

Catholic Junior College
JC 2 Preliminary Examination
Higher 2

CANDIDATE
NAME

CLASS

CHEMISTRY

9729/01

Paper 1 Multiple Choice

18 September 2025

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

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

Write your name, class and NRIC/FIN number on the Answer Sheet in the spaces provided.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer. Any rough working should be done in this booklet.

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

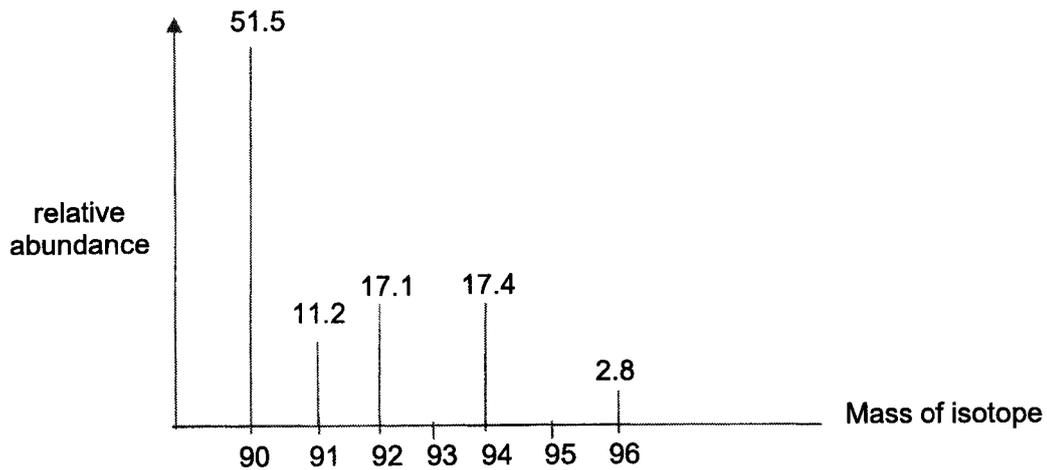
This document consists of **11** printed pages and **1** blank page.

9729/01 CJC JC2 Preliminary Examination 2025

[Turn over

2

- 1 The relative abundances of all the isotopes present in a sample of zirconium are shown.



What is the relative atomic mass of zirconium calculated from these data?

- A** 91.1 **B** 91.3 **C** 91.6 **D** 93.1
- 2 In the interhalogen compound ICl , there is a single polar covalent bond.
Which of the following statement(s) helps to explain the polarity of the $I-Cl$ covalent bond?
- Cl is more electronegative than I .
 - The outer shell electronic configuration of both elements is $s^2 p^6$.
 - The outer shell electrons are more shielded from nuclear charge in I than they are in Cl .
- A** 1, 2 and 3 **B** 1 and 2 **C** 1 and 3 **D** 1 only
- 3 In which pairs of compounds does the first molecule have a smaller bond angle than that in the second molecule?

- | | | |
|---|--------|---------|
| 1 | NF_3 | CCl_4 |
| 2 | H_2S | H_2O |
| 3 | SF_6 | CS_2 |
- A** 1, 2 and 3 **B** 1 and 2 **C** 2 and 3 **D** 3 only

3

- 4 The table shows the boiling point of three alcohols.

	boiling point / °C
pentan-1-ol	138
2-methylbutan-2-ol	129
2,2-dimethylpropanol	114

What is responsible for the differences in boiling point?

- A** different relative molecular mass
B different number of carbon-carbon bonds
C weaker hydrogen bonding between branched chain molecules
D more extensive instantaneous dipoles-induced dipoles attractions between straight chain molecules
- 5 Which statements about the behaviour of Group 17 elements from chlorine to iodine are correct?
- A** The elements become stronger oxidising agents.
B The volatility of the elements decreases.
C The thermal stability of the hydrogen halides increases.
D The bond energy of H-X bond increases.
- 6 0.10 mol of an oxide of nitrogen (N_xO_y) is mixed with an excess of hydrogen and passed over a catalyst at a suitable temperature.
 The water produced in this reaction has a mass of 7.2 g.
 The ammonia produced requires 200 cm³ of 1.0 mol dm⁻³ HCl for complete neutralisation.

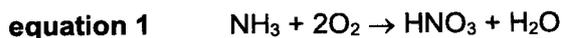
What is the formula of this oxide of nitrogen?

- A** N₂O **B** NO **C** NO₂ **D** N₂O₄
- 7 Sodium thiosulfate is used in the textile industry to remove an excess of chlorine from bleaching processes by reducing it to chloride ions.

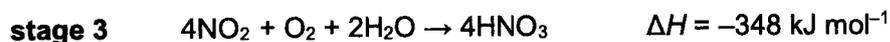
One mole of thiosulfate ions, S₂O₃²⁻, is able to remove 4 moles of chlorine, Cl₂, in this process. In this process, S₂O₃²⁻ is oxidised. What is the resultant sulfur-containing product in this reaction?

- A** HSO₄⁻ **B** S₄O₆²⁻ **C** SO₂ **D** S

- 8 Nitric acid is made industrially by the oxidation of ammonia. The overall equation for the process is shown.



The process happens in three stages. The equations and enthalpy changes for these stages are given.



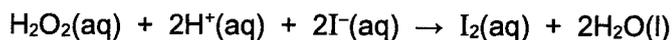
What is the enthalpy change of the process shown in equation 1?

- A $-1480 \text{ kJ mol}^{-1}$
B -370 kJ mol^{-1}
C $-341.5 \text{ kJ mol}^{-1}$
D $+82 \text{ kJ mol}^{-1}$
- 9 A radioactive element has 2 isotopes, **G** and **H**, with half-lives of 3 days and 6 days respectively. An experiment starts with 4 times as many atoms of **G** as of **H**.

Given that radioactive decay is a first-order reaction, how long will it be before the number of atoms of **G** left equals the number of atoms of **H** left?

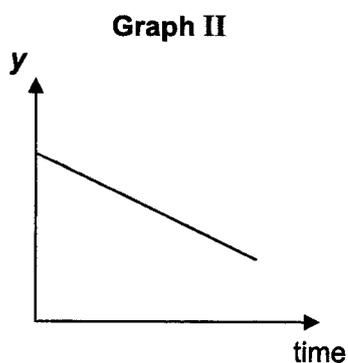
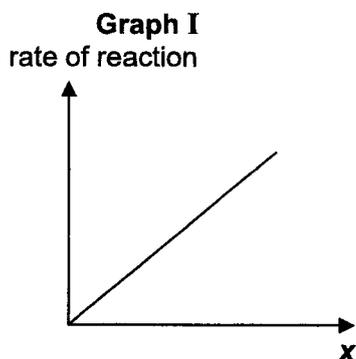
- A 12 days B 15 days C 24 days D 48 days

- 10 The kinetics of the reaction between hydrogen peroxide and acidified iodide ions were investigated.



The rate equation was found to be $\text{rate} = k[\text{H}_2\text{O}_2][\text{I}^-]$

Which of the following shows the correct labelling of the **x**-axis for **Graph I** and **y**-axis for **Graph II**?

