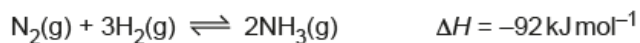


## CAMBRIDGE A LEVEL CHEMISTRY PRACTISE QUESTIONS

- (c) The Haber process involves the reaction of  $\text{N}_2$  and  $\text{H}_2$  to form ammonia,  $\text{NH}_3$ .

A catalyst is used, which allows the process to be carried out at a lower temperature and pressure.



- (i) Use the information in (c) to complete Table 3.1.

**Table 3.1**

compound	enthalpy change of formation, $\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{N}_2$	
$\text{H}_2$	
$\text{NH}_3$	

[2]

- (ii) Explain how the presence of a catalyst affects the reaction.

.....  
.....  
..... [1]

- (iii) State and explain the effect, if any, on the **rate** of the Haber process as the pressure is lowered.

.....  
.....  
.....  
..... [2]

- (d) The  $\text{N}_2\text{F}_2$  molecule has a double covalent bond between its nitrogen atoms. This consists of a  $\sigma$  and a  $\pi$  bond.

- (i) Complete Fig. 3.2 to show the dot-and-cross diagram for  $\text{N}_2\text{F}_2$ .

Show outer electrons only.

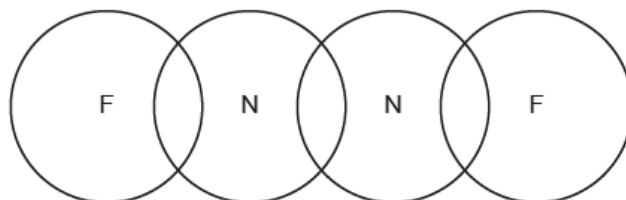


Fig. 3.2

[2]

- (ii) Deduce the hybridisation of the N atoms in  $\text{N}_2\text{F}_2$ .

..... [1]

- (iii) Draw a diagram of the  $\pi$  bond between the N atoms in  $\text{N}_2\text{F}_2$  and describe how it forms.

.....  
.....

[2]

- (a) Sulfur chloride,  $\text{SCl}_2$ , is a liquid at room temperature. When  $\text{SCl}_2$  is added to water, misty fumes are seen and a solution is made that turns universal indicator red.

(i) Identify the type of reaction that occurs when  $\text{SCl}_2$  is added to water.

..... [1]

(ii) Name a chloride of a different Period 3 element that is also a liquid at room temperature and produces misty fumes when added to water.

..... [1]

- (b) A molecule of  $\text{SCl}_2$  contains two S–Cl covalent bonds.

(i) Complete the dot-and-cross diagram in Fig. 2.1 to show the arrangement of the outer electrons in a molecule of  $\text{SCl}_2$ .

Use x to show electrons from the chlorine atoms.

Use • to show electrons from the sulfur atom.

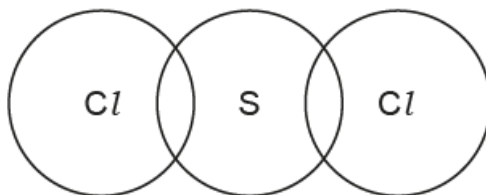


Fig. 2.1

[2]

(ii) Predict the shape of, and bond angle in, a molecule of  $\text{SCl}_2$  by using VSEPR theory.

shape .....

bond angle .....

[2]

- (c) Solid magnesium nitride,  $\text{Mg}_3\text{N}_2$ , is a crystalline solid.

(i) Deduce the oxidation numbers of magnesium and nitrogen in magnesium nitride to complete Table 2.1.

Table 2.1

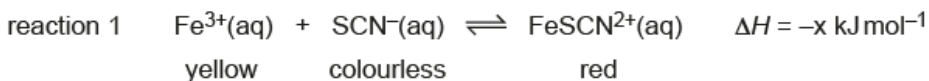
	oxidation number in $\text{Mg}_3\text{N}_2$
magnesium	
nitrogen	

[1]

(a) Define Le Chatelier's principle.

.....  
.....  
..... [2]

(b) Reaction 1 describes the reversible reaction between yellow  $\text{Fe}^{3+}(\text{aq})$  and colourless  $\text{SCN}^{-}(\text{aq})$  to produce red  $\text{FeSCN}^{2+}(\text{aq})$ .



A mixture of  $\text{Fe}^{3+}(\text{aq})$ ,  $\text{SCN}^{-}(\text{aq})$  and  $\text{FeSCN}^{2+}(\text{aq})$  is at equilibrium at  $20^{\circ}\text{C}$ .

The temperature of this mixture is then increased to  $50^{\circ}\text{C}$  and allowed to reach equilibrium.

Deduce the changes that occur, if any, in the equilibrium mixture at  $50^{\circ}\text{C}$  compared to the equilibrium mixture at  $20^{\circ}\text{C}$ .

- change in appearance

.....

- change in relative concentration of  $\text{FeSCN}^{2+}(\text{aq})$

.....

- change in value of the equilibrium constant,  $K_c$

.....

[3]

- (c) In another experiment, equimolar amounts of  $\text{Fe}^{3+}(\text{aq})$  and  $\text{SCN}^{-}(\text{aq})$  are mixed together and allowed to reach equilibrium. The total volume of the mixture is  $25.0\text{ cm}^3$ .



At equilibrium the mixture contains:

- $[\text{SCN}^{-}] = 1.30 \times 10^{-3} \text{ mol dm}^{-3}$
- $[\text{FeSCN}^{2+}] = 0.300 \times 10^{-3} \text{ mol dm}^{-3}$ .

- (i) Calculate the initial amount, in mol, of  $\text{Fe}^{3+}(\text{aq})$  added to  $\text{SCN}^{-}(\text{aq})$  to produce this mixture.

initial amount of  $\text{Fe}^{3+}(\text{aq}) = \dots\dots\dots \text{ mol}$  [2]

- (ii) Calculate  $K_c$  for reaction 1 and state its units.

Show your working.

$K_c = \dots\dots\dots$

units  $\dots\dots\dots$  [2]

(a) Define enthalpy change of formation.

.....  
.....  
..... [2]

(b) Iron is made when iron(III) oxide is heated with carbon monoxide, as shown by reaction 2.

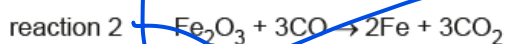


Table 4.1 shows enthalpy change of formation data measured at 298 K and 101 kPa.

