



NATIONAL JUNIOR COLLEGE
SH2 TIMED PRACTICE
Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

CHEMISTRY

Paper 1 Multiple Choice

9729/01

27 June 2024

1 hour

Additional Materials: Optical 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, subject class and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

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.

A Data Booklet is provided.

Instructions on how to fill in the Optical Mark Sheet

Shade the index number in a 5 digit format on the optical mark sheet:

2nd digit and the last 4 digits of the Registration Number.

Example:

Student	Examples of Registration No.	Shade:
	2305648	35648

This document consists of **12** printed pages.

1 Which statement about one mole of a metal is always correct?

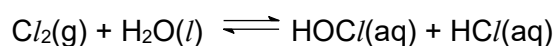
- A It contains the same number of atoms as 0.5 mol of hydrogen gas.
- B It contains the same number of atoms as $\frac{1}{12}$ mol of ^{12}C .
- C It has the same mass as 1 mol of hydrogen atoms.
- D It can be oxidized by a reaction with an acid.

2 10 cm³ of a gaseous hydrocarbon was reacted with an excess of oxygen. A contraction of 30 cm³ occurred. On treating the cooled resulting mixture with excess barium hydroxide, a further contraction of 40 cm³ occurred. All volumes were measured at room temperature and pressure.

What is the formula of the hydrocarbon?

- A C₂H₄ B C₂H₆ C C₄H₈ D C₄H₁₀

3 The following reaction occurs when chlorine is added to water.



Which statement about this reaction is correct?

- A Chlorine is both oxidised and reduced.
- B Chlorine is oxidised but **not** reduced.
- C Hydrogen is both oxidised and reduced.
- D Hydrogen is oxidised but **not** reduced.

- 4 **X** is either nitrogen or sulfur and forms pollutant oxide **Y** in a car engine.

Further oxidation of **Y** to **Z** occurs in the atmosphere. In this further oxidation, 1 mol of **Y** reacts with 0.5 mol of gaseous oxygen molecules.

Which statements about **X**, **Y** and **Z** can be correct?

1 The oxidation number of **X** increases by two from **Y** to **Z**.

2 **Y** has an unpaired electron in its molecules.

3 **Y** is a polar molecule.

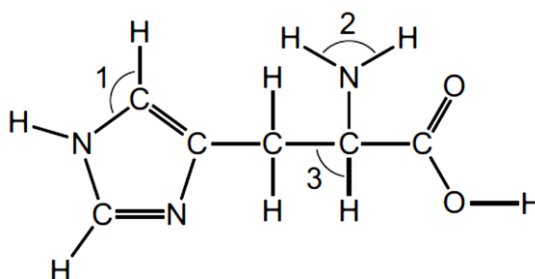
A 1 only

B 1 and 2

C 2 and 3

D 1, 2 and 3

- 6 Histidine is an amino acid.



Histidine

What are the approximate bond angles 1, 2 and 3?

	1	2	3
A	109.5°	107°	90°
B	120°	107°	109.5°
C	120°	120°	90°
D	120°	120°	109.5°

- 7 Ammonium ions, NH_4^+ , are formed when ammonia gas reacts with hydrogen chloride gas.

Which statement about the changes that occurs in this reaction is correct?

- A The dipole moment of an ammonium ion is greater than the dipole moment of an ammonia molecule.
- B The H–N–H bond angle decreases when an ammonium ion is formed.
- C The hybridisation of nitrogen does not change.
- D There is electron transfer from nitrogen to chlorine.

- 8 Ethylene glycol, $\text{HOCH}_2\text{CH}_2\text{OH}$, is used as a de-icer. It allows ice to melt at temperatures below 0°C .

Which statements are correct?

- 1 Ethylene glycol changes the extensive network of hydrogen bonds in ice.
- 2 Ethylene glycol molecules form hydrogen bonds with other ethylene glycol molecules.
- 3 Ethylene glycol molecules will dissolve in the water formed from the ice.

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

- 9 When an evacuated tube of volume 400 cm^3 is filled with gas at 300 K and 101 kPa , the mass of the tube increases by 0.65 g . Assume the gas behaves as an ideal gas.

What is the identity of the gas?

- A Argon
- B Helium
- C Krypton
- D Neon

- 10** Two identical bulbs at the same temperature contain ideal gases **A** and **B** separately. The density of gas **A** is twice that of gas **B** and the molecular mass of gas **A** is half that of gas **B**.

What is the ratio of the pressure of gas **A** to that of gas **B**?

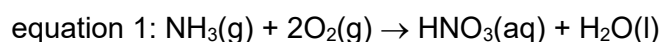
- A** 1 : 2 **B** 1 : 1 **C** 2 : 1 **D** 4 : 1

- 11** When 60 cm³ of 1 mol dm⁻³ of sulfuric acid and 40 cm³ of 2 mol dm⁻³ sodium hydroxide were mixed in a styrofoam cup, the temperature rose by 6.5 °C.

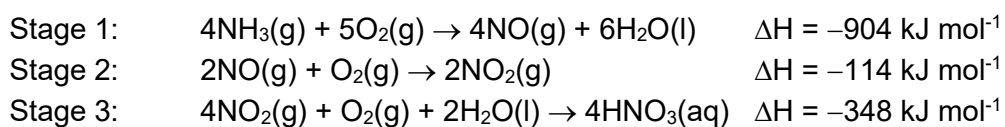
Calculate the standard enthalpy change of neutralisation in kJ mol⁻¹. Assume that the specific heat capacity of the solution is 4.18 J g⁻¹ K⁻¹.

- A** -22.6 **B** -34.0 **C** -45.3 **D** -57.0

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



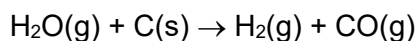
The process happens in three stages. The equations and enthalpy changes for these stages are given.



