VCE Chemistry 2024

Unit 3 & 4 Trial Examination

Assessment Guide & Suggested Solutions

Multiple Choice Answer Sheet

These solutions are provided as a guide and are our suggestions only.
Some questions may have alternative solution pathways which are also valid but are not shown.

SECTION A: Multiple Choice Answers

Question	Answer	Explanation
1	**C**	Use data book
2	**C**	Definition
3	**B**	OH has higher priority than NH_2
4	**B**	OH attached to C with 2 other C
5	**D**	From data book
6	**C**	10g is 10/46mol x1370 should produce ~298kJ. 250/298 x100 = 83.9%
7	**C**	Considered biogas
8	**A**	
9	**D**	2x175/100 x(4.5x17+9.9x37+29.9x16)
10	**A**	Protein contributes 1107kJ carbs1675
11	**D**	Longest C chain is 5, C=O on Caron 3
12	**D**	
13	**D**	N(prop) = 2.7/58, 1 :4 ratio for O2, so n(O2) is 2.7x4/58=0.186 V= 0.186x8.31x423/140
14	**B**	
15	**D**	
16	**B**	
17	**D**	(100/304) x4x2x126.9 4 C=C per molecule of arachidonic acid
18	**A**	Definition
19	**A**	
20	**B**	
21	**C**	The component that is attracted to the stationary phase the least will go the highest.

22	**B**	Biogas has low running costs. Everything else is true.
23	**A**	Matches the databook
24	**C**	See principles listed in data book.
25	**B**	Whilst there are examples of this reaction that could be enzyme catalysed, this reactoin can take place without enzymes, none of the others can.
26	**B**	
27	**B**	When time is zero, there shouldn't be any gas. So any graph that doesn't pass through the origin must have a systematic error.
28	**C**	
29	**C**	Bromine test identifies C=C.
30	**A**	

END OF SECTION A

Section B – Short Answer Questions

Instructions for Section B

Answer **all** questions in the spaces provided but if more space is needed, use the additional working space at the end and clearly label your answer.

Write using blue or black pen. No white out.

To obtain full marks you should:

- Give simplified answers, with an appropriate number of significant figures to all numerical questions; 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
- Make sure chemical equations are balanced and that the formulas for individual substances include indication of state; for example; e.g. $H_{2(g)}$, $NaCl_{(s)}$
- Unless otherwise indicated, the diagrams in this exam are **not** drawn to scale.

Question 1 (11 marks)

When chlorine gas is mixed with hexane, in the presence of UV light, a substitution reaction takes place.

a. If only one H atom is substituted in every hexane that reacts, how many possible isomers of chlorohexane can be produced? 1 mark

3

(1-chlorohexane, 2-chlorohexane, 3-chlorohexane)

Note: *Names not required.*

Chlorohexane can undergo a further substitution reaction to produce an amine.

b. **i.** Write a balanced chemical equation for the reaction of 1-chlorohexane to form an amine. States are not required. 2 marks

$$C_6H_{13}Cl + NH_3 \longrightarrow C_6H_{13}NH_2 + HCl$$

Marking Guide:

Deduct 1 mark per mistake.

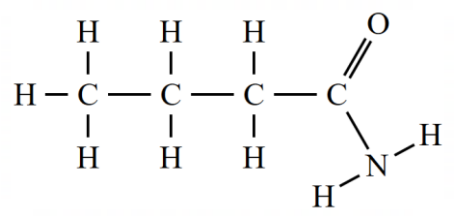
ii. Draw the skeletal structure of the organic product from **part i** and name that product. 2 marks

(1 mark)

Hexan-1-amine (1 mark)

Amines can be converted into amides by reacting the amine with an acid anhydride.

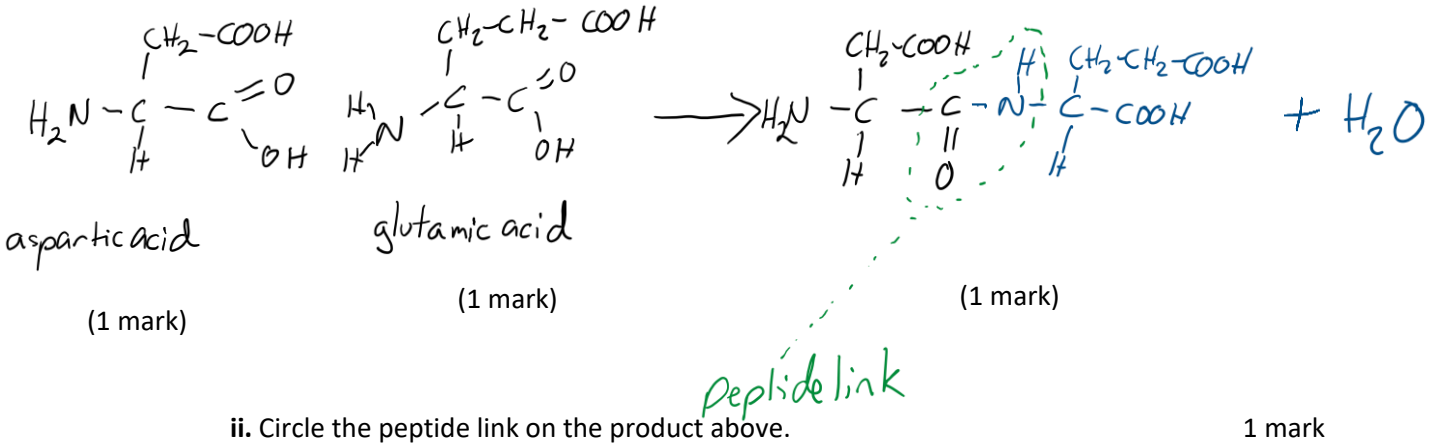
c. Draw the structural formula of a primary amide with four carbons 2 marks



Amines can also react with carboxylic acids to form an amide functional group.

d. **i.** Use aspartic acid and glutamic acid to show how an amide functional group can form.

