Billanook College

CHEMISTRY UNITS 3-4, 2018

July Examination

Friday 20 July 2018
Reading Time: 8.30 am to 8.45 am (15 minutes)
Writing time: 8.45 am to 11.15 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOKLET

NAME: Anne Swers

Structure of booklet

Section	Number of questions	Number of questions to be answered	Marks available
A - Multiple Choice	30	30	30
B - Short Answer	10	10	90
			Total marks available: 120

Directions to students

• Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
• Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white-out liquid/tape.

Materials supplied
• Question and answer book of 29 pages.
• A data book.
• Answer sheet for multiple-choice questions.

Instructions
• All written responses must be in English.

At the end of the examination
• Place the answer sheet for multiple-choice questions inside the front cover of this book.
• You may keep the data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – MULTIPLE-CHOICE QUESTIONS

Instructions for Section A

Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.
Choose the response that is **correct** or that **best answers** the question.
A correct answer scores 1 an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.
Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Question 1

Which one of the following energy transformations occurs in a galvanic cell but **not** in an electrolytic cell?

A. electrical energy to chemical energy
B. heat energy to chemical energy
C. electrical energy to heat energy
D. chemical energy to electrical energy

Question 2

Ethanol can be produced as a biofuel and can also be produced from fossil fuels. The following statements refer to ethanol from the two different sources.

I Combustion of the biofuel ethanol will produce less greenhouse gases than combustion of the ethanol derived from fossil fuels.

II Ethanol from fossil fuels contains more energy per gram than the biofuel ethanol.

III The biofuel ethanol is produced from grains grown on farmland which could be used to grow food crops.

IV Both types of ethanol have identical environmental impact associated with their extraction and production.

Which of these statements are **incorrect**?

A. I and II only
B. II and III only
C. I, II and IV only
D. III and IV only

Question 3

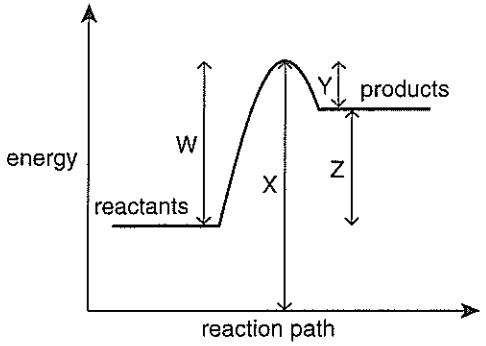
The salt bridge and connecting wire are removed from an operating galvanic cell and discarded.

If the contents of the two half-cells are placed in one container, what will be the likely outcome?

A. The reaction will continue as electrons can move through the liquid in the container.
B. The reaction will continue as heat energy rather than electrical energy is produced.
C. The reaction will stop as there is no salt bridge to transport the anions and cations.
D. The reaction will stop as there is no connecting wire allowing electrons to travel.

Use the following information to answer Questions 4–6.

The energy profile of a particular reaction involving only gases is shown below.



Question 4

Which one of the following shows the correct reaction type and bond strengths for the reaction represented in the profile above?

	Type of reaction	Molecules with the stronger bonds
A.	endothermic	reactants
B.	endothermic	products
C.	exothermic	reactants
D.	exothermic	products

Question 5

Product molecules will form

A. whenever reactant molecules collide in a particular orientation.

B. if reactant molecules with energy of exactly W collide in any orientation.

C. if reactant molecules with energy of exactly X collide in any orientation.

D. if reactant molecules with energy of at least Y + Z collide in a particular orientation.

Question 6

Which of the values will **not** be affected by the inclusion of a suitable catalyst for the reaction?

A. W only

B. X only

C. Z only

D. Y and Z only

Question 7

An oxidising agent and a reducing agent are mixed together under standard conditions but no reaction is apparent. Statements I to III may relate to the apparent lack of reaction.

I The weaker oxidising agent and reducing agent of the conjugate pairs were mixed.

II The rate of the redox reaction is extremely slow.

III The difference in $E°$ values between the relevant half-reactions is very low.

Which of these statements could possibly explain the lack of observed reaction?

A. I and II only
B. II and III only
C. I and III only
D. I, II and III

Use the following information to answer Questions 8–10.

Using unreactive electrodes, electrolysis of a concentrated sodium chloride solution will produce chlorine gas at one of the electrodes.

Question 8

Which one of the following products is generated at the other electrode?

A. hydrogen gas
B. sodium
C. oxygen gas
D. water

Question 9

The electrochemical series predicts that chlorine gas will **not** be produced during this electrolysis.

Which one of the following is the most likely reason that this prediction is unreliable?

A. A larger voltage than usual is used in the electrolytic cell.
B. Using unreactive electrodes makes predictions uncertain.
C. The conditions used for the cell are not standard.
D. One electrode had been coated with catalytic particles.

Question 10

In the industrial production of chlorine, the cell operates at 1.0×10^5 amperes.

What volume of chlorine gas (in L) would be collected at standard laboratory conditions (SLC) in 1.5 hours?

A. 1.2×10^3
B. 6.9×10^4
C. 1.4×10^5
D. 2.8×10^5

$n(e^-)F = It$

$n(e^-) = \frac{It}{F} = \frac{1.0 \times 10^5 \times 1.5 \times 60 \times 60}{96500}$

$= 5596 \text{ mol } e^-$

$\Rightarrow n(Cl_2) = 2798 \text{ mol}$

$V = V_m \times n = 24.8 \times 2798 = 69359 \text{ L}$

Question 11

Which one of the following listed pairs contains cells which use a non-spontaneous redox reaction?

A. an electrolytic cell and a rechargeable cell
B. a fuel cell and a primary cell
C. a rechargeable cell and a fuel cell
D. a primary cell and an electrolytic cell

Use the following information to answer Questions 12 and 13.

Oxygen is transported in the human body using the complex molecules haemoglobin and oxyhaemoglobin.

$$\text{haemoglobin} + \text{oxygen} \rightleftharpoons \text{oxyhaemoglobin}$$

Carbon monoxide (CO) gas is extremely poisonous and can be fatal even at low concentrations.

Question 12

How does CO affect oxygen transport in the body?

A. It acts as a catalyst, causing the oxyhaemoglobin molecule to break apart.
B. It combines with the oxygen molecules and prevents the formation of oxyhaemoglobin.
C. It bonds strongly to haemoglobin and consequently causes oxyhaemoglobin to break apart.
D. It is more soluble in the blood than oxygen and so exists at a greater concentration.

Question 13

Which one of the following is the appropriate treatment for CO poisoning?

A. Remove the victim from the poisoned atmosphere to allow breathing in normal air.
B. Give pure oxygen gas so that the CO reacts to form CO_2 which is breathed out.
C. Infuse a large dose of haemoglobin to increase the yield of oxyhaemoglobin
D. Free haemoglobin molecules from bonding to CO by administering oxygen gas.

Question 14

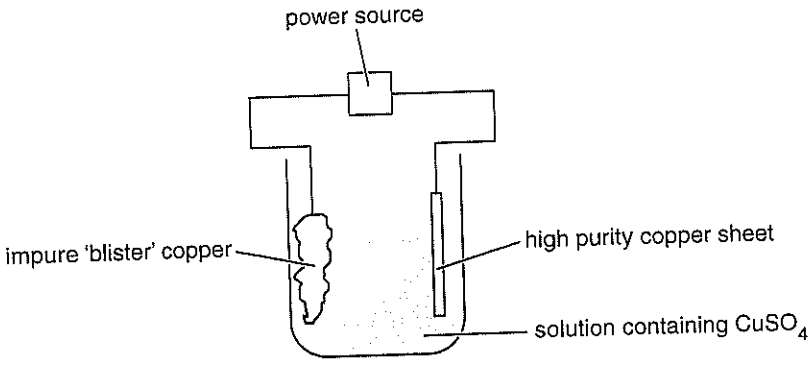
The hot gases formed by burning natural gas are used to spin a generator to produce electricity. For a set mass of natural gas, the total energy released is W joules.

If the same mass of natural gas was used in a fuel cell to produce electricity, how much energy will be released by the gas?

