

PIXE for the non physicist

PIXE Seminar

9/12/2008

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OUTLINE

- An Introduction to PIXE
- What we can do with it
- What we can't do with it
- PIXE vs XRF





General Remark

- As with all academic disciplines, we have come up with our own language and often forget that everyone doesn't speak this language. When I forget this, please stop me and ask questions.





What is PIXE?

- PIXE stands for **P**article **I**nduced **X**-ray **E**mission or in our case, **P**roton **I**nduced **X**-ray **E**mission, is a non destructive method of elemental analysis.
- It is not, PIXIE which is
 1. a fairy or sprite, esp. a mischievous one
 2. a small, pert, or mischievous person

(from <http://dictionary.reference.com/browse/pixie>)





What is PIXE?

- “**P**article **I**nduced” refers to the energy source which causes the **X**-ray **E**mission from the sample under study. In our case, we use an accelerated proton beam.
- The Proton is the positively charged nucleus of the Hydrogen Atom.
- An X-Ray is electromagnetic radiation (light) of a certain energy range.

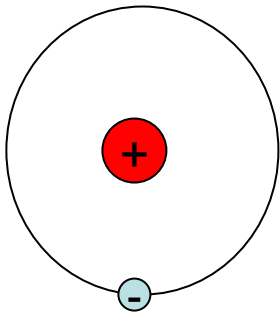




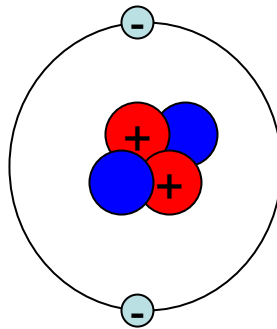
Protons, Electrons and other friendly particles.



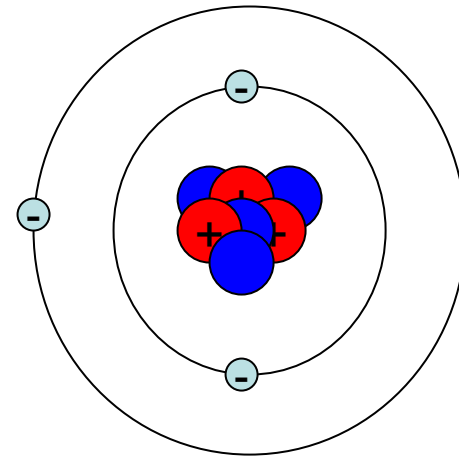
- All of the matter around is made up of atoms consisting of a nucleus of protons and neutrons surrounded by electrons. Each element has different number of protons (electrons) which is also called atomic number.



Hydrogen



Helium



Lithium





Periodic Table

Periodic Table of the Elements

Legend:

- hydrogen
- alkali metals
- alkali earth metals
- transition metals
- poor metals
- nonmetals
- noble gases
- rare earth metals

1 H																	2 He														
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne														
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar														
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr														
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe														
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn														
87 Fr	88 Ra	89 Ac	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une	110 Unn																						
																		58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
																		90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr





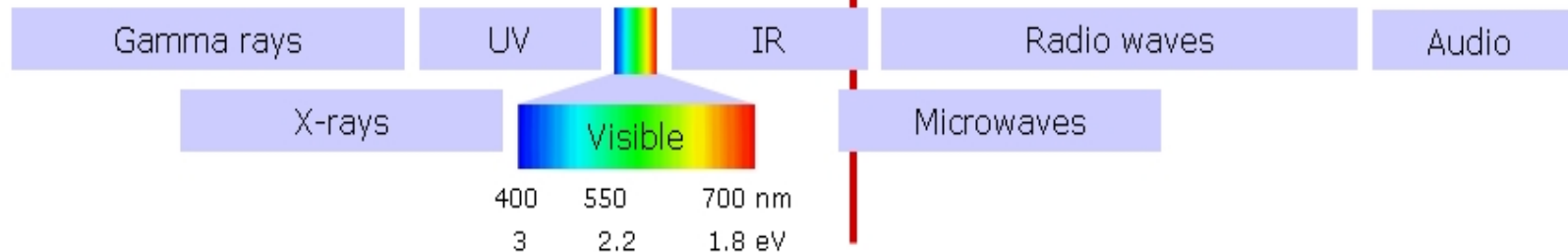
What are X-Ray's?