3 marks



(1 mark) (1 mark) (1 mark)

ii. Circle the peptide link on the product above. 1 mark

Question 2 (8 marks)

There are over 35 structural isomers for the molecular formula C_4H_8O.
Butan-2-one is one of the structural isomers. At room temperature it is a colourless liquid with a sweet smell. Whilst it can be found naturally in some fruits and vegetables, it is manufactured on an industrial scale to be used in paints.

a. Name, and draw skeletal structures, for two other isomers of C_4H_8O. 4 marks

Marking Guide: *Multiple answers possible.*
1 mark for each correct name and 1 mark for each correct matching structure.
2 examples below.

but-2-en-1-ol

butanal

b. Write the chemical equation for the complete combustion of butan-2-one? 2 marks

$$2C_4H_8O(l) + 11O_2(g) \longrightarrow 8CO_2(g) + 8H_2O(g)$$

c. If 27g of Butan-2-one is completely combusted, what volume of CO_2 gas will be produced at SLC?

2 marks

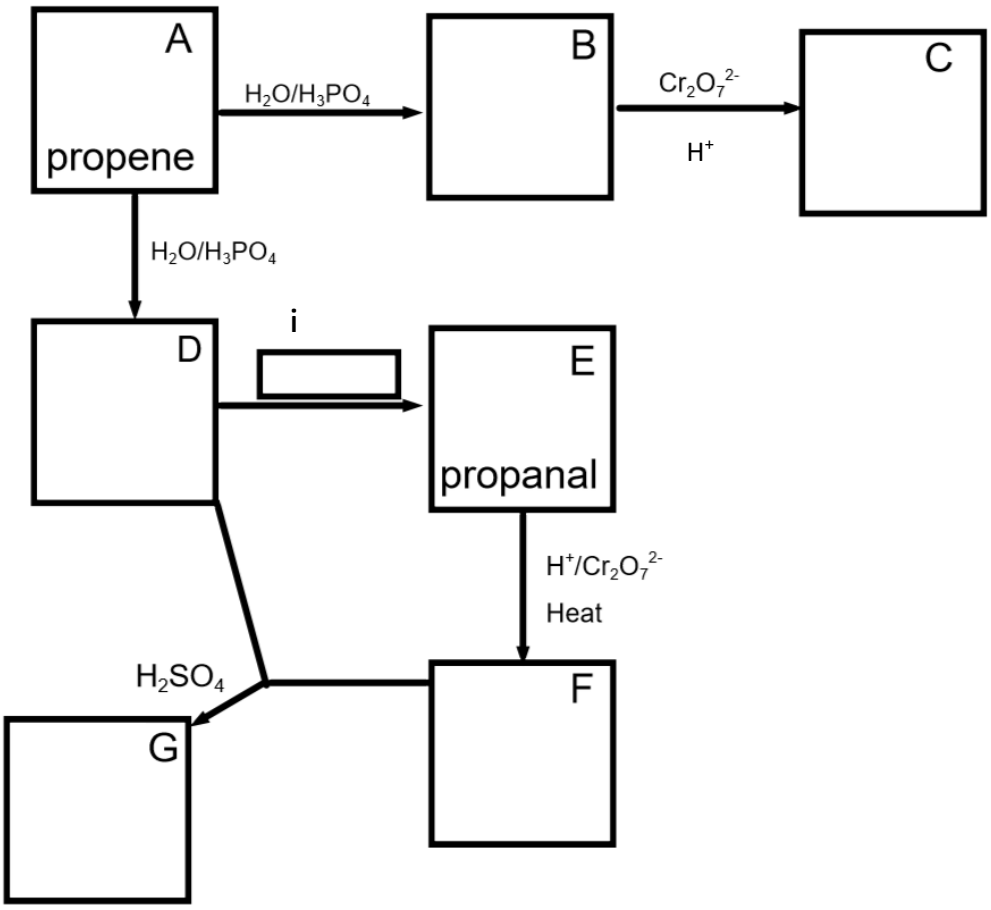
$$\text{n(butan-2-one)} = \frac{27}{72}$$

$$n(CO^2) = \ 4\text{n(butanone)} = \ 4 \times \frac{27}{72} = \ 1.5mol \ (1 \ \ \text{mark})$$

$$\text{Vol(CO2)slc} = 1.5 \times 24.8$$
$$= \ 37.2\text{L} \ \ (1 \ \ \text{mark})$$

Question 3 (8 marks)

Propene was used as the starting compound for series of reactions.



a. When propene is reacted with steam, in the presence of phosphoric acid, compounds B and D are produced in a 1:1 ratio.
Compounds B and D are known as what sort of isomers? 1 mark

Structural isomers

Half of compound D is reserved to react with compound F and half is reacted to form propanal

b. **i.** What reactant should go in the box marked i, so that D reacts to form propanal? 1 mark