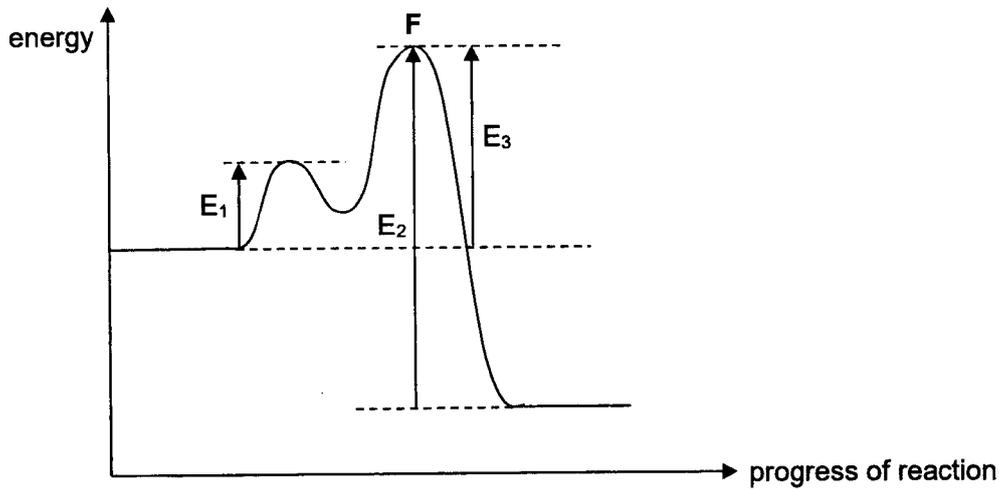


x-axis for **Graph I**

y-axis for **Graph II**

- | | | |
|----------|--------------------------------------|--------------------------------------|
| A | $[\text{I}^-]$ | $[\text{H}_2\text{O}_2][\text{I}^-]$ |
| B | $[\text{H}^+]$ | $[\text{I}_2]$ |
| C | $[\text{H}_2\text{O}_2][\text{I}^-]$ | $[\text{H}^+]$ |
| D | $[\text{H}_2\text{O}_2][\text{H}^+]$ | $[\text{I}^-]$ |
- 11 The reaction between HBr and O₂ is thought to occur via a multi-step mechanism:
- $$\begin{array}{ll} \text{HBr} + \text{O}_2 \rightarrow \text{HO}_2\text{Br} & \text{(slow)} \\ \text{HO}_2\text{Br} + \text{HBr} \rightarrow 2\text{HOBr} & \text{(fast)} \\ \text{HOBr} + \text{HBr} \rightarrow \text{Br}_2 + \text{H}_2\text{O} & \text{(fast)} \end{array}$$
- The overall reaction is $4\text{HBr} + \text{O}_2 \rightarrow 2\text{Br}_2 + 2\text{H}_2\text{O}$.
- Which statement is correct?
- A** The overall order of reaction is 3.
- B** HO₂Br is the only intermediate in the reaction.
- C** HOBr acts as a catalyst in the reaction.
- D** Units of the rate constant is mol⁻¹ dm³ s⁻¹.

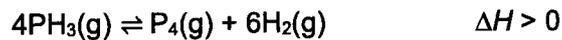
- 12 Which of the following statements is true about the following energy profile for a catalysed reaction shown below?



- 1 The reaction is catalysed by a heterogeneous catalyst.
- 2 The enthalpy change of the reaction is $E_3 - E_2$.
- 3 F is the intermediate formed.
- 4 The second step of the reaction is the rate determining step.

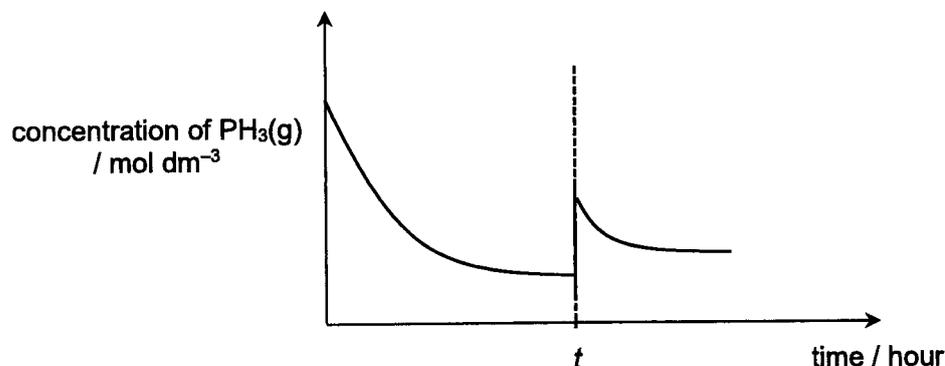
A 2 and 3 B 2 and 4 C 1 only D 4 only

- 13 Phosphine, PH_3 , decomposes to give phosphorus and hydrogen gas.



The graph below shows the change in concentration of PH_3 over time until the reaction mixture reaches equilibrium at a constant temperature of 400 K.

Which of the following is a possible change made at t hour?

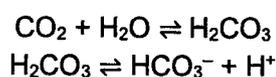


- A reduction of volume of the vessel
- B addition of PH_3
- C removal of P_4
- D addition of a catalyst

- 14 Which statement about the chemical properties of the oxides in the third period of the Periodic Table is true?
- A Na_2O and MgO can be mixed in water to give an approximately neutral solution.
- B Al_2O_3 is soluble in both KOH and HCl .
- C SO_3 is insoluble in water.
- D SiO_2 forms a solution of pH 2 when dissolved in water at room temperature.

- 15 Which one of the following statements about the behaviour of the Group 2 elements from magnesium to barium is correct?
- A They become weaker reducing agents.
- B The electronegativity increases.
- C The thermal stability of the metal carbonate increases.
- D The enthalpy change of hydration of the ions become more exothermic.

- 16 The concentration of carbon dioxide in the blood is regulated by the following equilibria.



During exercise, the production of lactic acid decreases the pH of blood. Which statements about these equilibria are correct when this happens?

- 1 The positions of both equilibria shift left.
 - 2 $[\text{H}^+]$ decreases.
 - 3 HCO_3^- acts as a Bronsted-Lowry acid.
- A 1 only B 2 only C 1 and 3 only D 1, 2 and 3
- 17 Equal volumes of aqueous KI and $0.200 \text{ mol dm}^{-3}$ of $\text{Pb}(\text{NO}_3)_2$ are mixed together to precipitate PbI_2 . Given that the K_{sp} value of PbI_2 is $8.70 \times 10^{-9} \text{ mol}^3 \text{ dm}^{-9}$, which one of the following could have been the initial concentration of KI ?
- A $8.70 \times 10^{-8} \text{ mol dm}^{-3}$
- B $2.95 \times 10^{-4} \text{ mol dm}^{-3}$
- C $5.50 \times 10^{-4} \text{ mol dm}^{-3}$
- D $1.50 \times 10^{-2} \text{ mol dm}^{-3}$

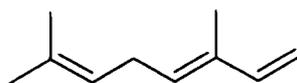
18 Which of the following reactions is ammonia acting as a Brønsted–Lowry base?

- A $\text{NH}_3 + \text{HF} \rightleftharpoons \text{NH}_4^+ + \text{F}^-$
 B $\text{NH}_3 + \text{CH}_3\text{Br} \rightarrow \text{CH}_3\text{NH}_2 + \text{HBr}$
 C $4\text{NH}_3 + [\text{Cu}(\text{H}_2\text{O})_6]^{2+} \rightleftharpoons [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$
 D $\text{NH}_3 + \text{BCl}_3 \rightarrow \text{NH}_3 \cdot \text{BCl}_3$

19 Which statement about benzene and cyclohexene is correct?

- A Both are planar molecules.
 B Both possess delocalised π electrons.
 C Both decolourise aqueous bromine in the presence of finely divided iron.
 D Both undergo complete combustion give the same products.

20 Ocimenes are a group of isomeric hydrocarbons with a sweet herbal scent and are commonly used in perfumes. The structure of one of its isomers is shown below.



β -ocimene

Which statements are correct?

- β -ocimene has a total of four stereoisomers.
- β -ocimene reacts with HBr to produce a major product containing two chiral centres.
- β -ocimene undergoes both electrophilic addition and free radical substitution in the presence of excess bromine in the dark.
- β -ocimene reacts with cold dilute alkaline potassium manganate(VII) to produce a major product with six –OH groups.

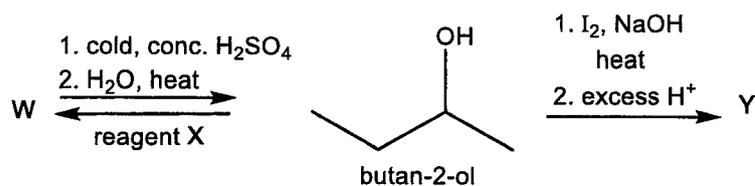
- A 1 and 3 B 2 and 4 C 1, 2 and 3 D 1, 2, 3 and 4

21 Methylbenzene reacts with bromine chloride, BrCl , in different ways, depending on the conditions used.

A reaction is carried out using an excess of methylbenzene in the absence of sunlight and in the presence of an iron-containing catalyst. What is the main reaction taking place?

- A substitution of one bromine atom into the –CH₃ side-chain
 B substitution of one chlorine atom into the –CH₃ side-chain
 C substitution of one bromine atom into the benzene ring
 D substitution of one chlorine atom into the benzene ring

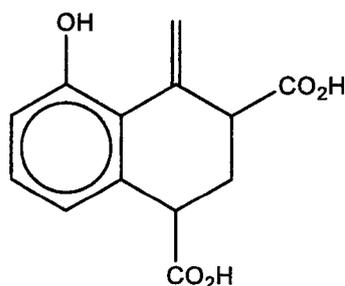
- 22 The diagram shows reactions involving butan-2-ol.



