

Paper Reference(s) 9CH0/01

Pearson Edexcel Level 3 GCE

Chemistry

Advanced

Paper 1: Advanced Inorganic and Physical Chemistry

Tuesday 13 June 2017 – Afternoon

Time: 1 hour 45 minutes plus your additional time allowance

INSTRUCTIONS TO CANDIDATES

Write your centre number, candidate number, surname, other names and your signature in the boxes below. Check that you have the correct question paper.

Centre No.					
Candidate No.					
Surname					
Other names					
Signature					
Paper Reference	9	C	H	0	/ 0 1



- Use **BLACK** ink or **BLACK** ball-point pen.
- Answer **ALL** questions.
- Answer the questions in the spaces provided – there may be more space than you need.

MATERIALS REQUIRED FOR EXAMINATION

Data Booklet, Scientific calculator, ruler

ITEMS INCLUDED WITH QUESTION PAPERS

Periodic table

INFORMATION FOR CANDIDATES

- 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.
- You may use a scientific calculator.
- For questions 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.

ADVICE TO CANDIDATES

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

(Turn over)

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 A phosphorus atom has mass number 31.

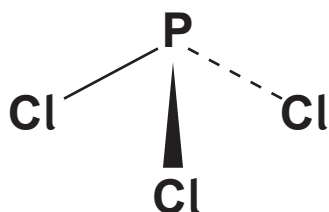
(a) How many of each sub-atomic particle are present in the phosphide ion, P^{3-} ? (1 mark)

	Number of protons	Number of neutrons	Number of electrons
<input type="checkbox"/> A	15	16	12
<input type="checkbox"/> B	15	16	18
<input type="checkbox"/> C	16	15	12
<input type="checkbox"/> D	16	15	18

(Question continues on next page)

(Turn over)

- (b) Phosphorus(III) chloride molecules are pyramidal with a bond angle less than 109.5° .



- (i) Explain why a phosphorus(III) chloride molecule has this shape and bond angle.
(2 marks)

(Question continues on next page)

(Turn over)

(ii) Which describes the polarity of the P—Cl bond and the polarity of the phosphorus(III) chloride molecule? (1 mark)

	Polarity of P—Cl bond	Polarity of molecule
<input type="checkbox"/> A	non-polar	non-polar
<input type="checkbox"/> B	non-polar	polar
<input type="checkbox"/> C	polar	non-polar
<input type="checkbox"/> D	polar	polar

(Question continues on next page)

- (c) Phosphorus has one naturally occurring isotope with mass number 31. Chlorine exists as two isotopes with mass numbers 35 and 37.

Give the formulae and mass/charge ratio of the ions responsible for the molecular ion peaks in the mass spectrum of phosphorus(III) chloride, PCl_3 .
(2 marks)

(TOTAL FOR QUESTION 1 = 6 MARKS)

(Questions continue on next page)

(Turn over)

- 2 Magnesium nitrate decomposes on heating as shown by the equation.



- (a) Explain, in terms of all the relevant oxidation numbers, why this is a redox reaction. (3 marks)

(Question continues on next page)

(Turn over)

- (b) Calcium nitrate decomposes in a similar way to magnesium nitrate, but requires a higher temperature for decomposition.

Explain this observation in terms of the charge and size of the cations. (3 marks)

(Continue your answer on next page)

(Turn over)

(TOTAL FOR QUESTION 2 = 6 MARKS)

(Questions continue on next page)

(Turn over)

3 This question is about halogens and redox reactions.

(a) The boiling temperatures of three halogens are shown in the table.

HALOGEN	BOILING TEMPERATURE / °C
chlorine	–35
bromine	59
iodine	184

Explain why the boiling temperatures increase from chlorine to iodine. (2 marks)

(Question continues on next page)

(Turn over)

(b) Potassium halides react with concentrated sulfuric acid to form potassium hydrogensulfate and the different products shown in the table.

