



VICTORIA JUNIOR COLLEGE
JC 2 PRELIMINARY EXAMINATION
Higher 2

CANDIDATE
NAME

CT GROUP

CHEMISTRY

9729/02

Paper 2 Structured

15 September 2020

Candidates answer on the Question Paper.

2 hours

Additional Materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and CT group 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 working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions.

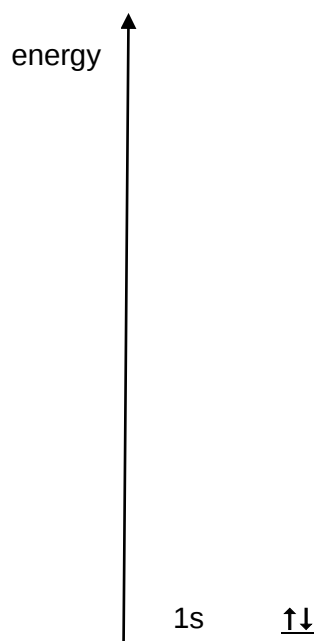
The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
1	/ 20
2	/ 11
3	/ 8
4	/ 19
5	/ 17
Total	/ 75

This document consists of **17** printed pages and **1** blank page..

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

- 1 (a) (i) Complete the diagram to show the relative energies of all the electrons in an iron atom.



[1]

- (ii) Write an equation for the second ionisation energy of iron.

..... [1]

- (iii) Explain why the second ionisation energy of iron is lower than that of chromium.

.....

 [1]

- (b) A piece of rusted iron was analysed to find out how much of the iron had been oxidised to rust (also known as hydrated iron(III) oxide). A small sample of the rusted iron was dissolved in excess dilute sulfuric acid to give 250 cm³ of solution. The resultant solution contains Fe²⁺ and Fe³⁺ from iron and rust respectively.

- (i) 25.0 cm³ of this solution required 16.90 cm³ of 0.0200 mol dm⁻³ KMnO₄ for complete oxidation of Fe²⁺. Calculate the amount of Fe²⁺ in 25.0 cm³ of the solution.
 $5\text{Fe}^{2+} + \text{MnO}_4^- + 8\text{H}^+ \rightarrow 5\text{Fe}^{3+} + \text{Mn}^{2+} + 4\text{H}_2\text{O}$

[1]

- (ii) To another 25.0 cm³ of the solution, an oxidising agent was added to convert all the Fe²⁺ ions present to Fe³⁺ ions. The Fe³⁺ ions were then titrated with 0.100 mol dm⁻³ EDTA⁴⁻ solution and 17.60 cm³ was required.

Assuming 1 mol of EDTA⁴⁻ reacts with 1 mol of Fe³⁺, calculate the amount of Fe³⁺ in 25.0 cm³ of the solution.

[1]

- (iii) From your answers in (b)(i) and (b)(ii), calculate the amount of original Fe³⁺ in 250 cm³ of the rusted iron solution.

[1]

- (iv) Determine the percentage of iron that had been oxidised to rust in the sample.

[1]

- (c) (i) Explain if a real gas, such as N₂O₃, behaves more or less ideally at:

- high pressures

.....

- high temperatures

.....

[2]

- (ii) At room temperature, N_2O_3 dissociates as shown.



This dissociation involves homolytic fission of N–N bond.

Draw a 'dot-and-cross' diagram for the N_2O_3 molecule.

[1]

- (iii) Hence, state the shape around **each** N atom in the N_2O_3 molecule.

..... [1]

- (iv) Suggest the common feature of NO and NO_2 that allows each of them to undergo dimerisation to form N_2O_2 and N_2O_4 respectively.

..... [1]

- (d) (i) With an appropriate sketch of Boltzmann distribution, explain how a catalyst is able to increase the rate of a chemical reaction for a given temperature T.

.....

 [2]

- (ii) On the sketch in d(i), draw a new distribution curve at a higher temperature T' , **clearly labelled T'** .

[1]

- (e) **X** is an organic liquid that is found as a contaminant in crude oil. It contains only C, H and S. When 0.841 g of **X** was subjected to complete combustion, 1.76 g of CO_2 , 0.360 g of H_2O and a gas which can decolourise acidified potassium manganate (VII) were formed.

(i) What is the empirical formula of **X**?

