SHIMADZU
Excellence in Science

Introduction to Elemental Analysis by ED-XRF

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Product Specialist
3 June 2015

SHIMADZU

Shimadzu Corporation

- Established in 1875. Headquartered in **Kyoto, Japan**

- Ranked Top 5 Instrument Providers in the world by Chemical and Engineering News

- Offer broad range of analytical solutions and technologies

Shimadzu Corporation

Chromatography

- HPLC & UHPLC
- GPC
- GC

Mass Spectrometry

- LCMS
- GCMS
- MALDI

Environmental Analyzers

- Total Organic Carbon
- Total Nitrogen
- Total Phosphorus

Spectroscopy

- UV-Vis-NIR
- FTIR
- Fluorescence
- AA
- ICP


Nexera UHPLC

MALDI-TOF/TOF


TQ GCMS-8030


TQ LCMS-8050

Shimadzu Corporation

Physical Measurement

- Tensile/Universal
- Hydraulic
- Concrete
- Fatigue
- Hardness
- Static/Dynamic Jack
- Impact
- Particle Size Analyzers
- Thermal Analyzers
- High-Speed Video Camera

X-ray

- XRD
- XRF
- EDX

Balances & Scales

DSC

Analytical Balance

Hardness

What is XRF?

- Analytical method to determine the elemental composition of many types of materials
- Can be used to determine the thickness and composition of layers, coatings, and platings.

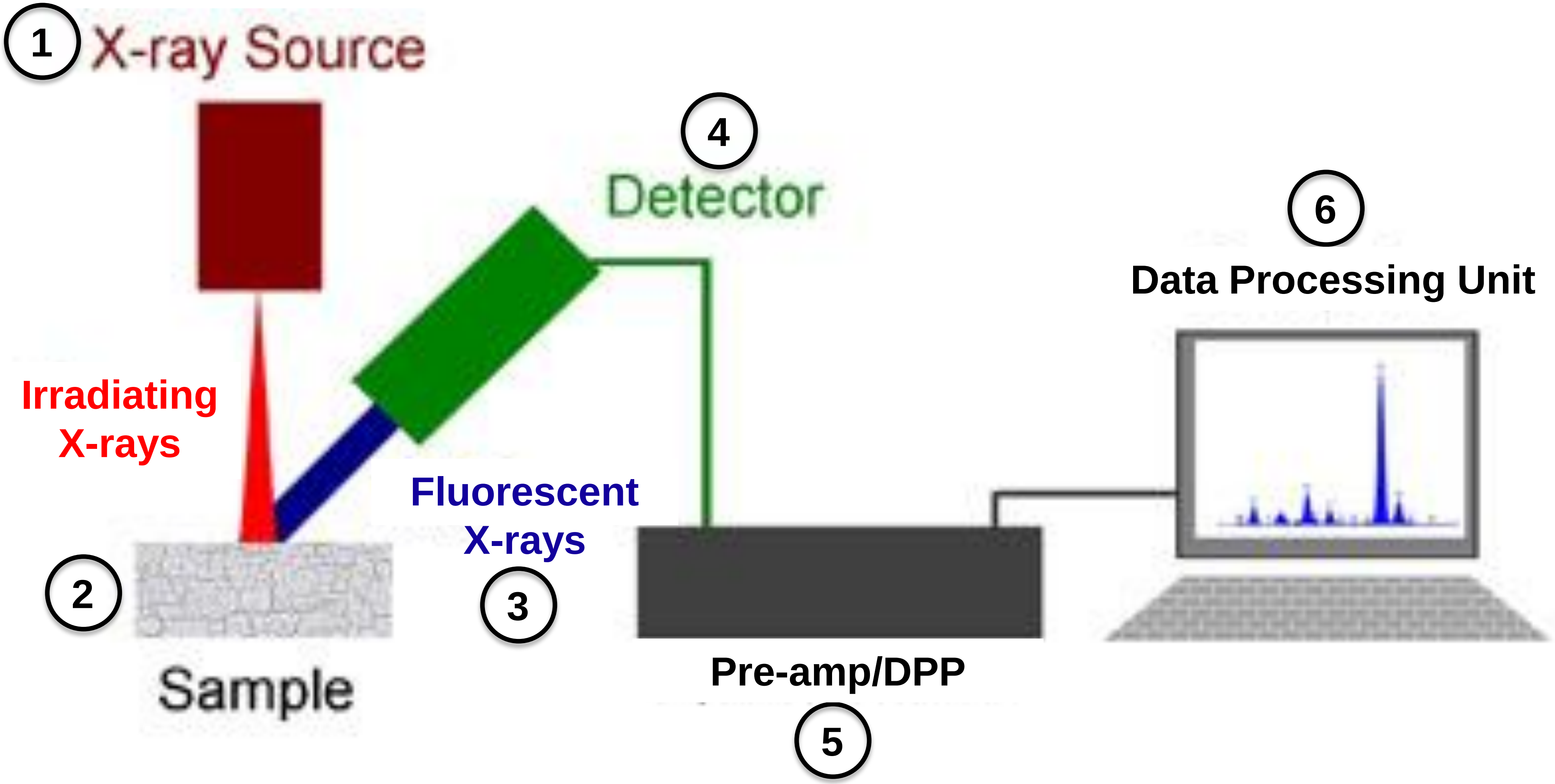
- Fast, accurate, non-destructive
- Requires minimal sample prep
- Samples can be in solid, liquid, powder, or filtered form

What is ED-XRF?

Energy-Dispersive X-Ray Fluorescence

- **Energy-dispersive:** Ability to discern the energies of x-rays
- **X-Ray:** Form of energy; source of ionizing radiation
- **Fluorescence:** Phenomenon of absorbing energy (short λ) and subsequently emitting energy (longer λ)

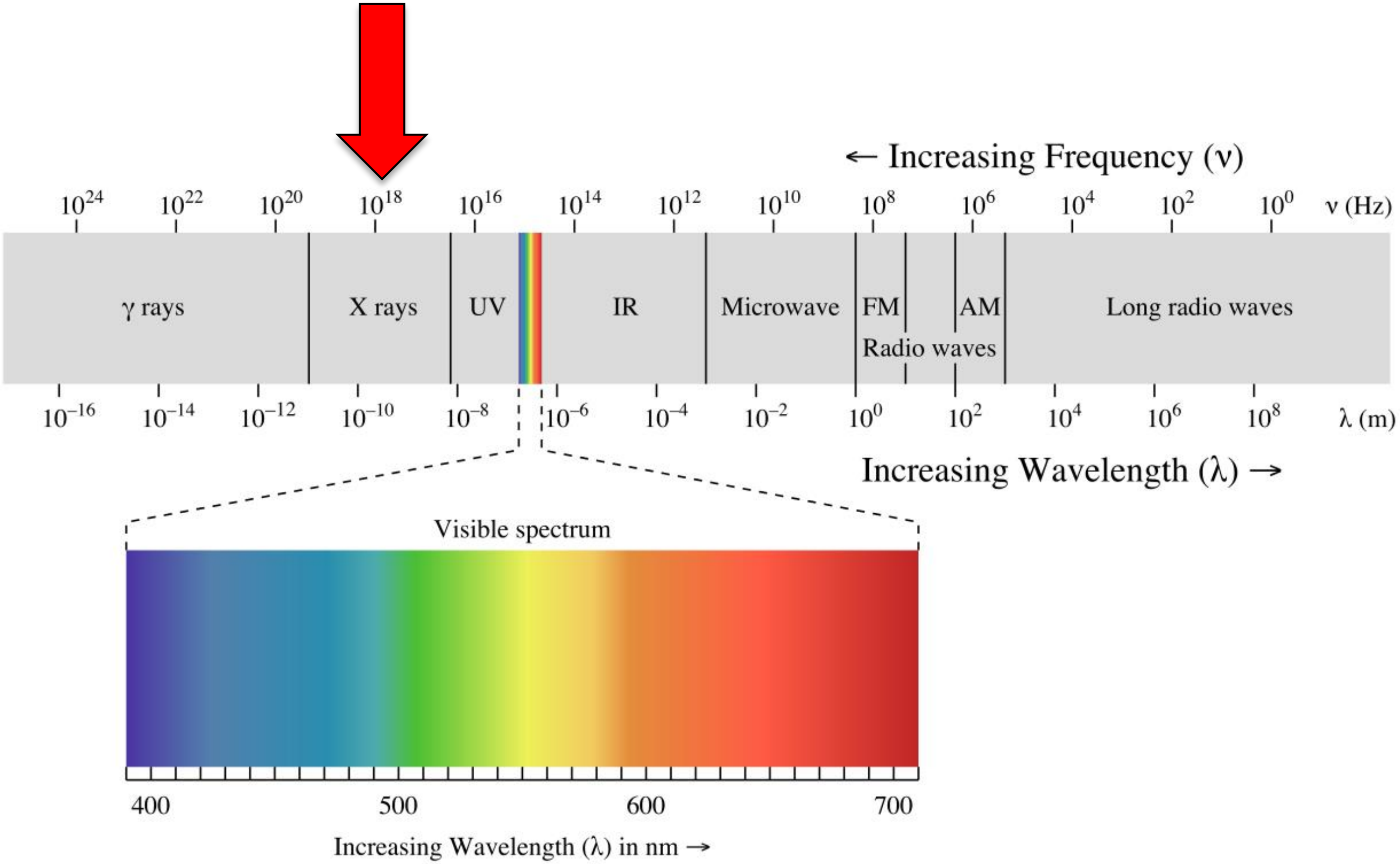
Basis of EDX



1
X-ray Source
4
Detector
6
Data Processing Unit
Irradiating
X-rays
Fluorescent
X-rays
2
3
Sample
Pre-amp/DPP
5

What are X-Rays?

- **X-rays are a kind of electromagnetic energy:**



0.01 – 10 nm

0.125 – 125 keV

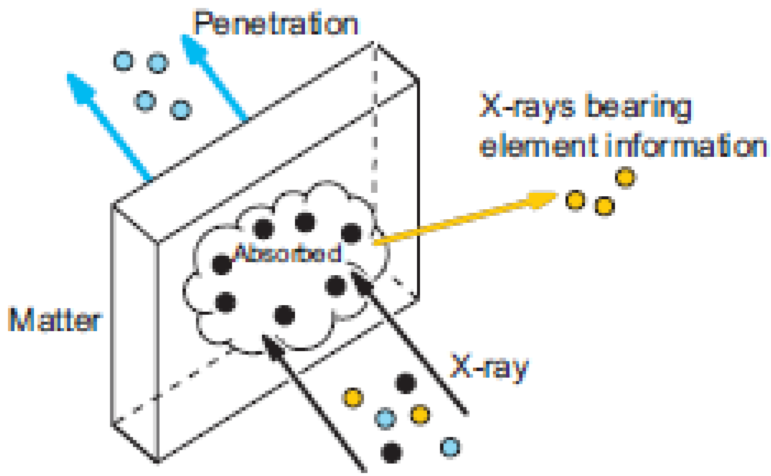
“Hard” X-rays:	>10 keV
“Soft” X-rays:	<10 keV

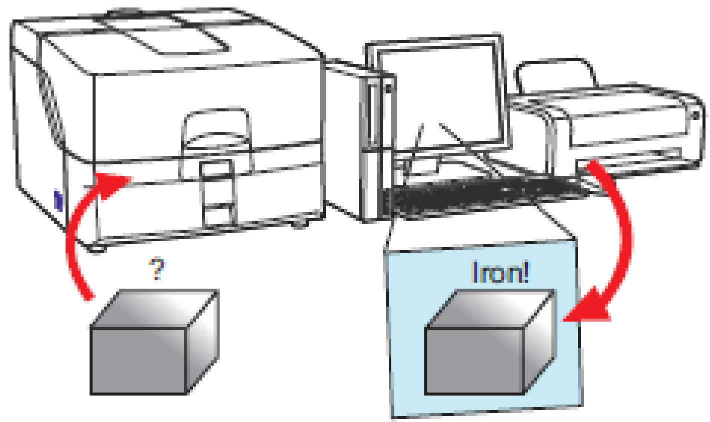
How Do X-Rays Interact with Matter?

