



VCE CHEMISTRY 2017

YEAR 12 TRIAL EXAM

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Units 3/4

Reading time: 15 minutes

Writing time: 2 hours 30 minutes

Section	Number of questions	Number of questions to be answered	Number of marks
A	30	30	30
B	9	9	90
			Total 120

To download the Chemistry Data Book please visit the VCAA website:
<http://www.vcaa.vic.edu.au/Documents/exams/chemistry/chemdata-w.pdf>

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STUDENT NUMBER

Figures

Words

Letter

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Student Name.....**VCE Chemistry 2017 Year 12 Trial Exam Unit 3/4****Student Answer Sheet**

Instructions for completing test. Use only a 2B pencil. If you make a mistake, erase it and enter the correct answer. Marks will not be deducted for incorrect answers.

Write your answers to the Short Answer Section in the space provided directly below the question. There are **30 Multiple Choice** questions to be answered by circling the correct letter in the table below.

Question 1 A B C D

Question 3 A B C D

Question 5 A B C D

Question 7 A B C D

Question 9 A B C D

Question 11 A B C D

Question 13 A B C D

Question 15 A B C D

Question 17 A B C D

Question 19 A B C D

Question 21 A B C D

Question 23 A B C D

Question 25 A B C D

Question 27 A B C D

Question 29 A B C D

Question 2 A B C D

Question 4 A B C D

Question 6 A B C D

Question 8 A B C D

Question 10 A B C D

Question 12 A B C D

Question 14 A B C D

Question 16 A B C D

Question 18 A B C D

Question 20 A B C D

Question 22 A B C D

Question 24 A B C D

Question 26 A B C D

Question 28 A B C D

Question 30 A B C D

VCE Chemistry 2017 Year 12 Trial Exam Unit 3/4

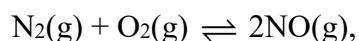
SECTION A – Multiple Choice Questions

(30 marks)

*Section A consists of 30 multiple-choice questions.
Choose the response that is **correct** or **best answers** the question.
A correct answer scores 1, an incorrect answer scores 0.
No mark is awarded if more than one answer is supplied for a question.
Indicate your choice on the answer sheet provided.*

Question 1

At 2300 K the equilibrium constant, K_c , for the formation of NO(g) according to the equilibrium



is 1.7×10^{-3}

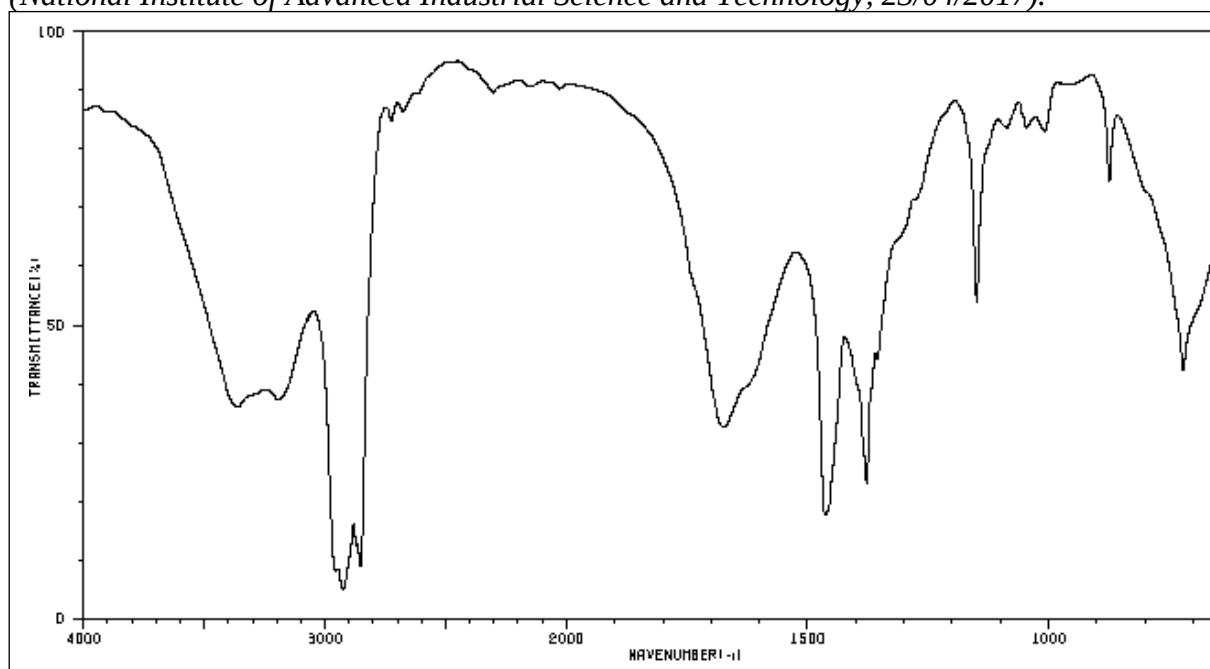
In a particular container at 2300 K the concentration of N_2 is 0.50 mol L^{-1} , the concentration of O_2 is 0.25 mol L^{-1} and the concentration of NO is $4.2 \times 10^{-3} \text{ mol L}^{-1}$.