Which row correctly identifies the unknown compounds and reagents?

	W	reagent X	Y
A	2-chlorobut-2-ene	PCl_5	butanoic acid
B	but-2-ene	ethanolic KOH	propanoic acid
C	2-chlorobutane	PCl_5	butanoic acid
D	but-2-ene	conc. H_2SO_4	propanoic acid

- 23 Compound A dissolves in heavy water, D_2O , to form compound B. Compound B contains a number of hydrogen atoms which can be replaced by deuterium, D. [D, deuterium = ^2H]



Compound A

What is the maximum number of deuterium atoms present in one molecule of compound B?

- A 1 B 2 C 3 D 4
- 24 Methanal, HCHO is the simplest aldehyde.
Which statements about methanal is correct?
- All four atoms in methanal lie in the same plane.
 - The carbon atom in methanal has an oxidation number of 0.
 - Complete combustion of 1 mol of methanal requires 1 mol of oxygen gas.
- A 1, 2 and 3 B 1 and 2 C 2 and 3 D 1 only

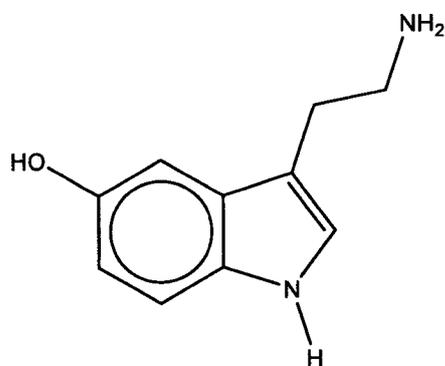
10

- 25 A liquid **P** is sparingly soluble in water. It dissolves readily in cold hydrochloric acid. Evaporation of this solution yields a crystalline solid.

Which could be **P**?

- A** $C_6H_5COCH_3$ **B** $C_6H_5CONH_2$ **C** $C_6H_5NH_2$ **D** C_6H_5OH

- 26 Serotonin is a neurotransmitter molecule.

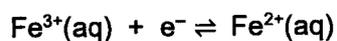
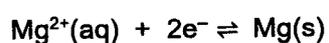


serotonin

Which one of the following reagents will not react with serotonin?

- A** CH_3COCl
B HCl
C $NaOH$
D PCl_5

- 27 A voltaic cell is set up using the Mg^{2+}/Mg and Fe^{3+}/Fe^{2+} half-cells.



$$E^\ominus_{Mg^{2+}/Mg} = -2.38 \text{ V}$$

$$E^\ominus_{Fe^{3+}/Fe^{2+}} = +0.77 \text{ V}$$

Under standard conditions, the cell e.m.f. would be 3.15 V. However, the voltmeter recorded a reading of 3.05 V.

What is the best explanation for this lower e.m.f.?

- 1 a higher concentration of Fe^{3+} was used
- 2 a higher concentration of Mg^{2+} was used
- 3 a smaller magnesium electrode was used

- A** 1 only **B** 2 only **C** 1 and 2 only **D** 1, 2 and 3

- 28 Use of the Data Booklet is relevant to this question.

The table below shows the properties of four metals K, Ca, Cr and Ga. Which set of properties belong to Cr?

	melting point / °C	density / g cm ⁻³
A	1860	7.19
B	30	5.91
C	63	0.86
D	842	1.55

- 29 Which statement best explains why the $[\text{TiCl}_6]^{2-}$ complex ion is expected to be colourless?

- A** The 3d subshell of the transition metal ion is empty.
B Electrons from the lower energy level absorb energy outside the visible spectrum.
C There is a large energy gap between the non-degenerate orbitals.
D There is no d-orbital splitting in the transition metal ion.

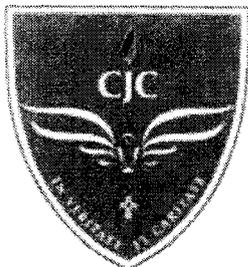
- 30 The cathode of an electrolytic cell is a square piece of copper with dimensions 0.1 m x 0.1 m. The electrolyte is copper(II) sulfate.

Assume that each copper atom occupies a cube of length 3.0×10^{-12} m, the piece of copper has no thickness and that there is a uniform coverage.

How long will it take a current of 4.0 A to cover both sides of the piece of copper with new copper to a total of depth of 1000 atoms?

- A** 178 s **B** 24.7 h **C** 49.4 h **D** 98.9 h

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Catholic Junior College
JC2 Preliminary Examination
Higher 2

CANDIDATE
NAME

CLASS

INDEX
NUMBER

CHEMISTRY
Paper 2 Structured Questions

9729/02
29 August 2025
2 hours

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.
 You may use an HB pencil for any diagrams or graphs.
 Do not use staples, 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.

A Data Booklet is provided.

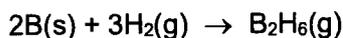
The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
Paper 1	30
Paper 2	Q1 /16
	Q2 / 7
	Q3 /10
	Q4 /18
	Q5 /13
	Q6 /11
	75
Paper 3	80
Paper 4	55
OVERALL (100%)	
GRADE	

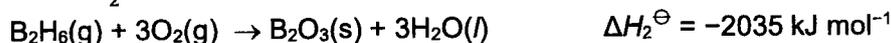
This document consists of 21 printed pages and 1 blank page.

Answer all the questions in the space provided.

- 1 (a) Many chemical compounds used for rocket fuel and propellants are highly reactive and hazardous. One of these compounds, diborane, B_2H_6 , can be formed from its elements according to the following equation:



Given the following data,



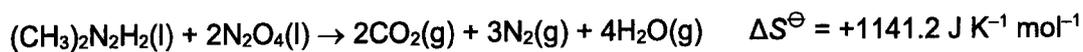
- (i) Name the enthalpy change represented by ΔH_1^\ominus .

..... [1]

- (ii) Construct a suitable energy cycle and calculate the enthalpy change of formation of diborane, $B_2H_6(g)$.

[3]

- (b) The reaction of 2,2-dimethylhydrazine, $(CH_3)_2N_2H_2$, with dinitrogen tetroxide, N_2O_4 , is another energy source for rockets.



- (i) One of the reactants in the above reaction, dinitrogen tetroxide, N_2O_4 , may be obtained from the more commonly available NO_2 . State and explain the effect on the entropy, S , of the chemical system during the conversion of $NO_2(g)$ to $N_2O_4(g)$.

.....

 [1]

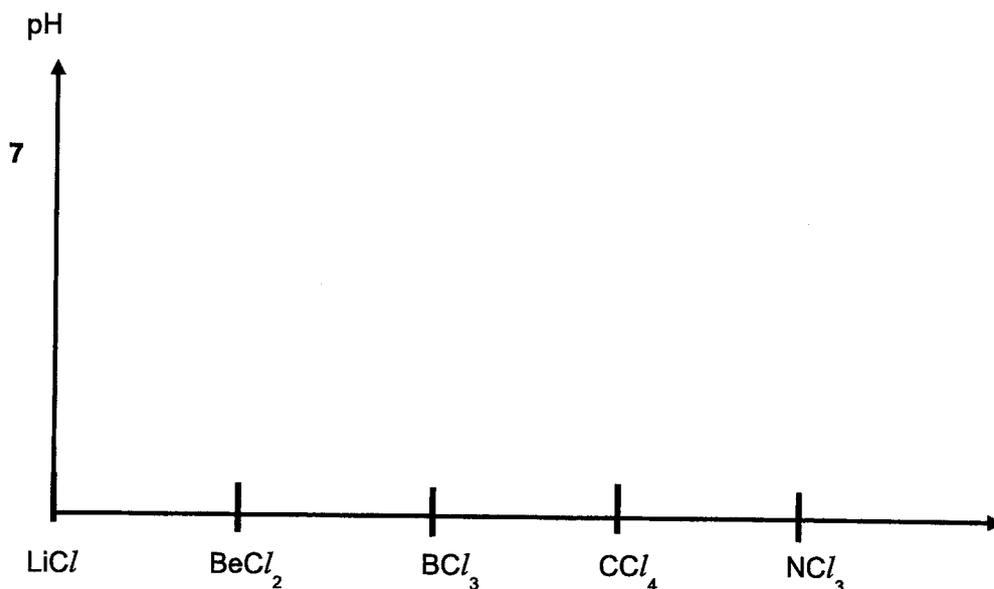
- (ii) By using the standard enthalpy change of formation, ΔH_f^\ominus , values given below, calculate the standard Gibbs free energy change, ΔG^\ominus , in kJ mol^{-1} for the reaction of $(\text{CH}_3)_2\text{N}_2\text{H}_2$ with N_2O_4 at 298 K.

substance	$(\text{CH}_3)_2\text{N}_2\text{H}_2(\text{l})$	$\text{N}_2\text{O}_4(\text{l})$	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{g})$
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	+48.9	-19.6	-393.5	-241.8

.....