**Table 4.1**

substance	equation	value for $\Delta H_f^\ominus / \text{kJ mol}^{-1}$
$\text{Fe}_2\text{O}_3$		-824.2
CO		-110.5
$\text{CO}_2$	$\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$	-393.5

(i) Complete Table 4.1 by adding equations with relevant state symbols to represent:

- standard enthalpy change of formation for  $\text{Fe}_2\text{O}_3$
- standard enthalpy change of formation for CO.

[2]

(ii) Use the data in Table 4.1 to calculate the enthalpy change of reaction,  $\Delta H_r$ , in  $\text{kJ mol}^{-1}$ , for reaction 2.

Show your working.

$$3 \times -393.5$$
$$- (-824.2 \times 3)$$

$$-24.8$$

$\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1}$  [2]

[Total: 6]

- 1 (a) Complete Table 1.1 using relevant information from the Periodic Table.

Table 1.1

	nucleon number	proton number	number of electrons
$\text{Mg}^{2+}$	24	12	10
$\text{Al}^{3+}$	27	13	10

[2]

- (b) State and explain the difference in the ionic radius of  $\text{Al}^{3+}$  compared to  $\text{Mg}^{2+}$ .

.....  
 .....  
 .....  
 ..... [3]

- (c) Draw a labelled diagram to show the structure and bonding in sodium.

[1]

- (d) Fig. 1.1 shows the variation in melting point of some Period 3 elements in their standard states at room temperature and pressure.

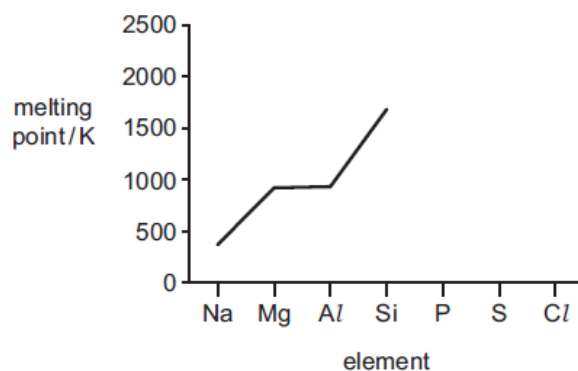


Fig. 1.1

- (i) Explain why Si has a high melting point.

.....  
 .....  
 ..... [1]

- (ii) Complete Fig. 1.1 to show the variation in the melting points of the elements P, S and Cl. [2]

- (e) Two Period 3 elements react with an excess of oxygen at room pressure.

- (i) Complete Table 1.2.

**Table 1.2**

1	2	3
Period 3 element	state of oxide at room temperature and pressure	approximate pH of solution made when oxide is added to water
Na		
S		

[2]

- (ii) The solutions made in column 3 of Table 1.2 are mixed together. Name the type of reaction that occurs.

..... [1]

- (iii) Write an equation to describe the reaction between  $P_4O_{10}$  and an excess of water.

..... [1]

- (f) Aluminium hydroxide is amphoteric.

- (i) Explain what is meant by amphoteric.

.....  
 ..... [1]

- (ii) Write an equation to describe the reaction that occurs when aluminium hydroxide,  $Al(OH)_3$ , reacts with  $NaOH(aq)$ .

..... [1]

- 2 Separate samples of  $\text{Na}_2\text{CO}_3$  and  $\text{NaHCO}_3$  react with  $\text{HCl}(\text{aq})$  to produce the same products, as shown in Table 2.1.

Table 2.1

reaction	equation	$\Delta H/\text{kJ mol}^{-1}$
1	$\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$	$\Delta H_1$
2	$\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$	$\Delta H_2 = +27.2$

- (a) Complete the reaction pathway diagram in Fig. 2.1 for reaction 2.

Label the diagram to show the enthalpy change,  $\Delta H_2$ , and the activation energy,  $E_A$ .

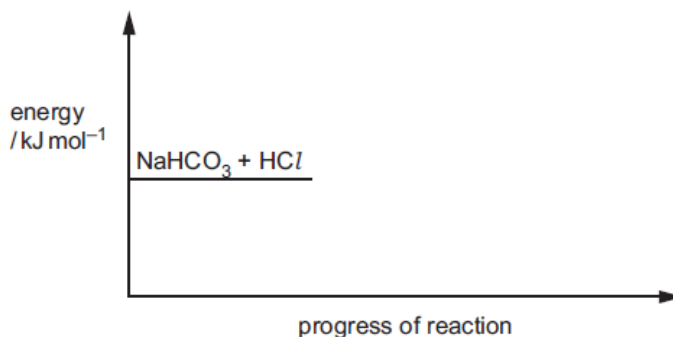


Fig. 2.1

[2]

- (b) The value for  $\Delta H_1$  is determined by experiment using the following method.

- $50.0\text{ cm}^3$  of  $2.00\text{ mol dm}^{-3}$   $\text{HCl}(\text{aq})$  is added to a polystyrene cup.
- The initial temperature of the acid is recorded as  $19.6^\circ\text{C}$ .
- $0.0400\text{ mol}$  of  $\text{Na}_2\text{CO}_3$  is added and the mixture is stirred.
- All the solid  $\text{Na}_2\text{CO}_3$  disappears and a colourless solution is produced.

The maximum temperature recorded during the reaction is  $26.2^\circ\text{C}$ .

- (i) Describe **one** other observation that shows the reaction is complete.

..... [1]

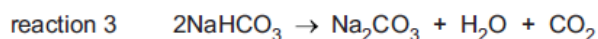
- (ii) Calculate the value of  $\Delta H_1$  in  $\text{kJ mol}^{-1}$ .

Assume the specific heat capacity of the reaction mixture is the same as for water and no heat is lost to the surroundings.

Show your working.

$$\Delta H_1 = \dots\dots\dots \text{kJ mol}^{-1} \quad [3]$$

- (iii) Thermal decomposition occurs when  $\text{NaHCO}_3$  is heated.



Calculate the enthalpy change for reaction 3,  $\Delta H_r$ , using the data in Table 2.1 and the value of  $\Delta H_1$  calculated in (b)(ii).

(If you were unable to calculate a value for  $\Delta H_1$  in (b)(ii), assume the enthalpy change is  $-38.4 \text{ kJ mol}^{-1}$ . This is **not** the correct value.)

$$\Delta H_r = \dots\dots\dots \text{kJ mol}^{-1} \quad [2]$$

- (c) Z is a salt that contains a Period 4 element from Group 2. When Z is heated brown gas forms.