POTASSIUM HALIDE	PRODUCTS
potassium chloride	hydrogen chloride
potassium bromide	hydrogen bromide, bromine and sulfur dioxide
potassium iodide	hydrogen iodide, iodine, hydrogen sulfide and sulfur

By referring to any changes in oxidation numbers when these halides react with concentrated sulfuric acid, explain which halide is the strongest reducing agent. (3 marks)

(Continue your answer on next page)

(Turn over)

(Question continues on next page)

(Turn over)

(c) Use these electrode potentials to answer the following questions.

ELECTRODE REACTION	E^{\ominus} / V
$\text{I}_2(\text{aq}) + 2\text{e}^{-} \rightleftharpoons 2\text{I}^{-}(\text{aq})$	+0.54
$\text{Fe}^{3+}(\text{aq}) + \text{e}^{-} \rightleftharpoons \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Br}_2(\text{aq}) + 2\text{e}^{-} \rightleftharpoons 2\text{Br}^{-}(\text{aq})$	+1.09
$\text{MnO}_2(\text{s}) + 4\text{H}^{+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Cl}_2(\text{aq}) + 2\text{e}^{-} \rightleftharpoons 2\text{Cl}^{-}(\text{aq})$	+1.36
$\text{MnO}_4^{-}(\text{aq}) + 8\text{H}^{+}(\text{aq}) + 5\text{e}^{-} \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51

(Question continues on next page)

(Turn over)

(i) Which species will oxidise $\text{Fe}^{2+}(\text{aq})$ to $\text{Fe}^{3+}(\text{aq})$? (1 mark)

☐ A $\text{Br}_2(\text{aq})$

☐ B $\text{Cl}^{-}(\text{aq})$

☐ C $\text{I}_2(\text{aq})$

☐ D $\text{Mn}^{2+}(\text{aq})$

(Question continues on next page)

- (ii) Write the ionic equation and calculate the $E_{\text{cell}}^{\ominus}$ value for the reaction between MnO_4^- ions and Br^- ions in acidic solution.
State symbols are not required. (3 marks)

(TOTAL FOR QUESTION 3 = 9 MARKS)

(Questions continue on next page)

(Turn over)

4 Iron and zinc are in the d-block of the Periodic Table.

(a) Which of these is the electronic configuration of an iron(II) ion, Fe^{2+} ? (1 mark)

	3d	4s						
<input type="checkbox"/> A [Ar]	<table><tr><td>↑↓</td><td>↑↓</td><td>↑↓</td><td></td><td></td></tr></table>	↑↓	↑↓	↑↓			<table><tr><td></td></tr></table>	
↑↓	↑↓	↑↓						
<input type="checkbox"/> B [Ar]	<table><tr><td>↑↓</td><td>↑</td><td>↑</td><td>↑</td><td>↑</td></tr></table>	↑↓	↑	↑	↑	↑	<table><tr><td></td></tr></table>	
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↑	↑	↑	↑					
↑↓								

(Question continues on next page)

- (b) Iron(II) ions, $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$, form a pale green solution but zinc ions, $[\text{Zn}(\text{H}_2\text{O})_6]^{2+}$, form a colourless solution.

Explain why zinc ions are colourless. (2 marks)

(Question continues on next page)

- (c) Hydrated iron(II) ions react with ethanedioate ions, $\text{C}_2\text{O}_4^{2-}$, to form a complex ion.



- (i) Draw a structure of the $[\text{Fe}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^{2-}$ ion, showing ALL of the bonds. (2 marks)

(Question continues on next page)

- (ii) Explain, in terms of entropy, why this reaction is feasible. (2 marks)

(Question continues on next page)

(d) Iodide ions, I^- , react with peroxodisulfate(VI) ions, $\text{S}_2\text{O}_8^{2-}$



This reaction is catalysed by iron(II) ions, $\text{Fe}^{2+}(\text{aq})$.

