NATIONAL JUNIOR COLLEGE

SH1 Promotional Examination

Higher 1

CANDIDATE NAME			
SUBJECT CLASS		REGISTRATION NUMBER	

CHEMISTRY 8873/02

Paper 2 Structured Questions

29 September 2022
1 hour 30 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THE INSTRUCTIONS FIRST

Write your subject class, registration number and name in the spaces at the top of this page.

Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams or graphs.
Do not use paper clips, highlighters, glue or correction fluid.

*Answer **all** questions on the Question Paper.*

The use of an approved 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.

Appropriate significant figures and units are expected for final numerical answers.

For Examiner's Use	
1	/17
2	/9
3	/8
4	/15
5	/11
Penalty	
Presentation	
Paper 2	/60
Paper 1	/20
Total	/80
Promo Percentage	/100

This document consists of **21** printed pages and **3** blank pages.

For Examiner's Use

1 Some properties of SCl_2, S_2Cl_2, S_8 and Cl_2 are shown in the table.

property	SCl_2	S_2Cl_2	S_8	Cl_2
density / g cm^{-3}	1.62	1.69	2.07	0.00290
melting point / °C	−78	−80	115	−102
boiling point / °C	decomposes at 59 °C	137	445	−34
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−49.8	−59.4		

(a) S_2Cl_2 can be made by direct combination of sulfur in its standard state, S_8, and chlorine gas, Cl_2.

(i) Write a thermochemical equation that represents the standard enthalpy change of formation of S_2Cl_2.

[2]

$\frac{1}{4}\ S_8\,(s) + Cl_2\,(g) \longrightarrow S_2Cl_2\,(l) \quad \Delta H_f^{\ominus} = -59.4\ kJ\ mol^{-1}$

Correct species (in particular S_8) and balanced eqn, with $\Delta H_f^{\ominus}$ value

Correct state symbols of all species

(ii) A chemist wishes to prepare 10.0 cm^3 of S_2Cl_2 from its elements.

Use the data in the table to calculate the mass of sulfur required to produce this volume of S_2Cl_2. Give your answer to 4 significant figures.

Mass of S_2Cl_2 = 1.69 g cm^{-3} × 10.0 cm^3 = 16.9 g

Amount of S_2Cl_2 = 16.9 / 135.2 = 0.125 mol

Amt of sulfur, S_8 = ¼ × 0.125 = 0.03125 mol

Mass of sulfur, S_8 = 0.03125 × (8 × 32.1) = 8.025 g (4 s.f.)

[2]

For Examiner's Use

(iii) Suggest a reason for the difference in physical state of S_8 and Cl_2 at room temperature and pressure.

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[2]

Both are non-polar simple covalent molecules.

S_8 has a higher M_r, hence larger electron cloud which is more easily distorted than that of Cl_2, forming stronger intermolecular instantaneous dipole-induced dipole (id-id) interactions.

Energy at room temperature and pressure is sufficient to overcome the weaker id-id between Cl_2 but insufficient to overcome the stronger id-id between S_8, hence, Cl_2 exists as a gas while S_8 exists as a solid at r.t.p.

(b) S_2Cl_2 can also be formed when SCl_2 decomposes, as shown in the equation below.

$$2SCl_2 \longrightarrow S_2Cl_2 + Cl_2$$

Using the data in the table, calculate the standard enthalpy change, $\Delta H_r^{\ominus}$, for this reaction.

$\Delta H_r^{\ominus} = \Sigma\Delta H_f^{\ominus}(\text{product}) - \Sigma\Delta H_f^{\ominus}(\text{reactant})$

$= -59.4 - 2(-49.8)$

$= +40.2 \text{ kJ mol}^{-1}$

Note: $\Delta H_f^{\ominus}\ Cl_2(g) = 0$

[1]

(c) S_2Cl_2 reacts with water, as shown in the equation below.

$$S_2Cl_2 + 2H_2O \longrightarrow SO_2 + H_2S + 2HCl$$

By considering the oxidation states of sulfur, state and explain the type of reaction taking place.

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[2]

Disproportionation.

The oxidation state of S increases from +1 in S_2Cl_2 to +4 on SO_2, and decreases to −2 in H_2S, hence it has been oxidized and reduced simultaneously.

(d) **(i)** Draw a dot-and-cross diagram to show the bonding present in S_2Cl_2. given that the atoms are bonded in the order C*l*–S–S–C*l*.