- A form type Electromagnetic radiation just like light.

The Electromagnetic Spectrum

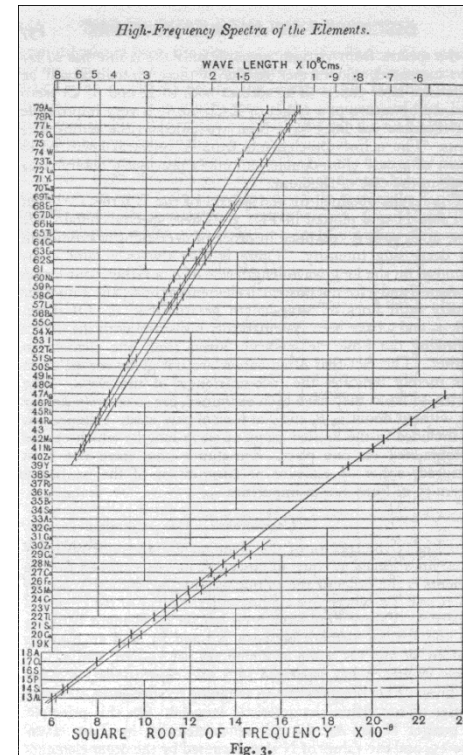
$k_B T_R$ -The thermal energy at room temperature

λ/m	10^{-13}	10^{-12}	10^{-11}	10^{-10}	10^{-9}	10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	1	10^1	10^2	10^3	10^4	10^5
	pm		Å	nm			μm			mm			m		km				
E/eV	10^7	10^6	10^5	10^4	10^3	10^2	10^1	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}		



Moseley's Law

- Henry Moseley (1913)
 - studied X-rays given off by a variety of materials
- Discovered the relationship between atomic number and the frequency of the X-rays given off



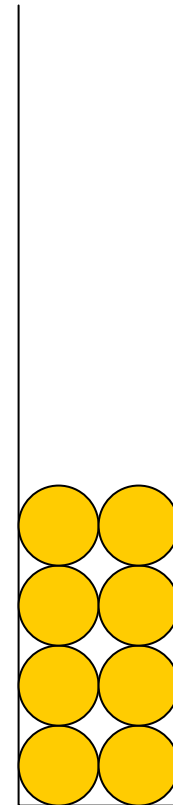
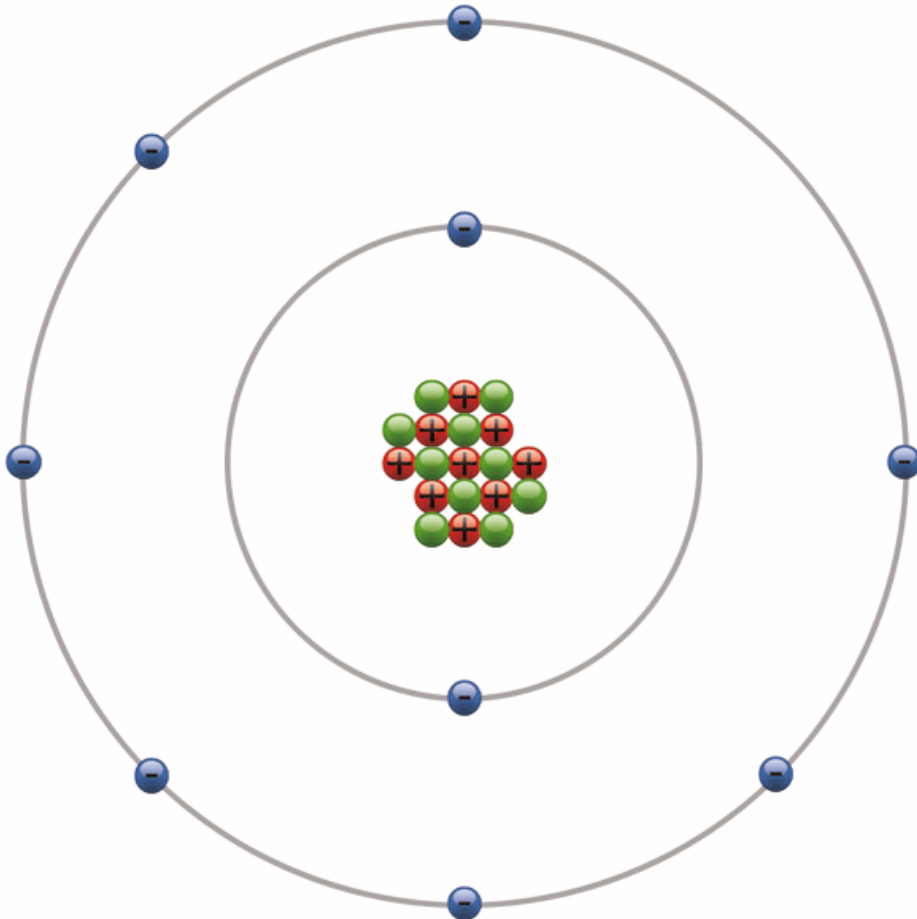
THE HIGH FREQUENCY SPECTRA OF THE ELEMENTS
By H. G. J. Moseley, M. A., *Phil. Mag.* (1913), p. 1024