Write TWO ionic equations to show how iron(II) ions act as a catalyst in this reaction.
State symbols are not required. (2 marks)

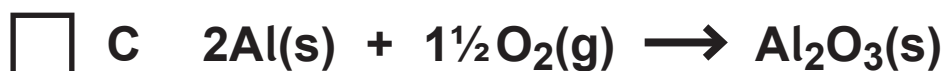
(TOTAL FOR QUESTION 4 = 9 MARKS)

(Questions continue on next page)

(Turn over)

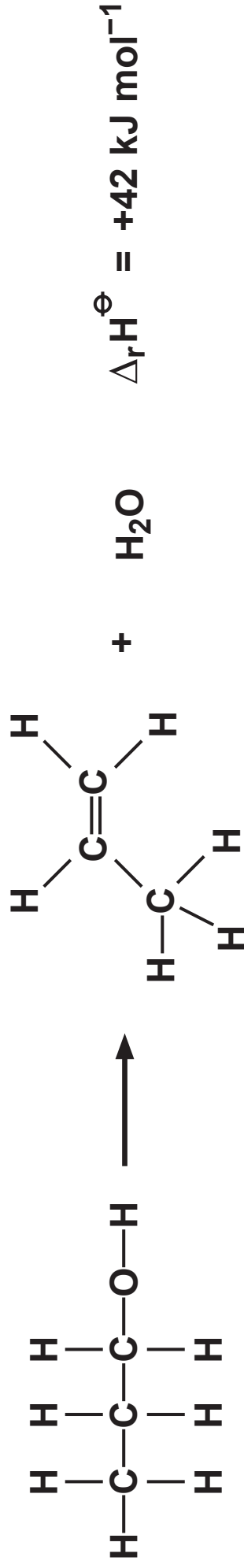
5 This question is about enthalpy changes and entropy changes.

(a) Which is the equation for the standard enthalpy change of formation, $\Delta_f H^\ominus$, of aluminium oxide?
(1 mark)



(Question continues on next page)

(b) Propan-1-ol is dehydrated to form propene.



The relevant mean bond enthalpies are given in the table.

Bond	Mean bond enthalpy / kJ mol^{-1}
C—C	347
C=C	612
C—H	413
O—H	464

(Question continues on next page)

(Turn over)

Calculate the C—O mean bond enthalpy, using the mean bond enthalpies given in the table and the enthalpy change of reaction. (3 marks)

(Question continues on next page)

(c) Which reaction has a negative value for ΔS_{system} ? (1 mark)



(Question continues on next page)

(d) What is the expression for ΔS_{total} ? (1 mark)

☐ A $\Delta S_{\text{surroundings}} + \frac{\Delta H}{T}$

☐ B $\Delta S_{\text{surroundings}} - \frac{\Delta H}{T}$

☐ C $\Delta S_{\text{system}} + \frac{\Delta H}{T}$

☐ D $\Delta S_{\text{system}} - \frac{\Delta H}{T}$

(e) Calcium carbonate decomposes on heating.



$$\Delta_r H = +178 \text{ kJ mol}^{-1}$$

$$\Delta S_{\text{system}} = +165 \text{ J mol}^{-1} \text{ K}^{-1}$$

Show, by calculating the value for the free energy change, ΔG , that this decomposition is not feasible at 298 K, and then calculate the minimum temperature to which calcium carbonate must be heated to make it decompose. (3 marks)

(Answer on next page)

(Turn over)

(TOTAL FOR QUESTION 5 = 9 MARKS)

(Questions continue on next page)

(Turn over)

6 Magnesium bromide, MgBr_2 , is an ionic compound.

(a) (i) Draw a dot-and-cross diagram to show the bonding in magnesium bromide. Only outer shell electrons are required. (1 mark)

(ii) State all the conditions under which magnesium bromide conducts electricity. (1 mark)

(Question continues on next page)

(Turn over)

