TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	

H2 CHEMISTRY

9729/02

Paper 2 Structured Questions

19 September 2019

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name and civics group in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams, graphs or rough working.

Do not use paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

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

The number of marks is given in brackets [ ] at the end of each question or part question.

Examiner's Use		
Paper 1	**MCQ**	**/ 30**
Paper 2	**Q1**	**/ 14**
	Q2	**/ 9**
	Q3	**/ 13**
	Q4	**/ 12**
	Q5	**/ 11**
	Q6	**/ 16**
		/ 75
Paper 3		**/ 80**
Paper 4		**/ 55**
Total		**/ 100**
Grade		

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

1 **(a)** Carbon forms compounds with Group 16 elements such as oxygen, sulfur and selenium. The properties of some of these compounds are given below.

compound	structure	net dipole moment	boiling point / °C
CO_2	O=C=O	0	sublimes
CS_2	S=C=S	0	46
COS	S=C=O	0.71	–50
COSe	Se=C=O	0.73	–22

(i) Explain, in terms of structure and bonding, the difference in the boiling points of CS_2 and COS.

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……[2]

(ii) Explain why

- CO_2 has no net dipole moment.
- COSe has a greater net dipole moment than COS.

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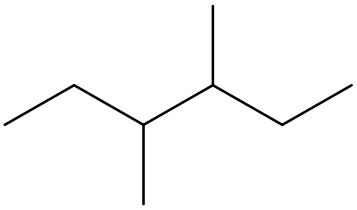
……[2]

Carbon forms the backbone of organic compounds. Hydrocarbons are the simplest organic compounds that contain carbon and hydrogen.

(b) Compound **A** is an isomer of the hydrocarbon octane, C_8H_{18}.



A

Controlled chlorination of compound **A** in the presence of UV light produces different mono-chlorinated products with a molecular formula of $C_8H_{17}Cl$.

(i) Suggest the total number of constitutional isomers which can be formed from the possible mono-chlorination of compound **A**. Draw the structural formulae of any **two** of these products.

Total number of possible mono-chlorinated products = ...

[3]

(ii) Draw the **skeletal** formula of the isomer of octane which could produce **only one** possible mono-chlorinated product if it undergoes free radical substitution.

[1]

(c) Besides reaction of alkanes with halogens, the process of thermal cracking, in which large alkane molecules are broken down into smaller alkanes and alkenes, proceeds via free radical mechanism.

The following are reactions involved when propane undergoes thermal cracking.

$CH_3CH_2CH_3 \longrightarrow \bullet CH_3 + \bullet CH_2CH_3$ -- (1)

$CH_3CH_2CH_3 \longrightarrow \bullet H + \bullet CH_2CH_2CH_3$ -- (2)

$\bullet CH_3 + CH_3CH_2CH_3 \longrightarrow CH_4 + \bullet CH_2CH_2CH_3$ -- (3)

$\bullet CH_2CH_3 \longrightarrow \bullet H + CH_2{=}CH_2$ -- (4)

$\bullet CH_3 + CH_2{=}CH_2 \longrightarrow \bullet CH_2CH_2CH_3$ -- (5)

$\bullet CH_3 + \bullet CH_3 \longrightarrow CH_3CH_3$ -- (6)

$2 \bullet CH_2CH_3 \longrightarrow CH_3CH_3 + CH_2{=}CH_2$ -- (7)

(i) Reactions (1) and (2) are termed initiation steps. By quoting relevant data from the *Data Booklet*, deduce which one is more likely to occur.

……

……[1]

(ii) From reactions (3) to (7), identify those which may be termed propagation steps in the mechanism.

……[1]

(iii) Which gas, if detected in the product mixture, would support the occurrence of both reactions (2) and (4)?

……[1]

(iv) Suggest why reaction (7) may be termed a *disproportionation* reaction.

……

……[1]

(d) Methanoic acid, H_2CO_2, is the simplest carboxylic acid.

Draw a dot-and-cross diagram of methanoic acid. Suggest the shape around the carbon atom in methanoic acid.

Shape around C atom ……..