The origin of X-Rays

Atom

Glass filled with Marbles



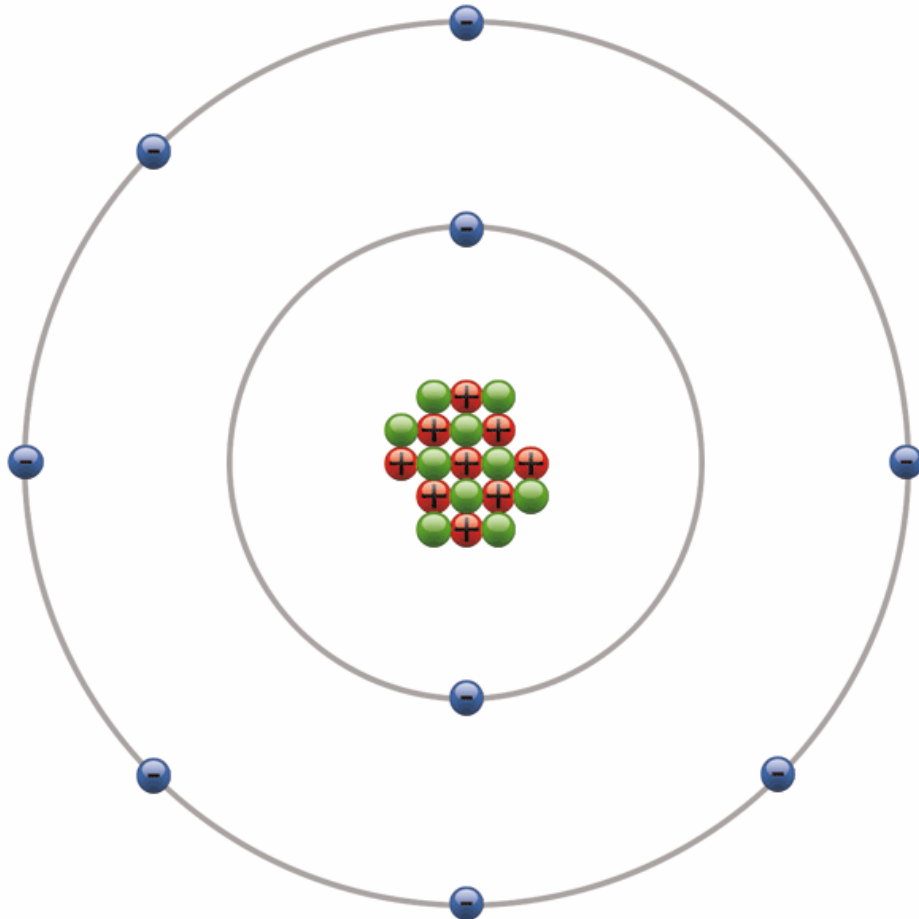
Particle Induced **X-Ray** Emission



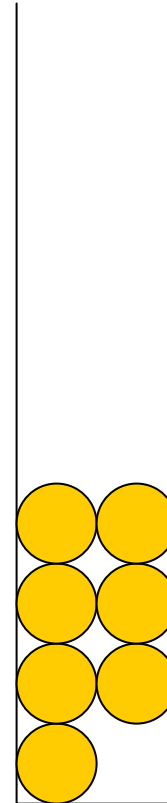


The origin of X-Rays

Atom



If we somehow remove one of the marbles at the bottom, the one's above will fall releasing some energy.

