SERANGOON JUNIOR COLLEGE
General Certificate of Education Advanced Level
Higher 2

CANDIDATE NAME	
CLASS	

CHEMISTRY 9647/02

JC2 Preliminary Examination 16 September 2016
Paper 2 Structured Questions (SPA) 2hr

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough work.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.
A Data Booklet is provided.

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

For Examiner's Use	
P1	/ 40
P2	/ 72
P3	/ 80
GRAND TOTAL	/ 192
%	
GRADE	

For Examiner's Use	
1(P)	/ 12
2	/ 15
3	/ 13
4	/ 11
5	/ 12
6	/ 9
TOTAL P2	/ 72

This document consists of **19** printed pages.

1(P) When a sparingly soluble salt, calcium hydroxide, $Ca(OH)_2$, is added to water, an equilibrium is established between the undissolved salt and a saturated solution of the salt.

$$Ca(OH)_2(s) \rightleftharpoons Ca^{2+}(aq) + 2OH^{-}(aq)$$

The solubility product at laboratory temperature can be found by determining the equilibrium concentration of the hydroxide ions in a saturated solution of calcium hydroxide. This equilibrium concentration can be found by titration with a standard solution of hydrochloric acid.

The numerical value of the solubility product of calcium hydroxide is approximately 5×10^{-6}.

(a) Write an expression for the solubility product of calcium hydroxide, stating its units.

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[1]

You are required to write a plan to determine the solubility product of calcium hydroxide at laboratory temperature.

You may assume that you are provided with:

- Solid $Ca(OH)_2$
- 0.200 mol dm^{-3} of stock solution of HC*l*
- deionised water
- indicators normally found in a school laboratory
- equipment normally found in a school laboratory

(b) (i) Calculate the minimum mass of $Ca(OH)_2$ that needs to be weighed in order to obtain 250 cm^3 of a saturated solution of $Ca(OH)_2$ at laboratory temperature.

[2]

(ii) Assuming that approximately 30.00 cm^3 of HC*l* was required to react with 25.0 cm^3 of saturated solution of $Ca(OH)_2$, calculate an appropriate concentration of HC*l* required. Hence, calculate the volume of the given solution of HC*l* required to prepare 250 cm^3 of this solution.

[2]

(iii) Using the information given above and the answers in **b(i)** and **b(ii)**, you are required to write a plan to determine the solubility product of calcium hydroxide.

You are also required to explain how the data you obtain from this experiment may be used to determine the solubility product of calcium hydroxide.

Your plan should include:

- the preparation of 250 cm^3 of the saturated solution of calcium hydroxide;
- the preparation of 250 cm^3 of standard solution of hydrochloric acid from the stock solution of hydrochloric acid;
- titration procedure;
- how the results obtained can be used to determine the solubility product of calcium hydroxide.

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[7]

[Total: 12]

2 The manufacture of ammonia from nitrogen and hydrogen takes place in two stages:

First Stage: The manufacture of hydrogen from methane.
Second Stage: The synthesis of ammonia (the Haber Process).

The First Stage occurs via a two-step process.

- *Steam Reforming*
- *Shift Reaction*

Both steps produce hydrogen gas that will be used in the Second Stage for the production of ammonia.

(a) *Steam Reforming* is a reaction that converts methane and steam to a mixture of carbon monoxide and hydrogen. There are two possible routes for it:

Primary Steam Reforming: Steam is supplied to start the reaction.
$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H^{\ominus} = +210$ kJ mol^{-1} ***eqm*** **(1)**

Secondary Steam Reforming: Some hydrogen is burnt to form steam which then reacts with methane to generate more hydrogen.
$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta H^{\ominus} = -482$ kJ mol^{-1}
$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H^{\ominus} = +210$ kJ mol^{-1}

(i) State if the overall process of *Secondary Steam Reforming* is an exothermic or endothemic process.

……..... [1]

(ii) Suggest and explain which steam reforming process (*Primary* or *Secondary*) is favoured by high temperature.

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…… [2]

(iii) The methane gas used usually contains some organic sulfur compounds, R-SH, and hydrogen sulfide, H_2S, both of which must be removed or it will poison the catalyst. Hence the methane mixture needs to be passed through a *desulfurisation unit* first.

- These organic sulfur compounds are first converted into hydrogen sulfide and a hydrocarbon by reduction with hydrogen gas.
- The hydrogen sulfide is reacted with zinc oxide (ZnO) to produce zinc sulfide (ZnS) as one of the products.

Construct two balanced chemical equations showing the reactions that occurred in the *desulfurisation unit*, using R-SH to represent organic sulfur compounds and RH to represent hydrocarbon.

