AQA

Please write clearly in block capitals.

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

Surname MODEL ANSWERS

Forename(s) ______

Candidate signature ______

A-level
CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Tuesday 4 June 2019 Afternoon Time allowed: 2 hours

Materials

For this paper you must have:

- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific 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 105.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
TOTAL	

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

0 1 **Figure 1** shows an incomplete Born–Haber cycle for the formation of caesium iodide. The diagram is not to scale.

Figure 1

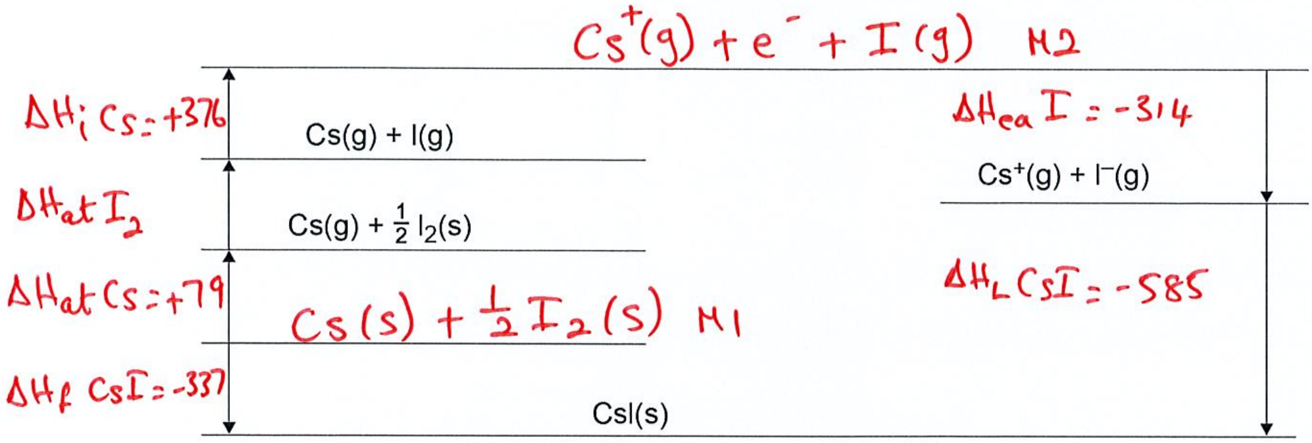

Table 1 gives values of some standard enthalpy changes.

Table 1

Name of enthalpy change	$\Delta H^\ominus$ / kJ mol^{-1}
Enthalpy of atomisation of caesium	+79
First ionisation energy of caesium	+376
Electron affinity of iodine	–314
Enthalpy of lattice formation of caesium iodide	–585
Enthalpy of formation of caesium iodide	–337

0 1 . 1 Complete **Figure 1** by writing the formulas, including state symbols, of the appropriate species on each of the two blank lines.

[2 marks]

0 1 . 2 Use **Figure 1** and the data in **Table 1** to calculate the standard enthalpy of atomisation of iodine.

[2 marks]

$\Delta H_f = \Delta H_{at} Cs + \Delta H_{at} I_2 + \Delta H_i Cs + \Delta H_{ea} I + \Delta H_L CsI$

$-337 = +79 + \Delta H_{at} I_2 + 376 + (-314) + (-585)$ M1

$\Delta H_{at} I_2 = -337 - 79 - 376 + 314 + 585$

Standard enthalpy of atomisation of iodine + 107 kJ mol^{-1} M2

Do not write outside the box

0 1 . 3 The enthalpy of lattice formation for caesium iodide in **Table 1** is a value obtained by experiment.
The value obtained by calculation using the perfect ionic model is –582 kJ mol^{-1}

Deduce what these values indicate about the bonding in caesium iodide.

