AQA

Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname MODEL ANSWERS

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.

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

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**.

Section A

Answer **all** questions in this section.

0 1 This question is about atomic structure.

0 1 . 1 Write the full electron configuration for each of the following species.

[2 marks]

Cl^- $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Fe^{2+} $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$

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]

$Mn^{2+}(g) \rightarrow Mn^{3+}(g) + e^-$

0 1 . 3 State which of the elements magnesium and aluminium has the lower first ionisation energy.

Explain your answer.

[3 marks]

- Al — M1
- electron is in 3p orbital — M2
- higher in energy or further from nucleus so easier to remove — M3

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 $^{58}Ni^{+}$ M1

$A_r = \dfrac{(58 \times 61.0) + (60 \times 29.1) + (61 \times 9.9)}{100}$ M2

$= \dfrac{5887.9}{100}$

Relative atomic mass 58.9 (1 d.p.) M3

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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. Fe_2O_3

[1 mark]

$2Fe(s) + 3/2\ O_2(g) \rightarrow Fe_2O_3(s)$

0 2 . 2 **Table 2** contains some standard enthalpy of formation data.

Table 2

	CO(g)	Fe_2O_3(s)
$\Delta_f H^\circ$ / kJ mol^{-1}	−111	−822

$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$ $\quad \Delta H = -19$ kJ mol^{-1}

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]

$\Delta H_r = \Sigma \Delta H_f (Prod) - \Sigma \Delta H_f (reactants)$ M1

$= (3\Delta H_f CO_2) - (\Delta H_f Fe_2O_3 + 3\Delta H_f CO)$

$-19 = 3\Delta H_f CO_2 - (-822 + 3(-111))$

$-19 = 3\Delta H_f CO_2 - (-1155)$

$3\Delta H_f CO_2 = -19 + -1155$ M2

$= -1174$

$\Delta H_f CO_3 = -391.4$

$\Delta_f H^\circ$ -391 (3 s.f.) kJ mol^{-1} M3

0 2 . 3 Some enthalpy data are given in **Table 3.**

Table 3

Process	ΔH / kJ mol^{-1}
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	−92
$N_2(g) \rightarrow 2N(g)$	+944
$H_2(g) \rightarrow 2H(g)$	+436

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

[3 marks]

$\Delta H_r = \Sigma \Delta H(BB) - \Sigma \Delta H(BF)$ M1

$\Delta H_r = (\Delta H N\equiv N + 3\Delta H\ H\text{-}H) - (6\ \Delta H N\text{-}H)$

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

$-92 = 2252 - 6\Delta H N\text{-}H$

$6\Delta H N\text{-}H = 2252 + 92$

$= 2344$ M2

$\Delta H N\text{-}H = 390.6$

N–H bond enthalpy 391 (3.S.f.) kJ mol^{-1} M3

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]

Data book values are from a range of different compounds

8

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.

$$Mg(s) + Zn^{2+}(aq) \rightarrow Mg^{2+}(aq) + Zn(s)$$

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. $\Delta T = 37.3$

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 J $K^{-1}g^{-1}$ and the density of the solution is 1.00 g cm^{-3}).

[6 marks]

$n = cv$ $\quad n\ ZnSO_4 = 1.0 \times 50 \times 10^{-3} = 0.05$ M1

$n = \frac{m}{Ar}$ $\quad n\ Mg = \frac{2.08}{24.3} = 0.09$ M2

Reactant in excess Mg

$q = mc\Delta T$ M3

$= 50 \times 4.18 \times 37.3 = 7795.7\ J$ M4

$\Delta H = \frac{q}{n}$

$= \frac{7.796}{0.05} = 155.9$ M5

Enthalpy of reaction 156 (3 s.f.) kJ mol^{-1} M6

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

Question 3 continues on the next page

0 3 . 3 CHALLENGING

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.

