Name: ( )	Class: 22S0_____

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RAFFLES INSTITUTION
2021 YEAR 5 JULY COMMON TEST

Higher 2

CHEMISTRY 9729

2 July 2021

2 hours 15 minutes

Additional Materials: Multiple Choice Answer (OMR) Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, index number and civics tutorial group in the spaces provided on the OMR Sheet, and the cover sheets on **pages 1** and **15**.
Do not use staples, paper clips, glue or correction fluid.

This paper consists of three sections, **A**, **B** and **C**.

Section A (15 marks)

Answer this section first. The OMR Sheet will be collected after the **first 30 minutes**.

There are **fifteen** questions in this section. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**. Choose the one you consider correct and record your choice in **soft pencil** on the OMR Sheet.

Read the instructions on the OMR Sheet very carefully.
Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in the question paper.

Section B (30 marks)

There are **three** questions in this section. Answer **all** questions. Answers to this section are to be written in the spaces provided in the question paper.

Section C (35 marks)

There are **two** questions in this section. Answer **all** questions. Answers to this section are to be written in the spaces provided in the question paper.

The use of an approved scientific calculator is expected, where appropriate.

Write in dark blue or black pen. You may use a pencil for any diagrams or graphs.

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use Only	
B1	**/ 12**
B2	**/ 8**
B3	**/ 10**

Section A (15 marks)

For each question, there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

1 *Use of the Data Booklet is relevant to this question.*

X and Y are hydrocarbons with the same empirical formula.

When 0.1 mol of X and 0.1 mol of Y were combusted together in excess oxygen gas, 39.6 g of CO_2 and 16.2 g of H_2O were formed. The M_r of Y is two times that of X.

Which row gives the correct empirical formula and molecular formula of Y?

	empirical formula of Y	molecular formula of Y
A	CH	C_3H_3
B	CH	C_6H_6
C	CH_2	C_3H_6
D	CH_2	C_6H_{12}

2 Under basic conditions, MnO_4^{2-} undergoes disproportionation to give two manganese-containing species in the ratio of 2 : 1. One of the species is MnO_4^-.

What could be the other species?

A $Mn(OH)_2$ **B** MnO_2 **C** Mn_2O_3 **D** Mn_2O_7

3 Equal volumes of 1.0 mol dm^{-3} HC*l*(aq) and 1.5 mol dm^{-3} NaOH(aq) are mixed.

What are the concentrations of NaOH(aq) and NaC*l*(aq) in the resulting solution?

	[NaOH(aq)] / mol dm^{-3}	[NaC*l*(aq)] / mol dm^{-3}
A	0.25	0.50
B	0.25	1.0
C	0.50	0.50
D	0.50	1.0

4 *Use of the Data Booklet is relevant to this question.*

Which ion contains the greatest number of unpaired electrons?

A N^- **B** F^{2+} **C** Cr^{2+} **D** Co^{2+}

5 Which statement regarding neutrons and electrons is incorrect?

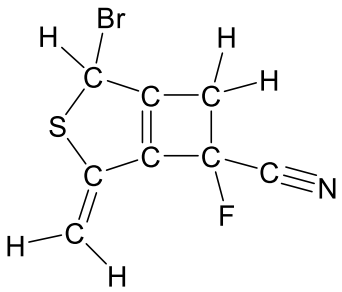
A They are oppositely charged.
B They are found in different parts of the atom.
C The neutron has a greater mass than the electron.
D The number of electrons in an atom may be different from the number of neutrons.

6 *Use of the Data Booklet is relevant to this question.*

Which statement regarding the valence shell of an atom of boron is correct?

A It contains three half-filled orbitals.
B Its orbitals are all of the same shape.
C Its electrons are all at the same energy level.
D It can accommodate a maximum of eight electrons.

7 Which row correctly describes the bonding in the molecule below?



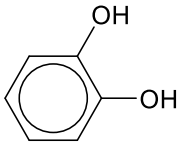
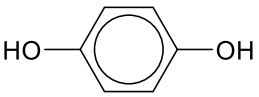
	number of σ bonds	number of π bonds
A	15	3
B	15	4
C	18	3
D	18	4

8 Which of the following statements is correct?

A SiO_2 has a higher boiling point than CO_2 as SiO_2 has stronger instantaneous dipole-induced dipole interactions.