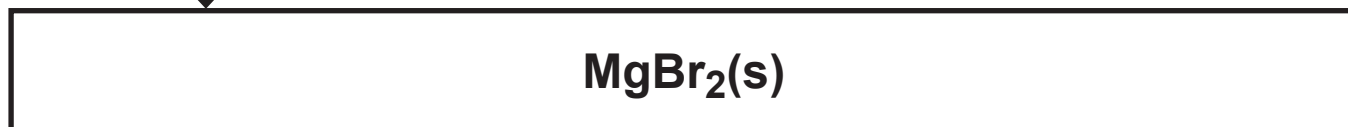
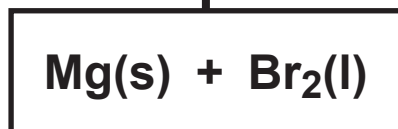
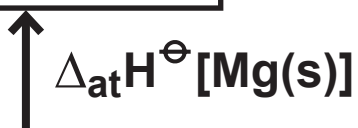
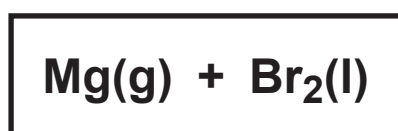
(b) The table shows the enthalpy changes needed to calculate the first electron affinity of bromine.

Enthalpy change	Value / kJ mol^{-1}
enthalpy change of atomisation of magnesium, $\Delta_{\text{at}}H^{\ominus}[\text{Mg(s)}]$	+148
1 st ionisation energy of magnesium, 1 st IE[Mg(g)]	+738
2 nd ionisation energy of magnesium, 2 nd IE[Mg ⁺ (g)]	+1 451
enthalpy change of atomisation of bromine, $\Delta_{\text{at}}H^{\ominus}[\frac{1}{2}\text{Br}_2(\text{l})]$	+112
lattice energy of magnesium bromide, LE[MgBr ₂ (s)]	−2 440
enthalpy change of formation of magnesium bromide, $\Delta_{\text{f}}H^{\ominus}[\text{MgBr}_2(\text{s})]$	−524

- (i) On page 29 complete the Born-Haber cycle for magnesium bromide with formulae, electrons and labelled arrows. The cycle is not drawn to scale. (3 marks)

(Question continues on next page)

(Turn over)



(Question continues on next page)

(Turn over)

- (ii) Calculate the first electron affinity of bromine, in kJ mol^{-1} . (2 marks)

(Question continues on next page)

(Turn over)

- (c) (i) The first ionisation energy of sodium is 496 kJ mol^{-1} .**

Explain why the first ionisation energy of magnesium is higher than that of sodium. (3 marks)

[illegible]

- (ii) Write the equation, including state symbols, to show the THIRD ionisation energy of magnesium. (1 mark)

(TOTAL FOR QUESTION 6 = 11 MARKS)

(Questions continue on next page)

7 In acid-base neutralisation reactions, there is a temperature change.

(a) The enthalpy change when hydrochloric acid reacts with aqueous ammonia is $-53.4 \text{ kJ mol}^{-1}$.



Calculate the temperature change you would expect when 25.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid is mixed with 25.0 cm^3 of 1.00 mol dm^{-3} aqueous ammonia.

Give your answer to an appropriate number of significant figures. (3 marks)

[Assume: the density of the solution is 1.00 g cm^{-3}
the specific heat capacity of the solution is $4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1}$]

(Continue your answer on next page)

(Turn over)

(Question continues on next page)

(Turn over)

- *(b) The table shows the enthalpy changes of reaction when 1 mol of different acids are neutralised by sodium hydroxide solution, at 298 K.**

Acid	Enthalpy change of reaction for 1 mol of acid / kJ mol^{-1}
hydrochloric acid, HCl	-58
nitric acid, HNO_3	-58
sulfuric acid, H_2SO_4	-115
ethanoic acid, CH_3COOH	-56

Comment on the relative enthalpy changes of reaction, using the data from the table and including any relevant equations. (6 marks)

(Continue your answer on next page)

(Turn over)

(Turn over)

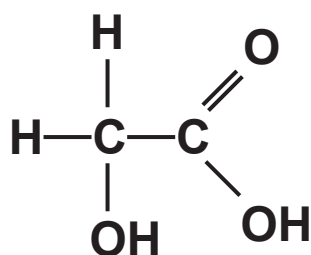
(TOTAL FOR QUESTION 7 = 9 MARKS)

(Questions continue on next page)

- 8 2-Hydroxyethanoic acid, also known as glycolic acid, CH_2OHCOOH , is an alpha hydroxy acid used in some skincare products.

It has a K_a value of $1.5 \times 10^{-4} \text{ mol dm}^{-3}$.