- When X-rays strike matter, some of them are absorbed and some pass through

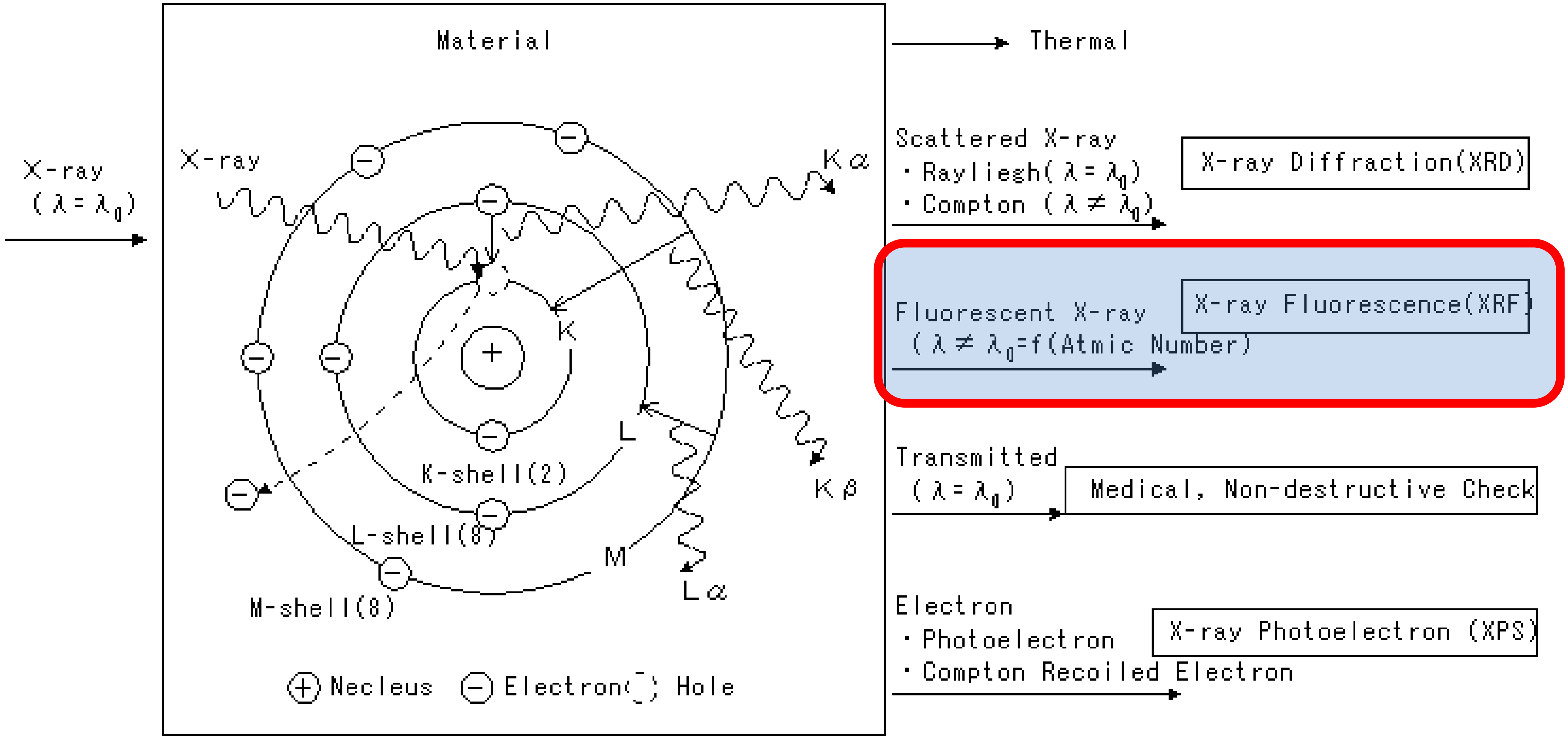
- Absorption and penetration depend on the elemental composition, density, and thickness of matter.

- A consequence of absorption is that **secondary X-rays are generated, which are characteristic of that matter**:





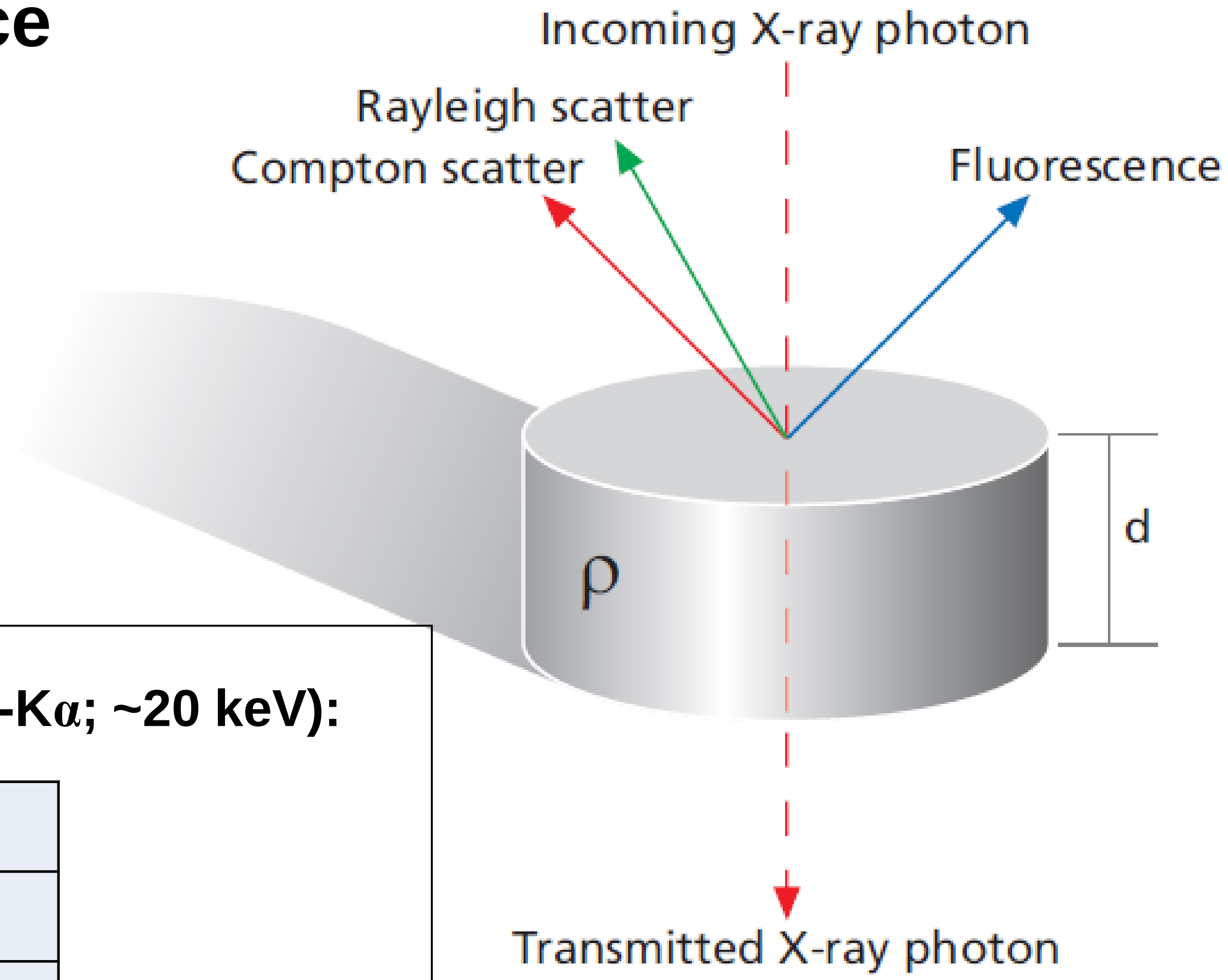
How Do X-Rays Interact with Matter?



How Do X-Rays Interact with Matter?

Degree of fluorescence depends on:

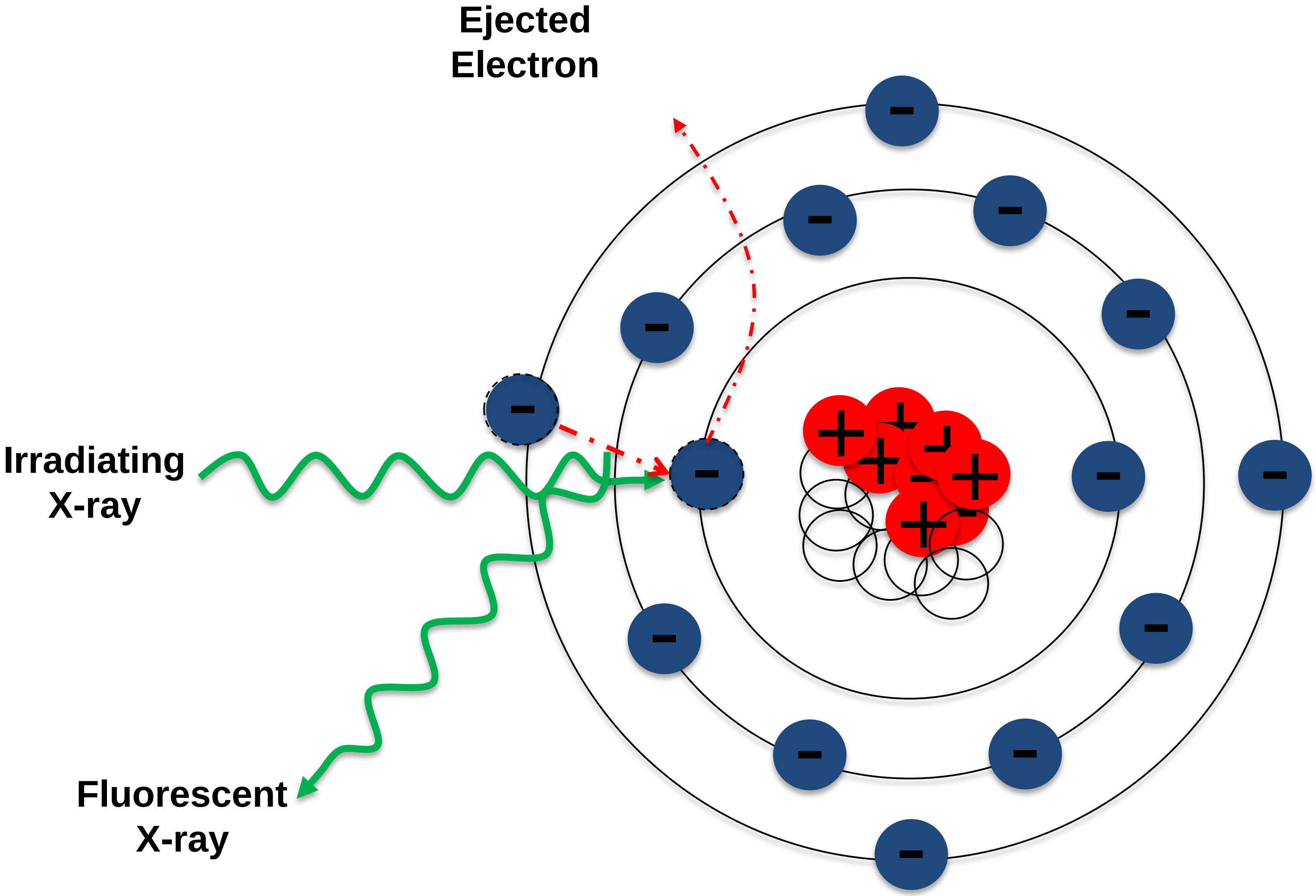
- **Thickness**
- **Density**
- **Sample material**