A. less than W joules
B. W joules
C. more than W joules
D. either more or less than W joules depending on the efficiency of the fuel cell

Question 15

When copper is extracted from its ores by roasting, the product is 'blister' copper; that is, copper containing 1–2% impurities including Zn, Fe, Ni, Ag, Au and Pt. This 'blister' copper is refined electrolytically. A simplified version of the electrolytic cell is shown below. The potential difference is adjusted to allow copper to be oxidised at the 'blister' copper anode.



In this electrorefining process the 'anodic mud' which collects under the anode is recovered.

This is done because the 'mud' contains atoms of

A. metals which are weaker reducing agents than copper.
B. metals which are stronger reducing agents than copper.
C. copper which have failed to adhere to the electrode during the refining process.
D. copper which have failed to be oxidised during the refining process.

Question 16

When heptane burns in oxygen gas,

A. carbon dioxide and water only can be formed.
B. carbon dioxide and carbon monoxide could be formed.
C. carbon monoxide and water will always be formed.
D. carbon dioxide, carbon monoxide and water will always be formed.

Question 17

A 1.60 mol sample of nitrosyl bromide (NOBr) was introduced into a 4.0 L vessel. At equilibrium the concentration of NOBr was found to be 0.0750 M. Reaction occurred according to the following equation:

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$$

Which one of the following shows the concentration of NO and Br_2 at equilibrium?

	NO concentration (M)	Br_2 concentration (M)
A.	0.33	0.16
B.	0.38	0.19
C.	0.40	0.20
D.	1.30	0.65

$n = cV = 0.0750 \times 4.0$
$= 0.30$ mol

	2NOBr	2NO	Br_2
I	1.60	0	0
C	−1.30	+1.30	+0.65
E	0.30	1.30	0.65

÷4 ÷4
0.3250 0.1625

Question 18

The following equation shows the chemical reaction which occurs in a galvanic cell.

$$2Cd(s) + 2OH^-(aq) + Ni_2O_3(s) + 3H_2O(l) \rightarrow 2Cd(OH)_2(s) + 2Ni(OH)_2(s)$$

Statements I to IV relate to the above chemical reaction.

I Cd undergoes oxidation.

II OH^- is the reducing agent.

III The oxidation number of nickel changes from +3 to +2.

IV The nickel ion undergoes reduction and so it is the oxidising agent.

Which of these statements are correct?

A. I and II only

B. II and III only

C. I, III and IV only

D. I, II, III and IV

Question 19

Iron reacts with oxygen according to the following equation:

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s) \qquad \Delta H = -1650 \text{ kJ mol}^{-1}$$

Which one of the following does **not** occur?

A. 825 kJ of energy is absorbed when 1 mole of Fe_2O_3 decomposes.

B. 825 kJ of energy is released when 111.6 g of Fe reacts.

C. 1650 kJ of energy is released when 96 g of O_2 reacts.

D. 1650 kJ of energy is absorbed when 2 mole of Fe_2O_3 forms.

Question 20

A fuel is best defined as

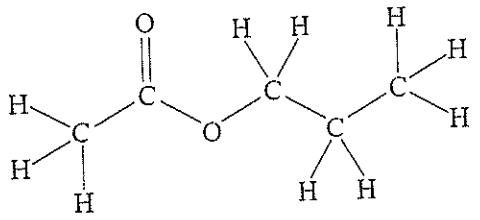
A. any solid, liquid or gas which will combust when ignited and release heat energy.

B. any substance containing a large amount of energy which is easily released.

C. a resource replaced by natural processes within a relatively short time period.

D. being composed of substances from fossil remains formed millions of years ago.

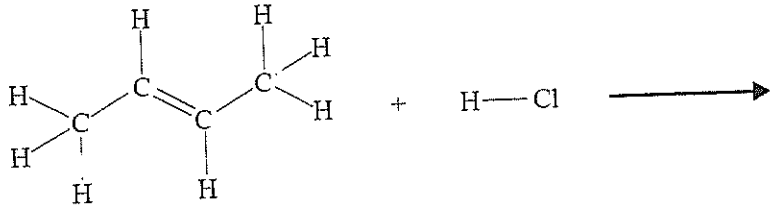
Question 21 (2013/9)



The systematic IUPAC name for the molecule shown above is

A. ethyl ethanoate.
B. ethyl propanoate.
C. propyl ethanoate.
D. methyl propanoate.

Question 22 (2013/10)



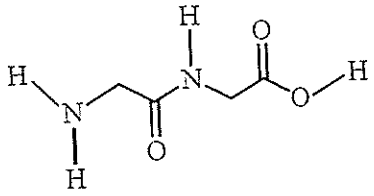
The systematic IUPAC name for the product of the above chemical reaction is

A. 1-chlorobutane.
B. 2-chlorobutane.
C. 3-chlorobutane.
D. 4-chlorobutane.

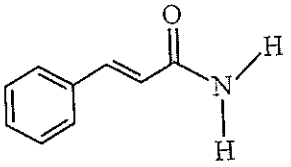
Question 23 (2017 Sample /27)

Which one of the following skeletal structures represents a primary amide?

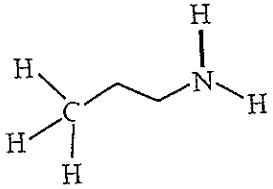
A.



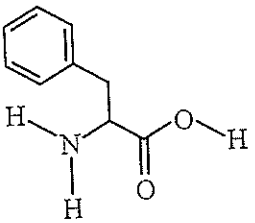
B.



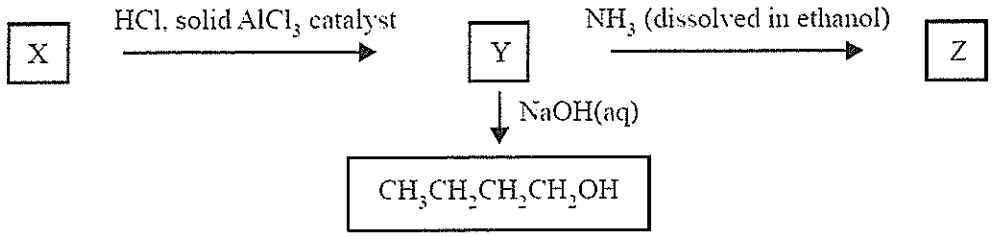
C.



D.



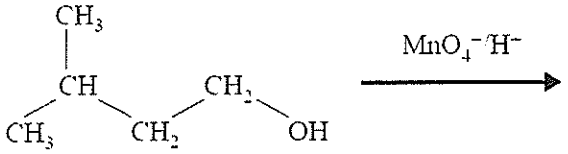
Question 24 (2017 Sample /28)



What are the semi-structural formulas of X, Y and Z for the reaction pathway shown above?

	X	Y	Z
A.	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CH_2Cl$	$CH_3CH_2CH_2CH_2NH_2$
B.	$CH_3CH_2CHCH_2$	$CH_3CH_2CHClCH_3$	$CH_3CH_2CHNH_2CH_3$
C.	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CHCl_2$	$CH_3CH_2CH_2CONH_2$
D.	$CH_3CH_2CHCH_2$	$CH_3CH_2CH_2CH_2Cl$	$CH_3CH_2CH_2CH_2NH_2$

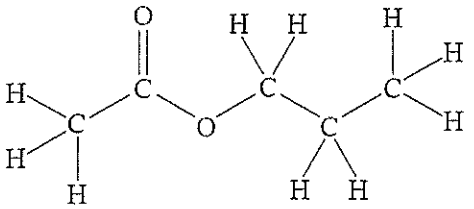
Question 25 (2014/19)



What is the systematic name for the product of the reaction above?

A. 2-methylpentanoic acid
B. 4-methylpentanoic acid
C. 2-methylbutanoic acid
D. 3-methylbutanoic acid

Question 21 (2013/9)



The systematic IUPAC name for the molecule shown above is

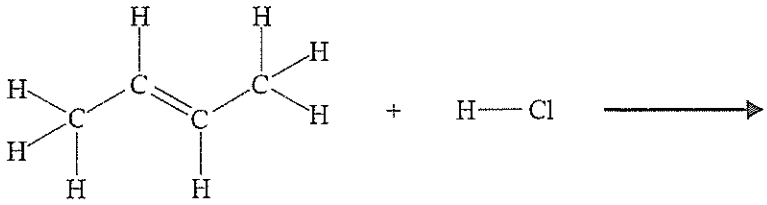
A. ethyl ethanoate.