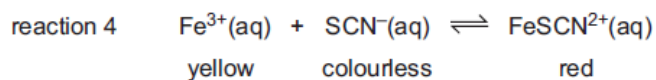
Identify the formula of Z and use it to write an equation for the reaction.

..... [2]

3 (a) Describe what is meant by dynamic equilibrium.

.....  
.....  
..... [2]

(b) Reaction 4 describes the reversible reaction between yellow  $\text{Fe}^{3+}(\text{aq})$  and colourless  $\text{SCN}^{-}(\text{aq})$  to produce red  $\text{FeSCN}^{2+}(\text{aq})$ .



An equilibrium mixture contains  $\text{Fe}^{3+}(\text{aq})$ ,  $\text{SCN}^{-}(\text{aq})$  and  $\text{FeSCN}^{2+}(\text{aq})$ . A few colourless crystals of soluble  $\text{KSCN}(\text{s})$  are added. The mixture is then left until it reaches equilibrium again. The temperature of both equilibrium mixtures is the same.

(i) Deduce the changes that occur, if any, in the equilibrium mixture after  $\text{KSCN}(\text{s})$  is added compared to the original equilibrium mixture.

- change in appearance

.....

- change in relative concentration of  $\text{Fe}^{3+}(\text{aq})$

.....

- change in value of the equilibrium constant,  $K_c$

.....

[3]

(ii) The expression for the equilibrium constant,  $K_c$ , for reaction 4 is shown.

$$K_c = \frac{[\text{FeSCN}^{2+}(\text{aq})]}{[\text{Fe}^{3+}(\text{aq})] \times [\text{SCN}^{-}(\text{aq})]}$$

$5.00 \times 10^{-5}$  mol of  $\text{Fe}^{3+}(\text{aq})$  and  $5.00 \times 10^{-5}$  mol of  $\text{SCN}^{-}(\text{aq})$  are added together and allowed to reach equilibrium. The total volume of the mixture is  $25.0 \text{ cm}^3$ .

At equilibrium the concentration of  $\text{FeSCN}^{2+}(\text{aq})$  is  $4.23 \times 10^{-4} \text{ mol dm}^{-3}$ .

Calculate the equilibrium constant,  $K_c$ , for reaction 4.

Include the units in your answer.

$K_c = \dots\dots\dots$

units  $\dots\dots\dots$

[4]

(c) Determine the full electronic configuration of  $\text{Fe}^{3+}$ .

..... [1]

(d)  $\text{SCN}^{-}(\text{aq})$  is colourless.

Complete the dot-and-cross diagram in Fig. 3.1 to show the arrangement of outer electrons in an  $\text{SCN}^{-}$  ion.

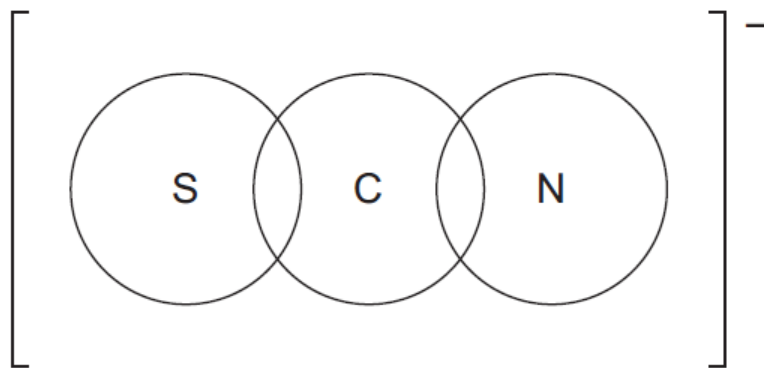


Fig. 3.1

[2]

- 1 Fig. 1.1 shows how **first** ionisation energies vary across Period 2.

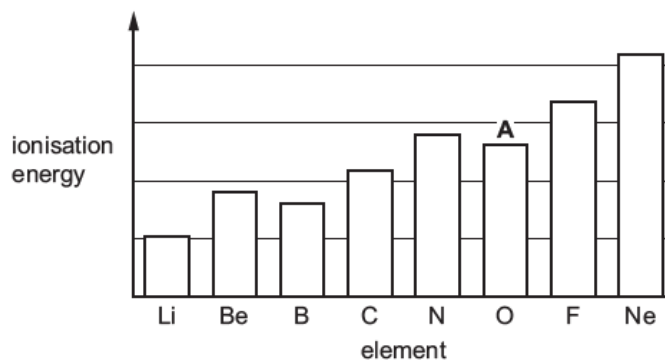


Fig. 1.1

- (a) Construct an equation to represent the **first** ionisation energy of oxygen. Include state symbols.

..... [1]

- (b) (i) State and explain the general trend in first ionisation energies across Period 2.

.....  
 .....  
 .....  
 .....  
 ..... [3]

- (ii) Explain why ionisation energy **A** in Fig. 1.1 does **not** follow the general trend in first ionisation energies across Period 2.

.....  
 .....  
 .....  
 ..... [2]

- (c) Element **E** is in Period 3 of the Periodic Table.  
The first eight ionisation energy values of **E** are shown in Table 1.1.

**Table 1.1**

ionisation	1st	2nd	3rd	4th	5th	6th	7th	8th
ionisation energy / kJ mol <sup>-1</sup>	577	1820	2740	11 600	14 800	18 400	23 400	27 500

Deduce the full electronic configuration of **E**.  
Explain your answer.

full electronic configuration of **E** =  $1s^2 2s^2 2p^6 3s^2 3p^1$   
 explanation the greatest jump between 3rd and 4th I.E indicates that they are  
 three electron in the outer most shell of the element E

[3]

Some oxides of elements in Period 3 are shown.



- (a) Na reacts with O<sub>2</sub> to form Na<sub>2</sub>O. Na is the reducing agent in this reaction.

- (i) Define reducing agent.

.....  
 ..... [1]

- (ii) Write an equation for the reaction of Na<sub>2</sub>O with water.

..... [1]

- (b) Al<sub>2</sub>O<sub>3</sub> is an amphoteric oxide found in bauxite.

- (i) State what is meant by amphoteric.

.....  
 ..... [1]

- (ii) Al<sub>2</sub>O<sub>3</sub> is purified from bauxite in several steps. The first step involves heating Al<sub>2</sub>O<sub>3</sub> with an excess of NaOH(aq). A colourless solution forms.

Write an equation for this reaction.

..... [1]

- (iii)  $\text{Al}_2\text{O}_3$  is used as a catalyst in the dehydration of alcohols.