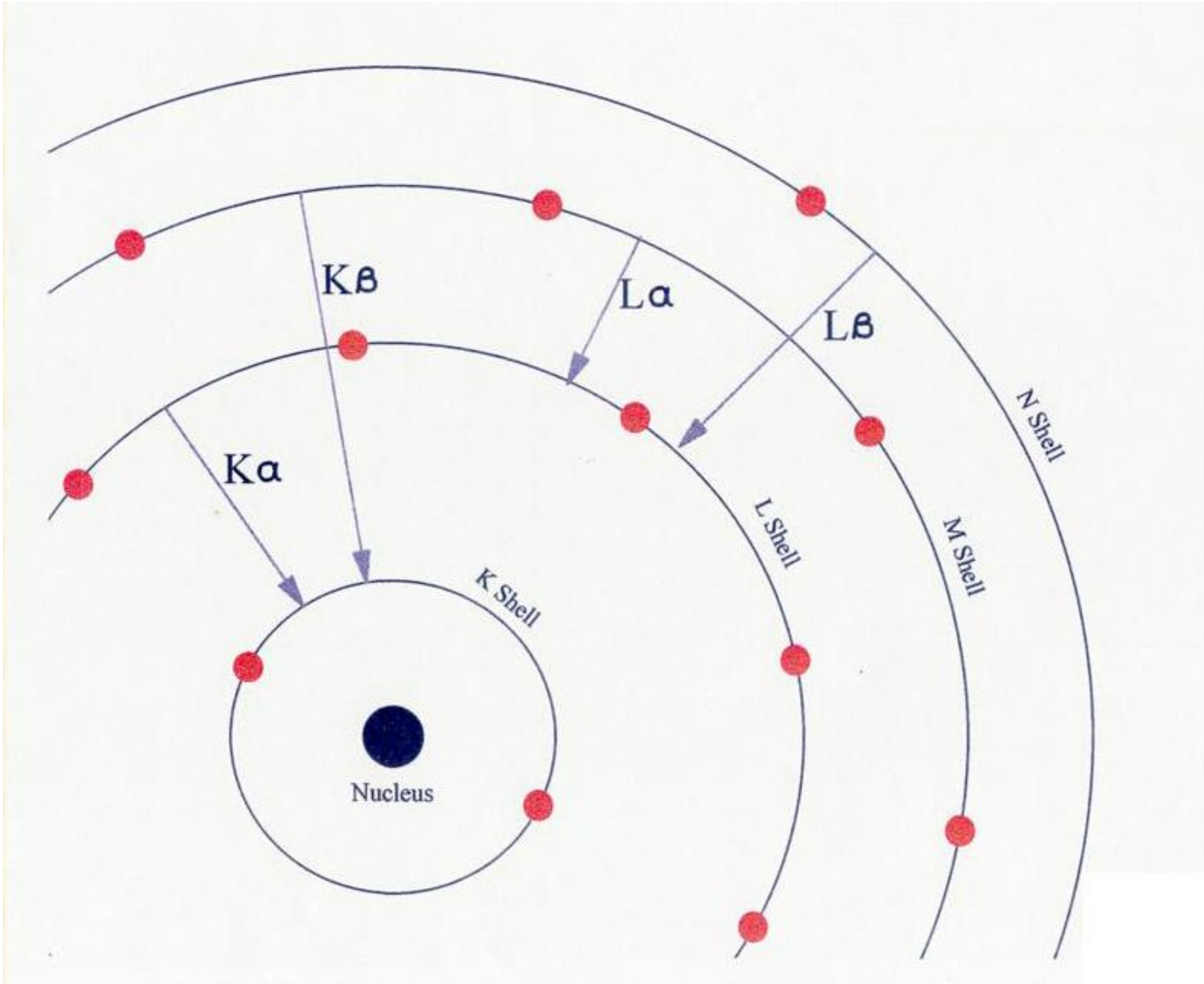
X-ray penetration depth (Rh-Kα; ~20 keV):

Pb	25 µm
Fe	200 µm
H_2O	3 cm

How Do X-Rays Interact with Atoms?



Types of Transitions



These are "Characteristic X-rays"

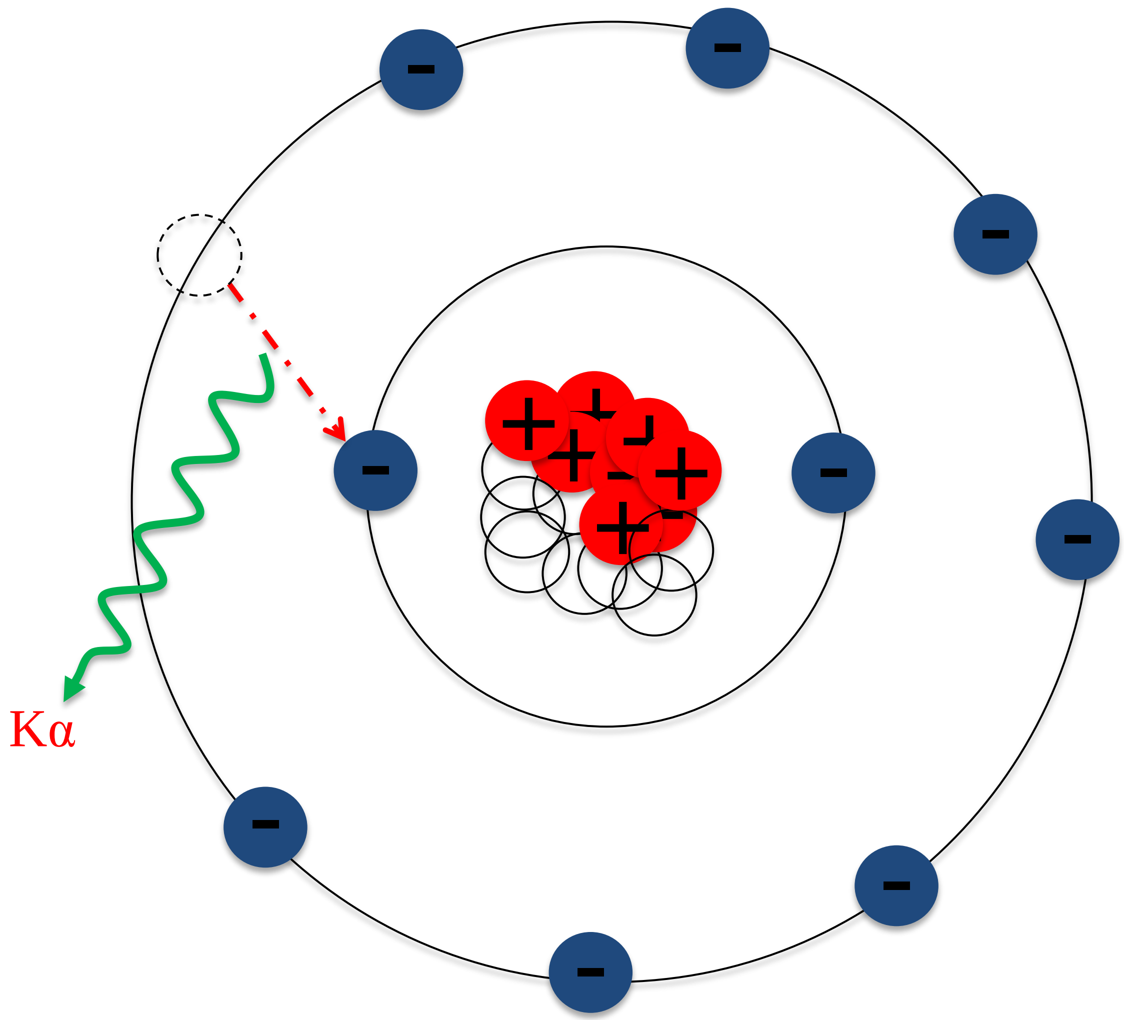
Energy of X-Rays: Example

$$E = \frac{hc}{\lambda}$$

$$= \frac{(4.14 \times 10^{-18} keV \cdot s) \times (3.00 \times 10^{17} nm \cdot s)}{0.194\ nm}$$