B. ethyl propanoate.

C. propyl ethanoate.

D. methyl propanoate.

Question 22 (2013/10)



The systematic IUPAC name for the product of the above chemical reaction is

A. 1-chlorobutane.

B. 2-chlorobutane.

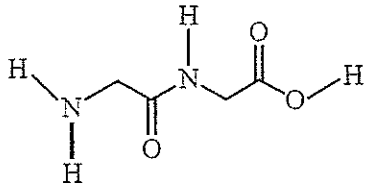
C. 3-chlorobutane.

D. 4-chlorobutane.

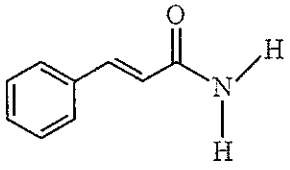
Question 23 (2017 Sample /27)

Which one of the following skeletal structures represents a primary amide?

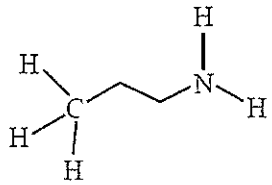
A.



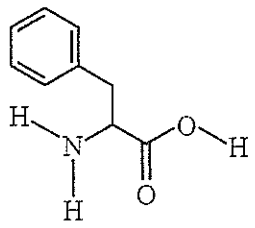
B.



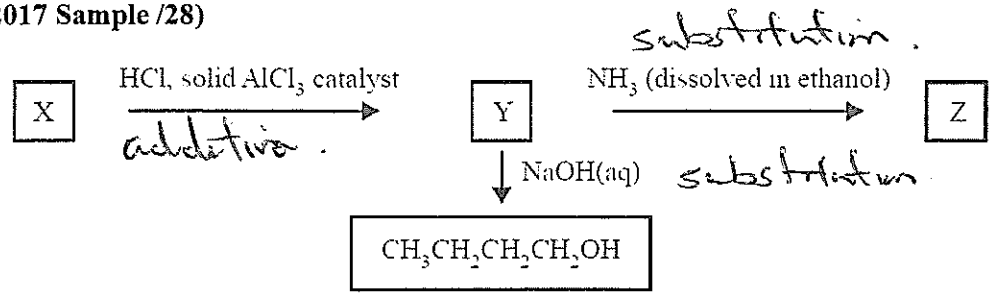
C.



D.



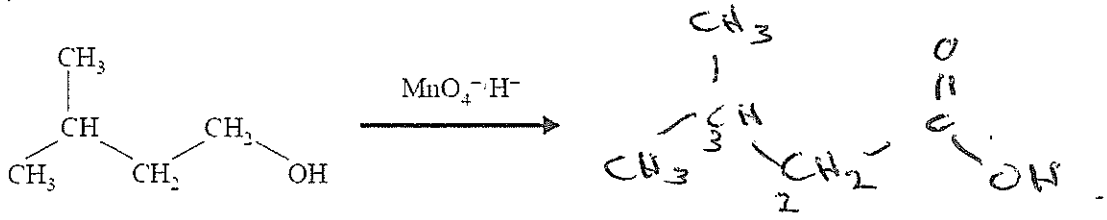
Question 24 (2017 Sample /28)



What are the semi-structural formulas of X, Y and Z for the reaction pathway shown above?

	X	Y	Z
A.	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CH_2Cl$	$CH_3CH_2CH_2CH_2NH_2$
B.	$CH_3CH_2CHCH_2$	$CH_3CH_2CHClCH_3$	$CH_3CH_2CHNH_2CH_3$
C.	$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CHCl_2$	$CH_3CH_2CH_2CONH_2$
D.	$CH_3CH_2CHCH_2$	$CH_3CH_2CH_2CH_2Cl$	$CH_3CH_2CH_2CH_2NH_2$

Question 25 (2014/19)



What is the systematic name for the product of the reaction above?

A. 2-methylpentanoic acid

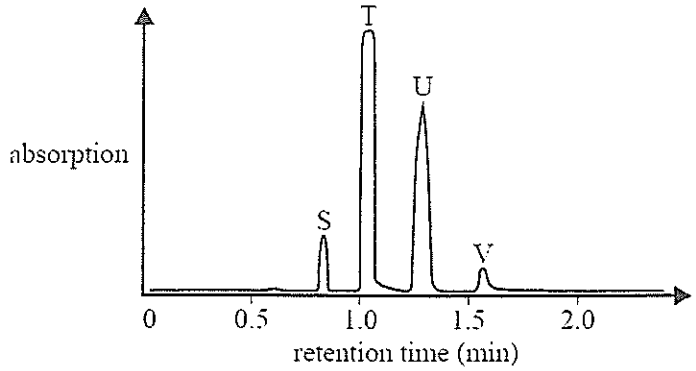
B. 4-methylpentanoic acid

C. 2-methylbutanoic acid

D. 3-methylbutanoic acid

Use the following information to answer questions 26 and 27 (Alkanol=alcohol in this context).

Four straight chain alkanols. S, T, U, V, with a general formula ROH, were analysed using a gas chromatograph combined with a mass spectrometer. The following chromatogram was produced.



Question 26 (2014/12)

What is the order of the alkanols from the highest molar mass to the lowest molar mass?

A. V, U, T, S

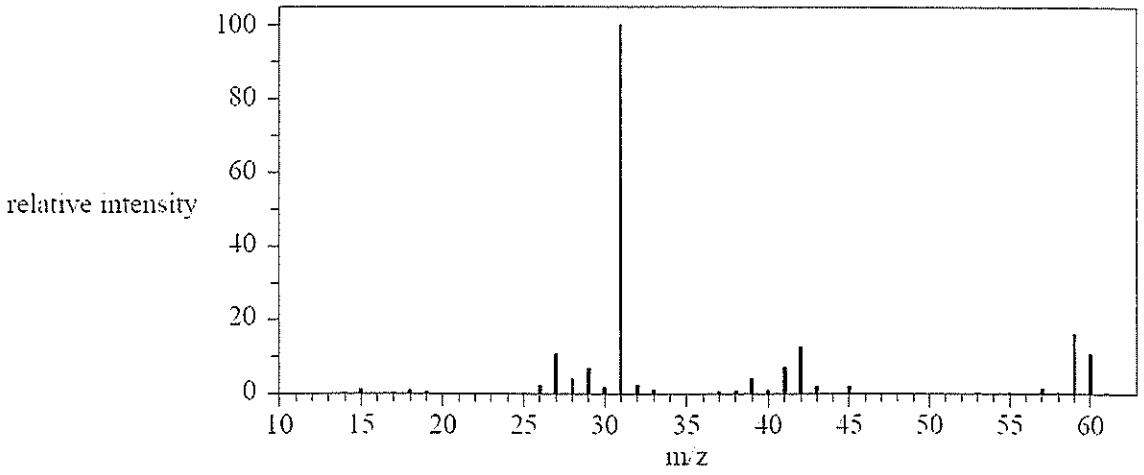
B. T, U, S, V

C. V, S, U, T

D. S, T, U, V

Question 27 (2014/13)

The mass spectrum of alkanol T is provided below.



Source: National Institute of Advanced Industrial Science and Technology

What is alkanol T?

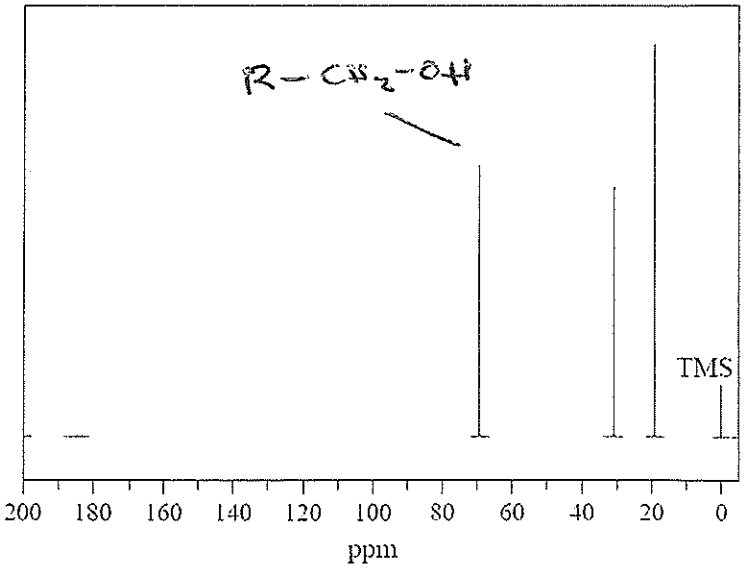
A. butan-1-ol

B. ethanol

C. methanol

D. propan-1-ol

Question 28 (2014/15)



Source: National Institute of Advanced Industrial Science and Technology

The ^{13}C NMR spectrum above corresponds to which one of the following compounds?

