HWA CHONG INSTITUTION
Preliminary Examinations
Higher 1

NAME		CT GROUP	16S

CHEMISTRY 8872/01

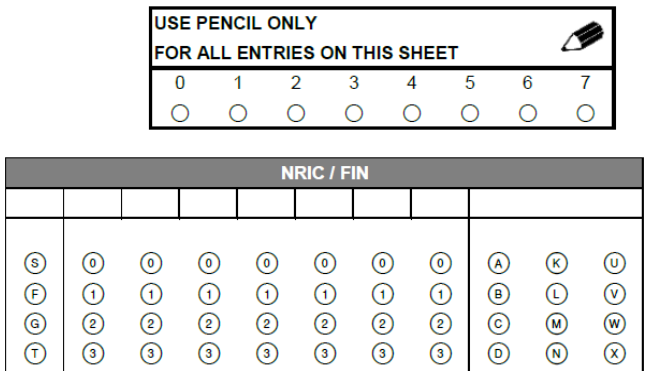
Paper 1 Multiple Choice **20 September 2017**

Additional Materials: Data Booklet **50 minutes**
Optical Mark Sheet (OMS)

INSTRUCTIONS TO CANDIDATES:

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, Centre number and index number on the Answer Sheet in the spaces provided.
Complete the information on the optical mark sheet (OMS) as shown below.

1. Enter your **NAME** (as in NRIC). _____
2. Enter the **PAPER NUMBER.** _____
3. Enter your **CT GROUP.** _____
4. Enter your **NRIC NUMBER** or **FIN Number**
5. Now **SHADE** the corresponding circles in the grid for **EACH DIGIT** or **LETTER**



There are **thirty** questions on this paper. Answer **all** questions. For each question, there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the OMS.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

Section A

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

1 *Use of the Data Booklet is relevant to this question.*

Which one of the following has the same number of particles as one mole of magnesium atoms?

A the number of ions in 2 dm^3 of 0.25 mol dm^{-3} of aqueous hydrochloric acid

B the number of delocalised electrons in one mol of copper metal

C the number of atoms in 71 g of chlorine gas

D the number of ions in 58.5 g of sodium chloride

2 What mass of carbon dioxide will be formed by the complete combustion of 4.00 g of butan-1-ol?

A 2.38 g **B** 3.03 g **C** 9.51 g **D** 12.1 g

3 The percentage by mass of water in a hydrated manganese(II) chloride salt is 36.4%.

What is the empirical formula of the hydrated salt?

A $MnCl_2.2H_2O$

B $MnCl_2.3H_2O$

C $MnCl_2.4H_2O$

D $MnCl_2.5H_2O$

4 Which of the following has the same electronic configuration as the chloride ion, Cl^-?

A Ca^{2+} **B** Na^+ **C** Ne **D** F^-

5 In which of the following reactions is the underlined element being reduced?

A $\underline{N}H_3 + HCl \rightarrow \underline{N}H_4Cl$

B $H_2\underline{O}_2 + 2I^- + 2H^+ \rightarrow 2H_2\underline{O} + I_2$

C $2\underline{V}^{3+} + H_2O_2 \rightarrow 2\underline{V}O^{2+} + 2H^+$

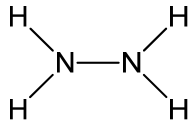
D $Ca\underline{C}O_3 \rightarrow CaO + \underline{C}O_2$

6 When heated, solid iodine forms iodine vapour.

What does this information suggest about the nature of the particles in these two physical states of iodine?

	solid	vapour
A	ionic	atomic
B	ionic	molecular
C	molecular	atomic
D	molecular	molecular

7 Hydrazine, N_2H_4, is useful as a rocket fuel. It has some properties that are similar to those of ammonia, NH_3.



hydrazine

Why are hydrazine molecules more soluble in water than ammonia molecules?

A There are more van der Waals' forces between hydrazine and water than between ammonia and water.

B There are more hydrogen bonds between hydrazine and water than between ammonia and water.

C There are stronger permanent dipole interactions between hydrazine and water than between ammonia and water.

D The covalent bonding in hydrazine is stronger than that in water.

8 Which of the equations correctly define the standard enthalpy change of formation of a compound?

A $2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow C_2H_5OH(l)$

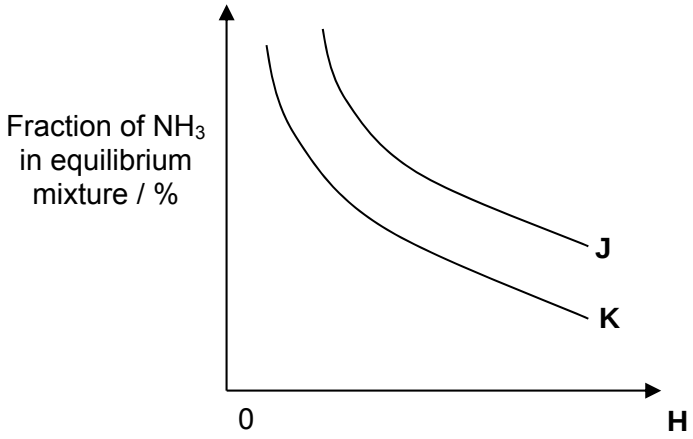
B $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$

C $Na(s) + Cl(g) \longrightarrow NaCl(s)$

D $C(g) + 2O(g) \longrightarrow CO_2(g)$

9 The graph below shows the fraction of ammonia in the equilibrium mixture obtainable if equilibrium was established under different temperature and pressure conditions during the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H < 0$$



What do **H**, **J** and **K** represent and what is the relative magnitude of **J** and **K**?