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[2]

(b) In the *Shift Reaction*, the carbon monoxide produced during the *Steam Reforming* process was converted to carbon dioxide and hydrogen gas. *Shift Reaction* is done via a two-step process:

- *High Temperature Shift Reaction* with iron(III) oxide catalyst.
- *Low Temperature Shift Reaction* with thermally unstable copper catalyst at 500 K. The carbon monoxide concentration is further reduced to 0.2%.

The reaction involved in the *Shift Reaction* is illustated in the following equation.

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H^{\ominus} = -42 \text{ kJ mol}^{-1}$ ***eqm* (2)**

(i) State the full electronic configuration of iron(III) ion and copper metal.

Fe^{3+}: $1s^2$……

Cu: $1s^2$……..

[2]

(ii) With reference to the *Shift Reaction*, state and explain if iron(III) oxide and copper is functioning as homogeneous or heterogenous catalyst.

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[2]

(c) Traces of carbon dioxide produced in the *Shift Reaction* is subsequently removed by passing it with hydrogen gas over a nickel catalyst at 600 K, a process known as *Methanation*.

$CO_2(g) + 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2O(g)$

Using the enthalpy change values of ***eqm(1)*** and ***eqm(2)***, determine the enthalpy change for this *Methanation* process.

[2]

(d) The main process of the Haber Process occurs in a fixed bed reactor.

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

The proportion of ammonia in the equilibrium mixture increases with increasing pressure and with decreasing temperature. Quantitative data are given in the table below.

Pressure/atm	**Percentage of ammonia present at equilibrium at a range of temperature**		
	373 K	**473 K**	**573 K**
10	-	50.7	14.7
25	91.7	63.6	27.4
50	94.5	74.0	39.5
100	96.7	81.7	52.5
200	98.4	89.0	66.7
400	99.4	94.6	79.7
1000	-	98.3	92.6

(i) To obtain a reasonable yield with favourable rate, high pressures, moderate temperatures and a catalyst are used. Using the data, select the temperature and pressure which will result in the highest yield of ammonia.

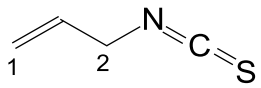
Temperature …… Pressure …….. [1]

(ii) Hence, using the data you have selected in **(d)(i)**, determine the volume of ammonia gas, nitrogen gas and hydrogen gas at equilibrium when 10 cm^3 of nitrogen gas is reacted with 30 cm^3 of hydrogen gas in the Haber Process. Leave your answer to two decimal places.

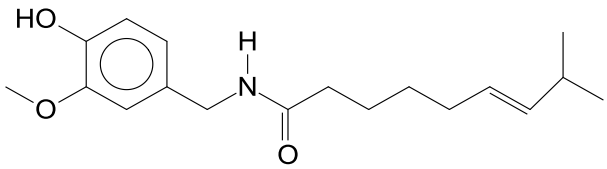
[3]

[Total: 15]

3 **(a)** Allyl isothiocyanate (AITC) is responsible for the pungent taste of wasabi while capsaicin is an active component of chilli pepper and is found in spiced products like curry.



AITC

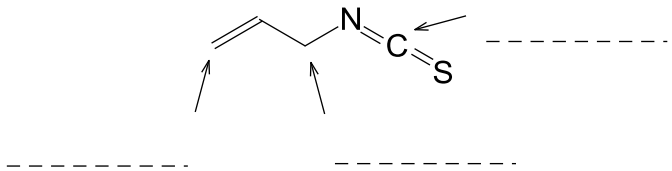


Capsaicin

(i) Using your concept of VSEPR, state the shape about the carbon labelled 1 and 2 on AITC.

Carbon 1: ……. Carbon 2: ……..… [2]

(ii) State the type of hybridisation of carbons indicated in AITC.



[2]

(iii) Besides the ether group 

, state the other functional groups that are present in Capsaicin.

…….[3]

(iv) Ignoring the effect of the –N=C=S group, write an equation showing how AITC reacts with liquid IBr. Hence, with reference to the *Data Booklet* and given that the bond energy of I-Br to be 180 kJ mol^{-1}, determine the enthalpy change of reaction when AITC reacts with liquid IBr.

[2]

(v) Using your knowledge in chemical bonding, suggest why the burning sensation of capsaicin cannot be washed away with water.

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[2]

(vi) Draw the structural formula of the products formed when capsaicin is reacted with hot aqueous potassium hydroxide.

[You are to ignore the effect of the  group]

[2]

[Total: 13]

4 (a) Phosgene is a compound with the formula $COCl_2$. It is not to be confused with cobalt(II) chloride with the formula $CoCl_2$.