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

- A** -1480 kJ mol⁻¹
B -370 kJ mol⁻¹
C -341.5 kJ mol⁻¹
D +82.0 kJ mol⁻¹

- 13** Hydrogen can be made from steam according to the following equation:



The Gibbs free energy change of reaction at two different temperatures are shown

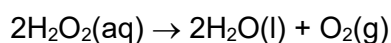
$$\Delta G_1 = +78 \text{ kJ mol}^{-1} \text{ at } 378 \text{ K}$$

$$\Delta G_2 = -58 \text{ kJ mol}^{-1} \text{ at } 1300 \text{ K}$$

Which row of the table gives the correct sign of ΔH and ΔS for this reaction?

	ΔH	ΔS
A	–	–
B	–	+
C	+	–
D	+	+

- 14** A student carried out two experiments using MnO_2 as a catalyst to decompose hydrogen peroxide. The equation for this reaction is shown.



The student's results are recorded in the table.

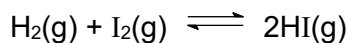
Experiment	Mass of MnO_2	Conditions	Vol of H_2O_2	Final vol of O_2	Time taken
1	0.25 g	r.t.p	10.0 cm ³	48 cm ³	200 s
2	0.25 g	r.t.p	10.0 cm ³	48 cm ³	500 s

Which statements are correct?

- The activation energy was the same for both experiments.
- The concentration of the hydrogen peroxide solution used was 0.4 mol dm⁻³.
- The MnO_2 used in experiment 1 was in a larger piece than the MnO_2 used in experiment 2.

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

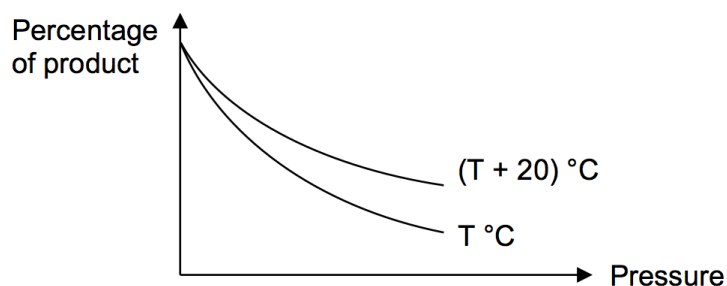
- 15 When an equimolar mixture of H_2 and I_2 react, the mole fraction of HI in the final mixture is x at 500°C



What is the equilibrium constant, K_p , for the reaction at 500°C ?

- A $\frac{x^2}{(1-x)^2}$
- B $\frac{x^2}{(1-2x)^2}$
- C $\frac{4x^2}{(1-x)^2}$
- D $\frac{4x^2}{(1-2x)^2}$

- 16 The graph below shows how the percentage of product present at equilibrium varies with temperature and pressure for a reaction.



- A $4\text{Fe}(\text{s}) + 3\text{O}_2(\text{g}) \rightleftharpoons 2\text{Fe}_2\text{O}_3(\text{s})$ $\Delta H = -1644 \text{ kJ mol}^{-1}$
- B $2\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$ $\Delta H = -222 \text{ kJ mol}^{-1}$
- C $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$ $\Delta H = +57 \text{ kJ mol}^{-1}$
- D $\text{CO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons \text{COCl}_2(\text{s})$ $\Delta H = +86 \text{ kJ mol}^{-1}$

- 17** At body temperature of 37 °C, K_w has a value of 2.4×10^{-14} .

What is the concentration of OH^- if the pH of blood is 7.4 under these conditions?

- A** $3.98 \times 10^{-8} \text{ mol dm}^{-3}$
- B** $2.51 \times 10^{-7} \text{ mol dm}^{-3}$
- C** $6.03 \times 10^{-7} \text{ mol dm}^{-3}$
- D** $7.00 \times 10^{-7} \text{ mol dm}^{-3}$

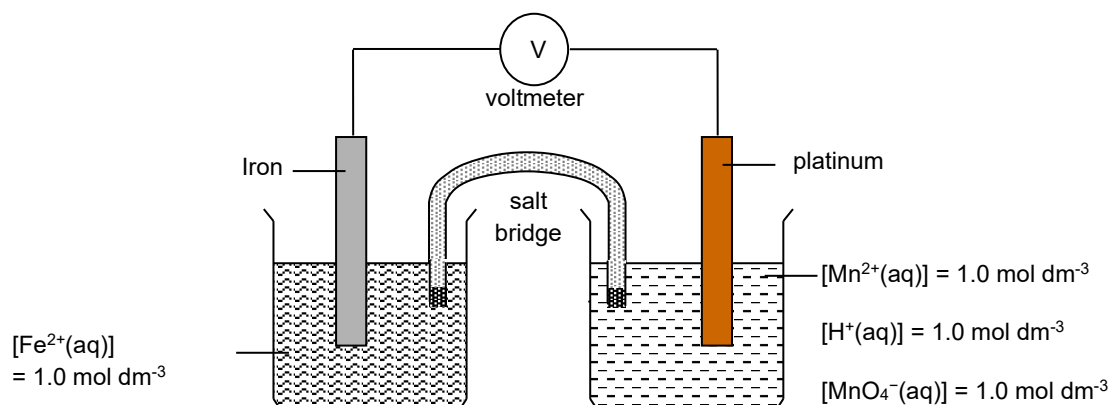
- 18** CaF_2 has a K_{sp} value of 3.9×10^{-11} at 25 °C. A sample of solid CaF_2 is dissolved in water to form a saturated solution.

What is the concentration of F^- ions in a saturated solution of CaF_2 at 25 °C?

- A** $2.1 \times 10^{-4} \text{ mol dm}^{-3}$
- B** $3.4 \times 10^{-4} \text{ mol dm}^{-3}$
- C** $4.3 \times 10^{-4} \text{ mol dm}^{-3}$
- D** $6.8 \times 10^{-4} \text{ mol dm}^{-3}$

19 The use of the Data Booklet is relevant to this question.

A cell is set up by connecting a Fe^{2+}/Fe half-cell and an acidified $\text{MnO}_4^-/\text{Mn}^{2+}$ half-cell.



Which option is a correct description of the effect on the e.m.f (potential difference) of the cell when the corresponding change is made?

