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2024 Trial Examination

STUDENT NUMBER									Letter

CHEMISTRY

Units 3 & 4 – Written examination

Reading time: 15 minutes
Writing time: 2 hour and 30 minutes

QUESTION & ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	10	10	90
			Total 120

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

Materials supplied.

- Question and answer book of 29 pages.

Instructions

- Print your name in the space provided on the top of this page.
- All written responses must be in English.

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

SECTION A – Multiple-choice questions

Instructions for Section A

Answer all questions in pen 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 book are not drawn to scale.

Question 1
The primary benefit of using bioethanol as an alternative to petrol is that:
A. bioethanol has a higher energy output than petrol.
B. bioethanol production is completely carbon neutral.
C. bioethanol can be sustainably sourced from renewable resources.
D. bioethanol production does not require land use.

Question 2
In the context of reaction direction and enthalpy changes, when the direction of a chemical reaction is reversed;
A. ΔH becomes zero.
B. the magnitude of ΔH decreases.
C. the sign of ΔH changes, but its magnitude remains the same.
D. both the magnitude and the sign of ΔH change.

Question 3
The purpose of calculating a calibration factor (CF) in calorimetry experiments is:
A. to determine the purity of the water used.
B. to ensure that temperature readings are consistent across different experiments.
C. to adjust for heat losses to the surroundings and calorimeter wall.
D. to calculate the specific heat capacity of the calorimeter itself.

Question 4
If the theoretical amount of energy produced by a reaction is 120 kJ, but the experimental measurement shows that only 90 kJ of energy was released. The percentage energy efficiency is:
A. 75%
B. 133%
C. 150%
D. 66%

SECTION A - continued

Question 5
The semi-structural formula for an isomer of $C_6H_{15}NO$ is $NH_2CH_2CH_2CH_2CH(CH_3)CH_2OH$
The correct systematic name for this molecule is
A. 5-amino-pentan-1-ol
B. 5-amino-2-methyl-pentan-1-ol
C. 5-hydroxy-3-methyl-pentan-1-amine
D. 1-hydroxy-2-methyl-4-amino-pentane

Questions 6-8 refer to the following information.

Cellular respiration is a crucial process that provides energy for the body and involves a type of redox reaction. The general equation for this reaction is as follows:

$$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

Photosynthesis is a vital biological process through which plants, algae, and some bacteria convert light energy into chemical energy stored as glucose. This process is also a type of redox reaction. The overall chemical equation

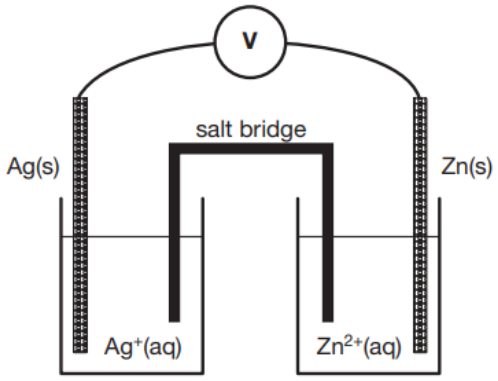
$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$$

Question 6
The type of energy transformation that occurs during photosynthesis is
A. chemical energy to thermal energy.
B. light energy to chemical energy.
C. electrical energy to chemical energy.
D. light energy to mechanical energy.

Question 7
During the cellular respiration reaction, which of the following occurs?
A. oxygen is reduced.
B. oxygen is oxidised.
C. oxygen acts as a catalyst.
D. oxygen remains unchanged.

Question 8
Photosynthesis is considered a non-spontaneous reaction, whereas cellular respiration is spontaneous. The reason for this is that
A. photosynthesis releases energy, while cellular respiration requires energy input.
B. photosynthesis requires energy input, while cellular respiration releases energy.
C. both photosynthesis and cellular respiration are non-spontaneous reactions.
D. both photosynthesis and cellular respiration are spontaneous reactions.

Refer to the following diagram of a galvanic cell to answer Questions 9-11.



Question 9

The purpose of the salt bridge in the electrochemical cell depicted in the image is to;

A. increase the voltage of the cell.

B. provide a path for the flow of electrons.

C. maintain electrical neutrality in the two half-cells by allowing ions to flow between them

D. separate the two different metals physically.

Question 10

In the electrochemical cell shown, the electrode that acts as the anode is:

A. Ag(s)

B. Ag^{+}(aq)

C. Zn(s)

D. Zn^{2+}(aq)

Question 11

As the electrochemical cell operates, the mass of which electrode will decrease?