Which of the following statements about the contents of this container is correct?

- A. The rates of the forward and reverse reactions are equal.
- B. The forward reaction is faster than the reverse reaction.
- C. The forward reaction is slower than the reverse reaction.
- D. The total number of molecules in the system is decreasing.

Question 2

Shown below is an IR spectrum of an organic compound. *SDBSWeb*: <http://sdb.sdb.aist.go.jp> (National Institute of Advanced Industrial Science and Technology, 23/04/2017).



The compound was most likely to be a/an

- A. alcohol.
- B. carboxylic acid.
- C. amide.
- D. aldehyde.

Question 3

Methane is produced by anaerobic digestion in garbage deposited in landfill and is also a component of coal seam gas. This suggests that methane may be classified as

- A. non-renewable.
- B. renewable.
- C. neither renewable nor non-renewable.
- D. both renewable and non-renewable.

Question 4

A student is instructed to determine, experimentally, the mass of ethanol consumed in raising the temperature of 200 mL of water in an open can by 20°C.

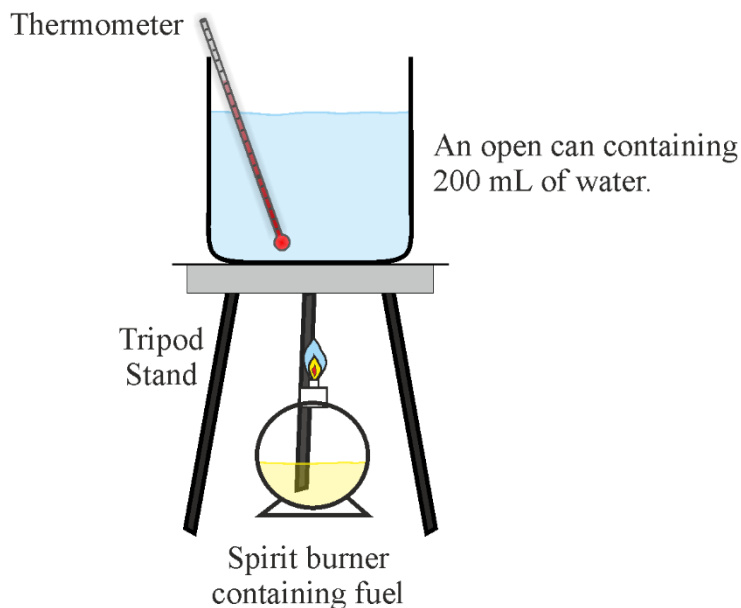


Figure 1

The balance used to weigh the spirit burner before and after heating the water was accurate. The spirit burners provided for the experiment all contained methanol, rather than ethanol. Which type of error will the use of the incorrect fuel lead to, and what will be the effect on the mass of fuel consumed in raising the temperature by 20°?

