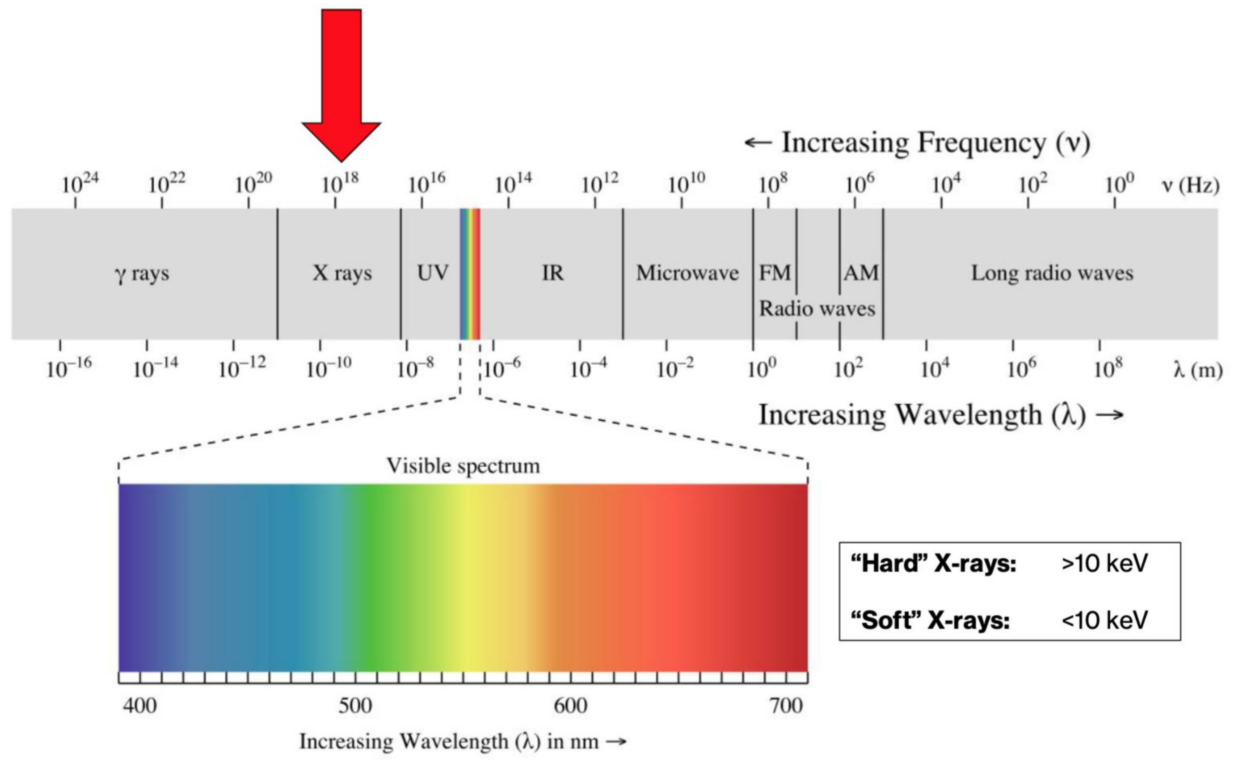
X-Ray Fluorescence

PHYS 199

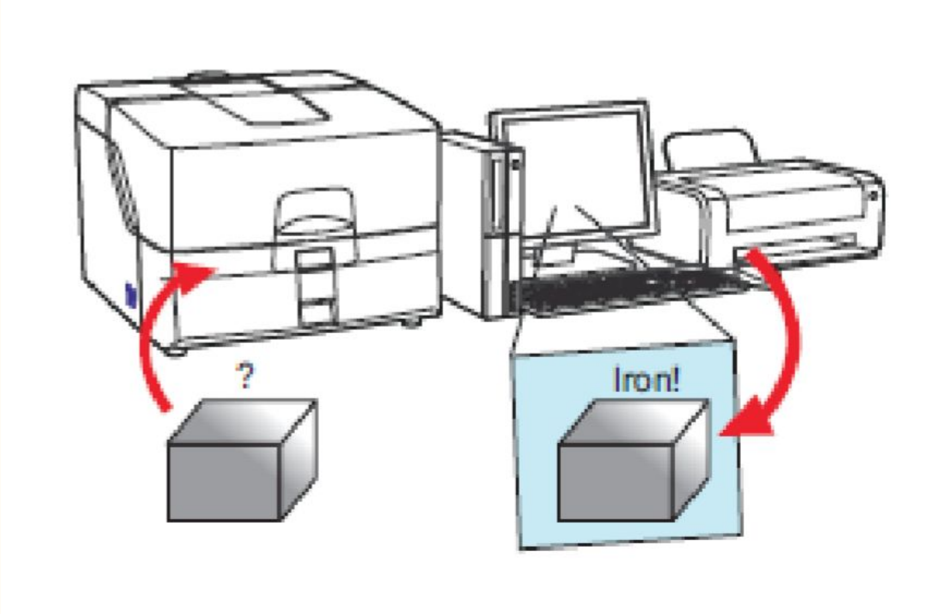
What are X-Rays?