B Mg has a higher melting point than Na as Mg has more valence electrons.

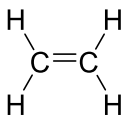
C $AlCl_3$ has a lower melting point than AlF_3 as $AlCl_3$ has weaker ionic bonds.

D  has a higher boiling point than  as the first compound has intramolecular hydrogen bonding.

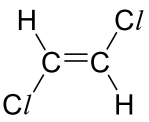
9 The electronegativity values of carbon and hydrogen are similar. Both oxygen and chlorine are more electronegative than carbon.

Which molecule has the largest overall dipole?

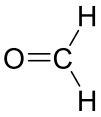
A



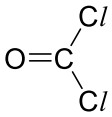
B



C



D



10 Which molecules contain at least one 90º bond angle?

1 PCl_5

2 SF_6

3 XeF_4

A 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 1, 2 and 3

[Turn Over

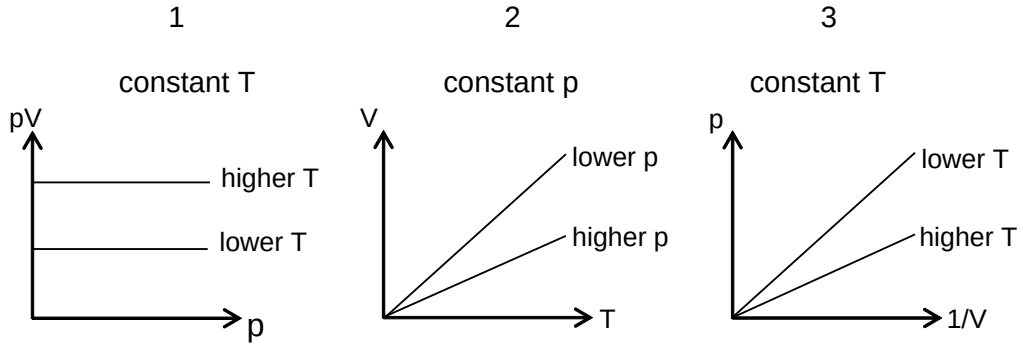
11 *Use of the Data Booklet is relevant to this question.*

The density of a mixture of helium and xenon is 5.00 g dm^{-3} at 25 °C and 100 kPa.

What is the mole fraction of helium in the mixture?

A 0.050 **B** 0.059 **C** 0.941 **D** 0.950

12 Which of the following graphs are correct for 1 mol of an ideal gas?



A 1 and 2 only **B** 1 and 3 only **C** 2 and 3 only **D** 2 only

13 *Use of the Data Booklet is relevant to this question.*

Which of the following shows the correct arrangement of ions in increasing magnitude of their hydration energies?

A $Cr^{2+} < Fe^{2+} < Ti^{3+}$

B $Fe^{2+} < Cr^{2+} < Ti^{3+}$

C $Ti^{3+} < Cr^{2+} < Fe^{2+}$

D $Ti^{3+} < Fe^{2+} < Cr^{2+}$

14 Which statement regarding the following reaction is incorrect?

$$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g) \qquad \Delta H_r < 0$$

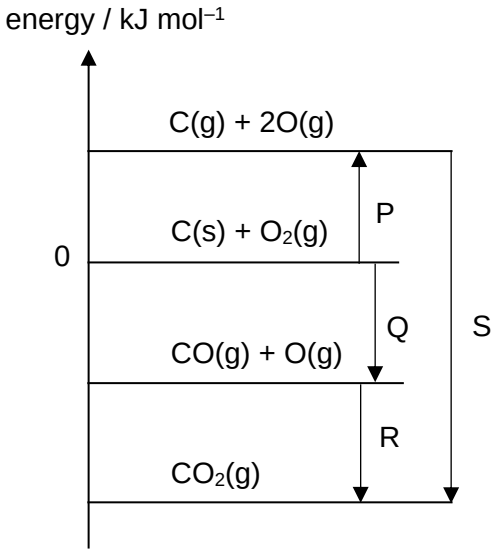
A More energy is released during bond forming than absorbed during bond breaking.