	Change	Effect on e.m.f of cell
A	Addition of $\text{NH}_3(\text{aq})$ into oxidation half-cell	Increases
B	Addition of $1 \text{ mol dm}^{-3} \text{H}_2\text{SO}_4(\text{aq})$ into reduction half-cell	Decreases
C	Addition of $\text{NaOH}(\text{aq})$ into reduction half-cell	Increases
D	Replace Iron with an alloy of Iron and zinc	Remains the same

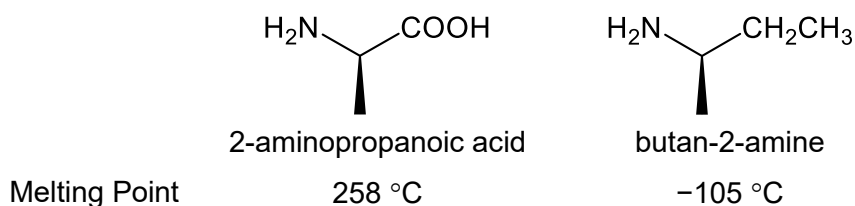
20 The use of the Data Booklet is relevant to this question.

Two separate students accidentally spilled chemicals on their clothes in the laboratory which resulted in brown MnO_2 stains and I_2 stains. Their teacher suggested the use of H_2O_2 for removal of these stains.

Which statement is true regarding the removal of the stains?

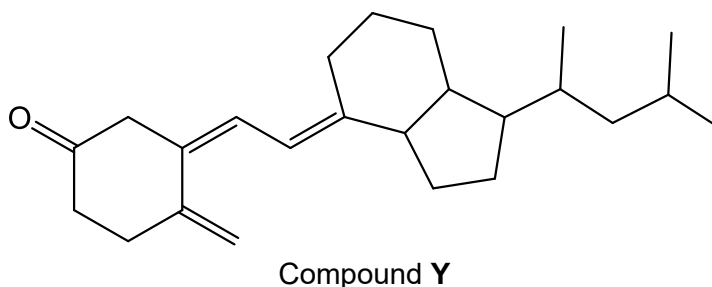
- A** Only I_2 will be successfully removed.
- B** Only MnO_2 will be successfully removed.
- C** Both MnO_2 and I_2 will be successfully removed.
- D** Both stains cannot be removed

- 21 The melting point of 2-aminopropanoic acid and butan-2-amine are as shown.



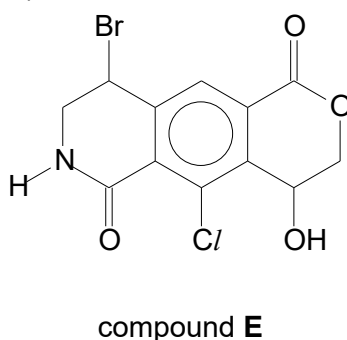
Which statement best explains the difference in melting point?

- A** 2-aminopropanoic acid molecules are held by more extensive hydrogen bonds than butan-2-amine.
- B** 2-aminopropanoic acid has a higher M_r than butan-2-amine.
- C** Weak covalent bonds are broken to melt butan-2-amine
- D** 2-aminopropanoic acid adopts a giant ionic lattice structure in crystalline state.
- 22 Compound **Y** can be reduced using NaBH_4 to form compound **Z**.



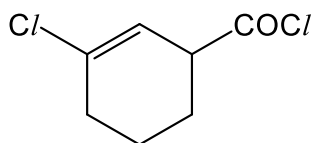
How many stereoisomers does compound **Z** have?

- A** 2^5 **B** 2^6 **C** 2^7 **D** 2^8
- 23 How many moles of NaOH(aq) will react with 1 mole of compound **E** when it is heated under reflux with an excess of NaOH(aq) ?



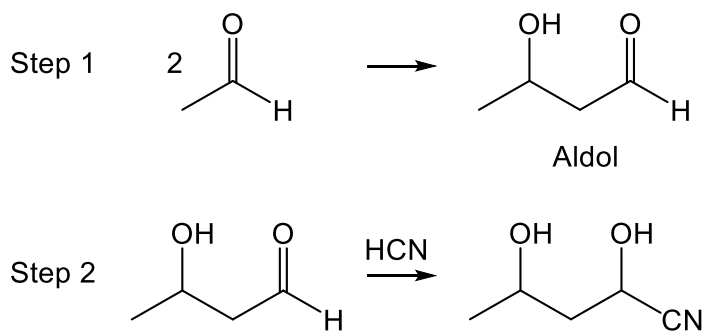
- A** 1 **B** 2 **C** 3 **D** 4

- 25 What is the mass of precipitate produced when excess ethanolic silver nitrate is added to 0.5 mol of compound **G**?

compound **G**

- A** 17.8 g **B** 35.5 g **C** 71.7 g **D** 143.4 g
- 27 Two aldehydes can combine to form an aldol. A base is required to generate the nucleophile for the reaction in step 1.

Aldol can be further reacted to form highly functionalised molecules.



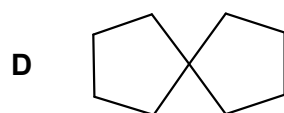
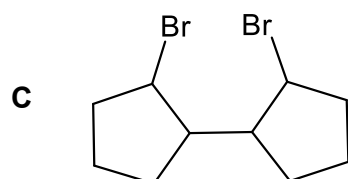
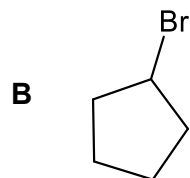
Which of the following best describes steps 1 and 2?

	<u>Step 1</u>	<u>Step 2</u>
A	Substitution	Reduction
B	Addition	Reduction
C	Substitution	Addition
D	Addition	Addition

- 28** A mixture of product is formed from when cyclopentane is heated with liquid bromine.

Which molecule could not be formed?