 [3]

- (c) (i) The chlorides of Period 2 elements behave similarly to chlorides of Period 3 elements. Based on your knowledge of chlorides of Period 3 elements, sketch a graph of pH against the chlorides of lithium to nitrogen. In your sketch, consider the chloride of carbon is immiscible with water. [3]



- (ii) Write an equation with state symbols to account for the pH of liquid NCl_3 when dissolved in water. Aqueous HNO_2 and steamy white fumes are formed in the reaction.

..... [2]

- (d) Describe and explain how the thermal stability of the hydrogen halides varies down Group 17. Include an equation for the thermal decomposition reaction in your answer.

.....
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.....
.....
.....
.....
.....[3]

[Total: 16]

- 2 Ammonia gas, NH_3 , is used in industrial refrigeration systems. A refrigeration chamber contains 0.686 mol of ammonia gas at a temperature of 360K. The chamber volume is 2.25 dm^3 .

(a) State two main assumptions of kinetic theory of gases.

.....

.....

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.....

.....

.....[2]

(b) Calculate the pressure of ammonia, in kPa, in the chamber using the ideal gas equation.

[1]

(c) To determine the pressure of ammonia in the chamber more precisely, the van der waals' equation shown below is used.

$$\left(p + \frac{n^2 a}{V^2}\right)(V - nb) = nRT \text{ (where } a \text{ and } b \text{ are constants)}$$

Given that the pressure obtained using van der waals' equation is lower than your answer in (b), explain the difference.

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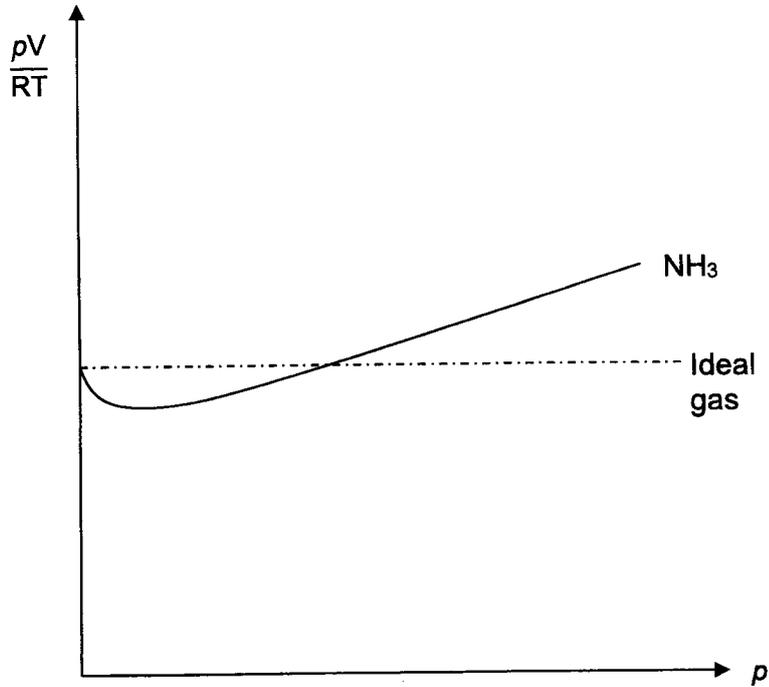
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.....[1]

(d) Under what conditions of temperature and pressure would you expect ammonia to be most like that of an ideal gas?

..... [1]

- (e) The graph below shows the compressibility curve of 1 mole of ammonia gas. On the same axes, draw the compressibility curve for 1 mole of ammonia at a lower temperature in the graph below and explain the shape of your graph. Your answer should include reference to intermolecular forces.



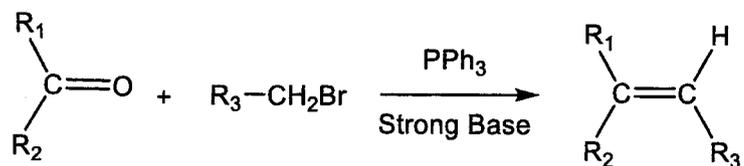
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 [2]

[Total: 7]

- 3 (a) A 2.67 g sample of a Period 3 chloride is heated to 227°C in a sealed flask. At this temperature, the chloride is a gas of volume 250 cm³ and the pressure in the flask is 323 kPa. Using the general gas equation, calculate the M_r of the Period 3 chloride. Deduce its formula. [3]

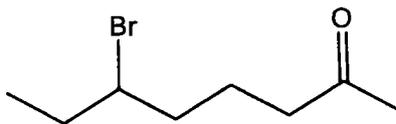
- (b) Triphenylphosphine (represented as PPh₃) is used in a type of reaction known as a Wittig reaction. In the Wittig reaction, a carbonyl compound reacts with a halogenoalkane to form an alkene. The conversion is shown in the following unbalanced equation.



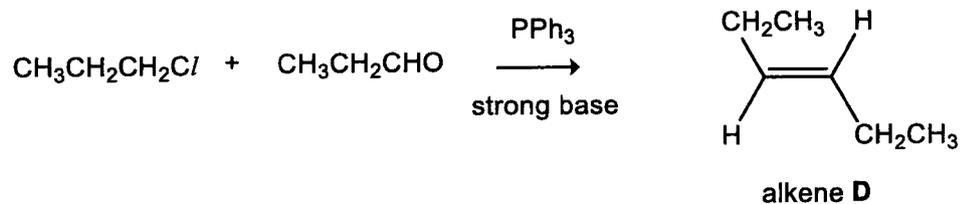
- (i) Draw the structure of the product formed from the Wittig reaction of the following compounds. [1]



- (ii) Predict the structural formula of the product formed when the following compound undergoes the Wittig reaction. [1]



- (iii) Alkene **D** can be formed from propanal, $\text{CH}_3\text{CH}_2\text{CHO}$ via the Wittig reaction. Propose a 2-step synthesis to form 1-chloropropane, from propanal, for the Wittig reaction to take place. [2]



- (c) Many transition metals and their complexes are paramagnetic. Paramagnetism is a property of a substance which allows it to be weakly attracted to a magnet. This property is due to the presence of unpaired electrons in the substance.

Nickel forms many complexes with a co-ordination number of 4. Complexes with a co-ordination number of 4 can take on either the tetrahedral or the square planar geometry.

Table 3.1 shows the relative paramagnetism of two nickel complexes with **different** geometry, which contain Ni^{2+} ion with a co-ordination number of 4.

Table 3.1

formula of complex	relative paramagnetism
$[\text{NiCl}_4]^{2-}$	2
$[\text{Ni}(\text{CN})_4]^{2-}$	0

Fig. 3.2 shows how the d-orbitals of a transition metal ion such as nickel are split in complexes with these two different geometries.