For Examiner's Use

[1]

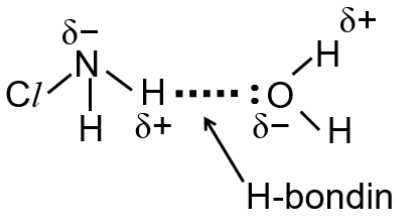
(ii) Predict the shape about the S atom and the C*l*–S–S bond angle in S_2Cl_2.

shape: ……..bent

bond angle: ……..105º [1]

(e) Chloramine, NH_2Cl, can be used in the treatment of drinking water to kill bacteria.

Draw a labelled diagram to show the interaction formed between NH_2Cl and a H_2O molecule.



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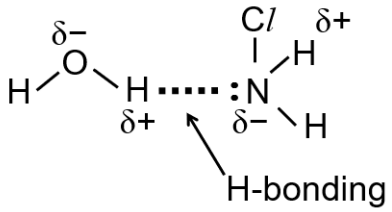

1) Lone pair electron on N/O interacting with δ+ H of H−O and H−N
2) Indicate δ+ and δ−
3) Clearly label "hydrogen bonding"

[2]

For Examiner's Use

(f) The ionic radii of some ions are shown in the table below.

species	ionic radius / nm
Cl^-	0.181
O^{2-}	0.140
S^{2-}	0.184

Using the data given, explain the difference in ionic radius of the following pairs of elements.

(i) Cl^- and S^{2-}

Cl^- : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ S^{2-} : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Nuclear charge of Cl^- is **larger** than S^{2-} (due to higher number of protons)

Shielding effect remains (relatively) constant (since same number of electrons in the inner principal quantum shells).

Nuclear attraction for the valence electrons in Cl^- is **larger** than S^{2-}. The valence electrons are pulled closer to the nucleus, hence **ionic radius for Cl^- is smaller**.

[2]

(ii) O^{2-} and S^{2-}

O^{2-} : $1s^2\ 2s^2\ 2p^6$ S^{2-} : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

The valence electron in S^{2-} is **further away from the nucleus** due to having 1 more filled principal quantum shell.

S^{2-} has a **larger shielding effect** than O^{2-}.

These factors **outweigh the increase in nuclear charge** for S^{2-}. **Nuclear attraction** for the valence electrons in S^{2-} is **lesser** than O^{2-}, hence valence electrons are less attracted to the nucleus and **ionic radius for S^{2-} is larger**.

[2]

[Total: 17]

For Examiner's Use

2 (a) Gold can be extracted from low-grade ore around the world by use of the *Elsner* reaction in which the impure gold ore is reacted with an aqueous solution of sodium cyanide, as shown in the equation below.

$$4Au + 8NaCN + O_2 + 2H_2O \longrightarrow 4NaAu(CN)_2 + 4NaOH$$

The experimental procedure to determine the percentage by mass of gold in the sample of impure gold ore is as follows:

- A sample of 35 g of impure gold ore was added to 250 cm^3 aqueous solution of sodium cyanide.
- 25.0 cm^3 of the resulting solution was neutralised with 15 cm^3 of 0.3 mol dm^{-3} sulfuric acid.
- The excess sulfuric acid was then titrated with 0.06 mol dm^{-3} potassium hydroxide solution. 17.00 cm^3 of KOH (aq) was required to reach the end point.

Calculate the percentage by mass of gold in the sample of impure gold ore.

Reaction 1: $4Au + 8NaCN + O_2 + 2H_2O \longrightarrow 4NaAu(CN)_2 + 4NaOH$

Reaction 2 (H_2SO_4 in excess): $2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$

Reaction 3 (neutralisation of remaining H_2SO_4): $2KOH + H_2SO_4 \longrightarrow K_2SO_4 + 2H_2O$

For reaction 3: Amount of KOH = $\frac{17.00}{1000} \times 0.06 = 1.020 \times 10^{-3}$ mol

$2KOH \equiv H_2SO_4$

Amount of remaining H_2SO_4 (reaction 3) = $\frac{1.02 \times 10^{-3}}{2} = 5.1 \times 10^{-4}$ mol

Initial amount of $H_2SO_4 = \frac{15}{1000} \times 0.3 = 0.0045$ mol

For reaction 2:
Amount of H_2SO_4 reacted with 25 cm^3 NaOH = $0.0045 - 5.1 \times 10^{-4}$
$= 3.99 \times 10^{-3}$ mol