B ΔH_r can be calculated using $\Delta H_{combustion}(C_2H_4(g))$ and $\Delta H_{combustion}(C_2H_6(g))$ only.

C $\Delta S < 0$ because the number of gaseous molecules decreases.

D The reaction is spontaneous only at low temperatures.

15 An energy level diagram involving carbon and oxygen is shown below.



Which equations are correct?

1 $P = \Delta H^{\ominus}_{atomisation}(C(s)) + \Delta H^{\ominus}_{atomisation}(O_2(g))$

2 $S = \Delta H^{\ominus}_{formation}(CO_2(g)) - P$

3 $Q = \Delta H^{\ominus}_{combustion}(C(s)) - R$

4 $R = \Delta H^{\ominus}_{combustion}(CO(g))$

A 1 and 3 only **B** 1 and 4 only **C** 2 and 3 only **D** 2, 3 and 4 only

Section B (30 marks)

This section consists of **3** questions.

Answer **all** the questions in this section in the spaces provided.

For examiner's use

1 *Use of the Data Booklet is relevant to this question.*

Thallium is a metal that can cause poisoning in animals, and thallium salts were used in rat poison in the past.

A toxicologist can determine the amount of thallium in the bones of a rat poisoned to death by following the procedures stated below.

Dissolving the bone:

1. A sample of the bone is weighed and dissolved in concentrated HNO_3.
2. Concentrated H_2SO_4 is added to the resulting solution from step 1. A lot of white precipitate, most of which is $CaSO_4$, would be formed at this stage and is filtered off.
3. Further treatment of the filtrate by processes such as heating removes most acid, and the resulting solution is made up to 100 cm^3 in a volumetric flask.

Determining the amount of thallium by precipitation:

4. 25 cm^3 of the solution from step 3 is transferred to a conical flask.
5. $SO_2(g)$ is bubbled through the test solution until saturated.
6. HBr(aq) is added to precipitate thallium as thallium(I) bromide, T*l*Br.
7. The resulting mixture is filtered and the precipitate is washed, dried and weighed.

Only 92.5% of thallium in the bone sample is recovered using this method.

(a) The two isotopes of thallium are thallium-203 and thallium-205.

(i) Use the relative atomic mass of thallium found in the Periodic Table to calculate the percentage abundances of thallium-203 and thallium-205.

[2]

(ii) Define the term *relative atomic mass*.

……

……[1]

For examiner's use

(b) A 50 g sample of bone from a poisoned dead rat was analysed. The mass of precipitate, T*l*Br, obtained in step 7 was 7.45×10^{-4} g.

(i) Calculate the percentage of thallium by mass in T*l*Br.

[1]

(ii) Hence or otherwise, calculate the mass of thallium in the bone.

[3]

(iii) Using your answer to **(b)(ii)**, calculate the concentration of thallium in the bone, giving your answer in ppm.
[1 ppm = 1 g per 10^6 g]

[1]

For examiner's use

(c) Br_2, which is formed from the decomposition of HBr, can oxidise Tl^+ to Tl^{3+}. During the entire analysis process, it is crucial to ensure that Tl^+ is not oxidised to Tl^{3+}, so that $TlBr_3$ is not formed.

(i) Br_2 is removed by SO_2, forming Br^- and SO_4^{2-} in the process.

Using oxidation numbers or otherwise, construct a balanced equation for this reaction.

…… [1]

(ii) A student did not follow the procedure strictly. As a result, the precipitate contained a small amount of $TlBr_3$. However, the student assumed that only TlBr was present in the precipitate. Suggest how this would affect the calculated concentration of thallium in the bone.

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……

……[1]

(d) Lead(II) ions, Pb^{2+}, that could be present in the bone, also gives a precipitate with Br^-, therefore affecting the accuracy of the analysis. Pb^{2+} is removed in step 2.

Explain how the reagent used in step 2 removes Pb^{2+}.

……

……[1]

(e) Suggest a suitable apparatus found in the school laboratory that can be used in step 4 to measure 25 cm^3 of the solution.

