

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

AS CHEMISTRY

Paper 1: Inorganic and Physical Chemistry

Friday 26 May 2017

Morning

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

Advice

- You are advised to spend about 65 minutes on **Section A** and 25 minutes on **Section B**.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
Section B	
TOTAL	



J U N 1 7 7 4 0 4 1 0 1

Section AAnswer **all** questions in this section.

0	1
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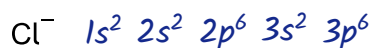
This question is about atomic structure.

0	1
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 .

1

Write the full electron configuration for each of the following species.

[2 marks]

0	1
---	---

 .

2

Write an equation, including state symbols, to represent the process that occurs when the third ionisation energy of manganese is measured.

[1 mark]

0	1
---	---

 .

3

State which of the elements magnesium and aluminium has the lower first ionisation energy.

Explain your answer.

[3 marks]

Aluminium has the lower first ionisation energy.

The outer electron in Al is in the 3p sub-level (orbital), whereas in Mg the outer electron is in the 3s sub-level.

The 3p electron is higher in energy and slightly further from the nucleus, so it is easier to remove and less energy is needed.



0 1 . 4

A sample of nickel was analysed in a time of flight (TOF) mass spectrometer. The sample was ionised by electron impact ionisation. The spectrum produced showed three peaks with abundances as set out in **Table 1**.

Table 1

m/z	Abundance/%
58	61.0
60	29.1
61	9.9

Give the symbol, including mass number, of the ion that would reach the detector first in the sample.

Calculate the relative atomic mass of the nickel in the sample.
Give your answer to one decimal place.

[3 marks]

Symbol of ion $^{58}\text{Ni}^+$ (lightest ion, so it travels fastest)

$$\begin{aligned} A_r &= [(58 \times 61.0) + (60 \times 29.1) + (61 \times 9.9)] \div 100 \\ &= (3538 + 1746 + 603.9) \div 100 \\ &= 5887.9 \div 100 = 58.879 \end{aligned}$$

Relative atomic mass 58.9



0 2

This question is about energetics.

0 2 . 1

Write an equation, including state symbols, for the reaction with an enthalpy change equal to the enthalpy of formation for iron(III) oxide.

[1 mark]

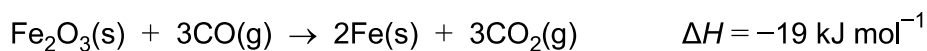


0 2 . 2

Table 2 contains some standard enthalpy of formation data.

Table 2

	CO(g)	Fe ₂ O ₃ (s)
$\Delta_f H^\circ / \text{kJ mol}^{-1}$	-111	-822



Use these data and the equation for the reaction of iron(III) oxide with carbon monoxide to calculate a value for the standard enthalpy of formation for carbon dioxide.

Show your working.

[3 marks]

$$\Delta H = \Sigma \Delta_f H(\text{products}) - \Sigma \Delta_f H(\text{reactants}) \quad (\Delta_f H \text{ of Fe} = 0)$$

$$-19 = 3\Delta_f H(\text{CO}_2) - [(-822) + 3(-111)]$$

$$3\Delta_f H(\text{CO}_2) = -19 + (-822) + 3(-111)$$

$$3\Delta_f H(\text{CO}_2) = -1174$$

$$\Delta_f H(\text{CO}_2) = -1174 \div 3 = -391 \text{ kJ mol}^{-1}$$

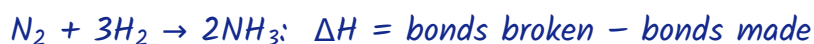
$$\Delta_f H^\circ \quad \underline{-391} \quad \text{kJ mol}^{-1}$$



0 2 . 3

Some enthalpy data are given in **Table 3**.**Table 3**

Process	$\Delta H / \text{kJ mol}^{-1}$
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$	-92
$\text{N}_2(\text{g}) \rightarrow 2\text{N}(\text{g})$	+944
$\text{H}_2(\text{g}) \rightarrow 2\text{H}(\text{g})$	+436

Use the data from **Table 3** to calculate the bond enthalpy for N–H in ammonia.**[3 marks]**

$$-92 = 944 + 3(436) - 6(\text{N-H})$$

$$6(\text{N-H}) = 944 + 3(+436) + 92$$

$$6(\text{N-H}) = 2344$$

$$\text{N-H} = 2344 \div 6 = +391 \text{ kJ mol}^{-1}$$

N–H bond enthalpy +391 kJ mol⁻¹

0 2 . 4

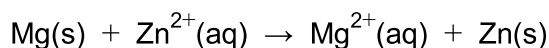
Give one reason why the bond enthalpy that you calculated in Question **2.3** is different from the mean bond enthalpy quoted in a data book (388 kJ mol⁻¹).**[1 mark]**

The data book value is a mean value derived from N–H bonds in a
number of different compounds, not just in ammonia (NH₃)
molecules.