$2NaOH \equiv H_2SO_4$

Amount of NaOH in 25 $cm^3 = 3.99 \times 10^{-3} \times 2 = 7.98 \times 10^{-3}$ mol

Amount of NaOH in 250 $cm^3 = 7.98 \times 10^{-3} \times \frac{250}{25} = 0.0798$ mol

For reaction 1: $Au \equiv NaOH$

Amount of Au = 0.0798 mol

Mass of Au = $0.0798 \times 197.0 = 15.72$ g

% by mass of Au in gold ore = $\frac{15.72}{35} \times 100 = 44.9\%$

[3]

(b) Gold can also be found in the sea water. It is believed that gold has a concentration of 11 parts per trillion by mass in sea water. Calculate the concentration of gold present in mol dm^{-3}, given that the density of sea water is 1.03 g cm^{-3}.

For Examiner's Use

[1 trillion = 10^{12}]

In 1 dm^3 of sea water,

Mass of sea water = $1.03 \times 1000 = 1030$ g

Mass of gold = $\frac{11}{10^{12}} \times 1030 = 1.133 \times 10^{-8}$ g

Amount of gold = $\frac{1.133 \times 10^{-8}}{197.0} = 5.75 \times 10^{-11}$ mol

Concentration of gold in mol dm^{-3} = 5.75×10^{-11} mol dm^{-3}

[2]

(c) Explain why gold is commonly used in electrical wiring in terms of its structure.

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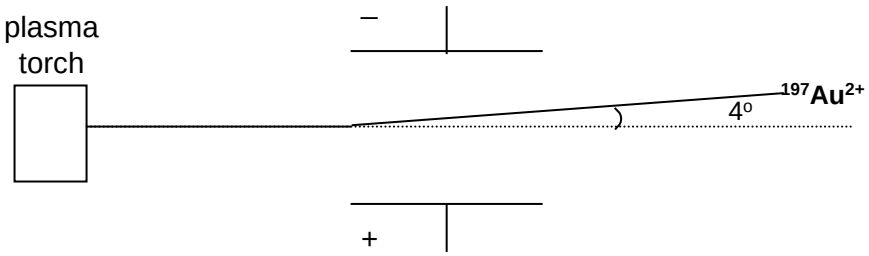
..... [1]

Gold has a metallic lattice structure with a **sea of delocalized / mobile electrons** to act as **charge carriers** to **conduct electricity**

For Examiner's Use

(d) In a biochemical laboratory, a plasma torch is often used to ionise a variety of samples during analysis. A sample of gold, Au, was allowed to pass through the plasma torch and the particles that emerged were routed through an electromagnet.

It was observed that a beam of $^{197}Au^{2+}$ gives an angle of deflection of +4°.



(i) Calculate the angle of deflection for a sample of $^{52}Cr^{3+}$ ions.

Angle of deflection = $k \times \frac{\text{charge}}{\text{mass}}$

For $^{197}Au^{2+}$ nuclei, $+4 = k\left(\frac{+2}{197}\right)$

$k = +394$

For $^{52}Cr^{3+}$, angle of deflection = $+394 \times \frac{+3}{52.0} = +22.7°$ **[1] answer with positive sign**

[1]

(ii) Write the full electronic configuration of Cr^{3+}.

.....

[1]

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

(iii) In alkaline medium, Cr^{3+} can be oxidized to CrO_4^{2-}.

Construct the oxidation half equation.

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[1]

[O] $Cr^{3+} + 8OH^- \longrightarrow CrO_4^{2-} + 4H_2O + 3e^-$

[Total: 9]

For Examiner's Use

3 **(a)** 0.03 moles of but-1-ene, $CH_2=CHCH_2CH_3$, are completely burnt in a 2 dm^3 sealed vessel containing 0.30 moles of oxygen gas at 450 °C. The vessel walls can withstand a maximum pressure of 2000 kPa.

(i) Construct a chemical equation, including state symbols, for the combustion of but-1-ene gas with oxygen in the 2 dm^3 sealed vessel at 450 °C.

[2]

$CH_2=CHCH_2CH_3(g) + 6O_2(g) \longrightarrow 4CO_2(g) + 4H_2O(g)$

balanced equation

correct state symbols

(ii) Calculate the total amount of gas present in the vessel when the combustion is completed at 450 °C.