[2]

- (ii) **X** is unsaturated and has a structure in which all the carbon and sulfur atoms are connected together in a five-membered ring. Draw the structure of **X**.

[1]

- (iii) Hence, construct the equation for the complete combustion of **X**.

..... [1]

- (iv) **X** behaves similarly like benzene in its reactions with electrophile. Suggest a possible structure when **X** is reacted with CH_3COCl in the presence of a Lewis acid catalyst.

[1]

[Total: 20]

- 2 (a)** Water is a very stable molecule and was thought to be a chemical element. In 1800, one of the earliest form of electrochemical cells was invented and scientists, Nicholson and Carlyle, caused a big stir by decomposing water into hydrogen and oxygen by electrolysis.

In one experiment to electrolyse water, copper was used at both electrodes. A gas was generated only at one electrode during the electrolysis.

Write half-equations for the reaction that took place during the electrolysis.

anode:

cathode:[1]

- (b)** In another electrolysis experiment with copper electrodes, the electrolyte was replaced with an acidified solution of copper(II) sulfate, CuSO_4 .

During this electrolysis, the mass of cathode increased and H_2 gas was evolved.

- (i)** When a constant current of 2.0 A was applied for 30 min, the mass of cathode increased by 0.635 g. Calculate the volume of H_2 evolved, measured at r.t.p.

[3]

- (ii)** When the concentration of Cu^{2+} in the electrolyte was $0.100 \text{ mol dm}^{-3}$, $\text{Cu}(\text{OH})_2(\text{s})$ started to precipitate at pH 4.84.

Write the expression for the solubility product, K_{sp} , of $\text{Cu}(\text{OH})_2(\text{s})$.

..... [1]

- (iii)** Calculate the K_{sp} of $\text{Cu}(\text{OH})_2(\text{s})$, stating the units.

[2]

- (c) For a reversible reaction, $M^{3+}(aq) + ne^{-} \rightleftharpoons M^{(3-n)+}(aq)$, the Nernst equation below shows the dependence of its reduction potential, $E_{M^{3+}/M^{(3-n)+}}$, to the concentration of M^{3+} and $M^{(3-n)+}$ as expressed in Q , at 298 K.

$$E_{M^{3+}/M^{(3-n)+}} = E^{\ominus}_{M^{3+}/M^{(3-n)+}} - \frac{0.0252}{n} \ln Q$$

where $E^{\ominus}_{M^{3+}/M^{(3-n)+}}$ is the standard reduction potential, n is the amount of electron transferred and Q is the reaction quotient, a measure of the relative concentrations of products and reactants present in a reaction at a given time.

For the reversible reaction, $Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s)$,

$$Q = \frac{1}{[Cu^{2+}]}$$

Q is numerically equal to the equilibrium constant, K_c , when the reaction achieves dynamic equilibrium.

- (i) Using Nernst equation, calculate the $E_{Cu^{2+}/Cu}$ at the start of the precipitation during the electrolysis in (b).

[1]

- (ii) Your answer to (c)(i) is also the reduction potential of equation 1 when the precipitation of $Cu(OH)_2$ just started as described in b(ii).



Calculate the standard reduction potential of equation 1 using the Nernst equation.

[2]

- (iii) Suggest why the electrolysis in (b) might stop if the electrolyte pH is allowed to rise above 4.84.

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 [1]

[Total: 11]

- 3 (a)** A yellow solution of chromate(VI), CrO_4^{2-} , is slowly reduced to green tetrahydroxochromate(III) ion, $[\text{Cr}(\text{OH})_4]^-$, in an alkaline medium by arsenic(III) oxide, As_2O_3 . The relevant half-equation involving arsenic oxides is given below.



- (i)** Write a balanced equation for the reaction between chromate(VI) and arsenic(III) oxide in an alkaline medium.

..... [1]

- (ii)** Briefly suggest, with explanation, one experimental method by which the rate of the reaction can be followed.