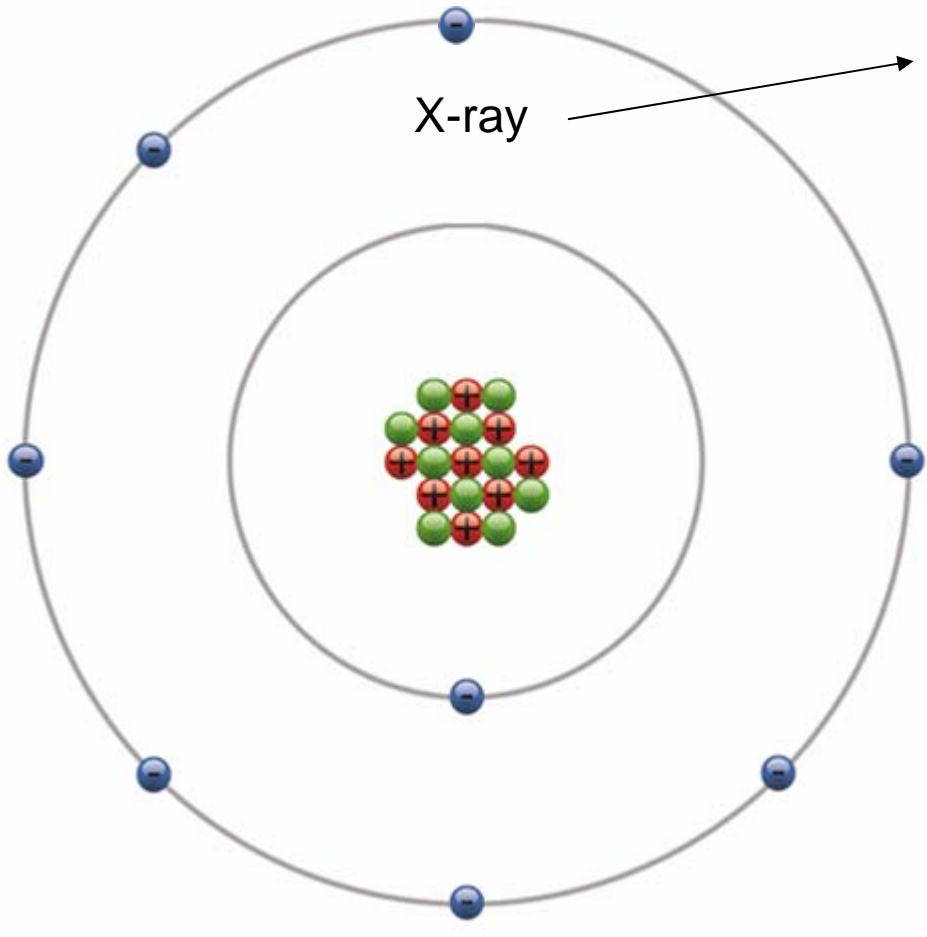




The origin of X-Rays

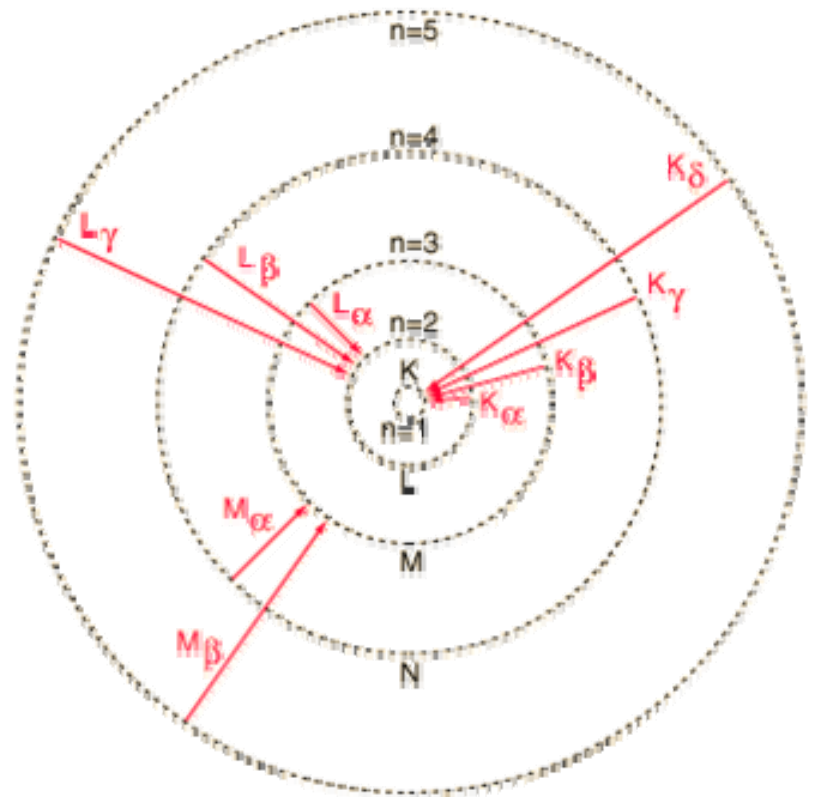
The same thing happens if we remove an inner shell electron