0 3

A student planned and carried out an experiment to determine the enthalpy of reaction when magnesium metal displaces zinc from aqueous zinc sulfate.



The student used this method:

- A measuring cylinder was used to transfer 50 cm^3 of a 1.00 mol dm^{-3} aqueous solution of zinc sulfate into a glass beaker.
- A thermometer was placed in the beaker.
- 2.08 g of magnesium metal powder were added to the beaker.
- The mixture was stirred and the maximum temperature recorded.

The student recorded a starting temperature of 23.9°C and a maximum temperature of 61.2°C .

0 3 . 1

Show by calculation which reactant was in excess.

Use the data to calculate the experimental value for enthalpy of reaction in kJ mol^{-1} (Assume that the specific heat capacity of the solution is $4.18 \text{ J K}^{-1} \text{ g}^{-1}$ and the density of the solution is 1.00 g cm^{-3}).

[6 marks]

$$\text{Amount ZnSO}_4 = 1.00 \times 50/1000 = 0.0500 \text{ mol}$$

$$\text{Amount Mg} = 2.08 \div 24.3 = 0.0856 \text{ mol}$$

1 : 1 ratio and $0.0856 > 0.0500$, so Mg is in excess

(Zn^{2+} is the limiting reagent)

Reactant in excess Magnesium (Mg)

$$Q = mc\Delta T, \quad \Delta T = 61.2 - 23.9 = 37.3 \text{ K}$$

$$Q = 50.0 \times 4.18 \times 37.3 = 7795.7 \text{ J} = 7.796 \text{ kJ}$$

$$\text{Energy released per mole} = 7.796 \div 0.0500$$

$$= 155.9 \text{ kJ mol}^{-1}, \text{ exothermic so } \Delta H \text{ is negative}$$

$$\Delta H = -156 \text{ kJ mol}^{-1}$$

Enthalpy of reaction -156 kJ mol^{-1}



0 3 . 2

Another student used the same method and obtained a value for the enthalpy of reaction of -142 kJ mol^{-1}

A data book value for the enthalpy of reaction is -310 kJ mol^{-1}

Suggest the most likely reason for the large difference between the student's experimental value and the data book value.

[1 mark]

Heat loss to the surroundings (the glass beaker is not insulated and has no lid), so the temperature rise measured is too small and the value is less exothermic.

Question 3 continues on the next page



0 3 . 3

Suggest how the students' method, and the analysis of the results, could be improved in order to determine a more accurate value for the enthalpy of reaction.

Justify your suggestions.

Do not refer to the precision of the measuring equipment. Do not change the amounts or the concentration of the chemicals.

[6 marks]

1. Improve the insulation: use a polystyrene cup instead of a glass beaker, and put a lid on it (insulate the cup). This reduces heat loss to the surroundings, so the measured temperature rise is closer to the true value.

2. Improve the temperature recording: record the temperature of the zinc sulfate solution for a suitable time (e.g. every minute for 3 minutes) before adding the magnesium. This establishes an accurate initial temperature.

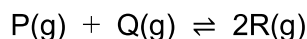
Then, after adding the magnesium, keep stirring and record the temperature at regular time intervals (e.g. every 30 seconds) for several minutes after the maximum, and plot the temperature results against time on a graph.

3. Improve the analysis: draw a line of best fit through the cooling part of the graph and extrapolate the cooling back to the time the magnesium was added (e.g. the 4th minute). This establishes the theoretical maximum temperature, so ΔT is corrected for the heat lost while the mixture was cooling (a cooling correction).



0 4

When substances **P** and **Q** react together to form substance **R** an equilibrium is established according to the equation



The equilibrium constant expression is $K_c = \frac{[\text{R}]^2}{[\text{P}][\text{Q}]}$

1.0 mol of **P** and 1.0 mol of **Q** were mixed in a container with volume 1.0 dm³

At equilibrium, x mol of **P** had reacted.

