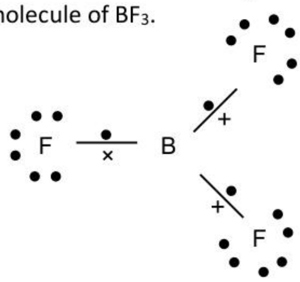
11. (*a*) Boron trifluoride (BF_3) is a colourless gas with an unpleasant odour.

(*i*) Draw a dot and cross diagram to show the arrangement of the valence electrons in a molecule of BF_3.



(4)

[award 2 marks if lone pair electrons are omitted from F(s)]

(*ii*) Would you expect a B–F bond to be polar or non-polar? Justify your answer.

polar **(3)**

(large) electronegativity difference **(3)**

(*iii*) Would you expect a BF_3 molecule to be polar or non-polar? Justify your answer.

non-polar **(3)**

symmetry / no net dipole / +ve and –ve centres coincide / B has no lone pair **(3)**

(*iv*) Phosphane (PH_3) is a colourless, flammable, highly toxic gas used in the semiconductor industry. Predict the shape of a molecule of PH_3. Explain your prediction.

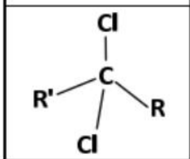
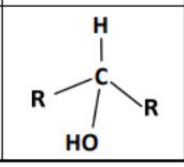
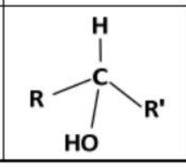
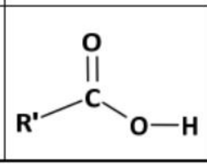
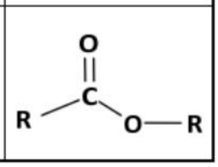
pyramidal / distorted tetrahedron / correct diagram drawn **(3)**

three bond pairs and one lone pair (on P) **(3)**

(*v*) Neither BF_3 nor PH_3 is very soluble in water. Explain why.

non-polar / little hydrogen bonding / little intermolecular forces **(3)**

11. (*b*) The table below shows compounds A to E, where R represents a CH_3 group and R' represents a C_2H_5 group.

A	B	C	D	E
				

(*i*) State the systematic IUPAC names for compounds A, B, C, D and E.

A: **2,2-dichlorobutane**

B: **propan-2-ol**

C: **butan-2-ol**

D: **propanoic acid**

E: **methyl ethanoate** **(5 × 3)**

(*ii*) Classify compound B as a primary alcohol or a secondary alcohol. Justify your answer.

secondary **(3)**

OH is bonded to a carbon which is bonded to two other carbons **(2)**

(*iii*) Are compounds D and E structural isomers? Justify your answer.

yes **(3)**

same number of atoms of each type / same molecular formula **(2)**

11. (*c*) Water hardness is caused by certain dissolved metal ions.

(*i*) Write the chemical formulae for the two metal ions that most commonly cause hardness when dissolved in water.

Ca^{2+}, Mg^{2+} ***[charges required]*** **(3 + 3)**

(*ii*) Identify an anion which is commonly dissolved in water with these metal ions when temporary hardness is involved.

hydrogencarbonate / bicarbonate **(3)**

(*iii*) Identify an anion which is commonly dissolved in water with these metal ions when permanent hardness is involved.

sulfate / chloride **(3)**

When hard water is boiled in a kettle, limescale deposits build up on the heating element.

(*iv*) Write a balanced chemical equation to describe the formation of limescale when hard water is boiled.

$Ca(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$ **(4 × 1 + 2)**

Hard water may be softened by deionising it.

(*v*) Explain how water may be deionised using ion exchange resins.
ions exchanged for H^+ and OH^- **(3)**

(*vi*) Explain why deionised water is not as pure as distilled water.
may contain dissolved gases / may contain non-ionic material /
may contain organic compounds / may contain suspended material **(4)**

11. (*d*)A Unlike many other environmental problems, stratospheric ozone depletion has been largely remedied by international agreement about the use of CFCs. The damaging effect of CFCs on the ozone layer was predicted by the Mexican chemist Mario Molina before the 'hole' in the ozone layer was observed.