[1 mark]

Values close
Mostly | purely ionic

0 1 . 4 Use data from **Table 2** to show that this reaction is **not** feasible at 298 K

$$CsI(s) \rightarrow Cs(s) + \frac{1}{2}I_2(s) \qquad \Delta H^\ominus = +337 \text{ kJ mol}^{-1}$$

Table 2

	CsI(s)	Cs(s)	I_2(s)
$S^\ominus$ / J K^{-1} mol^{-1}	130	82.8	117

[4 marks]

$\Delta S = \Sigma S(P) - \Sigma S(R)$
$= [82.8 + \frac{1}{2}(117)] - 130 = 11.3 \text{ J K}^{-1} \text{ mol}^{-1}$ M1

$\Delta G = \Delta H - T\Delta S$ M2
$= 337 - (298 \times 11.3 \times 10^{-3})$
$= 334 \text{ kJ mol}^{-1}$ M3 (converting units) M4

(positive value ∴ not feasible)

9

Turn over ►

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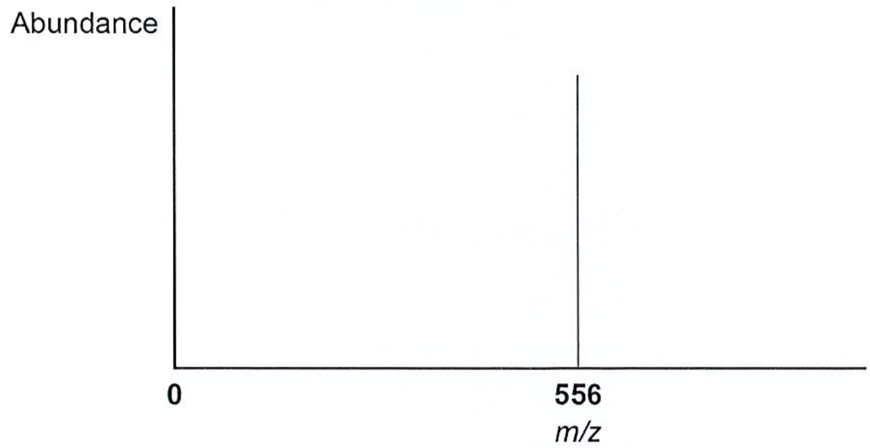
0 2 Time of flight (TOF) mass spectrometry can be used to analyse large molecules such as the pentapeptide, leucine encephalin (**P**).

P is ionised by electrospray ionisation and its mass spectrum is shown in **Figure 2**.

Figure 2



0 2 . 1 Describe the process of electrospray ionisation.

Give an equation to represent the ionisation of **P** in this process.

[4 marks]

Description

- Dissolved in a solvent M1
- Injected / passed through a (fine) needle with a high voltage applied M2
- Gains a proton M3

Equation

$P + H^+ \rightarrow PH^+$ M4

Do not write outside the box

0 2 . 2 What is the relative molecular mass of **P**?
Tick (✓) **one** box.

[1 mark]

555 ☑ 556 ☐ 557 ☐

0 2 . 3 A molecule **Q** is ionised by electron impact in a TOF mass spectrometer.
The Q^+ ion has a kinetic energy of 2.09×10^{-15} J
This ion takes 1.23×10^{-5} s to reach the detector.
The length of the flight tube is 1.50 m

Calculate the relative molecular mass of **Q**.

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = speed ($m\ s^{-1}$)

The Avogadro constant, $L = 6.022 \times 10^{23}\ mol^{-1}$

[5 marks]

$KE = \frac{1}{2}mv^2 \quad \therefore \quad m = \frac{2KE}{v^2}$

$v = \frac{d}{t} = \frac{1.5}{1.23 \times 10^{-5}} = 121951\ ms^{-1}$ M1

$m = \frac{2 \times 2.09 \times 10^{-15}}{(121951)^2} = \frac{4.18 \times 10^{-5}}{1.487 \times 10^{10}} = 2.81 \times 10^{-25}$ M2 M3

$m = \frac{M_r}{L} \quad \therefore \quad M_r = mL$ (kg)

$M_r = 2.81 \times 10^{-25} \times 6.022 \times 10^{23} = 0.169$ M4

$= 0.169 \times 10^3$

Relative molecular mass 169 M5

10

Turn over ▶

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0 3 This question is about periodicity, the Period 4 elements and their compounds.

0 3 . 1 State the meaning of the term periodicity.

[1 mark]

repeating pattern / trend

0 3 . 2 Identify the element in Period 4 with the highest electronegativity value.

[1 mark]

bromine / Br

0 3 . 3 Identify the element in Period 4 with the largest atomic radius.
Explain your answer.