	H	**J** and **K**	relative magnitude
A	pressure	temperature	**J** > **K**
B	pressure	temperature	**K** > **J**
C	temperature	pressure	**J** > **K**
D	temperature	pressure	**K** > **J**

10 The table shows some data on two acid-base indicators.

indicator	approximate pH range of colour change	colour change	
		acid	alkali
thymolphthalein	9 – 10	colourless	blue
chlorophenol red	6 – 7	yellow	red

Which conclusion can be drawn about a solution in which thymolphthalein is colourless and chlorophenol red is red?

A It is weakly acidic.

B It is weakly alkaline.

C It is neutral.

D It is strongly alkaline.

11 10 cm^3 of 0.01 mol dm^{-3} solution of H_2SO_4 is diluted with 90 cm^3 of water.

What is the pH of the resulting solution?

A 1.7 **B** 2.0 **C** 2.7 **D** 3.0

12 An enzyme required in laboratory process operates at maximum efficiency when placed in an aqueous solution buffered at pH 5.6.

Which combination of substances when dissolved in water would give the appropriate buffer solution?

A 0.5 mol of HC*l* and 1 mol of CH_3COONa

B 0.5 mol of HC*l* and 1 mol of CH_3COOH

C 1 mol of CH_3COOH and 1 mol of NaOH

D 1 mol of CH_3COONH_4

13 Which statement about the order of reaction is correct?

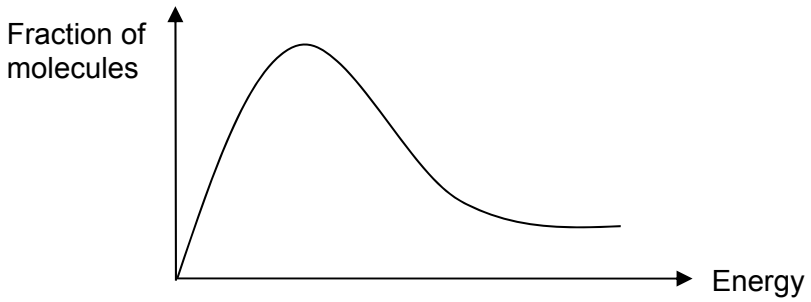
A It is the sum of the powers of the concentrations of the species included in the rate equation.

B It is the sum of the powers of the concentrations of the reactants and products.

C It is the sum of the number of species included in the rate equation.

D It is the sum of the number of moles on the left-hand side of the balanced chemical equation.

14 The diagram represents the Boltzmann distribution of molecular energies at a given temperature.



Which of the following statements is **incorrect**?

A The total number of molecules is constant at all temperatures.

B When temperature decreases, the maximum of the curve is displaced to the left.

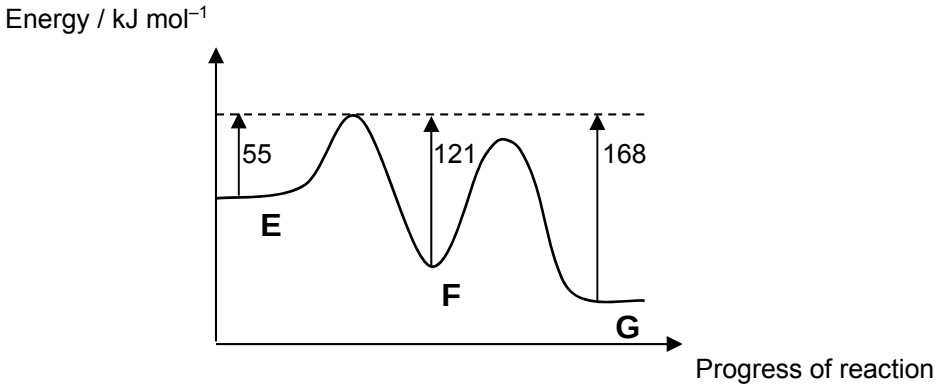
C When temperature increases, the fraction of molecules with any given energy also increases.

D When temperature increases, the fraction of molecules with energies greater than the activation energy increases.

15 The reaction pathway diagram for a two–step reaction is shown below.

Step 1: **E** ⇌ **F**

Step 2: **F** ⟶ **G**



Which statement about the reaction is correct?

A Step 2 is more exothermic than step 1.

B The enthalpy change of reaction for both the forward and backward reaction of step 1 is the same.

C The activation energy for the backward reaction of step 1 is 66 kJ mol^{-1}.

D The enthalpy change of reaction for the conversion of **E** to **G** is the sum of the enthalpy changes of step 1 and step 2.

16 The ions P^{3-}, S^{2-} and Cl^- have radii 0.212nm, 0.184nm and 0.181 nm respectively.

Which one of the following correctly explains the decrease in radius from P^{3-} to Cl^-?

A increase in both the total number of electrons and nuclear charge

B total number of electrons remaining constant with an increase in nuclear charge

C increase in the total number of electrons with nuclear charge remaining constant

D decrease in the total number of electrons with nuclear charge remaining constant

17 Which of the following statements about the electrical conductivity of elements across Period 3 is **incorrect**?

A Electrical conductivity increases from sodium to aluminium as the number of delocalised cations and electrons increases.

B Sodium, magnesium and aluminium are good electrical conductors as their metallic lattices contain delocalised electrons.

