^{6}
10^{3}
10
1
10^{-1}
10^{-3}
wavelength (nm)


X-rays

absorption

Absorption



$$I/I_o = e^{-\mu^* x} = 1/ e^{\mu^* x} = 1/ e^{\mu \rho x}$$

μ^* = linear attenuation coefficient

μ = mass attenuation coefficient

ρ = density of absorber

Absorption

μ - values for elements listed in various texts & International Tables for Crystallography

Note that μ changes with X-ray wavelength

Higher atomic no. --> larger μ, in general

Z		Cu Kα	Cr Kα	Fe Kα	Mo Kα	Z		Cu Kα	Cr Kα	Fe Kα	Mo Kα
1	H	0.435	0.545	0.483	0.380	51	Sb	270	288	472	33.1
2	He	0.383	0.813	0.569	0.207	52	Te	282	707	490	35.0
3	Li	0.716	1.96	1.25	0.217	53	I	294	722	506	37.1
4	Be	1.50	4.50	2.80	0.298	54	Xe	306	753	521	39.2
5	B	2.39	7.38	4.55	0.392	55	Cs	318	793	534	41.3
6	C	4.60	14.5	8.90	0.625	56	Ba	330	461	546	43.5
7	N	7.52	23.9	14.6	0.916	57	La	341	202	557	45.8
8	O	11.5	36.6	22.4	1.31	58	Ce	352	219	601	48.2
9	F	16.4	52.4	32.1	1.80	59	Pr	363	236	359	50.7
10	Ne	22.9	72.8	44.6	2.47	60	Nd	374	252	379	53.2
11	Na	30.1	95.3	58.6	3.21	61	Pm	386	268	172	55.9
12	Mg	38.6	121	74.8	4.11	62	Sm	397	284	182	58.6
13	Al	48.6	152	93.9	5.16	63	Eu	425	299	193	61.5
14	Si	60.6	189	117	6.44	64	Gd	439	314	203	64.4
15	P	74.1	229	142	7.89	65	Tb	273	329	214	67.5
16	S	89.1	272	170	9.55	66	Dy	286	344	224	70.6
17	Cl	106	318	200	11.4	67	Ho	128	359	234	73.9
18	Ar	123	366	232	13.5	68	Er	134	373	245	77.3
19	K	143	417	266	15.8	69	Tm	140	387	255	80.8
20	Ca	162	468	299	18.3	70	Ym	146	401	265	84.5
21	Sc	184	513	336	21.1	71	Lu	153	416	276	88.2
22	Ti	208	571	377	24.2	72	Hf	159	430	286	91.7
23	V	233	68.4	419	27.5	73	Ta	166	444	297	95.4
24	Cr	260	79.8	463	31.1	74	W	172	458	308	99.1
25	Mn	285	93.0	57.2	34.7	75	Re	179	473	319	103
26	Fe	308	108	66.4	38.5	76	Os	186	487	330	106
27	Co	313	125	76.8	42.5	77	Ir	193	502	341	110
28	Ni	45.7	144	88.6	46.6	78	Pt	200	517	353	113
29	Cu	53.0	166	103	50.9	79	Au	208	532	365	115
30	Zn	60.3	189	117	55.4	80	Hg	216	547	377	117
31	Ga	55.9	212	131	60.1	81	Tl	224	563	389	119
32	Ge	75.6	235	146	64.8	82	Pb	232	579	402	120
33	As	83.4	258	160	69.7	83	Bi	240	596	415	120
34	Se	91.4	281	175	74.7						
35	Br	99.6	305	190	79.8						
36	Kr	108	327	206	84.9						
37	Rb	117	351	221	90.0						
38	Sr	125	373	236	95.0						
39	Y	134	396	252	100.						
40	Zr	145	419	265	13.9						
41	Nb	153	441	284	17.1						
42	Mo	162	163	300	18.4						
43	Tc	172	485	316	19.7						
44	Ru	183	509	334	21.1						
45	Rh	194	534	352	22.6						
46	Pd	206	559	371	24.1						
47	Ag	210	586	391	25.8						
48	Cd	281	613	412	37.5						
49	In	243	638	432	29.3						
50	Sn	256	662	451	31.1						

Absorption

What element used for X-ray tube windows?

What element used for protection from X-rays?

