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<h1>Chemistry</h1> <h2>Advanced</h2> <h3>Paper 1: Advanced Inorganic and Physical Chemistry</h3>									
Tuesday 5 June 2018 – Afternoon							Paper Reference		
Time: 1 hour 45 minutes							9CH0/01		
Candidates must have: Data Booklet								Total Marks	
Scientific calculator								<input type="text"/>	

Instructions

- Use **black** ink or **black** ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided
– *there may be more space than you need.*

Information

- The total mark for this paper is 90.
- The marks for **each** question are shown in brackets
– *use this as a guide as to how much time to spend on each question.*
- For the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically showing the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Check your answers if you have time at the end.
- Show all your working in calculations and include units where appropriate.

Turn over ►

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Answer ALL questions.

Some questions must be answered with a cross in a box ☒.
If you change your mind about an answer, put a line through the box ☒
and then mark your new answer with a cross ☒.

- 1 An inorganic salt **A** contains one cation and one anion.
The results of two tests on salt **A** are shown in the table.

Test	Observation
Add aqueous sodium hydroxide to solid A . Warm the mixture. Test any gas evolved with damp red litmus paper.	A gas was evolved. The gas turned red litmus paper blue.
Add dilute nitric acid followed by aqueous silver nitrate to an aqueous solution of A .	A cream precipitate formed.

- (a) Deduce the **name** of salt **A**.

(2)

- (b) Describe additional tests, with the results, that will confirm the identity of the **anion** in the cream precipitate.

(2)

(Total for Question 1 = 4 marks)

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2 This question is about atoms, molecules and ions.

(a) Lithium exists as two isotopes.

Complete the table to show the numbers of subatomic particles in a ${}^6\text{Li}$ **atom** and a ${}^7\text{Li}^+$ **ion**.

(2)

Particle	Protons	Neutrons	Electrons
${}^6\text{Li}$			
${}^7\text{Li}^+$			

(b) The mass spectrum of a diatomic molecule, X_2 , has peaks at the following m/z values for the X_2^+ ion:

32, 33, 34, 35, 36

Deduce the formulae of all the species responsible for **each** of the peaks in the mass spectrum of X_2 , identifying element X and showing clearly the isotopes present.

(3)

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(c) Complete the table to show the maximum number of electrons which can fill each region of an atom.

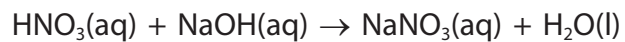
(3)

Region	Maximum number of electrons
the 1s orbital	
the 2p subshell	
the third quantum shell	

(Total for Question 2 = 8 marks)



3 Nitric acid reacts with sodium hydroxide solution in a neutralisation reaction.



In an experiment to determine the enthalpy change of neutralisation, the following results were obtained.

Volume of $1.00 \text{ mol dm}^{-3} \text{ HNO}_3 = 25.0 \text{ cm}^3$

Volume of $1.05 \text{ mol dm}^{-3} \text{ NaOH} = 25.0 \text{ cm}^3$

Temperature rise = 6.8°C

(a) Give a reason why excess sodium hydroxide was used.

(1)

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- (b) Calculate the enthalpy change of neutralisation for the reaction between nitric acid and sodium hydroxide solution, using the results of the experiment.

Give your answer to an appropriate number of significant figures.

$$\left[\begin{array}{ll} \text{Assume: density of the reaction mixture} & = 1.0 \text{ g cm}^{-3} \\ \text{specific heat capacity of the reaction mixture} & = 4.18 \text{ J g}^{-1} \text{ }^{\circ}\text{C}^{-1} \end{array} \right]$$

(4)

(Total for Question 3 = 5 marks)



4 This question is about transition metals.

(a) Which of these ions has the electronic configuration $[\text{Ar}]3d^5$?

(1)

- A Cr^{3+}
- B Fe^{2+}
- C Mn^{2+}
- D Mn^{3+}

(b) In which of these complex ions does the transition metal have the oxidation number +3?

(1)

- A $[\text{Ag}(\text{CN})_2]^-$
- B $[\text{CuCl}_4]^{2-}$
- C $[\text{Fe}(\text{CN})_6]^{3-}$
- D $[\text{Ni}(\text{EDTA})]^{2-}$

(c) Which type or types of bonding exist **within** the complex ion $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$?

(1)

- A dative covalent only
- B dative covalent and covalent only
- C dative covalent and ionic only
- D dative covalent, covalent and ionic

(d) Which **best** explains why $[\text{Cu}(\text{NH}_3)_2]^+$ ions are colourless?