C Silicon is a semiconductor as the electrons within the covalent bonds are held tightly and are not easily delocalised.

D Phosphorous, sulfur, chlorine and argon are non–conductors as there are no mobile charge carriers in their simple molecular structures.

18 Phosphorus can form PCl_3 and PCl_5. However, nitrogen can only form NCl_3.

Which statement is a correct explanation of this?

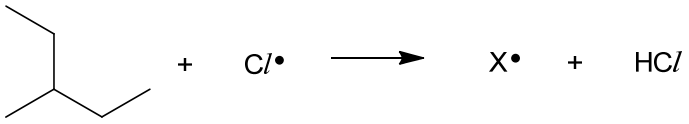
A Nitrogen can attain an oxidation state of +5.

B The N–C*l* bond is weaker than the P–C*l* bond.

C The valence orbitals of P are higher in energy than that of N.

D The n = 2 principal quantum shell can contain a maximum of 8 electrons.

19 When heated with chlorine, the following hydrocarbon undergoes free radical substitution. In the propagation step, the free radical X• is formed by the loss of one hydrogen atom.



How many different forms of X• are theoretically possible?

A 3 **B** 4 **C** 5 **D** 6

20 Dichlorodifluoromethane, CCl_2F_2, is widely used in aerosol propellants and as a refrigerant.

Which statement helps to explain why dichlorodifluoromethane is chemically inert?

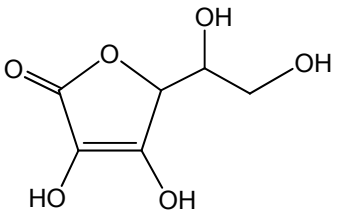
A The carbon–fluorine bond energy is large.

B Fluorine atoms have high electronegativity.

C The carbon–fluorine bond has a high polarity.

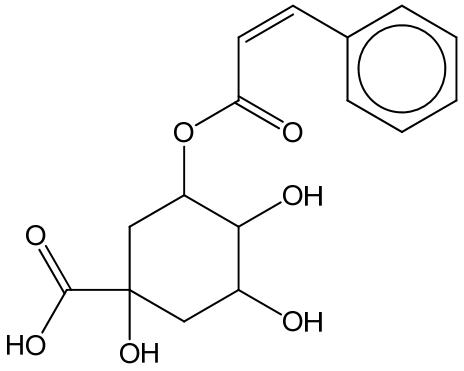
D Van der Waals' forces between CCl_2F_2 molecules are weak.

21 What is the total number of sigma bonds in a molecule of vitamin C as shown below?



A 12 **B** 14 **C** 16 **D** 20

22 Compound **Q** below is a derivative of chlorogenic acid which is found in coffee beans.



compound **Q**

Which of the following statements is correct?

A 1 mol of **Q** will react with 2 moles of NaOH(aq) on heating.

B 1 mol of **Q** will react with 4 moles of NaOH(aq) in the cold.

C When 1 mol of **Q** reacts with an excess of sodium carbonate, 1 mol of carbon dioxide gas and 1 mole of water will be formed.

D When 1 mol of **Q** reacts with an excess of sodium metal, 4 moles of hydrogen gas will be evolved.

23 Which of the following pairs of reagents can **both** be used separately to distinguish $CH_3COCH_2CH_3$ and $CH_3CH(OH)CH{=}CH_2$?

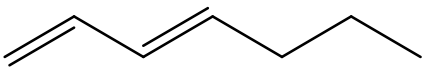
A alkaline aqueous iodine and sodium metal

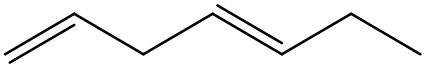
B 2,4-dinitrophenylhydrazine and hot acidified potassium manganate(VII)

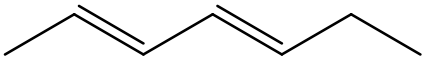
C Tollens' reagent and bromine in tetrachloromethane

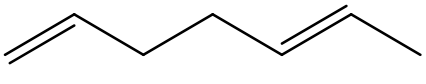
D H_2, nickel catalyst, heat and hot acidified potassium manganate(VII)

24 Which of the following will **not** be produced when 2,4–dibromoheptane reacts with hot ethanolic sodium hydroxide?

A 

B 

C 

D 

25 A sample of ethanal is treated with HCN in the presence of a little KCN. The organic product is then heated under reflux with dilute sulfuric acid.

What will be the final organic product?

A CH_3COCO_2H

B $CH_3CH_2CONH_2$

C $CH_3CH(OH)CO_2H$

D $CH_3CH(OH)CH_2NH_2$

Section B

For **questions 26-30**, one or more of the numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct.

The responses **A** to **D** should be selected on the basis of:

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is to be used as a correct response.

26 Which pairs of compounds contain one that is giant ionic and one that is simple molecular?

1 NaF and BH_3

2 HC*l* and I_2

3 Al_2O_3 and SiO_2

27 Which particles have the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$?

1 $_{24}Cr$

2 $_{25}Mn^+$

3 $_{26}Fe^{2+}$

28 Which statements containing the third period elements (sodium to argon) and their compounds are correct?

1 Electronegativity increases across Period 3 elements.

2 Aluminium oxide is the only oxide which is amphoteric.

3 The maximum oxidation state is shown by silicon.

29 An organic compound has the formula $C_4H_6Cl_2$.

Which are correctly named isomers of this compound?