- Electromagnetic radiation from 0.01 to 10 nm or 0.125-125 keV



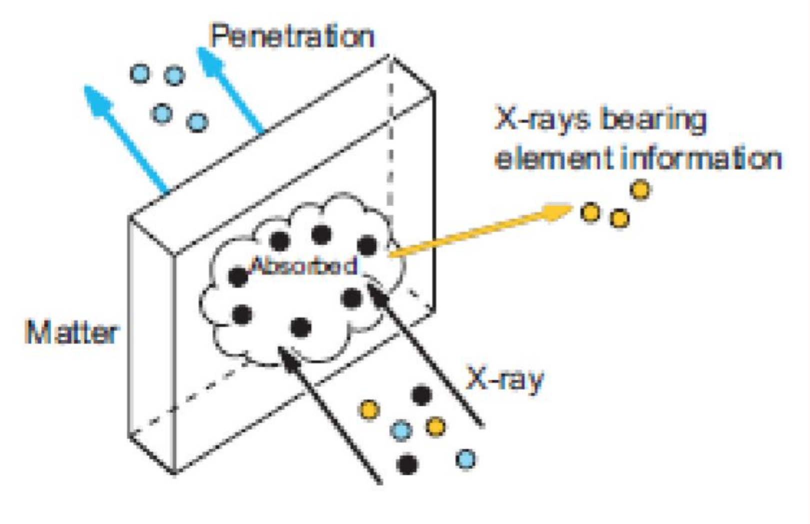
What is ED-XRF?

- Energy-dispersive X-Ray fluorescence
- Analytical method that determines elemental composition of a sample
- Fluorescence: process of absorbing energy (short λ) and emitting energy (longer λ)



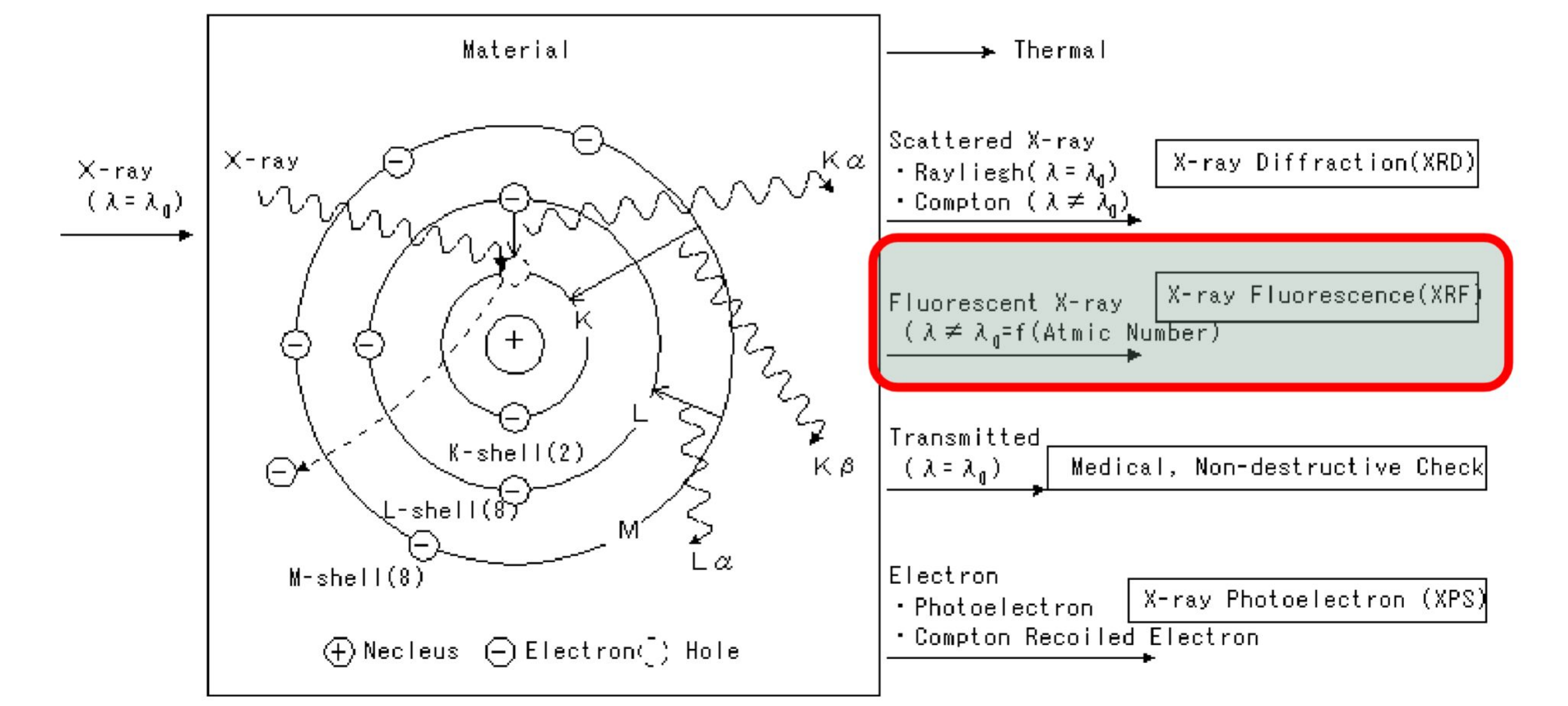
How do X-Rays interact with matter?