State the effect of using  $\text{Al}_2\text{O}_3$  as a catalyst in the dehydration of alcohols. Use the Boltzmann distribution in Fig. 2.1 to help explain your answer.

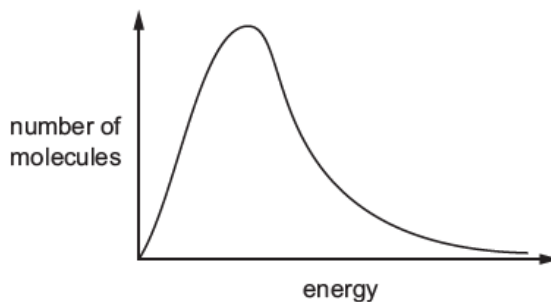


Fig. 2.1

.....  
.....  
..... [3]

- (c)  $\text{P}_4\text{O}_6$  is a white solid that has a melting point of  $24^\circ\text{C}$ . Solid  $\text{P}_4\text{O}_6$  reacts with water to form  $\text{H}_3\text{PO}_3$ .

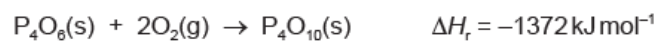
- (i) Deduce the type of structure and bonding shown by  $\text{P}_4\text{O}_6$ . Explain your answer.

.....simple molecular structure and covalent bon.....  
.....it can easily interact with water so its a covalent bond and it has no melting.....  
.....point..... [2]

- (ii) Determine the oxidation number of P in  $\text{H}_3\text{PO}_3$ .

..... [1]

(iii) When  $\text{P}_4\text{O}_6(\text{s})$  is heated with oxygen it forms  $\text{P}_4\text{O}_{10}(\text{s})$ .



The enthalpy change of formation,  $\Delta H_f$ , of  $\text{P}_4\text{O}_{10}(\text{s})$  is  $-3012 \text{ kJ mol}^{-1}$ .

Calculate the enthalpy change of formation,  $\Delta H_f$ , of  $\text{P}_4\text{O}_6(\text{s})$ .

$\Delta H_f$  of  $\text{P}_4\text{O}_6(\text{s}) = \dots\dots\dots \text{ kJ mol}^{-1}$  [1]

(iv) Write an equation for the reaction of  $\text{P}_4\text{O}_{10}$  with water.

$\dots\dots\dots$  [1]

Atoms with nuclei containing an odd number of protons tend to have fewer isotopes than those with an even number of protons.

(a) Gallium has two stable isotopes,  $^{69}\text{Ga}$  and  $^{71}\text{Ga}$ .

(i) Complete Table 1.1 to show the numbers of protons, neutrons and electrons in the two stable isotopes of gallium.

**Table 1.1**

isotope	number of protons	number of neutrons	number of electrons
$^{69}\text{Ga}$	31	38	31
$^{71}\text{Ga}$	31	40	31

[2]

(ii) Define relative atomic mass.

.....  
 .....  
 ..... [2]

(iii) The relative atomic mass of gallium,  $A_r$ , is 69.723.  
 The relative isotopic masses of  $^{69}\text{Ga}$  and  $^{71}\text{Ga}$  are:

$^{69}\text{Ga}$ , 68.926;  $^{71}\text{Ga}$ , 70.925.

Use this information to calculate the percentage abundance of  $^{69}\text{Ga}$  in elemental gallium.

Show your working.

Assume that the element contains only the  $^{69}\text{Ga}$  and  $^{71}\text{Ga}$  isotopes.

Give your answer to **four** significant figures.

percentage abundance of  $^{69}\text{Ga}$  = ..... %  
 [2]

**(b)** Potassium also has two stable isotopes. Both isotopes have the same chemical properties.

**(i)** Explain why both isotopes of potassium have the same chemical properties.

.....  
..... [1]

**(ii)** State the full electronic configuration of an atom of potassium.

..... [1]

**(iii)** The first, second and third ionisation energies of potassium are 418, 3070 and 4600 kJ mol<sup>-1</sup>, respectively.

Use this information to explain why potassium is in Group 1.

.....  
.....  
.....  
..... [2]

Species such as  $\text{NH}_4^+$ ,  $\text{CO}_3^{2-}$  and  $\text{PO}_4^{3-}$  are examples of molecular ions.

(a) Ionic and covalent bonds both involve an electrostatic attraction between different species.

Identify the species that are electrostatically attracted to one another in:

- an ionic bond

.....

- a covalent bond.

.....

[2]

(b) Complete Table 1.1 to show the total numbers of protons and electrons in the molecular ions  $\text{NH}_4^+$ ,  $\text{CO}_3^{2-}$  and  $\text{PO}_4^{3-}$ .

**Table 1.1**

molecular ion	total number of protons	total number of electrons
$\text{NH}_4^+$		
$\text{CO}_3^{2-}$		
$\text{PO}_4^{3-}$		

[3]

(c)  $\text{NH}_4^+$  is a Brønsted–Lowry acid.

(i) Define Brønsted–Lowry acid.

.....

..... [1]

(ii) When  $\text{NH}_4^+(\text{aq})$  is heated with  $\text{NaOH}(\text{aq})$ , a pungent gas is produced.

Write an ionic equation for this reaction.

..... [1]

- (iii) The nitrogen atom in  $\text{NH}_4^+$  is  $\text{sp}^3$  hybridised.  $\text{sp}^3$  orbitals form from the mixing of one 2s and three 2p orbitals.

Sketch the shapes of a 2s and a  $2\text{p}_x$  orbital on the axes in Fig. 1.1.

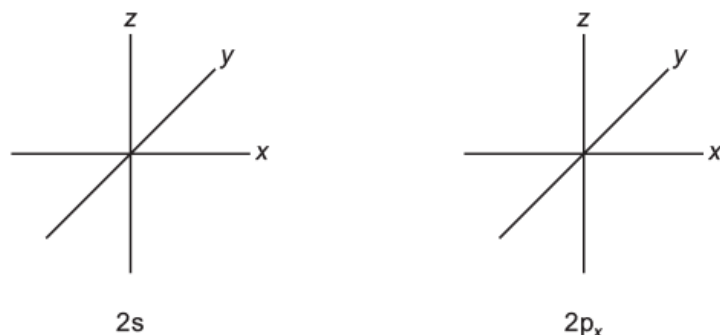


Fig. 1.1

[2]

- (d) There are many naturally occurring hydrated compounds that contain the anion  $\text{PO}_4^{3-}$ .

