

Index No.	Name	Form Class	Tutorial Class	Subject Tutor
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ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY
Higher 1

8872/02

Paper 2

16 August 2016
2 hours

Candidates answer Section A on the Question Paper

Additional Materials: Writing Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, index number, form class, tutorial class and subject tutor's name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, glue or correction fluid.

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.

For Examiner's Use	
Question no.	Marks
Section A	
B4	
B5	
B6	
TOTAL	

This document consists of **16** printed pages.



Section A

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

- 1 The element chromium was discovered in 1797 by French chemist Louis Nicolas Vauquelin. A number of naturally occurring isotopes of chromium have been identified as listed below.

isotope	relative isotopic mass	natural abundance (%)
^{50}Cr	49.95	4.34
^{52}Cr	51.94	83.79
^{53}Cr	52.94	9.50
^{54}Cr	53.94	2.37

- (a) Use the above data to calculate the relative atomic mass of chromium to **two** decimal places.

[2]

Chromium is a transition metal.

- (b) (i) Describe the bonding in the element chromium. Draw a diagram to illustrate your answer.

.....

..... [1]

- (ii) State **two** physical properties that you would expect chromium metal to possess. Explain, in terms of the bonding present, why it possesses these properties.

property

explanation

.....

.....

property

explanation

.....

.....[3]

- (iii) Chromium metal is produced by reducing chromium(III) oxide with aluminium or silicon.

State the full electronic configuration of a chromium atom, Cr and a chromium ion, Cr^{3+} .

Cr

Cr^{3+}

[2]

- (c) A student put 5 cm³ of dilute sulfuric acid in a boiling tube. He added 5 drops of potassium dichromate(VI) solution and then 2 drops of ethanol. He heated the mixture until it just boiled.

- (i) What colour change would the student see as he carried out this reaction?

from to [1]

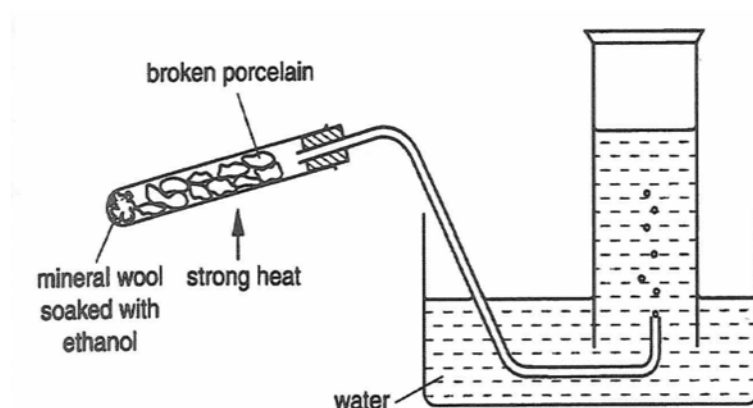
- (ii) Name the organic product formed and the type of reaction that has occurred.

product

type of reaction

[2]

- (d) The students then carried out another reaction of ethanol using the apparatus shown in the diagram below. The broken porcelain used contains Al_2O_3 .



- (i) What is the name of the gas collected in the gas jar?

..... [1]

- (ii) What type of reaction has the ethanol undergone?

..... [1]

- (e) What reagent and conditions are necessary to convert propanone into propan-2-ol?

..... [1]

[Total: 14]

- 2 Tin forms an oxide, **A**, that contains the metal in both oxidation states II and IV. The formula of **A** can be found by the following method.

- A sample of **A** was dissolved in $\text{H}_2\text{SO}_4(\text{aq})$, producing solution **B**, which was a mixture of tin(II) sulfate and tin(IV) sulfate.

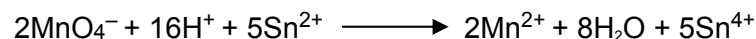
First titration

- A 25.0 cm^3 sample of solution **B** was titrated with $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4$. 13.50 cm^3 of KMnO_4 was required to reach the end-point.