- A. Systematic error, smaller mass of fuel.
- B. Systematic error, larger mass of fuel.
- C. Random error, smaller mass of fuel.
- D. Random error, larger mass of fuel.

Question 5

Which of the following substances has molecules which are not chiral?

- A. Cysteine.
- B. Ascorbic acid.
- C. Glycerol.
- D. Alanine.

Question 6

Hexadecane, $C_{16}H_{34}$, also known as cetane, is a liquid hydrocarbon that may be a component of petrodiesel. The density of cetane is 0.775 g mL^{-1} .

What volume, in ML, of carbon dioxide, collected at SLC, would be released during the complete combustion of twenty litres of cetane?

- A. 1.70
- B. 24.6
- C. 27.2
- D. 48.3

Question 7

Shown in **Figure 2** is the partly annotated energy profile for the complete combustion of one mole of methane.

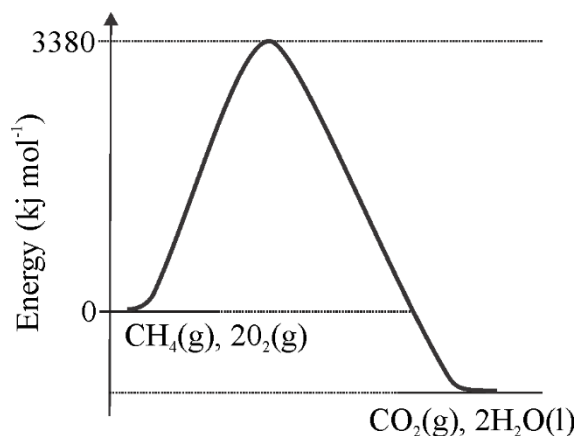
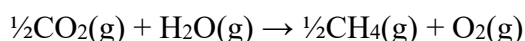


Figure 2

The activation energy for the reaction



would be

- A. 1635 kJ
- B. 2135 kJ
- C. 2490 kJ
- D. 4270 kJ

Question 8

Errors associated with the execution of a practical exercise are generally classified as either systematic or random. A commercial vinegar sample is exactly 0.0937 M with respect to ethanoic acid. A laboratory analysis to determine the ethanoic content of the vinegar is performed five times using the same technique, equipment and reagents.

The $c(\text{CH}_3\text{COOH})$ as determined by the analyses was found to be 0.0901 M, 0.0899 M, 0.0900 M, 0.0902 M, 0.0903 M.

Which of the following best describes the $c(\text{CH}_3\text{COOH})$ values obtained from the analyses?

- A. Low random error, low systematic error.
- B. Low random error, high systematic error.
- C. High random error, low systematic error.
- D. High random error, high systematic error.

Question 9

When molecular bromine is added to an aqueous solution of sodium hydroxide, the following equilibrium is established.



Which of the following changes ensues if the equilibrium mixture is cooled? The number of atoms with oxidation number

- A. +1 decreases.
- B. -2 decreases.
- C. -1 increases.
- D. 0 decreases.

Question 10

Consider the galvanic cell represented below in **Figure 3** at standard conditions.

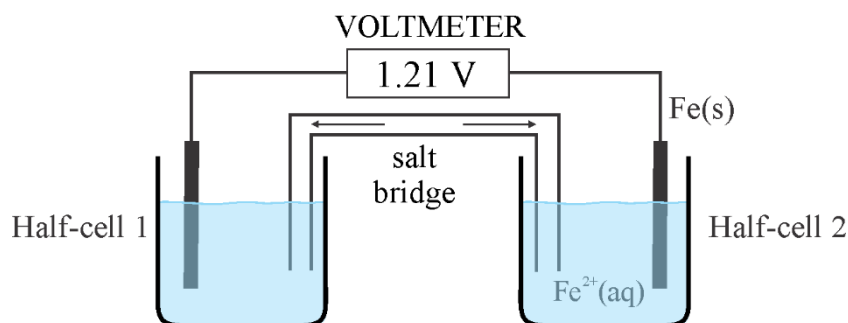


Figure 3

Which of the following species would most likely be present in Half-cell 1?