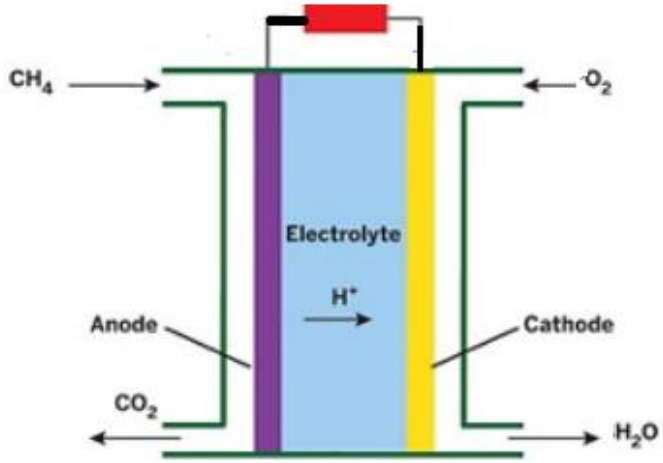
A. Ag(s)

B. Ag^{+}(aq)

C. Zn^{2+} (aq)

D. Zn(s)

To answer Questions 12-14, refer to the following diagram of a Solid Oxide Fuel cell



Source *: https://cen.acs.org/articles/93/i43/Best-Effort-Yet-Make-Direct.html*

Question 12
In the diagram shown above, the likely composition of the electrolyte in the fuel cell is:
A. a polymer membrane.
B. a metallic conductor.
C. a solid oxide material.
D. an aqueous solution.

Question 13
Considering the diagram, which byproduct will be released from the anode of the fuel cell?
A. Oxygen
B. Hydrogen
C. Carbon dioxide
D. Water

Question 14
Given the high operating temperatures of solid oxide fuel cells, which material property is most critical for the electrolyte?
A. High thermal conductivity.
B. Low electrical conductivity.
C. High ionic conductivity at high temperatures.
D. Low melting point.

Question 15
Which of the following best describes the energy source and process used to produce green hydrogen?

	Energy source	Process for production
A.	Fossil fuels	Combustion rection
B.	Renewable energy	Electrolysis
C.	Biomass	Anaerobic digestion
D.	Nuclear energy	Fission

Question 16
Which of the following substances is likely to be the most viscous at room temperature?
A. Water
B. Ethanol
C. Diesel
D. Petrol

Question 17
As the temperature is increased, the viscosity of a liquid;
A. increases.
B. decreases.
C. is not affected.
D. initially increases then decreases its viscosity.

Question 18
Which type of intermolecular force is predominantly found in cooking oil?
A. Hydrogen bonding.
B. Dipole-dipole interactions.
C. Dispersion forces.
D. Ionic bonding.

Question 19
Which of the following alkanes has the highest boiling point?
A. Methane
B. Ethane
C. Propane
D. Octane

Question 20
Hydrogenation reaction of ethene ($CH_2=CH_2$) produces which of the following?
A. ethene
B. ethane
C. ethanol
D. 1,2-dichloroethane

Question 21
The catalyst used in the hydration reaction of ethene to produce ethanol is:
A. nickel
B. phosphoric acid
C. sodium chloride
D. palladium

Question 22
A significant benefit of using catalysis in green chemistry for reaction selectivity is that:
A. it increases the formation of unwanted by-products.
B. it allows reactions to occur with greater specificity, reducing waste.
C. it prevents any reaction from occurring.
D. it requires more reagents to be used.

Question 23
Catalysts may contribute to energy conservation in industrial processes by:
A. enabling reactions at higher temperatures and pressures.
B. having no impact on the energy requirements of reactions.
C. requiring additional heating and cooling steps.
D. allowing reactions to proceed at lower temperatures and pressures.

Question 24
When bromine water is added to an alkene and an alkane in separate tests, only the alkene shows a color change to colorless. Which of the following best explains this observation?
A. Alkanes are fully saturated and do not react with bromine water.
B. Alkanes react more slowly with bromine water, so the change is not observed.
C. Alkenes are unsaturated and do not react with bromine water.
D. Alkanes react with bromine to form a colorless solution.

SECTION A- continued
TURN OVER

Question 25

In a laboratory, a student carries out a reaction with metal carbonates. The solution is suspected to contain a carboxyl group; however, they observe no bubbling. There could be conditions under which a carboxyl group is present but does not produce bubbling.

Which option best explains this scenario?

A. The carboxylic acid concentration is too low to observe bubbling.
B. The metal carbonate is not reactive enough to produce a visible reaction.
C. The solution pH neutralized the carboxylic acid, preventing the release of CO_2.
D. All of the above could be valid reasons for the lack of bubbling.