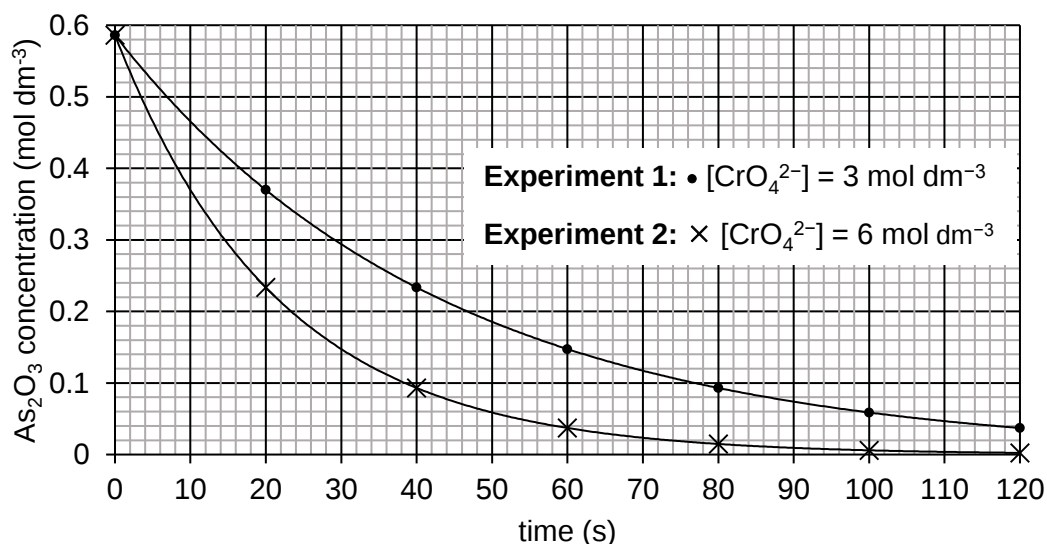
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..... [1]

- (b)** Two experiments were carried out, starting with different initial concentrations of chromate(VI) and the same initial concentration of As_2O_3 of 0.58 mol dm^{-3} .

At a fixed time interval, a portion of the reaction mixture was quenched and analysed to determine the concentration of As_2O_3 . The following graphs were obtained.



- (i) Use your graphs to determine the order of reaction with respect to As_2O_3 and CrO_4^{2-} , showing your working clearly.

[3]

- (ii) Write the rate equation for the reaction.

..... [1]

- (iii) The experiment was repeated one more time using 0.58 mol dm^{-3} aqueous chromate(VI) and 0.58 mol dm^{-3} aqueous As_2O_3 .

Suggest **two** differences to the graph of concentration of As_2O_3 (mol dm^{-3}) against time (s) obtained in this repeated experiment compared to that of experiment **1**.

.....

 [2]

[Total: 8]

- 4 (a) MgO is formed from the thermal decomposition of MgSiO_3 , a major component in mineral rock. In this process, SiO_2 is also produced.

- (i) During thermal decomposition of mineral rocks, SO_2 and Al_2O_3 are also produced. Arrange MgO , SO_2 and Al_2O_3 in the order of increasing pH when dissolved in water.

..... [1]

(ii) The melting points of the oxides are given below.

Compound	Melting point / °C
MgO	more than 2000
Al ₂ O ₃	more than 2000
SiO ₂	1710
SO ₂	-72

Explain the melting point of these oxides in terms of their structure and bonding.

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..... [3]

(iii) MgO is sparingly soluble in water but much more soluble in magnesium chloride solution. Explain the higher solubility of magnesium oxide in magnesium chloride solution with relevant equations.

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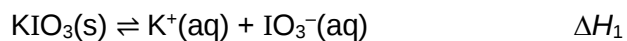
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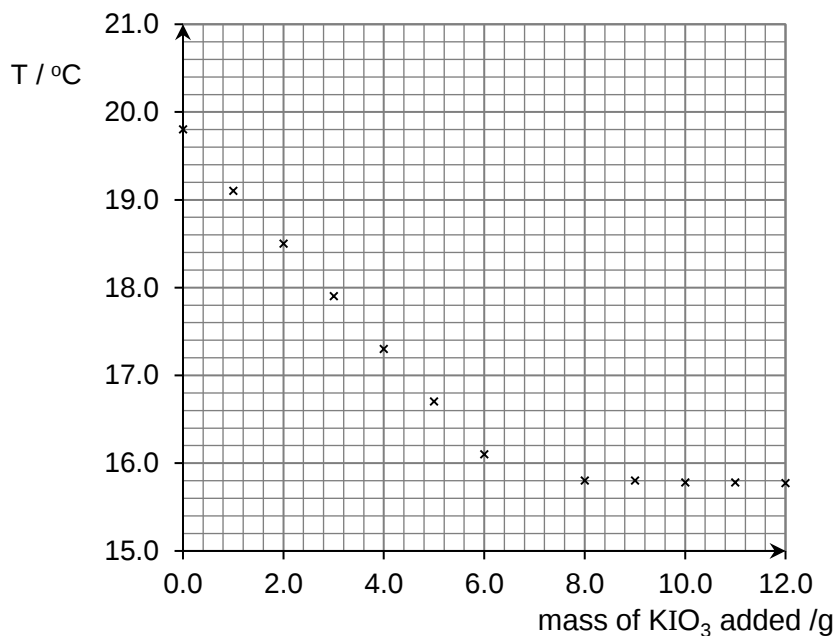
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..... [3]

