- Write the ground state electron configuration of the Ca^{2+} cation.

2

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

List the quantum numbers (n, l, m_l, m_s) that describe any one of the electrons in the ground state Ca^{2+} cation.

$1s^2$: $n = 1$, $l = 0$, $m_l = 0$ and $m_s = +½$ *or* $-½$

$2s^2$: $n = 2$, $l = 0$, $m_l = 0$ and $m_s = +½$ *or* $-½$

$2p^6$: $n = 2$, $l = 1$, $m_l = 1$, 0 or -1 and $m_s = +½$ *or* $-½$

$3s^2$: $n = 3$, $l = 0$, $m_l = 0$ and $m_s = +½$ *or* $-½$

- Write down the ground state electron configuration of the iron atom.

1

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

Marks
2

- Give the ground-state electron configuration of the aluminium atom.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ or [Ne] $3s^2\ 3p^1$

Provide one set of valid quantum numbers (n, l, m_l, m_s) for the highest energy electron.

For the $3p^1$ electron, there are six possible sets:

- **$n = 3$, $l = 1$, $m_l = 1$, $m_s = +½$**
- **$n = 3$, $l = 1$, $m_l = 1$, $m_s = -½$**
- **$n = 3$, $l = 1$, $m_l = 0$, $m_s = +½$**
- **$n = 3$, $l = 1$, $m_l = 0$, $m_s = -½$**
- **$n = 3$, $l = 1$, $m_l = -1$, $m_s = +½$**
- **$n = 3$, $l = 1$, $m_l = -1$, $m_s = -½$**

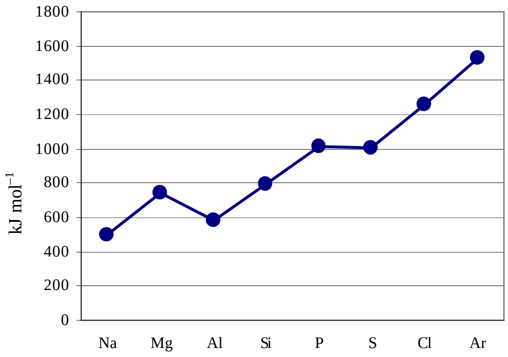
Marks
2

- In general terms, which elements in the periodic table are likely to be essential elements for living species and which ones are likely to be toxic. Explain.

Most of the lighter elements (at. no. up to 20) are essential elements. They are readily available in nature, so more likely to be utilised by organisms. Similarly most of the lighter *d*-block elements (Sc - Zn) are essential (utilised in redox and electron transport systems in the body) whereas the heavier transition metals are generally toxic.

3

- The diagram below shows the general trend for the first ionisation energy for some *s* and *p* block elements.



How will the general trend differ for the second ionisation energy of these elements (*i.e.* $X^+(g) \rightarrow X^{2+}(g) + e^-$)? Explain.

The second ionisation of Na will be off the scale as a core electron is ionised. (Actual value > 4500 kJ mol^{-1})

Mg^+ is isoelectronic with Na, Al^+ is isoelectronic with Mg, *etc*., so the second ionisations of the other elements follow the same trends as the first ionisations (for exactly the same reasons), but displaced one atomic number to the right and at a slightly higher energy (as Z_{eff} is greater).

Marks
5

- The radioactive isotopes ^{131}I and ^{137}Cs have been detected in drinking water near the Japanese Fukushima nuclear reactor. They have half lives of 8 days and 30 years, respectively. What is the definition of half-life?

Half-life is the amount of time required for the amount (or activity) of a sample to decrease to half its initial value.

What percentage of both isotopes will still be detectable after 25 years?

The number of nuclei, N, decays with time, t, according to $\ln(N_0/N_t) = \lambda t$ where λ is the activity coefficient. This is related to the half life, $t_{1/2}$ by $\lambda = \ln 2/t_{1/2}$.

For ^{131}I, $t_{1/2}$ = 8 days = 8/365 years:

$$\lambda = \ln 2 \,/\, (8/365) \text{ years}^{-1} = 32 \text{ years}^{-1}$$

When t = 25 years,

$$\ln(N_0/N_t) = \lambda t = (32 \text{ years}^{-1})(25 \text{ years})$$

$$N_0/N_t = e^{790} \quad \text{or } N_t / N_o \approx 0$$

N_t is very close to zero and effectively all of the ^{131}I has decayed.

For ^{137}Cs, $t_{1/2}$ = 30 years:

$$\lambda = \ln 2 \,/\, (30) \text{ years}^{-1} = 0.023 \text{ years}^{-1}$$

When t = 25 years,

$$\ln(N_0/N_t) = \lambda t = (0.023 \text{ years}^{-1})(25 \text{ years})$$

$$N_0/N_t = 1.8 \quad \text{or } N_t / N_o = 0.56 = 56\%$$

^{131}I: **0%**	^{137}Cs: **56%**

If you were exposed to equal concentrations of both isotopes for 1 hour, which isotope would do more damage? Explain.

^{131}I would do more damage.

It has the shorter half-life so undergoes more disintegrations and produces more radiation in a given time period.