Marks

- Reaction of nitrogen-14 with a neutron forms two products, one of which is carbon-14. Radiocarbon dating involves the carbon-14 isotope which undergoes β-decay (emission of an electron from the nucleus). Write the two nuclear equations that illustrate the formation and decay of carbon-14. **2**

^{14}C formation: $^{14}_{7}\text{N} + ^{1}_{0}\text{n} \rightarrow ^{14}_{6}\text{C} + ^{1}_{1}\text{p}$

^{14}C decay: $^{14}_{6}\text{C} \rightarrow ^{14}_{7}\text{N} + ^{0}_{-1}\text{e}$

- Complete the following table. **3**

Orbital	Principal quantum number, *n*	Angular momentum quantum number, *l*	Number of spherical nodes	Number of planar nodes
4*s*	**4**	**0**	**3**	0
3p	**3**	**1**	**1**	1
3d	3	**2**	**0**	2

- It requires 151 kJ mol^{-1} to break the bond in I_2. What is the minimum wavelength of light needed to break this bond? Give your answer in nm. **2**

151 kJ mol^{-1} corresponds to:

energy per molecule = $151 \times 10^3 / 6.022 \times 10^{23}$ J = 2.51×10^{-19} J

According to Planck's relationship between the energy and wavelength, λ, of light:

$E = hc / \lambda$

Hence

$\lambda = hc / E$
$= (6.626 \times 10^{-34}\ \text{J s}) \times (2.998 \times 10^{8}\ \text{m s}^{-1}) / (2.51 \times 10^{-19}\ \text{J})$
$= 7.90 \times 10^{-7}\ \text{m} = 790.\ \text{nm}$

Answer: **790. nm**

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY.

- Calculate the wavelength of light (in nm) emitted when an electron moves from the $n = 4$ to $n = 2$ energy levels in a hydrogen atom. **3**

The energy of an orbital in an 1-electron atom or ion is given by

$$E_n = -Z^2 E_R (1/n^2)$$

The energy difference between two levels is therefore:

$$\Delta E = E_{n1} - E_{n2} = [-Z^2 E_R (1/n_1^2)] - [-Z^2 E_R (1/n_2^2)] = Z^2 E_R (1/n_2^2 - 1/n_1^2)$$

The energy emitted when an electron moves from $n = 4$ to $n = 2$ for H with $Z = 1$ is therefore:

$$\Delta E = (1)^2 E_R (1/2^2 - 1/4^2)$$
$$= E_R \times (3/16) = (3/16) \times 2.18 \times 10^{-18} \text{ J} = 4.09 \times 10^{-19} \text{ J}$$

Using $E = hc / \lambda$, this corresponds to a wavelength of:

$$\lambda = hc / E = (6.626 \times 10^{-34} \text{ J s})(2.998 \times 10^{8} \text{ m s}^{-1}) / (4.09 \times 10^{-19} \text{ J})$$
$$= 4.86 \times 10^{-7} \text{ m}$$
$$= 486 \text{ nm}$$

Answer: **486 nm**

What is the energy of this radiation (in kJ mol^{-1})?

The energy of each photon is **4.09×10^{-19} J. Therefore, per mol:**

$$\text{energy of radiation} = (6.022 \times 10^{23} \text{ mol}^{-1}) \times (4.09 \times 10^{-19} \text{ J}) = 246 \text{ kJ mol}^{-1}$$

Answer: **246 kJ mol^{-1}**

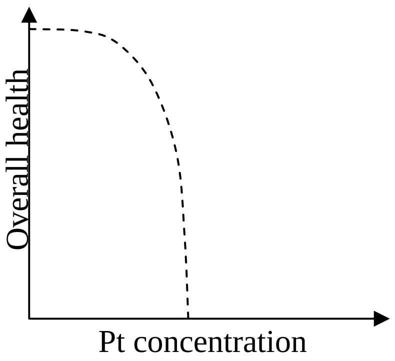
• Like most medicines, the platinum complex, cisplatin, *cis*-[$PtCl_2(NH_3)_2$], is both effective and toxic. What is cisplatin used to treat? **4**

Cisplatin is used to treat a number of cancers, including testicular and ovarian cancer.

What does the cisplatin react with in the body to cause most of the toxicity?

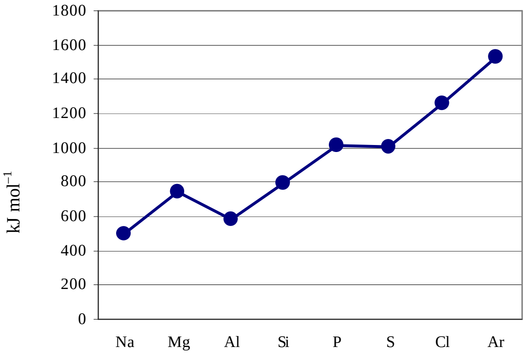
Sulfur containing enzymes in the kidneys

Draw a graph showing the relationship between overall health and the level of platinum in the body of a healthy person.