If we somehow remove one of the marbles at the bottom, the one's above will fall releasing some energy.



Some X Ray Nomenclature

- A bit more complicated because the electrons can skip levels.
- The orbits (or shells) are most often referred to by a letter rather than the principle quantum number (n=1 is the K shell, n=2 is the L shell, etc.)
- Transitions are labeled K_{α} , K_{β} , etc. as shown.





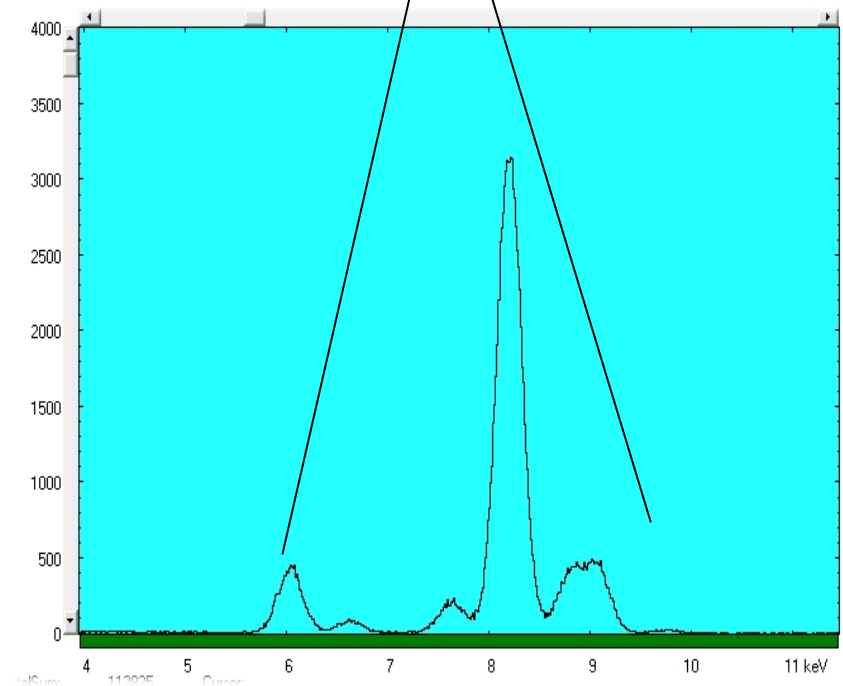
PIXE

- Particle Induced X-Ray Emission
 - An energetic particle, in our case an accelerated proton, interacts with an atom within a sample and removes an inner shell electron from its orbit. The atom then emits an X-ray as an electron from a higher orbit moves in to fill the vacancy.
- Each Element has different electron orbits and hence emits different energy X-rays.



Information from X-rays

- Just like our eyes take photons from the visible part of the electromagnetic spectrum and convert the different energies into different colors. We use a detector to differentiate one X-ray from the next.
- With the help of the computer, we measure a large number of photons and display the result in a histogram with the x-axis being the energy of the x rays.





What PIXE can tell us

- We can identify elements heavier than Al present in a localized position on the surface of a sample.
- Concentrations on the order of a percent are relatively easy to find depending on the other elements present.