- (i) Name the anion  $\text{PO}_4^{3-}$ .

..... [1]

- (ii) Struvite is a soft hydrated mineral with  $M_r = 245.3$ . The anhydrous form of the mineral has the formula  $\text{NH}_4\text{MgPO}_4$ .

Calculate the number of molecules of water of crystallisation in struvite.

Give your answer to the nearest integer. Show your working.

number of molecules of water of crystallisation = ..... [2]

The chlorides of some of the Period 3 elements are shown in Table 2.1.

**Table 2.1**

Period 3 chloride	$\text{NaCl}$	$\text{AlCl}_3$	$\text{SiCl}_4$	$\text{PCl}_5$	$\text{PCl}_3$	$\text{SCl}_2$
bonding					C	C
structure					S	S
oxidation state of Period 3 element						

(a) Complete Table 2.1.

- Identify the bonding shown by each chloride under standard conditions.  
Use C = covalent, I = ionic, M = metallic.
- Identify the structure shown by each chloride under standard conditions.  
Use G = giant, S = simple.
- Deduce the oxidation state of the Period 3 element in each chloride.

[4]

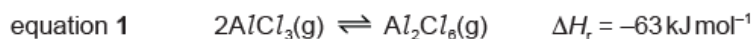
(b) Write equations for the reactions of  $\text{NaCl}$  and  $\text{PCl}_5$  with water.  
Include state symbols in both equations.

$\text{NaCl}$  .....

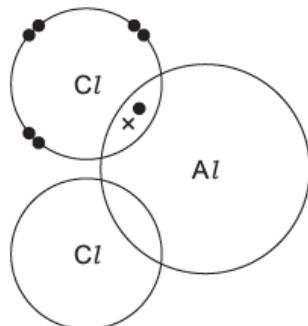
$\text{PCl}_5$  .....

[3]

(c) In the gas phase,  $AlCl_3(g)$  exists at equilibrium with  $Al_2Cl_6(g)$  as shown.



(i) Complete the dot-and-cross diagram to show the bonding in  $Al_2Cl_6$ .



[2]

(ii) State the effect of an increase in temperature on the equilibrium mixture in equation 1. Explain your answer.

.....  
 ..... [1]

(d) A 3.30 g sample of a Period 3 chloride is heated to 500 K in a sealed flask. At this temperature, the chloride is a gas of volume  $250 \text{ cm}^3$  and the pressure in the flask is 323 kPa.

Use the ideal gas equation  $pV = nRT$  to calculate the  $M_r$  of the Period 3 chloride. Deduce its formula.

$M_r =$  .....

formula of Period 3 chloride = ..... [3]

- (e) (i) An excess of  $\text{Cl}^-(\text{aq})$  is added to  $1\text{ cm}^3$  of  $\text{Br}_2(\text{aq})$ .

Describe what is observed. Explain your answer.

.....  
 .....  
 ..... [2]

- (ii)  $\text{SCl}_2$  has  $M_r = 103.1$  and is a liquid at room temperature.  $\text{SBr}_2$  has  $M_r = 191.9$  and is a gas at room temperature.

Explain the difference in the physical state of  $\text{SCl}_2$  and  $\text{SBr}_2$ . Give your answer in terms of intermolecular forces.

.....  
 .....  
 .....  
 ..... [2]

- (f) Bismuth is a dense metal in the same group as phosphorus.

- (i) Draw a labelled diagram to show the bonding in bismuth metal.

[2]

- (ii) Bismuth reacts with chlorine to form  $\text{BiCl}_3$ .  
 $\text{BiCl}_3$  is a solid at room temperature. It melts when heated gently.  
 $\text{BiCl}_3$  reacts vigorously with water at room temperature to form an acidic solution.

Suggest the type of bonding and structure shown by  $\text{BiCl}_3$ . Explain your answer.

.....  
 .....  
 ..... [2]

The rate of chemical reactions is affected by changes in temperature and pressure.

- (a) (i) Draw a curve on the axes to show the Boltzmann distribution of energy of particles in a sample of gaseous krypton atoms at a given temperature.

Label the curve **T1** and label the axes.



[2]

- (ii) On the diagram in (a)(i), draw a second curve to show the distribution of energies of the krypton atoms at a higher temperature.

Label the second curve **T2**.

[1]

- (b) The Boltzmann distribution assumes that the particles behave as an ideal gas.

- (i) State **two** assumptions of the kinetic theory as applied to an ideal gas.

1 .....

.....

2 .....

.....

[2]

- (ii) 2.00 g of krypton gas, Kr(g), is placed in a sealed 5.00 dm<sup>3</sup> container at 120 °C.

Calculate the pressure, in Pa, of Kr(g) in the container.  
Assume Kr(g) behaves as an ideal gas.

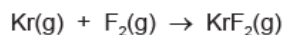
Show your working.

pressure = ..... Pa [3]

- (iii) State and explain the conditions at which krypton behaves most like an ideal gas.

.....  
.....  
.....  
..... [2]

- (c) Krypton reacts with fluorine in the presence of ultraviolet light to make krypton difluoride,  $\text{KrF}_2(\text{g})$ .

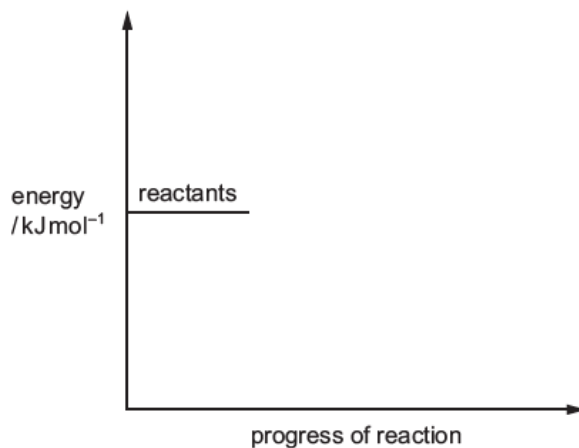


activation energy for the reaction,  $E_a = +385 \text{ kJ mol}^{-1}$

enthalpy change of formation of  $\text{KrF}_2$ ,  $\Delta H_f = +60.2 \text{ kJ mol}^{-1}$

- (i) Use this information to complete the reaction profile diagram for the formation of  $\text{KrF}_2$ . Label  $E_a$  and  $\Delta H_f$  on the diagram.

Assume the reaction proceeds in one step.



[2]

- (ii) Explain, in terms of activation energy,  $E_a$ , and the collision of particles, how an increase in temperature affects the rate of a chemical reaction.