(*i*) What is ozone?
O_3 **(4)**

(*ii*) Explain how ozone is formed in the stratosphere.
$O_2 \rightarrow 2O^{\bullet}$ **(3)**
$O^{\bullet} + O_2 \rightarrow O_3$ **(3)**
[Note: $^{\bullet}$ is not needed on O]

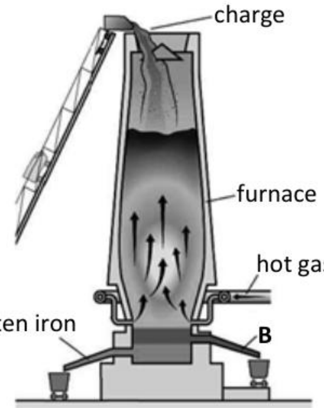
(*iii*) What are CFCs?
chlorofluorocarbons **(3)**

(*iv*) State one main use of CFCs.
refrigerant, aerosol/propellant, fire suppressant, blowing agent, solvent, chemical precursor **(3)**

(*v*) Explain how CFCs in the stratosphere damage the ozone layer.
source of free radicals / source of Cl (atoms) **(3)**
which cause ozone to become O_2 **(3)**

(*vi*) Identify one example of an ozone-friendly CFC replacement.
HCFCs / HFCs **(3)**

11. (*d*)B Iron metal is extracted from its ores by reduction in a blast furnace like that illustrated in the diagram on the right.



(*i*) Identify the two solid materials that are continually added with the iron ore in the charge at the top of the furnace.
coke / carbon **(3)**
limestone / calcium carbonate **(3)**

(*ii*) Identify the hot gas that is blown into the furnace above the hearth during production.
air / oxygen **(3)**

(*iii*) Identify by-product B that is removed at the bottom of the furnace.
slag / $CaSiO_3$ / $CaAl_2O_4$ **(4)**

Carbon monoxide acts as a reducing agent in the blast furnace.

(*iv*) Write a balanced chemical equation for the reaction of carbon monoxide with iron(III) oxide.
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ **(4 × 1 + 2)**

Steel is an alloy of iron.

(*v*) Name the main stages in the manufacture of steel using the electric arc process.
charging, melting, refining, tapping, casting ***[any three]*** **(3 × 2)**

QUESTION 3

(a) WHAT: **corrosive (corrosiveness, corrosion)** (4)

STATE: **do not allow contact with skin (eyes)** /
protective clothing (gloves, lab. coat) / **eye protection (glasses, screen)** (4)

(b) WHICH: **burette** (3)

(c) EXPLAIN: **get average (mean)** temperatures of the two solutions /
wait until both solutions at same (room) temperature /
using plot of temp. v time for both solutions (6)

(d) LIST: **thermometer to 0.2 °C** or better (**temperature sensor**, **"sensitive"**, **"accurate"**) // **add quickly** // **add without splashing** // **replace cover quickly (immediately)** // **stir** constantly // after addition **plot temperature at intervals and get highest temperature by extrapolating** back to time of mixing // **prevent heat loss (use of suitable insulation)** ANY THREE: (3 × 3)
[Do not accept "digital thermometer".]

(e) WHAT: polystyrene a good **insulator** / **glass & metal poor**er **insulators** (3)
[Accept "prevents heat loss" or "not a conductor" for "insulator"]

(f) CALCULATE: **0.05** mol (6)

$^{50}/_{1000}$	(3)	x 1 = 0.05	(3)

TAKING: **2814** J / **2.814** kJ (6)

420 x 6.7	(3)	= 2814	(3)

[If 4200 is used incorrectly minimum of 3 marks to be lost]

HENCE: – **56280** J mol^{-1} / – **56.28** (– **56.3**) kJ mol^{-1} [minus is in bold] (6)

$^{2814}/_{0.05}$	(3)	– 56280	(3)

(g) NAME: **bomb calorimeter** (3)

QUESTION 5

(a) WHAT: an element **cannot be broken (split, divided) into** anything **simpler***
an element is **a simple substance**
[Do not accept "smaller". Accept "further" and "simpler by chemical means".]* (5)