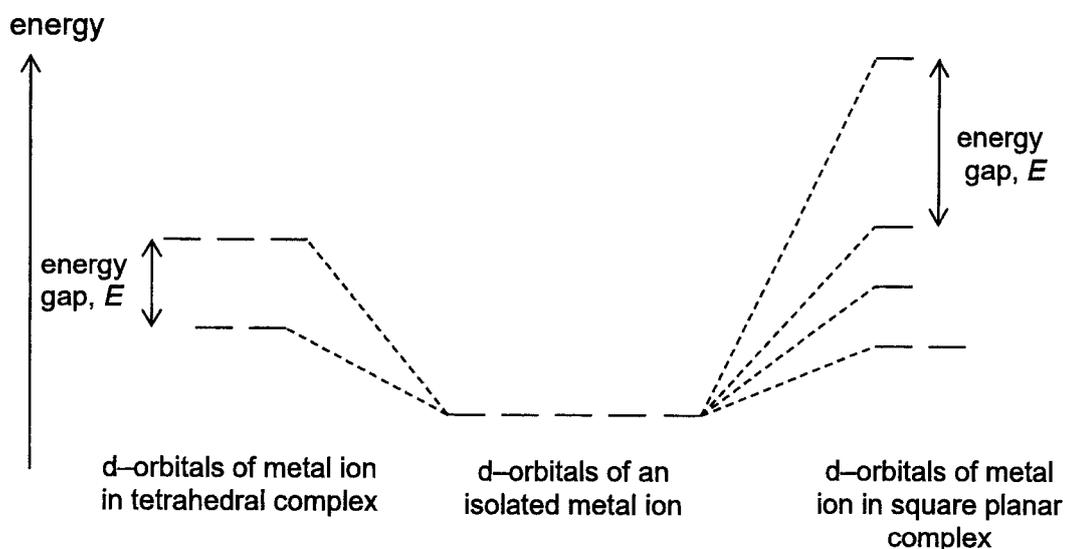
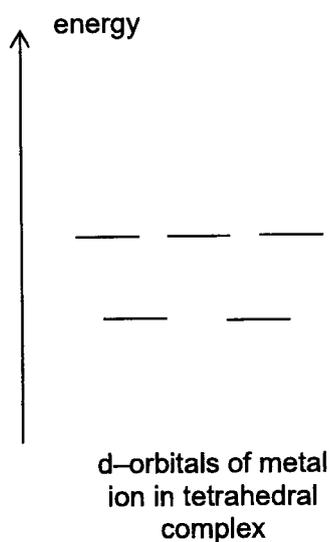


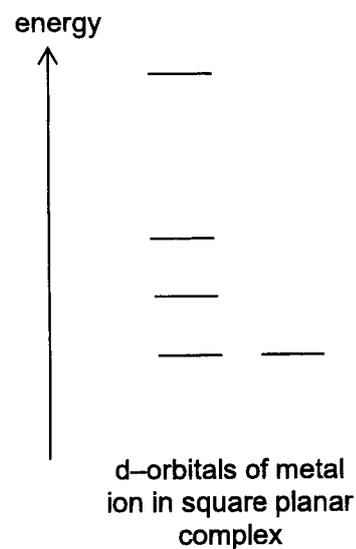
Fig. 3.2

- (i) Complete the diagram in Fig. 3.3 to show how the d electrons are arranged in the five non-degenerate d-orbitals.

in the tetrahedral $[\text{NiCl}_4]^{2-}$ complex



in the square planar $[\text{Ni}(\text{CN})_4]^{2-}$ complex



[2]

Fig. 3.3

- (ii) Nickel(II) chloride forms a square planar complex, $\text{Ni}(\text{PR}_3)_2\text{Cl}_2$, with the monodentate organic ligand, triethylphosphine which can be represented as PR_3 .

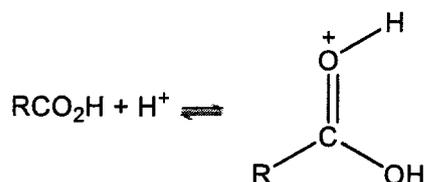
The complex can occur in two forms, **G** and **H**, where **G** has an overall dipole and **H** has none. Suggest the structure of **G**. [1]

[Total: 10]

- 4 Esters are derivatives of carboxylic acids. Simple esters tend to have pleasant, fruity odours and are widely used as flavours and fragrances. Esterification generally refers to the formation of esters from alcohol and carboxylic acids, as shown in Equation 1. This Fischer esterification mechanism is thought to involve 5 steps.



Step 1 : The carboxyl oxygen on the carboxylic acid gains a proton.



Step 2 : Next, the electron-rich oxygen atom of the alcohol attacks the carbon atom of the carboxylic acid to form a positively-charged tetrahedral intermediate.

Step 3 : This is followed by transferring a proton to the hydroxyl oxygen of the carboxyl group.

Step 4 : Subsequently, water is removed to form the positively charged ester.

Step 5 : The ester is formed when a proton is transferred to the base.

- (a) (i) Suggest why protonation in Step 1 is required before nucleophilic attack in Step 2 can occur.

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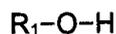
[1]

- (ii) State whether the acid catalyst acts as a homogeneous or heterogeneous catalyst in this reaction. Explain your answer.

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[1]

- (iii) Using the information given, propose the mechanism for Step 2 in the given boxes below. The structure of the alcohol, R-OH is shown below.

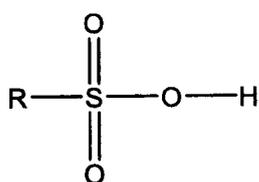


Suggest the mechanism for this reaction. Show all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows. [2]

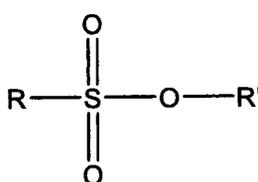
- (iv) Suggest the type of reaction taking place in Step 2.

.....[1]

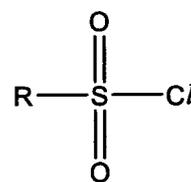
- (b) Organic sulfonic acids, RSO_2OH , sulfonic acid esters, RSO_2OR' , and sulfonyl chlorides, RSO_2Cl , show similar chemical properties to those of carboxylic acids, esters and acyl chlorides respectively. R and R' can represent alkyl groups or H atoms.



sulfonic acids



sulfonic acid esters



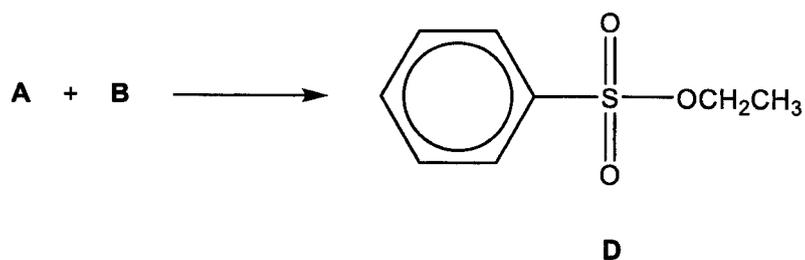
sulfonyl chlorides

- (i) Based on your answer in (a)(i), explain why the rate of esterification will be faster when sulfonic acid is used instead of carboxylic acid.

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[1]

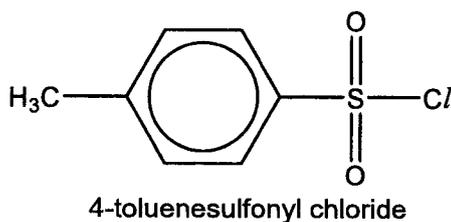
- (ii) The sulfonic acid ester **D** is synthesised from the corresponding sulfonic acid **A** and another organic molecule **B**.



Suggest the structure of **A** and **B**.

[2]

- (ii) Sulfonyl chlorides react with amines in a manner similar to acyl chlorides to form sulfonamide. 4-toluenesulfonyl chloride reacts readily with ethylamine, $\text{CH}_3\text{CH}_2\text{NH}_2$, at room temperature.



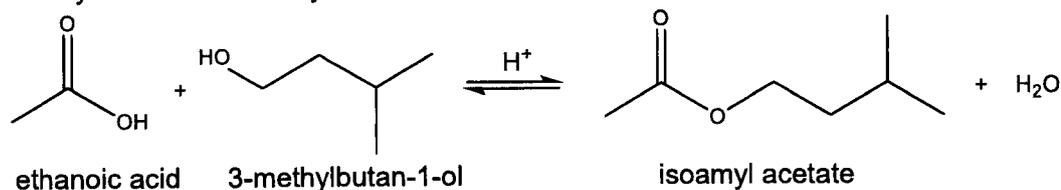
Suggest an equation for the reaction of 4-toluenesulfonyl chloride with ethylamine.

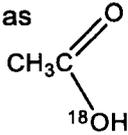
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[1]

- (c) At the newly opened Minion Land in Universal Studios Singapore, many banana-flavoured treats can be found at the stalls for visitors to immerse themselves in the Minions experience. The ester, isoamyl acetate with molecular formula $C_7H_{14}O_2$ is the compound responsible for the fruit's distinctive taste.

Isoamyl acetate can be synthesised via esterification as follows:



- (i) When isoamyl acetate undergoes acid hydrolysis in a solution containing H_2^{18}O , atoms of the ^{18}O isotope appear in the product as  and not as $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2^{18}\text{OH}$.