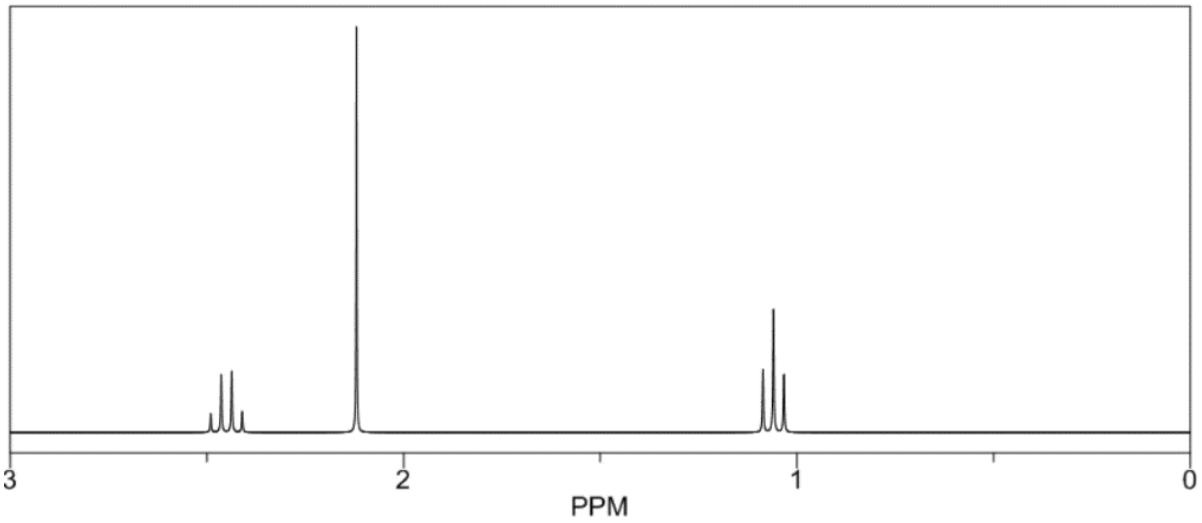
Question 26

What does a high iodine value indicate about a fat or oil?

A. It has a low degree of unsaturation.
B. It has a high degree of saturation.
C. It is predominantly composed of short-chain fatty acids.
D. It contains a high degree of unsaturation.

Question 27

The following is a high-resolution proton-NMR spectrum of a ketone molecule.



The IUPAC name of the molecule is

A. 3-methylbutan-2-one
B. pentan-3-one
C. butan-2-one
D. pentan-2-one

SECTION A- continued
TURN OVER

Question 28
Which of the following compounds is likely to be achiral?
A. A molecule with two mirror image forms.
B. A molecule with a central atom bonded to four different groups.
C. A molecule that is identical to its mirror image.
D. A molecule that can exist in left and right-handed forms.

Question 29
According to the lock-and-key model, how do enzymes and substrates interact?
A. The enzyme modifies its shape to fit the substrate.
B. The substrate modifies its shape to fit the enzyme.
C. The substrate fits perfectly into the enzyme's active site without alterations.
D. Both enzyme and substrate mutually adjust their structures to interact.

Question 30
What structural change occurs in enzymes because of pH alterations?
A. pH changes do not affect enzyme structure.
B. Changes in pH can lead to denaturation by disrupting ionic and hydrogen bonds.
C. Altered pH strengthens peptide bonds, increasing enzyme activity.
D. pH shifts result in the formation of more disulfide bridges.

END OF SECTION A
TURN OVER

SECTION B - Short-answer questions

Instructions for Section B

Answer all questions in the spaces provided. Give simplified answers to all numerical questions, with an appropriate number of significant figures; non-simplified 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 book are not drawn to scale.

Question 1 (6 marks)

a. Describe the chemical process used in the production of bioethanol from plants. Write the chemical equation for this process.

2 marks

b. Provide two reasons why biofuels are considered a more environmentally friendly alternative to fossil fuels.

2 marks

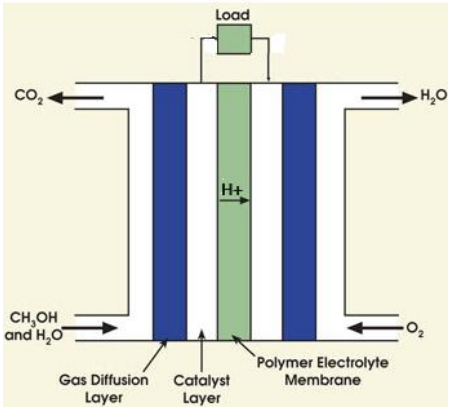
SECTION B - Question-1 - continued

c. Explain why land use is a critical factor when evaluating the sustainability of biofuels as alternative fuels.

2 marks

Question 2 (10 marks)

The image illustrates the components and operation of a Direct Methanol Fuel Cell (DMFC). In a DMFC, methanol is supplied to one electrode, along with water.



Source: *https://www.photonics.com/Articles/Testing_Methanol-Based_Fuel_Cells_Using_FTIR/a31877*

a. Based on the diagram of a Direct Methanol Fuel Cell, write a balanced chemical equation for the overall reaction occurring in the cell. Include the half-equations for the reactions occurring at the anode and cathode.

3 marks

SECTION B – Question -2 - continued

TURN OVER

b. Considering the Polymer Electrolyte Membrane's role in this cell, describe the impact of increasing the membrane's thickness on the efficiency of the fuel cell.

2 marks

c. Identify and explain the function of the catalyst applied to the electrodes in fuel cells. Predict the potential effect on cell performance of the fuel cell in the absence of such a catalyst.

3 marks

d. Describe what happens to a catalyst during a chemical reaction and explain how changes in its physical properties might impact the performance of a fuel cell.

