華中國際學校 Hwa Chong INTERNATIONAL SCHOOL
A MEMBER OF THE HWA CHONG FAMILY OF SCHOOLS

PRELIMINARY EXAMINATION
International Baccalaureate 2

Chemistry
Higher level
Paper 2

Tuesday 28 August 2018 (afternoon)

2 hour 15 minutes

Candidate name	
Candidate session number	Class

Instructions to candidates

- Write your candidate name and session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **Chemistry data booklet** is required for this paper.
- The maximum mark for this examination paper is **[95 marks]**.

For Examiner's Use	
Q1	/ 15
Q2	/ 22
Q3	/ 16
Q4	/ 20
Q5	/ 8
Q6	/ 14
Total	/ 95

Answer **all** questions. Write your answers in the boxes provided.

1. (a) Gallium exists as two isotopes ^{69}Ga (65%) and ^{71}Ga (35%).

(i) Define the term *relative atomic mass*. [1]

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(ii) Calculate the relative atomic mass of gallium. [1]

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(b) Gallium reacts with nitrogen gas to form gallium nitride, GaN.

$$2Ga\ (s) + N_2\ (g) \rightarrow 2GaN\ (s) \qquad \Delta H^{\theta} = -156.8\ kJ\ mol^{-1}$$

(i) State the full electron configuration of the gallium ion in GaN. [1]

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(ii) Deduce, giving your reason, whether the sign of ΔS^{θ} for the reaction would be positive or negative. [2]

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(This question continues on the following page)

(Question 1 continued)

(iii) Outline how the spontaneity of the reaction varies with temperatures. Explain your answer. [2]

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(iv) Calculate the volume of nitrogen, at standard temperature and pressure, needed to react completely with 10.0 ± 0.2 g of gallium, and its absolute uncertainty. [3]

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(This question continues on the following page)

(Question 1 continued)

(c) 2.00 g of an impure sample of gallium oxide, Ga_2O_3, was dissolved in 200 cm^3 of 0.300 mol dm^{-3} hydrochloric acid, HCl, solution. The chemical equation for the reaction is shown below.

$$Ga_2O_3\,(s) + 6HCl\,(aq) \rightarrow 2GaCl_3\,(aq) + 3H_2O\,(l)$$

The excess hydrochloric acid requires 14.00 cm^3 of 0.100 mol dm^{-3} sodium hydroxide, NaOH, solution for complete neutralisation.

(i) Calculate the amount (in moles) of sodium hydroxide required for complete neutralisation. [1]

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(ii) Calculate the amount (in moles) of hydrochloric acid that reacted with gallium oxide. [2]

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(iii) Calculate the mass of gallium oxide present in the impure sample. [2]

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2. The table below shows some data on the oxides of elements in Period 3 of the Periodic Table.

Oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_6	SO_2
Melting point / K	1193	3125	2345	1883	297	200

(a) Predict an approximate pH value for the solutions formed by adding Na_2O and P_4O_6 separately to water. Explain your answer. [3]

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(b) With reference to structure and bonding, explain the following.

(i) The melting point of MgO is higher than Na_2O. [3]

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(This question continues on the following page)

(Question 2 continued)

(ii) The melting point of SiO_2 is higher than that of P_4O_6. [3]

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(c) (i) SO_2 exists as two resonance structures. Draw the two Lewis structures. Label clearly the formal charge of each atom in both structures. [4]

Lewis structure I	Lewis structure II

(ii) Using your answer from part (c)(i), explain briefly which is the more stable structure. [1]

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(This question continues on the following page)

(Question 2 continued)

(iii) Identify the type of hybridisation found in O of SiO_2. [1]