Second titration

- Another 25.0 cm^3 sample of solution **B** was stirred with an excess of powdered zinc. This converted all the tin(IV) into tin(II). The excess of zinc powder was filtered off and the filtrate was also titrated with $0.0200 \text{ mol dm}^{-3} \text{ KMnO}_4$, as before. This time 20.30 cm^3 of KMnO_4 was required to reach the end-point.

The equation for the reaction occurring during the titration is as follows.



- (a) (i) Write a balanced ionic equation with state symbols for the reaction between Zn and Sn^{4+} .
.....[1]

- (ii) Use the results of the two titrations to calculate

- the number of moles of Sn^{2+} in the first titration sample,

- the number of moles of Sn^{2+} in the second titration sample.

[3]

- (iii) Use the results of your calculation in (ii) to deduce the $\text{Sn}^{2+}/\text{Sn}^{4+}$ ratio in the oxide **A**, and hence suggest the formula of **A**.

[2]

- (b) A major use of tin is to make 'tin plate', which is composed of thin sheets of mild steel electroplated with tin, for use in the manufacture of food and drinks cans. A tin coating of 1.0×10^{-5} m thickness is often used.

- (i) Calculate the volume of tin needed to coat a sheet of steel 1.0 m x 1.0 m to this thickness, on one side only.

[1]

- (ii) Calculate the number of moles of tin that this volume represents.
[The density of tin is 7.3 g cm^{-3} .]

[2]

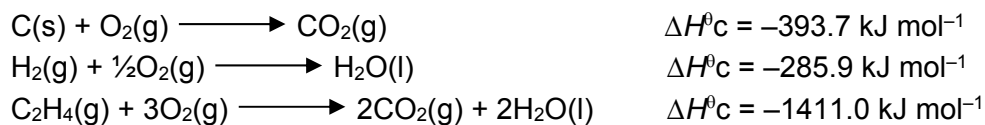
[Total: 9]

- 3 (a) (i) Define the term *standard enthalpy change of formation*.

.....

[1]

- (ii) Carbon, hydrogen and ethene each burn exothermically in an excess of air.



Write an equation for the standard enthalpy change of formation, $\Delta H^\circ_{\text{f}}$, of ethene.

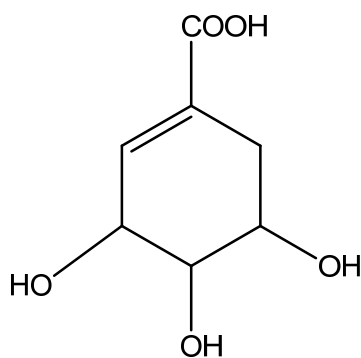
.....

Hence use the data to calculate the standard enthalpy change of formation, $\Delta H^\circ_{\text{f}}$, in kJ mol^{-1} , of ethene at 298 K.

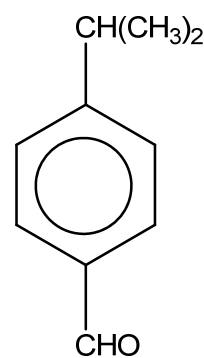
$$\Delta H^\circ_{\text{f}} = \dots\dots\dots \text{kJ mol}^{-1}$$

[3]

- (b) Shikimic acid and cuminaldehyde are naturally occurring compounds found in the spice plant star anise and the spice cummin respectively.



shikimic acid



cuminaldehyde

- (i) Explain why it is suggested that shikimic acid is more soluble in water than cuminaldehyde.

.....

.....[2]

- (ii) Explain why shikimic acid is more acidic than alcohol.

.....

.....

.....

.....[2]

- (c) For **each** of the following reagents, draw the structural formula of the product obtained for **each** of the two compounds. If no reaction occurs write **no reaction** in the box.

reagent	product with shikimic acid	product with cuminaldehyde
NaBH ₄ (methanol)		
NaOH(aq)		
Br ₂ (aq)		
H ₂ SO ₄ (aq), K ₂ Cr ₂ O ₇ (aq), heat under reflux		

[6]

- (d) Choose **one** of the above four reagents that could be used to distinguish between shikimic acid and cuminaldehyde. Describe the observations you would make with each compound. Write equation(s) for any reaction(s) that occurs.

reagent

observations

.....

equation

..... [3]

[Total : 17]

Section B

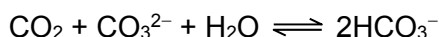
Answer **two** questions from this section on separate answer paper.