……[1]

[Total: 12]

For examiner's use

2 Helium balloons are a common sight at birthday parties. Such balloons can be inflated on site using readily available gas tanks.

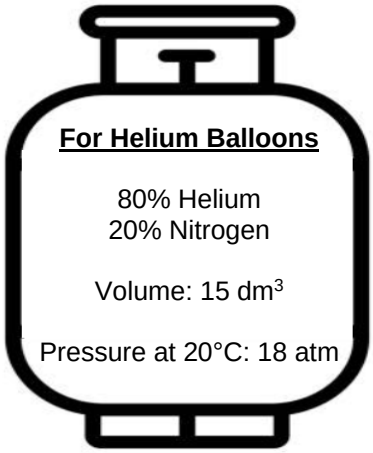
(a) State two assumptions of an ideal gas.

……..……..

……..……..

……..…….[2]

(b) A manufacturer produces helium gas tanks as shown below.



When a gas tank is completely used, the residual pressure in the tank is equal to the atmospheric pressure.

(i) Calculate the maximum amount of gas that can be released from the tank when used under room temperature and pressure.

[1]

(ii) The gas tank can be used to inflate balloons to a volume of 5.50 dm^3 at room temperature and pressure.

Assuming that the internal pressure of the inflated balloons is 1.2 atm, determine the maximum number of balloons that can be inflated.

[1]

For examiner's use

(c) A researcher requires pure helium for his experiment. He purchased a new gas tank from the manufacturer and cooled it to −200 °C, at which only nitrogen was liquefied. Determine the new internal pressure of the tank at this temperature, assuming the volume of the tank remains constant.

[2]

(d) Sketch and label on Fig. 2.1 the graphs of pV/RT against p for 1 mol of helium and 1 mol of nitrogen at 20 °C. Explain your answer.

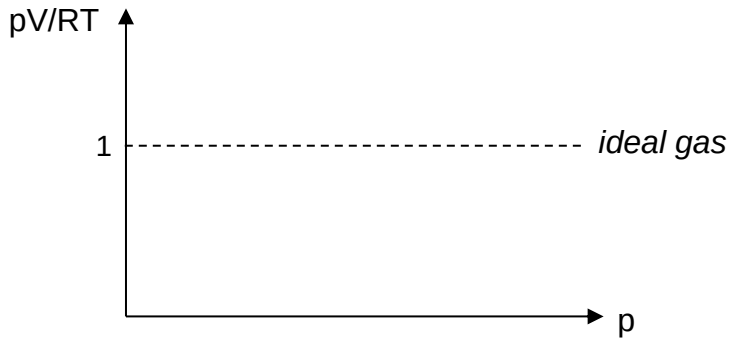


Fig. 2.1

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……..……[2]

[Total: 8]

For examiner's use

3 Equation 1 shows the reaction between sodium azide, NaN_3, and bromoethane, CH_3CH_2Br.

equation 1 $$NaN_3 + CH_3CH_2Br \longrightarrow CH_3CH_2N_3 + NaBr$$

(a) The azide ion, N_3^-, has a linear geometry. Draw a dot-and-cross diagram of N_3^-.

[1]

When aqueous NaN_3 is added to CH_3CH_2Br dissolved in a non-polar organic solvent, two immiscible layers are formed. To increase the solubility of NaN_3 in the non-polar organic solvent, crown ethers can be added to the reaction mixture.

Crown ethers are cyclic compounds that consist of a ring containing several C−O−C groups. Fig. 3.1 shows an example of a crown ether.

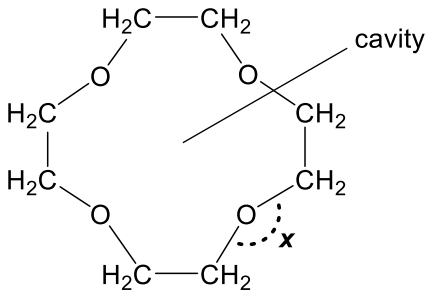


Fig. 3.1

(b) **(i)** State the shape and bond angle *x* about the oxygen atoms in the crown ether shown in Fig. 3.1. Explain your answer.