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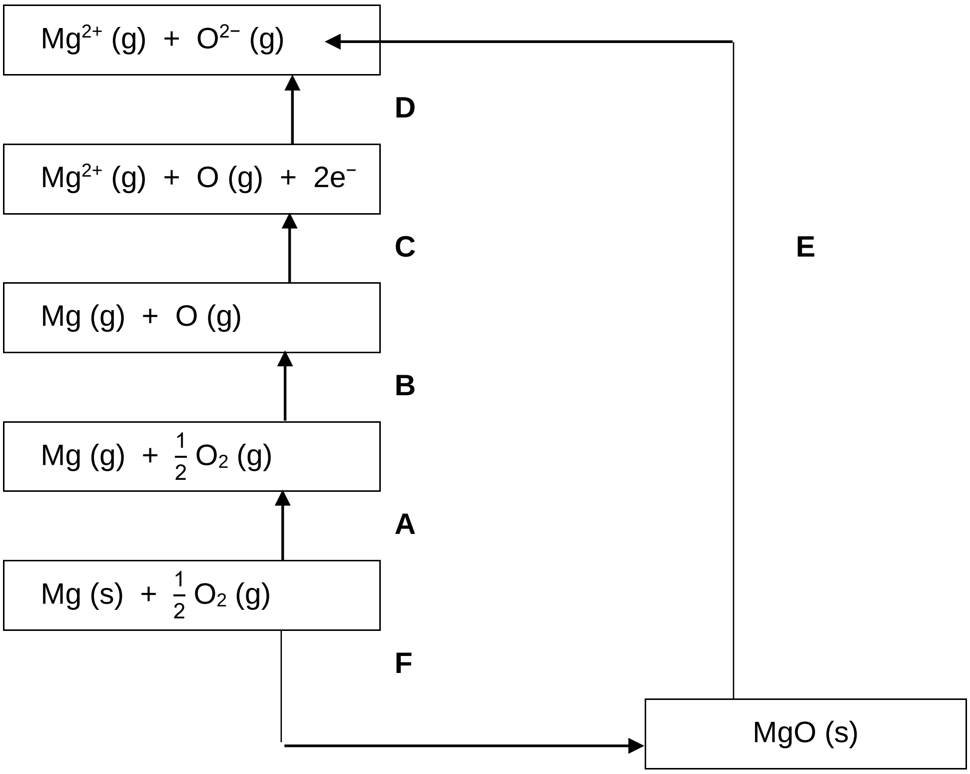
(d) The Born−Haber cycle for MgO under standard conditions is shown below.



The enthalpy change of the processes are shown in the table below.

Process	**Enthalpy change / kJ mol^{-1}**
A	+ 150
B	+ 248
C	+ 2186
D	+ 702
F	− 602

(This question continues on the following page)

(Question 2 continued)

(i) Define the enthalpy change, **F**. [1]

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(ii) Identify the processes **A** and **D** in the cycle. [2]

Process **A** :

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Process **D** :

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(iii) Determine the value of the enthalpy change for process **E**. [2]

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(This question continues on the following page)

(Question 2 continued)

(iv) Calculate a value for the second ionisation energy of Mg, using section 8 of the data booklet. Explain why the second ionisation energy is larger than the first ionisation energy. [2]

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3. (a) The equation for the decomposition of gaseous hydrogen iodide at 400 °C is shown.

$$2HI\,(g) \rightleftharpoons H_2\,(g) + I_2\,(g)$$

The values for the initial rates of decrease in hydrogen iodide concentration at various initial concentrations have been determined and shown in the table below.

Initial concentration / mol dm^{-3}	1.67	3.34	5.01	6.68
Initial rate / mol dm^{-3} s^{-1}	0.41	1.64	3.69	6.56

(i) Deduce the order of reaction with respect to hydrogen iodide. [1]

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(ii) Hence, state the rate equation for the forward reaction. [1]

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(iii) Calculate the value of the rate constant, stating its units, for the forward reaction. [2]

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(This question continues on the following page)

(Question 3 continued)

(iv) At 400 °C, the activation energy for the forward reaction is +184 kJ mol^{-1} and that for the reverse reaction is +163 kJ mol^{-1}. In the space below, sketch the reaction pathway diagram and indicate the value of enthalpy change of the forward reaction. [3]

(v) The rate of decomposition of hydrogen iodide can be increased by the addition of gold catalyst. Explain how the addition of catalyst increases the rate of decomposition. [3]

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(This question continues on the following page)

(Question 3 continued)

(b) Consider the following equilibrium reaction at 623 K.

$$2HI (g) \rightleftharpoons H_2 (g) + I_2 (g)$$

(i) State the equilibrium constant expression, K_c, for the decomposition of hydrogen iodide. [1]

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(ii) In a 2.00 dm^3 closed container at 623 K, 0.10 mol of HI was allowed to reach equilibrium. At equilibrium, 0.0564 mol of HI was present. Calculate a value for K_c. [3]

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(iii) State and explain the effect of increasing pressure on the yield of hydrogen gas. [2]

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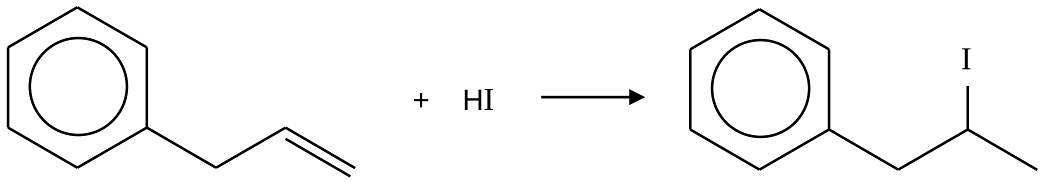
4. (a) 3−phenylpropene reacts with hydrogen iodide to form 2−iodo−1−phenylpropane as shown below.