$$= 6.40\ keV$$

Fe atom



Energy of X-Rays: Example

Energy Table

element	Kα	Kβ1	Kab	Lα1	Lβ1	Lβ2	Lγ1	LIab	LIIab	LIIIab	Mα1
1 H											
2 He											
3 Li											
4 Be											
5 B	0.183		0.192								
6 C	0.277		0.284								
7 N	0.392		0.400								
8 O	0.525		0.532								
9 F	0.677		0.687								
10 Ne	0.849		0.867								
11 Na	1.041	1.067	1.072								
12 Mg	1.254	1.296	1.303								
13 Al	1.487	1.553	1.560								
14 Si	1.740	1.829	1.840								
15 P	2.013	2.136	2.144								
16 S	2.308	2.464	2.471								
17 Cl	2.622	2.816	2.820								
18 Ar	2.957	3.191	3.203								
19 K	3.313	3.590	3.608								
20 Ca	3.691	4.013	4.038	0.341	0.345				0.353	0.349	
21 Sc	4.089	4.461	4.489	0.396	0.400						
22 Ti	4.509	4.932	4.965	0.452	0.458						
23 V	4.950	5.428	5.464	0.511	0.519						
24 Cr	5.412	5.947	5.989	0.573	0.583			0.742	0.693	0.599	
25 Mn	5.895	6.491	6.539	0.638	0.649						
26 Fe	6.400	7.058	7.111	0.705	0.718				0.721	0.708	
27 Co	6.925	7.650	7.710	0.776	0.791				0.794	0.779	
28 Ni	7.473	8.265	8.332	0.852	0.869				0.871	0.854	
29 Cu	8.042	8.906	8.981	0.930	0.950				0.953	0.933	
30 Zn	8.632	9.572	9.661	1.012	1.035			1.198	1.045	1.022	
31 Ga	9.243	10.265	10.368	1.098	1.125			1.303	1.145	1.117	
32 Ge	9.876	10.983	11.104	1.188	1.219			1.413	1.249	1.217	
33 As	10.532	11.727	11.865	1.282	1.317			1.529	1.359	1.324	
34 Se	11.209	12.496	12.655	1.379	1.419			1.653	1.475	1.434	
35 Br	11.909	13.292	13.471	1.481	1.526			1.782	1.599	1.553	
36 Kr	12.634	14.113	14.325	1.586	1.637			1.916	1.730	1.677	
37 Rb	13.376	14.961	15.204	1.694	1.752			2.064	1.866	1.807	
38 Sr	14.142	15.837	16.108	1.807	1.872			2.217	2.009	1.941	
39 Y	14.934	16.739	17.038	1.923	1.996			2.377	2.154	2.080	
40 Zr	15.748	17.669	18.000	2.042	2.125	2.219	2.303	2.541	2.305	2.222	
41 Nb	16.584	18.622	18.987	2.166	2.257	2.367	2.462	2.710	2.464	2.371	
42 Mo	17.446	19.609	20.004	2.293	2.395	2.518	2.624	2.881	2.627	2.524	
43 Tc	18.327	20.620	21.047	2.424	2.537			3.055	2.795	2.678	
44 Ru	19.237	21.657	22.120	2.559	2.683	2.836	2.965	3.233	2.966	2.838	
45 Rh	20.170	22.725	23.218	2.697	2.835	3.001	3.144	3.417	3.145	3.002	
46 Pd	21.125	23.820	24.349	2.839	2.990	3.172	3.329	3.608	3.330	3.173	
47 Ag	22.105	24.942	25.517	2.984	3.151	3.348	3.520	3.807	3.526	3.351	
48 Cd	23.110	26.097	26.715	3.134	3.317	3.528	3.717	4.019	3.728	3.538	
49 In	24.140	27.279	27.943	3.287	3.487	3.714	3.921	4.237	3.939	3.730	
50 Sn	25.195	28.489	29.194	3.444	3.663	3.905	4.131	4.465	4.157	3.929	
51 Sb	26.279	29.725	30.486	3.605	3.844	4.101	4.348	4.699	4.382	4.132	
52 Te	27.382	30.996	31.816	3.770	4.030	4.302	4.571	4.940	4.613	4.342	
53 I	28.515	32.296	33.169	3.938	4.221	4.508	4.801	5.192	4.854	4.599	
54 Xe	29.669	33.628	34.594	4.110				5.453	5.104	4.782	
55 Cs	30.857	34.985	35.990	4.287	4.620	4.936	5.281	5.721	5.358	5.012	
56 Ba	32.071	36.381	37.458	4.466	4.828	5.157	5.531	5.996	5.623	5.247	
57 La	33.302	37.800	38.940	4.651	5.042	5.384	5.789	6.268	5.889	5.484	0.833
58 Ce	34.575	39.261	40.452	4.840	5.262	5.613	6.052	6.548	6.161	5.724	0.883
59 Pr	35.865	40.744	42.000	5.034	5.489	5.850	6.322	6.835	6.439	5.963	0.929
60 Nd	37.188	42.272	43.580	5.231	5.722	6.090	6.602	7.130	6.724	6.210	0.978
61 Pm	38.541	43.826	45.201	5.433	5.962	6.339	6.892	7.436	7.014	6.461	
62 Sm	39.918	45.416	46.858	5.636	6.205	6.587	7.178	7.748	7.314	6.718	1.081
63 Eu	41.328	47.035	48.526	5.846	6.457	6.843	7.481	8.061	7.620	6.981	1.131
64 Gd	42.768	48.698	50.237	6.058	6.714	7.103	7.786	8.386	7.932	7.243	1.185
65 Tb	44.233	50.380	52.007	6.273	6.978	7.367	8.102	8.717	8.253	7.516	1.240
66 Dy	45.734	52.116	53.790	6.495	7.248	7.636	8.419	9.055	8.583	7.790	1.293
67 Ho	47.268	53.883	55.624	6.720	7.526	7.912	8.747	9.400	8.917	8.068	1.348
68 Er	48.813	55.674	57.480	6.949	7.811	8.189	9.089	9.758	9.262	8.358	1.406
69 Tm	50.421	57.507	59.380	7.180	8.102	8.469	9.426	10.121	9.617	8.650	1.462
70 Yb	52.051	59.380	61.318	7.416	8.402	8.759	9.780	10.491	9.978	8.944	1.522
71 Lu	53.696	61.288	63.290	7.656	8.709	9.049	10.144	10.874	10.345	9.249	1.581
72 Hf	55.400	63.225	65.324	7.899	9.023	9.348	10.516	11.274	10.737	9.558	1.645
73 Ta	57.110	65.221	67.420	8.146	9.343	9.652	10.896	11.682	11.133	9.877	1.710
74 W	59.372	67.237	69.498	8.398	9.673	9.962	11.286	12.100	11.539	10.200	1.776
75 Re	60.658	69.304	71.668	8.653	10.010	10.276	11.686	12.531	11.955	10.531	1.843
76 Os	62.492	71.420	73.845	8.912	10.355	10.599	12.096	12.972	12.381	10.868	1.914
77 Ir	64.341	73.582	76.111	9.175	10.709	10.921	12.512	13.424	12.820	11.212	1.980
78 Pt	66.267	75.739	78.372	9.443	11.071	11.251	12.942	13.883	13.273	11.563	2.050
79 Au	68.199	77.978	80.719	9.714	11.443	11.585	13.382	14.353	13.736	11.922	2.123
80 Hg	70.167	80.249	83.100	9.989	11.823	11.924	13.830	14.843	14.215	12.287	2.195
81 Tl	72.168	82.602	85.507	10.269	12.214	12.272	14.292	15.343	14.701	12.661	2.271
82 Pb	74.243	84.921	87.995	10.552	12.614	12.623	14.765	15.855	15.205	13.041	2.346
83 Bi	76.345	87.313	90.566	10.839	13.024	12.980	15.248	16.376	15.720	13.427	2.423
84 Po	78.472	89.779		11.131	13.447	13.340	15.744				
85 At	80.614	92.319		11.427	13.876		16.252				
86 Rn	82.878	94.862		11.728	14.315		16.771				
87 Fr	85.096	97.473		12.032	14.771	14.450	17.304				
88 Ra	87.437	100.149		12.341	15.235	14.841	17.850				
89 Ac	89.779	102.807		12.653	15.714		18.409				
90 Th	92.182	105.609	109.624	12.969	16.203	15.625	18.984	20.463	19.683	16.299	2.996
91 Pa	94.645	108.473		13.292	16.703	16.025	19.568	21.172	20.362	16.768	3.083
92 U	97.167	111.297	115.658	13.616	17.220	16.428	20.167	21.771	20.947	17.165	3.171
93 Np	99.427	113.748		13.945	17.750	16.841	20.785				
94 Pu											
95 Am											
96 Cm											
97 Bk											
98 Cf											
99 Es											
100 Fm											
101 Md											
102 No											
103 Lr											

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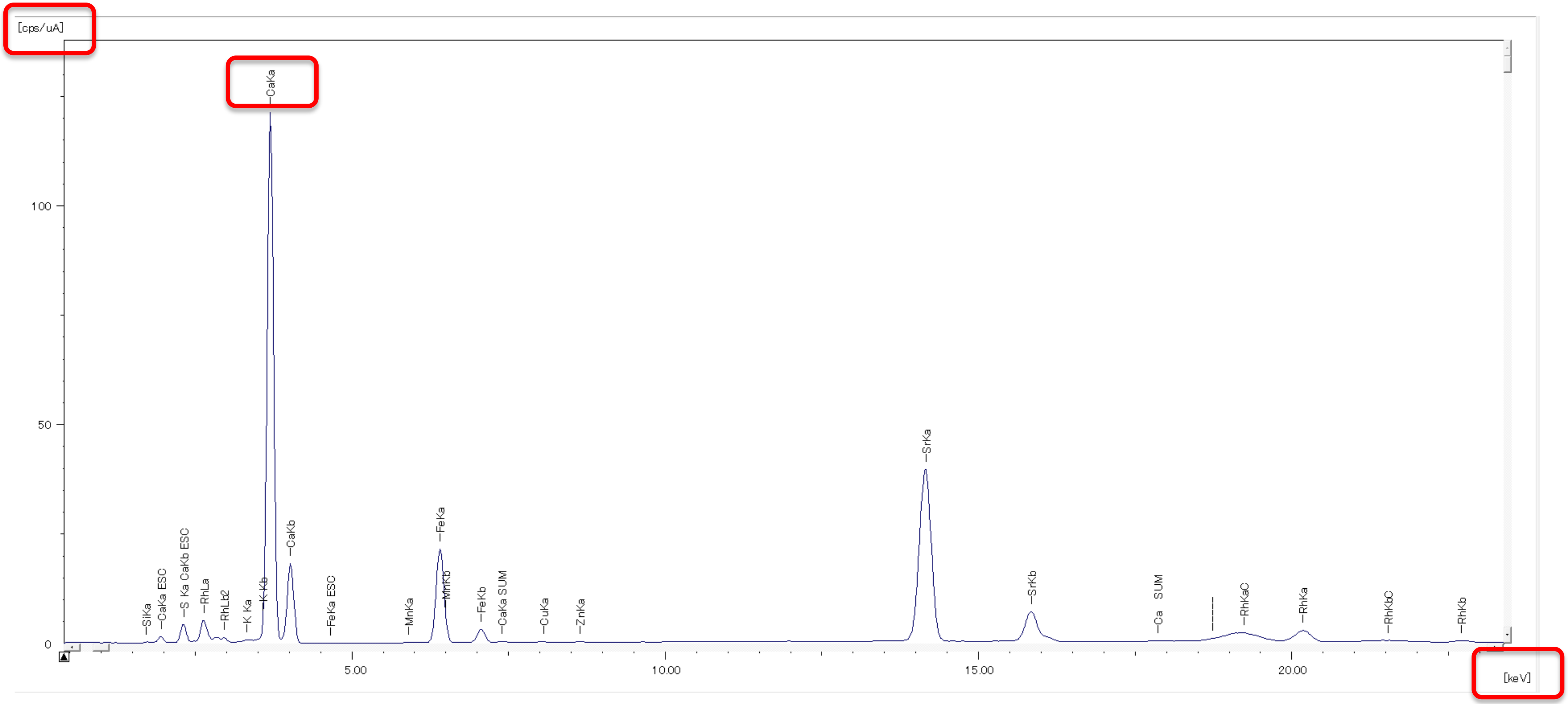
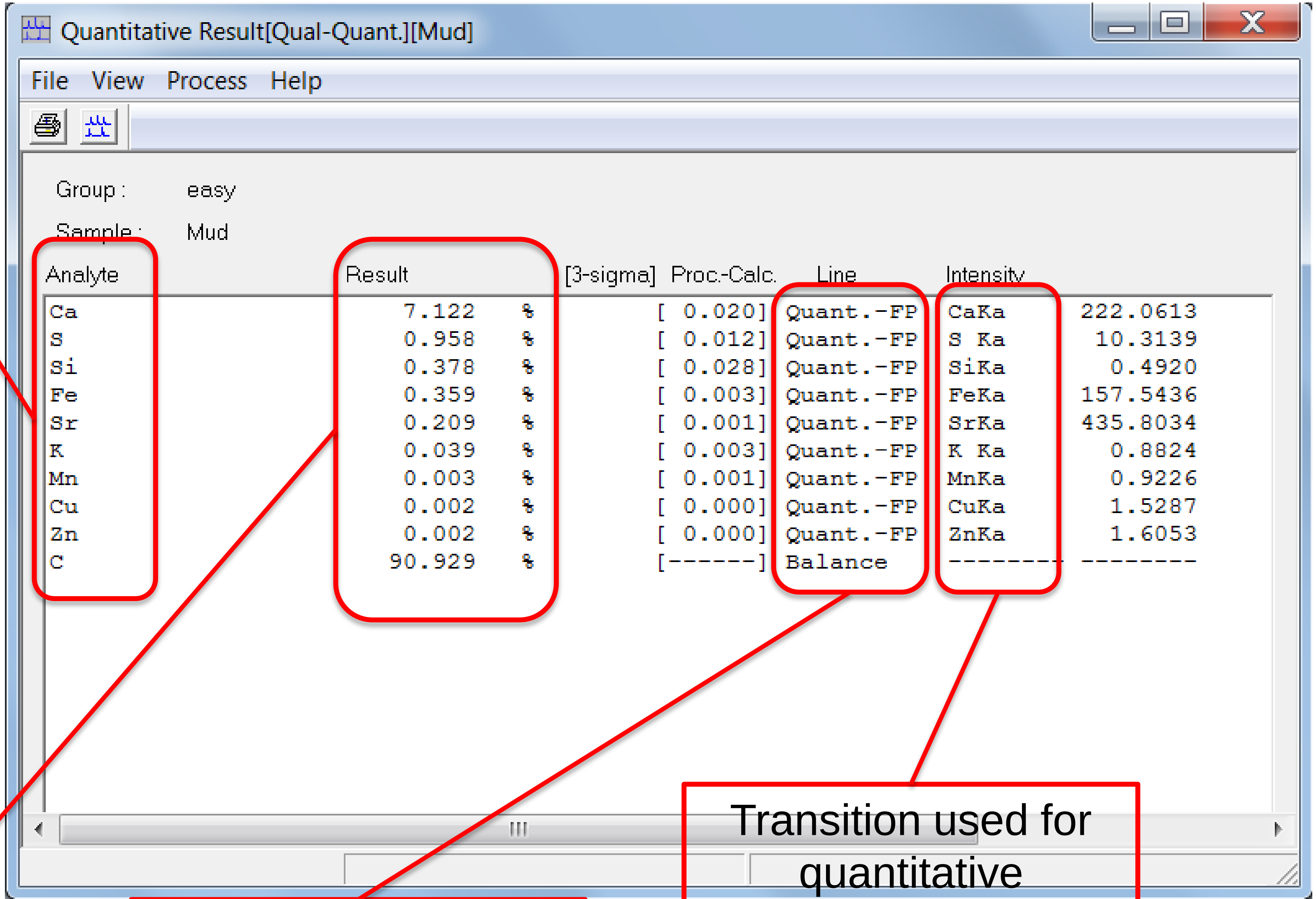
since 1875

