# Example: Young's Modulus of three metals.

(Q): Rank the following 3 metals in order of increasing Young's Modulus: W, Cr, Mo.

(A): Recall that bond energy is correlated with Young's Modulus, and that bond energy ~~is as~~ decreases down the periodic table. Then,

~~CR <~~

Cr > Mo > W

# Example: Elongation of a steel cable

(Q): A steel cable is 10 m long when pulled with a stress of 350 MPa. Assume that the Young's Modulus of the steel cable ~~of~~ is about 200 GPa. If only elastic deformation occurs, what is the resultant elongation in cm?

(A): We see that

$$350\ MPa = \left(\frac{\Delta L}{10\ m}\right) 200\ GPa$$

$$3500\ MPa\ m = \Delta L\ 200 \cdot 10^3\ MPa$$

$$\Delta L = 0.0175\ m = 1.75\ cm$$

# Example: A Nickel X-Ray Generator

(Q): An x-ray generator operated at a plate voltage of 7000 V is incapable of -using Ni $K_\alpha$ radiation. Calculate the minimum energy required for ballistic electron to produce Ni $K_\alpha$ radiation. Express your answer in units eV.

(A): Recall the formula

$$\Delta E_{a \to b} = (Z - \sigma)^2 K \left( \frac{1}{b^2} - \frac{1}{a^2} \right)$$

Then since

$Z = 28,$

$\sigma = 1,$

$K = 2.18 \cdot 10^{-18},$

$$\Delta E_{2 \to 1} = (27)^2 \, 2.18 \cdot 10^{-18} \left( \frac{3}{4} \right)$$

$$= 1.19 \cdot 10^{-15} \text{ J} = 7440 \text{ Ev}$$

Example: One element sneakily excites another

(Q): Determine the angle $\theta$ (in degrees) at which Mo $K\alpha$ will generate first order diffraction on (220) planes of gold (Au).

(A): Recall the equation

$$\frac{1}{\lambda_{K\alpha}} = \frac{3}{4} R (Z-1)^2$$

Where we let
$R = 1.097 \cdot 10^7 \ m^{-1}$ and
$Z = 42$; thus

$$\frac{1}{\lambda_{K\alpha}} = \frac{3}{4} 1.097 \cdot 10^7 \ m^{-1} \ (41)^2$$

$$\lambda_{K\alpha} = 7.23 \cdot 10^{-11} \ m$$

Then by Bragg's law where

$$\lambda_{K\alpha} = 2 \, d_{220} \sin(\theta_{220}),$$

we see that

$d_{220} = 1.44 \cdot 10^{-10} \ m$

and thus

$$\frac{7.23 \cdot 10^{-11} \ m}{2 \cdot 1.44 \cdot 10^{-10}} = \sin(\theta_{220})$$

$$0.2506 =$$

$$\Downarrow$$

$$\theta_{220} = 14.5^\circ$$

# Example: Potentially Diffactional!

(Q): Determine the acceleration potential (in Volts) that must be applied to electrons so that in an electron diffraction experiment of (200) planes of Ag, they will result in first order diffraction at $2\theta = 12°$

(A): We see by Braggs law that

$$\lambda_e = 2 d_{200} \sin(6°)$$

must be satisfied. We see that

$$a_{Ag} = 4.09 \cdot 10^{-8}\ \text{cm} \Rightarrow d_{200} = 2.04 \cdot 10^{-8}\ \text{cm}.$$

Thus

$$\lambda_e = 2\ 2.04 \cdot 10^{-8}\ \text{cm}\ \sin(6°) = 4.27 \cdot 10^{-9}$$

Then recall that

$$E = \frac{h^2}{2 m_e e \lambda_e^2} \text{ by } p = \frac{h}{\lambda_e}$$

$$= \frac{(6.63 \cdot 10^{-34})^2}{2 \cdot (9.1 \cdot 10^{-31})(1.6 \cdot 10^{-19})(4.27 \cdot 10^{-11})^2}$$

$$= 828 \text{ Volts}$$

# Example: The potential to diffract

(Q): Determine the smallest acceleration potential that must be applied to an X-ray generator so as to still achieve diffraction in solid Molybdenum, Mo.

(A): We see that Mo is BCC and by structure factors the plane we must consider is (110). Maximize the transferred energy by having $\sin(\theta)=1$, and see that

$$\lambda = 2 d_{110}$$

$$= 2 \cdot \frac{3.15 \cdot 10^{-8}\ \text{cm}}{\sqrt{2}} = 4.46 \cdot 10^{-8}\ \text{cm}$$

Then, by

$$E = eV = \frac{hc}{\lambda}, \quad V = \frac{hc}{e\lambda} = \frac{(6.63 \cdot 10^{-34})(3 \cdot 10^{18})}{(1.60 \cdot 10^{-19})(4.46 \cdot 10^{-10})}$$

$$= 2787 \text{ Volts}$$

# Example: Cupric Diffraction

(Q): Determine the longest wavelength (in cm) of X-rays that is still capable of produ-cing diffraction in copper, Cu.

(A): We see that Copper is FCC; consider the Bragg's Law where we let $\sin(\theta) = 1$ and the plane in question be (111) by structure factors:

$$\lambda_{max} = 2 d_{111} = 2 \frac{a}{\sqrt{3}}$$

$$= 2 \frac{3.61 \cdot 10^{-8}\,cm}{\sqrt{3}}$$

$$= 4.17 \cdot 10^{-8}\,cm$$

# Example: Wavelength of 3.091 Angstroms

(Q): Your X-ray lab has a monochromator ~~set up with~~ consisting of a single crystal of nickel cut so that the (111) plane lies in the cube face. At what angle (in degrees) should the cube face be tilted ~~so that~~ with respect to the incident beam in order to select radiation with a wavelength $\lambda = 3.091$ Å? The lattice constant of nickel is $a = 3.53$ Å.

(A): Recall Bragg's Law:

$$2 d_{111} \sin\theta = \lambda$$
$$= 3.091$$

and

$$d_{111} = \frac{3.53 \text{ Å}}{\sqrt{1+1+1}} = 2.04 \text{ Å}$$

$$4.08 \text{ Å} \sin\theta = 3.091 \text{ Å}$$

$$\Downarrow$$

$$\theta = 49.3^\circ$$