1 3,4-dichlorobut-3-ene

2 1,4-dichlorobut-2-ene

3 1,1-dichlorobut-1-ene

The responses **A** to **D** should be selected on the basis of:

A	B	C	D
1, **2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is to be used as a correct response.

30 Which alcohols can be formed by the reduction of a ketone?

1 2-methylbutan-2-ol

2 2-methylpentan-3-ol

3 hexan-2-ol

2017 H1 Chemistry Preliminary Examination Paper 1 Answer Key

Paper 1

1	2	3	4	5	6	7	8	9	10
A	C	C	A	B	D	B	A	C	B
11	12	13	14	15	16	17	18	19	20
C	A	A	C	D	B	A	D	B	A
21	22	23	24	25	26	27	28	29	30
D	A	B	D	C	D	B	B	C	C

HWA CHONG INSTITUTION
C2 Preliminary Examinations
Higher 1

CANDIDATE NAME		**CT GROUP**	**16S**
CENTRE NUMBER		**INDEX NUMBER**	

CHEMISTRY 8872/02

Paper 2 **11 September 2017**

Candidates answer Section A on the Question Paper. **2 hours**

Additional Materials: Answer paper
Data Booklet
Graph paper (2 sheets)

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue, correction fluid or tapes.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** the questions.

Section B
Answer **two** questions on separate answer paper.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

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			TOTAL
Multiple Choice	**Section A (Structured)**	**Section B (Free Response)**	
	Q1 / 20	**Q4 / 20**	
	Q2 / 10	**Q5 / 20**	
	Q3 / 10	**Q6 / 20**	
/ 30	**Subtotal / 40**	**Subtotal / 40**	**110**

Section A

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

1 **(a)** Nitrogen and hydrogen react together to form ammonia in the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

Industrially, the following conditions are used for the Haber process.

pressure	250 atm
temperature	450 ˚C
catalyst	finely divided iron catalyst

(i) With the aid of Le Chatelier's Principle, explain why a moderate temperature of 450 ^{o}C is used for the Haber process.

……

……

……

……

…… [2]

(ii) Explain how iron catalyst can increase the rate of formation of ammonia.

……

…… [1]

(iii) State and explain the effect of using a pressure of 400 atm on the position of equilibrium and the equilibrium constant.

……

……

……

……

…… [2]

Given that 4 moles of N_2 and 8 moles of H_2 are allowed to reach dynamic equilibrium in a 2 dm^3 vessel. It is found that the total number of moles of gases present in the vessel at equilibrium is 8.

(iv) Write a K_c expression for the equilibrium in the formation of ammonia.

[1]

(v) Calculate the number of moles of each gas at equilibrium, showing your workings clearly.

number of moles of N_2: ……...mol; H_2: ……...mol

NH_3: ……...mol
[2]

(vi) Hence, calculate the equilibrium constant and state its units.

K_c = ……. units = ……
[2]

(b) **(i)** Ammonia burns in oxygen to give nitrogen dioxide and steam. Write an equation, with state symbols, which represents the enthalpy change of combustion of ammonia.

…… [1]

(ii) Hence, use the following information to calculate a value for the enthalpy change of combustion of ammonia.

Enthalpy change of formation of nitrogen dioxide	- 34 kJ mol^{-1}
Enthalpy change of formation of steam	- 242 kJ mol^{-1}
Enthalpy change of formation of ammonia	- 46 kJ mol^{-1}

[2]

(iii) Using relevant information from the *Data Booklet* as well as your answer in **b(ii)**, calculate a value for the bond energy of the bond between the nitrogen atom and the oxygen atom in nitrogen dioxide, assuming that the bond energy of both bonds are the same.

bond energy: …… kJ mol^{-1}
[2]

(iv) The combustion of 44 g of ammonia produces 89 g of nitrogen dioxide. Calculate the percentage efficiency of this reaction.

[2]

(c) Ammonia reacts with bromoethane.

Write an equation for the reaction that occurs and give the reagent and conditions necessary. State fully which class of organic compound the product belongs to.

Equation: ……..

Reagents and conditions: ……..…….

Class of organic compound: …….. [3]

[Total: 20]

2 This question is about Period 3 elements and their compounds.

(a) Period 3 elements react with oxygen to form oxides.

(i) Describe the reaction of aluminium oxide and phosphorus(V) oxide with hydrochloric acid and sodium hydroxide, if any.

……

…… [2]

(ii) Write equations for all reactions that occur in **(b)(i)**.

aluminium oxide: ……

……

phosphorus oxide: ……

……
[3]

(b) **(i)** In the vapour phase, an equilibrium is established between aluminium chloride and its dimer as follows:

$$2AlCl_3(g) \rightleftharpoons Al_2Cl_6(g)$$

With the aid of a diagram, explain how the dimer is formed.

……

……

……

…… [3]

(ii) At 180 ^{o}C, aluminium chloride, Al_2Cl_6, sublimes. Explain, based on its structure and bonding, why it sublimes at a relatively low temperature.