$Cr_2O_7^{2-}$ OR MnO_4^{2-}

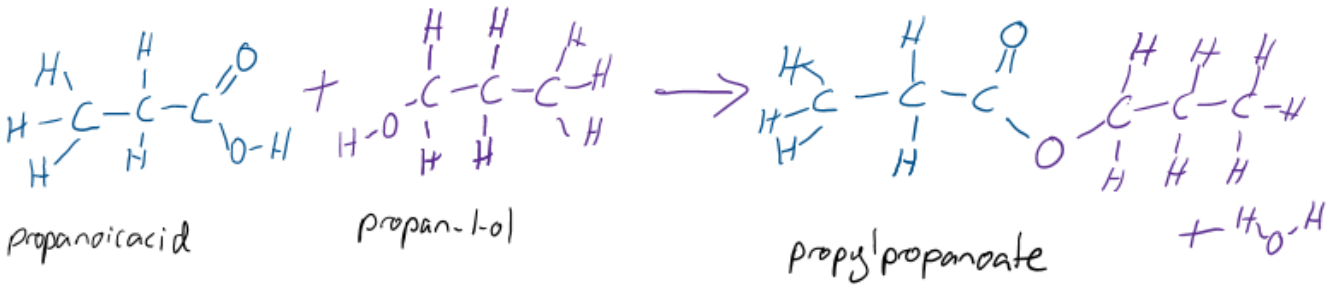
ii. What is the name of compound C?

1 mark

Propan-2-one

c. Compound G is a sweet-smelling organic liquid. Write a balanced chemical equation for the reaction of compounds D and F forming compound G. All reactants and products should be in full structural form. States are not required.

4 marks



Marking Guide: *1 mark for each correctly draw structure*

d. What is the name of the reaction type that occurs between compounds D and F?

1 mark

Esterification

Question 4 14 marks)

An unknown organic substance is being analysed in a laboratory. It is known that it is 69.8% by mass carbon, 11.6% by mass hydrogen and the rest oxygen.

a. Determine the empirical formula of the unknown substance.

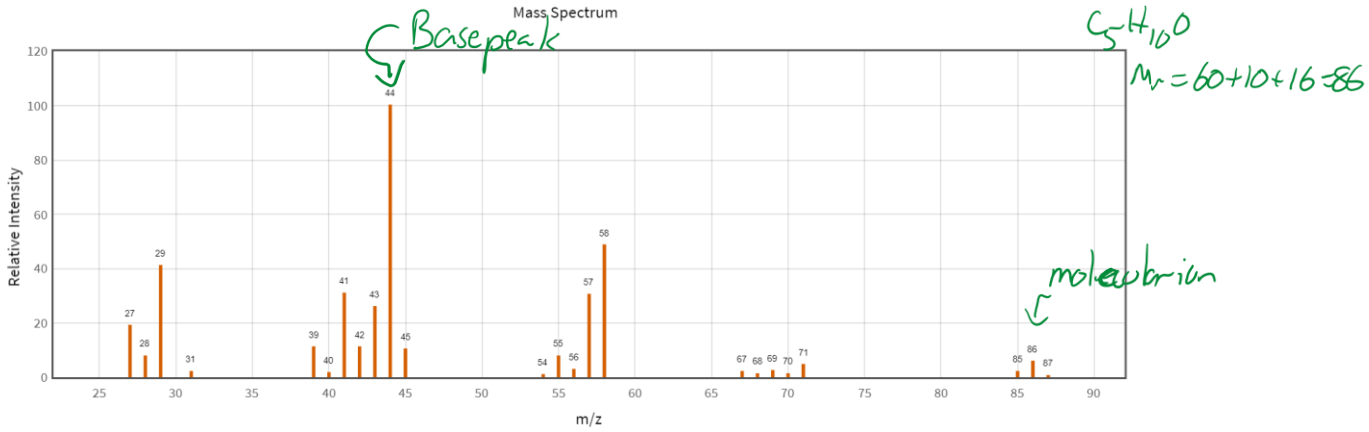
3 marks

	C	H	O
	69.8%	11.6%	18.6%
n	$\frac{69.8}{12}$	$\frac{11.6}{1}$	$\frac{18.6}{12}$
	5.81	11.6	1.1625
ratio	$\frac{5.81}{1.1625}$	$\frac{11.6}{1.1625}$	$\frac{1.1625}{1.1625}$
	4.997	9.97	1

Therefore, empirical formula is

$$C_5H_{10}O$$

A read out from the mass spectrometer is shown below.



Data: NIST Chemistry Webbook webbook.nist.gov
National Institute of Standards and Technology

b. **i.** Use the value of the molecular ion to determine the molecular formula of the unknown substance.