(b) USE: **the electron** in a hydrogen atom **occupies (is restricted to) fixed energy levels (fixed energy values** or **discrete energies) //**

in the ground state **electrons occupy the lowest** available **energy levels //**

the electron can move (jump, become excited) to a higher energy **level if it receives** a certain amount of **energy (heat, light, a photon** of energy) //

the energy (photon) absorbed must exactly **equal the energy difference between ground state (lower level) and excited state (higher level) /**
absorbing light (energy, photon) according to $E_2 - E_1 = hf$ (hυ), [$E_2 - E_1$ *symbols must be explained*] //

excited state unstable / excited state temporary / electron falls back to a lower level //

emitting (giving out) the excess energy in the form of **a photon** of light **(hf, hυ)** /
emitting (giving out) light of **definite frequency (wavelength) /**
emitting light* according to $E_2 - E_1 = hf$ (hυ), [$E_2 - E_1$ *symbols must be explained*]
[Accept "energy" for "light" if f(υ) is explained as frequency.]

ANY FIVE: (5 × 3)

[Marks may be awarded where the required information is clearly provided in diagrams.]

EXPLAIN: metal atoms of different elements have **different** sets of **energy levels (values){different electron configurations (arrangement), different numbers of electrons in shells}** / **individual (different, characteristic)** set of **electron transitions** for each metal //

therefore they **emit different (characteristic, unique, their own) frequencies (wavelengths,** *not colours*) of light /
therefore they have **different (characteristic, unique, their own) spectra** (2 × 3)

WHAT: **red (crimson)** (3)

DESCRIBE: **salt on platinum (nichrome) probe (wire) / salt on soaked** wooden **splint (stick) / salt in solution //**

hold **in (over, against edge, at top) of flame*** / for solution **spray into flame*** (2 × 3)
*[*Accept "Bunsen" for "flame."]*

(c) EXPLAIN **not possible to measure (find, know, get, etc,) the** exact **position (location) //**

and momentum (energy, velocity, speed) of electron (particle, named particle) in an atom **simultaneously (at the same time)** (2 × 3)
["position" and "momentum" are interchangeable.]

GIVE: **wave nature (properties)** of electron (**wave-particle** duality) / **higher resolution spectra / sublevels / Zeeman effect (splitting of spectral lines) / electron spin / failure** of theory **with higher elements (except for hydrogen, with multi-electron systems)** *[Do not accept "orbitals."]* ANY ONE: (3)

WHAT: **region (space, volume** *but not "area" or "place"*) around the nucleus of an atom //

where there is a 99% (high) probability (possibility) of finding an electron / where electron most **likely to be (has a high possibility of being) found**

or

space occupied by electron // described by solution of Schrödinger equation (2 × 3)

QUESTION 9

(a) WHAT: a state in which the **rate of the forward reaction equals** the **rate of the reverse (backward) reaction** / a **state where the concentrations of reactants and products are maintained (do not change)** at the same levels (5)

WHY: **reaction** has **not stopped (is continuing) / forward & reverse reaction(s)** still **occurring** (3)

STATE: if a system at **equilibrium** is subjected to a stress* (is disturbed) //

it tends (attempts, alters, moves) to oppose (minimise, relieve) the stress* (disturbance, influence) (2 × 3)

*[*The term "stress" may be replaced by "pressure, temp, conc" but only if all three are given. Do not accept "force" for stress.]*

(b) EXPLAIN: *(i)* **decrease** //

reaction **shifts forward (to right or red side) to oppose stress (decrease CNS^-** conc) (2 × 3)

[Do not accept "according to Le Chatelier's principle" for "to oppose stress."]

[Cancelling applies for a contradiction in <u>either</u> direction. Accept "compensate for" for "oppose."]