[3 marks]

Element potassium / K M1

Explanation

- lowest number protons / smallest nuclear charge M2
- similiar / same shielding M3

0 3 . 4 The equations for two reactions of arsenic(III) oxide are shown.

$$As_2O_3 + 6HCl \rightarrow 2AsCl_3 + 3H_2O$$

$$As_2O_3 + 6NaOH \rightarrow 2Na_3AsO_3 + 3H_2O$$

Name the property of arsenic(III) oxide that describes its ability to react in these two ways.

[1 mark]

amphoteric

0 3 . 5 Complete the equation for the formation of arsenic hydride.

[1 mark]

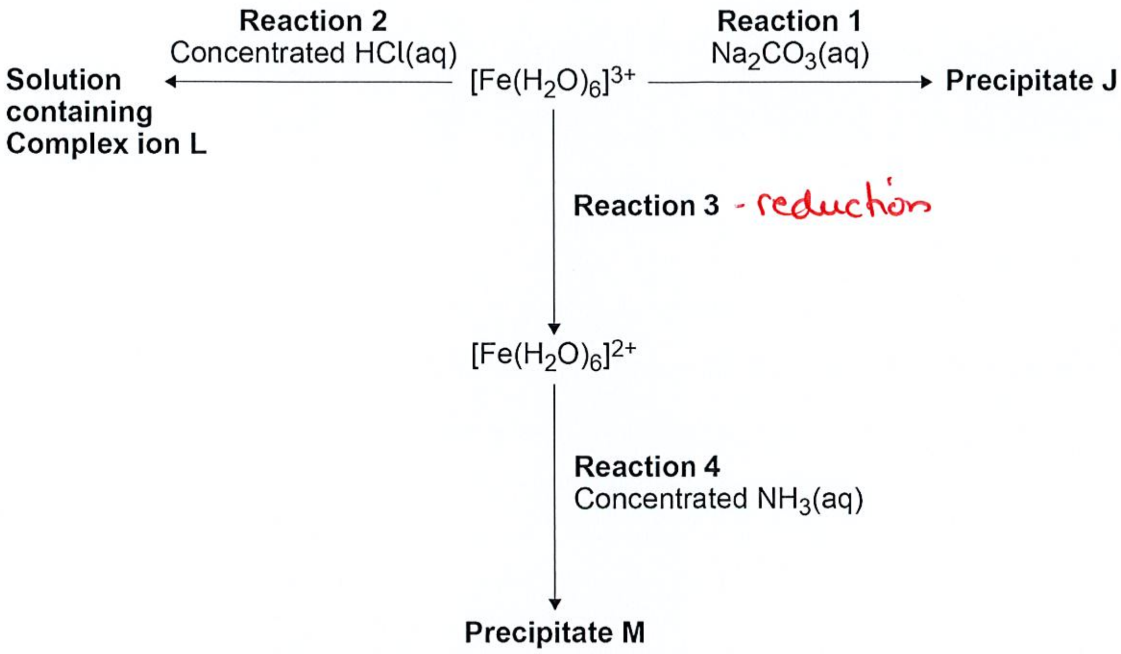
As_2O_3 + 6 Zn + 12 $HNO_3 \rightarrow$ 2 AsH_3 + 6 $Zn(NO_3)_2$ + 3 H_2O

7

Do not write outside the box

0 4 **Figure 3** shows some reactions of aqueous iron ions.

Figure 3



0 4 . 1 Give the formula of **Precipitate J** and state its colour.
Give an equation for **Reaction 1**.

[3 marks]

Formula of **J** $[Fe(OH_3)(H_2O)_3]$

Colour brown

Equation

$[Fe(H_2O)_3]^{3+} + 3CO_3^{2-} \rightarrow [Fe(OH_3)(H_2O)_3] + 3CO_2 + 3H_2O$

0 4 . 2 Give the formula of **L** and an equation for **Reaction 2**.

[2 marks]

Formula of **L** $[FeCl_4]^-$

Equation

$[Fe(H_2O)_6]^{3+} + 4Cl^- \rightarrow [FeCl_4]^- + 6H_2O$

0 4 . 3 Suggest a reagent for **Reaction 3**.