	$C_4H_8(g)$	+	$6O_2(g)$	→	$4CO_2(g)$	+	$4H_2O(g)$
Initial / mol	0.03		0.30		0		0
Change / mol	–0.03		–0.18		+0.12		+0.12
Final / mol	0.00		0.12		0.12		0.12

Total amount of gas present = 0.12 + 0.12 + 0.12 = 0.36 mol

[1]

(iii) At 450 °C, 1 mol of gas in a 2 dm^3 container would exert a total pressure of 3×10^6 Pa.

Suggest if the vessel will remain intact throughout the reaction.

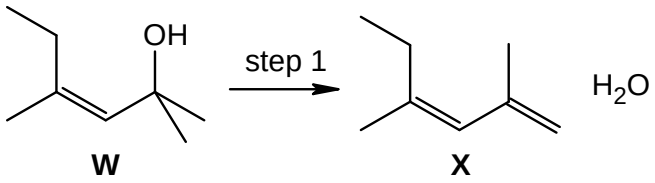
Total pressure exerted by the gas = $0.36 \times 3 \times 10^6 = 1.08 \times 10^6$ Pa = 1080 kPa

This is lower than the maximum pressure that the vessel wall can withstand, i.e. 2000 kPa. Hence, the vessel will remain intact throughout the reaction.

[1]

For Examiner's Use

(b) Compound **W** can undergo the following reaction.



W **X**

(i) Suggest the reagents and conditions for step 1.

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[1]

Step 1: Excess concentrated H_2SO_4, heat or Al_2O_3(s) heat

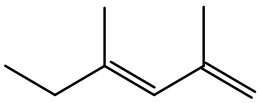
(ii) Using relevant information from the *Data Booklet*, calculate ΔH_r for step 1.

ΔH_r = BE(C–O) + BE(C–H) + BE(C–C) – BE(O–H) – BE(C=C)

= 360 + 410 + 350 – 460 – 610 = +50 kJ mol^{-1}

[2]

(iii) Draw the structure of the stereoisomer of **X**.



Note: show the cis-trans isomer of X

[1]

[Total: 8]

For Examiner's Use

4 **(a)** In an experiment, 40 cm^3 of 1.00 mol dm^{-3} sodium hydroxide is added to 10 cm^3 of 1.00 mol dm^{-3} sulfuric acid. The temperature of the mixture rises by 5.4 °C.

$$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$$

(i) Calculate the enthalpy change of neutralisation.

Amount of NaOH = $\frac{40}{1000} \times 1.00 = 0.04$ mol

Amount of H_2SO_4 = $\frac{10}{1000} \times 1.00 = 0.01$ mol

H_2SO_4 is the limiting reagent.

Amount of H_2O formed = 0.02 mol

$$\Delta H_n = -\frac{mc\Delta T}{n_{H2O\ formed}} = -\frac{50 \times 4.18 \times (+5.4)}{0.02}$$

$$= -56430 \text{ J mol}^{-1} \approx -56.4 \text{ kJ mol}^{-1}$$

Note: m is mass of aq solution.

ΔH_n is defined for 1 mol of H_2O formed from acid-base reaction.

[2]

(ii) The above reaction is repeated using H_2CO_3, a weak acid, in place of sulfuric acid.

Suggest the effect on the temperature rise of the reaction mixture.

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..... [2]

Weak acid only partially dissociated in aqueous solution. Part of the energy released from $H^+(aq)$ reacting with $OH^-(aq)$, is used to provide the energy to complete the dissociation of the weak acid. Hence the enthalpy change is less exothermic than that of a strong acid−strong base neutralisation.

The temperature rise of the reaction mixture will be of a smaller.

For Examiner's Use

(b) A student investigated the rate of reaction between 2-chloropropanoic acid and aqueous sodium carbonate by measuring how long it takes for 10.0 cm^3 of gas to be collected.

A series of experiments were carried out to study the order of reaction with respect to 2-chloropropanoic acid and sodium carbonate. The following results were obtained.

Experiment Number	Volume / cm^3			Time / s
	2-chloropropanoic acid	Na_2CO_3	H_2O	
1	20.0	40.0	40.0	75
2	20.0	30.0	50.0	100
3	10.0	30.0	60.0	100
4	15.0	***x***	***y***	200

(i) State the relationship between rate of reaction and time taken to collect 10.0 cm^3 of gas.