……

……

……

……

……[2]

The crown ether helps to increase solubility of NaN_3 in the non-polar organic solvent by encapsulating the sodium ion in its cavity. This stabilises the sodium ion in the non-polar organic solvent and enables the azide ion to enter the non-polar organic solvent. Consequently, the azide ion reacts with bromoethane as shown in equation 1.

For examiner's use

(ii) On Fig. 3.2, draw and label the interaction between the sodium ion and the crown ether.

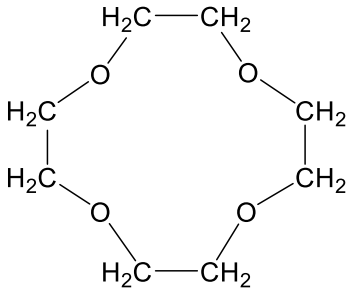
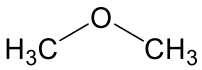


Fig. 3.2

[1]

(iii) Hence, explain why in a non-polar solvent, **one** molecule of crown ether stabilises the sodium ion more than **one** molecule of dimethyl ether.



dimethyl ether

……

……[1]

(iv) Although the crown ether with the encapsulated sodium ion has an overall positive charge, it is still able to dissolve in the non-polar organic solvent.

With reference to the structure of the crown ether, explain why this is so.

……

……[1]

For examiner's use

(v) Suggest why the crown ether with the encapsulated sodium ion enables the azide ion to enter the non-polar organic solvent.

……

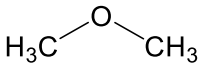
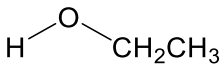
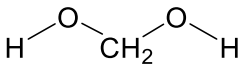
……

……

……[1]

(c) Table 3.1 shows the boiling points of dimethyl ether and two other compounds.

Table 3.1

compound	structure	boiling point / ^{o}C
dimethyl ether		–24
A		78
B		194

Give reasons for the difference in boiling points of the compounds in Table 3.1.

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……

……

……

……

……[3]

[Total: 10]

RAFFLES INSTITUTION
2021 YEAR 5 JULY COMMON TEST

Higher 2

CANDIDATE NAME

CLASS

INDEX NUMBER

CHEMISTRY 9729

2 July 2021

Section		Marks
A		/ 15
B	B1	/ 12
	B2	/ 8
	B3	/ 10
C	C1	/ 15
	C2	/ 20
Total		/ 80
Percentage		/100
Penalty		
Overall		/100
Grade		

[Turn Over

For examiner's use

Section C (35 marks)

This section consists of **2** questions.

Answer **all** the questions in this section in the spaces provided.

1 *Use of the Data Booklet is relevant to this question.*

Nuclear fusion is the process that generates energy for stars and creates various elements that make up the universe.

This process involves two stages:

1. Two or more atomic nuclei are forced to combine under high temperature and pressure.
2. The release of energy generated by the fusion of the nuclei.

The process begins by forcing hydrogen atoms together to form heavier elements such as helium and carbon. This cycle continues, and the combination of different atomic nuclei results in the formation of different elements in stars.

(a) Suggest why a large amount of energy is required for the combination of atomic nuclei.

……..……..

……..……[1]

Carbon fusion is an example of nuclear fusion where carbon atoms are fused together to form larger elements in Periods 2 and 3.

The following reactions illustrate the common carbon fusion reactions in a star's core.

$$^{12}C + {}^{12}C \rightarrow {}^{20}Ne + {}^{4}He$$

$$^{12}C + {}^{12}C \rightarrow \mathbf{X} + {}^{1}H$$

$$^{12}C + {}^{12}C \rightarrow {}^{23}Mg + \mathbf{Y}$$

(b) Suggest the identities of **X** and **Y**.

X: …….. **Y**: …… [2]

For examiner's use

(c) In larger stars, the nuclear fusion reactions become more extensive as larger atomic nuclei fuse together to form heavier elements in Period 4.

As the nuclear fusion reactions involve larger elements, higher temperatures and pressures are required for the nuclear fusion to occur. Eventually, the nuclear fusion chain reaction comes to a stop when iron, Fe, is formed.

(i) State the electronic configurations of Fe and Fe^{2+}.