[2]

[Total: 14]

2 Hydrogen peroxide reacts with acidified iodide ions to liberate iodine, according to the following equation:

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

In investigations of this reaction, the following results were obtained by varying the volumes of hydrogen peroxide and iodide ions.

experiment	volume of H_2O_2 / cm^3	volume of I^- / cm^3	volume of H_2O / cm^3	initial rate / mol dm^{-3} s^{-1}
1	20.0	20.0	20.0	1.2×10^{-2}
2	20.0	30.0	10.0	1.8×10^{-2}
3	50.0	10.0	0.0	1.5×10^{-2}

(a) Explain why water was added to experiments 1 and 2.

……..

……..[1]

(b) The reaction was determined to be **zero order** with respect to hydrogen ions.

(i) Sketch the rate-concentration graph for H^+ ions.

[1]

(ii) Determine the order of reaction with respect to the other two reactants.

Hence, write down the rate equation.

[3]

(c) In order to further investigate the kinetics of the reaction, experiments 4 and 5 were conducted. The following results were obtained by varying the concentrations of hydrogen peroxide and iodide ions.

experiment	initial $[H_2O_2(aq)]$ / mol dm^{-3}	initial $[I^-(aq)]$ / mol dm^{-3}
4	0.020	0.500
5	0.050	1.000

The half-life of hydrogen peroxide was 9.6 min in experiment 4. Explain and predict the half-life of hydrogen peroxide in experiment 5.

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……...

……..…….[2]

(d) An alternative method of investigating the rate of the above reaction is by withdrawing aliquots at specified time intervals and titrating the iodine formed in each aliquot with sodium thiosulfate solution.

Suggest how the reaction can be quenched at specified time intervals.

……..

……..[1]

(e) Hydrogen peroxide decomposes easily. Suggest a method whereby the shelf-life of the hydrogen peroxide solution could be increased.

……..

……..[1]

[Total: 9]

3 Lithium forms various compounds used for a wide range of purposes. For example, Li_2CO_3 is used as a mood-stabilising drug and LiF is used to record ionising radiation exposure from gamma rays, beta particles and neutrons.

(a) Numerical values of the solubility products of some lithium salts at 298 K are given in the table below.

salt	solubility product
LiF	2.68×10^{-3}
Li_2CO_3	2.14×10^{-2}
Li_3PO_4	3.20×10^{-9}

(i) Write an expression for the solubility product, K_{sp}, of lithium phosphate, including its units.

[2]

(ii) Using the data above, calculate a value for the solubility of lithium phosphate.

[2]

(iii) LiF was precipitated when equal volumes of a solution of 0.050 mol dm^{-3} $LiNO_3$ and a solution of KF were mixed.

Calculate the minimum concentration of the KF solution required for precipitation to occur.

[2]

(iv) Describe and explain how the solubility of Li_2CO_3 is affected by adding solid Na_2CO_3 into the solution.

……

……

……

……[2]

(b) When a precipitate is formed, $\Delta G^{\ominus}_{ppt}$, in J mol^{-1}, is given by the following expression.

$$\Delta G^{\ominus}_{ppt} = 2.303\ RT \log K_{sp}$$

For lithium sulfate, Li_2SO_4, K_{sp} = 128 $mol^3\ dm^{-9}$ at 298 K.

Using the above expression, determine whether lithium sulfate is soluble in water at 298 K. Explain your answer.

[2]

(c) Another use of Li_2CO_3 is in the processing of metal oxides. When Li_2CO_3 decomposes, it forms Li_2O solid and CO_2 gas according to the following equation.

$$Li_2CO_3(s) \rightarrow Li_2O(s) + CO_2(g)$$

(i) Calculate the standard enthalpy change of reaction for the decomposition of Li_2CO_3 using the following standard enthalpy changes of formation, $\Delta H_f^{\ominus}$.

compound	Li_2CO_3	Li_2O	CO_2
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−1216	−596	−394

[1]

(ii) The entropy change for the decomposition reaction is positive. Explain the effect on spontaneity of this decomposition reaction as temperature increases.

[2]

[Total: 13]

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

(a) Chemical companies manufacture containers filled with liquid butane for use by campers. The complete combustion of butane produces carbon dioxide and water. The enthalpy change of combustion of butane is –3000 kJ mol^{-1}.

A camper estimates that the liquid butane left in a container would give 1.2 dm^3 of butane gas (measured at room temperature of 20 °C and pressure of 1 atm).