1 mark

Molecular ion suggests Mr is 86. From empirical formula molar mass is 86 so molecular formula is $C_5H_{10}O$

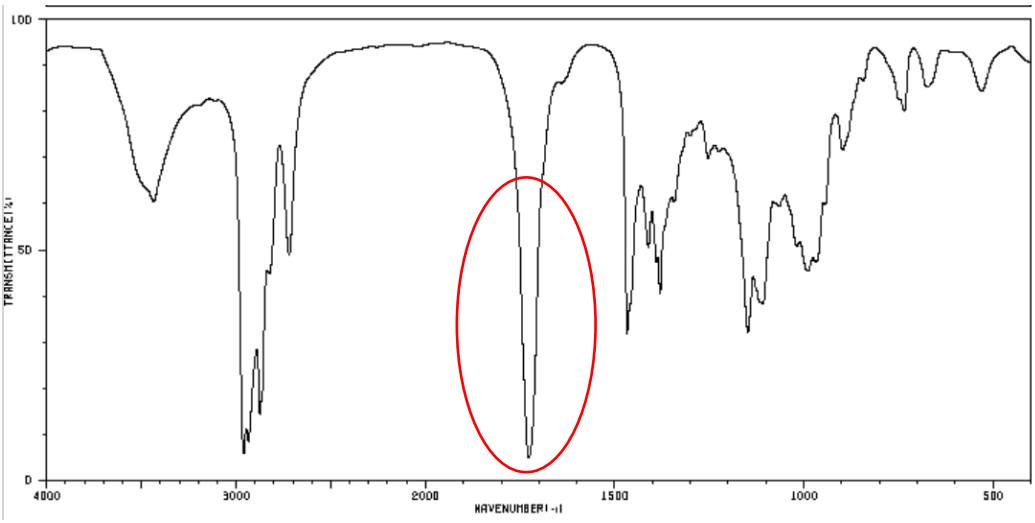
ii. What is the value of the base peak and what is the significance of it?

3 marks

Base peak has m/z of 44 (1 mark)

It is produced by the most abundant (1 mark) and stable (1 mark) fragment ion

The IR spectrum for the unknown substance is given below.



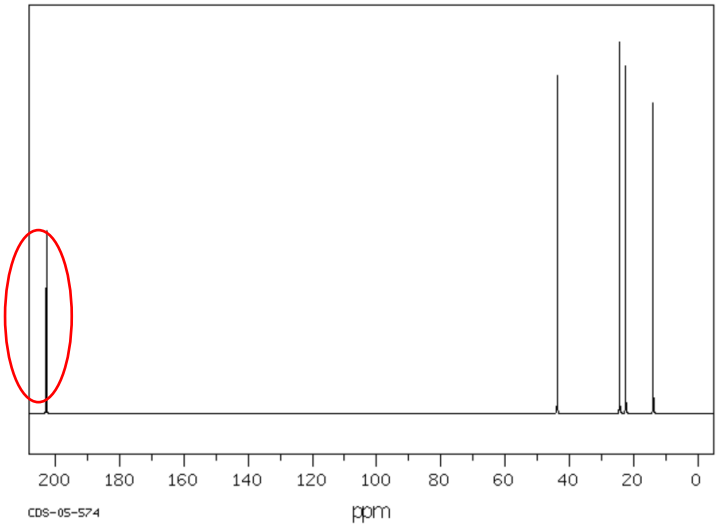
Data: SDBS web http://sdbs.db.aist.go.jp
National Institute of Advanced Industrial Science and Technology

c. There are five C=O bonds listed in **item 22** of the data book that might account for the absorption band that is circled. Explain why the "acids" bond can be discounted.

1 mark

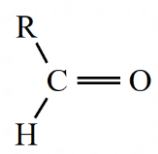
To be an acid there needs to be an accompanying absorption band at 2500-3500 cm^{-1} . Because there is no band at in that range, it cannot be an acid.

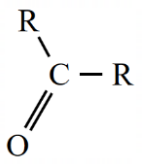
C-NMR



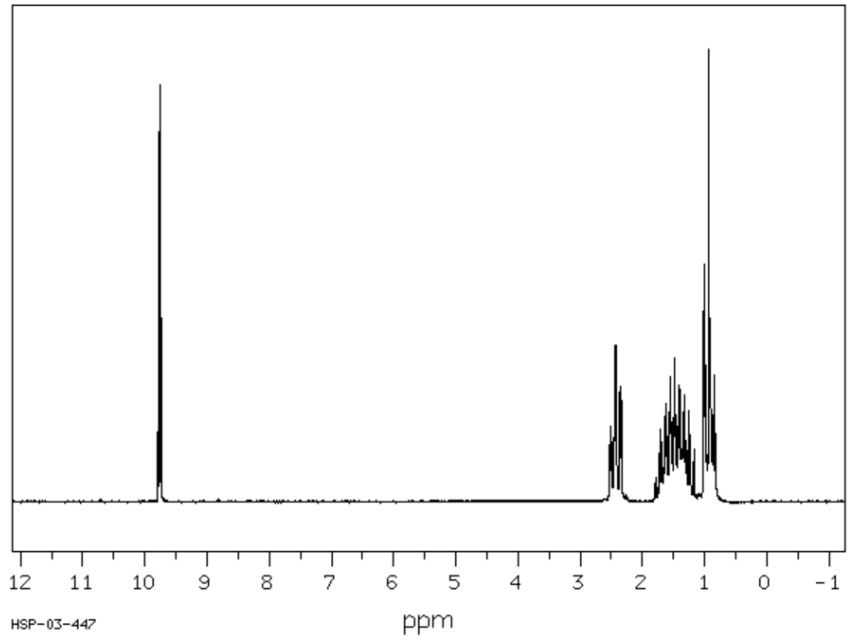
Data: SDBS web http://sdbs.db.aist.go.jp
National Institute of Advanced Industrial Science and Technology

d. Using **item 23** of the data book, draw two possible "Type of carbon" that might have generated the circled peak on the C-NMR above. 2 marks





H-NMR



Data: SDBS web http://sdbs.db.aist.go.jp
National Institute of Advanced Industrial Science and Technology

e. The three peaks on the right side of the high-resolution H-NMR above are split. Explain what causes the signals to split. In your response, make mention of the "n+1 rule".