A. propane

B. 2-methylbutane

C. 2-methylpropan-1-ol

D. 2-methylpropan-2-ol

Question 29 (2015/8)

Consider the following statements about a high-performance liquid chromatography (HPLC) column that uses a polar solvent and a non-polar stationary phase to analyse a solution:

Statement I – Polar molecules in the solution will be attracted to the solvent particles by dipole-dipole attraction.

Statement II – Non-polar molecules in the solution will be attracted to the stationary phase by dispersion forces.

Statement III – Polar molecules in the solution will travel through the HPLC column more rapidly than non-polar molecules.

Which of these statements are true?

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Question 30 (2015/9)

Which two isomers of $C_3H_6Br_2$ have two peaks (other than the TMS peak) in their ^{13}C NMR spectrum?

A. $CH_3CBr_2CH_3$ and $CHBr_2CH_2CH_3$

B. $CHBr_2CH_2CH_3$ and $CH_2BrCHBrCH_3$

C. $CH_2BrCHBrCH_3$ and $CH_2BrCH_2CH_2Br$

D. $CH_2BrCH_2CH_2Br$ and $CH_3CBr_2CH_3$

SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using blue or black pen.

Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.

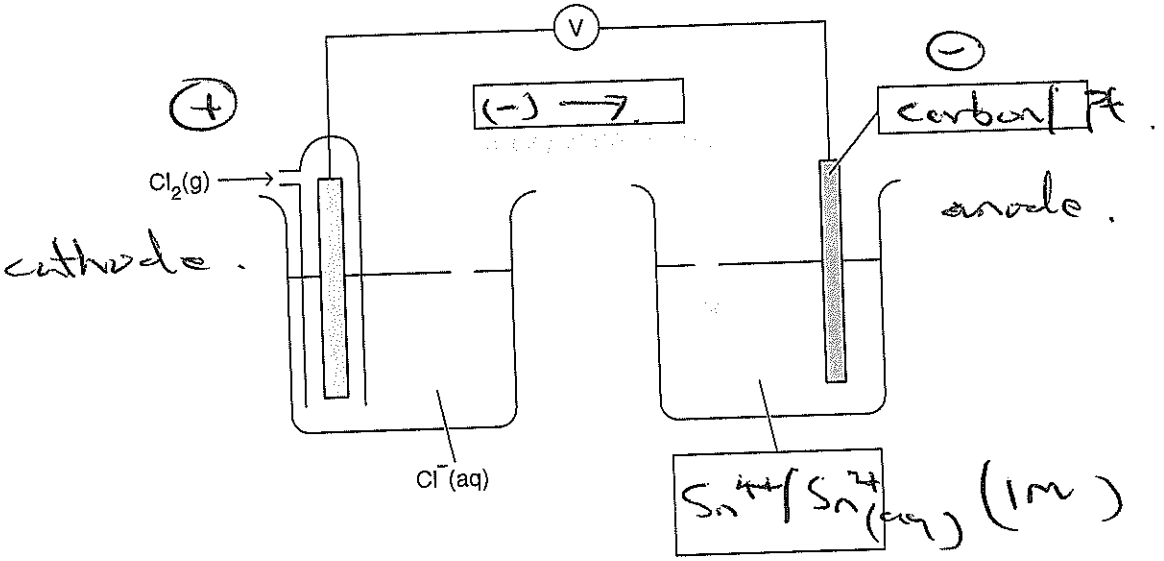
Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.

Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$, NaCl(s).

Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Question 1 (7 marks)

a. A student wanted to construct a galvanic cell under standard conditions with a cell voltage of exactly 1.21 V, using the Cl_2/Cl^- half-cell. The largely unlabelled diagram below shows the planned galvanic cell. $1.36 - 1.21 = 0.15 \Rightarrow Sn^{4+}|Sn^{2+}$



3 marks

i. Complete the diagram by adding the features listed below.

- an arrow in the box directly above the internal circuit to indicate the direction of movement of negative ions
- the composition of the electrolyte of the non-chlorine half-cell
- the composition of the electrode of the non-chlorine half-cell

1 mark

ii. Tick **one** box in the table below to show the polarity and type of reaction which occurs in the non-chlorine half-cell.

	Positive	Negative
Oxidation		✓
Reduction		

b. For a practical investigation, a student's aim was to establish an electrochemical series for four reduction half-equations using the results of experiments. The four reduction half-equations (A to D) investigated are shown below.

Half-cell	Half-equation
A	$Be^{2+}(aq) + 2e^- \rightleftharpoons Be(s)$
B	$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightleftharpoons NO(g) + 2H_2O(l)$
C	$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$
D	$Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr(s)$

The student constructed three galvanic cells from various combinations of two of the relevant half-cells. Observations for the three cells are given in the table below.

Cell	Half-cells connected	Experimental observations
1	A and B	hydrogen ion concentration decreases in half-cell B
2	C and D	chromium electrode loses mass
3	A and D	electrons travel from the beryllium electrode to the chromium electrode

B → A ∈
C → D ∈
D → A ∈

Write a conclusion for the student's investigation, including a relevant electrochemical series order from highest to lowest for the reduction half-equations A to D if possible. Indicate any further experimentation that may be needed to successfully achieve the aim of the investigation. 3 marks

C > D > A

It is possible to determine the order from highest to lowest reduction potentials for C, D and A (C > D > A) but Further information is needed to determine if B > C or C > B* (B > A) as cell with B and C linked would determine this

* If C > B, then an exp with B + D is also needed.

Question 2 (9 marks)

a. Liquefied petroleum gas (LPG) is used in cars and trucks to replace petrol (mostly octane). LPG is a mixture of mainly propane and butane.

i. Propane and butane are gases at room temperature.

Explain why it is necessary to liquefy them to be used in transport vehicles. 2 marks

Liquids have a much higher energy density per volume
To be able to replace octane, it is necessary to have comparable energy densities

ii. The LPG tank is placed in the boot of a car and operates without using very low temperatures.

How is LPG maintained as a liquid? 1 mark

At high pressure

b. Petrodiesel and biodiesel are fuels often used in larger transport vehicles.

Outline and explain the effect of lowering the temperature to near 0°C on the viscosity of each of these fuels. 2 marks

Low temperatures increase the viscosity of biodiesel due to the dipole-dipole bonding that will occur.
whereas petrodiesel only has dispersion forces between the molecules which are weaker ⇒ still flows freely at low temperature

c. In the table below, tick **one** box in each row to show whether the described feature applies to petrodiesel only, to biodiesel only, to both fuels or to neither fuel. 4 marks

Feature	Petrodiesel only	Biodiesel only	Both fuels	Neither fuel
The fuel molecules consist only of hydrogen atoms and carbon atoms.	✓			
Combustion of the fuel produces gases which contribute to the greenhouse effect.			✓	
During the industrial production of the fuel, the fuel is produced in a chemical reaction.		✓		
When the fuel undergoes combustion the oxidation number of the carbon decreases.				✓

Question 3 (11 marks)

a. Methane is a major component of coal seam gas (CSG).

Why is methane from this source classed as non-renewable? 1 mark

In this form it is a fossil fuel, not formed in human timescales

b. **i.** For the complete combustion reaction of methane, calculate the mass of carbon dioxide produced when 1.00 MJ of energy is generated. 2 marks

$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O$ (1)

$-890\ kJ/mol$ $\quad m = n_{CO_2}$

$\frac{1000}{890} = 1.124\ mol$ $\quad = 44.0 \times 1.124 = 49.4\ g$

ii. A 2.00 L tank of methane is used at 15.0°C and 1.05 atmospheres to heat water from 18.5°C to 65.0°C.