[1]

Inversely proportional.

(ii) Determine the order of the reaction with respect to 2-chloropropanoic acid and sodium carbonate.

Relative rate of Expt 1 = $\frac{1}{75}$ = 0.0133

Relative rate of Expt 2 = $\frac{1}{100}$ = 0.0100

Relative rate of Expt 3 = $\frac{1}{100}$ = 0.0100

Relative rate of Expt 4 = $\frac{1}{200}$ = 0.0050

Comparing Expt 1 and 2, while volume of 2-chloropropanoic acid is kept constant and V_{Na2CO3} in Expt 1 = $\frac{4}{3}$ × V_{Na2CO3} in Expt 2,

rate for Expt 1 = $\frac{4}{3}$ × rate for Expt 2.

Hence, order of reaction with respect to Na_2CO_3 is 1.

Comparing Expt 2 and 3, while volume of Na_2CO_3 is kept constant and $V_{CH3CH2C/CO2H}$ in Expt 2 = 2 × $V_{CH3CH2C/CO2H}$ in Expt 3,

rate for Expt 2 = rate for Expt 3.
Hence, order of reaction with respect to CH_3CH_2C/CO_2H is 0.

[2]

For Examiner's Use

(iii) Hence, write the rate equation.

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[1]

Rate = $k[Na_2CO_3]$

(iv) State the value of ***x*** and ***y*** *i*n Experiment 4.

$$\frac{\text{rate (4)}}{\text{rate (3)}} = \frac{k(x)^1}{k(30)^1}$$

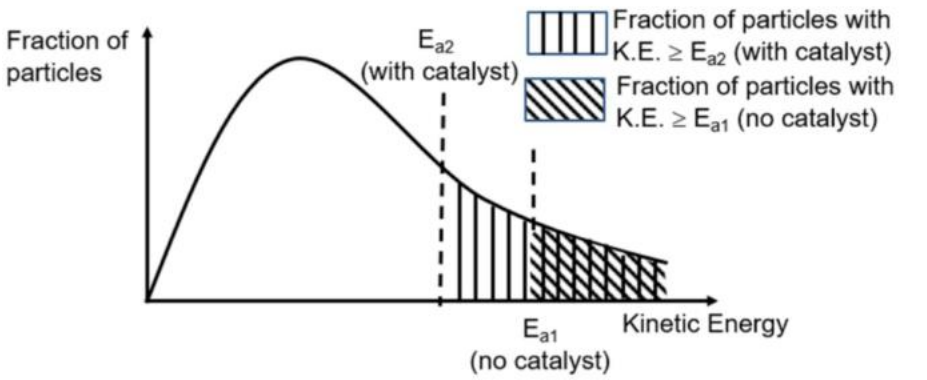
$$\frac{0.0050}{0.010} = \frac{(x)}{(30)}$$

$x = 15$

Hence, $y = 100 - 15 - 15 = 70$ (total volume of 100 cm^3)

[1]

(v) With the aid of an appropriate diagram, explain how the addition of a catalyst can affect the rate of reaction between 2-chloropropanoic acid and sodium carbonate.



A catalyst provides an alternative pathway for the reaction with a lower activation energy, E_{a2}. Hence, there is a greater fraction of particles with kinetic energy greater than or equal to activation energy. Frequency of effective collisions increases, leading to an increase in rate of reaction.

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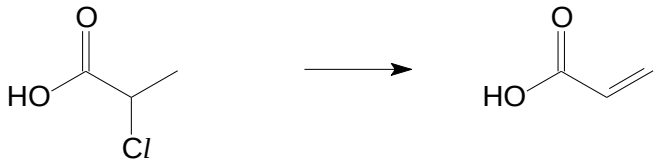
[3]

For Examiner's Use

(c) 2-chloropropanoic acid can be converted into propenoic acid.



(i) State the type of reaction.

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[1]

Elimination

(ii) Suggest a simple chemical test to distinguish between 2-chloropropanoic acid and propenoic acid.

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[2]

Br_2 in CCl_4 solvent, room temperature.
Orange-red Br_2 decolourised for propenoic acid, orange-red Br_2 remains for 2-chloropropanoic acid.

[Total: 15]

For Examiner's Use

5 **(a)** Ethanoic acid can be made from different classes of compound. Choose two starting organic compounds that have different functional groups that can be converted to ethanoic acid. Describe the reactions to form ethanoic acid including reagents, equations and any observations in your answer.