.....  
.....  
.....  
..... [2]

0.020 mol of element **Z** reacts with excess  $\text{Cl}_2$  to form 0.020 mol of a liquid chloride.

The liquid chloride has formula  $\text{ZCl}_n$ , where  $n$  is an integer.

$\text{ZCl}_n$  reacts vigorously with water at room temperature to give an acidic solution and a white solid.

When excess  $\text{AgNO}_3(\text{aq})$  is added to the solution, 11.54 g of  $\text{AgCl}(\text{s})$  forms.

(i) Suggest the type of bonding and structure shown by  $\text{ZCl}_n$ .

..... [1]

(ii) Calculate the value of  $n$  in  $\text{ZCl}_n$ .

$n =$  ..... [2]

1 Ethanedioic acid,  $\text{HO}_2\text{CCO}_2\text{H}$ , has a relative molecular mass of 90.0.

(a) (i) Explain what is meant by the term *relative molecular mass*.

.....  
.....  
..... [2]

(ii) State the empirical formula of ethanedioic acid.

..... [1]

(iii) Calculate how many atoms of carbon are present in 0.18 g of ethanedioic acid,  $\text{HO}_2\text{CCO}_2\text{H}$ .

Show your working.

atoms of carbon present = ..... [3]

(b) Solid ethanedioic acid reacts with aqueous calcium ions to make a precipitate of calcium ethanedioate,  $\text{CaC}_2\text{O}_4$ .

$\text{CaC}_2\text{O}_4$  breaks down when heated to form calcium oxide, carbon dioxide and carbon monoxide.

(i) Construct an equation to represent the reaction of  $\text{CaC}_2\text{O}_4$  when heated. Include state symbols.

..... [2]

(ii) Identify the type of reaction which occurs when  $\text{CaC}_2\text{O}_4$  is heated.

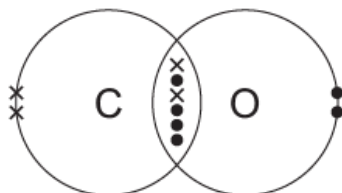
..... [1]

(iii) Identify another compound containing calcium ions which will also produce carbon dioxide and calcium oxide when it is heated.

..... [1]

Carbon monoxide gas,  $\text{CO(g)}$ , and nitrogen gas,  $\text{N}_2(\text{g})$ , are both diatomic molecules.

(a) The diagram shows the arrangement of outer electrons in a molecule of  $\text{CO(g)}$ .



(i) State **one** similarity and **one** difference in the way the atoms in a carbon monoxide molecule are bonded together compared to the atoms in a nitrogen molecule.

.....  
 .....  
 ..... [2]

(ii) The table states the electronegativity values of carbon, nitrogen and oxygen atoms.

	C	N	O
electronegativity	2.5	3.0	3.5

Use the electronegativity values and relevant details from the *Data Booklet* to complete the table below.

	$\text{N}_2$	$\text{CO}$
number of electrons per molecule		
type(s) of intermolecular (van der Waals') force		

[2]

(b)  $\text{N}_2(\text{g})$  is less reactive than  $\text{CO(g)}$  even though  $\text{N}_2(\text{g})$  has a lower bond energy than  $\text{CO(g)}$ .

Suggest why  $\text{CO(g)}$  is more reactive than  $\text{N}_2(\text{g})$ .

.....  
 ..... [1]

(c) Both carbon monoxide and nitrogen are gases at room temperature and pressure.

They both behave like ideal gases under certain conditions.

(i) State the **two** conditions necessary for these two gases to approach ideal gas behaviour.

.....  
..... [1]

(ii) Explain why  $\text{N}_2(\text{g})$  behaves more like an ideal gas than  $\text{CO}(\text{g})$  does at  $20.0^\circ\text{C}$  and  $101\text{ kPa}$ .

.....  
.....  
..... [2]

(d) Calculate the amount, in mol, of pure nitrogen gas which occupies  $100\text{ cm}^3$  at  $101\text{ kPa}$  and  $20.0^\circ\text{C}$ .

Use relevant information from the *Data Booklet*. Show your working.

Assume nitrogen behaves as an ideal gas.

..... mol  
[3]

A Group 2 metal combines with bromine to form a crystalline solid,  $\text{MBr}_2$ .

Excess aqueous  $\text{AgNO}_3$  is added to a solution of  $\text{MBr}_2$  and a precipitate forms. The mixture is filtered. The precipitate is dried and the mass of the precipitate is recorded.

(a) State the formula and colour of the precipitate.

..... [2]

(b) Complete the equation to represent the reaction between  $\text{MBr}_2$  and  $\text{AgNO}_3$ .

..... $\text{MBr}_2$  + ..... $\text{AgNO}_3 \rightarrow$  ..... [1]

(c) A 0.250 g sample of pure  $\text{MBr}_2$  contains  $8.415 \times 10^{-4} \text{ mol MBr}_2$ .

Calculate the relative formula mass,  $M_r$ , of  $\text{MBr}_2$ . Use this to identify **M**.

Show your working.

$M_r =$  .....

**M** = ..... [3]

(d) A sample of  $\text{MBr}_2$  is dissolved in water. Chlorine gas is then bubbled into the solution.

(i) Describe the observations for this reaction.

.....  
..... [1]

(ii) Name the type of reaction that occurs when  $\text{MBr}_2$  reacts with chlorine gas.

..... [1]

- (e) Compound **Y** is a pure **insoluble** solid which contains halide ions.

A single reagent is added directly to compound **Y** to determine the halide ion present.

Identify the reagent added. State the observation which would confirm that **Y** contains bromide ions.

reagent .....

observation ..... [2]

- (f) Separate 1.0g samples of three different magnesium salts are tested in order to identify the anion present in each sample.

- (i) Explain how the action of heat is used to identify which sample is:

- $\text{MgCO}_3$
- $\text{Mg}(\text{NO}_3)_2$
- $\text{MgO}$ .

.....  
.....  
.....  
.....  
..... [3]

- (ii) Complete the electron configuration of the magnesium cation present in these salts.

$1s^2$  ..... [1]

- (g) A sample of  $\text{MgCO}_3(\text{s})$  is distinguished from a sample of  $\text{Mg}(\text{OH})_2(\text{s})$  by adding a small amount of each solid to  $\text{HCl}(\text{aq})$ .

State **one** similarity and **one** difference in these two reactions.

similarity .....

.....

difference .....

..... [2]

The strength of interaction between particles determines whether the substance is a solid, liquid or gas at room temperature.