LEVELLED

[6 marks]

Stage 1: Improve insulation
- Insulate the beaker or use a polystyrene cup
- to reduce the heat loss

Stage 2: Improve temperature recording
- Record the temperature of the solution for a suitable time before adding the metal
- to establish an accurate initial temperature

or
- record temperature values at regular intervals
- to plot the temperature against time

Stage 3: Improve analysis
- Extrapolate the cooling back to the point of addition
- to establish a maximum temperature

Level 3 (5-6): 3 stages with reasons

Level 2 (3-4): 2 stages with reasons
or 3 stages but incomplete reasons

Level 1 (1-2): 1 stage with reasons
or 2 stages but incomplete reasons

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0 4 When substances **P** and **Q** react together to form substance **R** an equilibrium is established according to the equation

$$P(g) + Q(g) \rightleftharpoons 2R(g)$$

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

1.0 mol of **P** and 1.0 mol of **Q** were mixed in a container with volume 1.0 dm^3

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 $K_c = 3.6$

CHALLENGING

Calculate a value for the equilibrium concentration, in mol dm^{-3}, of **R**.

[3 marks]

$K_c = \dfrac{[R]^2}{[P][Q]} = 3.6$

$3.6 = \dfrac{(2x)^2}{(1-x)^2}$ M1

$\sqrt{3.6} = \dfrac{2x}{1-x}$

$\sqrt{3.6}(1-x) = 2x$

$\sqrt{3.6} - \sqrt{3.6}x = 2x$

$1.9 - 1.9x = 2x$

$1.9 = 2x + 1.9x$

$1.9 = 3.9x$ M2

$x = 0.49$

$[R] = 2x$ M3

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]

Power of an atom to attract a pair of electrons in a covalent bond

0 5 . 2 Explain how permanent dipole-dipole forces arise between hydrogen chloride molecules.

[2 marks]

- Difference in electronegativity between H and C leads to a polar bond. M1
- The δ^+ end of one molecule attracts to the δ^- end of another molecule M2

$H^{\delta+}-Cl^{\delta-} \cdots H^{\delta+}-Cl^{\delta-}$ (optional)

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	tetrahedral	
PH_3	trigonal pyramidal	✓
$BeCl_2$	linear	
CH_3Cl	tetrahedral	✓

7

0 6 Copper can be produced from rock that contains $CuFeS_2$

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

[2 marks]

4 $CuFeS_2$ + 9.5 O_2 + 4 SiO_2 → ..... Cu_2S + ... Cu_2O + 7 SO_2 + 4 $FeSiO_3$

..... Cu_2S + 2 Cu_2O → 6 Cu + ... SO_2

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

[2 marks]

Reason 1 prevents acid rain

Reason 2 causes breathing problems

Question 6 continues on the next page

0 6 . 3 A passenger jet contains 4050 kg of copper wiring.

CHALLENGING 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]

Method 1

$$n\ Cu = \frac{4050 \times 10^3}{63.5} = 63780$$

$$m\ Cu\ in\ rock = 63780 \times 183.5 = 1.17 \times 10^7\ g$$

$$m\ rock = 1.17 \times 10^7 \times \frac{100}{1.25}$$

Method 2

$$\%\ Cu\ in\ CuFeS_2 = \frac{63.5}{183.5} \times 100 = 34.6\%$$

$$\%\ Cu\ in\ rock = 34.6 \times 1.25\% = 0.4325\%$$

$$m\ rock = 4050 \times \frac{100}{0.4325}$$

$$= 936416\ kg$$

Mass of rock 936 tonnes

(allow 936 - 937)

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

$$2CuO + C \rightarrow 2Cu + CO_2$$

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]

% Atom economy = $\frac{\text{total mass desired product}}{\text{total mass all reactants}} \times 100$ M1

$\frac{(2 \times 63.5)}{(2 \times 79.5) + 12.0} \times 100$

Percentage atom economy 74.3% (3 s.f.) M2

10

0 7 CHALLENGING

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

0 7 . 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 $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

0 7 . 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^-

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

4

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

[2 marks]

NO_2^- +3

NO +2

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

[1 mark]