[1 mark]

Zn | HCl

0 4 . 4 Give the formula of **Precipitate M** and state its colour.

[2 marks]

Formula of **M** [Fe (OH)$_2$ (H$_2$O)$_4$]

Colour green

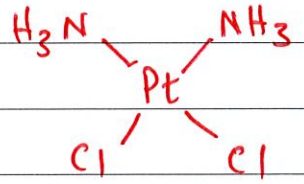
0 4 . 5 Transition metal complexes have different shapes and many show isomerism.

Describe the different shapes of complexes and show how they lead to different types of isomerism.
Use examples of complexes of cobalt(II) and platinum(II).

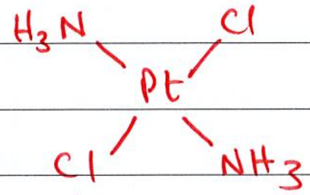
You should draw the structures of the examples chosen.

[6 marks]

- Square planar complexes with two different ligands shows cis/trans geometric isomerism

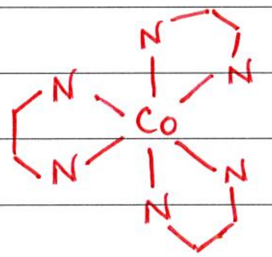
e.g. 

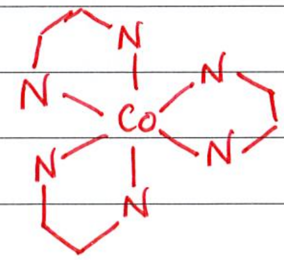
cis-platin



trans-platin

- Octahedral complexes with bidentate or multidentate ligands show optical isomerism

eg. 



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Turn over ►

0 5 This question is about some Group 7 compounds.

0 5 . 1 Solid sodium chloride reacts with concentrated sulfuric acid.

Give an equation for this reaction.
State the role of the sulfuric acid in this reaction.

[2 marks]

Equation

$NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$

Role acid | proton donor

0 5 . 2 Fumes of sulfur dioxide are formed when sodium bromide reacts with concentrated sulfuric acid.

For **this** reaction
- give an equation
- give **one** other observation
- state the role of the sulfuric acid.

[3 marks]

Equation

$2NaBr + H_2SO_4 \rightarrow Na_2SO_4 + SO_2 + Br_2 + 2H_2O$

Observation

orange gas | fumes

Role oxidising agent

0 5 . 3 Chlorine reacts with hot aqueous sodium hydroxide as shown in the equation.

$$3Cl_2 + 6NaOH \rightarrow NaClO_3 + 5NaCl + 3H_2O$$

Give the oxidation state of chlorine in $NaClO_3$ and in NaCl

[1 mark]

$NaClO_3$ +5

NaCl −1

Do not write outside the box

0 5 . 4 State, in terms of redox, what happens to chlorine in the reaction in Question **05.3**.

[1 mark]

oxidised and reduced

undergoes disproportionation

0 5 . 5 Solution **Y** contains **two** different negative ions.

To a sample of solution **Y** in a test tube a student adds

- silver nitrate solution
- then an excess of dilute nitric acid
- finally an excess of concentrated ammonia solution.

The observations after each addition are recorded in **Table 3**.

Table 3

Reagent added to solution Y	Observation
silver nitrate solution	cream precipitate containing compound **D** and compound **E**
excess dilute nitric acid	cream precipitate **D** and bubbles of gas **F**
excess concentrated ammonia solution	colourless solution containing complex ion **G**

Give the formulas of **D, E** and **F**.

Give an **ionic** equation to show the formation of **E**.

Give an equation to show the conversion of **D** into **G**.

[6 marks]

Formula of **D** $AgBr$

Formula of **E** Ag_2CO_3

Formula of **F** CO_2

Ionic equation to form **E**

$2Ag^+ + CO_3^{2-} \rightarrow Ag_2CO_3$

Equation to show the conversion of **D** into **G**

$AgBr + 2NH_3 \rightarrow [Ag(NH_3)_2]^+ + Br^-$

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Turn over ▶

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0 6 A student does an experiment to determine the percentage of copper in an alloy.