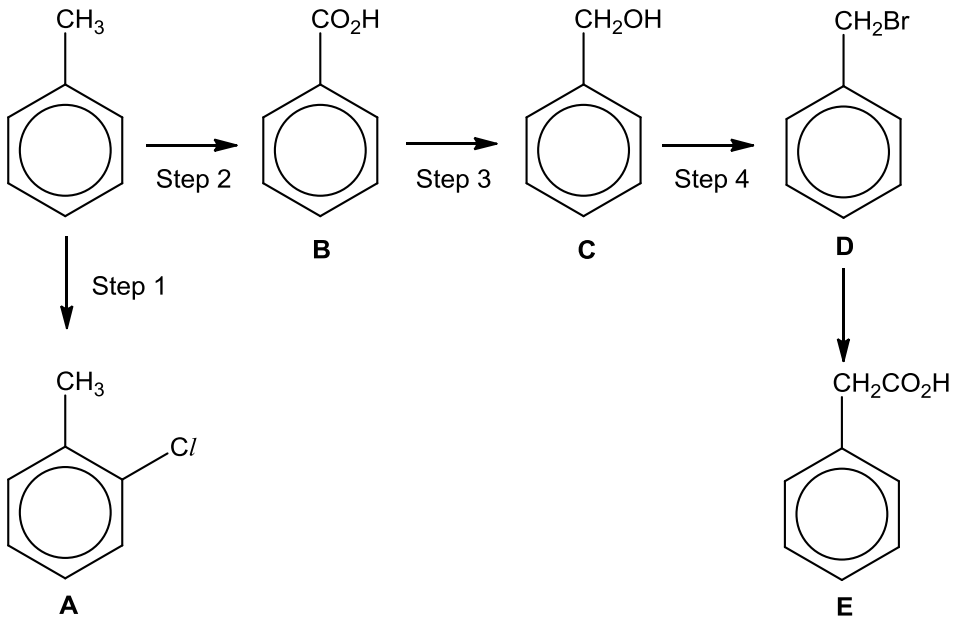
……

……

…… [2]

[Total: 10]

3 The following diagram shows some reactions of methylbenzene.



(a) State the reagents and conditions necessary for Step 1.

Reagents and conditions: ……[1]

(b) State the types of reaction for Steps 2 and 3.

Step 2: ……..

Step 3: ……...
[2]

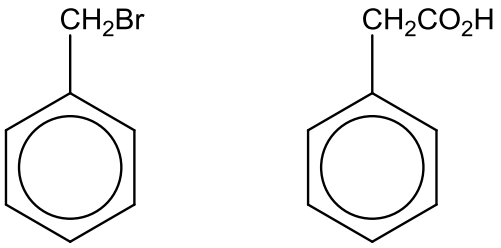
(c) Explain why **B** is acidic.

……

……

……..…… [2]

The structures of **D** and **E** are shown again below for parts **(d)** and **(e)**.



D **E**

(d) There is *another* method to obtain **D** from methylbenzene in *one* step. Give the reagents and conditions for this method and explain why this method is **not** preferred.

Reagents and conditions: ……..

……

…… [2]

(e) Propose a 2-step synthesis for the conversion of **D** to **E**. Give the reagents and conditions for all steps and the structure of any intermediate.

[3]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer paper.

4 **(a)** In the production of instant noodles, a key step involves deep frying the noodles in cooking oil to remove all traces of moisture. By dehydrating the noodles in this manner, the shelf life of the product increases dramatically.

(i) Cooking oil is primarily made up of long hydrocarbon chains, and has an approximate boiling point of 300 °C, whereas water has a boiling point of 100 °C.

Explain why cooking oil has a higher boiling point by reference to the type of bonding involved. [3]

(ii) Predict and explain what you would observe when equal volumes of cooking oil and water is mixed. [2]

(iii) Using your answers from **(a)(i)** and **(a)(ii)**, explain how deep frying removes moisture from the noodles. [2]

(b) NaC*l*, also known as table salt, is an important seasoning used in instant noodles.

(i) Draw a 'dot-and-cross' diagram that shows the bonding in sodium chloride. [1]

(ii) Describe the structure and bonding of sodium chloride, and explain why sodium chloride has a high melting point, and is brittle. [3]

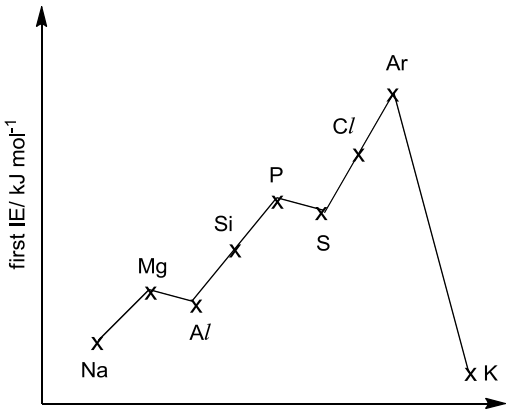
(iii) Define the term *lattice energy*. Explain how and why the lattice energies of sodium chloride, and sodium oxide, Na_2O, have different numerical values. [4]

(iv) Describe the reactions of sodium chloride, aluminium chloride, A*l*C*l*$_3$, and silicon chloride, SiC*l*$_4$, with excess water. Write equations where appropriate. [4]

(v) Suggest what influence the type of bonding present in these three chlorides in **(b)(iv)** has on their reaction with water. [1]

[Total: 20]

5 **(a)** The diagram below shows the first ionisation energies of the elements sodium to potassium.



(i) Define the term *first ionisation energy*. [1]

(ii) Several factors influence the values of the first ionisation energies shown above.

For each of the pairs of elements listed below, explain the difference between the values of their first ionisation energies. You should use a different explanation for each pair.

sodium and potassium
magnesium and aluminium
phosphorus and sulfur
chlorine and argon [5]

(iii) **X** and **Y** are elements from Period 3.