Fe: …… Fe^{2+}: …… [2]

(ii) Hence, explain the difference between the radius of Fe and Fe^{2+}.

……

……

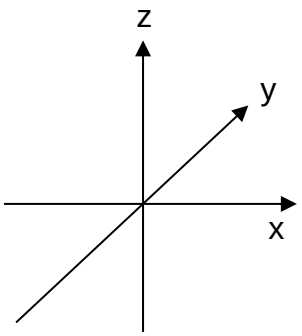
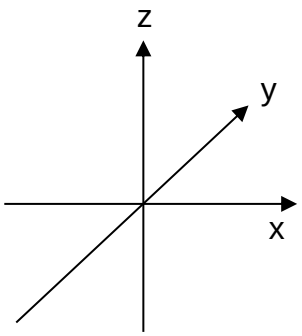
……

……[1]

(iii) Iron is a transition metal with variable oxidation states. Common ions of iron include Fe^{2+} and Fe^{3+}.

In Table 1.1, sketch, on the axes provided, the orbitals from which the second and third electrons of Fe are removed. Label the orbitals.

Table 1.1

second electron removed	third electron removed
 name of orbital:	 name of orbital: .....

[2]

For examiner's use

(iv) Besides the shapes and energies of the orbitals, describe another difference between the orbitals drawn in **(c)(iii)**.

……

……[1]

(v) Beams of charged particles are deflected by an electric field. In a particular experimental set-up, deuterium ions, $^{2}D^{-}$, are deflected through an angle of –18º.

Assuming an identical set of experimental conditions, calculate the angle of deflection when $^{56}Fe^{2+}$ is placed in the electric field.

[1]

(d) Elements **A** to **I** are nine consecutive elements in Periods 2 to 3, with atomic numbers less than 20. The letters are **not** the symbols of the elements.

Fig. 1.1 can be used to plot the second ionisation energies of elements **A** to **I**. Seven of these elements have been plotted.

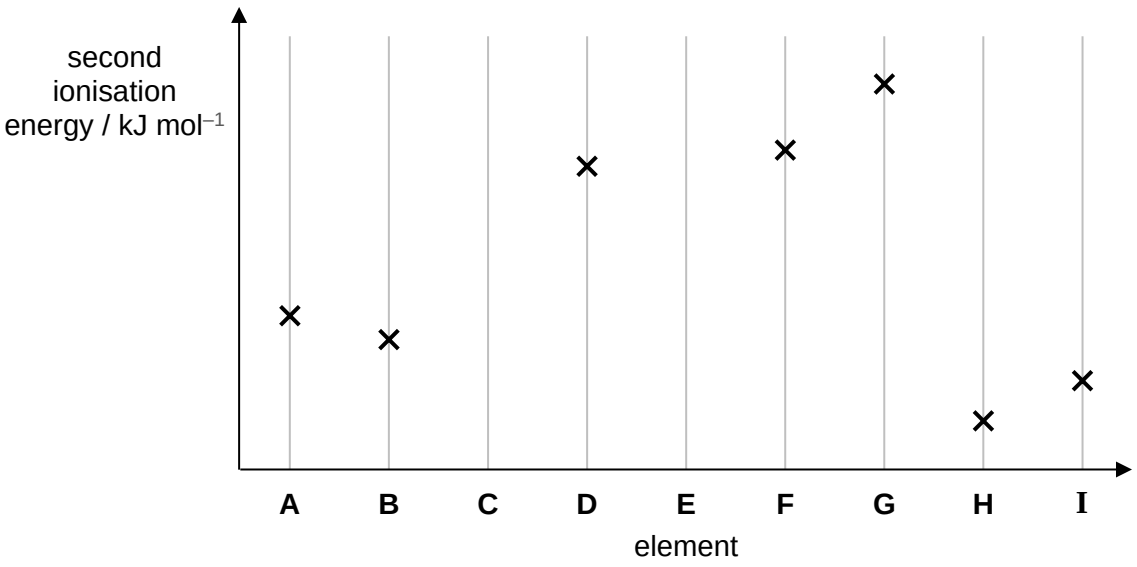


Fig. 1.1

For examiner's use

(i) Write an equation that represents the second ionisation energy of **A**.