- 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



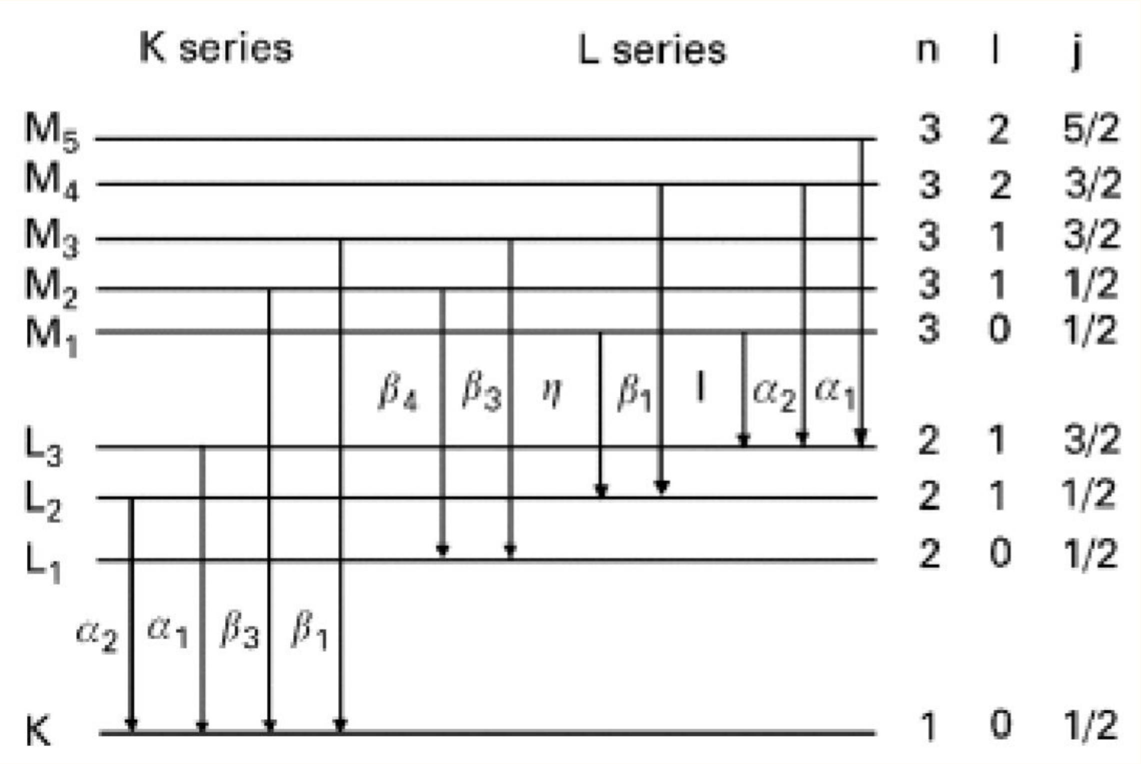
Effects X-Ray absorbance

- We focus on an X-ray excitation a lower-shell electron, ejection excited lower-shell electron, relaxation of a higher-shell electrons to fill vacancy, and emittance of a secondary X-ray as fluorescence



X-Ray Fluorescence: K-shell emission

- K-shell emission of secondary X-Rays occur when L or M shell electrons fill vacancies within K- shell electrons (2s and 2p electrons drop to the 1s shell)