0 4 . 1

The amount, in moles, of each of **P** and **Q** at equilibrium is $(1-x)$.

Deduce in terms of x the amount, in moles, of **R** in the equilibrium mixture.

[1 mark]

2x

0 4 . 2

At 298 K the value of the equilibrium constant $K_c = 3.6$

Calculate a value for the equilibrium concentration, in mol dm⁻³, of **R**.

[3 marks]

Volume = 1.0 dm³, so concentration = amount in moles

$$K_c = (2x)^2 \div (1-x)^2 = 3.6$$

$$\sqrt{3.6} = 2x \div (1-x) \quad (\text{positive root only})$$

$$1.897 - 1.897x = 2x$$

$$1.897 = 3.897x, \text{ so } x = 0.487$$

$$[\text{R}] = 2x = 2 \times 0.487 = 0.974 \text{ mol dm}^{-3}$$

Equilibrium concentration of **R** 0.97 mol dm⁻³

4



0 5

This question is about intermolecular forces.

0 5 . 1

Give the meaning of the term electronegativity.

[1 mark]

The power of an atom to attract the pair of electrons in a covalent bond.

0 5 . 2

Explain how permanent dipole-dipole forces arise between hydrogen chloride molecules.

[2 marks]

Chlorine is more electronegative than hydrogen, so the difference in electronegativity makes the H-Cl bond polar: $H^{\delta+}-Cl^{\delta-}$.

Each HCl molecule has a permanent dipole, and there is an attraction between the $\delta+$ H on one molecule and the $\delta-$ Cl on another molecule.

0 5 . 3

Complete **Table 4** by naming the shape of each molecule.

Place a tick (✓) in the final column if the molecule has a permanent dipole.

[4 marks]

Table 4

Molecule	Name of shape	Tick (✓) if molecule has a permanent dipole
SiH ₄	<i>Tetrahedral</i>	
PH ₃	<i>Trigonal pyramidal</i>	✓
BeCl ₂	<i>Linear</i>	
CH ₃ Cl	<i>Tetrahedral</i>	✓

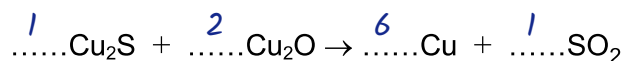
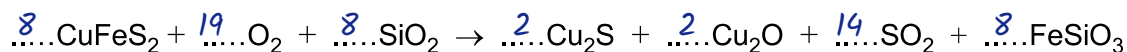


0	6
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Copper can be produced from rock that contains CuFeS_2

0	6	.	1
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Balance the equations for the two stages in this process.

[2 marks]

0	6	.	2
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Suggest two reasons why the sulfur dioxide by-product of this process is removed from the exhaust gases.

[2 marks]

Reason 1 SO_2 causes acid rain, which damages buildings and the ecology (plants and lakes).

Reason 2 SO_2 is toxic and causes breathing problems.

Question 6 continues on the next page

0 6 . 3

A passenger jet contains 4050 kg of copper wiring.

A rock sample contains 1.25% CuFeS_2 by mass.

Calculate the mass, in tonnes, of rock needed to produce enough copper wire for a passenger jet. (1 tonne = 1000 kg)

[4 marks]

$$\text{Moles Cu} = (4050 \times 1000) \div 63.5 = 63\,780 \text{ mol}$$

$$1 \text{ mol CuFeS}_2 \text{ gives 1 mol Cu, so moles CuFeS}_2 = 63\,780 \text{ mol}$$

$$M_r \text{ CuFeS}_2 = 63.5 + 55.8 + 2(32.1) = 183.5$$

$$\text{Mass CuFeS}_2 = 63\,780 \times 183.5 = 1.17 \times 10^7 \text{ g}$$

$$\text{Mass rock} = 1.17 \times 10^7 \times 100 \div 1.25 = 9.36 \times 10^8 \text{ g}$$

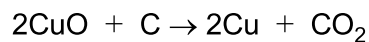
$$= 9.36 \times 10^5 \text{ kg} = 936 \text{ tonnes}$$

Mass of rock 936 tonnes



0	6	.	4
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Copper can also be produced by the reaction of carbon with copper(II) oxide according to the equation



Calculate the percentage atom economy for the production of copper by this process.

Give your answer to the appropriate number of significant figures.