2 marks

SECTION B - continued

Question 3 (8 marks)
The two different coloured Co(II) complex ions, $[Co(H_2O)_6]^{2+}$ and $CoCl_4^{2-}$, exist together in equilibrium in solution in the presence of chloride ions:

$$[Co(H_2O)_6]^{2+}_{(aq)} + 4Cl^-_{(aq)} \rightleftharpoons CoCl_4^{2-}_{(aq)} + 6H_2O_{(l)} \qquad \Delta H > 0$$
(pink) (blue)

a. Describe what happens to the position of equilibrium in the above system when the temperature is increased. Explain your answer using Le Chatelier's principle.

3 marks

b. What effect does adding concentrated hydrochloric acid have on the colour of the solution containing $[Co(H_2O)_6]^{2+}$ and $CoCl_4^{2-}$?
Justify your response based on changes in ion concentration.

3 marks

SECTION B – Question 3 - continued

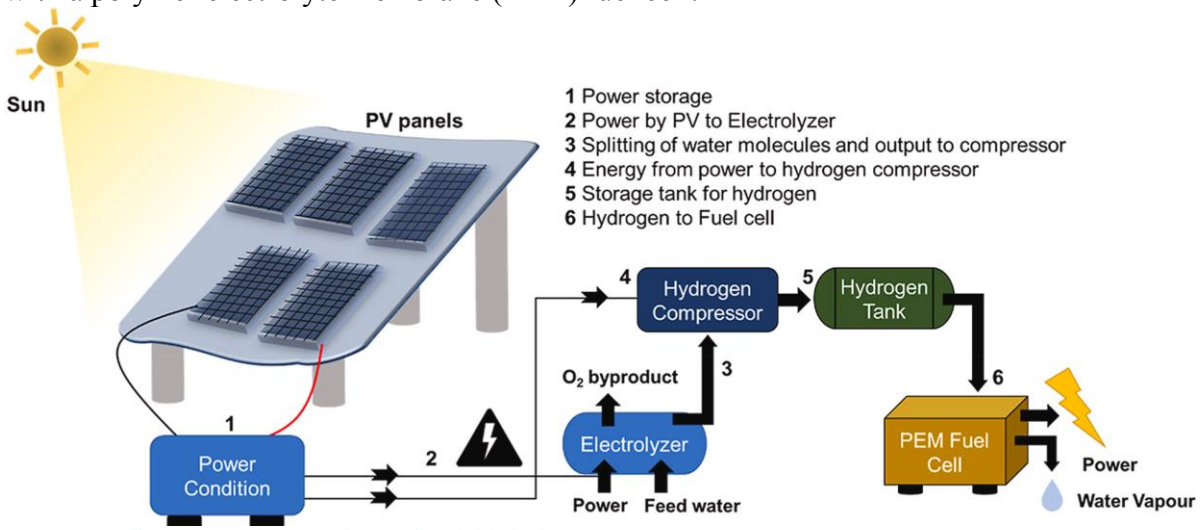
TURN OVER

c. Initially there is a 1.0 M concentration of $[Co(H_2O)_6]^{2+}$ in a solution. If 60% of the $[Co(H_2O)_6]^{2+}$ is converted to $CoCl_4^{2-}$ at equilibrium, calculate the final concentration of $[Co(H_2O)_6]^{2+}$ in the solution.

2 marks

Question 4 (13 marks)

Using solar-based energy as the primary input for the production of hydrogen gas makes the system completely renewable, as shown in the diagram below. This important method involves producing hydrogen gas from water through an electrolyser, and then converting it to electricity with a polymer electrolyte membrane (PEM) fuel cell.



Source: *https://www.sciencedirect.com/science/article/abs/pii/S0360319922058892X*

a. At which electrode in a water electrolysis system is hydrogen gas produced? Provide the balanced half-equation for the reaction at this electrode.

2 marks

SECTION B-Question-4 -continued

b. Provide the half-equations for the reactions occurring at both of the electrodes in the Proton Exchange Membrane (PEM) fuel cell.

2 marks

c. What is green hydrogen? List one advantage and one challenge associated with its use.

3 marks

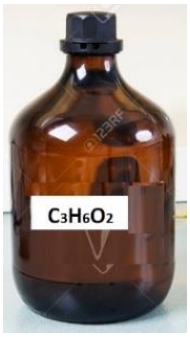
d. Evaluate the sustainability of hydrogen fuel cells as renewable energy sources.

4 marks

e. Discuss the necessity of employing a hydrogen compressor for the storage of hydrogen gas in terms of the physical properties and storage challenges associated with hydrogen.

2 marks

SECTION B - continued



Question 5 (9 marks)
A student found a half-filled chemical bottle in the lab which was labelled with the molecular formula $C_3H_6O_2$, but they could not find the name of the chemical on the bottle. They decided to run infrared (IR) and nuclear magnetic resonance (NMR) spectroscopy to confirm the chemical structure. The spectra are shown on the next page.

a. Using the infrared absorption data from the VCAA Data Book, identify the functional group that is associated with the absorption **labelled X** on the infrared spectrum.

1 mark

_____

b. How many carbon environments are there in the unknown compound? Justify your answer.

2 marks

_____

_____

_____

_____

c. How many hydrogen environments are there in the unknown compound? Justify your answer.

