

2011-AL-CHEM

Paper I

BEACON COLLEGE

MOCK EXAMINATION - 2011

**CHEMISTRY A-LEVEL PAPER 1
Question-Answer Book**

3 hours

Dr. Kelvin Lau

1. There are THREE sections in this paper, Section A, Section B and Section C.
2. Section A carries 60 marks
Section B carries 20 marks
Section C carries 20 marks
3. Answer ALL questions in Sections A and B, and ONE question in Section C
4. Some constants, characteristic infra-red absorption wavenumber ranges, standard reduction potentials and a Periodic Table can be found on page 24 and 25 of this Question-Answer Book.
5. Write your answers in the spaces provided in this Question-Answer Book. Do not write in the margins. Answers written in the margins will not be marked.
6. Supplementary answer sheets will be supplied on request. Write your name, fill in the question number and fasten them with string INSIDE this book.

Candidate Name:

Class:

Class Number:

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A Total	

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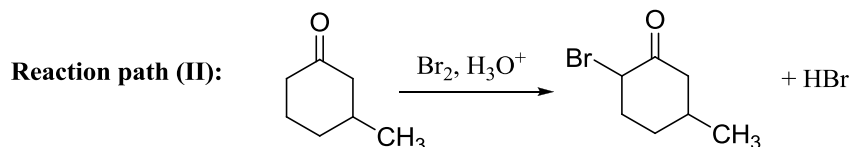
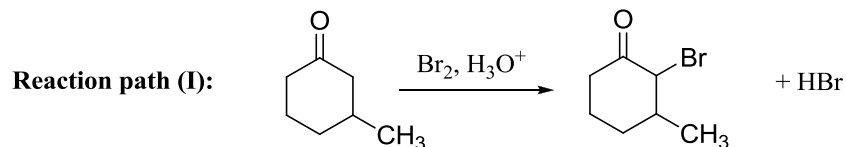
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Section A

Answer **ALL** questions. Write your answers in the spaces provided.

1. (a) Consider the following acid-catalyzed reactions:



Given the standard bond enthalpies below:

Bond	Standard bond enthalpies (kJmol ⁻¹)
C-H	+ 416
C-Br	+276
Br-Br	+ 193
O-H	+ 463
H-Br	+ 364

- (i) By using the standard bond enthalpies given, calculate the standard enthalpy change of Reaction path (I)
- (ii) The standard enthalpy change of reaction of Reaction path (II) calculated by the above method is the same as that of Reaction path (I). However, experiments show that these two values are different. Explain this phenomenon. Which experimental data is expected to be more positive? Explain your answer.

(5 marks)

Answers written in the margins will not be marked

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1. (b) A containing vessel holds a gaseous mixture of three inert gases A, B and C. The number of mole of B is twice than that of A. The pressure in the vessel at 300 °C is 5.8 atm.

At -30 °C the liquid C completely condenses and the pressure drops to 1.4 atm.

(i) Calculate the mole fraction of A, B and C in the original gaseous mixture.

(ii) State an assumption in the above calculation.

[4 marks]

Answers written in the margins will not be marked

Page Total

2. (a) Write appropriate equations to represent the following energy changes:
- (i) Second ionization enthalpy of barium

 - (ii) Lattice enthalpy of magnesium nitride

 - (iii) First electron affinity of hydrogen

 - (iv) Standard enthalpy change of combustion of 2,3-dimethylhexan-1-ol

[2 marks]

- (b) Write the ionic equations (with physical states) for the following reactions and state the observable changes.

(i) Fluorine is added to cold and dilute caesium hydroxide solution.

(ii) Household bleach is exposed to sunlight.

(iii) Sodium tetrachlorocobaltate(II) solid is added to water.

[6 marks]

Answers written in the margins will not be marked

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2 (c) (i) Describe the lattice structure of sodium chloride

(ii) Given that the density of sodium chloride is 2.165 g cm^{-3} . Calculate the edge of the unit cell of sodium chloride.