Based on the data below, suggest the identities of the following elements, **X** and **Y**, from their successive ionisation energies in kJ mol^{-1} and explain your reasoning.

	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
X	737	1451	7733	10542	13630	18020	21711	25661	31653	35458
Y	1251	2298	3822	5159	6542	9362	11018	33604	38600	43961

[4]

(b) Compound **A** has the molecular formula $C_9H_{12}O$. When **A** is exposed *uv* light in the presence of chlorine gas, it forms 3 monosubstituted compounds.

When **A** is heated with acidified potassium dichromate(VI), $K_2Cr_2O_7$, it forms compound **B**, which gives an orange precipitate in the presence of 2,4-dinitrophenylhydrazine.

When **A** is heated with excess concentrated sulfuric acid, it forms compounds **C**, **D**, and **E**, which are isomers of each other. In addition, **C** and **D** are stereoisomers.

Identify and suggest structures for **A**, **B**, **C**, **D** and **E**. Show how you deduced these structures and suggest the types of reactions that are occurring. [10]

[Total: 20]

6 **(a)** **(i)** Draw a 'dot-and-cross' diagram that shows the bonding in H_2O_2. [1]

(ii) Use your diagram in **(a)(i)** to suggest and explain the shape of H_2O_2. [2]

(iii) Suggest a value for the bond angle in H_2O_2, giving reasons for your choice. [2]

(b) H_2O_2 can be oxidised or reduced, depending on the species it is mixed with.

A stock solution of H_2O_2 was diluted by adding 20.0 cm^3 of the stock solution into a standard flask which was filled with distilled water to make a 100 cm^3 standard solution. 25.0 cm^3 of the standard solution was titrated with 0.200 mol dm^{-3} $KMnO_4$. 21.80 cm^3 of $KMnO_4$ solution was required to reach the end point. The following reaction occurs.

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

(i) Explain whether H_2O_2 is acting as an oxidising agent or reducing agent in the titration. [1]

(ii) Determine the amount of H_2O_2, in moles, that reacted with $KMnO_4$. [2]

(iii) Hence, determine the concentration of H_2O_2 in the stock solution. [2]

(c) Hydrogen peroxide reacts with acidified iodide ions to liberate iodine according to the following reaction:

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

The rate of reaction was followed by measuring the concentration of the remaining iodide ions after fixed time intervals. An experiment was carried out, starting using 0.05 mol dm^{-3} hydrogen peroxide. The following results were obtained.

Time/s	**Experiment 1** $[H_2O_2]$ = 0.0500 mol dm^{-3}
	$[I^-]$/ mol dm^{-3}
0	10.00×10^{-4}
25	7.45×10^{-4}
50	5.60×10^{-4}
75	4.25×10^{-4}
100	3.15×10^{-4}

(i) Plot a graph of $[I^-]$ against time. [3]

(ii) Use your graph to find the order of reaction with respect to I^-. [2]

(iii) **Experiment 2** was carried out using 0.100 mol^{-3} H_2O_2 instead, and it was found that the initial rate of reaction doubled. State and explain the order of reaction with respect to H_2O_2. [1]

(iv) The order of reaction with respect to H^+ is zero. Hence, write the rate equation for the reaction. [1]

(v) Determine the initial rate of reaction. Hence, calculate the rate constant, giving its units. [3]

[Total: 20]

2017 H1 Chemistry Preliminary Examination Paper 2 Answers

Section A

1 (a) (i) Since the forward reaction is exothermic, a low temperature will cause the position of equilibrium to shift to the right to produce more heat and thus producing more NH_3. However, the rate of reaction will be slow at low temperature, therefore, to increase the rate of reaction, a moderate temperature of 450°C is used.

(ii) Iron catalyst provides an alternative reaction pathway with a lower activation energy.

(iii) At a higher pressure, position of equilibrium shifts to the right so as to decrease the pressure by favouring the production of fewer number of moles of gases. The equilibrium is not affected as it is only affected by temperature.

(iv) $$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

(v) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Let the number of moles of N_2 reacted be x

	N_2	$3H_2$	$2NH_3$
Initial no. of moles / mol	4	8	0
Change in no. of moles / mol	- x	- 3x	+ 2x
Equilibrium no. of moles / mol	4 - x	8 - 3x	2x

Given that the total number of moles of gases at equilibrium is 8,
4 - x + 8 – 3x + 2x = 8
Solving for x, x = 2
At equilibrium, there is 2 mol of N_2, 2 mol of H_2 and 4 mol of NH_3.

(vi) $$K_c = \frac{\left(4/2\right)^2}{\left(2/2\right)\left(2/2\right)^3} = 1.00 \text{ mol}^{-2}\text{ dm}^6$$

(b) **(i)** $NH_3(g) + \frac{7}{4}O_2(g) \rightarrow NO_2(g) + \frac{3}{2}H_2O(g)$

(ii) $\Delta H = \Delta H_f(NO_2) + \frac{3}{2}\Delta H_f(H_2O) - \Delta H_f(NH_3) - \frac{7}{4}\Delta H_f(O_2)$

$\Delta H = (-34) + (\frac{3}{2} \times -242) - (-46) - 0 = -351 \text{ kJ mol}^{-1}$

(iii) $\Delta H = \Sigma BE(\text{bonds broken}) - \Sigma BE(\text{bonds formed})$

Bonds broken = $3BE(N\text{-}H) + \frac{7}{4}BE(O=O)$

$= 3 \times 390 + \frac{7}{4} \times 496 = 2038 \text{ kJ mol}^{-1}$

Bonds formed = $3BE(O\text{-}H) + 2BE(N\text{-}O) = 3 \times 460 + 2BE(N\text{-}O)$