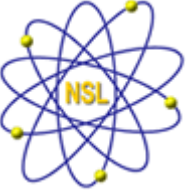




What PIXE can't tell us

- Elements lighter than Al will not be detected with our current setup.
- The significance or origin of the elements detected.
- Bulk composition, especially if the material is highly inhomogeneous.
- Isotopic composition.





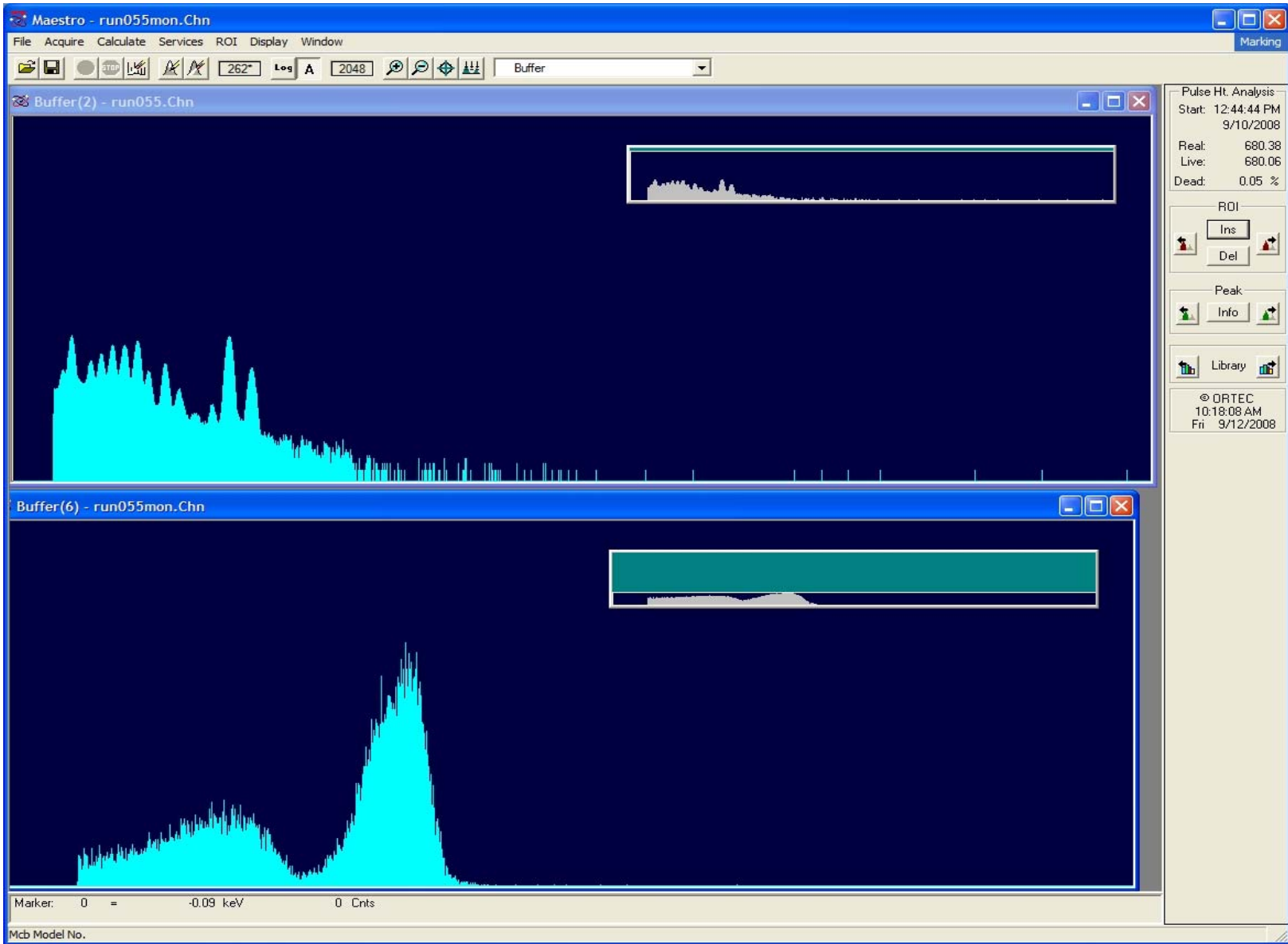
XRF

- A similar technique is X-Ray Fluorescence which uses the same principles but uses x-rays to excite the sample instead of particles.
- Advantages include not needing an accelerator lab, i.e. costs and portability.
- Disadvantages include higher background, typically less spatial sensitivity.