2 marks

_____

_____

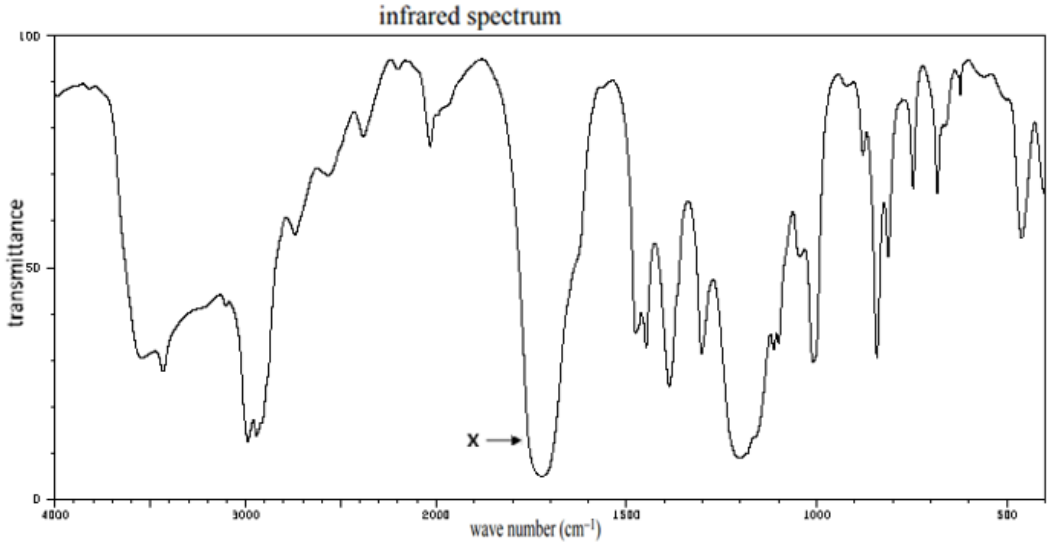
_____

_____

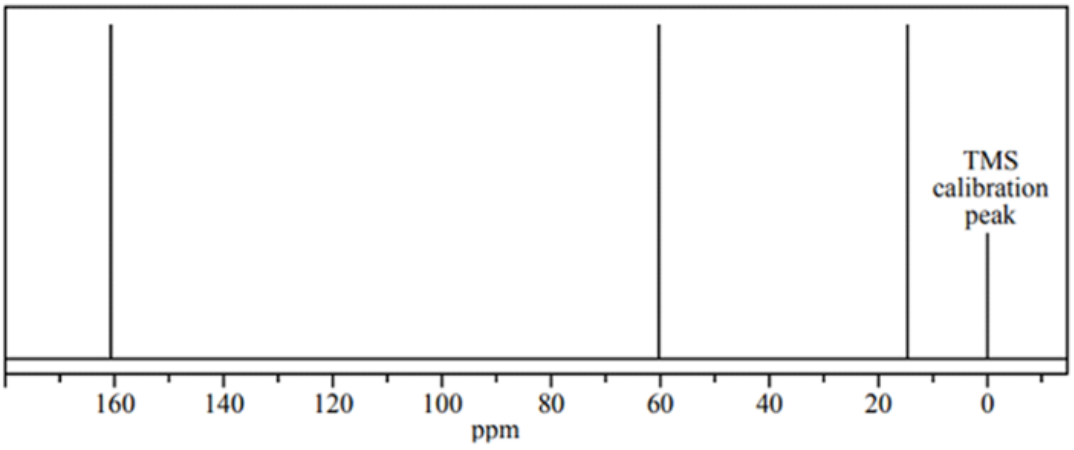
SECTION B - Question 5 - continued

TURN OVER

SPECTRA FOR UNKOWN CHEMICAL, $C_3H_6O_2$

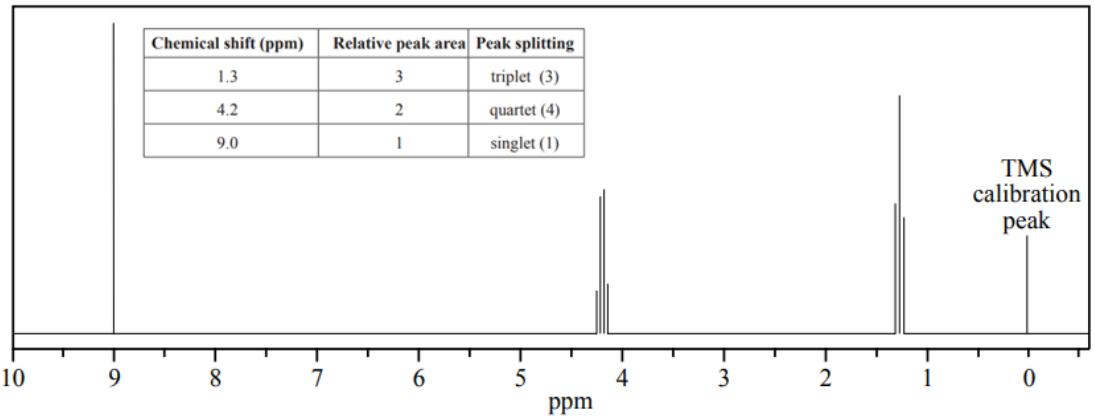


^{13}C NMR



^{1}H NMR

Chemical shift (ppm)	Relative peak area	Peak splitting
1.3	3	triplet (3)
4.2	2	quartet (4)
9.0	1	singlet (1)



(Source: *https://sdbs.db.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi)*

SECTION B - Question-5 - continued

d. The signal at 1.3 ppm on the ^{1}H-NMR spectrum is split into a triplet. What is the number of equivalent protons bonded to the adjacent carbon atom?