25 Mn	5.895
26 Fe	6.400
27 Co	6.925

EDX Spectrum



EDX Data Output



Analyte	Result		[3-sigma]	Proc.-Calc.	Line	Intensity
Ca	7.122	%	[0.020]	Quant.-FP	CaKa	222.0613
S	0.958	%	[0.012]	Quant.-FP	S Ka	10.3139
Si	0.378	%	[0.028]	Quant.-FP	SiKa	0.4920
Fe	0.359	%	[0.003]	Quant.-FP	FeKa	157.5436
Sr	0.209	%	[0.001]	Quant.-FP	SrKa	435.8034
K	0.039	%	[0.003]	Quant.-FP	K Ka	0.8824
Mn	0.003	%	[0.001]	Quant.-FP	MnKa	0.9226
Cu	0.002	%	[0.000]	Quant.-FP	CuKa	1.5287
Zn	0.002	%	[0.000]	Quant.-FP	ZnKa	1.6053
C	90.929	%	[------]	Balance	--------	--------

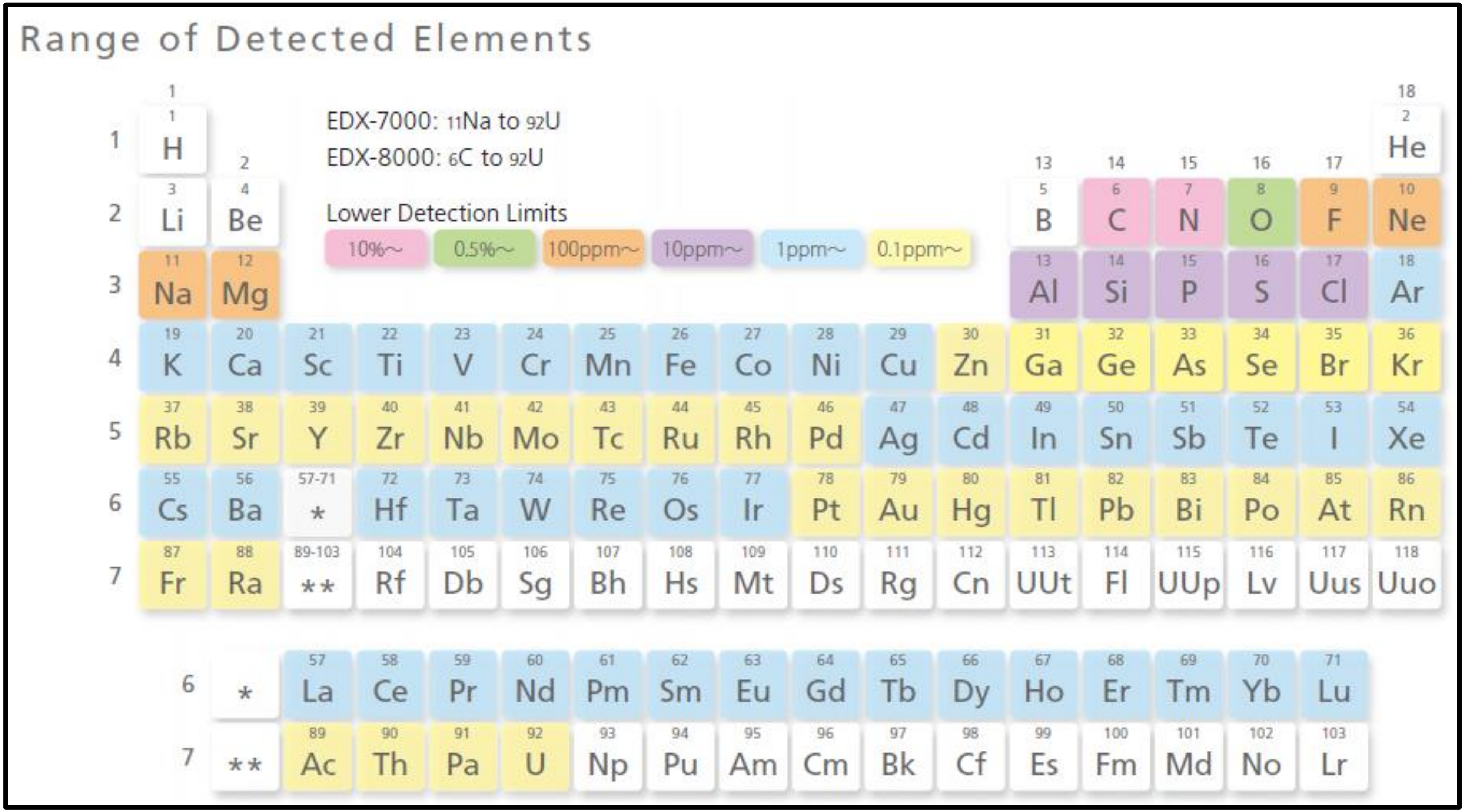
List of elements present, including carbon as a balance

Amount present in sample; can be reported in various units

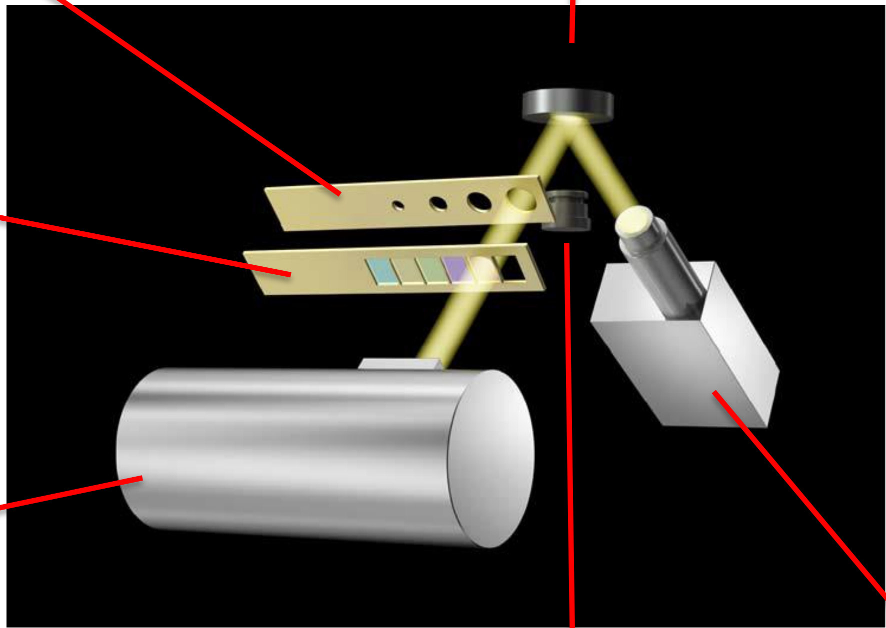
Type of analysis

Transition used for quantitative calculation

Analytical Range



EDX System


Sample
Collimator
Filters
X-ray tube
C-MOS camera
Detector (SDD)

Why use EDX?

- **Elemental analysis is traditionally done by AA/ICP**
    - This requires significant sample prep and cost of analysis is high
- With EDX, there is:
    - Minimal to no sample prep (solvents, TDS, etc. are not a concern)
    - Detection limits for heavy (high Z) elements ≤ 0.1 ppm
    - Low cost of analysis in terms of both time and money
        - No gas requirements
        - No exhaust
        - No sample waste
        - Uses less bench space
        - Easy to use

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Example Applications

Electrical/electronic materials

- RoHS and halogen screening
- Thin-film analysis for semiconductors, discs, liquid crystals, and solar cells

Automobiles and machinery

- ELV hazardous element screening
- Composition analysis, plating thickness measurement, and chemical conversion coating film weight measurement for machine parts

Ferrous/non-ferrous metals

- Main component analysis and impurity analysis of raw materials, alloys, solder, and precious metals
- Composition analysis of slag

Mining

- Grade analysis for mineral processing

Ceramics

- Analysis of ceramics, cement, glass, bricks, and clay

Oil and petrochemicals

- Analysis of sulfur in oil
- Analysis of additive elements and mixed elements in lubricating oil

Chemicals

- Analysis of products and organic/inorganic raw materials
- Analysis of catalysts, pigments, paints, rubber, and plastics

Environment

- Analysis of soil, effluent, combustion ash, filters, and fine particulate matter

Pharmaceuticals

- Analysis of residual catalyst during synthesis
- Analysis of impurities and foreign matter in active pharmaceutical ingredients

Agriculture and foods

- Analysis of soil, fertilizer, and plants
- Analysis of raw ingredients, control of added elements, and analysis of foreign matter in foods

Others

- Composition analysis of archeological samples and precious stones, analysis of toxic heavy metals in toys and everyday goods

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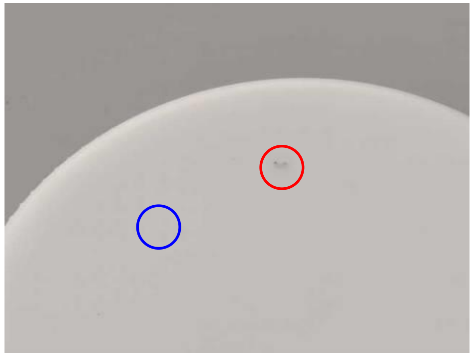
Application: Foreign Matter Identification