(ii) equilibrium **in solution** / **liquid** phase / **liquid (solution) not compressible** / **no gases** involved *[Accept "**in** aqueous **solution**".]* (3)

(c) WRITE: $\dfrac{[Fe(CNS)^{2+}]}{[Fe^{3+}][CNS^-]}$ *[Accept $FeCNS^{2+}$ for $Fe(CNS)^{2+}$.]*

[Expression inverted (0).] (6)

CALCULATE: **138.87 (138.9, 139)** M^{-1} (12)

	Fe^{3+}	+	CNS^-	⇋	$Fe(CNS)^{2+}$
Start (M)	1.0×10^{-3}		1.0×10^{-3}		0
Equil (M)	**8.9×10^{-4}** (3)		**Ms the same** (3)		1.1×10^{-4} mol

$$K_c = \frac{1.1 \times 10^{-4}}{(8.9 \times 10^{-4})^2} \quad (3)$$

[Accept correct use of an incorrect K_c expression from (c) WRITE.]

$$= 138.87\ (138.9,\ 139) \quad (3)$$

(d) STATE: **smaller** (3)

IS: **endothermic** (3)

JUSTIFY: **cooling (ice-water) shifts in the backward (left or yellow side) direction** for this reaction**, therefore backward (left) is exothermic (gives out heat)** /

cooling always **shifts in exothermic direction (side that releases heat) which is the backward (left or yellow side) direction** for this reaction (3)

[IS & JUSTIFY are linked.]

QUESTION 1

(*a*) (*i*) IDENTIFY: **calcium (Ca)** ions **/ Ca^{2+} //**
magnesium (Mg) ions **/ Mg^{2+}** (3 + 2)

(*ii*) EXPLAIN: sum of (all, total) **permanent and temporary** hardness **/**
due to sum of (all, total) dissolved **Ca^{2+} and Mg^{2+} (calcium and magnesium ions, salts** of **calcium and magnesium)** (3)

(*b*) (*i*) NAME: **Solocrome** Black **(Eriochrome** Black T, **Erio T**) (3)
[Black T insufficient]

(*ii*) WHAT: **wine (red, wine-red)** to **//**
to **blue** (2 × 3)
[Allow (3) for colours in reverse or for either correct colour where only one colour is stated.][Allow pink for wine (red, wine-red).]

(*c*) (*i*) WHAT: **10** (3)
[Accept answer in range 9 to 11]

(*ii*) WHY: to ensure **sharp (accurate, colour change at) end-point /**
to ensure only **calcium ions (Ca^{2+}, magnesium ions, Mg^{2+}, M^{2+}) detected /**
to ensure all **calcium ions (Ca^{2+}, magnesium ions, Mg^{2+}, M^{2+}) react (complex)** with edta **/**
to ensure **non-alkaline earth metal ions do not react (do not complex, not detected) /**
to ensure **indicator works properly /**
MY^{2-} stable only **at high pH** for calcium and magnesium **/**
alkaline conditions needed (acidic conditions unsuitable) for edta to complex with M^{2+} (calcium ions, Ca^{2+}, magnesium ions, Mg^{2+}) (3)

(*d*) DESCRIBE: **clamp vertically //**

fill above zero (mark) / fill to zero (mark) using dropper //

fill part **below tap (nozzle)** before adjusting to initial mark **//**

fill with clean dry **funnel //**

remove funnel before adjusting to initial mark **//**

ensure no bubbles (tap to remove bubbles) before adjusting to initial mark **//**

bottom of meniscus on zero (mark) //

read at eye-level / use card (paper, etc) behind burette when reading /
avoid parallax errors **when reading**

ANY THREE: (6 + 3 + 3)

(*e*) CALCULATE:

(*i*) 0.**000092** (**9.2 × 10^{-5}, 23/250000**) moles edta (3)

$\frac{9.2 \times 0.010}{1000}$ = 0.**000092** (**9.2 × 10^{-5}, 23/250000**) moles edta (3)

(*ii*) 0.**000092** (**9.2 × 10^{-5}, 23/250000**) moles of M^{2+} (3)

M^{2+} : edta = 1 : 1 ⇒ 0.**000092 (9.2 × 10^{-5}, 23/250000)** moles of M^{2+} (3)

(*iii*) 0.**00368** (**3.68 × 10^{-3}, 23/6250**) – 0.**0037** moles of M^{2+} removed from one litre (3)