The structure of glycolic acid is



- (a) A solution of glycolic acid of concentration 0.1 mol dm^{-3} has a pH of 2.4

What is the approximate pH of the resulting solution after it has been diluted by a factor of 100? (1 mark)

☐ A 1.4

☐ B 2.4

☐ C 3.4

☐ D 4.4

(Question continues on next page)

(b) Another solution of glycolic acid has a pH of 2.0

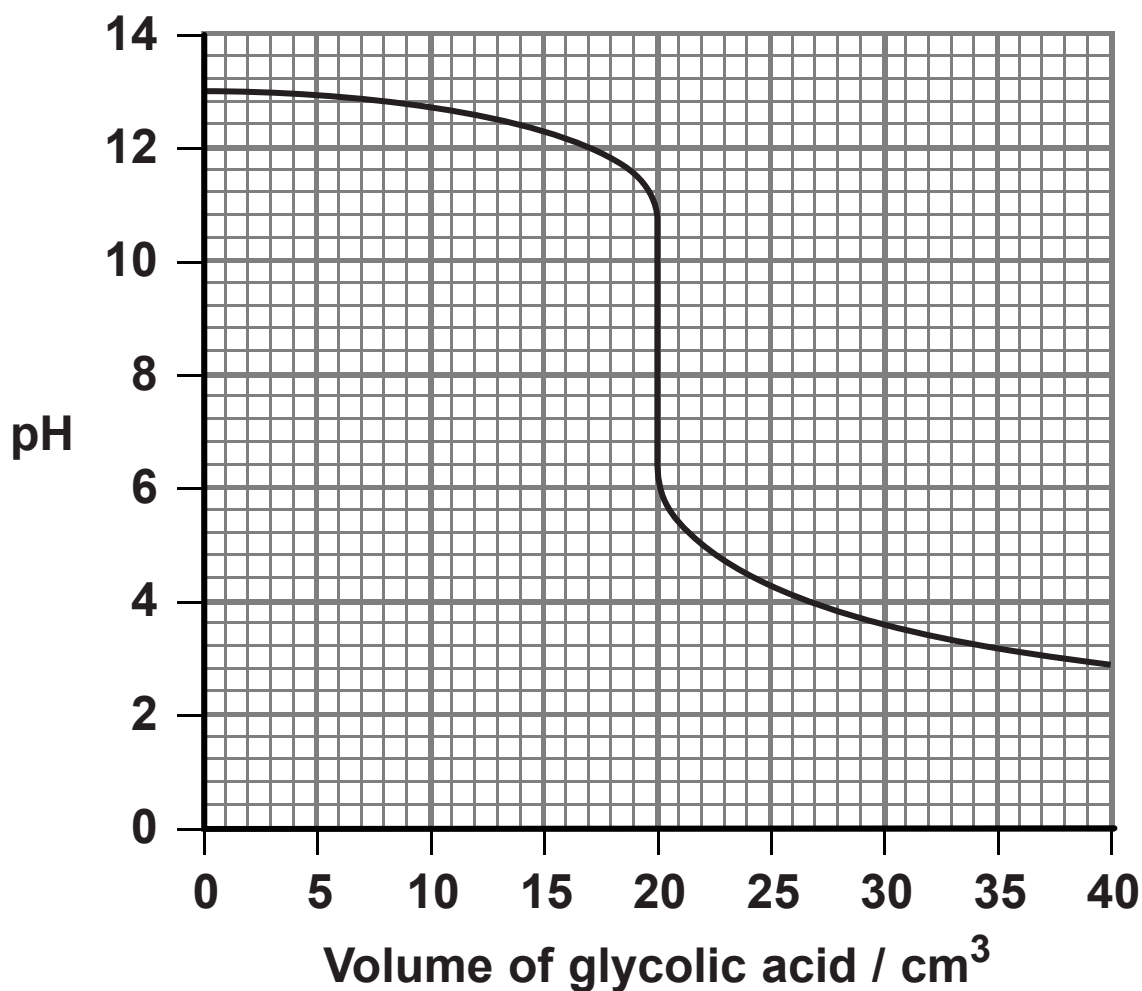
Calculate the concentration of this solution.