(i) Calculate the mass of water at room temperature that could be brought to boiling point at 100 °C by completely burning this mass of butane, given that the process is only 80% efficient.

[3]

(ii) Suggest a reason why the combustion process is only 80% efficient.

…….

…….[1]

(b) When burnt in a limited supply of air, butane forms carbon and water. The enthalpy change of this reaction is –1400 kJ mol^{-1}.

(i) Construct a balanced equation for this reaction.

…….[1]

(ii) Explain why the enthalpy changes of the two combustion reactions in **(a)** and **(b)** are different.

…….[1]

(iii) State the quantitative information that can be obtained from this difference in enthalpy changes.

…….[1]

(c) The carbon-oxygen *bond energy* in carbon monoxide, CO, is 1077 kJ mol^{-1}.

Carbon monoxide can be formed by the following reaction:

$$C(s) + CO_2(g) \rightarrow 2CO(g) \qquad \Delta H^{\ominus} = +172.5 \text{ kJ mol}^{-1}$$

(i) Explain, with the aid of a suitable equation, what is meant by the term *bond energy* of carbon monoxide.

……

……

……[2]

(ii) Determine the enthalpy change of atomisation of carbon by using relevant bond energy data from the *Data Booklet* to complete the energy cycle below. Include relevant information in your cycle.

$$C(s) + CO_2(g) \xrightarrow{\Delta H = +172.5 \text{ kJ mol}^{-1}} 2CO(g)$$

[3]

[Total: 12]

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

A student wanted to study the following reaction.

$$2Au^{3+} + 3Zn \rightleftharpoons 2Au + 3Zn^{2+}$$

He first sets up an electrochemical cell which comprises of Au^{3+}/Au and Zn^{2+}/Zn half-cells prepared under standard conditions.

(a) **(i)** Draw a fully labelled diagram of the electrochemical cell under standard conditions.

[2]

(ii) Given that $E^{\ominus}_{Au^{3+}/Au}$ is +1.50 V, calculate the $E^{\ominus}_{cell}$ of this cell.

[1]

(iii) Suggest a replacement transition element ion-ion half-cell for the Zn^{2+}/Zn half-cell so that the direction of electron flow is reversed.

……[1]

(b) When the reaction in **(a)** begins, $[Au^{3+}]$ starts to decrease while $[Zn^{2+}]$ increases. In the study of electrochemical cells, the *Nernst equation*, given below, can be applied to determine the cell potential under non-standard conditions.

$$E_{cell} = E^{\ominus}_{cell} - \frac{0.0592}{n} \log_{10} Q$$

where n is the number of moles of electrons transferred and Q is the reaction quotient given by $\frac{[Zn^{2+}]}{[Au^{3+}]}$.

(i) Using your answer in **(a)(ii)**, calculate the new E_{cell} using the Nernst equation, when $[Au^{3+}]$ and $[Zn^{2+}]$ are 0.02 mol dm^{-3} and 2.47 mol dm^{-3} respectively.

[1]

(ii) Suggest the value of E_{cell} when the reaction goes to completion.

[1]

(c) The redox reaction in **(a)** is an example of a spontaneous reaction which proceeds as predicted by the cell potential. However, not every chemical reaction agrees with the theoretical prediction. One example is the reaction between acidified $K_2Cr_2O_7$ and water.

(i) Using information from the *Data Booklet*, calculate $\Delta G^{\ominus}$ for the reaction between acidified $K_2Cr_2O_7$ and water. Based on your value for $\Delta G^{\ominus}$, comment on the spontaneity of the reaction.

[3]

(ii) The reaction between water and acidified $K_2Cr_2O_7$ has an $E^{\ominus}_{cell}$ greater than 0 V under standard conditions, yet the reaction does not proceed. Suggest a reason for this observation.

……

……[1]

(iii) Another example of a reaction that does not agree with the theoretical prediction is the reaction between Cu^{2+} and I^- according to the equation below.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightleftharpoons 2CuI(s) + I_2(aq) \qquad E^{\ominus}_{cell} = -0.39\ V$$

White precipitate of CuI is formed during the reaction. Suggest a reason why the reaction proceeds despite the $E^{\ominus}_{cell}$ being less than 0 V.