2 marks

The splitting of signals in a high-resolution H-NMR spectrum is due to spin-spin coupling between protons. (H atoms) OR effect of neighbouring H atoms. (1 mark)

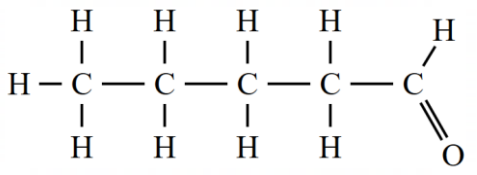
The n+1 rule helps predict the number of peaks in a signal based on the number of equivalent protons (H atoms) on adjacent/neighbouring carbon atoms. (1 mark)

This splitting pattern is useful for determining the structure of the molecule and the environment of each proton. (H atom)

Note: *Teacher discretion can be used here with the exact wording of this answer.*

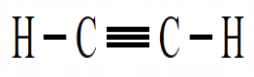
f. Based on all the information provided, what is the name and structure of the unknown molecule? 2 marks

Pentanal



Question 5 (5 marks)

Acetylene is the common name for ethyne. It is a colourless gas that is widely used in the welding industry. It has the structural formula:



a. Write a balanced chemical equation for the complete combustion of acetylene. 1 mark

$$2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$$

b. Use **items 10 and 11** of the Data Book to calculate the theoretical enthalpy change for the complete combustion of 1 mole of acetylene.

3 marks

Bonds broken	Bonds formed	***Marking Guide:***
2x2xC-H = 4x414	4x2xC=O = 8x804	*1 mark for equating bonds and*
2xC≡C = 2x839	2x2xOH = 4x463	*energy values*
5x O=O =5x498		*1 mark for multiplying by*
Total 5824kJ/mol	8284 kJ/mol	coefficients

ΔH = 5824 – 8284 = -2460 kJ/mol *1 mark for value*

c. Using your answer from **part b.** identify if the reaction is exothermic or endothermic.

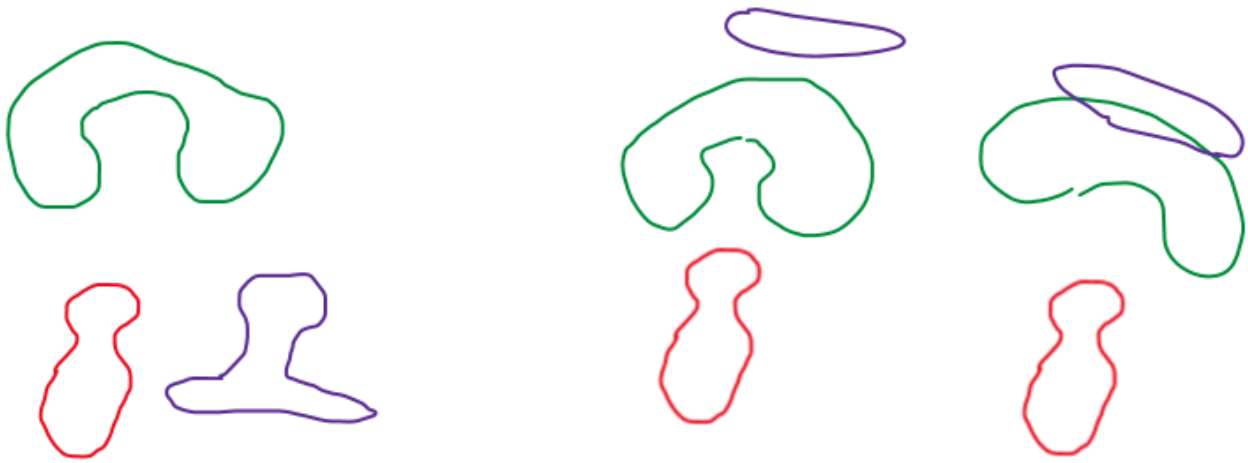
1 mark

Exothermic (consequential)

Question 6 (6 marks)

Enzymes catalyse multiple reactions within the human body. Some of these reactions are healthy e.g. they help us breath and process nutrients. Other enzyme catalysed reactions are unhealthy, like those responsible for inflammation.

Describe the process of how competitive and non-competitive enzyme inhibitors stop enzymes from acting as catalysts. In your response include examples and diagrams.



(2 marks for diagram)

A competitive enzyme inhibitor has a similar shape to the molecule that seeks to occupy the active site. (1 mark)

It replaces the substrate and stops the desired/undesired reaction from occurring. (1 mark)

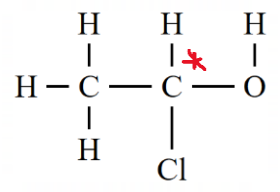
A non-competitive enzyme inhibitor binds to the enzyme in a position other than the active site, and by doing so changes the shape of the active site. (1 mark)

This means that the substrate no longer matches the shape of the active site. (1 mark)

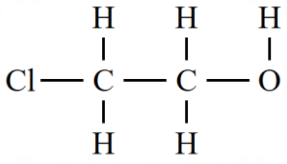
In the diagram above the red shape is the substrate and the purple shapes are the inhibitors.

Question 7 (6 marks)

The molecule C_2H_5ClO has multiple isomers. Use it to show the difference between structural isomers and optical isomers. As part of your answer, you are required to name two structural isomers. Diagrams are not required to obtain full marks, but maybe helpful in demonstrating your understanding of these concepts.