1 mark

_____

e. The student added a base into the chemical but did not see any reaction at all. What information has she gained from this result?

1 mark

_____

_____

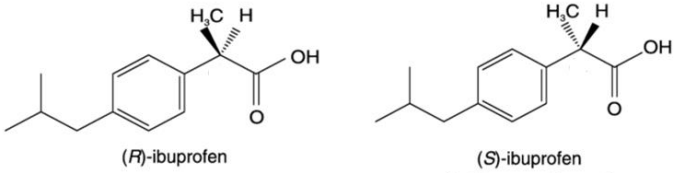
f. Based on the evidence collected by the student, write the systematic name and draw the structural formula of the chemical in the bottle.

2 marks

SECTION B-continued

TURN OVER

Question 6 (11 marks)
Ibuprofen, a medicine commonly used in the treatment of pain and inflammation, exists as a pair of enantiomers. Both enantiomers are formed in the production of ibuprofen, but only the ***(S)*** enantiomer is biologically active. Both enantiomers are shown below.



a. Define chiral center. Circle the chiral center in the active enantiomer of ibuprofen in the image above.

2 marks

b. Identify partial charges on any polar part of (S)-ibuprofen.

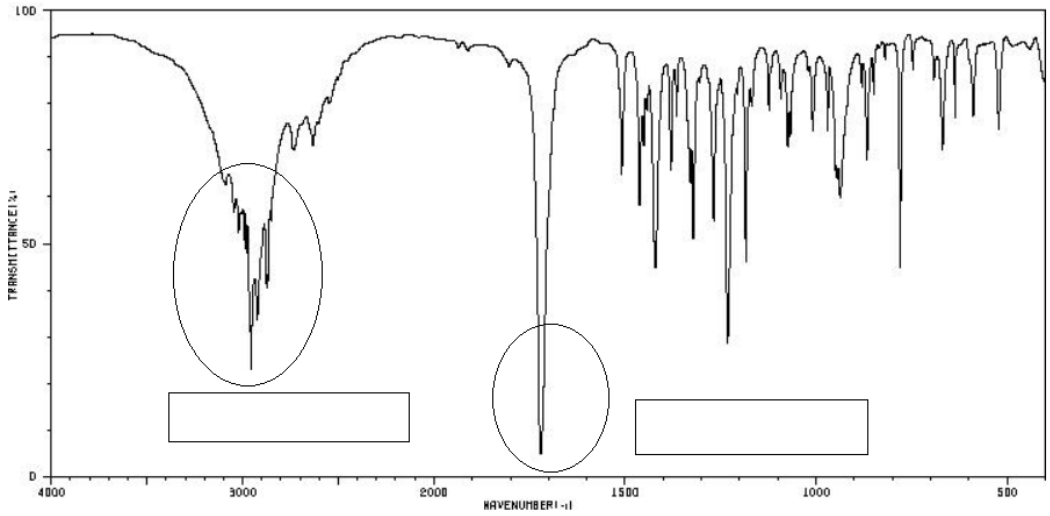
2 marks

c. Explain why the (S) enantiomer of ibuprofen is biologically active while the other (R) enantiomer is inactive, despite both having the same molecular formula and sequence of bonded atoms.

3 marks

SECTION B - Question 6 - continued

A student conducted an infrared spectroscopy analysis of ibuprofen, and the following spectrum was produced.



Source: https://www.chemicalbook.com/SpectrumEN_15687-27-1_IR1.htm

d. Determine the functional group highlighted in each circle and label it in the provided spaces adjacent to each circle.

2 marks

e. Why does ibuprofen dissolve better in ethanol than in water?