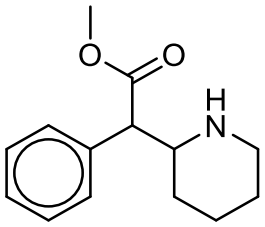
……

……[1]

[Total: 11]

6 Adrenaline is a naturally occurring hormone and stimulant released in the body during times of danger or stress. Stimulant drugs that can mimic the effect of adrenaline have been developed for treatment of various conditions.

(a) Methylphenidate is a stimulant drug commonly used in the treatment of Attention Deficit Hyperactive Disorder (ADHD).



methylphenidate

(i) Draw the structures of the organic products formed when methylphenidate is heated with dilute hydrochloric acid.

[2]

(ii) An isomer of methylphenidate, compound **X**, is neutral and has the following structural properties:

- contains one aromatic six-membered ring
- contains 

Suggest a structure for compound **X** and state its isomeric relationship to methylphenidate.

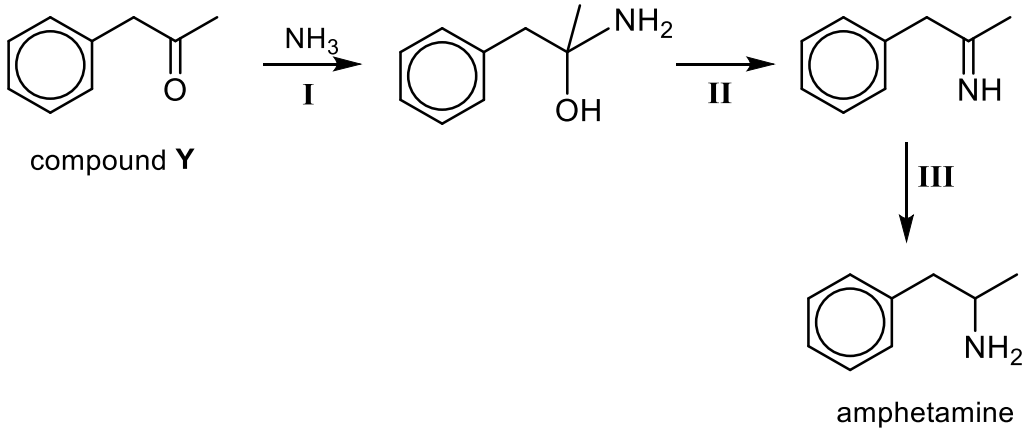
X

isomeric relationship to methylphenidate:

……..

[2]

(b) Another stimulant, amphetamine, is prepared commercially from compound **Y** as shown below.



compound **Y**

amphetamine

(i) Suggest the type of reaction occurring in:

Step **II** ……

Step **III** …… [2]

(ii) Suggest suitable reagents and conditions for the conversion in step **III**. You may assume the R=NH group reacts in a similar manner to the carbonyl group.

reagents and conditions …… [1]

(iii) Reaction **I** which occurs between compound **Y** and NH_3 is a nucleophilic addition reaction.

Draw the mechanism for this reaction, given that in the rate-determining step, the nucleophilic attack by NH_3, results in an intermediate species containing both a positive and negative charge.

[3]

(iv) With reference to the mechanism you have drawn in **(iii)**, explain why the product from step **I** is expected to be optically inactive.

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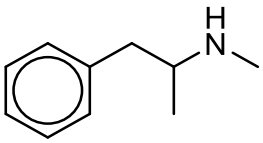
……[2]

(c) Methamphetamine is a stimulant which has a structure similar to amphetamine.



methamphetamine

(i) The hydrochloride salt of methamphetamine exists as colourless crystals.

Methamphetamine is immiscible with water whereas the salt is soluble in water.

With reference to the interactions formed between each of the compounds and water, explain the difference in the solubility of methamphetamine and its salt in water.

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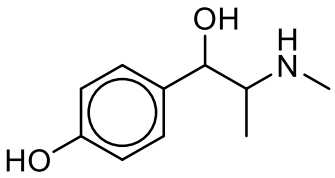
……[2]

(ii) In the human body, methamphetamine can be converted to compound **Z**.



Z

Describe a simple chemical test which could be used to distinguish between methamphetamine and compound **Z**.

You should state the reagents and conditions required, together with the expected observations for each compound.

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……[2]

[Total: 16]

End of Paper 2