- 4 (a) Define what is meant by a Bronsted base. [1]
- (b) Carbon dioxide, CO_2 , from burning of fossil fuels, is changing the fundamental chemistry of our oceans. When carbon dioxide reacts with water, it forms carbonic acid, H_2CO_3 . H_2CO_3 subsequently dissociates into bicarbonate ions, HCO_3^- , and hydrogen ions, H^+ , into the sea, lowering pH and causing “acidification” of the ocean.

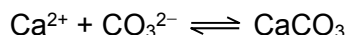
A solution of $0.100 \text{ mol dm}^{-3}$ H_2CO_3 has a pH of 3.68.

Due to the increasing levels of atmospheric CO_2 , the oceans have become approximately 30% more acidic (in terms of concentration of H^+ ions) over the last 150 years as the pH of seawater decreases from approximately 8.25 to 8.14.

Chemical species like HCO_3^- and CO_3^{2-} are the essential components of the carbonate buffer system which regulates the pH of seawater. The equilibrium reaction for CO_2 chemistry in seawater that most cogently captures its behaviour is shown below.



The natural pH of the ocean is determined by a need to balance the deposition and burial of CaCO_3 on the sea floor against the influx of Ca^{2+} and CO_3^{2-} into the ocean from weathering of limestone rocks and other minerals on land. Coral reefs are built from limestone, CaCO_3 , by the reaction shown below.



When CO_2 increases too rapidly, the natural equilibrium of calcium carbonate is upset. This alters the balance of the buffers and gradually allows the oceans to become more acidic.

- (i) Explain, with the aid of appropriate calculations, whether carbonic acid, H_2CO_3 , is a strong or weak acid. You may assume that carbonic acid, H_2CO_3 , to be monoprotic in your calculations. [2]
- (ii) Calculate the percentage increase in the concentration of H^+ ions in the last 150 years. [2]
- (iii) With the aid of two balanced equations, show how the carbonate buffer system regulates the pH of the seawater. [2]
- (iv) Other than increasing levels of atmospheric carbon dioxide gas, suggest another environmental phenomenon that can contribute to ocean acidification. [1]

- (c) In an experiment, 20 cm³ of 1.00 mol dm⁻³ sodium hydrogen carbonate, is added to 10 cm³ of 1.00 mol dm⁻³ aqueous hydrochloric acid.

- (i) Deduce with appropriate working, which is the limiting reagent. [1]
- (ii) If the temperature fell by 3.7°C, calculate the enthalpy change of the above reaction. [1]
- (iii) A student was told that the concentration of hydrochloric acid might not be exactly 1.00 mol dm⁻³. He decided to carry out titration against a standard solution of sodium hydrogen carbonate to determine the concentration of hydrochloric acid. Suggest an indicator he could use. [1]
- (iv) Another student repeated the experiment with 40 cm³ of 1.00 mol dm⁻³ sodium hydrogen carbonate added to 10 cm³ of 1.00 mol dm⁻³ aqueous hydrochloric acid, all other experimental conditions are kept constant.

Suggest whether the temperature fall will be above or below 3.7 °C and hence suggest the enthalpy change of the reaction. [2]

- (d) *Use of the Data Booklet is relevant to this question.*

Part of the Periodic Table is shown below.

Group	I	II		III	IV	V	VI	VII	VIII
	Li	Be		B	C	N	O	F	Ne
Period 3	Na	Mg		Al	Si	P	S	Cl	Ar

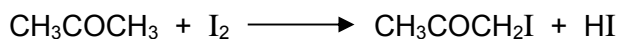
From the elements shown in the table, identify the one which exhibits each of the following property.