1-chloroethanol



2-chloroethanol

(1 mark each for each correct name)

1-chloroethanol and 2-chloroethanol are structural isomers, whilst they have the same amount of each type of atom (1 mark), the ordering of the atoms is different. (1 mark)

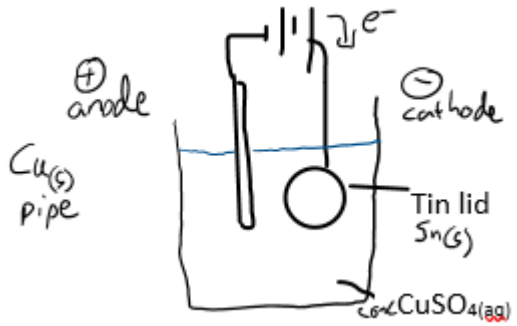
1-chloroethanol has a chiral centre, that is, a carbon with 4 different groups around it (indicated with an asterisk). (1 mark)

Whilst the arrangement of the atoms is the same, there are two possible ways the four groups can form around the Carbon atom in 3D space. (1 mark)

Question 8 (7 marks)

To help engage the year 8 science class during the Olympics games, a chemistry teacher decides to make some "Olympic medals" with the students. Whilst gold and silver are too expensive, the teacher does have some old copper pipe left over from a bathroom renovation a few years ago. The teacher collects some empty tin cans that once contained tomatoes, corn and beans. After carefully cutting the circular ends off, and washing them thoroughly, they are ready to use these as the medals.

a. Draw a labelled diagram and describe how the teacher could use some common school chemicals and laboratory equipment, and the left-over copper, to set up an electrolytic cell to make "Olympics medals" with the year 8 students.



The teacher can use:

- a beaker large enough to fit the tin lids in
- recycled copper as anode
- a power source
- 2 alligator clips/wires
- Copper(II)sulphate solution

Connect the tin lids to the power source on the negative terminal the cathode.

The positive terminal is connected to the Copper as the anode

A high concentration $CuSO_4$ solution is used as the electrolyte

Marking Guide:

1 mark for diagram

1 mark for equipment list

1 mark for description of set

The teacher believes that to make a well-coated medal, it will need 2.5g of copper to be used per medal. There are 22 students in the class. The teacher will have students work in pairs. The class runs for 45 minutes, but the teacher knows that the students will only have 30 minutes to run the practical due to set up and instruction time.

b. If the power supply runs at 8.5 amps, and the students run the equipment for exactly 30.0 minutes, will each student have enough time to coat their medal with 2.5g of copper?

4 marks

$$n(Cu^{2+}) = \frac{5}{63.5} \qquad (1mark)$$

$$\text{n(e-)} = \frac{2 \times 5}{63.5}$$

$$Q = \text{n(e-)} \times F = \frac{2 \times 5}{63.5} \times 96\,500 \ (1 \ \text{mark})$$

$$Q = \text{It}$$

$$\text{So } t = \frac{Q}{I}$$

$$\text{So } t = \frac{2 \times 5 \times 96\,500}{63.5 \times 8.5} \qquad (1mark)$$

$$= 1\,787 \text{ sec}$$

$$= 29.8 \text{ minutes} \qquad (1mark)$$

Yes, there is enough time for each student to coat their “medal” with 13 seconds to spare.

Question 9 (10 marks)

Scientists are observing the equilibrium system

$$2NO(g) + O_2(g) \longleftrightarrow 2NO_2(g)$$

The scientists observe that at a particular time, the concentration of NO is 0.5 M, O_2 is 0.1 M and NO_2 is 0.2 M. This reaction is taking place at 300 °C

a. If the equilibrium constant, K, is 350 M^{-1} at 300 °C, by first calculating the reaction quotient, Q, determine if the reaction is moving left or right towards equilibrium

2 marks

$$Q = \frac{(0.2)^2}{0.1 \times (0.5)^2}$$ *1 mark for finding Q=1.6*

$$= 1.6\ M^{-1}$$

$$\therefore Q < K$$

Moving to the right (1 mark)

Another group of scientists were studying the same system, but had written the equation:

$$2NO_2(g) \longleftrightarrow 2NO(g) + O_2(g)$$

b. In this case what would the value of K (including units) be at 300 °C. 2 marks

$$\text{Krev} = \frac{1}{350}\ M$$ ***Marking Guide:*** *1 mark for value, 1 mark for correct unit*

Note: accept 0.00286 M

c. Given that NO_2 is a brownish red colour, and that both NO and O_2 are colourless, use Le Chatelier's principle to describe how the colour would change if additional O_2 was injected into the system. In your answer indicate the colour change immediately after the injection and then some time later.