$= 1380 + 2BE(N\text{-}O)$

$-351 = 2038 - 1380 - 2BE(N\text{-}O)$

$BE(N\text{-}O) = +504 \text{ kJ mol}^{-1}$

(iv) $n(\text{ammonia}) = \frac{44}{17} = 2.59 \text{ mol} = n(NO_2)$

Theoretical mass of $NO_2 = 2.59 \times 46 = 119.14$ g

Percentage efficiency = $\frac{89}{119.14} \times 100 = 74.7\%$

(c) $NH_3 + CH_3CH_2Br \rightarrow CH_3CH_2NH_2 + HBr$

Ethanolic concentrated NH_3, heat in a sealed tube

The organic products belongs to the primary amine functional group.

[Total: 20]

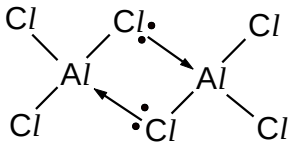
2 **(a)** **(i)** Al_2O_3 dissolves in both HCl and excess NaOH. P_4O_{10} dissolves in NaOH.

(ii) $Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$

$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2Na[Al(OH)_4](aq)$

$P_4O_{10}(s) + 12NaOH(aq) \rightarrow 4Na_3PO_4(aq) + 6H_2O(l)$

(b) **(i)**



The aluminium atom in $AlCl_3$ has only 6 electrons surrounding it hence it is electron-deficient. The lone pair of electrons from a chlorine atom in a neighbouring molecule would be donated via a dative bond, resulting in a dimer.

(ii) Al_2Cl_6 has simple molecular structure. The dispersion forces between the Al_2Cl_6 molecules are weak and hence, only a small amount of energy is needed to overcome the weak interactions.

[Total: 10]

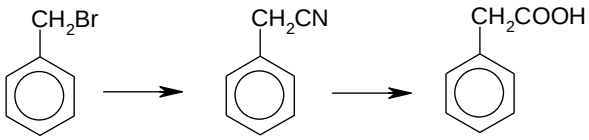
3 **(a)** Cl_2(g), $AlCl_3$, (rt)

(b) Step 2: oxidation
Step 3: reduction

(c) **B** dissociates to give H^+ and the conjugate base, $C_6H_5CO_2^-$ (benzoate). The negative charge on the benzoate ion is delocalised equally over two highly electronegative oxygen atoms. The negative charge is dispersed and the carboxylate anion is greatly stabilised.

(d) Reagents and conditions: $Br_2(l)$, UV light
The substitution is uncontrollable and multi-substituted products may be obtained.

(e)



Step 1: Ethanolic KCN, heat
Step 2: Dilute H_2SO_4, heat

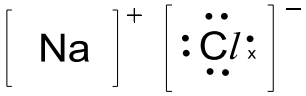
[Total: 10]

Section B

4 (a) (i) Cooking oil is primarily made up of long hydrocarbon chains, and experiences dispersion forces between molecules, whereas water experiences hydrogen bonding between water molecules. Because of the long hydrocarbon chains, the dispersion forces experienced by these molecules is extensive and stronger than the hydrogen bonding experienced by water molecules. Thus, more energy is required to overcome the dispersion forces in cooking oil compared to water, and the boiling point of cooking oil is thus higher.

(ii) The cooking oil and water is immiscible (no need to comment on relative density). This is because the molecules in cooking oil are largely non-polar, and do not form favourable interactions with the polar water molecules.

(iii) When the noodles undergoes deep frying, the high temperature of the heated oil causes the water in the noodles to vaporize. As water molecules do not form favourable interactions with the cooking oil, the water molecules escape as steam, thus drying out the noodles.

(b) (i) 

(ii) Sodium chloride has a giant ionic lattice structure, and experiences strong electrostatic forces of attraction between oppositely charged cations and anions.

The attraction between oppositely charged ions is very strong and requires a lot of energy to overcome. Thus, a high temperature must be achieved to provide enough energy for melting to occur.

In the giant ionic lattice, the cations and anions are arranged in an alternating fashion. When a force is applied, the lattice structure is disrupted, causing similarly charged ions to be aligned with one another. The resulting repulsion between like charges causes the lattice to shatter, thus accounting for sodium chloride's brittle nature.

(iii) Lattice energy is the heat evolved when one mole of pure ionic solid is formed from its constituent gaseous ions.

$$LE \propto \frac{q^+q^-}{r^+ + r^-}$$

The chloride anion has a smaller charge (–1) compared to the oxide anion (–2). The chloride anion has a larger ionic radii compared to the oxide anion (period 3 vs period 2). Since lattice energy is directly proportional to charge and inversely proportional to ionic radii, the magnitude of the lattice energy of sodium chloride is smaller than that of sodium oxide.

(iv) Sodium chloride dissolves in water to form a colourless solution of neutral pH.

$NaCl_{(s)} + aq \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$

In an excess of water, $AlCl_3$ dissolves to form a colourless solution of acidic pH. Al^{3+} forms a complex ion with 6 water molecules, as shown below.

$AlCl_{3(s)} + 6\ H_2O_{(l)} \rightarrow [Al(H_2O)_6]^{3+}_{(aq)} + 3\ Cl^-_{(aq)}$

$[Al(H_2O)_6]^{3+}_{(aq)} + H_2O_{(l)} \rightleftharpoons [Al(H_2O)_5OH]^{2+}_{(aq)} + H_3O^+_{(aq)}$

A violent reaction with water producing fumes of HCl gas. Complete hydrolysis occurs in this case.