A HBr



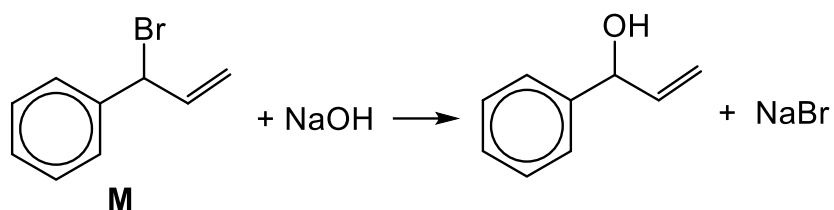
- 29** Benzene can react with ethanoyl chloride, CH_3COCl , in the presence of anhydrous AlCl_3 .

Which statements are true for above reaction?

- 1** The organic product gives an orange precipitate with 2,4-DNPH solution.
- 2** The organic product gives a yellow precipitate when warm with alkaline iodine.
- 3** The reaction intermediate has 5 delocalised pi electrons.

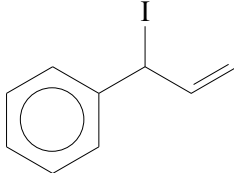
A 1 only **B** 1 and 2 **C** 2 and 3 **D** 1, 2 and 3

- 30 Compound **M** reacts with sodium hydroxide to form 2 isomeric alcohols.



Which statement do not describe the above reaction?

- A** The resultant mixture is not optically active.
B The reaction intermediate is planar in structure.

- C** The rate of reaction increases when  is used.

- D** Increasing the concentration of OH^- used will result in shorter reaction time.



NATIONAL JUNIOR COLLEGE
SH2 MID YEAR TIMED PRACTICE
Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

CHEMISTRY

Paper 2 Structured Questions

9729/02

24 June 2024

2 hours

Candidates answer on Question Paper.

Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft 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

1

/15

2

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5

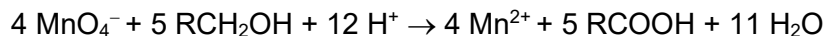
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**Paper 2
Total**

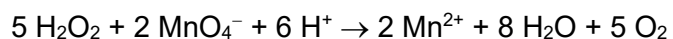
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This document consists of **21** printed pages.

- 1 (a) 1.20 g of an unknown alcohol, RCH_2OH was diluted with water to give a 250 cm^3 solution. 25.0 cm^3 of the solution was pipetted out and added to 25.0 cm^3 of 0.16 mol dm^{-3} acidified KMnO_4 in a hot water bath. KMnO_4 reacts with RCH_2OH as shown in the following equation:



The unreacted KMnO_4 in the resultant solution requires 24.00 cm^3 of $0.200 \text{ mol dm}^{-3}$ of H_2O_2 for complete reaction.



- (i) Draw the dot-and-cross diagram for H_2O_2 .

[1]

- (ii) Calculate the amount of KMnO_4 reacted with H_2O_2 and the amount of KMnO_4 that reacted with the alcohol from the 25.0 cm^3 of solution.

[2]

(iii) Calculate the amount of alcohol in 250 cm³ solution and the M_r of the alcohol.

[2]

(iv) Using your answer to (iii), determine the structure of the alcohol.

[1]

- (b) A double salt is a salt that contains more than one cation or more than one anion in its ionic lattice. To identify the ions that make up a double salt, its individual ions are passed through the same electric field and their angle of deflection are recorded in Table 1.

The angle of deflection of Na^+ in an electric field can be used as a reference to determine the mass of the ions. When passed through an electric field, a beam of Na^+ give an angle of deflection of $+3.00^\circ$.

Table 1

Charged particle	Angle of deflection
X^{2+}	$+5.68^\circ$
Y^-	-1.94°
Z^+	$+1.76^\circ$

- (i) Determine the mass of each of the ions and suggest their identity.

[2]

- (ii) Hence, suggest the formula of the salt.

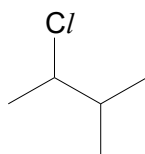
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[1]

- (c) (i) Suggest a synthetic route for the conversion of 2-chloro-3-methylbutane to 2-methylpropanoic acid.

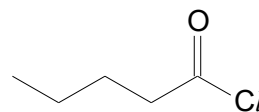
You should state the reagents and conditions needed for each step, and show clearly the structure of any intermediate compounds.

[4]

- (ii) 2-chloro-3-methylbutane and pentanoyl chloride can both undergo hydrolysis. State and explain how the rate of hydrolysis differs.



2-chloro-3-methylbutane



pentanoyl chloride

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[2]

[Total: 15]

- 2** Interhalogens are compounds that are made up of two or more different halogens. They are generally used as non-aqueous solvents.

ICl and IBr are two such examples.

- (a)** Explain why IBr has a higher boiling point than ICl by making reference to their structure and bonding.

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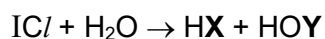
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[2]

- (b)** ICl reacts with water in which water is acting as the nucleophile.



- (i)** Considering electronegativities of the halogens, identify **X** and **Y**.

.....

.....

[1]

- (ii)** Hence propose a two-step mechanism for this reaction. Show relevant lone pairs of electrons, dipoles and curly arrows.

[2]

(c) ICl_3 exists as a planar dimer I_2Cl_6 in solid state.

- (i) Draw the structure of the dimer. Label the co-ordinate bonds on your structure.

[1]

- (ii) The molten form of ICl_3 is able to conduct electricity because it undergoes auto-ionisation to form an ionic compound **X** with molar mass of 466.8 g mol^{-1}

The cation formed is bent while the anion formed is square planar.

Deduce the formulae of the cation and the anion in compound **X**.

.....

[2]

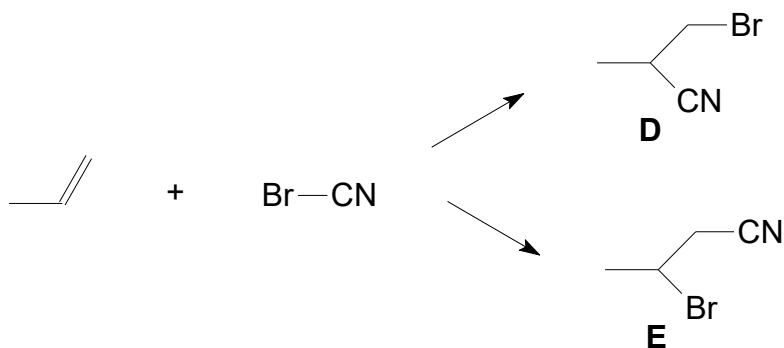
(d) Cyanogen bromide, $BrCN$, undergoes substitution with phenol and addition reaction with propene.