(1)

- A all complex ions having a metal ion with a +1 charge are colourless
- B no electronic transitions can take place between d -orbitals
- C the d -orbitals cannot split in energy
- D there are no electrons in the d -subshell

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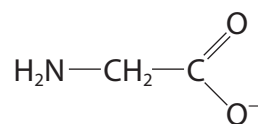
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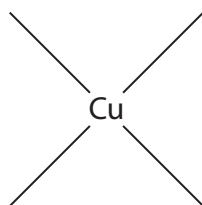


(e) Glycinate ions are bidentate ligands and can be represented by the structure

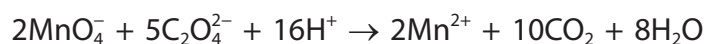


Complete the diagram below to show the structure of the $[\text{Cu}(\text{NH}_2\text{CH}_2\text{COO})_2]$ complex, which is square planar.

(2)



(f) Manganate(VII) ions, MnO_4^- , react with ethanedioate ions in acid solution.



The reaction starts slowly, the rate of reaction then increases, before it decreases again. Explain this sequence.

(3)

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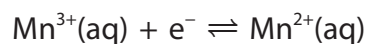
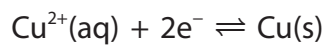
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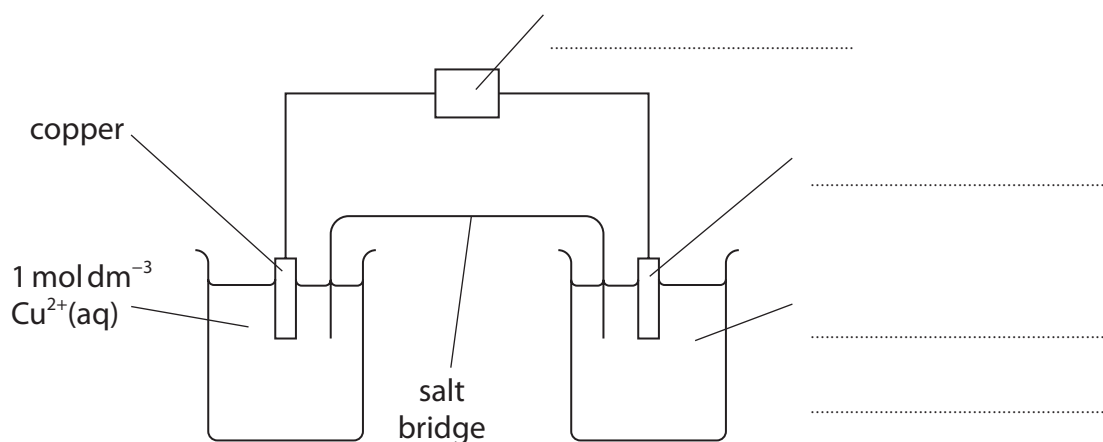
(Total for Question 4 = 9 marks)



- 5 An electrochemical cell is made from the electrode systems represented by these half-equations.



The $E_{\text{cell}}^{\ominus}$ value is measured using the apparatus shown.



- (a) Complete the diagram by adding labels on the dotted lines provided. (3)
- (b) A salt bridge is used to connect the two half-cells.
- (i) State what chemical is contained in the salt bridge. (1)
- (ii) Give a possible reason why the salt bridge cannot be replaced by an unreactive metal wire. (1)

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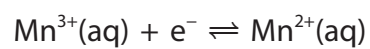
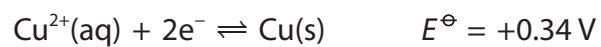
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(c) In this cell, the copper is oxidised and $E_{\text{cell}}^{\ominus} = +1.15\text{V}$.



- (i) Write the overall ionic equation for the reaction taking place.
State symbols are not required.

(1)

- (ii) Calculate the value of the standard electrode potential for the
 $\text{Mn}^{3+}(\text{aq}) \mid \text{Mn}^{2+}(\text{aq})$ half-cell.

(1)

(Total for Question 5 = 7 marks)



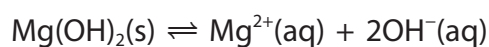
6 This question is about the solubility of metal hydroxides.

(a) Which of these metal hydroxides is the most soluble in water?

(1)

- A barium hydroxide
- B calcium hydroxide
- C magnesium hydroxide
- D potassium hydroxide

(b) When excess magnesium hydroxide is added to water and shaken, a saturated solution is formed and the mixture reaches equilibrium.



The equilibrium constant, K_c , for this reaction is

$$K_c = [\text{Mg}^{2+}(\text{aq})][\text{OH}^{-}(\text{aq})]^2$$

(i) Give a reason why the magnesium hydroxide is not included in the expression for K_c .