Phosgene is produced industrially with carbon monoxide and chlorine gas.

$$CO\ (g) + Cl_2\ (g) \rightleftharpoons COCl_2\ (g) \qquad \Delta H^{\ominus} = -107.6\ kJ\ mol^{-1}$$

The K_p of this process is $0.05\ atm^{-1}$ at 300 K. A mixture contains 2 mol of carbon monoxide and 2 mol of chlorine initially was reacted and allow to reach equilibrium. The equilibrium mixture is found to contain 1.5 mol of phosgene.

(i) Draw the Lewis structure of phosgene.

[1]

(ii) Write an expression for K_p for the equilibrium between CO, Cl_2 and phosgene and hence using the information provided calculate the total pressure of the system at equilibrium.

[3]

(iii) Suggest if chlorine or phosgene will deviate more from ideal gas behaviour.

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[2]

(b) Crystals of hydrated cobalt(II) chloride, $CoCl_2.6H_2O$, lose water when they are heated, forming anhydrous cobalt(II) chloride, $CoCl_2$.

$$CoCl_2.6H_2O(s) \rightarrow CoCl_2(s) + 6H_2O(l)$$

(i) The standard enthalpy change for the reaction, $\Delta H^{\ominus}$, is +88.1 kJ mol^{-1}. Given that the calculation for entropy change to be similar to that of enthalpy change, use the following entropy data to determine the standard entropy change of the reaction at 298 K. Give your answer to **four** significant figures.

Compound	$S^{\ominus}$ **/ J $mol^{-1}K^{-1}$**
$CoCl_2.6H_2O$ (s)	343.0
$CoCl_2$ (s)	109.2
H_2O (*l*)	69.9
H_2O (g)	188.7

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…….

[1]

(ii) Hence, explain by using calculation, whether hydrated cobalt(II) chloride can be stored at 298K without decomposition.

[2]

(c) With the aid of a chemical equation, explain why a solution of cobalt(II) chloride has a pH of 4.6.

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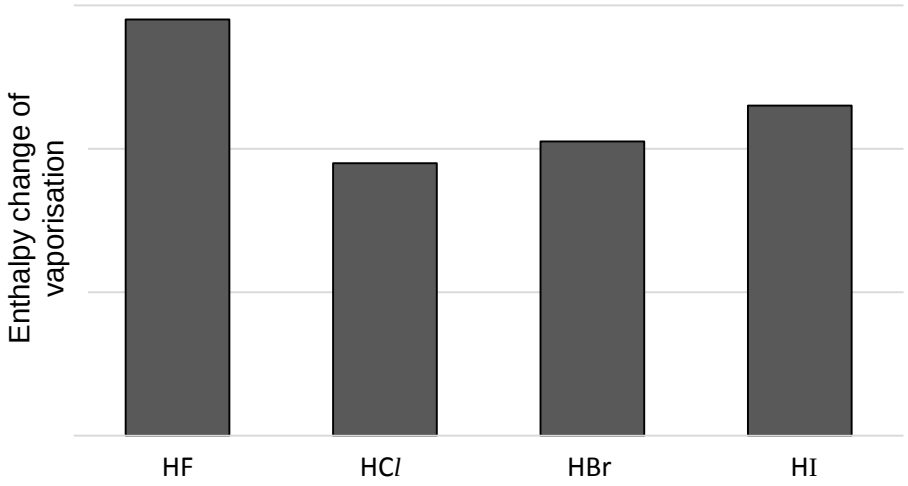
[2]

[Total: 11]

5 Group VII hydrides are colourless gases at room temperature. The figures below shows the relative enthalpy change of vaporisation of the hydrides.

Figure 1: Enthalpy change of vaporisation of H*X*



(a) With reference to **Figure 1**, explain the abnormally high enthalpy change of vaporisation of hydrogen fluoride.

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[2]

(b) The table below shows the pK_a of the respective compounds when they are dissolved in water.

Compounds	pK_a		Compounds	pK_a
			Hydrogen bromide	-9.00
Hydrogen chloride	-7.00		Hydrogen iodide	-10.00
Methanoic acid	3.77		Water	7.00

(i) Using relevant information from the *Data Booklet*, rank the acid strength of aqueous solution containing HC*l*, HBr and HI, in increasing order. Explain your answer.

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[2]

(ii) Account for the relative acidities of methanoic acid and water.

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[2]

(c) Unlike other Group VII hydrides, hydrogen fluoride, HF, behaves as a weak acid in water.

A solution of HF was titrated against aqueous potassium hydroxide until 25% of the HF present was neutralised.