Explain why this is the case.

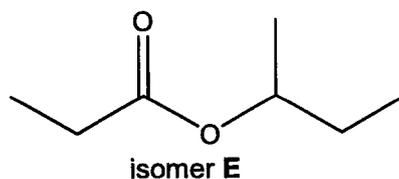
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.....[1]

- (ii) An isomer of isoamyl acetate with molecular formula, $C_7H_{14}O_2$, **E** has the following structure. Describe a reaction by which you could distinguish between isoamyl acetate and isomer **E**.



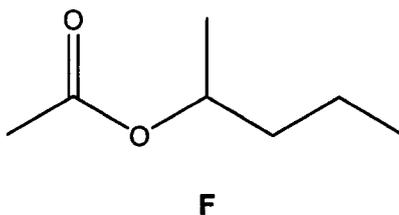
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..... [2]

- (iii) Another isomer with molecular formula $C_7H_{14}O_2$, **F** contains a chiral centre. Use an asterisk (*) to mark the chiral centre present on the molecule of **F**. [1]



- (d) Ethanoyl chloride instead of ethanoic acid may be used to synthesise isoamyl acetate.

- (i) Write an equation for the reaction of ethanoyl chloride with water and hence explain why the solution has a lower pH as compared to ethanoic acid.

.....

 [2]

- (ii) Chloroethanoyl chloride, $CH_2ClCOCl$, **H**, can be obtained from ethanoic acid by heating it with Cl_2 and PCl_5 .

H can then be used to produce **J**, $C_4H_{10}NCI$, via compound **I**, as shown in Fig. 4.1.

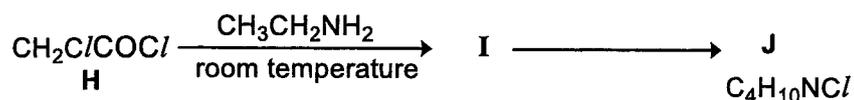
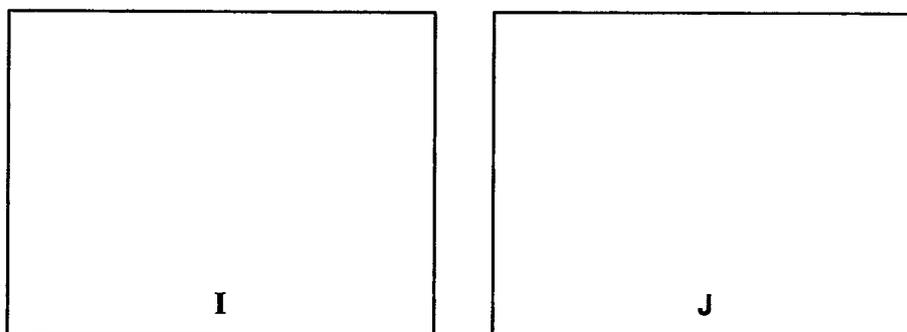


Fig. 4.1

Suggest structures for compounds **I** and **J** in Fig. 4.1.

[2]



- (iii) State the reagents and conditions to convert **I** to **J**.

..... [1]

[Total: 18]

- 5 (a) Ammonia in aqueous solution is a weak base, its dissociation constant, K_b , being $1 \times 10^{-5} \text{ mol dm}^{-3}$.

What is the pH of a $0.100 \text{ mol dm}^{-3}$ aqueous solution of ammonia? [2]

- (b) 45.4 cm^3 of ammonia gas is passed into 25.00 cm^3 of $0.0400 \text{ mol dm}^{-3}$ of sulfuric acid at standard temperature and pressure (s.t.p). All the ammonia is neutralised by the acid to form ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$.

- (i) Write a balanced equation, with state symbols, for the reaction between ammonia and sulfuric acid.

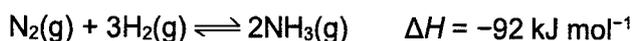
.....[1]

- (ii) Calculate the amount of ammonia gas passed into the acid. [1]

- (iii) Calculate the concentration of NH_4^+ ions formed in the solution. [1]

- (iv) Calculate the pH of the aqueous solution of the salt formed, assuming K_w is $1 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$. [2]

- (c) The Haber process is the principal commercial method used to manufacture ammonia gas from nitrogen and hydrogen, as shown in the following equation:



The table below shows the percentage of ammonia gas by volume in the equilibrium mixtures at various temperatures and pressures. In all cases, the molar ratio of N_2 and H_2 in the mixtures is 1:3.

temperature/ °C	% of ammonia gas		
	at 1 atm	at 10 atm	at 100 atm
200	1.10	7.42	25.8
300	0.22	1.94	12.6
400	0.07	0.61	5.2

- (i) State Le Chatelier's *principle*.

.....

[1]

- (ii) From the data provided above, state how the percentage of ammonia gas varies with changes in temperature, at a fixed pressure and how the percentage of ammonia gas varies with changes in pressure, at a fixed temperature, in the equilibrium mixture.

.....

[1]

- (iii) Hence, explain how changes in temperature and pressure affect the percentage of ammonia, in the equilibrium mixture, with reference to Le Chatelier's principle.

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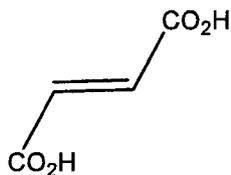
[2]

- (iv) Calculate the partial pressure of each gas in the equilibrium mixture at a pressure of 100 atm and a temperature of 300 °C. Hence, determine K_p at 300 °C, stating the units. [2]

[Total: 13]

- 6 Double indicator acid-base titrations can be used to determine the composition of a mixture of acids in addition to the pH of buffer solutions formed from polyprotic acids.

Maleic acid is a diprotic weak acid, H_2A and its structure is as shown below:



- (a) The table below gives the pK_a values of maleic acid at 298 K.

equation	pK_a
$H_2A \rightleftharpoons HA^- + H^+$	1.90 (pK_{a1})
$HA^- \rightleftharpoons A^{2-} + H^+$	6.20 (pK_{a2})

Explain why the value of pK_{a2} is higher than that of pK_{a1} .

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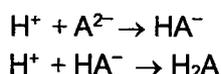
[1]

- (b) A double indicator titration was performed to determine the pH of the buffer solution that was prepared by mixing unknown volumes of Na_2A and $NaHA$.

25.0 cm^3 of the buffer solution was titrated against 0.200 $mol\ dm^{-3}$ HCl using bromocresol green as an indicator for the first end-point. 16.90 cm^3 of the titrant was required for this titration.

An additional titre volume of 19.20 cm^3 was required to reach the second end point using thymol blue as an indicator.

The reaction between A^{2-} and H^+ from HCl occurs in two steps:



- (i) Calculate the concentration of A^{2-} present in the buffer solution initially.

[1]

- (ii) Calculate the volume of hydrochloric acid used to fully react with the HA^- present in the buffer solution **initially** and hence calculate the initial concentration of HA^- .

[2]

- (iii) Using your answers to (b)(i) and (ii), calculate the initial pH of the buffer solution.

[1]

- (iv) Hence using your calculations from (b)(i) and (ii), calculate the concentration of H_2A at the second equivalence point.

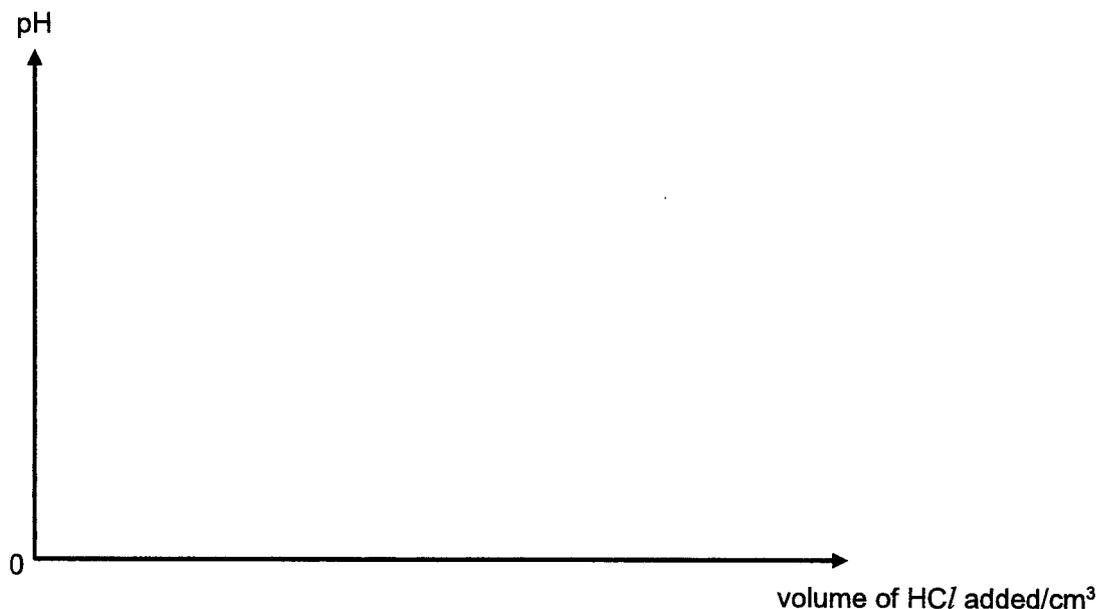
[1]

- (v) Hence, calculate the pH of H_2A at the second equivalence point.