(1)

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(ii) Give the units for K_c .

(1)

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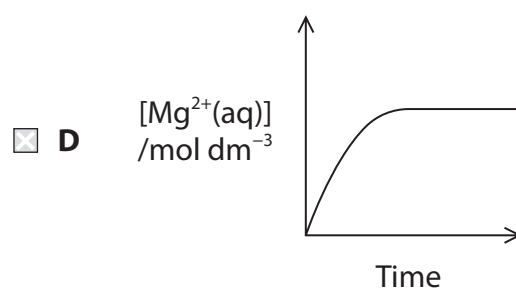
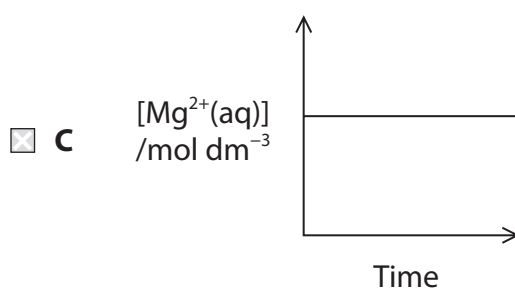
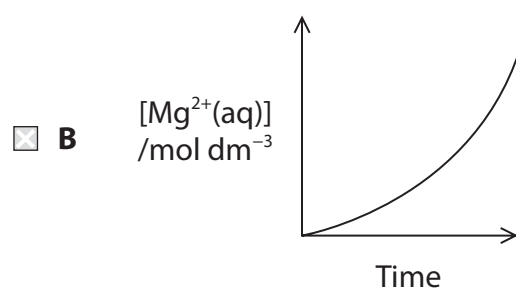
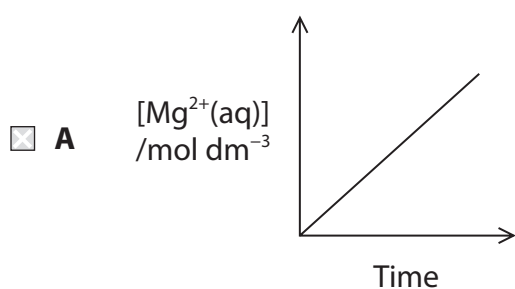
(iii) Calculate the enthalpy change of solution of magnesium hydroxide, using the following data.

Energy or enthalpy change	Value / kJ mol^{-1}
Lattice energy of $\text{Mg}(\text{OH})_2(\text{s})$	-2842
$\Delta_{\text{hyd}}H (\text{Mg}^{2+}(\text{aq}))$	-1920
$\Delta_{\text{hyd}}H (\text{OH}^{-}(\text{aq}))$	-460

(2)

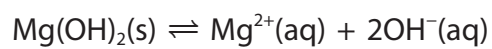
(iv) Which graph shows the change in the concentration of the $\text{Mg}^{2+}(\text{aq})$ ions when some solid magnesium hydroxide is shaken with water and left to reach equilibrium?

(1)



P 5 2 3 0 2 R A 0 1 1 2 8

- (v) Predict the effect, if any, of adding each of the following to a saturated solution of magnesium hydroxide in contact with solid magnesium hydroxide. Justify your answers in terms of the effect on the equilibrium.



(4)

Magnesium sulfate solution

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Dilute hydrochloric acid

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(Total for Question 6 = 10 marks)

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7 Boric acid, H_3BO_3 , is a weak acid with antiseptic properties.

(a) Boric acid can be prepared by reacting borax, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$, with hydrochloric acid.

Write the equation for this reaction. State symbols are not required.

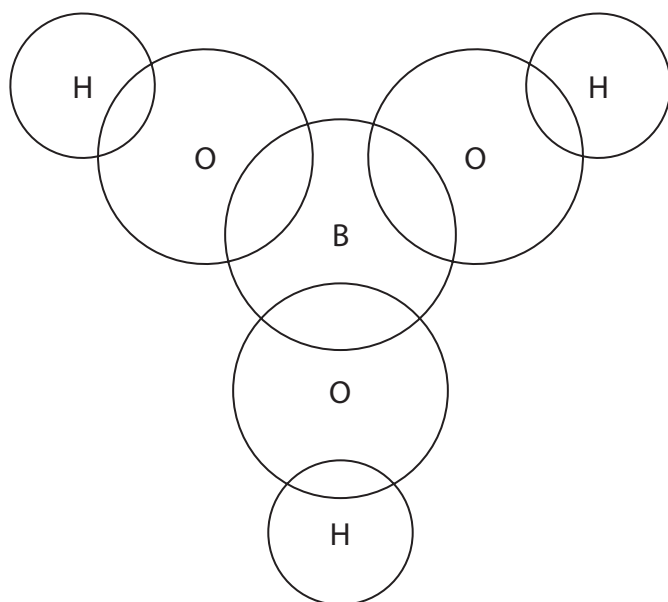
(1)

(b) The formula of boric acid can also be written as $\text{B}(\text{OH})_3$.