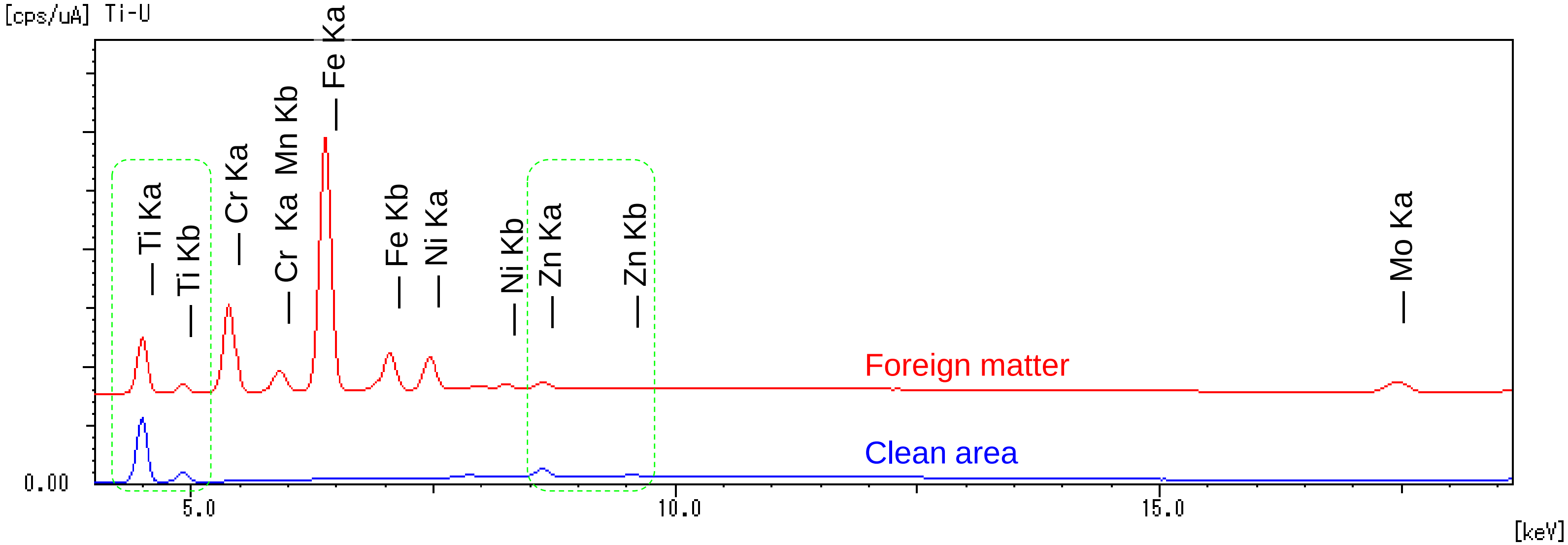
Analysis Example: Foreign Matter Adhering to a Plastic Extruded Part



Sample Appearance

Red circle: Foreign matter

Blue circle: Clean area



Analyte	Result	
Fe	68.287	%
Cr	16.166	%
Ni	11.424	%
Mo	2.505	%
Mn	1.619	%

Quantitative Analysis Results for Foreign Matter by FP Method
(Ti and Zn are excluded from the quantitative calculations.)

Matching Results ⇒

Matching Result

Candidate	Diff. Factor
SUS_316	0.72200
SUS_316N	0.72200
SUS_316LN	1.10292
SUS_321	1.17556
SUS_305	1.18874
SUS_347	1.24270
SUS_316L	1.34046
SUS_304L	1.40968
SUS_304LN	1.49044
SUS_304N2	1.65853

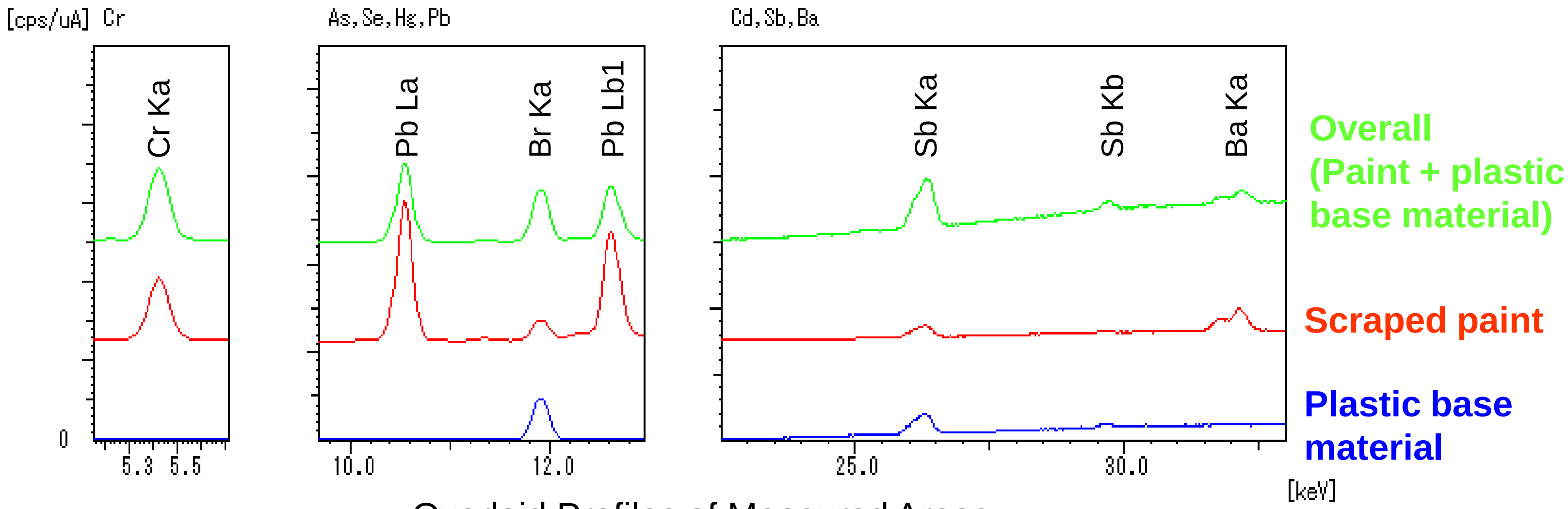
Display Data... Print Close

Application: Hazardous Substances in Products

Analysis Example: Screening Analysis for 8 Controlled Elements in Toys

Sample Appearance

PE Resin Standard Samples Containing the 8 Controlled Elements in Toys



Overlaid Profiles of Measured Areas

Units: mm N.D. = not detected

Element	Sb	As	Ba	Cd	Cr	Pb	Hg	Se
Overall	326	N.D	351	N.D	2697	5010	N.D	12.8
Scraped paint	293	N.D	983	N.D	2013	7918	N.D	19.1
Plastic base material	351	N.D	51	N.D	29	77	N.D	N.D

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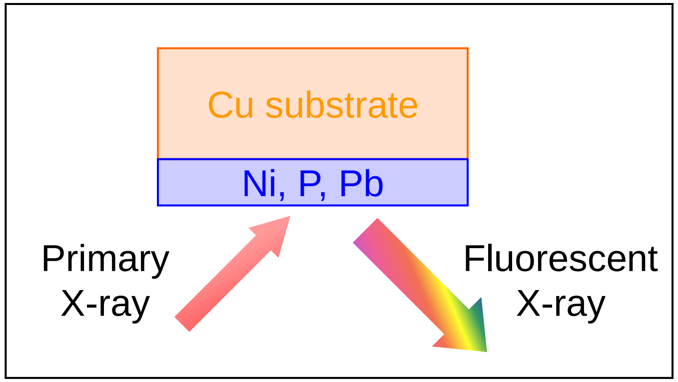
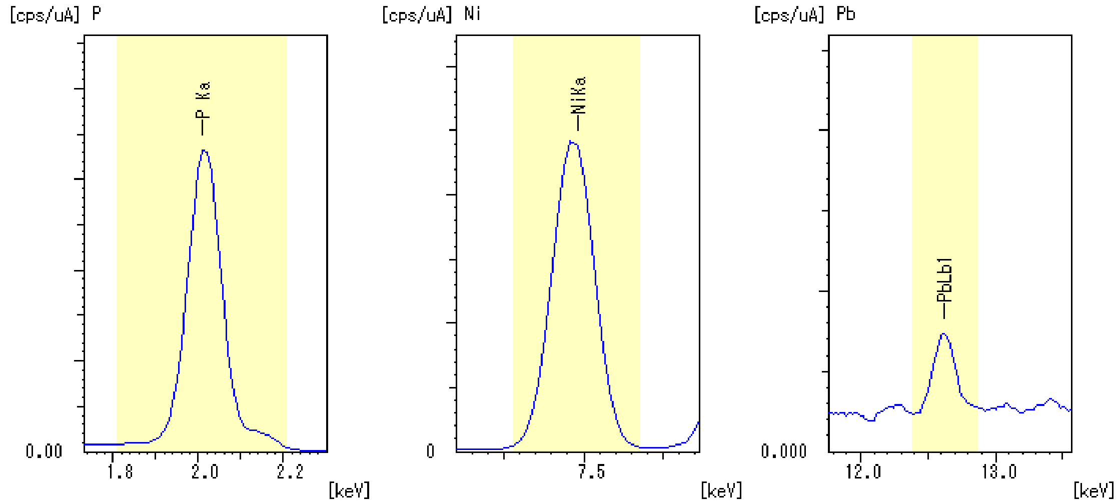
Application: Thin Films

Analysis Example: Film Thickness and Composition Measurements of Electro-less Nickel Plating





Peak Profiles of Ni, P, and Pb

Layer Info		Analyte	Result		[3-sigma]	Proc.-Calc.	Line
1	Layer1						
1	Layer	Layer1	1.805	um	[------]	Total	--------
1	Elem.	P	11.244	%	[0.036]	Quant.-FP	P Ka
1	Elem.	Ni	88.738	%	[0.145]	Quant.-FP	NiKa
1	Elem.	Pb	0.018	%	[0.003]	Quant.-FP	PbLb1
B	Base						
B	Elem.	Cu	100.000	%	[------]	Fix	--------

Quantitative Analysis Results by Film FP Method

Application: Cement

Analysis Example: Qualitative Analysis of Cement

Sample

NIST Certificate of Analysis Standard Reference Materials® Portland Cement
SRM 1880b, 1881a, 1884b, 1886a, 1887b, 1888b, 1889a
Table 1 shows the standard values.

Table 1 Standard Values

[mass%]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O
1880b	20.42	5.183	3.681	64.16	1.176	2.710	0.646	0.091
1881a	22.26	7.060	3.090	57.58	2.981	3.366	1.228	0.199
1884b	19.30	4.851	2.937	61.31	4.740	4.034	0.957	0.278
1886a	22.38	3.875	0.152	67.87	1.932	2.086	0.093	0.021
1887b	19.59	4.911	2.471	61.15	3.624	4.599	0.961	0.288
1888b	20.42	4.277	3.062	63.13	3.562	2.634	0.658	0.136
1889a	20.66	3.89	1.937	65.34	0.814	2.690	0.605	0.195