[Relative atomic masses: Na = 23.0; Cl = 35.5]

[4 marks]

Answers written in the margins will not be marked

Page Total

3. Read the passage below and answer the questions that follow:

Formaldehyde

Formaldehyde (systematic name: methanal) is an organic compound with the formula CH_2O . As the simplest aldehyde, it is an important precursor to many other chemical compounds, especially for thermosetting plastics. Despite of its widespread use, toxicity and volatility, exposure to formaldehyde is a significant consideration for human health. 5

Formaldehydes exhibits most of the chemical properties of other aldehydes but is more reactive. For example, it is readily oxidized by the atmospheric oxygen and hydrogen peroxide to form formic acid. It can also be oxidized by acidified potassium permanganate to form carbon dioxide. 10

Formaldehyde is more complicated than many simple carbon compounds because it adopts different forms. This compound can be converted to a variety of derivatives. These derivatives generally behave similarly to gaseous formaldehyde and are used in industry. One important derivative is the cyclic compound trioxane, the "trimer" of formaldehyde with formula is $(\text{CH}_2\text{O})_3$. When dissolved in water, formaldehyde converts to $\text{H}_2\text{C}(\text{OH})_2$, which is a well known intermediate in the oxidation of formaldehyde to carboxylic acid. The above reaction is reversible. 15

Aqueous solutions of formaldehyde are referred to as formalin. "100%" formalin consists of a saturated solution of formaldehyde (this is about 40% by volume or 37% by mass) in water, with a small amount of stabilizer, usually methanol to limit the oxidation of methanal. The diol also exists in equilibrium with a series of short polymers (called oligomers), depending on the concentration and temperature. The infinite polymer formed from formaldehyde is called paraformaldehyde. The cyclic trimer is called metaformaldehyde (or 1,3,5-trioxane). 20

Answers written in the margins will not be marked

3. (a) Draw the structure of a monomer that can react with formaldehyde to form a thermosetting plastic. State the catalyst of the reaction.

[2 marks]

(b) Account for the reactivity difference of formaldehyde and other typical aldehydes (line 6).

[2 marks]

(c) Draw the structure of the “trimer” in the third paragraph (line 14). State the hybridization states of the carbon and oxygen atoms in the molecule.

[2 marks]

(d) Draw the mechanism for the reaction between formaldehyde and water to form diol (line 15).

[2 marks]

Answers written in the margins will not be marked

Page Total

3. (e) Draw the mechanism for the reaction between methanol and methanal. Hence explain how methanol can suppress the oxidation of methanal to methanoic acid (line 19)

[Hints: line 14-16]

[2 marks]

- (f) Draw the repeating unit of paraformaldehyde in paragraph 4 (line 23)

[1 mark]

Answers written in the margins will not be marked

4 Cracking is an important industrial process which can convert large petroleum fractions to smaller molecules. A student has conducted the cracking of octane in the laboratory. In an experiment, the cracking of octane in the absence of air produced propene, propane and ethene as the only product.

(a) What is the common catalyst used for cracking? Explain why the reaction must be conducted in the absence of air.

[2 marks]

(b) Given the following data:

	Standard enthalpy change of combustion/ kJmol^{-1}
Octane, $\text{C}_8\text{H}_{18}(\text{l})$	-5476
Propene, $\text{C}_3\text{H}_6(\text{g})$	-2220
Propane, $\text{C}_3\text{H}_8(\text{g})$	-2058
	Standard enthalpy change of formation/ / kJmol^{-1}
Water, $\text{H}_2\text{O}(\text{l})$	-286
Carbon dioxide, $\text{CO}_2(\text{g})$	-394
Ethene, $\text{C}_2\text{H}_4(\text{g})$	+52

Relative atomic mass: C = 12.0; H = 1.0

By drawing an appropriate Born-Haber cycle, calculate the enthalpy change when 1g octane undergoes complete cracking.

[5 marks]

Answers written in the margins will not be marked

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4 (c) Explain why the enthalpy change of the above reaction cannot directly determined.

[1 mark]

(d) If propene is the only desired while propane and ethene are treated as the by-products. Calculate the percentage atom economy for the reaction. In the view of green chemistry, do you think this is a good method to prepare propene? Give TWO reasons to support your answer.