Calculate the mass of water heated, assuming all of the energy from the burning methane was used to heat the water. 4 marks

$n(CH_4) = \frac{PV}{RT} = \frac{1.05}{0.987} \times 100 \times 2.00$

$8.31 \times (273 + 15.0)$

$= 0.0889\ mol$ — (2)

$0.0889 \times 890 = 79.12\ kJ$ — (1)

$E = mc\Delta T$. $\quad m = \frac{E}{c\Delta T} = \frac{79120}{4.18 \times (65.0 - 18.5)} = 407\ g$ — (1)

c. Methane can be used as the energy source in a fuel cell which converts oxygen gas in the air to **oxide ions** at the cathode.

i. Write the half-equation for the reaction at the cathode (states are not required). 1 mark

$O_2 + 4e^- \rightarrow 2O^{2-}$

ii. At the anode, methane gas reacts with oxide ions to produce carbon dioxide and water.

Write the half-equation for the reaction at the anode (states are not required). 1 mark

$CH_4 + 4O^{2-} \rightarrow CO_2 + 2H_2O + 8e^-$

iii. Identify **one** design feature in this fuel cell which is common to all fuel cells which have gaseous reactants. 1 mark

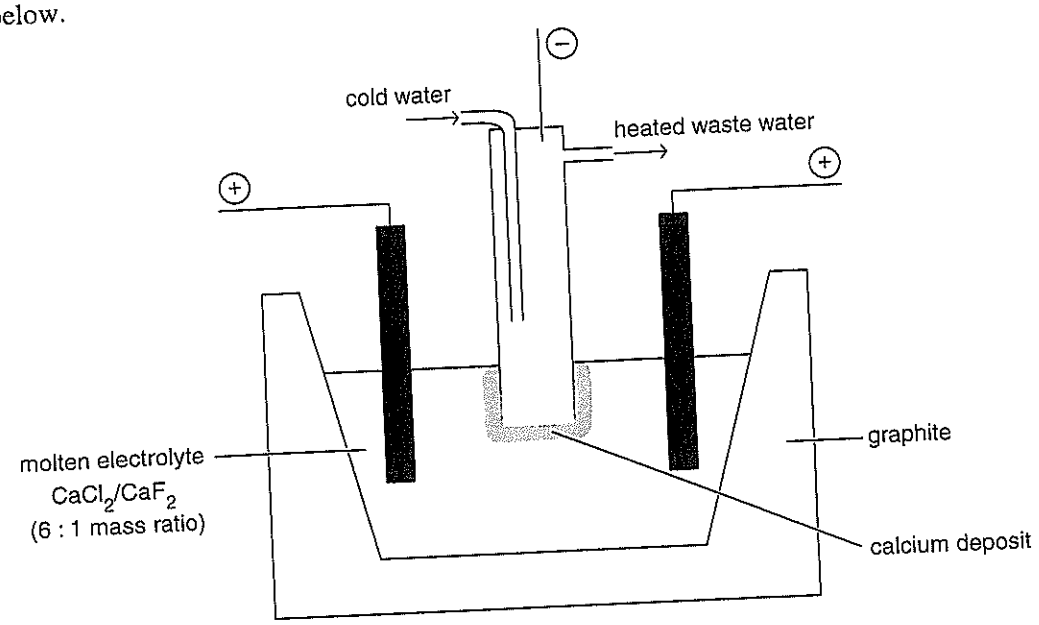
Porous electrodes

iv. Identify **one** significant difference in the operation of this cell compared to a galvanic cell. 1 mark

Reactants continuously supplied to a fuel cell whereas a galvanic cell has a fixed amount of reactants.

Question 4 (11 marks)

Calcium metal is produced in an electrolytic cell using carbon blocks as the positive electrodes and a water-cooled steel cylinder as the negative electrode. The basic design of the cell is shown in the diagram below.



a. Write the equation for the chemical reaction which occurs at the negative electrode. 1 mark

$Ca^{2+}(l) + 2e^- \rightarrow Ca(l)$

b. A mixed, molten electrolyte is used rather than an aqueous solution.

i. Why is this use of a molten electrolyte a **disadvantage** for the industrial producer of calcium? 1 mark

High T ⇒ high energy cost.

ii. Suggest why a mixture of $CaCl_2$ and CaF_2 is used as the electrolyte rather than using $CaCl_2$ only. 1 mark

lowers the M.P. ⇒ saves energy

c. Electrolytic cells must be designed so that the products of the cell reaction do not come into contact. 2 marks

Explain why this is necessary.

Electrolytic cell enables a non-spontaneous reaction.

If products come into contact a spontaneous reversal of the rxn will occu

d. One of the uses of calcium metal is to add a small amount in the manufacture of the lead plates in lead–acid car batteries. The addition of calcium improves the properties of the lead plates in these secondary cells.

The equation for the overall reaction when a car battery produces energy is as follows:

$$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

i. The reaction which occurs at the negative electrode during discharge is as follows:

$$Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$$

If the battery operates at 12.0 V, how much energy is produced for each 1.00 g of lead used? 3 marks

$E = VIt = VQ = V\,n(e^-)\,F$

$n(Pb) = \frac{1.00}{207.2} = 0.00483$ mol

$n(e^-) = 2 \times n(Pb) = 2 \times 0.00483 = 0.00965$ mol (1)

$E = 12.0 \times 0.00965 \times 96500 = 11,177$ J

$= 11.2$ kJ (2)

ii. Write the equation for the reaction which occurs at the positive electrode when the battery is being recharged. 1 mark

$PbSO_{4(s)} + 2H_2O_{(l)} \rightarrow PbO_2 + SO_4^{2-} + 4H^+_{(aq)} + 2e^-$

e. Despite the benefits of using a small amount of calcium in the lead plates, there are disadvantages. When a battery is left discharged for a long period of time, the calcium–lead alloy plate develops a hard, impermeable layer of calcium sulfate.

Explain how this occurrence could prevent the battery from being recharged. 2 marks

$CaSO_4$ is ionic – does not conduct electricity – prevents transfer of e^-

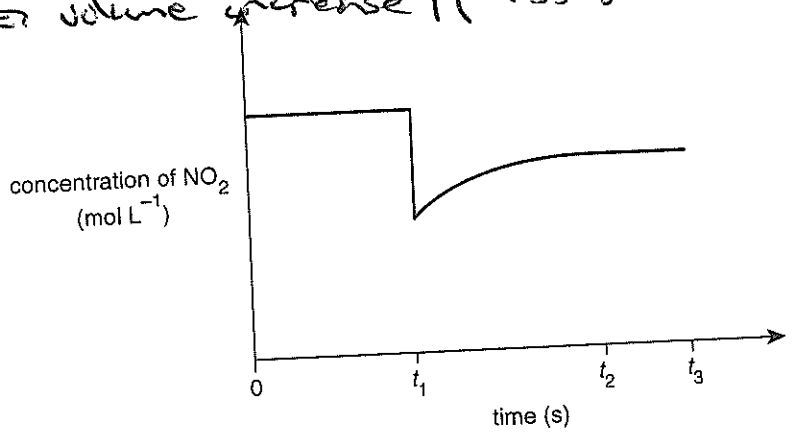
Question 5 (5 marks)

One example of a reversible reaction is shown by the following equation:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

In an experiment, a mixture of the two gases of the reaction is at equilibrium. At time t_1, at constant temperature, a change is made to the conditions of the reaction mixture, but no chemical is added or removed. The graph below shows the concentration of NO_2 in the mixture.

⇒ volume increase / pressure decrease.



a. What change was made to the system at time t_1? 1 mark

volume increase = pressure decrease.

b. The list below contains some correct and some incorrect statements about the information shown in the graph.

I The rate of the forward reaction is lower than the rate of the reverse reaction while the system is reaching equilibrium after t_1.

II There are two time intervals during which the rate of the forward reaction equals the rate of the reverse reaction.

III Addition of an inert gas to the mixture at constant volume at t_2 will not alter the NO_2 concentration.

IV The value of the equilibrium constant is higher in the time interval between 0 and t_1 than in the time interval between t_2 and t_3.

V No new molecules of NO_2 are being formed in the time interval between t_2 and t_3.