[2 marks]

$$\text{Total } M_r \text{ of reactants} = 2(63.5 + 16.0) + 12.0 = 171$$

$$\% \text{ atom economy} = (2 \times 63.5) \div 171 \times 100$$

$$= 127 \div 171 \times 100 = 74.27$$

Percentage atom economy 74.3% (3 s.f.)



07

An aqueous solution **Y** is known to contain one type of group 2 metal ion and one type of negative ion.

Aqueous solutions of sulfuric acid and magnesium nitrate are added to separate samples of solution **Y**. The observations are shown in **Table 5**.

Table 5

Solution added	Observation with solution Y
Sulfuric acid	A white precipitate forms
Magnesium nitrate	A white precipitate forms

07.1

Suggest the identity of the group 2 metal ion present in solution **Y**.

Write an ionic equation, including state symbols, for the reaction that takes place when sulfuric acid is added to solution **Y**.

[2 marks]

Group 2 metal ion Ba^{2+}

Ionic equation $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

07.2

Suggest the identity of the negative ion present in solution **Y**.

Write an ionic equation, including state symbols, for the reaction that takes place when magnesium nitrate is added to solution **Y**.

[2 marks]

Negative ion OH^- (hydroxide)

Ionic equation $Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$



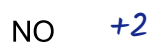
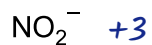
0	8
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When an acidified solution of sodium nitrite (NaNO_2) is added to aqueous potassium iodide, iodine and nitrogen monoxide (NO) are formed.

0	8	.	1
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Give the oxidation state of nitrogen in the following species.

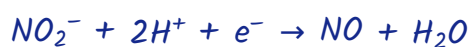
[2 marks]



0	8	.	2
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Write a half-equation for the conversion of NO_2^- in an acidic solution into NO

[1 mark]



0	8	.	3
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Write a half-equation for the conversion of I^- into I_2

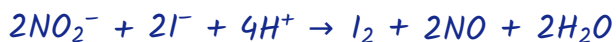
[1 mark]



0	8	.	4
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Write an overall ionic equation for the reaction of NO_2^- in an acidic solution with I^-

[1 mark]



0	8	.	5
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State the role of NO_2^- in the reaction with I^-

[1 mark]

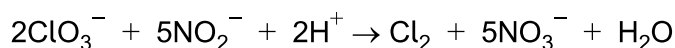
Oxidising agent (it accepts electrons from I^-)

Question 8 continues on the next page



0 8 . 6

In aqueous solution, nitrite ions react with acidified chlorate(V) ions according to the equation



A 25.0 cm^3 sample of an aqueous solution of sodium nitrite required 27.40 cm^3 of a $0.0200 \text{ mol dm}^{-3}$ solution of potassium chlorate(V) for complete reaction.

Calculate the concentration, in g dm^{-3} , of sodium nitrite in the sample.

[4 marks]

$$\text{Moles } \text{ClO}_3^- = 0.0200 \times 27.40/1000 = 5.48 \times 10^{-4} \text{ mol}$$

$$\text{Moles } \text{NO}_2^- = 5.48 \times 10^{-4} \times 5/2 = 1.37 \times 10^{-3} \text{ mol}$$

$$[\text{NaNO}_2] = 1.37 \times 10^{-3} \div (25.0/1000) = 0.0548 \text{ mol dm}^{-3}$$

$$M_r \text{ NaNO}_2 = 23.0 + 14.0 + 2(16.0) = 69.0$$

$$\text{Concentration} = 0.0548 \times 69.0 = 3.78 \text{ g dm}^{-3}$$

Concentration of sodium nitrite 3.78 g dm^{-3}



Section B

Answer **all** questions in this section.Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD



WRONG METHODS



If you want to change your answer you must cross out your original answer as shown.



If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.



You may do your working in the blank space around each question but this will not be marked.

Do **not** use additional sheets for this working.

0 9

Which is the correct crystal structure for the substance named?

[1 mark]

	Substance	Structure
A	Iodine	Simple molecular
B	Diamond	Ionic
C	Sodium chloride	Giant covalent
D	Graphite	Metallic



1 0

Which is the best technique to remove the silver chloride that forms when aqueous solutions of silver nitrate and sodium chloride react?

[1 mark]

A Refluxing



B Evaporation



C Filtration



D Distillation



1	1
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Which statement about astatine is correct?

[1 mark]

- A** Astatine has a greater electronegativity than bromine
- B** Astatine is a better oxidising agent than bromine
- C** Astatine has a greater boiling point than bromine
- D** Astatine has a greater first ionisation energy than bromine

☐☐☒☐

1	2
---	---

Which statement about time of flight mass spectrometry is correct?