0.000092 (9.2 × 10^{-5}, 23/250000) × 40 = 0.**00368** (**3.68 × 10^{-3}, 23/6250**) – 0.**0037** moles of M^{2+} removed from one litre [Multiply (*ii*) by **40** essential.] (3)

or

$$\frac{25.0 \times M}{1} = \frac{9.2 \times 0.010}{1} \Rightarrow M = 0.00368\ (3.68 \times 10^{-3},\ 23/6250) - 0.0037 \text{ moles of } M^{2+}$$
removed from one litre (3)

(*iv*) 0.**368** (**3.68 × 10^{-1}, 46/125**) – 0.**37** g $CaCO_3$ hardness removed from one litre (3)

= 0.00368 (3.68 × 10^{-3}, 23/6250) × 100*=
0.**368** (**3.68 × 10^{-1}, 46/125**) – 0.**37** g $CaCO_3$ hardness removed from one litre
[Multiply (*iii*) by **100*** essential.] (3)

[**Addition must be shown for error to be treated as slip.*]

368 – 370 p.p.m. $CaCO_3$ hardness removed from one litre (3)

= 0.368 (3.68 × 10^{-1}, 46/125) × 1000 =
368 – 370 p.p.m. $CaCO_3$ hardness removed from one litre
[Multiply by **1000** essential.] (3)

[*1 mark to be deducted for* ***each*** *mathematical slip, e.g. transposing numbers, addition error in *M_r where atomic masses* ***shown*** *but added incorrectly, etc.*]

QUESTION 4

Eight items to be answered. Six marks to be allocated to each item and one additional mark to be added to each of the first two items for which the highest marks are awarded.

(*a*) REFER: Li, Na, and K (groups) have similar chemical **properties //**
atomic mass (weight) of Na (one) is **average of (midway between)** those of **Li and K (of other two) / mass number of one (Na) is average** of the mass numbers **of** the **others (Li and K) / 23 = (7 + 39) ÷ 2** (2 × 3)

(*b*) WHY: electron in **outer** energy **level (shell, *n* = 3) has more energy /**
electron in **excited (higher, outer)** state **has more energy /**
electron in **inner** energy **level (shell, *n* = 2) has less energy /**
electron **loses energy /** electron moves **from higher to lower energy** level **/**
$E_2 - E_1 = hf$ (6)

(*c*) WHY: second **electron** comes **from full (new, closed) shell** (main **energy level, 1*s* sublevel, 1*s* orbital) /**
second **electron** comes **from shell** (main **energy level) closer to nucleus /**
second outermost **electron** comes **from 1st** main **energy level (shell)**
while first electron comes **from 2nd /**
1st electron removed (lost) is only electron in outer (2nd) shell (main **energy level) /**
second **electron** comes **from** a species with **a stable helium (noble gas)**
electron **configuration /**
second **electron less (not) shielded (screened)** from nucleus than first (6)

Where 6 marks not awarded above 5 marks may be awarded any *one* of the following.
more difficult to remove electron from positive ion than from neutral atom **/**
greater electrostatic force (attraction) between Li^+ **ion and electron /**
1st electron farther from nucleus / 2nd **electron closer to nucleus /**
ionic radius smaller than atomic radius **/**
effective nuclear charge increased when 1st electron is removed /
more protons than electrons in the ion

(*d*) WHAT: (*i*) **red / crimson //**
(*ii*) **blue-green / green** (4 + 2)
[Allow blue/green for blue-green]

(*e*) STATE: **at the same temperature and pressure //**
equal volumes of gases have **equal (the same) number(s) of particles (atoms, molecules, moles)** (2 × 3)
[Do not allow s.t.p for 'same temperature and pressure'.]