The student

- reacts 985 mg of the alloy with concentrated nitric acid to form a solution (all of the copper in the alloy reacts to form aqueous copper(II) ions)
- pours the solution into a volumetric flask and makes the volume up to 250 cm^3 with distilled water
- shakes the flask thoroughly
- transfers 25.0 cm^3 of the solution into a conical flask and adds an excess of potassium iodide
- uses exactly 9.00 cm^3 of 0.0800 mol dm^{-3} sodium thiosulfate ($Na_2S_2O_3$) solution to react with all the iodine produced.

The equations for the reactions are

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

$$2S_2O_3^{2-} + I_2 \rightarrow 2I^- + S_4O_6^{2-}$$

0 6 . 1 Calculate the percentage of copper by mass in the alloy.

Give your answer to the appropriate number of significant figures.

[6 marks]

mass alloy = 0.985g M5

n $S_2O_3^{2-}$ = $0.08 \times 9 \times 10^{-3} = 7.2 \times 10^{-4}$ M1

n I_2 = $7.2 \times 10^{-4} / 2 = 3.6 \times 10^{-4}$

n Cu^{2+} = $3.6 \times 10^{-4} \times 2 = 7.2 \times 10^{-4}$ M2

m Cu^{2+} = $7.2 \times 10^{-4} \times 63.5 = 0.04572$g in 25$cm^3$

m Cu^{2+} = $0.04572 \times \frac{250}{25} = 0.4572$g in 250$cm^3$ M3/M4

% mass = $\frac{0.4572}{0.985} \times 100 = 46.4\%$

% copper 46.4 M6

Do not write outside the box

0 6 . 2 Suggest **two** ways that the student could reduce the percentage uncertainty in the measurement of the volume of sodium thiosulfate solution, using the same apparatus as this experiment.

[2 marks]

1 Bigger mass of alloy

2 Lower concentration of thiosulphate or lower mass to make solution

0 6 . 3 State the role of iodine in the reaction with sodium thiosulfate.

[1 mark]

oxidising agent

0 6 . 4 Give the full electron configuration of a copper(II) ion. Cu^{2+}

[1 mark]

$1s^2 2s^2 2p^6 3s^2 3p^9$

0 6 . 5 Copper(I) iodide is a white solid.

Explain why copper(I) iodide is white.

[2 marks]

Cu^+ has a full 3d shell ($3d^{10}$) M1
Not able to absorb visible light M2

Question 6 continues on the next page

Turn over ►

Do not write outside the box

0 6 . 6 Iodine vaporises easily.

Calculate the volume, in cm^3, that 5.00 g of iodine vapour occupies at 185 °C and 100 kPa

The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$

Give your answer to 3 significant figures.

[4 marks]

$n I_2 = \frac{5}{253.8} = 0.0197$ mol M1

$T = 185 + 273 = 458$ K M2

$P = 100 \times 10^3 = 100{,}000$ Pa

$PV = nRT$

$V = \frac{nRT}{P}$

$= \frac{0.0197 \times 8.31 \times 458}{100{,}000} = 7.498 \times 10^{-3}\ m^3$ M3

$\times 10^6$

Volume 750 M4 cm^3

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Do not write outside the box

0 7 Sulfur trioxide decomposes on heating to form an equilibrium mixture containing sulfur dioxide and oxygen.

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$$

0 7 . 1 A sample of sulfur trioxide was heated and allowed to reach equilibrium at a given temperature.
The equilibrium mixture contained 6.08 g of sulfur dioxide.

Calculate the mass, in g, of oxygen gas in the equilibrium mixture.

[2 marks]

$n\ SO_2 = \frac{6.08}{64.1} = 0.0949$

$n\ O_2 = \frac{0.0949}{2} = 0.0474$

$m\ O_2 = 0.0474 \times 32$

Mass 1.52 g

Question 7 continues on the next page

Turn over ►

Do not write outside the box

0 7 . 2 A different mass of sulfur trioxide was heated and allowed to reach equilibrium at 1050 K

$$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$$

The amounts of each substance in the equilibrium mixture are shown in **Table 4**.

Table 4

Substance	Amount at equilibrium / mol
sulfur trioxide	0.320
sulfur dioxide	1.20
oxygen	0.600

= 2.12

For this reaction at 1050 K the equilibrium constant, $K_p = 7.62 \times 10^5$ Pa

Calculate the mole fraction of each substance at equilibrium.
Give the expression for the equilibrium constant, K_p
Calculate the total pressure, in Pa, of this equilibrium mixture.

