CHEM1901 Answers to Problem Sheet 2

1. (a) $^{20}_{10}\text{Ne} + ^{1}_{0}\text{n} \rightarrow ^{20}_{9}\text{F} + \mathbf{^{1}_{1}p}$

(b) $^{15}_{7}\text{N} + ^{1}_{1}\text{p} \rightarrow \mathbf{^{15}_{8}O} + ^{1}_{0}\text{n}$

(c) $^{16}_{8}\text{O} + ^{1}_{1}\text{p} \rightarrow ^{13}_{7}\text{N} + \mathbf{^{4}_{2}He}$

2. (a) $^{18}_{9}\text{F}$ **- fewer neutrons than stable nucleus so decays by β^+ emission (conversion of a proton into a neutron and a positron):**

$$^{18}_{9}\text{F} \rightarrow ^{18}_{8}\text{O} + ^{0}_{1}\text{e}$$

(b) $^{20}_{9}\text{F}$ **- more neutrons than stable nucleus so decays by β^- emission (conversion of a neutron into a proton and an electron):**

$$^{20}_{9}\text{F} \rightarrow ^{20}_{10}\text{Ne} + ^{0}_{-1}\text{e}$$

3. **The ^{14}C age is given by:**

$$t = 8033\ \text{years} \times \ln\left(\frac{A_0}{A_t}\right)$$

where A_0 is the activity of freshly formed ^{14}C and A_t is its activity after *t* years.

If the activity is 0.344 of the modern standard, $A_0 / A_t = 1/0.344$ and so,

$$t = 8033\ \text{years} \times \ln(1/0.344) = 8570\ \text{BP}$$

4. **The molar activity is given by:**

$$A_{mol} = \lambda N_a$$

where λ is the decay constant which is related to the half life $t_{1/2}$ by:

$$\lambda = \frac{\ln 2}{t_{1/2}}$$

The half life = 12.26 years or 12.26 × 365.25 × 24 × 3600 s = 3.87 x 10^8 s.

Hence the molar activity is:

$$A_{mol} = \left(\frac{\ln 2}{3.87 \times 10^8}\right) \times (6.02 \times 10^{23}) = 1.08 \times 10^{15}\ \text{disintegrations s}^{-1}\ \text{mol}^{-1}$$

As 1 Ci = 3.70 × 10^{10} disintegrations s^{-1}, the molar activity in Curie is:

$$A_{mol} = \frac{1.08 \times 10^{15}}{3.70 \times 10^{10}} = 2.92 \times 10^{4}\ \mathrm{Ci\,mol^{-1}}$$

5. **Ionization energy increases across a period as the effective nuclear charge increases and decreases down a group as the n-shell increases. Hence, the ionization energy increases in the order:**

   Na < Mg < C < N < F < Ne

6. **Atomic radii decrease across a period, as the effective nuclear charge increases, but increases down a group, as the n-shell increases. This is the basis of the 'diagonal relationship' between elements, in which the second element is in the next group and in the next period.**

   Li (group 1, period 2), Mg (group 2, period 3), Sc (group 3, period 4) and Zr (group 4, period 5) have similar atomic radii.

7. **For the reasons given in Q6, the largest element is at the bottom of group 1 and the smallest is at the top of group 18:**

   Largest atom – Cs
   Smallest atom – He

   Note that this answer considers only the stable elements. Reliable data is not available on many of the unstable elements at the foot of the periodic table. Relativistic effects, discussed in the article following Problem Sheet 3, become as important as quantum mechanical effects in these elements and may well reverse the increase in shell size down a group in the superheavy elements.

Optional question.

(i) **The mass of 6 H atoms (i.e. 6 protons and 6 electrons) and 6 neutrons is:**

$$(6 \times 1.007825) + (6 \times 1.008665) = 12.09894\ \text{amu}$$

As ^{12}C has a mass of 12.000000 amu, the *loss* in mass is:

$$\text{mass defect} = 12.09894 - 12.00000 = 0.09894\ \text{amu}$$

(ii) **Einstein's $E = mc^2$ equation gives the relationship between mass and its energy equivalent. The mass defect for a mole of ^{12}C is 0.09894 g or 9.9894 × 10^{-5} kg. The energy equivalent is:**

$$E = (9.894 \times 10^{-5}\ \mathrm{kg\,mol^{-1}})(2.998 \times 10^{8}\ \mathrm{m\,s^{-1}})^2$$
$$= 8.893 \times 10^{12}\ \mathrm{J\,mol^{-1}} \text{ or } 8.893 \times 10^{9}\ \mathrm{kJ\,mol^{-1}}$$