(*f*) CALCULATE: 0.**2**00 g (6)

18.3 × 12 = **219.6** g C (3)

1098 carats = 219.6 g

⇒ one carat = $\frac{219.6}{1098}$ = 0.**2**00 g (3)

or

$\frac{18.3}{1098} = \frac{\mathbf{1}}{\mathbf{60}}$ (0.**016667**) moles C per carat (3)

⇒ one carat = 0.016667 × 12

= 0.**2**00 g (3)

or

$\frac{1098}{18.3}$ = **60** carats per mole C (per 12 g C) (3)

⇒ one carat = $\frac{\mathbf{12}}{\mathbf{60}}$

= 0.**2**00 g (3)

(*g*) WHAT: **iron(II) sulfate ($FeSO_4$,** ammonium **iron(II) sulfate) /**
$(C_6H_5)_2NH$ (diphenylamine) and **NH_4Cl (ammonium chloride) /**
copper (Cu) //
concentrated **sulfuric acid (H_2SO_4)**
or
sodium hydroxide (NaOH) solution **//**
aluminium (Al) / copper (Cu) / zinc (Zn) (4 + 2)

(*h*) IDENTIFY: (*i*) **aluminium sulfate (alum, $Al_2(SO_4)_3$) / polyacrylamide ($(-CH_2CHCONH_2-)_n$) / sodium silicate (Na_2SiO_3, Na_4SiO_4, $Na_6Si_2O_7$, etc) / sodium aluminate ($NaAlO_2$, $NaAl(OH)_4\cdot(H_2O)_x$, $Na_2O\cdot Al_2O_3$, $Na_2Al_2O_4$) / aluminium chlorohydrate ($Al_nCl_{3n-m}(OH)_m$) / iron(II) sulfate ($FeSO_4$) / iron(III) chloride ($FeCl_3$) / calcium oxide (CaO) / calcium hydroxide ($Ca(OH)_2$)**
[Allow polyelectrolyte]

(*ii*) **sodium fluoride (NaF) / hexafluorosilicic acid (H_2SiF_6) / sodium fluorosilicate (Na_2SiF_6) /**
[Allow **fluoride** ion **(F^-), fluoride** salt.]

(4 + 2)

(*i*) WHAT: **iodine (I_2) //**
hydrogen (H_2) (4 + 2)
[Allow I and H]

(*j*) WHICH: **ethyne (C_2H_2)** (6)

(*k*) CALCULATE: **72**.0 mg (6)

M_r aspirin ($C_9H_8O_4$) = 180	*or*	M_r aspirin ($C_9H_8O_4$) = 180
0.146 × 180* = **26.28**0 g aspirin (3)		0.146 ÷ 365 = **4 × 10^{-4} (1/2500)** mol per day (2)
26.28 ÷ 365 = 0.**072**0 **(9/125)** g per day (2)		4 × 10^{-4} × 180* = 0.**072**0 **(9/125)** g per day (3)
⇒ 0.0720 × 1000 = **72**.0 mg per day (1)		⇒ 0.0720 × 1000 = **72**.0 mg aspirin per day (1)

[**Addition must be shown for error to be treated as slip.*]

(*l*) **A** WRITE: $CO_2 + H_2O \rightarrow H_2CO_3$
$H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + H^+$ / $H_2CO_3 + H_2O \rightleftharpoons (\rightarrow) HCO_3^- + H_3O^+$ //
$HCO_3^- \rightleftharpoons (\rightarrow) CO_3^{2-} + H^+$ / $HCO_3^- + H_2O \rightleftharpoons (\rightarrow) CO_3^{2-} + H_3O^+$ (2 × 3)
or
$H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + H^+ \rightleftharpoons (\rightarrow) CO_3^{2-} + 2H^+$ (6)
[Allow **$2H_2CO_3 \rightleftharpoons (\rightarrow) HCO_3^- + CO_3^{2-} + 3H^+$** or
$2H_2CO_3 + 3H_2O \rightleftharpoons (\rightarrow) HCO_3^- + CO_3^{2-} + 3H_3O^+$]

or

B WHAT: **molecules occupy (at) lattice points //**
held together by (contain) **intermolecular (van der Waals, London, dispersion, dipole-dipole, hydrogen) bonds (forces, interactions)** (2 × 3)

QUESTION 5

a	b	c	d
5	9	15	21

(*a*) WHAT: **subatomic particle / particle orbiting** atomic **nucleus / particle located in electron cloud** of atom **/ particle located within** electron cloud of **atom //**
negative (–) //
mass 1/1840 amu / negligible mass / very small mass ANY TWO: (3 + 2)