- (i) Benzene can only react with $BrCN$ in the presence of a suitable catalyst. Suggest why there is a difference in the condition required for benzene and phenol to react with $BrCN$.

.....

[2]

- (ii) When propene is reacted with BrCN, compound **D** is produced as the major product.



Describe the reaction mechanism for the formation of **D**. Show relevant lone pairs of electrons, dipoles and curly arrows. Hence explain the preferential production of compound **D**.

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[3]

- (iii) When separate samples of 4-bromophenol and compound **D** was heated with ethanolic AgNO_3 , they give different observations. State and explain the difference in observation.

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[2]

[Total : 15]

- 3 Methanol is the simplest alcohol, and is a volatile, colourless and flammable liquid. Methanol is mainly used as an antifreeze, solvent or fuel.

(a) Define the term *standard enthalpy change of combustion of methanol* in words.

.....
.....

[1]

- (b) (i) Using appropriate data from the *Data Booklet*, calculate the ΔH_r of the following reaction.



[2]

- (ii) Hence determine the standard enthalpy change of combustion of methanol.

.....
.....

[1]

- (c) The theoretical standard enthalpy change of combustion of methanol is -715 kJ mol^{-1} . Give a reason to explain the discrepancy between this value and your answer in (b)(ii).

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[1]

- (d) In a laboratory, methanol can also be oxidised using suitable chemicals.

Give the appropriate reagents and conditions required for the following conversion.

I: Methanol $\rightarrow$ Methanal

Reagents and conditions:

II: Methanol $\rightarrow$ Methanoic acid

Reagents and conditions:

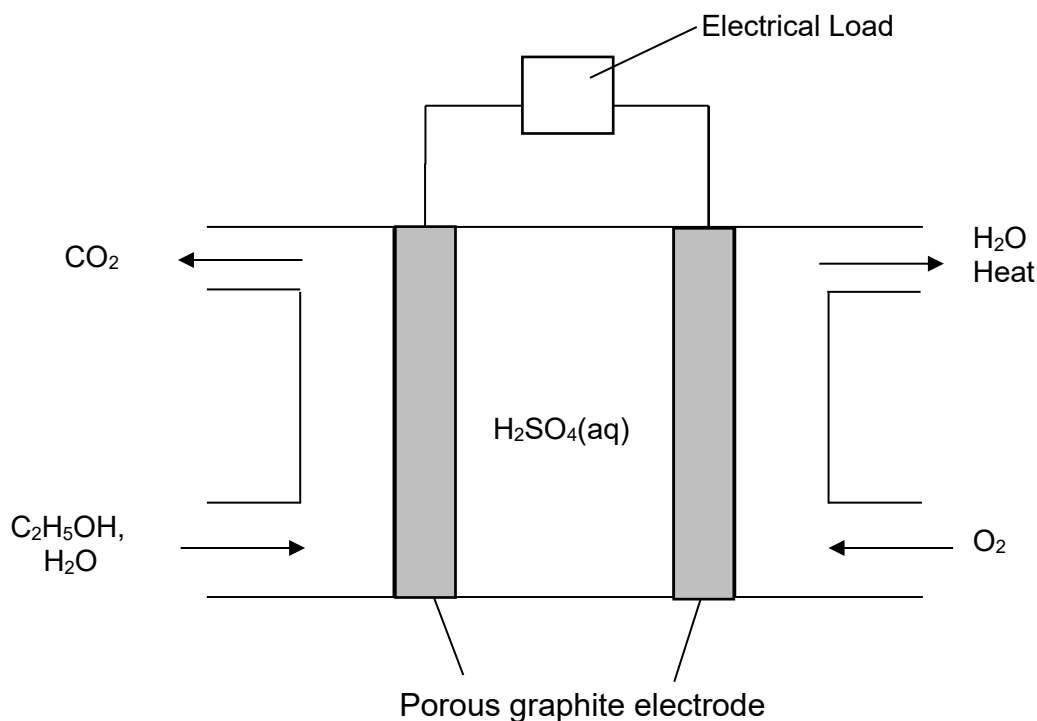
III: Methanol $\rightarrow$ Carbon dioxide

Reagents and conditions:

[3]

A fuel cell is an electrochemical cell that converts heat energy into electrical energy. The direct oxidation of alcohols in a fuel cell is one of the methods used.

(e) The diagram below illustrates the functional parts of a fuel cell.



- (i) Write the ion–electron half–equations for the reactions which take place at the electrodes of the fuel cell, and hence an overall equation for the cell reaction.

Anode:

Cathode:

Overall equation:

[2]

- (ii) Indicate on the diagram, the direction of electron flow and the polarity of each electrode.

[2]

- (iii) The fuel cell has a standard cell potential, E°_{cell} , of 1.61 V. By using suitable data from the *Data Booklet*, calculate the E° value for the $\text{CO}_2/\text{C}_2\text{H}_5\text{OH}$ half-cell.

[1]

- (iv) Hence, determine the standard Gibbs free energy change (ΔG°) for the overall cell reaction.

[1]

- (v) Discuss the effect on the cell potential of the above cell if the ethanol used has a concentration of 0.5 mol dm^{-3} .

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[2]

- (vi) Name an advantage that a fuel cell has over a conventional battery in which the reactive materials are stored within the cell.

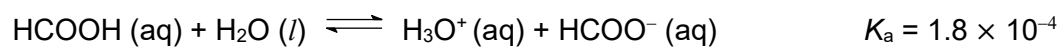
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[1]

[Total : 17]

- 4 (a) Methanoic acid, HCOOH , ionise according to the following equation.



- (i) Write the expression of the acid dissociation constant, K_a .