$NO_2^- + e^- + 2H^+ \rightarrow NO + H_2O$

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

[1 mark]

$2I^- \rightarrow I_2 + 2e^-$

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

[1 mark]

$2NO_2^- + 2I^- + 4H^+ \rightarrow 2NO + I_2 + 2H_2O$

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

[1 mark]

oxidising agent

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

$$2ClO_3^- + 5NO_2^- + 2H^+ \rightarrow Cl_2 + 5NO_3^- + H_2O$$

A 25.0 cm^3 sample of an aqueous solution of sodium nitrite required 27.40 cm^3 of a 0.0200 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]

$n = cV$ $n\ KClO_3 = 0.02 \times 27.4 \times 10^{-3} = 5.48 \times 10^{-4}$ M1

$n\ NaNO_3 = \frac{5}{2} \times 5.48 \times 10^{-4} = 1.37 \times 10^{-3}$ M2

$c = \frac{n}{V}$ $c\ NaNO_3 = \frac{1.37 \times 10^{-3}}{25 \times 10^{-3}} = 0.0548$ mol dm^{-3} M3

$m = nM_r$ $m\ NaNO_3$ $0.0548 \times 69.0 = 3.78$ g

Concentration of sodium nitrite 3.78 g dm^{-3} M4

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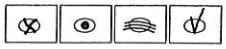
Section B

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?

insoluble

[1 mark]

A Refluxing

B Evaporation

C Filtration

D Distillation

1 1 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 3:1

Which 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]

Na_2SO_4

$n\ Na_2SO_4 = \frac{4.85}{142.1} = 0.0341$

$c = \frac{0.0341}{250 \times 10^{-3}}$

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 I_2 2 atoms ○

B 1.54×10^{-4} kg of phosphorus P_4 4 atoms ○

C 81.0 mg of carbon dioxide CO_2 3 atoms ○

D 1.70×10^{-4} kg of ammonia NH_3 4 atoms ●

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 this would dilute the solution ●

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 ○

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

What is the formula of the metal bromide?

$n MBr_n = 0.4 \times 20 \times 10^{-3} = 0.008$

$n AgNO_3 = 0.1 \times 160 \times 10^{-3} = 0.016$

ratio Ag : Br

0.016 : 0.008

AgBr will form

so need 2 x 0.008 Br

[1 mark]

A MBr ○

B MBr_2 ●

C MBr_3 ○

D MBr_4 ○

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

[1 mark]

A CH_4 tetrahedral ○

B NH_4^+ tetrahedral ○

C ClF_4^- octahedral ●

D $AlCl_4^-$ tetrahedral ○

19 The forward reaction in this equilibrium is endothermic

$$COCl_2\,(g) \rightleftharpoons CO(g) + Cl_2\,(g)$$

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 ○
moves to LHS so $COCl_2$ increases

B Use of a catalyst will increase the proportion of $COCl_2$ in the equilibrium mixture at constant temperature and pressure ○
no effect

C Reducing the equilibrium concentration of CO will increase the value of the equilibrium constant ○
no effect

D Raising the temperature from 373 K to 473 K will increase the value of the equilibrium constant ●
moves to RHS so K_c increases

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

[1 mark]

A $Cu_2O + H_2SO_4 \rightarrow CuSO_4 + Cu + H_2O$ ○

B $MgO + 2HCl \rightarrow MgCl_2 + H_2O$ ●

C $SnCl_2 + HgCl_2 \rightarrow Hg + SnCl_4$ ○

D $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$ ○

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

increase across a period

[1 mark]

A Na ○

B Al ○

C Si ○

D Cl ●

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

[1 mark]

N O
26 74
n 26/14 = 1.857 74/16 = 4.625
1 : 2.5 × 2

A NO_2 ○

B N_2O_3 ○

C N_2O_5 ●

D N_4O_5 ○

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

[1 mark]

A Na_2SO_4 acid-base reaction ●

B H_2S ○

C S ○

D SO_2 ○

END OF QUESTIONS

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