(*b*) (*i*) WHY: **too much energy / excited / gained energy / gained heat** energy **(heated) / absorbed a photon / absorbed electrical energy** (3)

(*ii*) WHAT: **red** (3)

(*iii*) NAME: **Balmer** (3)

(*c*) (*i*) HOW: **3** (3)

(*ii*) WHAT: **space (volume, region)** around nucleus of an atom **//**
where there is a relatively **high probability (possibility) of finding an electron / where an electron is likely to be found**
[‘*Area*’ around nucleus not acceptable.]

or

approximate **solution //**
to (of) a **Schrödinger (wave) equation** for an electron in an atom (2 × 3)

(*iii*) HOW: **4** (3)

(*iv*) WHAT: **18** (3)

(*d*) WRITE: *Be*: $1s^2\,2s^2$ / [He] $2s^2$ (3)

Ne: $1s^2\,2s^2\,2p^6$ / $1s^2\,2s^2\,2p_x^2 2p_y^2 2p_z^2$ / [He] $2s^2\,2p^6$ (3)

Mg: $1s^2\,2s^2\,2p^6\,3s^2$ / $1s^2\,2s^2\,2p_x^2 2p_y^2 2p_z^2\,3s^2$ / [Ne] $3s^2$ (3)

Kr: $1s^2\,2s^2\,2p^6\,3s^2\,3p^6 4s^2\,3d^{10}\,4p^6$ /
$1s^2\,2s^2\,2p_x^2 2p_y^2 2p_z^2\,3s^2\,3p_x^2 3p_y^2 3p_z^2 4s^2\,3d^{10}\,4p^6$ /
[Ar] $4s^2\,3d^{10}\,4p^6$ (3)
[*Allow subscripts instead of superscripts.*]
[*Arrows to represent numbers of electrons acceptable but sub-level symbols must be given.*]

EXPLAIN: (*i*) have **stable** full **outer octet** ($ns^2\,np^6$) electrons **/**
8 electrons in outer shell (energy level) is **stable /**
satisfy octet rule /
6 electrons in outer *p*-sublevel (*p*-subshell) is **stable /**
full outer *p*-sublevel (*p*-subshell) is **stable /**
closed shell of valence electrons (8 valence electrons, valence sublevels full) is **stable** (3)

[‘Set of full sublevels stable’ unacceptable and does not cancel.]
[‘Have full outer shells which is stable’ incorrect but does not cancel.]

EXPLAIN: (*ii*) **do not have** stable full **outer octet** ($ns^2\,np^6$) electrons **/**
do not have 8 electrons in outer shell (energy level) /
do not satisfy octet rule /
only **2 electrons in** an incomplete **outer shell (energy level) /**
would **need to lose** 2 **electrons to achieve Group 18 (noble gas, inert gas, stable) configuration** (3)

[Where no marks awarded above for EXPLAIN (*i*) and EXPLAIN (*ii*) allow one (3) if both ‘**stable** electron configuration (arrangement of electrons)’ is given in (*i*) and ‘**unstable** electron configuration (arrangement of electrons)’ is given in (*ii*).]

WHY: Mg **has greater atomic radius / more energy levels (shells)** in Mg **/**
more screening (shielding) of nucleus by electrons in inner shells in Mg **/**

more screening (shielding) of nucleus by electrons in inner shells in Mg /
Mg has **smaller ionisation energy /**
attraction of Mg **nucleus for outer electrons less /**
outer electrons of Mg **farther from nucleus** (3)
Accept opposite statements in terms of Be but Be must be specified.]

11. (*a*) The Environmental Protection Agency (EPA) recommend that household wells are checked for water quality. A water sample from a hard water area may be tested for total hardness.

(*i*) What is meant by total hardness?

temporary hardness and permanent hardness / all calcium ions and all magnesium ions **(3)**

(*ii*) Write the full name for edta, a reagent used to determine total hardness.

ethylenediaminetetraacetic acid **(3)**

(*iii*) Name a suitable method for removing total hardness from water for domestic use.

ion-exchange / use of deioniser **(3)**

A water sample from an agricultural area may contain nitrate ions.