**(a)** Lithium sulfide,  $\text{Li}_2\text{S}$ , is a crystalline solid with a melting point of  $938^\circ\text{C}$ . It conducts electricity when it is molten.

**(i)** Give the formulae of the particles present in solid lithium sulfide.

..... [1]

**(ii)** Explain, in terms of the structure of the crystalline solid, why lithium sulfide has a high melting point.

.....  
..... [2]

**(b)** Carbon monoxide,  $\text{CO}$ , is a gas at room temperature and pressure. It contains a coordinate bond.

**(i)** Explain what is meant by *coordinate bond*.

.....  
..... [1]

**(ii)** Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons in  $\text{CO}$ .

Show the electrons belonging to the C atom as  $\times$ .

Show the electrons belonging to the O atom as  $\bullet$ .

[2]

(c) Nitrogen,  $\text{N}_2$ , is also a gas at room temperature and pressure. Neither CO nor  $\text{N}_2$  is an ideal gas.

(i) State two assumptions that are made about the behaviour of particles in an ideal gas.

- 1 .....
- 2 .....
- [2]

(ii) Explain why  $\text{N}_2$  does not behave as an ideal gas at very high pressures.

- .....
- .....
- .....
- [2]

(iii) Complete the table by naming **all** the types of intermolecular forces (van der Waals') in separate samples of  $\text{N}_2(\text{g})$  and  $\text{CO}(\text{g})$ .

	$\text{N}_2(\text{g})$	$\text{CO}(\text{g})$
number of electrons per molecule	14	14
presence of a dipole moment	$\times$	$\checkmark$
boiling point/ $^{\circ}\text{C}$	-195.8	-191.5
intermolecular forces (van der Waals')		

[2]

(iv) Suggest why the bond in a molecule of CO contains a dipole moment.

- ..... [1]

A large excess of 2-bromo-2-methylpropane is added to 0.0010 mol of NaOH(aq), which contains a few drops of phenolphthalein indicator. A stopwatch is started as soon as the substances are mixed. The time taken for the pink colour to disappear is recorded.

The experiment is repeated at different temperatures, keeping all concentrations and volumes of reagents constant.

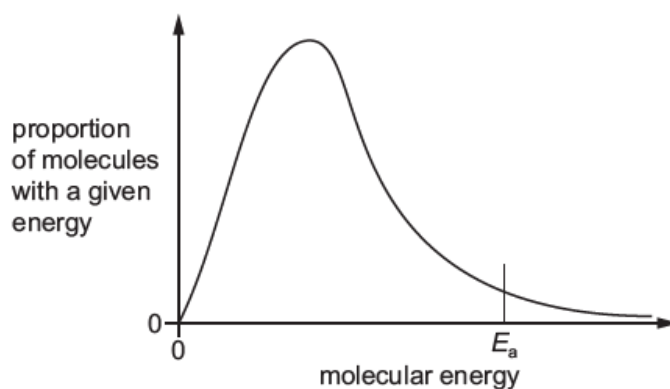
temperature / °C	time taken for pink colour to disappear / s
20	300
25	65
35	20

- (a) Explain what is meant by the term *rate of reaction*.

.....  
 ..... [1]

- (b) The graph shows the energy distribution of molecules in a sample of 2-bromo-2-methylpropane at 25 °C.

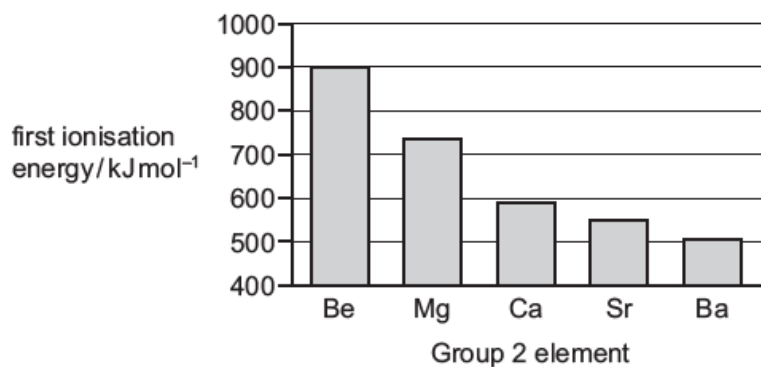
$E_a$  represents the activation energy for the reaction.



- (i) Label the graph to show the proportion of 2-bromo-2-methylpropane molecules which have sufficient energy to react. [1]
- (ii) Use the same axes to sketch the distribution of energies of molecules in a sample of 2-bromo-2-methylpropane at 50 °C. [2]
- (iii) State the effect of an increase in temperature on  $E_a$  for this reaction.

..... [1]

The graph shows the first ionisation energies of some of the elements in Group 2.



(a) Write an equation for the first ionisation energy of Mg.

Include state symbols.

..... [1]

(b) Explain the observed trend in first ionisation energies down Group 2.

.....  
.....  
.....  
.....  
.....  
..... [3]

(c) The second ionisation energy of Be is 1757 kJ mol<sup>-1</sup>.

Explain why the second ionisation energy of Be is higher than the first ionisation energy of Be.

.....  
.....  
.....  
.....  
..... [2]

Phosphorus, sulfur and chlorine can all react with oxygen to form oxides.

(a) Phosphorus reacts with an excess of oxygen to form phosphorus(V) oxide.

(i) Write an equation to show the reaction of phosphorus with excess oxygen.

..... [1]

(ii) Describe the reaction of phosphorus(V) oxide with water.

.....  
.....  
..... [2]

(iii) State the structure and bonding of solid phosphorus(V) oxide.

..... [1]

(b) The two most common oxides of sulfur are SO<sub>2</sub> and SO<sub>3</sub>.

When SO<sub>2</sub> dissolves in water, a small proportion of it reacts with water to form a weak Brønsted-Lowry acid.

(i) Explain the meaning of the term *weak Brønsted-Lowry acid*.

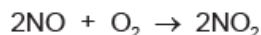
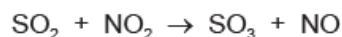
.....  
..... [2]

(ii) Write the equation for the reaction of SO<sub>2</sub> with water.

..... [1]

(iii) SO<sub>2</sub> reacts with NO<sub>2</sub> in the atmosphere to form SO<sub>3</sub> and NO.

NO is then oxidised in air to form NO<sub>2</sub>.