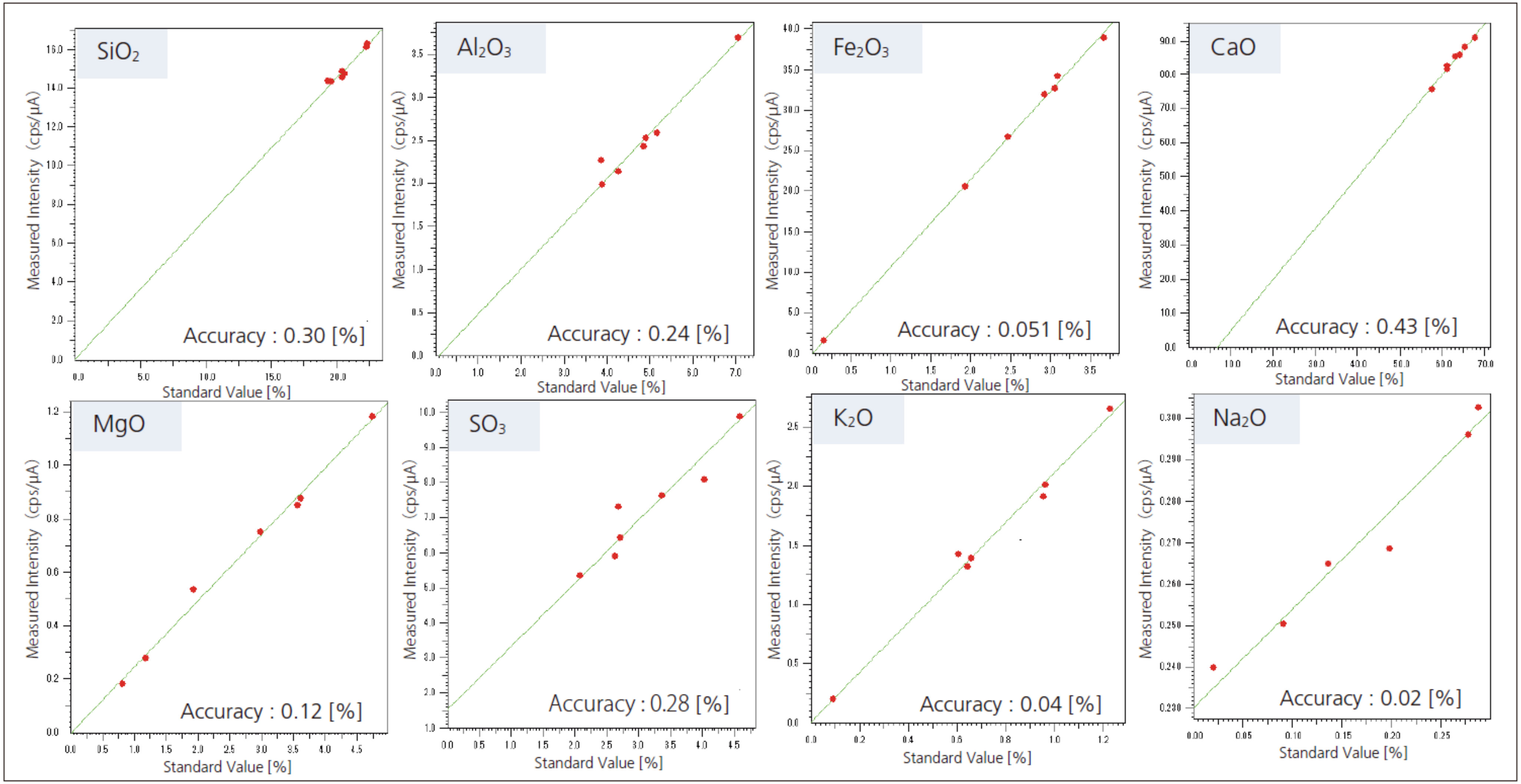
Application: Cement

Sample Preparation

Pressure forming was conducted using a vinyl chloride ring (inner diameter 35 mmϕ), with a total pressure of 250 kN for 60 seconds. A photograph of the sample is shown in Fig. 1.

Fig. 1 Pressure-Formed Briquette of Cement

Application: Cement



Application: Cement

Lower Limits of Detection (L.L.D.)

The lower limits of detection calculated using the above calibration curves are shown in Table 2.

Table 2 Lower Limits of Detection (300 sec, 100 sec only for Fe_2O_3)

[mass%]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O
Lower Limit of Detection (LLD)	–	0.0083	0.0022	–	0.0157	0.0066	0.0049	0.0159

Repeatability

Using the above calibration curve method, the repeatability test results for SRM 1880b shown in Table 3 were obtained by simply conducting 10 repeat measurements. The X-ray fluorescence spectra for each measurement element of each sample are shown in Fig. 3.

Table 3 Repeatability for SRM 1880b (300 sec, 100 sec only for Fe_2O_3)

[mass%]

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O
1	20.09	5.032	3.615	64.12	1.088	2.729	0.622	0.100
2	20.05	5.031	3.609	64.15	1.087	2.740	0.621	0.098
3	20.04	5.043	3.615	64.18	1.087	2.736	0.612	0.107
4	20.01	5.022	3.625	64.16	1.089	2.738	0.616	0.105
5	19.96	5.038	3.618	64.18	1.148	2.744	0.620	0.100
6	20.02	5.045	3.625	64.18	1.094	2.744	0.615	0.114
7	20.11	5.052	3.630	64.18	1.157	2.743	0.616	0.110
8	20.09	5.037	3.628	64.17	1.174	2.740	0.619	0.112
9	19.98	5.032	3.631	64.17	1.101	2.741	0.616	0.109
10	20.14	5.040	3.614	64.21	1.158	2.745	0.621	0.100
Average	20.05	5.037	3.621	64.17	1.118	2.740	0.618	0.105
Standard Deviation	0.059	0.008	0.008	0.025	0.036	0.005	0.003	0.006
Coefficient of Variation [%]	0.30	0.17	0.22	0.04	3.2	0.17	0.52	5.5

Application: Polymer Film

Analysis Example: Determination of Thickness and Concentration

- Shimadzu's newly-developed "Background FP" method (BG-FP) incorporates X-ray scattering theory into the standard FP calculation
- Uses Compton scattering to determine thickness of a polymer film while simultaneously determining its constituent elements

Application: Polymer Film

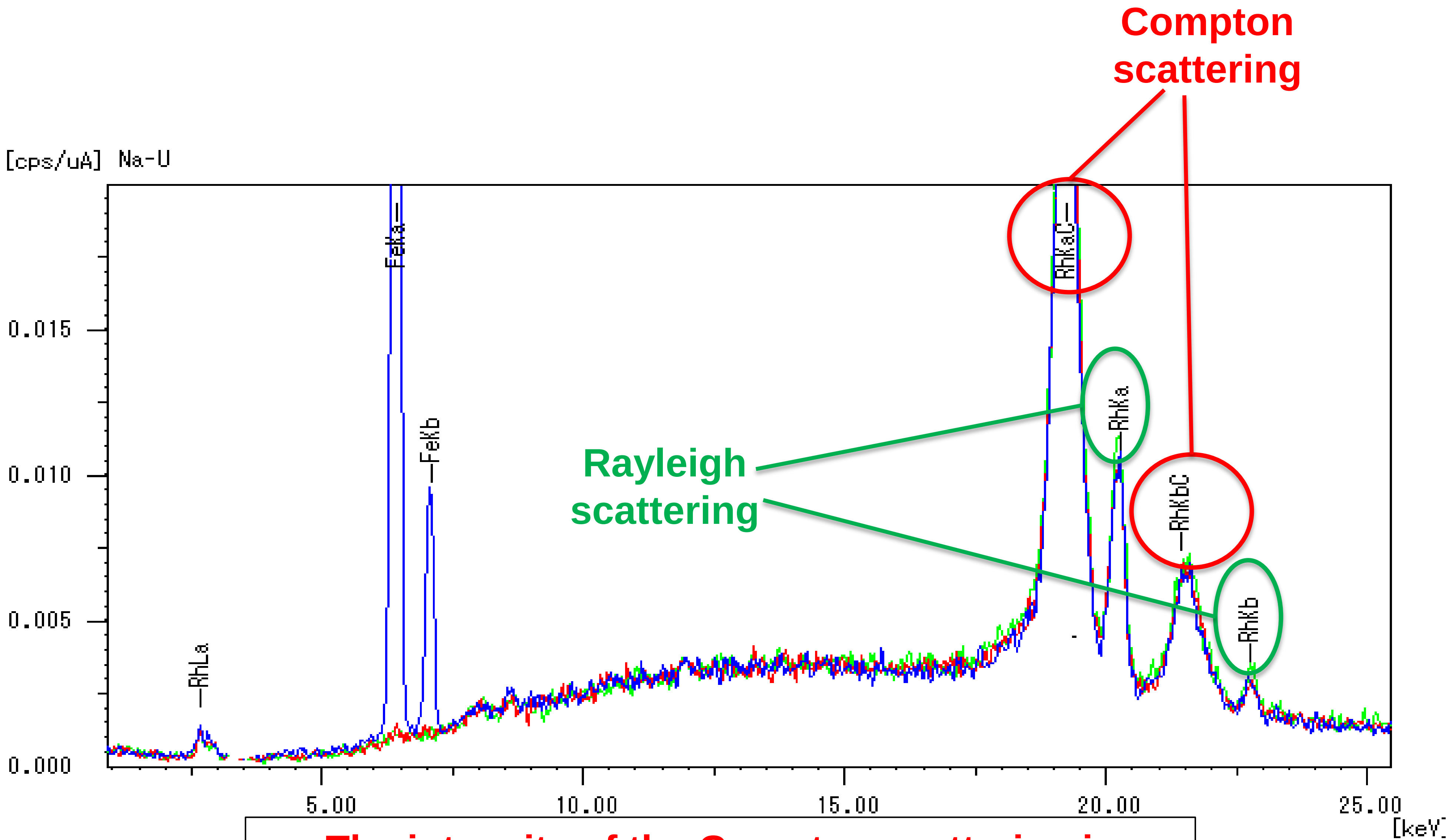
Scattered Radiation

Some of the X-rays from the tube do not generate fluorescent X-rays when they strike the sample. Instead, they are scattered within the sample. There are two types scattering radiation:

Compton Scattering: When the source characteristic X-rays (Rh) that strike the material suffer from some energy loss (inelastic scattering)

Rayleigh Scattering: When the source characteristic X-rays (Rh) strike the sample without any change in energy (elastic scattering)

Application: Polymer Film

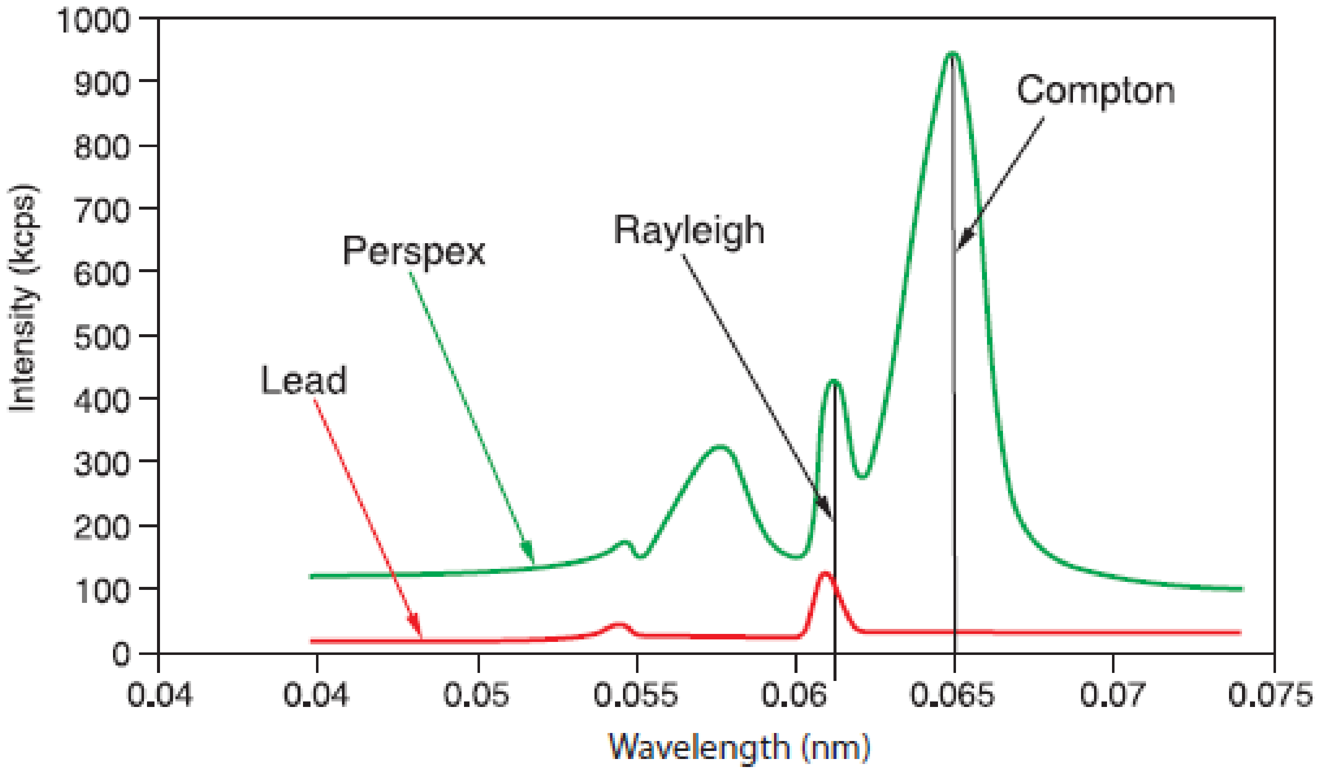


The intensity of the Compton scattering is influenced by the material/density of the sample