[4 marks]

SO_3 : 0.32 / 2.12 = 0.15

SO_2 : 1.20 / 2.12 = 0.57

O_2 : 0.6 / 2.12 = 0.28

Mole fraction SO_3 0.15 M1

Mole fraction SO_2 0.57

Mole fraction O_2 0.28

$K_p = \frac{(p\,SO_2)^2 (p\,O_2)}{(p\,SO_3)^2}$ M2

pp = mole fraction × P

$K_p = \frac{(\text{mol frac } SO_2)^2 P^2 \times (\text{mol frac } O_2) P}{(\text{mol frac } SO_3)^2 P^2}$

$P = \frac{7.62 \times 10^5 \times 0.225}{0.3249 \times 0.28} = 189207$ Pa M3

Total pressure 1.89×10^5 Pa M4

(Allow 1.88×10^5 to 1.94×10^5)

Do not write outside the box

0 7 . 3 For this reaction at 1050 K the equilibrium constant, $K_p = 7.62 \times 10^5$ Pa
For this reaction at 500 K the equilibrium constant, $K_p = 3.94 \times 10^4$ Pa

Explain how this information can be used to deduce that the forward reaction is endothermic.

[2 marks]

• Higher temperature favours endothermic reaction – equilibrium shifts to right M1
• Higher kp indicates equilibrium is more to the right hand side M2

0 7 . 4 Use data from Question **07.3** to calculate the value of K_p, at 500 K, for the equilibrium represented by this equation.
Deduce the units of K_p

$$SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$$

[2 marks]

$$Kp = \frac{(pSO_2)^2(pO_2)}{(pSO_3)^2} \quad \text{so} \quad \frac{(pSO_2)(pO_2)^{1/2}}{(pSO_3)} = \sqrt{Kp}$$

$$\sqrt{3.94 \times 10^4} = 198.49$$

$$\text{units} = \frac{Pa \times Pa^{1/2}}{Pa}$$

K_p 198.5

Units $Pa^{1/2}$

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Turn over for the next question

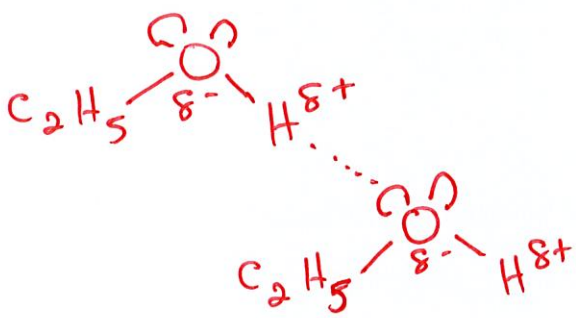
Do not write outside the box

0 8 This question is about structure and bonding.

0 8 . 1 Draw a diagram to show the strongest type of interaction between two molecules of ethanol (C_2H_5OH) in the liquid phase.

Include all lone pairs and partial charges in your diagram.

[3 marks]



M1 = 2 lone pairs each O atom and δ+ | δ- each O-H

M2 = dotted line lone pair and H atom

M3 = H····O-H straight line

0 8 . 2 Methoxymethane (CH_3OCH_3) is an isomer of ethanol.

Table 5 shows the boiling points of ethanol and methoxymethane.

Table 5

Compound	Boiling point / °C
ethanol	78
methoxymethane	–24

In terms of the intermolecular forces involved, explain the difference in boiling points.

[3 marks]

- hydrogen bonds between ethanol molecules M1
- van der Waals' or dipole-dipole forces between methoxymethane M2
- hydrogen bonds are stronger intermolecular forces M3

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Extra space ______________________________

0 8 . 3 Draw the shape of the $POCl_3$ molecule and the shape of the ClF_4^- ion.
Include any lone pairs of electrons that influence the shapes.

In a $POCl_3$ molecule the oxygen atom is attached to the phosphorus atom by a double bond that uses two electrons from phosphorus.

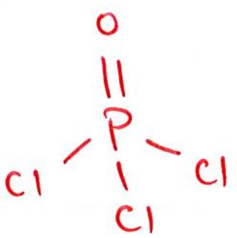
Name each shape.