(b) Potassium iodate (KIO_3 , $M_r = 214.0$) dissolves to a limited extent in water.



To find ΔH_1 , small portions of solid were successively added to 100 cm^3 of water in a well-insulated container. After each addition, the mixture was stirred extensively and the lowest temperature was recorded. The results were plotted below.



You may assume that

- the specific heat capacity of solution is $4.18 \text{ J cm}^{-3} \text{ K}^{-1}$,
- the volume of solution remains the same during the experiment, and
- the heat capacity of the insulated container is zero.

(i) Use the graph above to calculate the solubility of KIO_3 in mol dm^{-3} .

[3]

(ii) Calculate the enthalpy change of dissolution of KIO_3 , ΔH_1 .

[2]

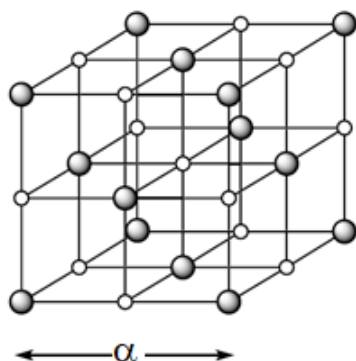
- (iii) $\Delta S^\ominus$ for the dissolution of some ionic salts could have a **negative** sign. Suggest why this is so.

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..... [1]

- (c) The binary compounds of lithium, LiX (X = H, F, Cl, Br, and I), all crystallise in the cubic lattice similar to NaCl lattice. One unit cell of this structure (small circles = Li^+ , large circles = X^-) is shown below. The length of the edge of the unit cell is abbreviated α .



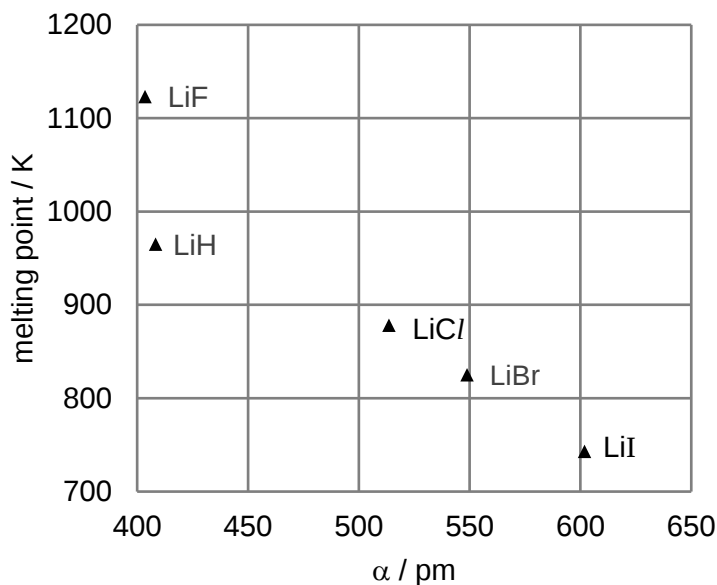
compound	α / pm
LiH	408.3
LiF	403.5
LiCl	513.6
LiBr	548.9
LiI	601.9

$$1 \text{ pm} = 1 \times 10^{-10} \text{ cm}$$

- (i) Given that there are four Li^+ ions and four X^- ions in one unit cell, calculate the mass of one unit cell and hence the density of LiCl in g cm^{-3} .
[Density, $\rho = \text{mass} / \text{volume}$]

[2]

The melting points of the lithium halides and of lithium hydride are plotted against the unit cell edge length, α , as shown below.



- (ii) Explain the relationship observed between α values and melting points of the lithium halides.

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..... [2]

- (iii) Lithium hydride and lithium fluoride have similar α values. Suggest an explanation on why the melting point of lithium hydride is much lower than that of lithium fluoride.