(i) Complete the dot-and-cross diagram of a molecule of boric acid. Show the outer shell electrons only.

Use dots (•) for the hydrogen electrons, crosses (×) for the oxygen electrons and triangles (Δ) for the boron electrons.

(2)



(ii) What are the O—B—O and B—O—H bond angles in a molecule of boric acid?

(1)

	O—B—O bond angle	B—O—H bond angle
<input type="checkbox"/> A	109.5°	104.5°
<input type="checkbox"/> B	109.5°	180°
<input type="checkbox"/> C	120°	104.5°
<input type="checkbox"/> D	120°	180°



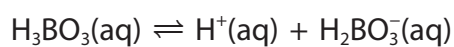
(c) Boric acid is a solid with melting temperature 171 °C.

What are the strongest interactions between the molecules in solid boric acid?

(1)

- A covalent bonds
- B hydrogen bonds
- C ionic bonds
- D London forces

(d) In aqueous solution, boric acid dissociates into ions in three stages.
The equation for the first dissociation is



pK_a for this dissociation is 9.24

(i) Calculate the pH of a $0.0500 \text{ mol dm}^{-3}$ solution of boric acid from the pK_a value for the first dissociation.

(3)

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(ii) State any assumptions you made in your calculation in (d)(i).

(2)

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(e) Boric acid can undergo further dissociation.

Which is the conjugate acid of the HBO_3^{2-} ion?

(1)

- A BO_3^{3-}
- B H_2BO_3^-
- C H_3BO_3
- D H_3O^+

(Total for Question 7 = 11 marks)



8 This question is about ions and ionic compounds.

(a) The first three ionisation energies of calcium are shown in the table.

	First ionisation	Second ionisation	Third ionisation
Ionisation energy / kJ mol^{-1}	590	1145	4912
Orbital			

(i) Complete the table by identifying the specific orbital from which each electron is removed. (2)

(ii) Write the equation for the **third** ionisation energy of calcium. Include state symbols. (1)

(iii) Explain why the difference between the second and third ionisation energies of calcium is much larger than the difference between the first and second ionisation energies. (2)

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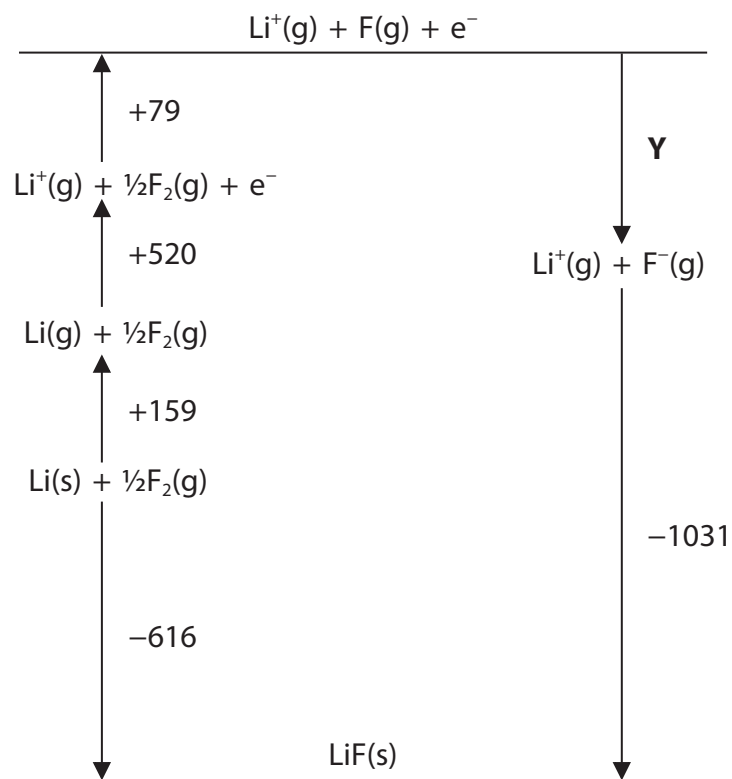
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(b) The diagram, which is not drawn to scale, shows the Born-Haber cycle for lithium fluoride. The energy changes are given in kJ mol^{-1} .