3−phenylpropene 2−iodo−1−phenylpropane

(i) State the type of reaction between 3−phenylpropene and HI. [1]

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(ii) Deduce the mechanism for the reaction, using curly arrows to indicate the movement of electron pairs. [3]

(This question continues on the following page)

(Question 4 continued)

(iii) State the type of polymerisation which 3−phenylpropene can undergo. [1]

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(iv) Draw two repeating units of the polymer formed by 3−phenylpropene. [1]

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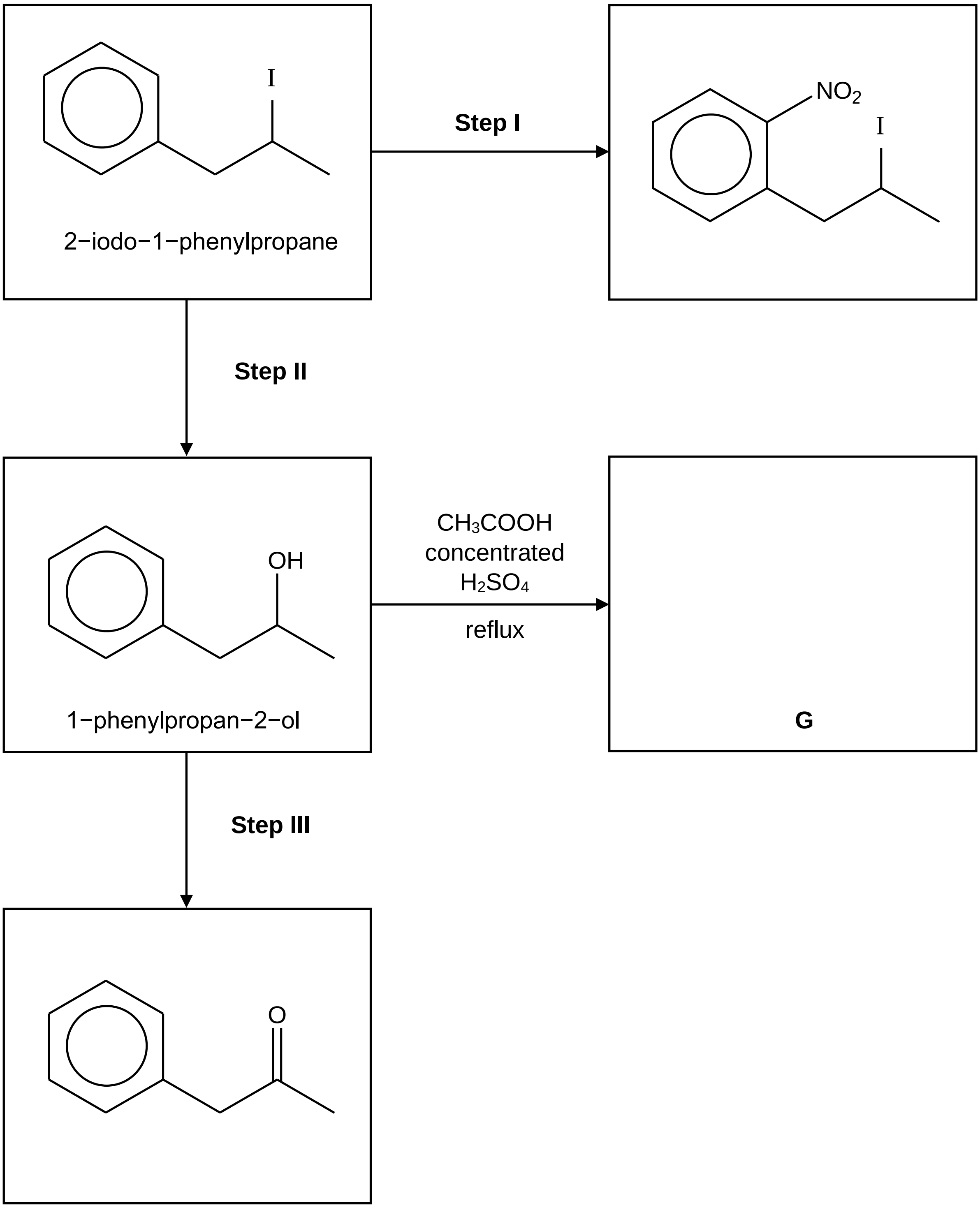
(Question 4 continued)

(b) The synthetic pathways below show reactions using 2−iodo−1−phenylpropane as a starting material.