Application: Polymer Film

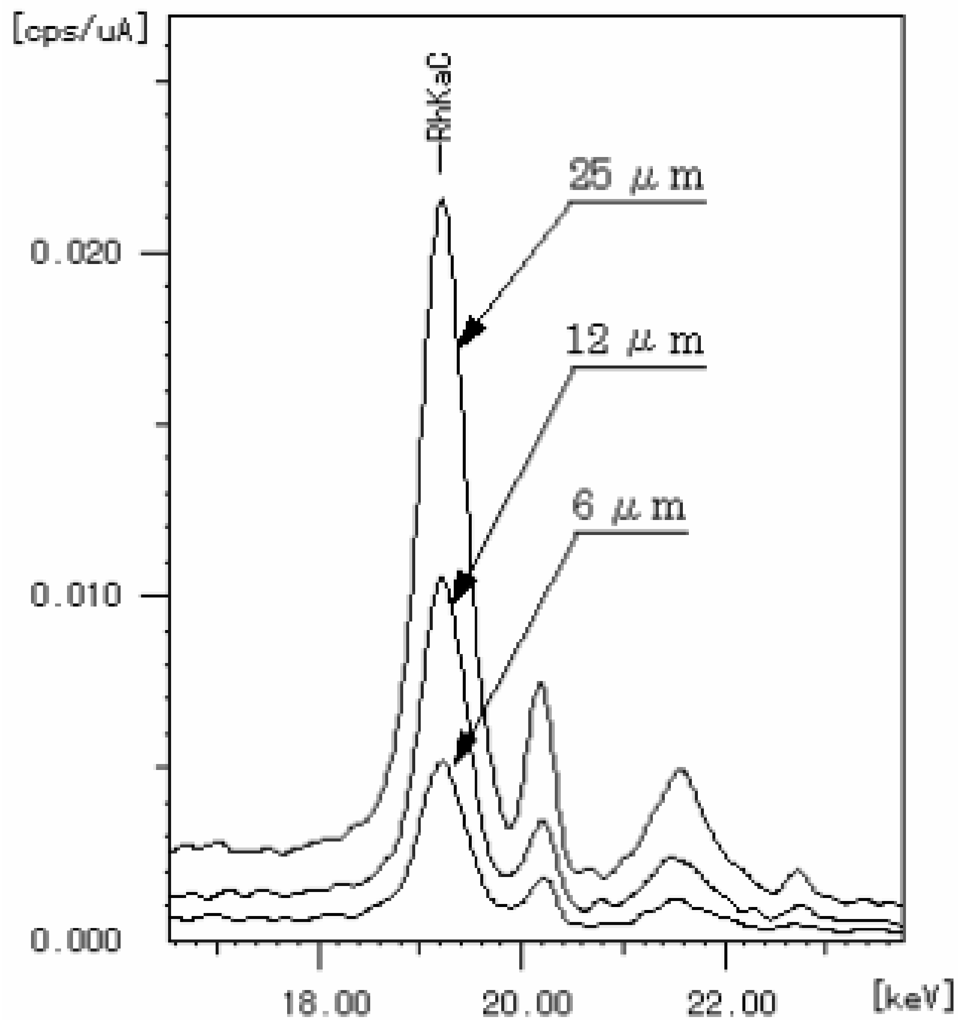
- **Samples with light elements give rise to high Compton scatter and low Rayleigh scatter**
  - **This is because they have more loosely bound electrons**

- **With very heavy elements, the Compton scattering disappears completely**



Application: Polymer Film

Qualitative Analysis of Polyester Films
In the BG-FP method of polymer film thickness determination, the Compton scattering lines of the “characteristic” X-rays of the X-ray tube target (Rh) is measured. The RhKa Compton scattering profiles of the 3 polymer films of differing thickness is shown superimposed on the same graph in Fig. 2. From this it can be seen that the intensity of the RhKa Compton scattering lines becomes greater as the thickness of the film increases.



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Application: Polymer Film

Determining the Thickness of Polyester Films

The results of the thickness determination analysis by BG-FP method are shown in Table 1. In order to calculate the film's thickness the density of the film is required. In this case the 1.39 g/cm3 density of polyester is used. In addition it was assumed that the composition of the film was $C_{10}H_8O_4$.

Table 1 Thickness Determination of Polyester Films by Background FP Method

Sample	Chemical Formula	Film Density	Determined Value	Reference Value	by Micrometer
Polyester Films	$(C_8H_{10}O_4)n$	1.39 g/cm^3	7.2 µm 14.5 µm 29.7 µm	6 µm 12 µm 25 µm	7-14 µm 14 µm 26-30 µm

Application: Polymer Film

Determination of Both the Thickness and the Concentration

The thickness of polyethylene that includes the elements Cr, Mn, Fe, Co, Ni, Cu and Zn was determined at the same time as the content of the elements within the polyethylene.
The quantitative profiles are shown in Fig. 3, while in Table 2 the values calculated from the quantitative profiles by the BG-FP method is shown together with their equivalent area density (30 mmφ) conversion values and standard values. Note that the major was assumed to be polyethylene $(CH_2)n$ and used as the balance(residue balance), while the density of the film was assumed to be that of polyethylene (0.92 g/cm^3).

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Application: Polymer Film

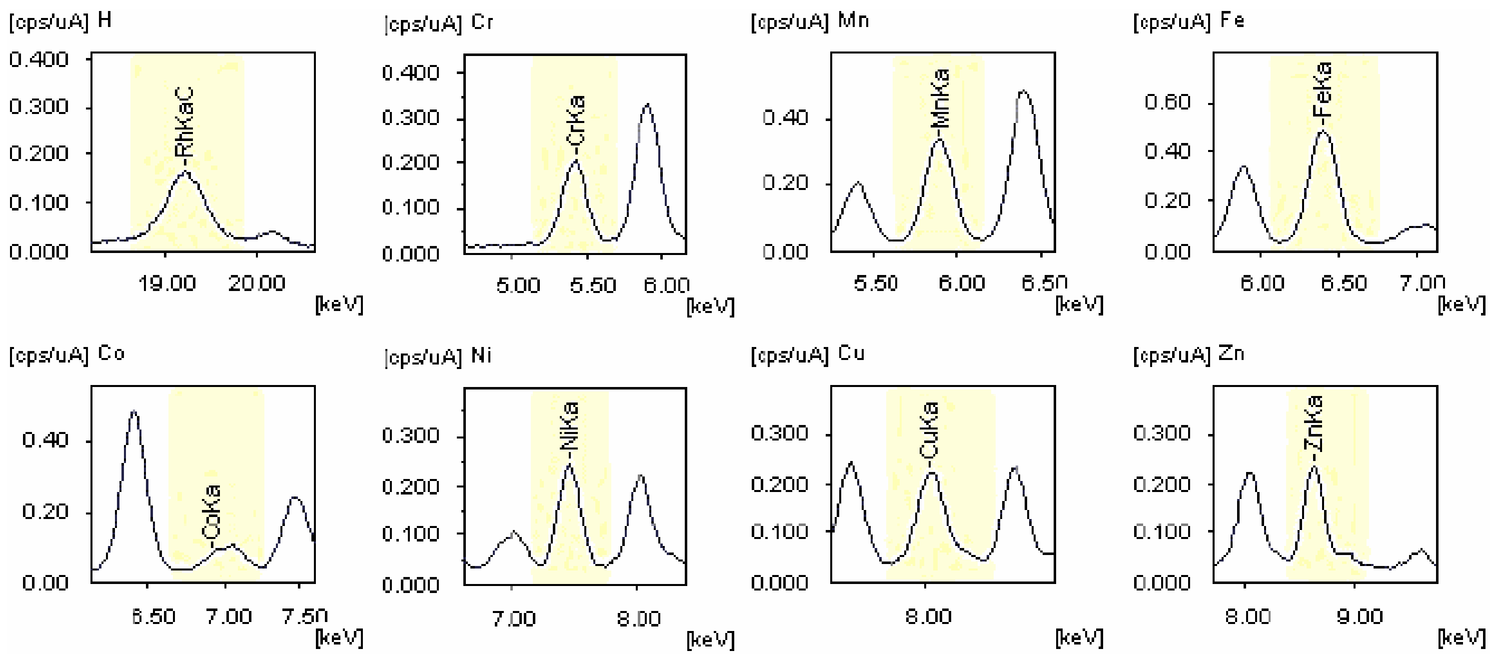

Fig.3 Profiles of Polyethylene Film for Quantitative Analysis

Table 2 Determined Thickness and Concentration of/in Polyethylene Film by Background FP Method

Sample	Film Density	Determined Value	Standard Value
Polyethylene Film including Inorganic Compounds	0.92 g/cm^3 $((CH_2)n)$	Cr 91 µg/30 mmφ (645 ppm)	100 µg/30mmφ (769ppm)
		Mn 297 (2096)	300 (2307)
		Fe 219 (1546)	200 (1538)
		Co 21 (149)	20 (154)
		Ni 87 (612)	100 (769)
		Cu 85 (598)	100 (769)
		Zn 88 (620)	100 (769)
		Thickness 218 µm	200 µm

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Application Notes

Screening Analysis with EDX-7000 Navi Software
Quantitative Analysis of Elements in Small Quantity of Organic Matter by EDXRF - New Feature of Background FP Method -
Quantitative Analysis of Cement by EDX-8000
Quantitative Analysis of Waste Oil by EDX-7000
TC Measurement and Elemental Composition Analysis of Fly Ash - Quantitation by TOC and XRF -
Quantitative Analysis of Tin (Sn) in Plastics by EDXRF
Analysis of Aqueous Solution by EDX-LE - Performance in Air Atmosphere -
Quantitative Analysis of Fluorine ($_9F$) by EDXRF
Quantitative Analysis of Antimony (Sb) in Plastics by EDXRF
Qualitative and Quantitative Analysis of Seafood by EDXRF
EDXRF Analysis of Arsenic and Lead in Dietary Supplement
QC Analysis of Magnesium Alloy Die Castings by EDXRF
EDXRF Analysis of PM2.5 (Particle Matter)

EDXRF Analysis of Sulfur and Other Elements in Oil
EDXRF Analysis of Lead, Cadmium, Silver, Copper in Lead-Free Solder Materials
Determination of Arsenic and Lead in Earth and Sand Using EDXRF [JIS K 0470]
Comparison of Calibration Curves of Lead, Cadmium and Chromium in Zinc Alloy and Copper Alloy
EDXRF Analysis of Lead, Cadmium, Mercury and Chromium in Zinc Alloy
EDXRF Analysis of Chlorine in Irregularly Shaped Plastic Samples
Analysis of Foreign Matter in Food Using EDX
EDXRF Analysis of Heavy Elements in a Toy and a Cup
EDXRF Analysis of Chlorine in Plastic (PE) Materials
Analysis of Sulfur in Oil Using Energy Dispersive X-Ray Fluorescence Spectrometer
Analysis of Foreign Matter Using CCD
EDXRF Analysis of Arsenic in Foods

Additional Information

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