Oxidation of ethanol with $KMnO_4$, $H_2SO_4(aq)$, heat or $K_2Cr_2O_7$, $H_2SO_4(aq)$, heat
Observation: Purple $KMnO_4$ decolourises or Orange $K_2Cr_2O_7$ turns green.
Equation: $CH_3CH_2OH + 2[O] \longrightarrow CH_3COOH + H_2O$

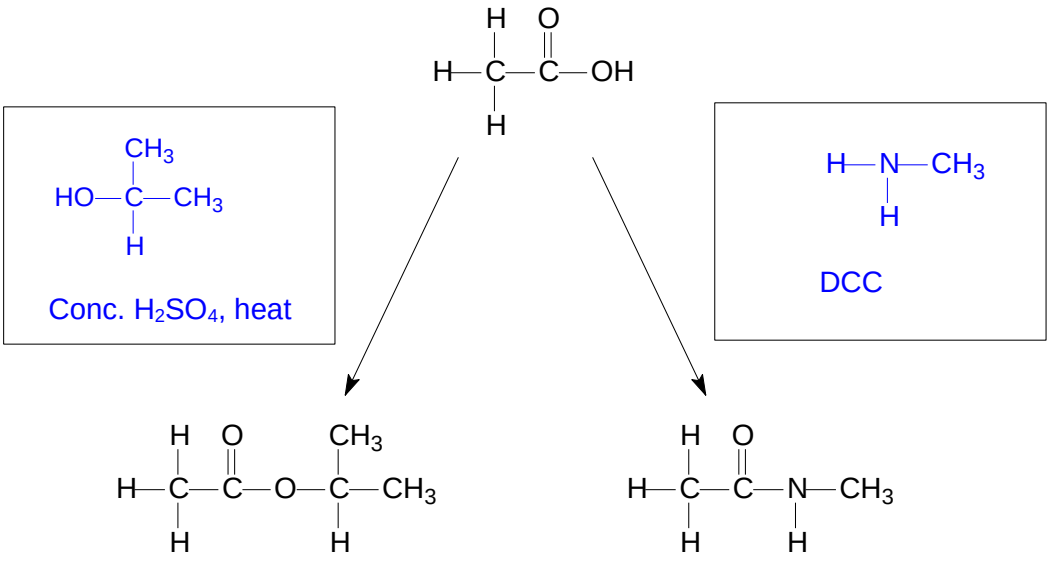
Oxidation of ethanal with $KMnO_4$, $H_2SO_4(aq)$, heat or $K_2Cr_2O_7$, $H_2SO_4(aq)$, heat
Observation: Purple $KMnO_4$ decolourises or Orange $K_2Cr_2O_7$ turns green.
Equation: $CH_3CHO + [O] \longrightarrow CH_3COOH$

Hydrolysis of ester with $H_2SO_4(aq)/HCl(aq)$, heat
Observation: No observable change.
Equation: $CH_3COOCH_3 + H_2O \longrightarrow CH_3COOH + CH_3OH$

Hydrolysis of amide with $H_2SO_4(aq)/HCl(aq)$, heat
Observation: No observable change.
Equation: $CH_3CONH_2 + H_2O + H^+ \longrightarrow CH_3COOH + NH_4^+$

(b) Ethanoic acid can be converted to ester and amide.

Give the reagents and conditions for the following conversions.



[2]

For Examiner's Use

(c) In a sample, one molecule of ethanoic acid has a relative molecular mass of 60 and another molecule of ethanoic acid has a relative molecular mass of 61. Suggest a reason for this difference in relative molecular mass.

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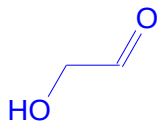
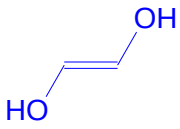
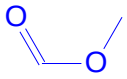
[2]

Structural formula of ethanoic acid is CH_3COOH (M_r = 60.0). The molecule with M_r of 61 could contain an atom C/H/O with a larger isotopic mass such as C (^{13}C), H (^{2}H) or O (^{17}O).

(d) Draw the skeletal structure of a functional group isomer of ethanoic acid. Name the functional groups present in this isomer.

Molecular formula of ethanoic acid is $C_2H_4O_2$.

Possible structures of functional group isomers are

		
Alcohol and aldehyde	Alkene and alcohol	ester

[2]

[Total: 11]