Suggest a value for the bond angle in ClF_4^-

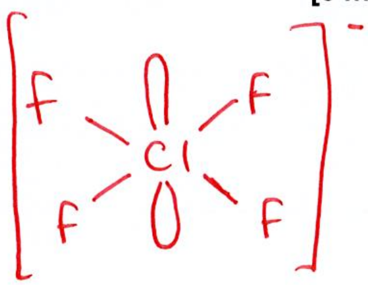
Shape of $POCl_3$ | Shape of ClF_4^-

[5 marks]

P = 5
O = 2
Cl = 3
10
5 pairs
1 double
= 4 pairs



Cl = 7
F = 4
ion = 1
12
6 pairs
4 bonding
2 non-bonding



Name of shape of $POCl_3$ tetrahedral

Name of shape of ClF_4^- square planar

Bond angle in ClF_4^- 90°

11

Turn over for the next question

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There are no questions printed on this page

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ANSWER IN THE SPACES PROVIDED

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0 9 This question is about different pH values.

0 9 . 1 For pure water at 40 °C, pH = 6.67
A student thought that the water was acidic.

Explain why the student was incorrect.

Determine the value of K_w at this temperature.

[4 marks]

Explanation Pure water $[H^+] = [OH^-]$

$kw = [H^+][OH^-] = [H^+]^2$

$[H^+] = 10^{-6.67} = 2.138 \times 10^{-7}$

$kw = (2.138 \times 10^{-7})^2$

K_w 4.57×10^{-14} $mol^2\ dm^{-6}$

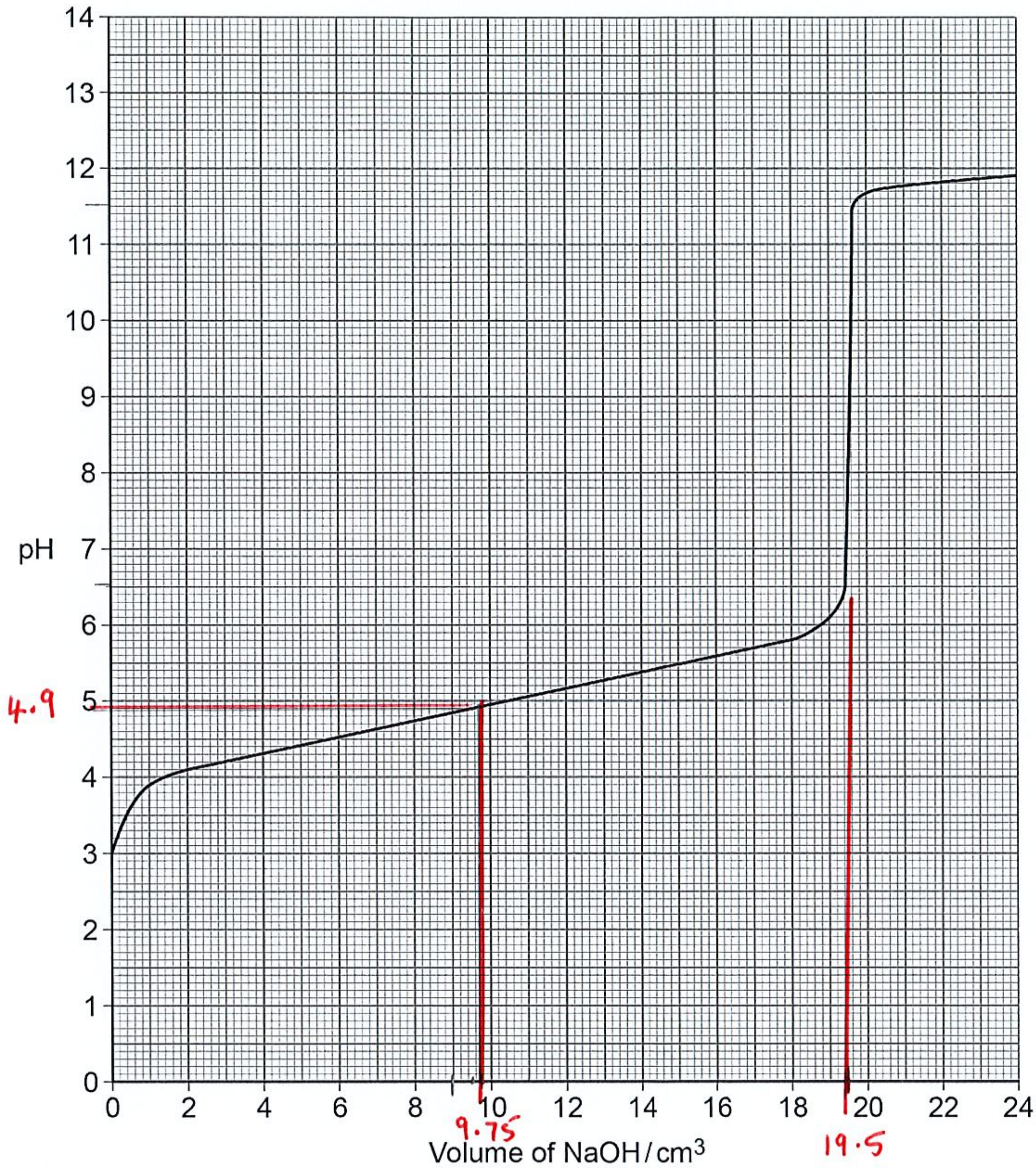
Question 9 continues on the next page

Do not write outside the box

0 9 . 2 Sodium hydroxide solution was added gradually from a burette to 25 cm^3 of 0.080 mol dm^{-3} propanoic acid at 25 °C
The pH was measured and recorded at regular intervals.

The results are shown in **Figure 4**.

Figure 4



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Use **Figure 4** to determine the value of K_a for propanoic acid at 25 °C

Show your working.

[3 marks]

pka = pH at half-equivalence

volume half-equivalence = $\frac{19.5}{2}$ = 9.75 cm^3

pH half-equivalence = 4.9 (= pka)

ka = $10^{-4.9}$