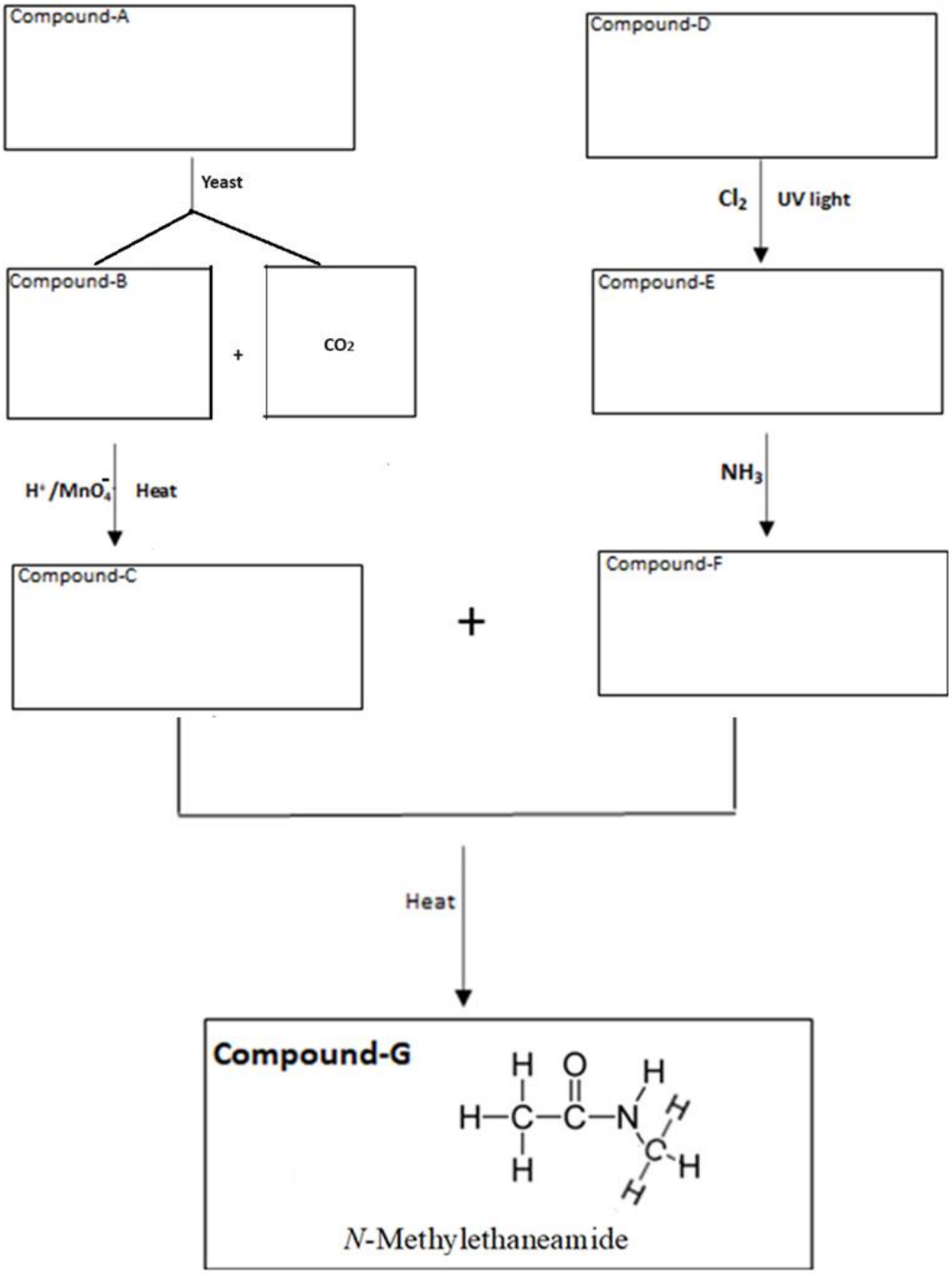
2 marks

Question 7 (6 marks)

A student wanted to prepare the product *N*-Methylethaneamide via the following reaction pathway.

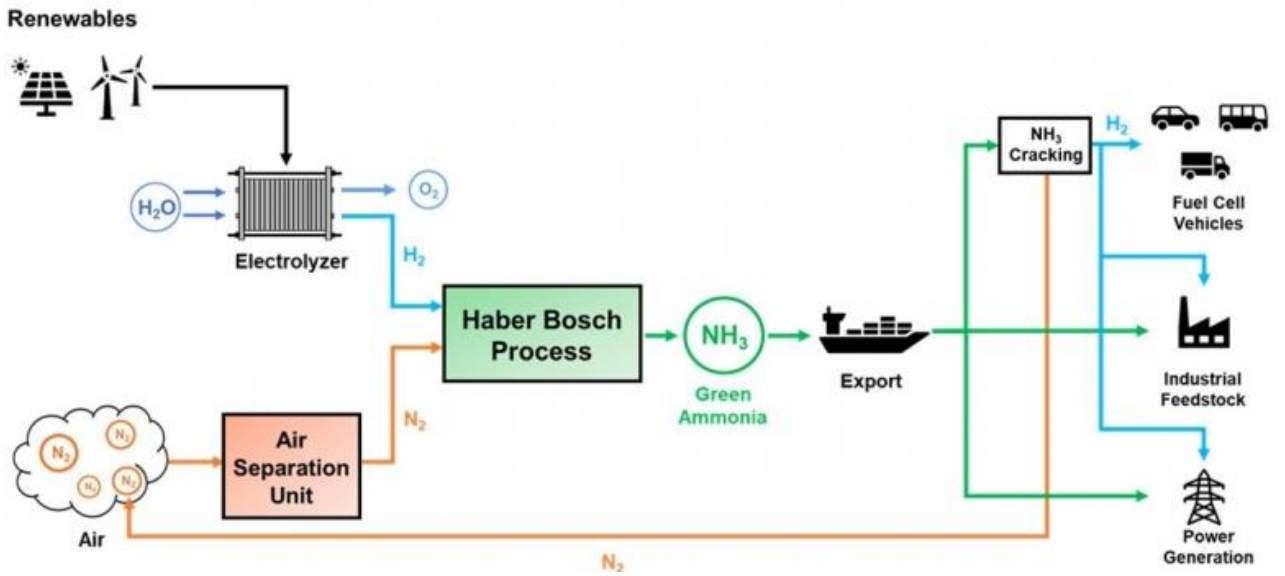
a. Write down **semi-structural formula** of compound A.