[1 mark]

- A** The current in the detector is proportional to the ion abundance
- B** Sample particles gain electrons to form positive ions
- C** Particles are detected in the order of their kinetic energies
- D** Ions are accelerated by a magnetic field

☒☐☐☐

1	3
---	---

Chlorine exists as two isotopes ^{35}Cl and ^{37}Cl in the ratio 3:1Which statement about peaks in the mass spectrum of Cl_2 is correct?**[1 mark]**

- A** Peaks at $m/z = 70$ and 74 in the ratio 3:1
- B** Peaks at $m/z = 70, 72$ and 74 in the ratio 9:6:1
- C** Peaks at $m/z = 70, 72$ and 74 in the ratio 9:3:1
- D** Peaks at $m/z = 70$ and 72 in the ratio 3:1

☐☒☐☐

1	4
---	---

A 4.85 g sample of anhydrous sodium sulfate is dissolved in water and the solution made up to 250 cm^3 in a volumetric flask.

What is the concentration in mol dm^{-3} of sodium sulfate in the solution?

[1 mark]

A 0.0341

☐

B 0.137

☒

C 0.163

☐

D 0.273

☐

1	5
---	---

Which of these contains the greatest number of atoms?

[1 mark]

A 127 mg of iodine

☐

B $1.54 \times 10^{-4} \text{ kg}$ of phosphorus

☐

C 81.0 mg of carbon dioxide

☐

D $1.70 \times 10^{-4} \text{ kg}$ of ammonia

☒

1	6
---	---

25.0 cm^3 samples of NaOH solution were taken by pipette from a beaker. These were then titrated with an aqueous solution of ethanoic acid. The concentration of ethanoic acid calculated from the experimental results was found to be lower than the actual value.

Which of these could explain the difference?

[1 mark]

A Rinsing the pipette with distilled water before filling with NaOH

☐

B Rinsing the burette with distilled water before filling with ethanoic acid

☒

C Rinsing the walls of the conical flask with distilled water during the titration

☐

D Rinsing the beaker with distilled water before filling with NaOH

☐

1 7

A 20.0 cm^3 sample of a $0.400 \text{ mol dm}^{-3}$ aqueous solution of a metal bromide (MBr_n) reacts exactly with 160 cm^3 of $0.100 \text{ mol dm}^{-3}$ aqueous silver nitrate.

What is the formula of the metal bromide?

[1 mark]

A MBr

☐

B MBr_2

☒

C MBr_3

☐

D MBr_4

☐

1 8

Which species has one or more bond angle(s) of 90° ?

[1 mark]

A CH_4

☐

B NH_4^+

☐

C ClF_4^-

☒

D AlCl_4^-

☐

1 9

The forward reaction in this equilibrium is endothermic



Which statement is correct?

[1 mark]

A If the total pressure is increased at constant temperature, the proportion of COCl_2 in the equilibrium mixture will decrease

☐

B Use of a catalyst will increase the proportion of COCl_2 in the equilibrium mixture at constant temperature and pressure

☐

C Reducing the equilibrium concentration of CO will increase the value of the equilibrium constant

☐

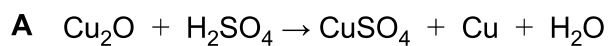
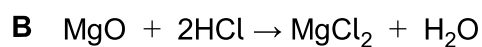
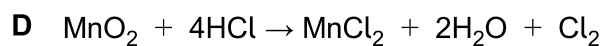
D Raising the temperature from 373 K to 473 K will increase the value of the equilibrium constant

☒

2	0
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Which of these is **not** a redox reaction?

[1 mark]

☐☒☐☐

2	1
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Which of these has the highest first ionisation energy?

[1 mark]

A Na

☐

B Al

☐

C Si

☐

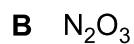
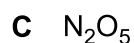
D Cl

☒

2	2
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What is the empirical formula of an oxide of nitrogen that contains 26% nitrogen by mass?

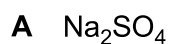
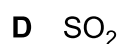
[1 mark]

☐☐☒☐

2	3
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Which species is **not** produced by a redox reaction between solid sodium iodide and concentrated sulfuric acid?

[1 mark]

☒☐☐☐

END OF QUESTIONS

15



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ANSWER IN THE SPACES PROVIDED**



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