Identify **two** incorrect statements (using the relevant numerals I to V) and explain why each statement is incorrect. 4 marks

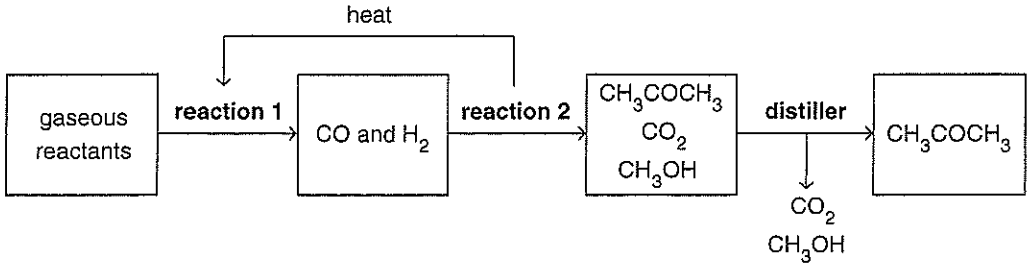
I There will be a net fwd after t_1 so rates not equal

IV T remains constant, so once eqm is established the K_c will be constant.

V Rates of fwd + back rxns equal, so NO_2 being formed and decomposed at the same rate.

Question 6 (12 marks)

a. The industrial production of the widely used compound dimethyl ether (CH_3COCH_3) is shown in the flowchart below.



i. Reaction 1 is a gaseous reaction which uses high pressure.

Using collision theory, explain how the use of high pressure increases the rate of the reaction. 2 marks

High pressure results in gaseous particles being close together ① which results in more collisions ① (same % of successful collisions).

ii. The high pressure used in reaction 1 also maximises the yield.

Explain what deduction can be made about reaction 1 from this information. 2 marks

There are fewer particles on the reactant side of the reaction ① so when pressure is increased a net fwd rxn is favoured. ①

iii. The addition of heat also maximises the yield in reaction 1.

Explain what deduction can be made about reaction 1 from this information. 2 marks

The reaction is endothermic ① so addition of heat causes a net fwd rxn. ①

iv. For reaction 2, very fine bubbles of the reactant gases are passed through a liquid medium in which a powdered catalyst is suspended.

How is the rate of reaction maximised by this arrangement? 2 marks

Small reactant particles and small catalyst particles increase surface area ⇒ chance of collision is high ①
Catalyst promotes reaction rate by providing an alternate reaction pathway with a lower activation energy. ①

b. Dimethyl ether can also be produced from methanol in a reaction shown by the following equation:

$$2CH_3OH(g) \rightleftharpoons CH_3COCH_3(g) + H_2O(g) \qquad \Delta H = -24 \text{ kJ mol}^{-1}$$

At 350°C, the value of K_c for this reaction is 5.74.

i. In one experiment at 350°C, a 10 L vessel contained the following amounts of gases: 0.180 mol CH_3OH; 0.435 mol CH_3COCH_3; and 0.240 mol H_2O.

Show that the reaction is **not** at equilibrium. 3 marks

$$K = \frac{[CH_3COCH_3][H_2O]}{[CH_3OH]^2}$$

$$= \frac{0.0435 \times 0.0240}{0.0180^2} = 3.22$$

As $3.22 \neq 5.74$ rxn not at eqm (fwd rxn needed) 1 mark

ii. Calculate the value of the equilibrium constant at 350°C for the equation below.

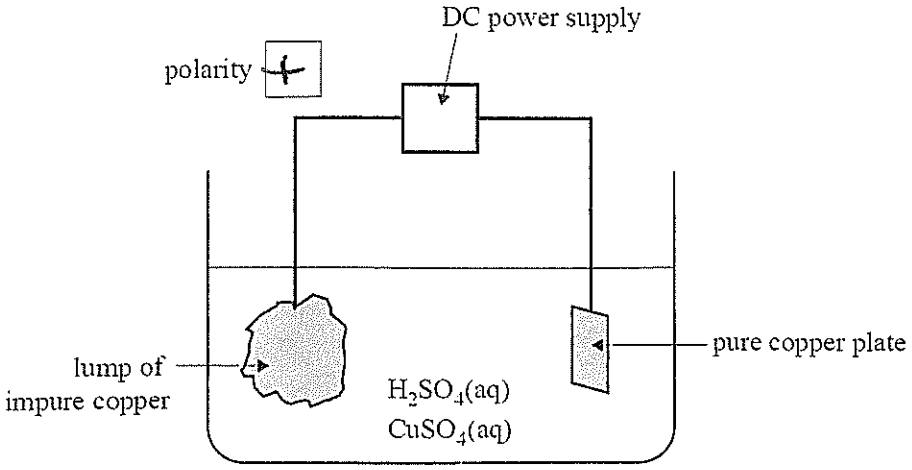
$$\frac{1}{2}CH_3COCH_3(g) + \frac{1}{2}H_2O(g) \rightleftharpoons CH_3OH(g)$$

$$K_{c2} = \frac{1}{\sqrt{K_{c1}}} = \frac{1}{\sqrt{5.74}} = 0.417$$

THIS PAGE IS INTENTIONALLY BLANK – TURN OVER

Question 7 (2013/7)

An electrolytic process known as electrorefining is the final stage in producing highly purified copper. In a small-scale trial, a lump of impure copper is used as one electrode and a small plate of pure copper is used as the other electrode. The electrolyte is a mixture of aqueous sulfuric acid and copper sulfate.



a. Indicate in the box labelled 'polarity' on the diagram above, the polarity of the impure copper electrode. 1 mark

In a trial experiment, the electrodes were weighed before and after electrolysis.
The results are provided in the following table.

	Mass of lump of impure copper	**Mass of pure copper**
before electrolysis	10.30 kg	1.55 kg
after electrolysis	0.855 kg	9.80 kg

Δm $-9.445\,kg$ (1) $+8.25\,kg$ (1)

b. On the basis of these results

- calculate a percentage purity of the lump of impure copper 4 marks

$\frac{8.25}{9.445} \times 100 = 87.3\%$ pure. (1)

- indicate **one** factor that may affect the accuracy of these results.

- not all reduced copper may adhere to the cathod (1)
- electrodes not dried before weighing.

c. Conditions in the electrolytic cell shown in the diagram are carefully controlled to ensure a high degree of copper purity and electrical efficiency.

Use the mass of pure copper deposited that is given in the table in **part a.** to determine the time, in days, taken for this electrolysis reaction to be completed. Assume the current was a constant 24 A. 5 marks

$It = n(e^-)F$

$t = \frac{n(e^-)F}{I}$

$n(Cu)\text{ reduced} = \frac{8250}{63.5} = 129.92\text{ mol}$ - (1)

$n(e^-) = 2 \times n(Cu) = 2 \times 129.92 = 259.84\text{ mol } e^-$ - (1)

$t = \frac{259.84 \times 96500}{24} = 1.04 \times 10^6\text{ s}$ - (1)

$1.04 \times 10^6\text{ s} \div (60 \times 60 \times 24) = 12\text{ days}$ (1)

2 Sig. Figures - (1)

Lumps of impure copper typically contain impurities such as silver, gold, cobalt, nickel and zinc. Cobalt, nickel and zinc are oxidised from the copper lump and exist as ions in the electrolyte. Silver and gold are not oxidised and form part of an insoluble sludge at the base of the cell.

d. Why is it important that silver and gold are not present as cations in the electrolyte? 1 mark

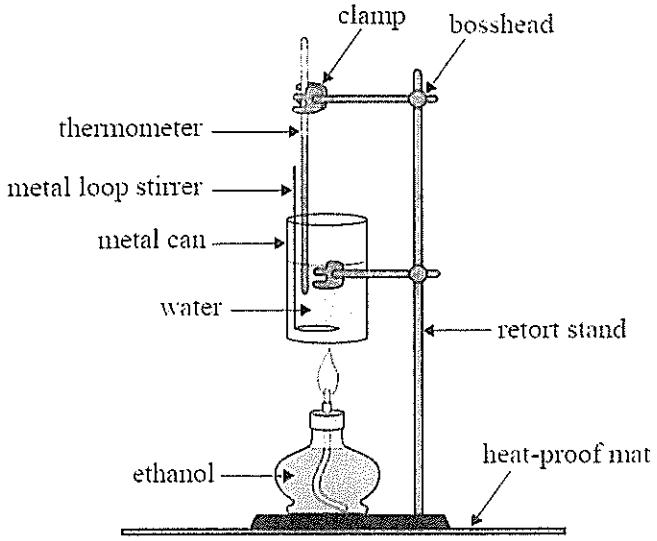
As Au^+ and Ag^+ are stronger oxidants than Cu^{2+}, if they were present they would be preferentially reduced at the cathode instead of Cu^{2+} to Cu.