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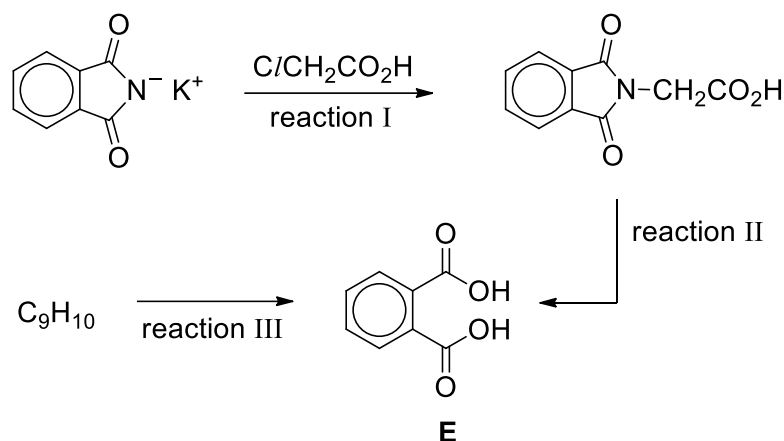
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..... [2]

[Total: 19]

5 (a) The following reaction scheme involves compound **E**, benzene-1,2-dicarboxylic acid.



(i) Suggest **two** structures of C_9H_{10} that could be used in reaction III to form compound **E**.

[1]

(ii) Suggest the reagents and conditions for reaction III.

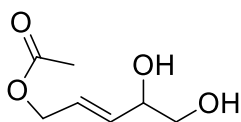
..... [1]

(iii) State the types of reaction for reactions I and II.

reaction I:

reaction II: [1]

(b) The structure of compound **G** is shown below.



compound **G**

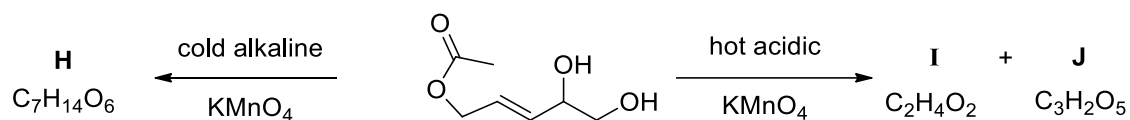
(i) State the types of stereoisomerism exhibited by compound **G** and the total number of stereoisomers of **G**.

..... [1]

(ii) Draw all the possible stereoisomers of compound **G**.

[2]

(iii) Compound **G** reacts with KMnO_4 under different conditions to give different products.

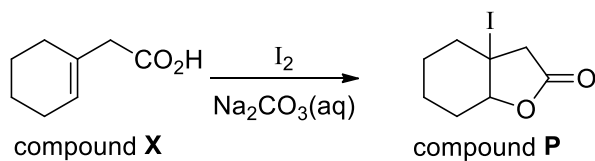


Suggest structures for compounds **H**, **I** and **J**.

H	I	J
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[3]

- (c) In the presence of a base such as aqueous sodium carbonate, compound **X** can react with iodine to form compound **P** as shown below.

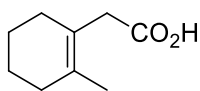


- (i) Propose a three-step mechanism for this reaction. The first step of the mechanism involves the neutralisation of **X** by carbonate. Show clearly any intermediates that may be formed, all charges and use curly arrows to indicate the movement of electron pairs, and state the role of iodine in this reaction.

Role of iodine:

[3]

- (ii) Describe a chemical method with not more than two steps for distinguishing between compounds **X** and **Y**. State the observations clearly.



compound **Y**

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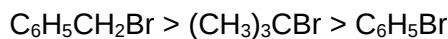
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..... [3]

- (d) When the compounds shown below were reacted with aqueous sodium hydroxide at 55 °C, the rate of reaction decreases in the following order.



- i. Both $\text{C}_6\text{H}_5\text{CH}_2\text{Br}$ and $(\text{CH}_3)_3\text{CBr}$ undergo unimolecular nucleophilic substitution with aqueous sodium hydroxide. Explain their relative rates of reaction.

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..... [1]

- ii. Explain why $\text{C}_6\text{H}_5\text{Br}$ has almost no reaction with aqueous sodium hydroxide at 55 °C.

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..... [1]

[Total: 17]