[1]

- (ii) Calculate the pH of a 0.25 mol dm^{-3} solution of HCOOH .

[2]

- (iii) Calculate the volume of 0.50 mol dm^{-3} aqueous sodium hydroxide added to 10.0 cm^3 of 0.25 mol dm^{-3} aqueous methanoic acid to produce a solution of pH 4.

[3]

- (b) When a catalyst is added to a solution of $\text{HCOOH}(\text{aq})$, the following reaction occurs.

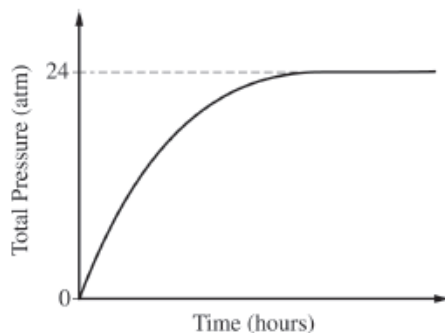
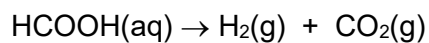


Figure 4

The pressure exerted by the gaseous products in a 4.3 dm^3 vessel maintained at 25°C is measured with time as shown in Figure 4.

Calculate the number of moles of CO_2 produced in the reaction.
[Assume that the amount of $\text{CO}_2(\text{g})$ dissolved in the solution is negligible.]

[2]

- (c) Suggest how would the actual pressure of CO_2 differ from that of an ideal gas.

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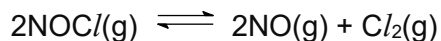
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[2]

- (d) A gaseous chemical equilibrium is established in a 2 dm³ container at 500 K for the following reaction:



The initial amount of NOCl is 0.3 mol. At equilibrium, 0.05 mol of Cl₂ is present.

- (i) Calculate the K_c for the reaction, stating the units.

[3]

- (ii) If the volume of the container is increased while keeping the temperature constant, explain how the position of equilibrium would be affected.

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[2]

[Total : 15]

- 5 Most of the 20 different common amino acids found in humans have the same general structure.

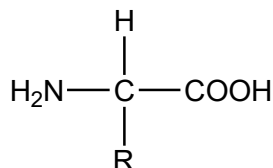


Table 5.1 shows the structural formulae of some amino acids and their respective taste.

Table 5.1

Abbreviation	Amino acid	Formula of –R group	Taste
ala	alanine	–CH ₃	sweet
asp	aspartic acid	–CH ₂ CO ₂ H	sour
gly	glycine	–H	sweet
phe	phenylalanine	–CH ₂ C ₆ H ₅	bitter
ser	serine	–CH ₂ OH	sweet
val	valine	–CH(CH ₃) ₂	bitter

- (a) (i) Draw the structure of the dipeptide gly-val.

[1]

- (ii) The sequence of amino acids in a polypeptide may be determined by partial hydrolysis of the chain into smaller pieces, often tripeptides. Following such a partial hydrolysis, the following tripeptides were obtained from a given polypeptide.

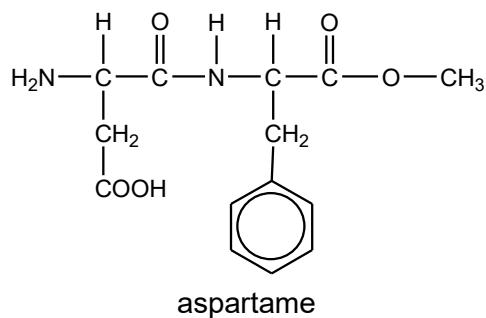
ala-gly-asp phe-val-ser ser-ala-gly val-ser-ala

Suggest the amino acid sequence of the **shortest** polypeptide that would give the above tripeptides.

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[1]

- (b) Use of the data in Table 5.1 is relevant to parts of this question.

Aspartame, an artificial sweetener, is used in soft drinks and in sugar-free foods for people with diabetes.



Alkaline hydrolysis of aspartame produces three products.

- (i) Suggest the three products obtained from the alkaline hydrolysis of aspartame.

[2]

- (ii) Hence suggest why aspartame is not used to sweeten foods that are to be boiled.

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[1]

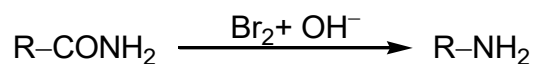
- (c) Glycine, $\text{H}_2\text{NCH}_2\text{CO}_2\text{H}$, is the simplest amino acid. There are two pK_a values associated with glycine: 2.34 and 9.60.

Suggest the major species present in solutions of glycine at the following pH values.

pH 1	pH 6

[2]

- (d) Hoffmann degradation whereby treating a primary amide with aqueous alkaline bromine produces a primary amine.



The Hoffmann degradation can be used as the last step in the synthesis of phenylamine from benzoic acid.

Suggest a 3-stage synthesis of phenylamine from benzoic acid.

You should state the reagents and conditions needed for each step, and show clearly the structure of any intermediate compounds.

[4]

- (e) Compound **R**, $\text{C}_6\text{H}_{12}\text{O}_3$, is optically active.

Three chemical tests are carried out on portions of **R** and the results are described in Table 5.2.

Table 5.2

Reagents	Observations
Excess Sodium metal	Effervescence. 1 mol of R produces 1 mol of gas
Hot acidified $\text{K}_2\text{Cr}_2\text{O}_7$	Orange solution remains
Na_2CO_3 (aq)	Effervescence

Draw the structure of **R**.

[2]

[Total : 13]



NATIONAL JUNIOR COLLEGE
SH2 MID YEAR TIMED PRACTICE
Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

CHEMISTRY

9729/03

Paper 3 Free Response

27 June 2024

1 hour

Candidates answer on Question Paper.

Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams or graphs.

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

Answer **all** questions.

A Data Booklet is provided.

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.

For Examiner's Use	
1	/20
2	/20
Paper 3 Total	/40

This document consists of **14** printed pages.

- 1 (a) Propene and lactic acid are commonly used as feedstock for polymers. **Fig 1.1** shows the synthesis of lactic acid from propene.