[3 marks]

Answers written in the margins will not be marked

Page Total

5 (a) Iron belongs to period 4 elements, which forms a variety of compounds with different oxidation states such as iron (II) oxide, iron (III) oxide and sodium ferrate (VI) (Na_2FeO_4).

(i) Account for the fact that iron can form compounds with different oxidation states while calcium, which is also a period 4 element, can only form compounds with one oxidation state.

(ii) Iron (II) oxide is readily oxidized by air to form iron (III) oxide. Account for this phenomenon

[3 marks]

(b) Sodium ferrate (VI) is a very strong oxidizing agent. Write the ionic equations for the following reactions (You are required to show the physical states of each substance):

(i) Alkaline sodium ferrate (VI) solution oxidizes aqueous ethanol to carbon dioxide and it is reduced to iron (III) hydroxide.

(ii) In acidic medium, sodium ferrate (VI) solution oxidizes sulphuric acid to peroxosulphate (VI) ($\text{S}_2\text{O}_8^{2-}$) and it is reduced to iron (III) ions.

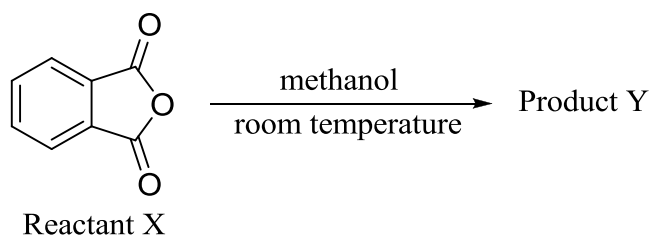
[3 marks]

(c) Polyatomic ions with high oxidation state in their central atoms are generally strong oxidizing agents. Account for this phenomenon.

Answers written in the margins will not be marked

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6 Consider the following reaction:



Given that Product Y has an ester functional group

(a) Draw the structure of Product Y

[1 mark]

(b) Draw the mechanism of the reaction.

[3 marks]

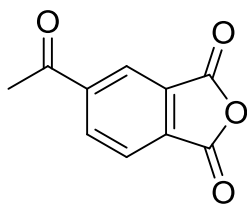
(c) If trifluoromethanol is used to replace methanol, there is no reaction. Account for this phenomenon.

[2 marks]

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6 (d) The structure of Reactant Z is shown below



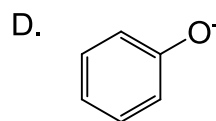
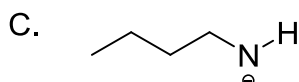
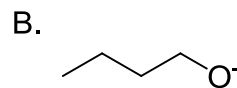
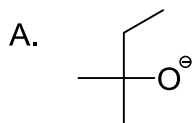
If Reactant Z is used to replace Reactant X. Explain how the reaction rate will be affected.

[2 marks]

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7. (a) Which of the following compounds is the strongest nucleophile towards 2-bromopropane ?



Answer:

[1 mark]

(b) Which of the following compounds has the highest solubility in water?

- A. acetone
- B. benzaldehyde
- C. diethylether
- D. dichloroethane

Answer:

[1 mark]

Answers written in the margins will not be marked

Section B

Answer **ALL** questions. Write your answers in the spaces provided.

8. Sodium potassium tartrate (KNaC_4O_6) is known as Rochelle salt, which is highly soluble in hot water and has a cooling taste. The following experiment is to prepare a hydrated Rochelle salt ($\text{KNaC}_4\text{O}_6 \cdot y\text{H}_2\text{O}$) and determine the number of water of crystallization in the prepared sample.

Step 1: 50 cm^3 of 2 M sodium carbonate was added to 100 cm^3 of 2 M hot potassium bitartrate (KHC_4O_6)

Step 2: The hot solution was filtered.

Step 3: The residual was concentrated to white solid, dried to a constant mass in air.

Step 4: The dried sample was weighted, the mass was found to be 44.5g

Step 5: The sample was put into an oven and heated to a constant mass.