Question 8 (2014/3)

The enthalpy for the combustion of ethanol is provided in the data book. This combustion of ethanol is represented by the following equation.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

A spirit burner used 1.80 g of ethanol to raise the temperature of 100.0 g of water in a metal can from 25.0 °C to 40.0 °C



a. Calculate the percentage of heat lost to the environment and to the apparatus. 5 marks

Theoretical: $n(C_2H_5OH) = \frac{1.80}{46.0} = 0.0391$ mol. -①

$\Rightarrow$ E from 1.80g $= 0.0391 \times 1360 = 53.2$ kJ. -①

Reality: $E = mc\Delta T = 100.0 \times 4.18 \times (40.0 - 25.0)$

$= 6270$ J. $= 6.27$ kJ -①

$53.2 - 6.27 = 46.9$ kJ lost. -①

$\%$ E lost $= \frac{46.9}{53.2} \times 100 = 88.2\%$ -①

b. Identify **one** way to limit heat loss to the environment. 1 mark

- Insulate around flame
- Insulate sides of can
- Lid on can

c. Biodiesel may be produced by reacting canola oil with methanol in the presence of a strong base. Since canola oil contains a mixture of triglycerides, the reaction produces glycerol and a mixture of biodiesel molecules. A typical biodiesel molecule derived from canola oil has the chemical formula $C_{15}H_{30}O_2$.

i. Write the semi-structural formula of this molecule, then circle and name the functional group present. 2 marks

$H_3C(CH_2)_{12}COOCH_3$ / $H_3COOC_{13}H_{27}$ -(1)

Ester functional group -(1)

ii. The heat content of canola oil can be determined by placing it in the spirit burner in place of ethanol. A typical result is 17 kJ g^{-1}

Suggest why the heat content of fuels such as canola oil and biodiesel are measured in kJ g^{-1} and not kJ mol^{-1} 1 mark

Canola oil is a blend of more than one chemical species, so it is not possible to specify energy per mole but needs to be expressed per mass (or volume).

Question 9 (2014/4)

A small organic molecule has the molecular formula of the form $C_xH_yO_2Cl$.
A pH probe was inserted into a dilute aqueous solution of this compound and the pH was 4.5. – acidic
The mass spectrum, infrared spectrum, ^1H NMR spectrum and ^{13}C NMR spectrum of this compound are provided on pages 27-28.

a. On the infrared spectrum, label the peaks that correspond to the presence of two functional groups in this compound. Note: The peak due to the C-Cl stretch has been labelled. 2 marks

b. Use the data provided to determine the values of x and y in $C_xH_yO_2Cl$. 2 marks

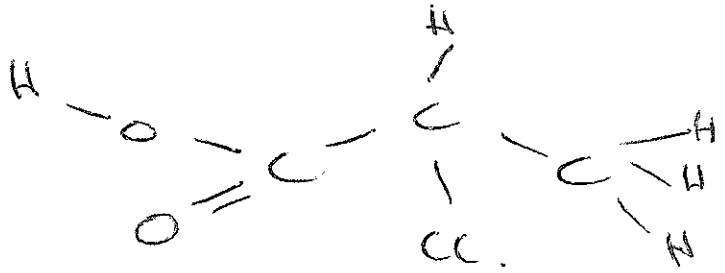
x = 3 y = 5

m with ^{35}Cl = 108 gmol^{-1}. 108 - 35 - 32 = 41
3 C environments = 3 × C. = 36.
41 - 36 = 5 Hydrogens.

c. **i.** What specific information about the structure of the compound is provided by the splitting pattern in the ^1H NMR spectrum? 1 mark

3 H environments. One OH hydrogen.
One with 3 neighboring Hs (quartet).
One with 2 neighboring H (doublet).

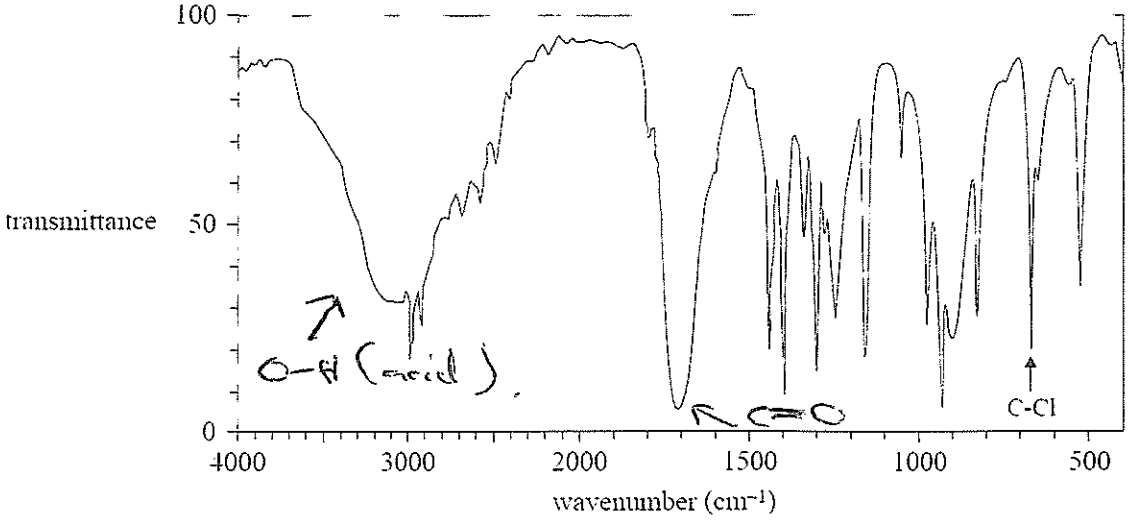
ii. Draw the complete molecular structure for this molecule. 1 mark



d. Give a reason why the mass spectrum shows two molecular ion peaks at m/z = 108 and 110, rather than just one. 1 mark

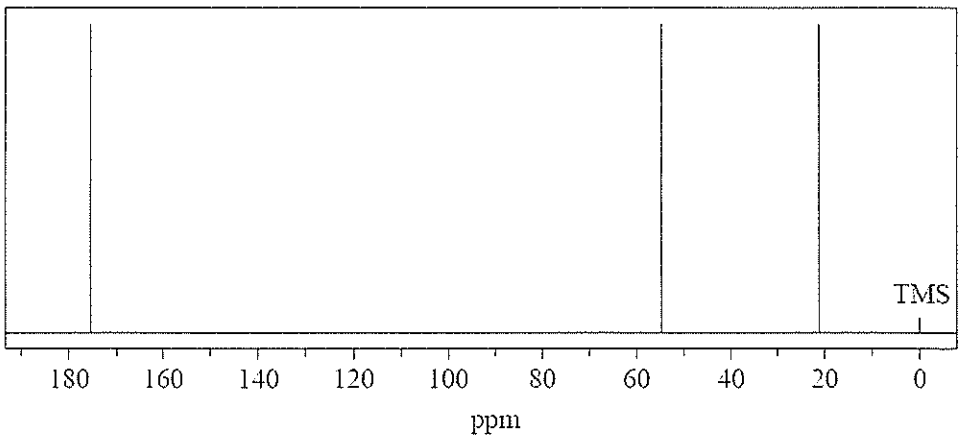
Two isotopes of Cl in significant proportions
with - ^{35}Cl - adds to 108
- ^{37}Cl - adds to 110.