3 marks

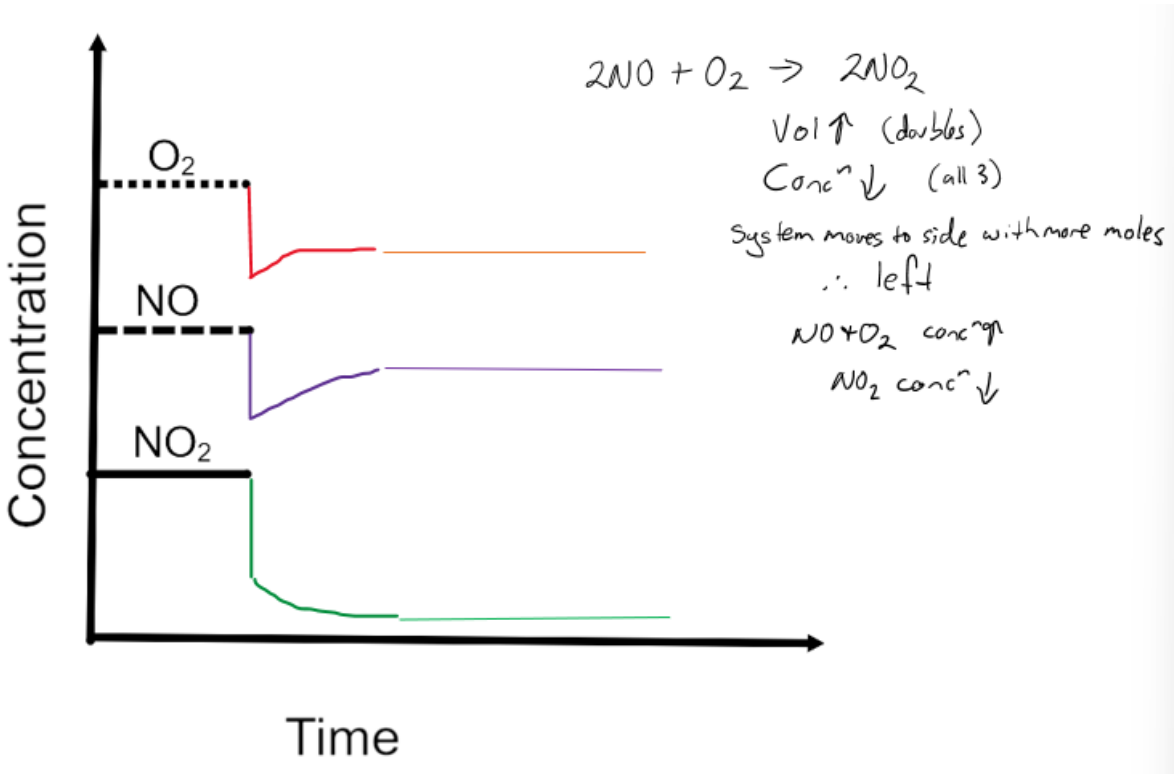
Initially when the oxygen is injected there will be no colour change. Although there is more O_2, the concentration of NO_2 doesn't change initially. (1 mark)

Le Chatelier's principle states that an equilibrium system subjected to change will try to oppose the change. In this case it will try to remove the additional O_2. (1 mark)

The system moves to right (forwards) to remove the extra O_2 and at the same time this increases the amount of NO_2, so the colour will finish a darker brownish red than it started. (1 mark)

d. On the Concentration versus time graph below, show what would happen to the concentrations of all three gases if the size of the container was instantly doubled.

3 marks



Marking Guide:

1 mark for all 3 going straight down at beginning

1 mark for second section (curved) watch the O_2 goes up by half of NO

1 mark for horizontal for all 3 starting at the same place/time

Question 10 (4 marks)

Platinum is used as a catalyst in a number of applications that help reduce energy usage.

a. Discuss how using a platinum catalyst, can lower the energy requirements of a reaction.

2 marks

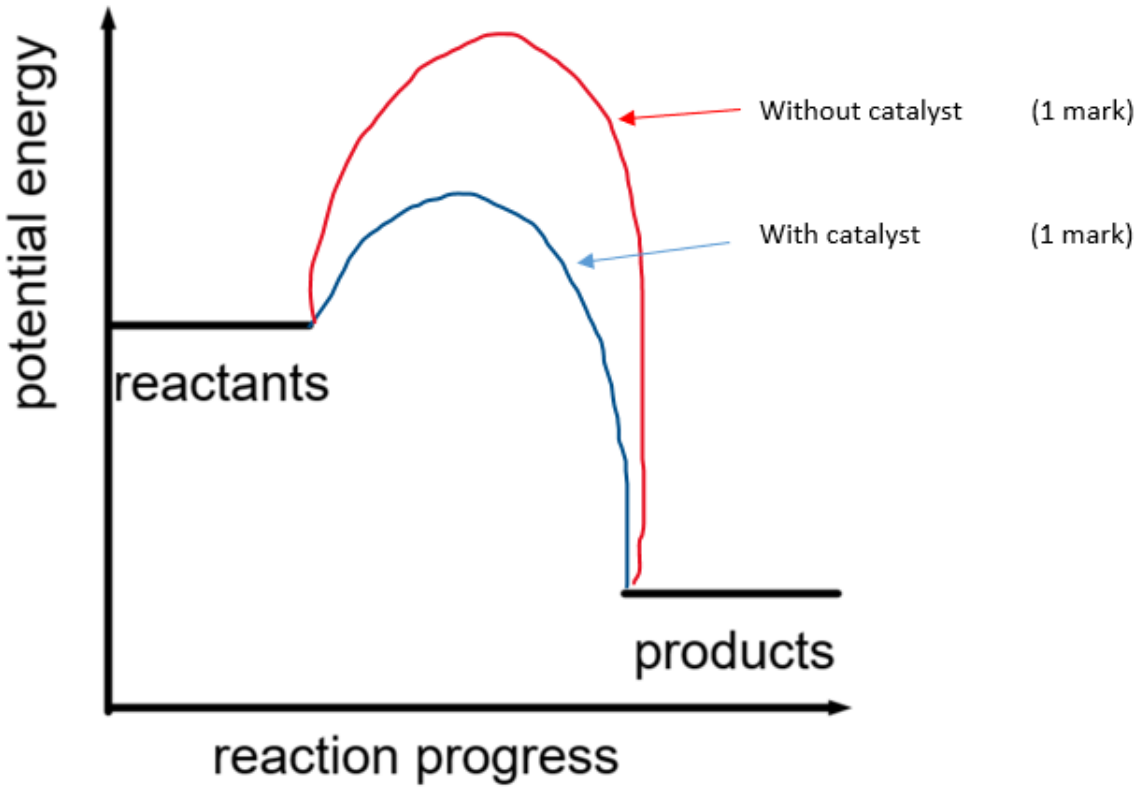
Lower Activation Energy: A platinum catalyst provides an alternative reaction pathway with a lower activation energy. This means that the energy barrier for the reaction to proceed is reduced. As a result, the reaction can occur more easily and at a lower temperature compared to an uncatalyzed reaction. [1 mark]

