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,

$e = \frac{96\ 500\ \text{C}}{6.02\times10^{23}} = 1.60\times10^{-19}\ \text{C}$.

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

$$\frac{3\ 600\ \text{C}}{1.60\times10^{-19}\ \text{C}} = 2.25\times10^{22}\ \text{electrons.}$$

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

$$\text{The number of Cu atoms} = \frac{\text{number of electrons}}{2} = 1.125\times10^{22}\ \text{Cu atoms.}$$

(b) So the weight (mass) of a Cu atom is: $\frac{1.185\ \text{g}}{1.125\times10^{22}\ \text{atoms}} = 1.05\times10^{-22}\ \text{g}$.

(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) $\frac{q}{m} \approx \frac{V\theta}{B^2 ld} = (2\ 000\ \text{V})\frac{0.20\ \text{radians}}{(4.57\times10^{-2}\ \text{T})^2(0.10\ \text{m})(0.02\ \text{m})} = 9.58\times10^{7}\ \text{C/kg}$

(b) As the particle is attracted by the negative plate, it carries a positive charge and is a proton. $\left(\frac{q}{m_p} = \frac{1.60\times10^{-19}\ \text{C}}{1.67\times10^{-27}\ \text{kg}} = 9.58\times10^{7}\ \text{C/kg}\right)$

(c) $v_x = \frac{E}{B} = \frac{V}{\text{d}B} = \frac{2\ 000\ \text{V}}{0.02\ \text{m}\,(4.57\times10^{-2}\ \text{T})} = 2.19\times10^{6}\ \text{m/s}$

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

4-8 (a) From Equation 4.16 we have $\Delta n \propto \left(\frac{\sin\phi}{2}\right)^{-4}$ 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 $\frac{\Delta\, n_{\text{Cu}}}{\Delta\, n_{\text{Au}}} = \frac{Z_{\text{Cu}}^2 N_{\text{Cu}}}{Z_{\text{Au}}^2 N_{\text{Au}}}$, $Z_{\text{Cu}} = 29$, $Z_{\text{Au}} = 79$.

$$\begin{aligned} N_{\text{Cu}} &= \text{number of Cu nuclei per unit area} \\ &= \text{number of Cu nuclei per unit volume * foil thickness} \\ &= \left[\left(8.9 \text{ g/cm}^3\right)\left(\frac{6.02\times 10^{23} \text{ nuclei}}{63.54 \text{ g}}\right)\right]t = 8.43\times 10^{22}\,t \\ N_{\text{Au}} &= \left[\left(19.3 \text{ g/cm}^3\right)\left(\frac{6.02\times 10^{23} \text{ nuclei}}{197.0 \text{ g}}\right)\right]t = 5.90\times 10^{22}\,t \end{aligned}$$

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

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 $k(2e)\frac{Ze}{r}$ where r is approximately equal to the nuclear radius of copper. Invoking conservation of energy $E_i = E_f$, $K_\alpha = (k)\frac{2Ze^2}{r}$ or

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