IR spectrum



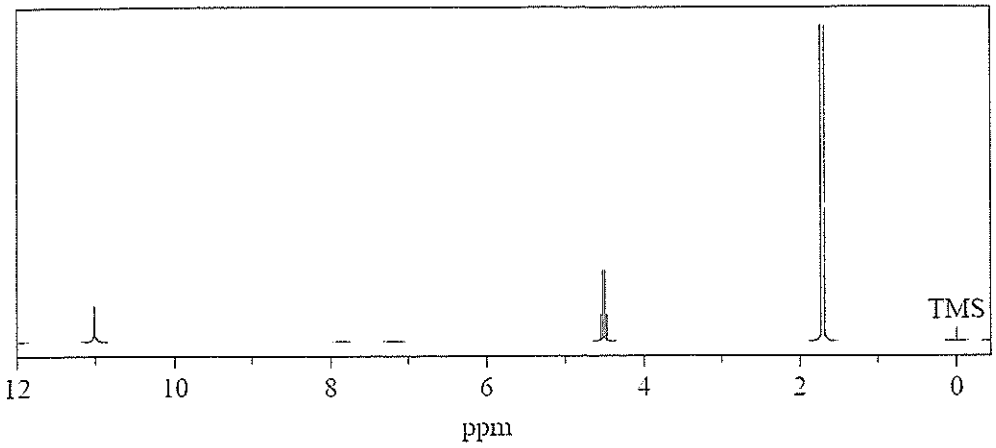
Data: National Institute of Advanced Industrial Science and Technology

^{13}C NMR spectrum



Data: National Institute of Advanced Industrial Science and Technology

^{1}H NMR spectrum

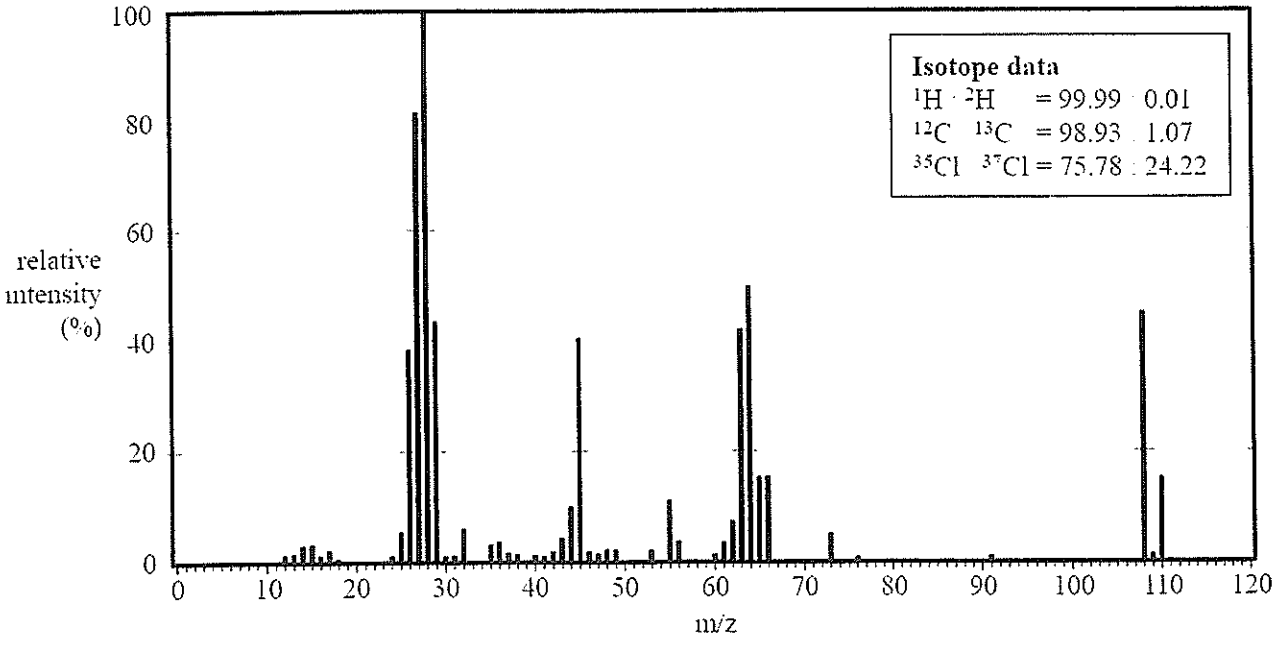


Data: National Institute of Advanced Industrial Science and Technology

^{1}H NMR data

Chemical shift (ppm)	Peak splitting	Relative peak area
1.7	doublet (2 peaks)	3
4.5	quartet (4 peaks)	1
11.2	singlet (1 peak)	1

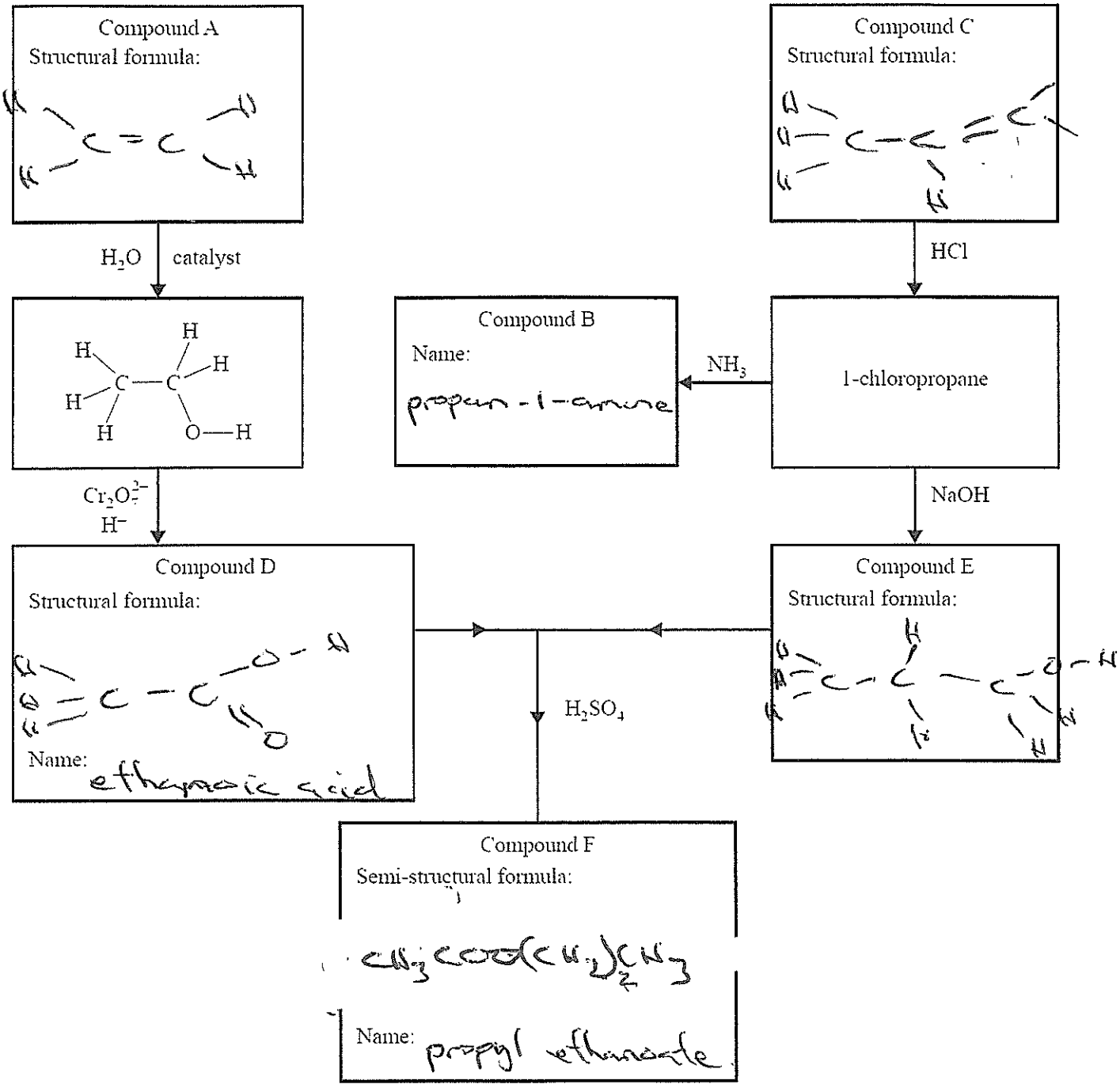
$C_xH_yO_2Cl$ mass spectrum



Data: National Institute of Advanced Industrial Science and Technology

Question 10 (2014/2)

Compounds B and F may be synthesised as follows.



a. Draw the structural formulas of Compounds A, C, D and E in the boxes provided. 4 marks

b. Write the systematic **names** of Compounds B and D in the appropriate boxes. 2 marks

c. Insert the semi-structural formula and systematic name of Compound F in the box provided. 2 marks

END OF QUESTION AND ANSWER BOOKLET