[1]

- (c) Using the information provided in the question in addition to your answers from (b)(iii) – (b)(v), sketch a graph to show the pH changes that occur when 50.00 cm³ of 0.200 mol dm⁻³ HCl is added to 25.0 cm³ of the initial buffer solution.

Indicate clearly in your sketch, all relevant pH and volumes of HCl used.



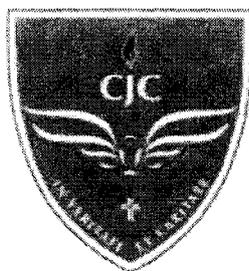
[3]

- (d) Explain why a weak acid cannot be used in place of hydrochloric acid as a titrant for this titration.

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.....[1]

[Total: 11]

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Catholic Junior College
JC2 Preliminary Examination
Higher 2

CANDIDATE
NAME

CLASS

2T

INDEX
NUMBER

CHEMISTRY

9729/03

Paper 3 Free Response

15 September 2025

2 hours

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.

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

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

Answer **all** questions in the spaces provided on the Question Paper.
 If additional space is required, you should use the pages at the end of this booklet. The question number must be clearly shown.

Section A

Answer **all** questions.

Section B

Answer **one** question.

A Data Booklet is provided.

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

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		
Section A	Q1	/21
	Q2	/20
	Q3	/19
Section B	Q4	/20
	OR Q5	/20
TOTAL	80	

This document consists of **32** printed pages.

- (c) The position of substitution in the electrophilic substitution of mono-substituted arenes depends on the nature of the group already attached to the ring. This selectivity can be explained based on the stability of the intermediate formed in the first step. Fig. 1.1 shows three isomers **P**, **Q**, **R**, with the same molecular formula, $C_9H_{11}NO_2$, as phenylalanine that can be formed from an appropriate starting alkylbenzene.

Use this information to predict which isomer in Fig. 1.1 will be formed the least and which isomer will be formed the most. Explain your reasoning. [3]

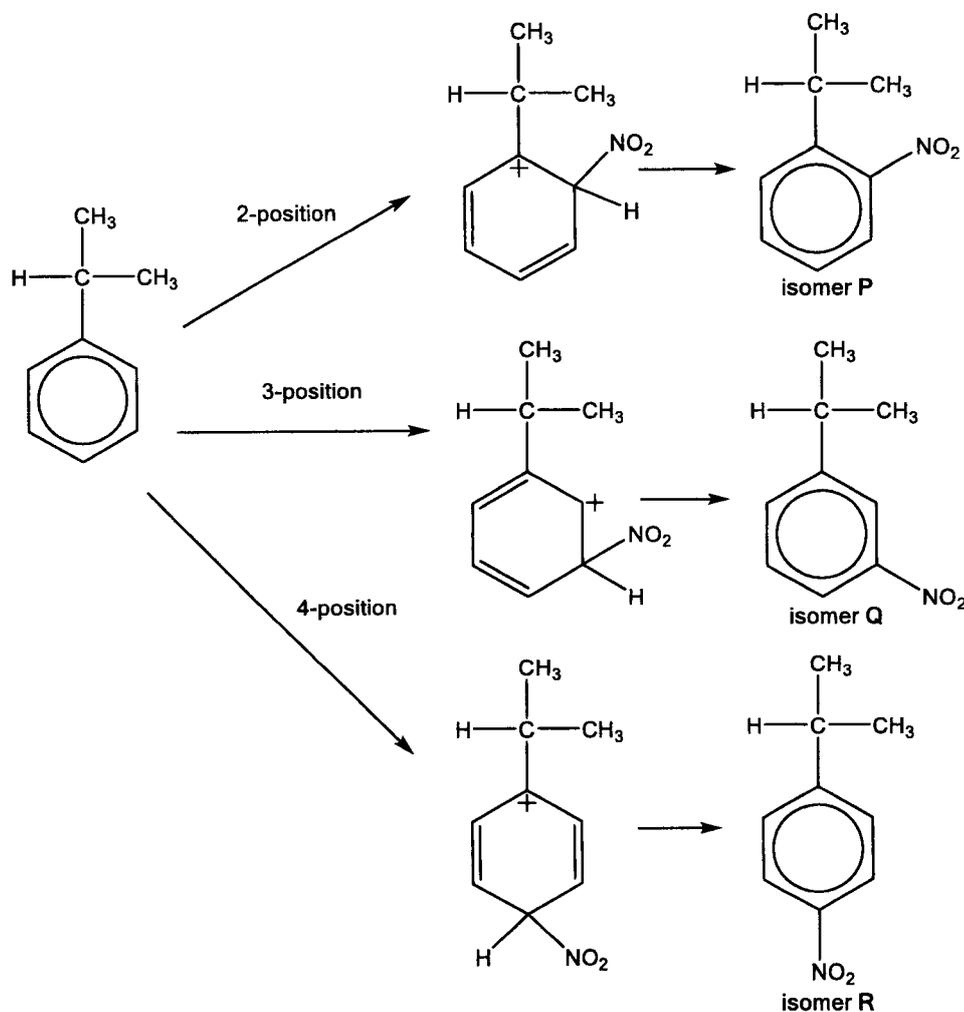


Fig. 1.1

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- (d) Diazonium salts are commonly used to produce synthetic dyes with intense colours that do not occur naturally. The cation of a diazonium salt can be made by reacting an arylamine, RNH_2 , with nitrous acid, HNO_2 .

The five stages of the reaction are described in Table 1.2.

Table 1.2

stage	description of stage	equation
1		$\text{R}-\text{NH}_2 + \begin{array}{c} \delta^+ \quad \text{OH} \\ \diagdown \quad / \\ \text{N} \\ \diagup \quad \diagdown \\ \quad \quad \text{O} \end{array} \longrightarrow \begin{array}{c} \text{H} \\ \\ \text{R}-\text{N}^+-\text{N}=\text{O} \\ \\ \text{H} \end{array} + \text{OH}^-$
2	deprotonation	$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{N}^+-\text{N}=\text{O} \\ \\ \text{H} \end{array} \longrightarrow \begin{array}{c} \text{H} \\ \\ \text{R}-\text{N}-\text{N}=\text{O} \\ \\ \text{H} \end{array} + \text{H}^+$
3	protonation and electron pair movement	$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{N}-\text{N}=\text{O} \\ \\ \text{H} \end{array} + \text{H}^+ \longrightarrow \begin{array}{c} \text{H} \\ \\ \text{R}-\text{N}^+=\text{N}-\text{OH} \\ \\ \text{H} \end{array}$
4	deprotonation and protonation	$\begin{array}{c} \text{H} \\ \\ \text{R}-\text{N}^+=\text{N}-\text{OH} \\ \\ \text{H} \end{array} \longrightarrow \begin{array}{c} \text{H} \\ \diagup \\ \text{R}-\text{N}=\text{N}-\text{O}^+ \\ \diagdown \\ \text{H} \end{array}$
5	Electron pair movement and heterolytic cleavage of N-O bond	$\begin{array}{c} \text{H} \\ \diagup \\ \text{R}-\text{N}=\text{N}-\text{O}^+ \\ \diagdown \\ \text{H} \end{array} \longrightarrow \begin{array}{c} \text{H} \\ \\ \text{R}-\text{N}^+\equiv\text{N} \\ \\ \text{H} \end{array} + \begin{array}{c} \text{H} \\ \diagup \\ \text{O} \\ \diagdown \\ \text{H} \end{array}$

- (i) Name the type of reaction in stage 1. [1]
- (ii) Complete the mechanism in stage 1 by adding a lone pair and curly arrows in Table 1.2. [2]
- (iii) Complete the mechanisms in stage 3 and stage 5 by adding lone pairs and relevant curly arrows. [2]

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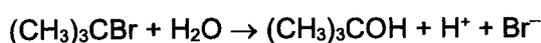
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- (b) The hydrolysis of another isomer, 2-bromo-2-methylpropane takes place as follows.