K_a 1.25×10^{-5} mol dm^{-3}

0 9 . 3 Suggest which indicator is the most appropriate for the reaction in Question **09.2**?
Tick (✓) **one** box.

[1 mark]

Indicator	**pH range**	**Tick (✓) one box**
methyl orange	3.1 – 4.4	
bromothymol blue	6.0 – 7.6	
cresolphthalein	8.2 – 9.8	✓
indigo carmine	11.6 – 13.0	

Question 9 continues on the next page

Turn over ►

Do not write outside the box

0 9 . 4 A student prepared a buffer solution by adding 0.0136 mol of a salt KX to 100 cm^3 of a 0.500 mol dm^{-3} solution of a weak acid HX and mixing thoroughly.

The student then added 3.00×10^{-4} mol of potassium hydroxide to the buffer solution.

Calculate the pH of the buffer solution after adding the potassium hydroxide.

For the weak acid HX at 25 °C the value of the acid dissociation constant, $K_a = 1.41 \times 10^{-5}$ mol dm^{-3}.

Give your answer to two decimal places.

[6 marks]

$HX \rightleftharpoons H^+ + X^-$

$k_a = \frac{[H^+][X^-]}{[HX]}$ ∴ $[H^+] = \frac{k_a [HX]}{[X^-]}$ ← weak acid ← salt

n NaOH added = 3.00×10^{-4} reacts with acid - reduces shift eqm - salt increases

n HX initially = $0.5 \times 100 \times 10^{-3} = 0.05$

n HX after = $0.05 - 3.00 \times 10^{-4} = 0.0497$

n KX after = $0.0136 + 3.00 \times 10^{-4} = 0.0139$

$[H^+] = \frac{1.41 \times 10^{-5} \times 0.0497}{0.0139} = 5.04 \times 10^{-5}$

$pH = -\log 5.04 \times 10^{-5}$

pH 4.30

Do not write outside the box

0 9 . 5 A buffer solution has a constant pH even when diluted.

Use a mathematical expression to explain this.

[1 mark]

In expression $[H^+] = Ka \frac{[HX]}{[X^-]}$

Ka is a constant

ratio $\frac{[HX]}{[X^-]}$ remains almost constant

15

END OF QUESTIONS