$SiCl_{4(l)} + 4\ H_2O_{(l)} \rightarrow SiO_2.2H_2O_{(s)} + 4\ HCl_{(aq)}$

(v) Sodium chloride is an ionic compound while silicon chloride is a covalent compound. Therefore, as the degree of covalency increases across the period, so does the extent of hydrolysis with water.

5 (a) (i) First ionisation energy is the energy required to form 1 mol of unipositively charged cations from 1 mol of gaseous atoms.

(ii) Potassium has one more quantum shell than sodium, thus the outermost electron is further away from the nucleus in potassium compared to sodium. Therefore, the attraction between the outermost electron and the nucleus of potassium is weaker, and requires less energy to remove compared to that of sodium.

The 3*p* subshell of aluminium is further away from the nucleus than the 3*s* subshell. There is weaker attraction between the nucleus and the outermost electron. Hence less energy is required to remove the 3*p* electron from aluminium, resulting in a lower ionisation energy for aluminium.

Sulfur has a set of paired electrons in the p subshell, whereas the p orbitals in phosphorus are singly filled. The inter-electronic repulsion between the paired electrons causes the outermost electron of sulfur to be easier to remove, thus less energy is required to ionise sulfur.

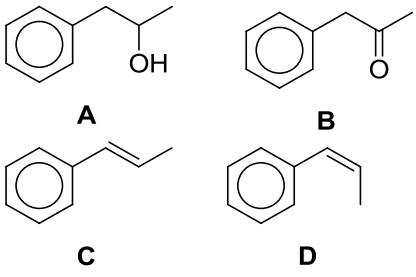
Argon has more protons than chlorine, thus the nuclear charge of argon is higher. As electrons are added to the same quantum shell, shielding effect is relatively constant for chlorine and argon. Thus the effective nuclear charge increases from chlorine to argon, implying that the attraction between the nucleus and the outermost electron has increased. Thus, more energy is required to remove the electron.

(iii) X is magnesium
After the 2nd ionisation energy, there is a large increase in the 3rd IE, which suggests that the 3rd electron is from an inner quantum shell. Thus X is a Group 2 element.

Y is chlorine
After the 7th ionisation energy, there is a large increase in the 8th IE, which suggests that the 8th electron is from an inner quantum shell. Thus X is a Group 17 element.

(b)

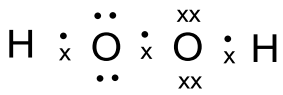
Observations	**Deductions**
Molecular formula of $C_9H_{12}O$	• High C:H ratio, benzene ring may be present. • One oxygen atom present suggests an alcohol or a ketone may be present.
exposed *uv* light in the presence of chlorine gas	• Substitution reaction
3 monosubstituted compounds	• Molecule is highly symmetrical / only 3 possible positions where substitution can occur
heated with acidified $K_2Cr_2O_7$	• Oxidation has occurred, **A** must be an alcohol
B gives an orange precipitate with 2,4-DNPH	• Carbonyl compound present
heated with excess concentrated sulfuric acid	• Dehydration
C and **D** are stereoisomers	• C=C bond present, **C** and **D** are geometic isomers.



A **B**

C **D** **E**

6 **(a)** **(i)**



(ii) Around each oxygen atom, there are 2 bond pairs and 2 lone pairs of electrons. Thus, it is bent around each oxygen atom.

(iii) The bond angle is 104.5°. As the lone pair-lone pair repulsion is greater than the bond pair-bond pair repulsion, the bond pairs will be pushed closer together thus bond angle smaller than 109.5°.

(b) **(i)** H_2O_2 is reducing agent. The oxidation state of Mn is reduced from +7 to +2.

(ii) $n(MnO_4^-) = (21.80 \div 1000) \times 0.200 = 4.36 \times 10^{-3}$ mol
$n(H_2O_2) = 4.36 \times 10^{-3} \times 5/2 = 0.0109$ mol

(iii) $n(H_2O_2)$ in 100 cm^3 standard solution $= 0.0109 \times 4 = 0.0436$ mol
$[H_2O_2]$ in stock solution $= 0.0436 \div 20/1000 = 2.18$ mol dm^{-3}

(c) **(i)** correct axis, labels, units
suitable scale
shape of graph

(ii) construction lines to show at least 2 constant half-life, $t_{1/2} \approx 60$ s
conclude that reaction is 1st order with respect to I^-

(iii) When the $[H_2O_2]$ is doubled, the initial rate doubles. Thus rate is directly proportional to $[H_2O_2]$, thus the order with respect to H_2O_2 is 1.

(iv) Rate = $k\,[H_2O_2][I^-]$

(v) Determine initial rate by drawing tangent at t = 0 s
Initial rate $= -[(3.00 - 4.00 \times 10^{-4}) \div (63 - 0)] = 1.11 \times 10^{-5}$ mol dm^{-3} s^{-1}

Using the rate equation,
$1.11 \times 10^{-5} = k(0.05)(10.00 \times 10^{-4})$
$k = 0.222$ mol^{-1} dm^3 s^{-1}

OR

$t_{1/2} = \ln 2 / k[H_2O_2]$
$60 = \ln 2 / k(0.05)$
$k = 0.231$ mol^{-1} dm^3 s^{-1}