b. Draw the structural formulae of the compounds **B-F** in the boxes provided.



Question 8 (7 marks)
Ammonia (NH_3) can potentially be made directly from the nitrogen (N_2) that makes up 78% of the air we breathe, and hydrogen (H_2) from the electrolysis of water.

If the electricity used to make this ammonia comes from renewable sources, then the ammonia would be considered green. This means the most important fertiliser on Earth – responsible for the increased agricultural yields that allows the planet to sustain its present population – could be created sustainably. Green ammonia is not as well-known as green hydrogen, but it may be more practical replacement for fossil fuels.



Source: *https://www.pcrg.unsw.edu.au/alternative-green-and-cost-effective-processes-ammonia-production-green-ammonia*

a. What are green fuels? Provide two examples of green fuels and outline their environmental effects.

3 marks

_____

_____

_____

_____

_____

SECTION B – Question 8 - continued

TURN OVER

Currently, the Haber-Bosch process is the primary commercial method for the production of ammonia using the following reaction.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -93 \text{ KJ}$$

b. With reference to Le Chatelier's principle to identify and explain two reaction conditions that will maximise the yield of ammonia.

4 marks

Question 9 (12 marks)
Potassium permanganate ($KMnO_4$) is a strong oxidising agent in an acidic medium as shown below.

$$\underset{\text{Purple}}{MnO_4^-} + 8H^+ + 5e^- \rightarrow \underset{\text{Colourless}}{Mn^{2+}} + 4H_2O$$

A student wanted to investigate how varying temperatures would affect the rate at which oxalic acid solution would decolourise an acidified potassium permanganate solution.

Materials

A selection of syringes	100 mL glass beakers
White tile	Bunsen burner, heating mat & tripod
Timer	Thermometer
0.2 M ethanedioic (oxalic) acid	1 M sulphuric acid
0.02 M potassium permanganate	Deionised water
Glass stirring rod	

Method

1. Using syringes, add 5 mL of sulphuric acid, 2 mL of potassium permanganate and 40 mL of water to a 100 mL dry glass beaker.
2. Heat the mixture to about 40°C
3. Place the beaker on a white tile and measure 1 mL of oxalic acid solution into a syringe.
4. Add the oxalic acid to the mixture in the beaker as quickly as possible and at the same time, start the timer.
5. Gently stir the reaction mixture with the stirrer.
6. When the reaction mixture just turns colourless, stop the timer, and record the time (in seconds).
7. Measure and record the temperature
8. Repeat the experiment another three times but heat the initial sulphuric acid / potassium permanganate water mixtures first to 50°C then to 60°C and finally to 70°C.
9. In each experiment, measure and record the time it takes for the reaction mixture to just turn colourless, and measure and record the temperature when this happens.

Observations
The student observed that as the temperature increases from 40°C to 70°C, the time taken for the reaction mixture to turn colourless decreases.

SECTION B - Question 9 - continued

Answer the following questions related to the above experiment.

a. Identify the independent and dependent variables.

2 marks

b. Write a hypothesis for the investigation.

2 marks

c. Outline a difference between systematic and random errors. Use an example of each from this investigation to support your answer.

4 marks

SECTION B - Question 9 - continued

d. What are the key differences between repeatability and reproducibility, and how do they affect the accuracy and precision of experimental results?

4 marks

SECTION B - continued

TURN OVER

Question 10 (8 marks)
Renewable diesel (also referred to as hydrotreated vegetable oil (HVO), or green diesel) uses the same feedstocks as biodiesel but employs different production processes. Utilising a process termed "Hydrotreatment," which involves complex chemical reactions that remove oxygen atoms, and create a product chemically identical to conventional diesel. This makes renewable diesel a "drop-in" that it is free from sulfur and other pollutant-free. Renewable diesel can replace diesel in engines without modification.

a. Compare the Renewable diesel with Biodiesel and Petrodiesel. In your answer refer to
- Chemical structure
- Physical properties

4 marks

_____

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SECTION B - Question 10 - continued

b. Discuss how the production and utilisation of biodiesel and renewable diesel contribute to sustainable development goals compared to traditional petrodiesel. Include the following aspects of sustainability in your answers.

- Impact on the environment
- Sustainable use of resources

4 marks

END OF QUESTION AND ANSWER BOOK