Z		Cu Kα	Cr Kα	Fe Kα	Mo Kα	Z		Cu Kα	Cr Kα	Fe Kα	Mo Kα
1	H	0.435	0.545	0.483	0.380	51	Sb	270	288	472	33.1
2	He	0.383	0.813	0.569	0.207	52	Te	282	707	490	35.0
3	Li	0.716	1.96	1.25	0.217	53	I	294	722	506	37.1
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22	Ti	208	571	377	24.2	72	Hf	159	430	286	91.7
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36	Kr	108	327	206	84.9						
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38	Sr	125	373	236	95.0						
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40	Zr	145	419	265	13.9						
41	Nb	153	441	284	17.1						
42	Mo	162	163	300	18.4						
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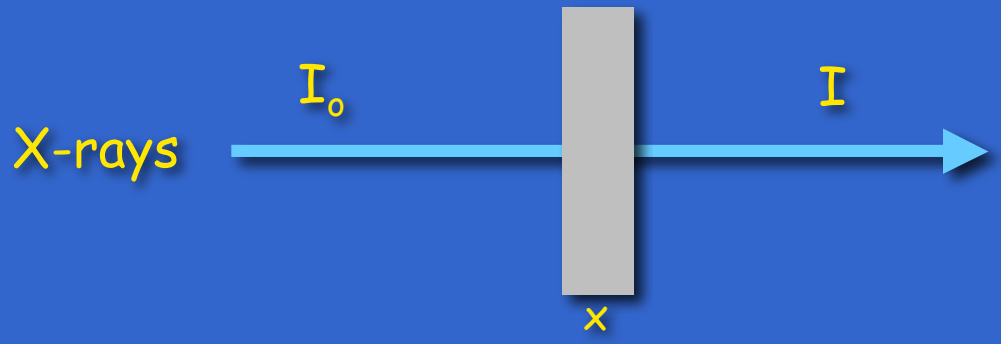
47	Ag	210	586	391	25.8						
48	Cd	281	613	412	37.5						
49	In	243	638	432	29.3						
50	Sn	256	662	451	31.1						

Absorption



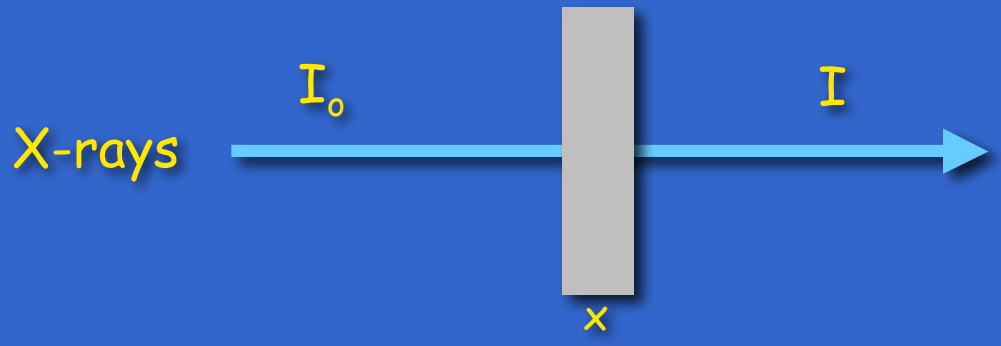
$$I/I_o = e^{-\mu^* x} = 1/ e^{\mu^* x} = 1/ e^{\mu \rho x}$$

For compounds & mixtures,

calculate μ from

$$\mu_{\text{compd or mixture}} = \Sigma\ (\text{wt. fraction})_{\text{element}} \times \mu_{\text{element}}$$

Absorption



$$I/I_o = e^{-\mu^* x} = 1/ e^{\mu^* x} = 1/ e^{\mu \rho x}$$

Example for NaCl ($Cu_{K\alpha}$):

$(\text{wt. fraction})_{Na} = 23/58.5 = 0.393$, $(\text{wt. fraction})_{Cl} = 0.607$