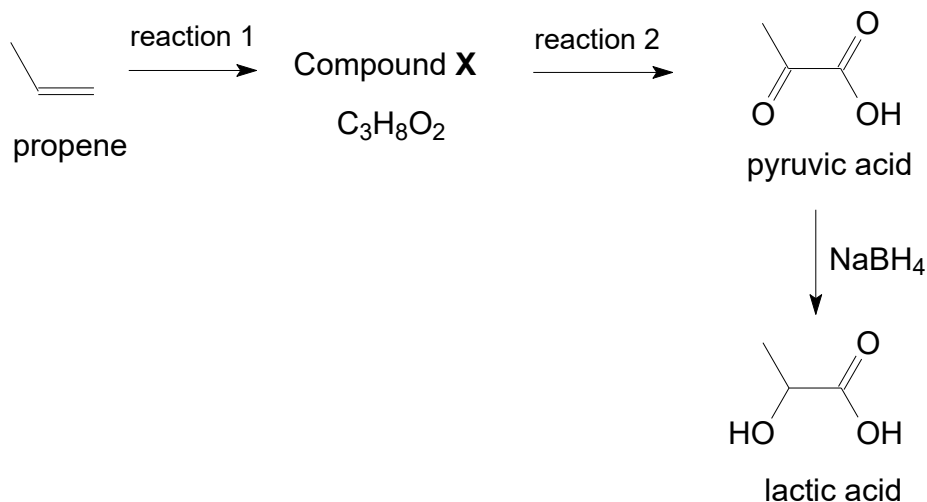


Fig 1.1

- (i) Suggest the displayed formula of compound **X**. [1]
- (ii) Suggest reagents and conditions for reaction 1 and 2. [2]
- (iii) Explain why sodium borohydride can reduce the carbonyl C=O bond in pyruvic acid but not C=C bond in propene. [1]

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- (b) Compound **Y**, $C_6H_8O_4$, is formed when lactic acid reacts in the presence of hot concentrated H_2SO_4 . **Y** is a cyclic compound that does not react with sodium carbonate.

(i) Deduce the structure of compound **Y**.

[1]

(ii) Explain why compound **Y** have low solubility in methanol.

[2]

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- (c) Compound **Z**, $C_5H_8O_2$, can be derived from further reactions between lactic acid molecules.

One mole of compound **Z** reacts with 2 moles of 2,4-dinitrophenylhydrazine. It forms 1 mole of CHI_3 upon reaction with aqueous alkaline iodine and does not give silver mirror with Tollen's reagent.

Deduce the structure of compound **Z**.

[1]

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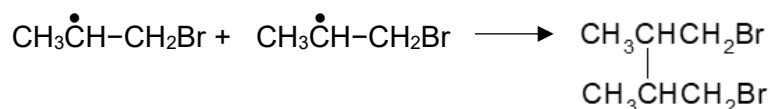
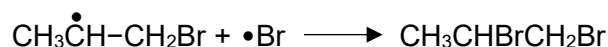
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- (d) Hydrogen halides usually react with alkenes via an electrophilic addition mechanism. However, in the presence of organic peroxides, RO—OR, hydrogen halide reacts with alkenes via a different mechanism, free radical addition.

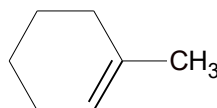
The *first 4 steps*, **A** to **D**, of the reaction between HBr and propene, in the presence of RO—OR take place as follow:

- A** Homolytic fission of RO—OR to produce two RO• radicals.
 - B** RO• reacts with one HBr molecule to produce Br• radical.
 - C** the bromine radical formed in step **B** react with propene to form $\text{CH}_3\dot{\text{C}}\text{HCH}_2\text{Br}$ radical
 - D** $\text{CH}_3\dot{\text{C}}\text{HCH}_2\text{Br}$ radical react with HBr molecule to form $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ as one of the organic products of the free radical addition reaction.
- (i) Outline the mechanism for steps **C** and **D** of the free radical addition mechanism, using curly arrows to indicate the movement of electrons. [2]
- (ii) The reaction starts when the reactants are exposed to bright light. Suggest a reason why the reaction continues at a high rate after the brief exposure to the bright light has stopped. [1]
- (iii) Explain why HCl does not react with alkenes via free radical addition under the same conditions, unlike HBr. [1]

In the *final* stage of the free-radical addition reaction, two other organic products are obtained via the termination steps shown below.



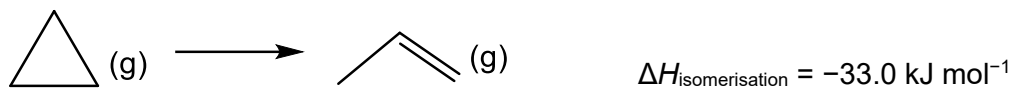
- (iv) Suggest the structural formula of **two** organic products formed when 1-methylcyclohexene undergoes free radical addition with HBr in the presence of peroxide radicals.



1-methylcyclohexene

[2]

- (e) Propene can be formed from the isomerization of an explosive and colourless gas, cyclopropane, as shown in the equation below, at 298K.



	$\Delta H_f^\ominus / \text{kJ mol}^{-1}$
standard enthalpy change of formation of $\text{CO}_2(g)$	-394
standard enthalpy change of formation of $\text{H}_2\text{O}(l)$	-286
standard enthalpy change of combustion of cyclopropane (g)	-2091

Using the data given above, construct a suitable energy cycle and calculate the enthalpy change of formation of propene at 298 K.

[3]

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- [2]

[Total: 20]

- 2 (a) The kinetics of urea synthesis, $\text{CO}(\text{NH}_2)_2$, are investigated by using different concentrations of CO_2 and NH_3 in the presence of Fe_2O_3 catalyst at high temperature and pressure in a 10 dm^3 vessel, as shown in Table 2.1.