(i) Draw the structural formula of product **G** in the box above. [1]

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(Question 4 continued)

(ii) 2−iodo−1−phenylpropane is optically active. Draw the three−dimensional shape of each enantiomer, showing their spatial relationship to each other. [2]

(iii) When one enantiomer of 2−iodo−1−phenylpropane undergoes step II, approximately 75% of the product molecules show inversion of configuration. Comment on the mechanisms that occur. [2]

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(iv) Suggest why the rate of step II of 2−iodo−1−phenylpropane is greater than that of 2−bromo−1−phenylpropane. [1]

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(This question continues on the following page)

(Question 4 continued)

(v) State the reagent(s) and condition(s) required for step I and step III. [2]

Step I :

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Step III :

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(c) Typical proton chemical shift values are given in section 27 of the data booklet. The ^{1}H NMR of 1−phenylpropan−2−ol contains 5 peaks. Some details of the peaks are shown in the table below.

Chemical shift / ppm	**Splitting**	**Integration factor**
1.2	Doublet	3
2.0	Singlet	
2.7	Doublet	
3.8	Multiplet	
7.2	Singlet	

(i) Complete the table above by suggesting the integration factors of the remaining 4 peaks. [2]

(ii) Explain the splitting pattern of the peak at chemical shift 3.8 ppm. [2]

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(Question 4 continued)

(d) The characteristic ranges for infrared absorptions are shown in section 26 of the data booklet. Identify one range in which the infrared spectra of 2−iodo−1−phenylpropane and 1−phenylpropan−2−ol would be similar and one range in which they would differ. [2]

One similarity :

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One difference :

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5. (a) "Acidity regulators" are food additives that have a buffering action on the pH of foodstuffs. Mixtures of citric acid, $C_5H_7O_5CO_2H$, and its sodium salt are often used as buffer solution for this purpose.

$$C_5H_7O_5CO_2H\ (aq) \rightleftharpoons C_5H_7O_5CO_2^-\ (aq) + H^+\ (aq)$$

(i) Write an expression for K_a for citric acid. [1]

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(ii) The concentration of citric acid in lemon juice is 0.22 mol dm^{-3}. Assuming that no other acid is present, calculate the pH of lemon juice.
K_a of citric acid = 7.4×10^{-4} mol dm^{-3}. [1]

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(iii) Explain the term *buffer solution*. [1]

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(iv) Write an equation to show how the citric acid / sodium citrate buffer system regulates the acidity on the addition of H^+ (aq) ions and OH^- (aq) ions respectively. [2]

On addition of H^+ :

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On addition of OH^- :

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(This question continues on the following page)

(Question 5 continued)

(v) Calculate the pH of a solution containing 0.10 mol dm^{-3} citric acid and 0.10 mol dm^{-3} sodium citrate. [1]

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(b) Explain why pH of water decreases with increasing temperature. [2]

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6. (a) Electrolysis of a blue, dilute solution of copper (II) chloride, $CuCl_2$, can be carried out using platinum electrodes.

(i) Write balanced half−equations, with state symbols, for the reactions occurring at the anode and cathode. [2]

Anode :

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Cathode :

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(ii) Describe two observations that occur during the electrolysis. [2]

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(iii) State one factor that affect the quantity of products produced during the electrolysis of the aqueous copper (II) chloride. [1]

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(This question continues on the following page)

(Question 6 continued)

(iv) The same process is carried out using concentrated aqueous copper (II) chloride and another product is formed at the anode. Identify the product and explain its formation. [3]

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(v) Explain why aqueous copper (II) chloride is coloured. [3]

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(This question continues on the following page)

(Question 6 continued)

(b) An iron half−cell, $Fe(s) \mid Fe^{2+}(aq)$, is connected to a copper half−cell, $Cu (s) \mid Cu^{2+} (aq)$, via a salt bridge and an external circuit.

(i) State the function of the salt bridge. [1]

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(ii) Determine the standard cell potential for the cell, using section 24 of the data booklet. [1]

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(iii) State the direction of electron flow in the external circuit. [1]

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