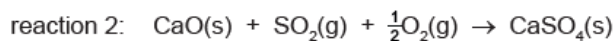
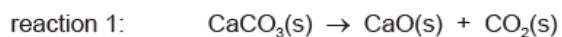


State the role of NO<sub>2</sub> in this two-stage process.

..... [1]

- (c) Emissions of  $\text{SO}_2$  from coal-fired power stations can be reduced by mixing the coal with powdered limestone.

Limestone is heated to form  $\text{CaO}$  in reaction 1. This then reacts with  $\text{SO}_2$  and  $\text{O}_2$  to form  $\text{CaSO}_4$  in reaction 2.



- (i) State the type of reaction occurring in reaction 1.

..... [1]

- (ii) Use the data to calculate the enthalpy change of reaction 2.

compound	$\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{CaO}(\text{s})$	-635
$\text{SO}_2(\text{g})$	-297
$\text{CaSO}_4(\text{s})$	-1434

enthalpy change of reaction 2 = .....  $\text{kJ mol}^{-1}$  [2]

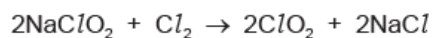
(d) Chlorine forms several oxides, including  $Cl_2O$ ,  $ClO_2$  and  $Cl_2O_6$ .

(i) Draw a 'dot-and-cross' diagram of  $Cl_2O$ . Show outer-shell electrons only.

[1]

(ii)  $ClO_2$  can be prepared by reacting  $NaClO_2$  with  $Cl_2$ .

Write the oxidation state of chlorine in each species in the boxes provided.



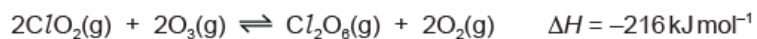
oxidation state of chlorine:





[1]

(iii)  $Cl_2O_6(g)$  is produced by the reaction of  $ClO_2(g)$  with  $O_3(g)$ .



The reaction takes place at 500 K and 100 kPa.

State and explain the effect on the yield of  $Cl_2O_6(g)$  when the experiment is carried out:

- at 1000 K and 100 kPa

.....

.....

.....

.....

- at 500 K and 500 kPa.

.....

.....

.....

.....

[4]

- (e) Element **E** is a Period 5 element.

**E** reacts with oxygen to form an insoluble white oxide that has a melting point of 1910 °C. The oxide of **E** conducts electricity only when liquid.

**E** also reacts readily with  $\text{Cl}_2(\text{g})$  to form a white solid that reacts exothermically with water. The resulting solution reacts with aqueous silver nitrate to form a white precipitate that dissolves in dilute ammonia.

- (i) Suggest the type of bonding shown by the **oxide** of **E**. Explain your answer.

.....  
.....  
..... [2]

- (ii) Suggest the type of bonding shown by the **chloride** of **E**. Explain your answer.

.....  
.....  
..... [2]

The reducing agent  $\text{LiAlH}_4$  can be synthesised by reacting aluminium chloride with lithium hydride,  $\text{LiH}$ .

- (a) (i) At  $200^\circ\text{C}$ , aluminium chloride exists as  $\text{Al}_2\text{Cl}_6(\text{g})$ .

Draw the structure of  $\text{Al}_2\text{Cl}_6(\text{g})$ , showing fully any coordinate (dative covalent) bonds in the molecule.

[2]

- (ii) At  $1000^\circ\text{C}$ , aluminium chloride exists as  $\text{AlCl}_3(\text{g})$ .

State the bond angle in  $\text{AlCl}_3(\text{g})$ .

.....  $^\circ$  [1]

- (iii) Lithium hydride contains the ions  $\text{Li}^+$  and  $\text{H}^-$ .

State the electronic configuration of these two ions.

$\text{Li}^+$  .....  $\text{H}^-$  ..... [1]

- (iv)  $\text{LiAlH}_4$  decomposes slowly to form  $\text{LiAl}(\text{s})$  and  $\text{H}_2(\text{g})$ .



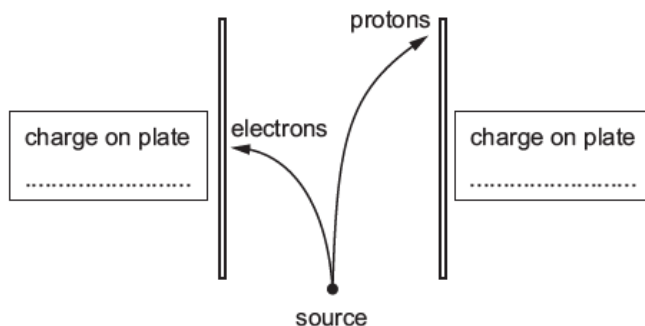
$\text{LiAl}(\text{s})$  shows metallic bonding.

Describe metallic bonding.

.....  
.....  
..... [1]

- 1 Atoms contain the subatomic particles electrons, protons and neutrons. Protons and electrons were discovered by observations of their behaviours in electric fields.

- (a) The diagram shows the behaviour of separate beams of electrons and protons in an electric field.

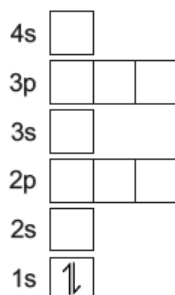


- (i) Complete the diagram with the relative charge of each of the electrically charged plates. [1]
- (ii) On the diagram, draw a line to show how a separate beam of neutrons from the same source behaves in the same electric field. [1]
- (b) Electrons in atoms up to  $_{36}\text{Kr}$  are distributed in s, p and d orbitals.
- (i) State the number of occupied orbitals in an isolated atom of  $_{36}\text{Kr}$ .

type of orbital	s	p	d
number of orbitals			

[3]

- (ii) Complete the diagram to show the number and relative energies of the electrons in an isolated atom of  $_{14}\text{Si}$ .



[2]

- (iii) The diagram shows a type of orbital.



State the total number of electrons that exist in all orbitals of this type in an atom of  $_9\text{F}$ .

..... [1]

- (iv) The first ionisation energies of elements in the first row of the d block ( $_{21}\text{Sc}$  to  $_{29}\text{Cu}$ ) are very similar. For all these elements, it is a 4s electron that is lost during the first ionisation.

Suggest why the first ionisation energies of these elements are very similar.

.....  
 .....  
 .....  
 ..... [3]

- (c) *Hydron* is a general term used to represent the ions  $^1\text{H}^+$ ,  $^2\text{H}^+$  and  $^3\text{H}^+$ .

State, in terms of subatomic particles in the nucleus, what is the same about each of these ions and what is different.

same .....

different .....

[1]