…… [1]

(ii) Use your knowledge of the variation in second ionisation energy of the elements of Periods 2 to 3 to estimate and plot, on Fig. 1.1, the second ionisation energies of the other two elements: **C** and **E**. [2]

(iii) Justify your answers in **(d)(ii)**, by explaining why the second ionisation energy of **each** element you have plotted is higher / lower / similar compared to the element to its left on the graph.

……

……

……

……

……

……

……

……..[2]

[Total: 15]

For examiner's use

2 (a) (i) Complete the table by placing one tick (✓) in each row to indicate the sign of each type of energy change under standard conditions.

energy change	always positive	always negative	either positive or negative
enthalpy change of combustion			
enthalpy change of formation of compound			

[1]

(ii) Explain what is meant by the standard enthalpy change of solution of potassium phosphate, $K_3PO_4(s)$.

……..…..

……..[1]

(iii) Table 2.1 shows some enthalpy changes.

Table 2.1

	$\Delta H^{\ominus}$ / kJ mol^{-1}
standard enthalpy change of formation of $K_3PO_4(s)$	−2035
standard enthalpy change of $P(s) + 2O_2(g) + 3e^- \rightarrow PO_4^{3-}(aq)$	−1284
standard enthalpy change of $K(s) \rightarrow K^+(aq) + e^-$	−251

Using the data given above, construct an energy cycle to determine the standard enthalpy change of solution of potassium phosphate, $K_3PO_4(s)$.

[3]

For examiner's use

(iv) The value of $\Delta G^{\ominus}$ at 298 K for $K(s) \rightarrow K^{+}(aq) + e^{-}$ is −283 kJ mol^{-1}.

Calculate $\Delta S^{\ominus}$ for the reaction and explain its sign.

……

……

……[2]

(b) In acid-base neutralisation reactions, there are temperature changes.

(i) The standard enthalpy change of neutralisation when hydrochloric acid reacts with aqueous ammonia is −53.4 kJ mol^{-1}.

A student mixed 30.0 cm^3 of 1.20 mol dm^{-3} hydrochloric acid with 40.0 cm^3 of 0.85 mol dm^{-3} aqueous ammonia in a calorimeter at 25.0 °C.

Calculate the temperature change he would expect.

Assume : the density of the solution is 1.00 g cm^{-3}
the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}
the heat capacity of the calorimeter is 15.0 J K^{-1}

[2]

For examiner's use

(ii) Table 2.2 shows the enthalpy changes of reaction when 1 mol of different acids in dilute aqueous solutions are completely neutralised by sodium hydroxide solution at 298 K.

Table 2.2

acid	formula	enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}
hydrochloric acid	HC*l*	−58
nitric acid	HNO_3	−58
sulfuric acid	H_2SO_4	−115
ethanoic acid	CH_3COOH	−53

Comment on the enthalpy changes of reaction.

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……[3]

For examiner's use

(c) Magnesium occurs naturally only in combination with other elements and forms compounds such as magnesium fluoride, $MgF_2(s)$, magnesium bromide, $MgBr_2(s)$, and magnesium nitride, $Mg_3N_2(s)$.

(i) Table 2.3 shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Table 2.3

	value / kJ mol^{-1}
enthalpy change of atomisation of Mg(s)	+148
enthalpy change of vaporisation of $Br_2(l)$	+28.5
lattice energy of $MgBr_2(s)$	−2440
enthalpy change of formation of $MgBr_2(s)$	−524

Using data given above and from the *Data Booklet*, construct the Born-Haber cycle for magnesium bromide and calculate the first electron affinity of bromine.

enthalpy / kJ mol^{-1}

[4]

For examiner's use

(ii) Suggest, with reasons, how the magnitude of the lattice energy of magnesium bromide might compare to that of magnesium nitride.

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……[2]

(iii) The experimental lattice energy for magnesium fluoride is only −49 kJ mol^{-1} more exothermic than that predicted using the ionic model.

In contrast, the experimental lattice energy for magnesium bromide is −361 kJ mol^{-1} more exothermic than that predicted using the ionic model.

Suggest why this is so.

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[Total: 20]

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