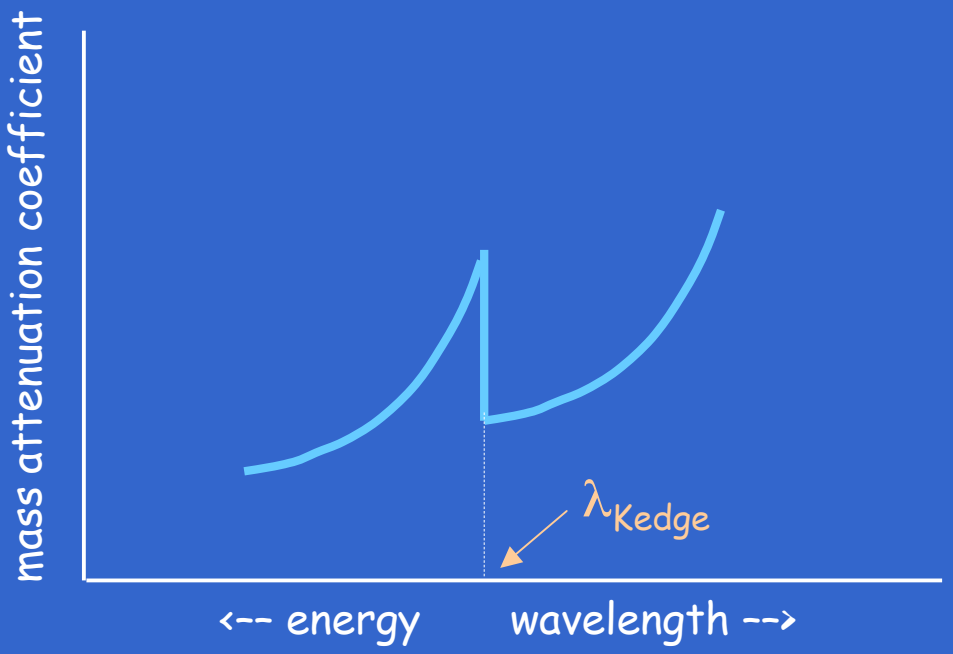
$\mu_{Na} = 30.1 \qquad \mu_{Cl} = 106$

$$\mu_{NaCl} = (\text{wt. fraction})_{Na} \times \mu_{Na} + (\text{wt. fraction})_{Cl} \times \mu_{Cl}$$

$$\mu_{NaCl} = 0.393 \times 30.1 + 106 \times .607 = 76.2$$

Absorption

Mass attenuation coefficient for an element changes with X-ray wavelength (energy) like this:



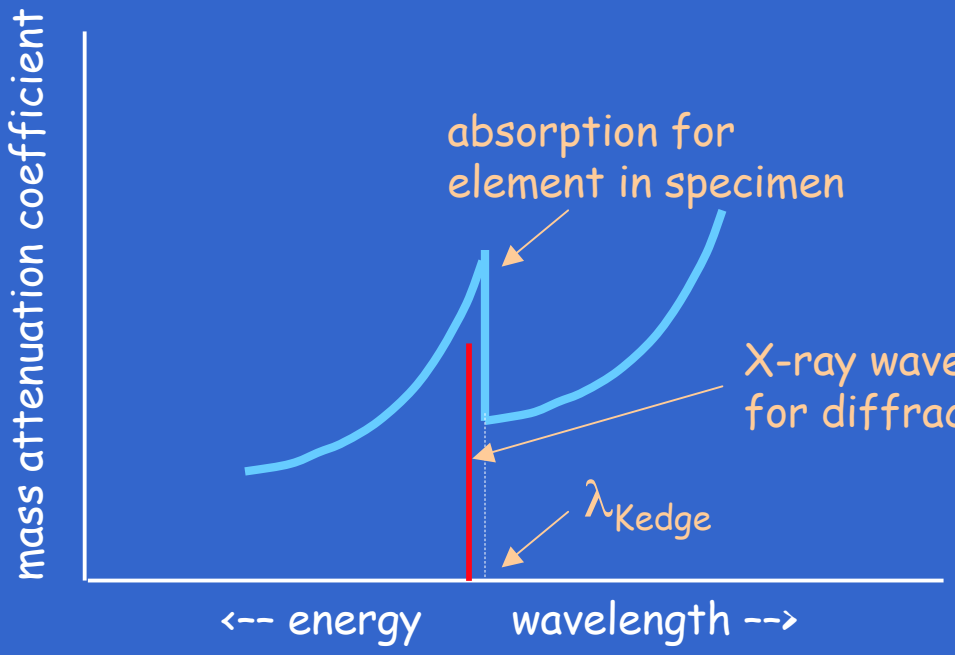
Good news/bad news

Absorption

Bad news

Absorbed energy re-emitted as fluorescent X-rays

Suppose:



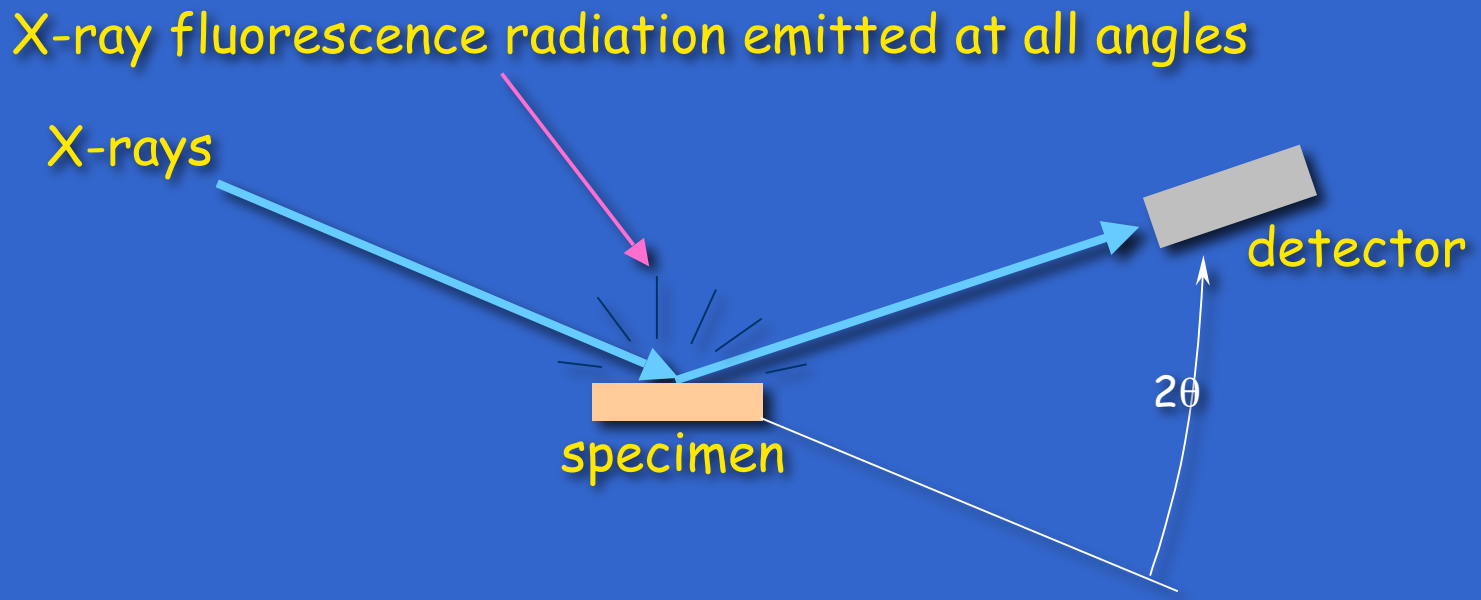
Then:

Absorption high

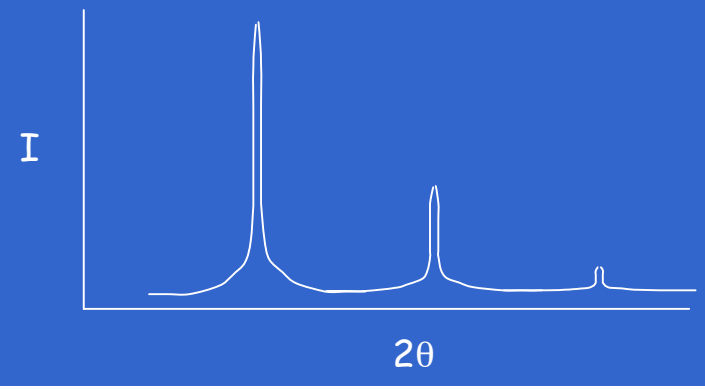
Lots of fluorescence

Absorption

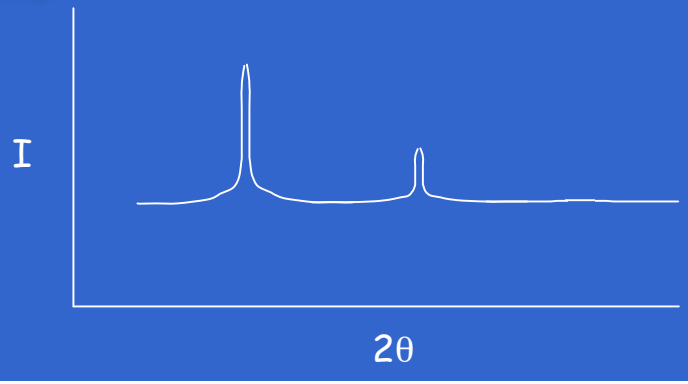
Bad news



instead of this:

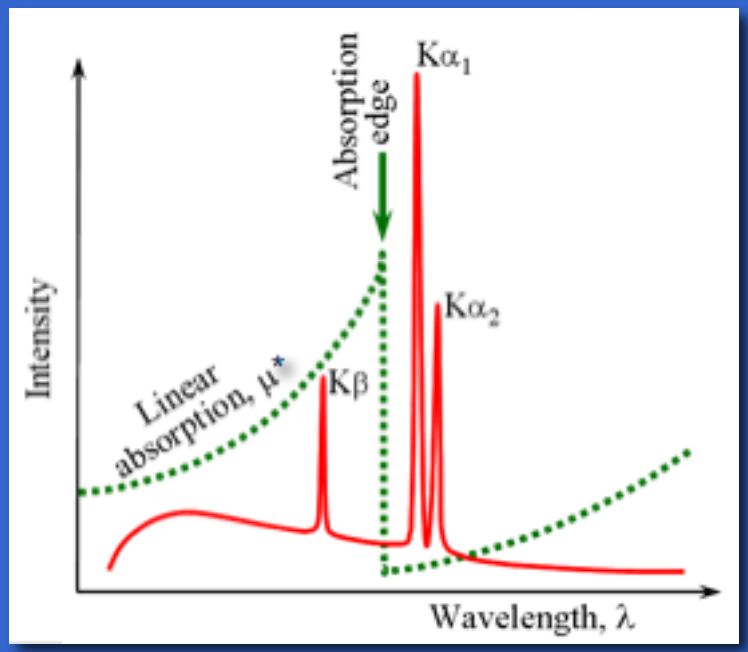


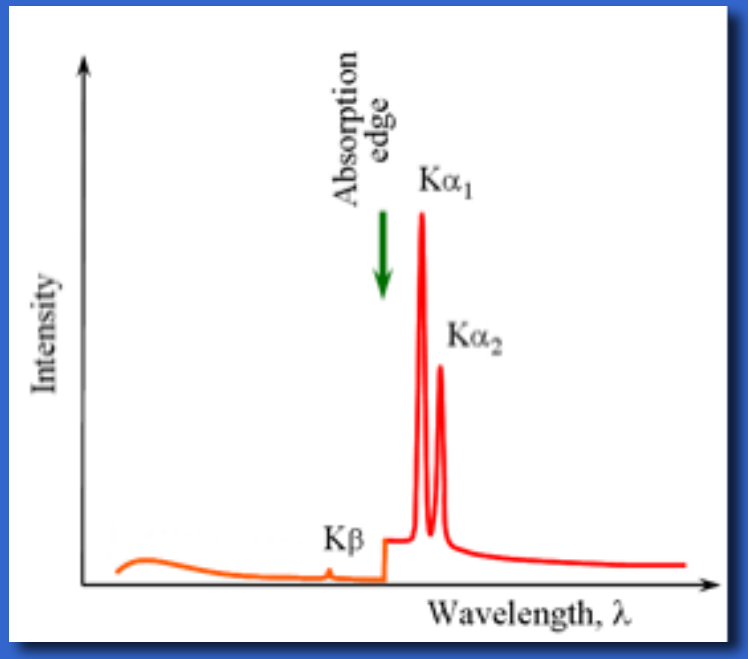
get this:



Absorption

Good news - β-filters





β-filter materials have atomic nos. 1 or 2 less than anode

50-60% beam attenuation

Absorption

Good news - β-filters

placing after specimen/before detector
filters most of specimen fluorescence