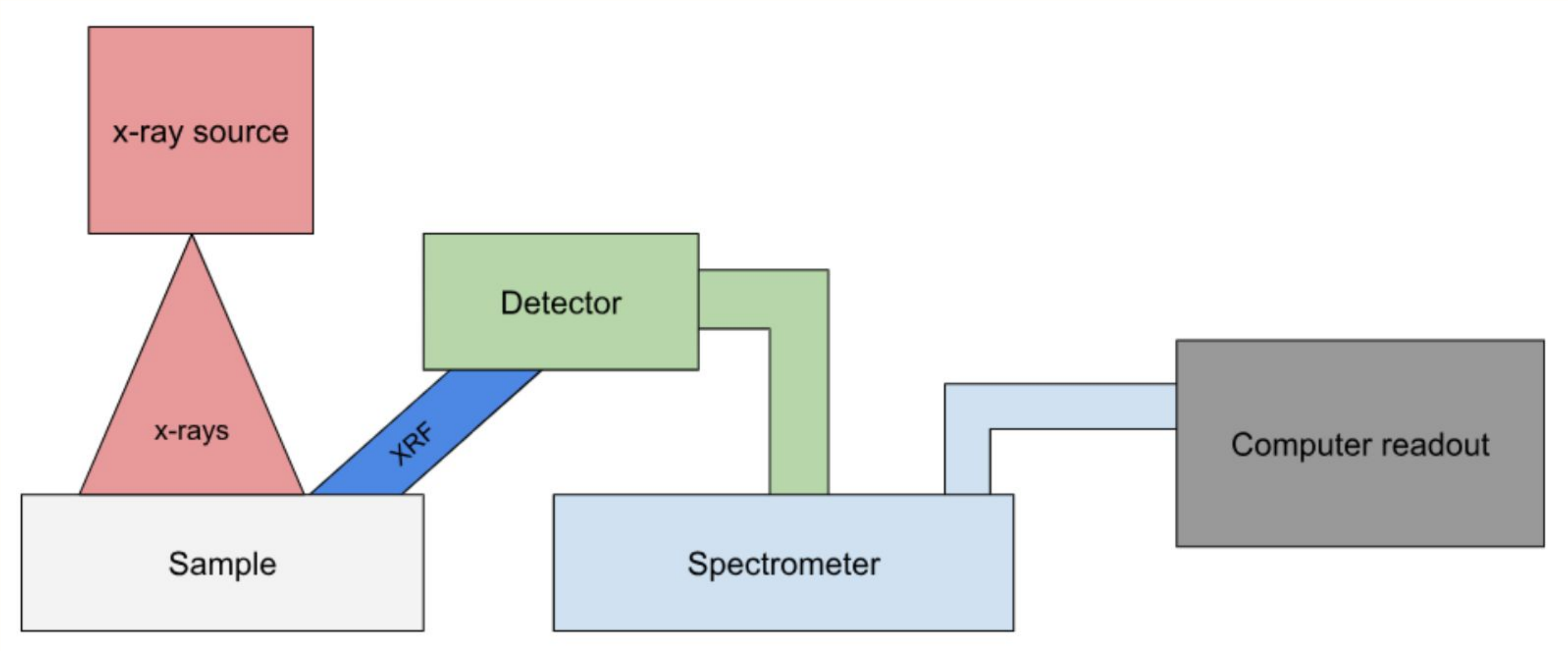


- n = principal quantum number
- l = angular momentum
- j = total angular and spin momentum

- Most ED-XRF devices are calibrated for Kα and Kβ lines
- Kα and Kβ lines are unique for every element

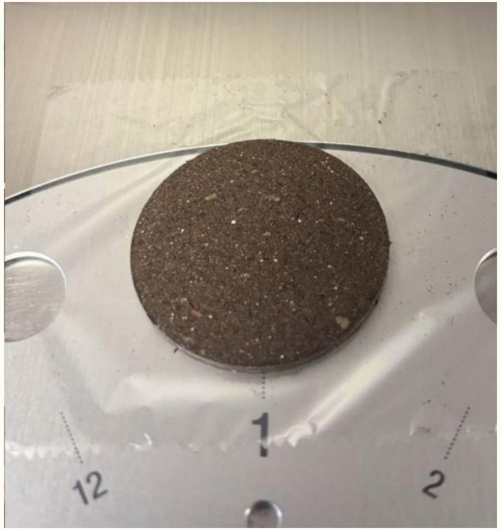
ED-XRF Schematic

- ED-XRF devices target a sample with electromagnetic radiation across the X-ray spectrum and detects all secondary X-rays
- From data scans, you can determine weight percent composition by element