- (i) It has the highest first ionisation energy.
- (ii) It has the largest ionic radius.
- (iii) It has an electronegativity similar to that of aluminium.
- (iv) It has a hydride that forms the strongest intermolecular hydrogen bonds.
- (v) It has a trifluoride with molecules which has trigonal planar shape.
- (vi) It has a chloride that neither reacts with nor dissolves in water.
- (vii) It has an oxide with a giant structure and a chloride which is readily hydrolysed in water.
- (viii) It has an oxide that produces a strong acid when treated with water.
- (ix) Write equations for the reactions for both (vii) and (viii).

[7]

[Total: 20]

- 5 (a) Propanone reacts with iodine in the presence of acid according to the equation:



A student, Mark, wanted to study the kinetics of the above reaction.

He prepared a mixture containing:

- 5 cm³ of propanone of concentration 1.0 mol dm⁻³,
- 10 cm³ of sulfuric acid of concentration 1.0 mol dm⁻³,
- 10 cm³ of a solution of iodine of concentration 1.0 x 10⁻³ mol dm⁻³,
- 75 cm³ of distilled water.

At every five minutes interval, 10.0 cm³ samples were removed and 10 cm³ of aqueous sodium hydrogencarbonate was added, followed by a titration against a solution of sodium thiosulfate(VI).

The experiment was repeated using 20 cm³ of sulfuric acid in the reaction mixture, with 65 cm³ of water to keep total volume constant.

The following results were obtained.

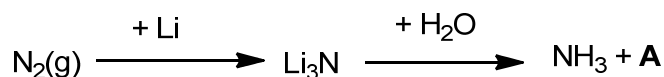
Time/min		5	10	15	20	25
Titre/cm ³	for 10 cm ³ acid (experiment 1)	18.50	17.00	15.50	14.00	12.50
	for 20 cm ³ acid (experiment 2)	17.00	14.00	11.00	8.00	5.00

- (i) State the roles of iodine and sulfuric acid in this reaction. [2]
- (ii) Explain why sodium hydrogencarbonate was added prior to the titration. [1]
- (iii) Mark went to plot the graph of titre volume against time for both experiment 1 and 2 on the same graph. He obtained a straight line with a negative gradient for both graphs. He also found that the gradient for the experiment 1 was half of that for the experiment 2.
- (I) Using the above information, deduce the order of reaction with respect to iodine and sulfuric acid respectively.
- (II) What does the magnitude of gradient represent?
- (III) If the experiment was repeated at a higher temperature, how would you expect the magnitude of the gradient to change? [4]
- (iv) Write a balanced equation for the titration reaction. [1]

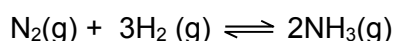
- (v) Mark found that volume of thiosulfate required was 20.00 cm^3 as he extrapolated the graph to the y-axis at $t = 0 \text{ min}$ in a 10.0 cm^3 reaction mixture. Calculate the concentration of the sodium thiosulfate(VI) solution used in the titration. [2]
- (vi) Sketch a concentration-time graph for sulfuric acid in this reaction. [1]
- (vii) With the aid of a Maxwell-Boltzmann distribution curve, explain how the rate of reaction will be affected if the reaction was carried out at a higher temperature. [4]
- (b) Draw a dot-and-cross diagram for propanone. Hence, determine the bond angles in C-C-O and also the H-C-C. [2]
- (c) Describe the bonding of sp^3 carbon in terms of orbital overlap in propanone. Illustrate your answer with a clearly labelled diagram. [3]

[Total: 20]

- 6 (a) Nitrogen makes up about 79% of the Earth's atmosphere. As a constituent element of proteins, it is present in living organisms. Oxygen is by far more reactive than nitrogen gas. State one reason why the molecule of nitrogen, N_2 is unreactive. [1]
- (b) Lithium reacts readily with nitrogen, and because of this Li_3N has been considered as a possible intermediate in the fixing of nitrogen to make ammonia-based fertilisers.