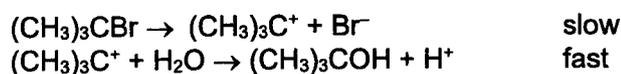


An experiment was conducted to determine the order of reaction with respect to 2-bromo-2-methylpropane. The following results were obtained for the product, $(\text{CH}_3)_3\text{COH}$.

time/ s	19	28	50	70	154
$[(\text{CH}_3)_3\text{COH}] / \text{mol dm}^{-3}$	0.0030	0.0040	0.0060	0.0072	0.0095

It was found that the order of reaction with respect to 2-bromo-2-methylpropane is one and the half-life of the reaction is 35 s.

- (i) Using a non-graphical method, show that the concentration of 2-bromo-2-methylpropane at the start of the experiment is $0.0096 \text{ mol dm}^{-3}$. [2]
- (ii) Hence, deduce how long the reaction has proceeded when concentration of $(\text{CH}_3)_3\text{COH}$ obtained is $0.0084 \text{ mol dm}^{-3}$. [1]
- (iii) The following mechanism for the above reaction is as shown.



Explain why the mechanism shows an overall first order kinetics. [1]

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Section B

Answer **one** question in this section.

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

- (a) (i) State the *spdf* electronic configuration of sodium. [1]
- (ii) Draw and label an orbital from which the second electron of sodium is removed. [1]
- (iii) With the aid of a relevant equation, explain what is meant by the second ionisation energy of sodium. [2]

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- (b) Sodium vapour lamp is a gas-discharge lamp that is commonly used in street lighting due to its characteristic yellow-orange hue. These lamps consist of a gas tube containing solid sodium and a small amount of neon gas.

The process of producing light involves the ionisation of gaseous sodium and neon atoms in an electric field.

- (i) Explain why sodium has a lower first ionisation energy than neon. [1]
- (ii) Suggest why the pinkish glow of neon is observed before the orange glow of sodium when the lamp is first turned on. [1]

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- (c) Describe the reactions, if any, of the oxides Na_2O and SO_3 with water. Include the approximate pH value of any resulting solutions and write equations for any reactions that occur. [2]

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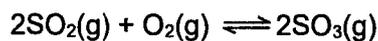
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- (d) The manufacture of sulfuric acid involves the reaction between sulfur dioxide and oxygen gas.



When an equimolar mixture of SO_2 and O_2 is passed over a catalyst at an initial pressure of 2 atm, the percentage conversion of $\text{SO}_2(\text{g})$ is 98%.

- (i) Calculate the equilibrium partial pressure of each of the three gases. [2]
- (ii) Write the expression for the equilibrium constant, K_p , for this reaction. Use your answer in (d)(i) to calculate the value of K_p for this reaction including its units. [2]
- (iii) Some sulfur dioxide gas was added to the existing equilibrium system to increase the partial pressure of SO_2 to y atm at constant temperature. The system was then allowed to establish a new equilibrium. The partial pressure of SO_3 was found to be 1.50 atm at this new equilibrium.

Calculate the value of y in atm. [2]

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- (b) Gold is an unreactive metal that can only be oxidised under specific conditions. Some relevant half-equations and their standard electrode potentials are given.

	half-equation	E^\ominus / V
1	$\text{Au}^{3+}(\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Au}(\text{s})$	+1.50
2	$[\text{AuCl}_4]^- (\text{aq}) + 3\text{e}^- \rightleftharpoons \text{Au}(\text{s}) + 4\text{Cl}^- (\text{aq})$	+1.00
3	$\text{NO}_3^- (\text{aq}) + 4\text{H}^+ (\text{aq}) + 3\text{e}^- \rightleftharpoons \text{NO}(\text{g}) + 2\text{H}_2\text{O}(\text{l})$	+0.96

- (i) Draw a fully labelled diagram of the experimental set-up used to measure the standard cell potential, E^\ominus_{cell} , of $\text{Au}^{3+}(\text{aq})/\text{Au}(\text{s})$ and $\text{HNO}_3(\text{aq})/\text{NO}(\text{g})$. Include all necessary chemicals. [2]
- (ii) Gold can be only oxidised by a mixture of concentrated hydrochloric acid and concentrated nitric acid, known as aqua regia.

Using the half-equations 2 and 3, construct a balanced equation for the reaction and explain why it would be expected that this redox reaction would **not** occur if it is carried out under standard conditions. [2]

- (iii) In fact, gold dissolves when the concentration of hydrochloric acid is 12 mol dm^{-3} and the concentration of nitric acid is 16 mol dm^{-3} .

State and explain what effect the use of concentrated hydrochloric acid and concentrated nitric acid in aqua regia have on the electrode potential, E values, of half-equations 2 and 3 respectively and thus the overall E_{cell} . [2]

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- (d) The reaction of phenylethanone with 1,4-dibromobutane, $\text{BrCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$ in the presence of FeBr_3 is shown below in Fig. 5.1.

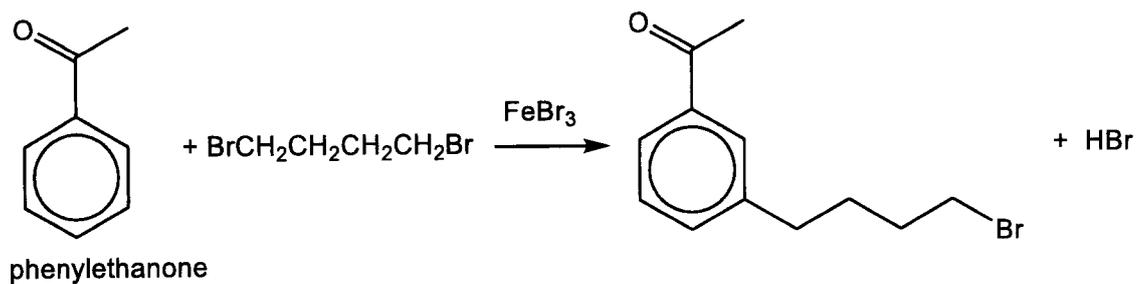


Fig. 5.1

The mechanism of this reaction is similar to that of the alkylation of benzene.

- (i) The reaction forms small amounts of two by-products, **A** ($\text{C}_{20}\text{H}_{22}\text{O}_2$) and **B** ($\text{C}_{12}\text{H}_{14}\text{O}$). Suggest structures for **A** and **B**. [2]
- (ii) Compound **F** can be synthesised from benzene in three steps by the route shown in Fig. 5.2. Give the structure of intermediate compounds **D** and **E** and the reagents and conditions for step 2. [3]

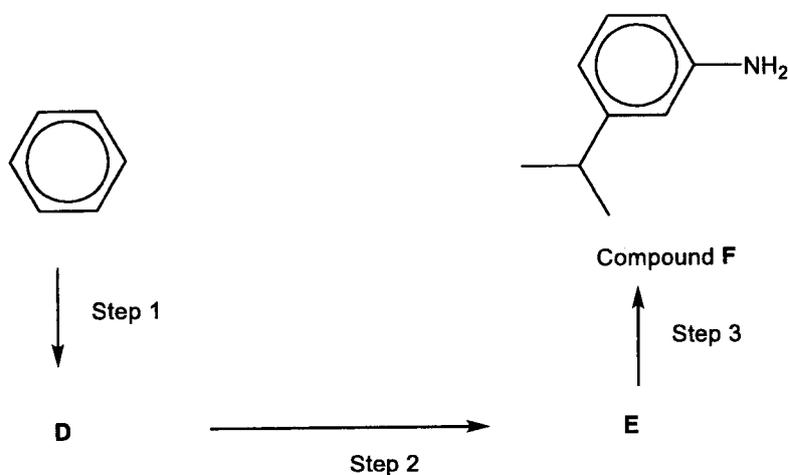


Fig. 5.2

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