Soil science application

- ED-XRF measures intensity (cps/uA) from 0.125-40 keV X-rays
- Each secondary X-ray is unique
- From data, you can determine weight percent composition by element

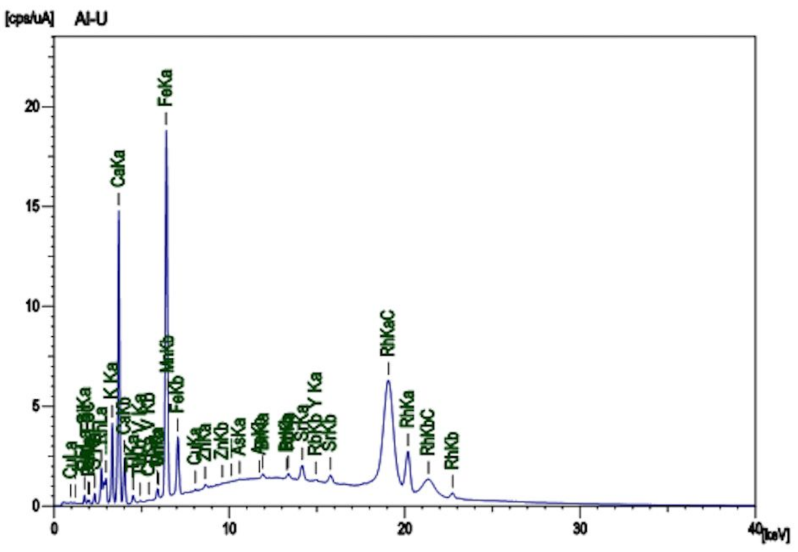


Analyte	Result
Ca	38.554 %
Si	24.712 %
K	13.382 %
Fe	11.996 %
S	4.750 %
P	4.730 %
Ti	0.853 %
Mn	0.444 %

Miracle-Gro® Indoor Potting Mix

Analyte	Result	[3-sigma]	Proc.-Calc.	Line	Int.(cps/uA)
Ca	38.554 %	[0.113]	Quan-FP	CaKa	87.3268
Si	24.712 %	[1.189]	Quan-FP	SiKa	1.8121
K	13.382 %	[0.076]	Quan-FP	K Ka	22.9147
Fe	11.996 %	[0.028]	Quan-FP	FeKa	135.4684
S	4.750 %	[0.065]	Quan-FP	S Ka	2.5702
P	4.730 %	[0.290]	Quan-FP	P Ka	0.7759
Ti	0.853 %	[0.036]	Quan-FP	TiKa	2.6699
Mn	0.444 %	[0.018]	Quan-FP	MnKa	3.7083
Sr	0.180 %	[0.007]	Quan-FP	SrKa	8.7959
Zn	0.088 %	[0.012]	Quan-FP	ZnKa	1.8651
Br	0.070 %	[0.008]	Quan-FP	BrKa	2.6929
Rb	0.064 %	[0.007]	Quan-FP	RbKa	2.8735
V	0.057 %	[0.020]	Quan-FP	V Ka	0.2577
As	0.042 %	[0.048]	Quan-FP	AsKb	0.2660
Cr	0.040 %	[0.016]	Quan-FP	CrKa	0.2590
Cu	0.027 %	[0.011]	Quan-FP	CuKa	0.4820
Y	0.011 %	[0.006]	Quan-FP	Y Ka	0.5493

☑ Profile



Applications of ED-XRF

- XRF is widely used in the agriculture and mining industry
- XRF is one of the many tools (along with ICP-OES) that is used for soil composition analysis
- Used to predict mineral stability, microbial/plant interactions, texture, pH buffering, aggregation, etc

References

(1) Deno, N. C.; Richey, H. G.; Liu, J. S.; Lincoln, D. N.; Turner, J. O. J. *Am. Chem. Soc.* **1965,** *87*, 4533-4538.

(2) Felder, R. M.; Rousseau, R. W. Elementary *Principles of Chemical Processes*, J. Wiley: New York, 2004, p. 6.

(3) Skoog, D. A.; Holler, J. F.; Crouch, S. R. *Principles of Instrumental Analysis*, 7th ed.; Cengage Learning: Boston, Mass., **2018**.

(4) Wang, N.; Bajko, J.; Crow, A.; Dumpert, L.; Hansell, A.; Prasad, C.; Rani, S.; Vidanelage, D.; Pickell, E.; Experiment 2. *CHEM 315 Laboratory Notes* [Online] **2025**. http://canvas.illinois.edu (accessed 28/09, 2025)