Increased Reaction Rate: By lowering the activation energy, the platinum catalyst increases the rate at which reactants are converted into products. This means that the reaction can proceed more quickly, requiring less overall energy input to achieve the desired conversion within a given time frame. [1 mark]

Note: *Student responses do not need to be this detailed.*

b. Draw and label the energy profile of an exothermic reaction with, and without, a catalyst.

2 marks



Question 11 (11 marks)

Halogens react with carbon-carbon double bonds via addition reactions. Iodine is used to determine the degree of unsaturation of organic molecules with carbon-carbon double bonds. Iodine is used as it is safer and more stable than bromine.

As part of their extended practical investigation, two students plan to investigate the iodine number (IN) of an unknown vegetable oil. To do this, they will react the oil with an excess amount of iodine that has been added to a mixture of cyclohexane and acetic acid. Once the reaction has gone to completion, the excess iodine will be titrated with sodium thiosulfate to determine how much iodine reacted with the oil.

Starch turns blue in the presence of iodine. It will go clear once the iodine has been used up.

AIM: To determine the iodine number of sunflower

Method:

Step 1. Dissolve six separate samples of 0.400g of the unknown oil in a mixture of cyclohexane and acetic acid.

Step 2. Add 0.800g of iodine in each sample. This is a known excess of I_2.

Step 3. Leave the samples in dark for a fixed period of time to allow the reaction to come to completion.

Step 4. Titrate the excess iodine with standard 0.100M sodium thiosulfate ($Na_2S_2O_3$). Use starch as an indicator.

Step 5. Repeat Step 4 until three concordant titres are found. (If samples run out, return to Step 1 and start again.)

a. What is the independent variable?

1 mark

Number of carbon-carbon double bonds in the oil

b. List two controlled variables.

2 marks

Marking Guide: *Any 2 of the following:*

- mass of I_2 added
- concentration of sodium thiosulfate
- time in dark for reaction
- indicator
- temperature, etc.

Results

Table 1 Results for first unknown oil			
Titration	Initial burette reading (mL)	Final burette reading (mL)	Titre (mL)
1	0.55	6.55	**6.00**
2	6.55	12.51	**5.96**
3	12.51	18.39	**5.88**
4	18.39	24.25	**5.86**

c. What is the average of the concordant titres?

1 mark

$$\text{Ave} = \frac{5.96 + 5.88 + 5.86}{3}$$

= 5.90 mL (6.00 outside concordant range)

The ionic equation for the reaction between iodine and sodium thiosulfate is:

$$I_2(aq) + 2S_2O_3^{2-} \longrightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

d. Calculate the mass of excess iodine that was reacted with thiosulfate

3 marks

$$n(s^2o^3) = c \times V$$
$$= 0.1 \times \frac{5.9}{1\,000}$$
$$= 0.00059$$
$$\text{n(xs } I) = \frac{1}{2} \times 0.00059$$
$$= 0.000295$$
$$\text{mass I} = 0.000295 \times 2 \times 126.9$$
$$= 0.074871g$$

Marking Guide:

1 mark $n(S_2O_3^{2-})$

1 mark $n(xs\ I_2)$

1 mark for final mass

e. Use your answer from **part d.** to calculate the IN of the unknown oil. 1 mark

Mass of I_2 used is 0.800 – 0.07487 = 0.72513g

$$\frac{0.725}{0.400} = \frac{x}{100}$$
$$x = 181.25$$

The students were told by their teacher that the unknown oil was sunflower oil, and that sunflower oil is primarily linoleic oil.

f. The students misheard the teacher and thought they said linolenic oil. Calculate the IN of linolenic oil.

1 mark

n(100g of linolenic) $= \frac{100}{12 \times 18 + 30 + 32}$ $= 0.35971223$ there are 3 C=C in linolenic so $n(I_2) = 3*0.3597$

m(I2) = 3 * 0.3597*2*126.9 = 273.88

g. Identify one systematic error that might have occurred during this practical. Discuss what effect this error would have had on the results, if any.

2 marks

Errors in the calibration of the mass balance or the burette, resulting in incorrect masses of oil or iodine, or consistently adding too much sodium thiosulfate solution in the titration (overshooting the endpoint).

Marking Guide:

1 mark for identifying a systematic error

1 mark for effect

END OF SUGGESTED SOLUTIONS