

Lecture 1 – Atomic Structure

Lecture 2 – The Ultraviolet Catastrophe

Lecture 3 – Particle Nature of Light

Lecture 4 – Atomic Energy Levels and Spectra

Lecture 5 – X-ray Production and Diffraction

# Lecture 6 – X-ray Spectra

Lecture 7 – Matter Waves

Lecture 8 – Wave-Particle Duality

Lecture 9 – Wave functions for Quantum Particles

Lecture 10 – A Quantum Mechanical Wave Equation

Lecture 11 – Applications of Schrödinger's Equation



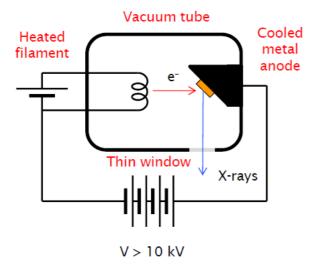
#### **Recap of Lecture 5**

- How to produce X-rays fire high voltage electrons into metal target in vacuum
- It's hard to measure the wavelength ('to disperse') X-rays prisms don't work, and they are the size of atoms, so gratings seem hard..
- But we can use solid materials with periodic crystal structure as 3D gratings
- 2 Bragg conditions,  $\theta_{in} = \theta_{out} \& n\lambda = 2dsin\theta$  for constructive interference
- Fire X-rays at an angled crystal of known lattice plane spacing to measure/select a wavelength
- Or Fire known monochromatic X-rays at an unknown crystal, changing angle, to measure the crystal

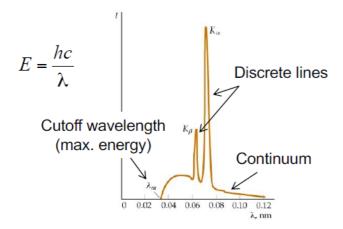
#### In this lecture

- The production of X-rays the spectrum created
- Attenuation of X-rays in matter
- Absorption of X-rays in materials & 'absorption edges'

### X-Ray spectra



- Typical energy spectrum
  - Plot as a function of wavelength



## Bremsstrahlung



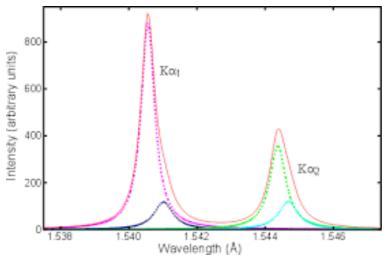
#### K alpha/beta in Cu and Mo

Just for interest...

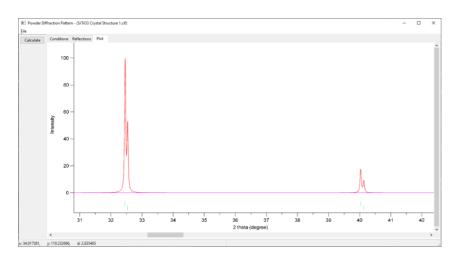
Common lab X-ray sources:

Cu:  $K_{\alpha} = 1.54 \text{ Å}$  $K_{\beta} = 1.39 \text{ Å}$ 

(In fact, as always in atomic physics, there is more complexity and another splitting and the  $K_{\alpha}$  is actually two lines,  $K_{\alpha 1}$  and  $K_{\alpha 2}$  very close together..)



So if use this for crystallography, every peak from a crystal's d-spacing becomes 2:

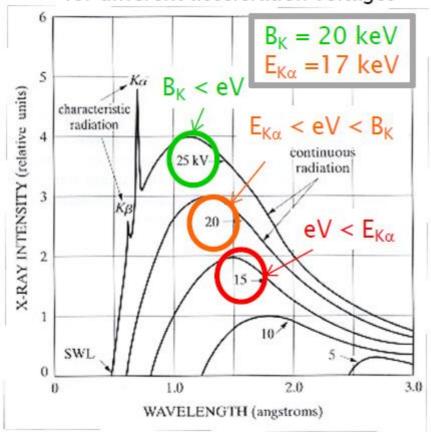


Commonly use a filter to remove the  $K_{\alpha 2}$ 

**Mo**  $K_{\alpha} = 0.7 \text{ Å}$  (this wavelength isn't absorbed by diamonds!)

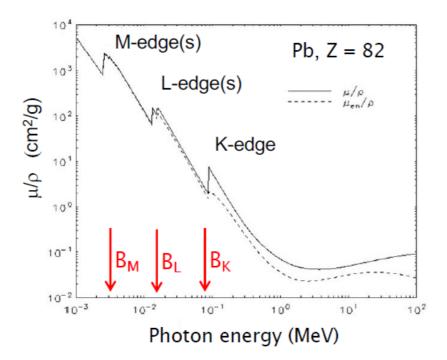
#### Mo X-Ray spectra

### Molybdenum X-ray spectra for different acceleration voltages



1 angstrom (Å) = 0.1 nm (useful unit for crystal structures)

## **Absorption Edges**



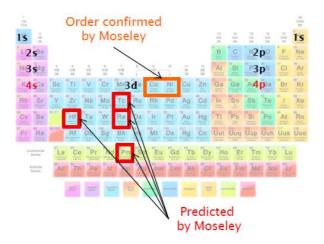
#### Moseley's Law



Henry Gwyn-Jeffreys Moseley (1887-1915)

$$f_{K_{\alpha}} = (2.48 \times 10^{15} \text{ Hz}) \times (Z - 1)^2$$

 This discovery enabled the periodic table to be ordered correctly by atomic number (Z) rather than atomic mass



 Moseley would have almost certainly been awarded a Nobel Prize had he not died in the Battle of Gallipoli (1915)