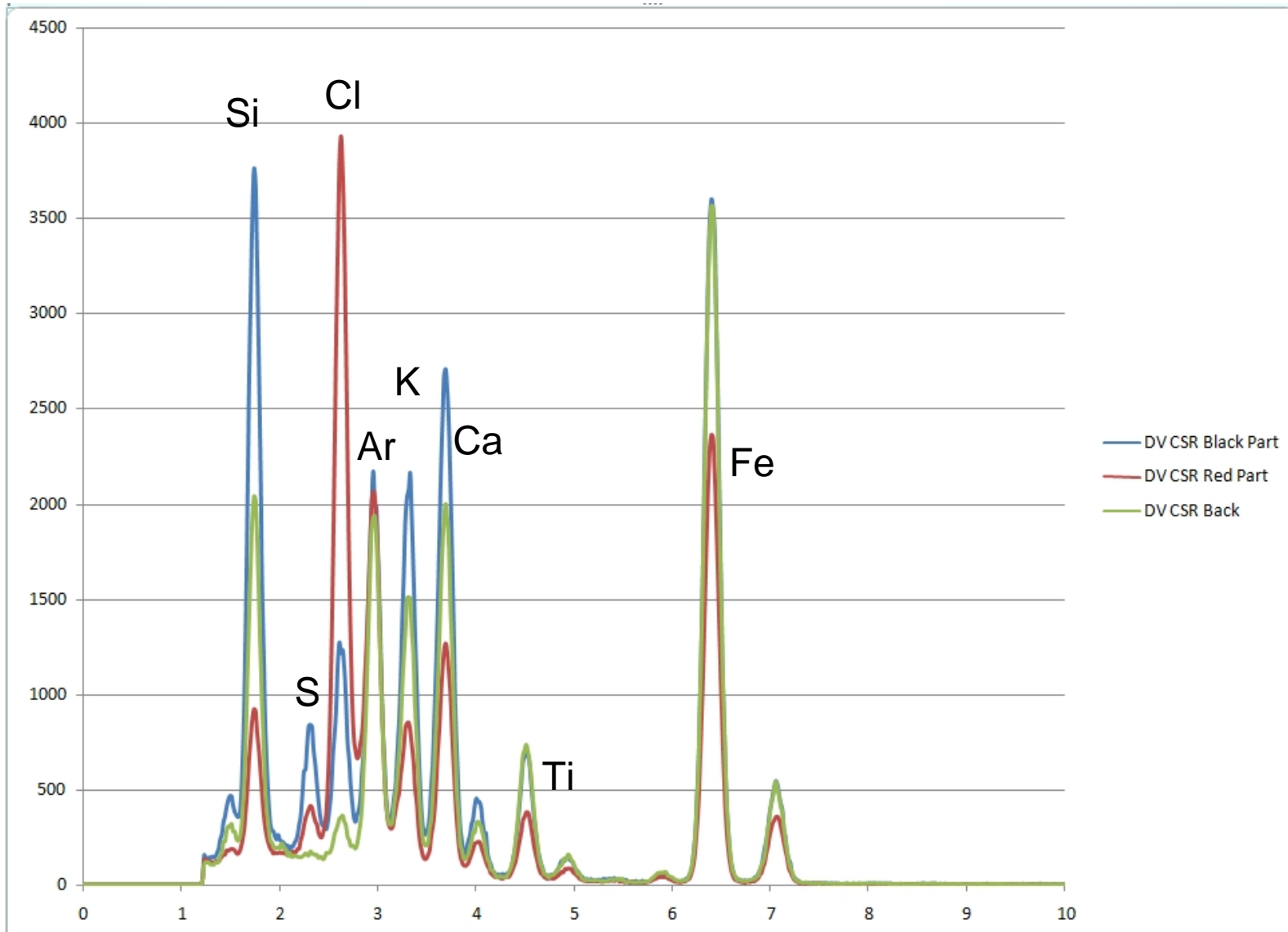


Sample From this week





DV-CSR Data (Preliminary)





Future Talks

- During future talks we will look at the data more carefully and examine the process and challenges of determining concentrations.