(i) Write the acid dissociation constant expression, K_a, for HF.

[1]

(ii) Given that the pH of the resulting solution described above is 2.88, calculate K_a of HF.

[3]

(d) One of the most common ways to make hydrogen chloride is to react sodium chloride with concentrated sulfuric acid, H_2SO_4 or concentrated phosphoric(V) acid, H_3PO_4. Both reactions occur similarly, releasing white fumes of gas.

(i) Construct a balanced equation involving sodium chloride and concentrated phosphoric(V) acid.

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[1]

(ii) In the reaction with sodium bromide, concentrated sulfuric acid produces a reddish-brown solution while concentrated phosphoric(V) acid produces white fumes.

Suggest a reason for the observations above.

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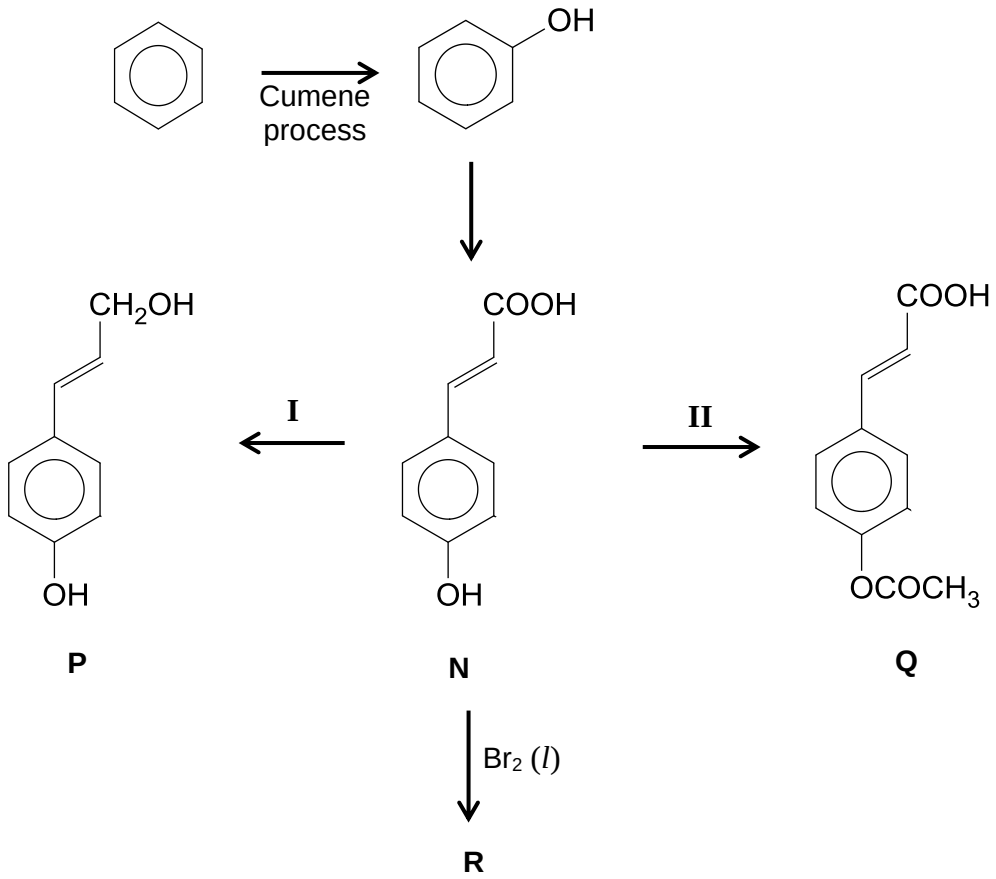
[1]

[Total: 12]

6 **(a)** The chemical structure and some reactions involving compound **N** are shown below.



(i) State the reagents and conditions involved in Steps **I** and **II**.

Step **I**: ……..…..

Step **II**: ……..

[2]

(ii) Draw the structure of organic product **R**.

[1]

(iii) Propose a chemical test to distinguish between **P** and **N**, in which a positive test is observed for **P only**. Write a balanced chemical equation for the reaction that has occurred.

Test: ……

Observation: ……

Equation:

[3]

(b) In the cumene process one mole of benzene reacts with one mole of propene in the presence of oxygen from air to form phenol and organic substance **T**. Substance **T** does not give any positive observation with diammine silver complex or phosphorus pentachloride.

(i) From the information provided, identify substance **T**.

[1]

(ii) Hence, with an aid of a chemical equation, show how the functional group in substance **T** can be positively identified.

Observation:……..

Equation:

[2]

[Total: 9]

END OF PAPER