- (i) Construct an equation for the reaction between Li_3N and H_2O and hence identify compound **A**. [2]
- (ii) Ammonia is produced in the Haber process. The volume of the reaction vessel is 2 dm^3 .

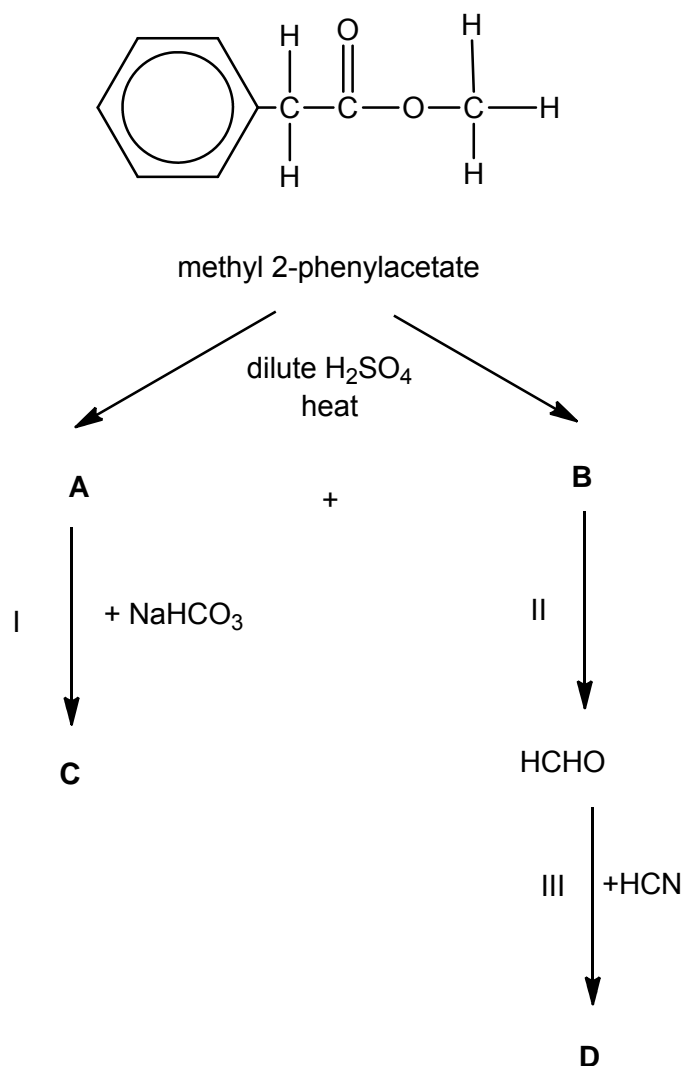


1 mol of nitrogen and 2 mol of hydrogen are placed in a reaction vessel of 2 dm^3 . After equilibrium is reached, the amount of nitrogen remaining is 0.4 mol.

Write an expression for the equilibrium constant, K_c and calculate the value of K_c for this equilibrium stating its units. [3]

- (iii) Using your knowledge of the Haber process, state one advantage and one disadvantage of using lithium as a means of fixing nitrogen, rather than the Haber process. [2]
- (iv) State one large-scale use for ammonia, other than in the production of fertilisers. [1]
- (v) Like water, liquid ammonia can also undergo self-ionisation. Write an equation to represent the self-ionisation of liquid ammonia and draw the dot-and-cross diagrams to show the bonding in the species formed. [3]
- (c) Boron nitride is a heat resistant refractory compound which is made up of boron and nitrogen atoms. It has the chemical formula BN. The hexagonal form corresponds to graphite and is the more stable compound among the BN polymorphs.
- (i) Explain the high melting point of boron nitride in terms of its structure and bonding. [2]
- (ii) Suggest a possible industrial use of hexagonal boron nitride. [1]

(d) A sequence of reactions, starting from methyl 2-phenylacetate, is shown below.



- (i) Draw the structures of compounds **A**, **B**, **C** and **D**. [4]
- (ii) The aldehyde CH_3CHO can be converted into ethanoic acid. How may this conversion be achieved in a college laboratory? [1]

[Total: 20]