(3 marks)

(Question continues on next page)

(Turn over)

- (c) The titration curve for adding glycolic acid to 25.0 cm^3 of 0.100 mol dm^{-3} sodium hydroxide is shown.



(Question continues on next page)

- (i) Use the information given in your Data Booklet to select a suitable indicator for this titration, including the colour change you would expect to see.

Justify your selection. (3 marks)

(Question continues on next page)

(Turn over)

(ii) What is the concentration of this glycolic acid in mol dm^{-3} ? (1 mark)

☐ A 0.080

☐ B 0.100

☐ C 0.125

☐ D 0.250

(iii) The pH of the solution containing just sodium glycolate and water is (1 mark)

☐ A 2.8

☐ B 6.0

☐ C 8.3

☐ D 11.0

(Question continues on next page)

(Turn over)

(d) Glycolic acid has an acid dissociation constant of $1.5 \times 10^{-4} \text{ mol dm}^{-3}$ compared with a value of $1.7 \times 10^{-5} \text{ mol dm}^{-3}$ for ethanoic acid.

(i) Give a possible explanation as to why the value of K_a for glycolic acid is approximately ten times larger than that of ethanoic acid.
(2 marks)

(Question continues on next page)

(Turn over)

- (ii) Complete the equation to show the conjugate acid-base pairs that would be produced when pure samples of glycolic acid and ethanoic acid are mixed. (1 mark)



(TOTAL FOR QUESTION 8 = 12 MARKS)

(Questions continue on next page)

9 This question is about buffer solutions.

- (a) A buffer solution is formed from disodium hydrogenphosphate, containing HPO_4^{2-} ions, and sodium dihydrogenphosphate, containing H_2PO_4^- ions.**

Write the IONIC equations involving HPO_4^{2-} and H_2PO_4^- ions to show how this solution acts as a buffer solution. (2 marks)

(Question continues on next page)

- (b) Another buffer solution was formed by mixing 20.0 cm^3 of sodium hydroxide solution of concentration $0.100 \text{ mol dm}^{-3}$ with 25.0 cm^3 of ethanoic acid of concentration $0.150 \text{ mol dm}^{-3}$.



Calculate the pH of this buffer solution. (5 marks)

[K_a for ethanoic acid = $1.74 \times 10^{-5} \text{ mol dm}^{-3}$]

(TOTAL FOR QUESTION 9 = 7 MARKS)

(Questions continue on next page)

(Turn over)

10 Hydrogen is produced on a large scale by several different processes.

(a) One process for producing hydrogen involves reacting white-hot carbon with steam.



The expression for the equilibrium constant, K_p , is

$$K_p = \frac{p(\text{H}_2)p(\text{CO})}{p(\text{H}_2\text{O})}$$

(i) Give a reason why the partial pressure of carbon is not included in the expression. (1 mark)

(Question continues on next page)

(Turn over)

- (ii) Explain the effect of an increase in pressure on the equilibrium position of this reaction.
(2 marks)

(Question continues on next page)

- (iii) Explain, by reference to any change in the value of K_p , the effect of an increase in temperature on the equilibrium position of this reaction. (2 marks)

- (iv) At 1000 K and a total pressure of 2.0 atm, 1.00 mol of steam reacted with excess carbon.

At equilibrium, 0.81 mol of hydrogen was present.

Calculate the value of K_p at 1000 K, stating any units. (4 marks)

(Answer on next page)

(Turn over)

(Question continues on next page)

(Turn over)

(b) Carbon monoxide reacts with steam.



At 1100 K, $K_c = 1.00$

In an experiment, 1 mol of carbon monoxide was mixed with 1 mol of steam, 2 mol of carbon dioxide and 2 mol of hydrogen.

Deduce, with reasons, the direction in which the reaction will shift to reach equilibrium. (3 marks)

(Continue your answer on next page)

(Turn over)

(TOTAL FOR QUESTION 10 = 12 MARKS)

TOTAL FOR PAPER = 90 MARKS
END