3-37 When waves are scattered between two adjacent planes of a single crystal, constructive wave interference will occur when the path length difference between such reflected waves is an integer multiple of wavelengths. This condition is expressed by the Bragg equation for constructive interference, $2d\sin\theta = n\lambda$ where d is the distance between adjacent crystalline planes, θ is the angle of incidence of the x-ray beam of photons, n is an integer for constructive interference, and λ is the wavelength of the photon beam which is in this case, 0.062 6 nm. Ignoring the incident beam that is not scattered, the first three angles for which maxima of x-ray intensities are found are $1\lambda = 2d\sin\theta_1$ or

$$\sin\theta_1 = \frac{\lambda}{2d} = \frac{0.626\times 10^{-10}\ \text{m}}{8\times 10^{-10}\ \text{m}}$$

$$\theta_1 = 0.078\ 3\ \text{radians} = 4.49^\circ$$

$2\lambda = 2d\sin\theta_2$ or

$$\sin\theta_2 = \frac{\lambda}{d} = \frac{0.626\times 10^{-10}\ \text{m}}{4.0\times 10^{-10}\ \text{m}} = 0.156\ 5,\ \theta = 9.00^\circ$$

$3\lambda = 2d\sin\theta_3$ or

$$\sin\theta_3 = \frac{3\lambda}{2d} = \frac{3\left(0.626\times 10^{-10}\ \text{m}\right)}{8\times 10^{-10}\ \text{m}} = 0.234\ 75,\ \theta_3 = 13.6^\circ$$

4-1 F corresponds to the charge passed to deposit one mole of monovalent element at a cathode. As one mole contains Avogadro's number of atoms,

$e = \frac{96\ 500\ \text{C}}{6.02 \times 10^{23}} = 1.60 \times 10^{-19}\ \text{C}$.

4-2 (a) Total charge passed $= i * t = (1.00\ \text{A})(3\,600\ \text{s}) = 3\ 600\ \text{C}$. This is

$$\frac{3\ 600\ \text{C}}{1.60 \times 10^{-19}\ \text{C}} = 2.25 \times 10^{22}\ \text{electrons.}$$

As the valence of the copper ion is two, two electrons are required to deposit each ion as a neutral atom on the cathode.

$$\text{The number of Cu atoms } = \frac{\text{number of electrons}}{2} = 1.125 \times 10^{22}\ \text{Cu atoms.}$$

(b) So the weight (mass) of a Cu atom is: $\frac{1.185\ \text{g}}{1.125 \times 10^{22}\ \text{atoms}} = 1.05 \times 10^{-22}\ \text{g}$.

(c) $m = q\frac{\text{molar weight}}{96\ 500}(2)$ or

$$\text{molar weight} = m(96\ 500)\frac{2}{q} = (1.185\ \text{g})(96\ 500\ \text{C})\frac{2}{3\ 600\ \text{C}} = 63.53\ \text{g}.$$

4-3 Thomson's device will work for positive and negative particles, so we may apply $\frac{q}{m} \approx \frac{V\theta}{B^2 ld}$.

(a) $\frac{q}{m} \approx \frac{V\theta}{B^2 ld} = (2\ 000\ \text{V})\frac{0.20\ \text{radians}}{(4.57 \times 10^{-2}\ \text{T})^2}(0.10\ \text{m})(0.02\ \text{m}) = 9.58 \times 10^7\ \text{C/kg}$

(b) As the particle is attracted by the negative plate, it carries a positive charge and is a proton. $\left(\frac{q}{m_p} = \frac{1.60 \times 10^{-19}\ \text{C}}{1.67 \times 10^{-27}\ \text{kg}} = 9.58 \times 10^7\ \text{C/kg}\right)$

(c) $v_x = \frac{E}{B} = \frac{V}{\text{d}B} = \frac{2\ 000\ \text{V}}{0.02\ \text{m}}(4.57 \times 10^{-2}\ \text{T}) = 2.19 \times 10^6\ \text{m/s}$

(d) As $v_x \sim 0.01c$ there is no need for relativistic mechanics.

4-8 (a) From Equation 4.16 we have $\Delta n \infty \left(\frac{\sin\phi}{2}\right)^{-4}$ or $\Delta n_2 = \Delta n_1 \frac{\left(\frac{\sin\phi_1}{2}\right)^4}{\left(\frac{\sin\phi_2}{2}\right)^4}$. Thus the number of α's scattered at 40 degrees is given by

$$\Delta n_2 = (100\ \text{cpm})\frac{\left(\sin\frac{20}{2}\right)^4}{\left(\sin\frac{40}{2}\right)^4} = (100\ \text{cpm})\left(\frac{\sin 10}{\sin 20}\right)^4 = 6.64\ \text{cpm}.$$

Similarly

$$\Delta\, n \text{ at 60 degrees} = 1.45 \text{ cpm}$$
$$\Delta\, n \text{ at 80 degrees} = 0.533 \text{ cpm}$$
$$\Delta\, n \text{ at 100 degrees} = 0.264 \text{ cpm}$$

(b) From 4.16 doubling $\left(\frac{1}{2}\right) m_\alpha v_\alpha^2$ reduces $\Delta\, n$ by a factor of 4. Thus $\Delta\, n$ at 20 degrees $= \left(\frac{1}{4}\right)(100 \text{ cpm}) = 25 \text{ cpm}$.

(c) From 4.16 we find $\dfrac{\Delta\, n_{\text{Cu}}}{\Delta\, n_{\text{Au}}} = \dfrac{Z_{\text{Cu}}^2 N_{\text{Cu}}}{Z_{\text{Au}}^2 N_{\text{Au}}}$, $Z_{\text{Cu}} = 29$, $Z_{\text{Au}} = 79$.

$$\begin{aligned} N_{\text{Cu}} &= \text{number of Cu nuclei per unit area} \\ &= \text{number of Cu nuclei per unit volume * foil thickness} \\ &= \left[\left(8.9 \text{ g/cm}^3\right)\left(\frac{6.02 \times 10^{23} \text{ nuclei}}{63.54 \text{ g}}\right)\right] t = 8.43 \times 10^{22}\, t \end{aligned}$$

$$N_{\text{Au}} = \left[\left(19.3 \text{ g/cm}^3\right)\left(\frac{6.02 \times 10^{23} \text{ nuclei}}{197.0 \text{ g}}\right)\right] t = 5.90 \times 10^{22}\, t$$

So $\Delta\, n_{\text{Cu}} = \Delta\, n_{\text{Au}} (29)^2 \dfrac{8.43 \times 10^{22}}{(79)^2}\left(5.90 \times 10^2\right) = (100)\left(\dfrac{29}{79}\right)^2\left(\dfrac{8.43}{5.90}\right) = 19.3 \text{ cpm}$.

4-9 The initial energy of the system of α plus copper nucleus is 13.9 MeV and is just the kinetic energy of the α when the α is far from the nucleus. The final energy of the system may be evaluated at the point of closest approach when the kinetic energy is zero and the potential energy is $k(2e)\dfrac{Ze}{r}$ where r is approximately equal to the nuclear radius of copper. Invoking conservation of energy $E_i = E_f$, $K_\alpha = (k)\dfrac{2Ze^2}{r}$ or

$$r = (k)\frac{2Ze^2}{K_\alpha} = \frac{(2)(29)\left(1.60 \times 10^{-19}\right)^2\left(8.99 \times 10^9\right)}{\left(13.9 \times 10^6 \text{ eV}\right)\left(1.60 \times 10^{-19} \text{ J/eV}\right)} = 6.00 \times 10^{-15} \text{ m}.$$