(*iv*) Describe a chemical test to confirm the presence of nitrate ions in a water sample.

add iron(II) sulfate solution / $FeSO_4$ **(2)**

add concentrated sulfuric acid / H_2SO_4 **(2)**

brown ring forms (at interface) **(2)**

Lead ions from the disposal of batteries may enter a water supply.

(*v*) Identify an instrumental method of analysis that could be used to detect and measure the concentration of lead ions in a water sample.

atomic absorption spectrometry / AAS **(2)**

(*vi*) Describe how lead ions can be removed from a water supply.

precipitation / reverse osmosis **(2)**

Chlorination may be carried out on a water supply from a household well using a solution of sodium hypochlorite (NaOCl). This solution is prepared by diluting 5.0 litres of a 1% (w/v) solution of sodium hypochlorite to 25 litres with water.

(*vii*) Calculate the final concentration in p.p.m. (mg per litre) of the sodium hypochlorite solution after dilution to 25 litres.

(1% =) 1 g per 100 cm^3/ 10 g per 1 litre/ 50 g per 5 litres **(2)**

1000 mg per 100 cm^3/ 10000 mg per 1 litre/ 50000 mg per 5 litres **(2)**

multiply by dilution factor = 2000 (p.p.m.) **(2)**

(*b*) In an experiment to measure the heat of reaction (ΔH) of hydrochloric acid with sodium hydroxide, 80 cm^3 of 1.0 M hydrochloric acid solution at room temperature were added to 80 cm^3 of 1.0 M sodium hydroxide solution, also at room temperature in a suitable container. The temperature of the mixture rose by 6.8 K and then began to fall. The reaction is described by the following balanced chemical equation:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

(*i*) Why did the temperature rise when the solutions were mixed?

heat released / exothermic reaction **(3)**

(*ii*) Explain what is meant by the term heat of reaction.

heat change **(3)**

when the number of moles of reactants in a balanced equation react completely **(3)**

(*iii*) Calculate the number of moles of hydrochloric acid in 80 cm^3 of 1.0 M hydrochloric acid solution.

$\frac{80}{1000}$ **= 0.08 (moles)** **(6)**

(*iv*) Calculate the heat energy produced in the reaction mixture, assuming the density of the resultant sodium chloride solution is 1.0 g cm^{-3} and the specific heat capacity of the solution is 4.2 kJ kg^{-1} K^{-1}.

mass = 0.160 (kg) **(2)**

$mc\Delta\theta$ / (0.160)(4.2)(6.8) **(2)**

4.5696 (kJ) / 4569.6 J **(2)**

(*v*) Calculate the value of ΔH, the heat of reaction.

4.5696 ÷ 0.08 = 57.12 **(2)**

ΔH = – 57.12 kJ mol^{-1} **(2)**

(*c*) Between 1908 and 1948 luminous paints containing compounds of radioactive radium–226 were used on the inside of watches and clocks so that they could be read in the dark.

Radium–226 emits alpha radiation. It has a half-life of 1600 years.

(*i*) Name one scientist credited with the discovery of the element radium.

(Marie / Pierre) Curie **(4)**

(*ii*) What is an alpha particle?

(particle consisting of) 2 protons and 2 neutrons / helium nucleus **(3)**

(*iii*) Identify the radioisotope produced when radium–226 emits an alpha particle.

Rn–222 / radon–222 **(3)**

(*iv*) Explain why a person wearing a watch containing this luminous paint is not at risk from the alpha radiation emitted by the radium–226.

low penetrating ability (of alpha radiation) **(3)**

(*v*) State a reason why a radium watch manufactured 100 years ago is still considered a source of ionising radiation.

long half-life / very little of sample will have decayed in 100 years **(3)**

The nuclear equation below represents the beta-particle decay of another isotope of radium, radium–225.

$$^{225}_{88}\mathbf{Ra} \rightarrow {}^{X}_{Y}\mathbf{Z} + {}^{0}_{-1}\mathbf{e}$$

(*vi*) Identify the number **X**.
225 **(3)**

(*vii*) Identify the number **Y**.
89 **(3)**

(*viii*) Identify the element **Z**.
actinium / Ac **(3)**