What is the value for **Y**, in kJ mol^{-1} ?

(1)

- A** -273
- B** -343
- C** -432
- D** -889



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Handwriting practice area with 20 horizontal dotted lines.

(Total for Question 8 = 12 marks)



9 This question is about entropy and free energy.

(a) Complete the table by giving the sign of the entropy change of the system, ΔS_{system} , for each reaction. (2)

Reaction	Sign of ΔS_{system}
$\text{CO}_2(\text{s}) \rightarrow \text{CO}_2(\text{g})$	
$\text{NaCl}(\text{s}) + \text{aq} \rightarrow \text{NaCl}(\text{aq})$	
$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$	

(b) Calculate the total entropy change, ΔS_{total} , for the thermal decomposition of calcium carbonate at 298 K.



[Data: $\Delta_r H = +178 \text{ kJ mol}^{-1}$ $\Delta S_{\text{system}} = +160 \text{ JK}^{-1} \text{ mol}^{-1}$]

(3)

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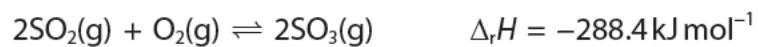
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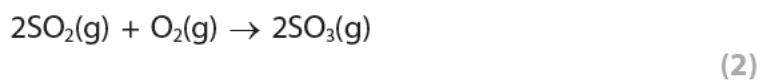
(c) Sulfur dioxide reacts with oxygen to form sulfur trioxide.



The standard molar entropy values at 298 K are given in the table.

	$\text{SO}_2(\text{g})$	$\text{O}_2(\text{g})$	$\text{SO}_3(\text{g})$
$S^\ominus / \text{JK}^{-1} \text{mol}^{-1}$	+248.1	+205.0	+95.6

- (i) Calculate the entropy change of the system, ΔS_{system} , for the forward reaction. Include a sign and units in your answer.



- (ii) Calculate the free energy change, ΔG , at 298 K and hence deduce whether the reaction is feasible.

(3)

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(iii) In industry, the reaction is carried out at about 700 K using a vanadium(V) oxide catalyst.

Calculate the value of the equilibrium constant, K , at 700 K.

ΔG at 700 K is -60 kJ mol^{-1}

(3)

(iv) The equilibrium constant has a larger value at 298 K than at 700 K. Explain why the reaction is carried out at 700 K and not at 298 K.

(2)

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(Total for Question 9 = 15 marks)

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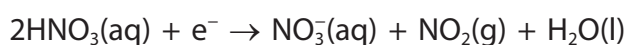
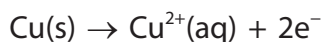
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10 Yellow gold is used to make jewellery. It is an alloy of copper, gold and silver. The purity of gold is measured in carats. The higher the carat, the higher the percentage of gold in the alloy. Pure gold is 24 carat.

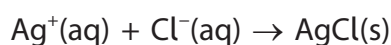
A sample of yellow gold is analysed using the steps below.

Step 1 Excess concentrated nitric acid is reacted with 1.250 g of the alloy. The gold does **not** react but the copper and silver do react. The half-equations are



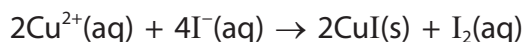
Step 2 The mixture is diluted with distilled water and the gold is filtered off.

Step 3 Excess hydrochloric acid is added to the filtrate. It reacts with the silver ions to form a precipitate of silver chloride.

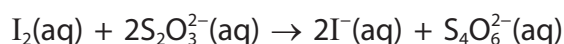


Step 4 The silver chloride precipitate is filtered off, washed, dried and weighed. The mass of silver chloride formed is 0.706 g.

Step 5 Excess potassium iodide is added to the remaining solution. A precipitate of copper(I) iodide and a solution of iodine forms.



Step 6 The resulting mixture is titrated with $0.100 \text{ mol dm}^{-3}$ sodium thiosulfate solution.



The titre is 39.40 cm^3 .

(a) Write the equation for the reaction of copper with concentrated nitric acid, using the half-equations given in Step 1. State symbols are not required.

(1)

(b) State the indicator used and its colour change at the end-point in the titration in Step 6.

(2)

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(c) The table shows the percentage by mass of gold in four different carats of yellow gold.

Carat	Percentage by mass of gold
9	37.5
10	41.7
14	58.3
18	75.0

Determine, using the experimental data, the carat of the sample of yellow gold that was analysed.

(6)

(Total for Question 10 = 9 marks)

TOTAL FOR PAPER = 90 MARKS



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