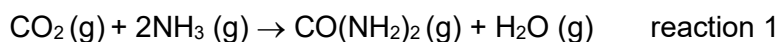


Table 2.1

experiment	initial $[\text{CO}_2]$ / mol dm^{-3}	initial $[\text{NH}_3]$ / mol dm^{-3}
A	0.03	2.00
B	0.03	1.00

Fig. 2.1 shows how $[\text{CO}(\text{NH}_2)_2]$ in the reaction mixture varies with time for experiments A and B.

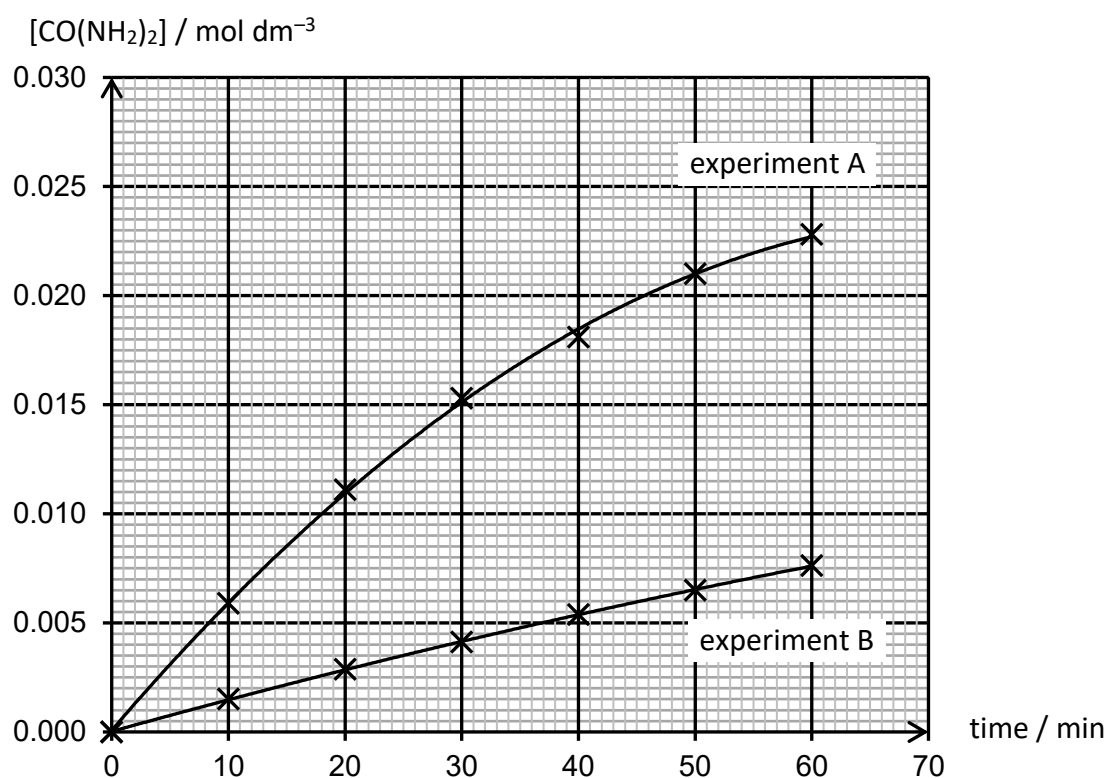


Fig. 2.1

- (i) Using Table 2.1, calculate the concentration of urea, $\text{CO}(\text{NH}_2)_2$ at the end of the reaction using Experiment A.
- [1]
- (ii) Using the graphs in Fig. 2.1, show that the reaction is first order with respect to CO_2 and second order with respect NH_3 . You are required to show clearly all working, including any construction lines on Fig. 2.1.

[3]

- (iii) Using the graph of experiment **A**, calculate a value for the rate constant, k , of the urea synthesis reaction, and state its units. [2]
- (iv) With the aid of a Boltzmann distribution curve, explain how Fe_2O_3 catalyst increases the rate of the reaction. [2]

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[illegible]

- (b) The synthesis of urea involves the formation of compound **Y**.

Under suitable conditions, CO_2 reacts with NH_3 to form compound **Y** as the only product.



Compound **Y**, a white solid, is made up of a cation and an anion in 1:1 mole ratio. The cation liberates NH_3 when compound **Y** is heated with aqueous NaOH .

Suggest the identity of the cation and anion of compound **Y**. [2]

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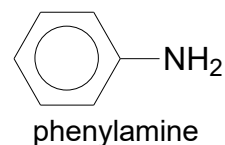
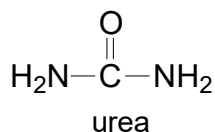
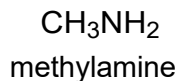
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- (c) Arrange the following compounds in order of increasing base strength. Explain your answer. [3]



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- (d) Oxalic acid, $\text{C}_2\text{H}_2\text{O}_4$, commonly found in vegetables such as spinach and rhubarb, is known to contribute to the formation of calcium oxalate kidney stones, CaC_2O_4 , in the human body.

The solubility product, K_{sp} , of CaC_2O_4 is $2.7 \times 10^{-9} \text{ mol}^2 \text{ dm}^{-6}$ at 298 K.

- (i) Write an expression for the solubility product, K_{sp} , of CaC_2O_4 . [1]

- (ii) Explain how the addition of solid calcium nitrate, $\text{Ca}(\text{NO}_3)_2$ at 298 K will affect the solubility and solubility product of CaC_2O_4 . [2]

- (iii) The value of solubility product, K_{sp} , of $\text{Ag}_2\text{C}_2\text{O}_4$ is 5.40×10^{-12} .

Determine whether precipitation will be observed when $1.80 \times 10^{-7} \text{ mol}$ of solid AgNO_3 was added to 25.0 cm^3 of $3.50 \times 10^{-3} \text{ mol dm}^{-3} \text{ K}_2\text{C}_2\text{O}_4$. [2]

- (iv) Describe and explain how the solubility of $\text{Ag}_2\text{C}_2\text{O}_4$ is affected by the addition of excess aqueous NH_3 . [2]

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Additional answer space

If you use the following pages to complete the answer to any question, the question number must be clearly shown.

[illegible]