Marks
3

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

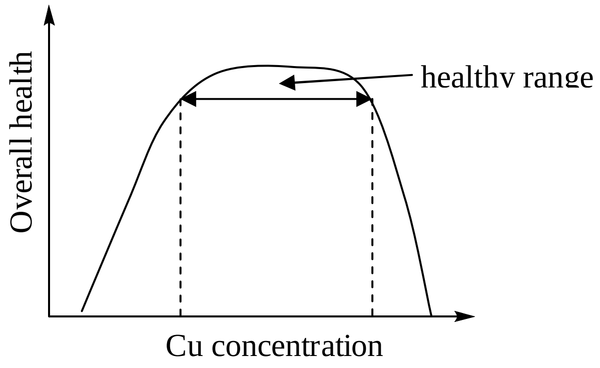


How will the general trend differ for the second ionisation energy of these elements (*i.e.* $X^+(g) \rightarrow X^{2+}(g) + e^-$)? Explain.

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).

- Copper is an essential element in human biology, deficiencies leading to blood disorders. Excess copper can occur in cases of poisoning or in Wilson's disease. Draw a graph showing the relationship between overall health and the level of copper in the body and identify the 'healthy' range. **4**



Describe one biological function of copper.

Copper enzymes are involved in electron transport systems due to the ability of copper to change its oxidation state.

In some organisms, copper enzymes are involved in oxygen transport.

Suggest one approach for treating an excess level of copper.

Treatment with a complexing agent such as EDTA leads to the formation of stable water-soluble complex that can be excreted from the body.

- Indicate a biological function for each of the following elements.

Marks 5

Element	Biological Function
cobalt	**Cobalt is found in the active site of the vitamin B_{12}. Lack of this metalloenzyme can cause pernicious anæmia.**
sodium	**The sodium cation is the main extracellular (outside cells) cation in animals and is important for nerve function in animals.**
iodine	**Iodine is found as I^- in the thyroid hormones. Lack of iodine can cause goitre.**
magnesium	**Magnesium is found in the centre of chlorophylls which are responsible for the green colour of plants. Magnesium is also required for the proper working of some enzymes. Magnesium is essential to the nuclei acids.**
zinc	**Zinc is the key component of many enzymes and is found in the protein hormone insulin. It plays a role in reproduction and sexual maturation. Zinc deficiency results in stunted growth and in male sexual immaturity.**

Marks

- Gamma emission involves the radiation of high energy γ photons and accompanies most types of radioactive decay processes. γ photons typically have wavelengths less than 0.1 Å. Calculate the energy of a photon with wavelength λ = 0.1 Å. Give your answer in J per photon and kJ mol^{-1}. **3**

The energy of a photon with wavelength λ is given by:

$$E = hc / \lambda$$

If λ = 0.1 Å = 0.1 × 10^{10} m, the energy is

$$E = (6.634 \times 10^{-34}\ J\ s)\times(2.998 \times 10^{8}\ m\ s^{-1})/(0.1 \times 10^{-10}\ m) = 2.0\times10^{-14}\ J\ per\ photon$$

or

$$E = (2.0 \times 10^{-14})\times(6.02 \times 10^{23}) = 1.2 \times 10^{10}\ J\ mol^{-1} = 1.2 \times 10^{7}\ kJ\ mol^{-1}$$

E = **2.0 × 10^{-14}** J per photon	*E* = **1.2 × 10^{7}** kJ mol^{-1}

Why is high energy or gamma radiation called ionising radiation?

The radiation has sufficient energy to ionise atoms in living tissues. The free radicals thus formed are highly reactive (due to having unpaired electrons) and cause unwanted chemical reactions in the tissues. This in turn can lead to cell damage, destruction of DNA, etc.

- What are two of the key results arising from a wavelike description of matter? **2**

Electrons in atoms and molecules can only have certain energies.
Energy is quantized, leading to spectroscopy and physical properties like colour.
The positions of electrons in atoms and molecules are not known precisely and are described by orbitals.

- Each of the following electron configurations represents an atom in an excited state. Identify the element and write its ground state electron configuration. **2**

Electron configuration of excited state	Element	Electron configuration of ground state
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4\ 4s^1$	**Chlorine**	$\mathbf{1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5}$
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^3\ 4p^1$	**Chromium**	$\mathbf{1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5}$

- The atomic radius decreases across a period and increases down a group within the periodic table. Explain these observations. **2**

Across a period, the nuclear charge increases but the electrons occupy the same shell. The increase in attraction to the nucleus causes a decrease in the atomic size.

Down a group, the outer electrons occupy shells with higher *n* quantum numbers with large average orbits and the size increases.