Step 6: The dried sample was weighted, the mass was found to be 33.0 g

- (a) Write an chemical equation to illustrate the formation of Rochelle salts solution in Step 1. (you are required to show the physical state of each substance)

(2 marks)

- (b) Explain why the mole ratio of sodium carbonate and potassium bitartrate has to be exactly 1 : 2 in Step 1.

(1 marks)

- (c) Explain why the reaction mixture has to be filtered when it is hot in Step 2.

(1 marks)

Answers written in the margins will not be marked

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- (d) Calculate the number of water of crystallization (the value of y) in the sample.
[RAM of K = 39.1; Na = 23.0; O = 16.0; C = 12.0; H = 1.0]

[2 marks]

- (e) Calculate the percentage yield of the reaction in Step 4.

[2 marks]

- (f) Suggest how to test the purity of the product.

[1 mark]

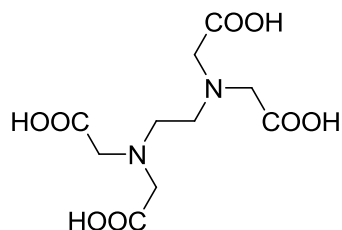
- (g) Give one application of Rochelle salt in daily life

[1 mark]

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9. (a) Given the structure of H₄EDTA (C₁₀H₁₆N₂O₈):



The following experiment is to prepare sodium iron(III) EDTA complex, NaFeEDTA

Step 1: Dissolve 4 g H₄EDTA into 100 cm³ solution.

Step 2: Add 27.4 cm³ of 2 M sodium hydroxide solution

Step 3. Dissolve 3.33 g of iron(III) chloride hexahydrate into 50 cm³ water. Add the solution into the reaction mixture.

Step 4: Heat the solution for 30 minutes.

Step 5: Cool the solution in ice bath, a yellow precipitate was formed.

Step 6: Perform the suction filtration, wash solid with little cold distill water and cold ethanol.

Step 7: Dry and weigh the sample. The mass of found to be 1.63 g

(i) Write the ionic equation involved in Step 1. Account for the use of sodium hydroxide in experiment.

[2 marks]

(ii) Calculate the mole ratio of H₄EDTA and sodium hydroxide. Explain why sodium hydroxide cannot be in excess.

[2 marks]

Answers written in the margins will not be marked

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9. (a) (iii) Draw the 3-D Lewis structure of FeEDTA^-

[2 marks]

(iv) Calculate the percentage yield of the reaction.

[2 marks]

(b) Sodium thiocyanate (NaSCN) solution was added to the solution. Account for the observable change.

[2 marks]

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Section C

Answer ONE question only and write your answer in the spaces provided.

Marks will be allocated approximately as follows:

chemical knowledge	50%
organization	30%
presentation (including use of language)	20%

Equations, suitable diagrams and examples are expected where appropriate.

The examiners are looking for the abilities to analyze, to evaluate and to express ideas clearly.

10. Write an essay to discuss the discovery and development of drugs.
11. Write an essay to compare the chemical properties of derivatives of carboxylic acid and discuss their inter-conversions.

Answers written in the margins will not be marked

Page Total

Lined area for writing answers.

Answers written in the margins will not be marked

END OF PAPER

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Constants

Gas constant, $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$

Avogadro constant, $L = 6.02 \times 10^{23} \text{ mol}^{-1}$

Planck constant, $h = 6.63 \times 10^{-34} \text{ J s}$

Speed of light in vacuum, $c = 3 \times 10^8 \text{ m s}^{-1}$

Ionic product of water at 298 K, $K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$

Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes)

Bond	Compound type	Wavenumber range / cm^{-1}
C=C	Alkenes	1610 to 1680
C=O	Aldehydes, ketones, carboxylic acid and derivatives	1680 to 1800
C≡C	Alkynes	2070 to 2250
C≡N	Nitriles	2200 to 2280
O-H	Acids (Hydrogen –bonded)	2500 to 3300
C-H	Alkanes, alkenes, arenes	2840 to 3095
O-H	Alcohols, phenols (hydrogen-bonded)	3230 to 3670
N-H	Amines	3350 to 3500