- A. Pt(s) or C(s)
- B. Al³⁺(aq)
- C. Fe(s)
- D. H₂(g)

Question 11

Temperature and pressure are key factors in the production of common chemicals via equilibrium reactions. The data below show the relationships between percentage yield of product, temperature and pressure for the industrial production of a chemical.

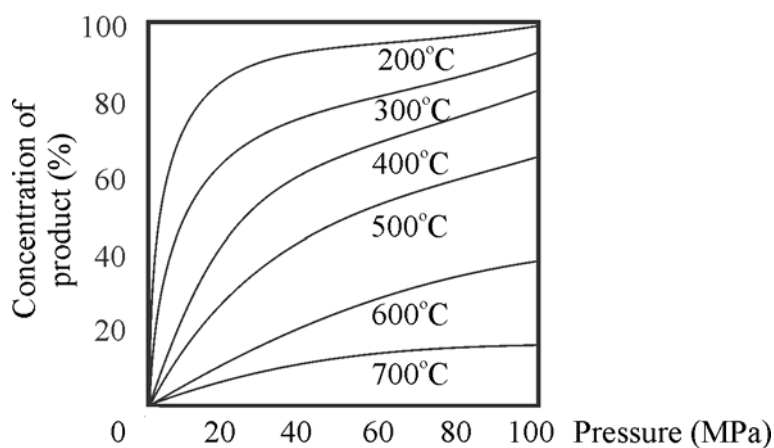


Figure 4

According to the data in **Figure 4**, the forward reaction is

- A. exothermic, and the product is on the side with fewer particles.
- B. endothermic, and the product is on the side with more particles.
- C. exothermic, and the product is on the side with more particles.
- D. endothermic, and the product is on the side with fewer particles.

Figure 5 below relates to Questions 12 and 13.

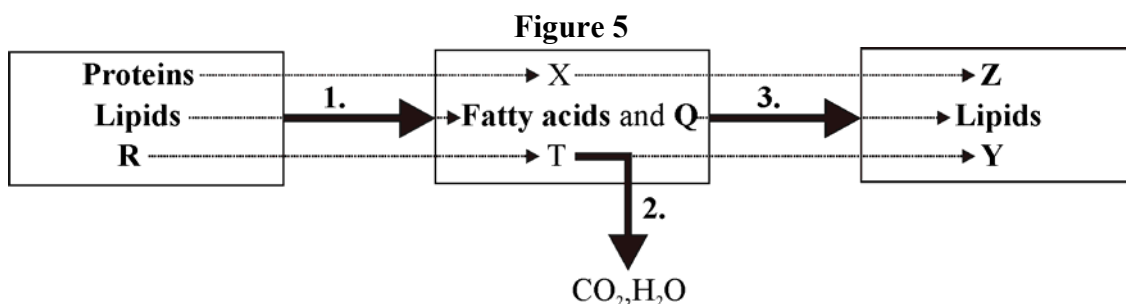


Figure 5: Digestion of the major dietary food groups

Question 12

The reactions represented by **1**, **2**, and **3** are

- A. 1 – condensation, 2 – respiration, 3 – hydrolysis.
- B. 1 – respiration, 2 – hydrolysis, 3 – condensation.
- C. 1 – condensation, 2 – hydrolysis, 3 – respiration.
- D. 1 – hydrolysis, 2 – respiration, 3 – condensation.

Question 13

The substance containing the greatest percentage, by mass, of oxygen is represented by

- A. Q
- B. X
- C. Y
- D. Z

Question 14

In January 2017, nine of forty-eight Nickel-hydrogen (Ni-H₂) batteries used on the International Space Station to store electrical energy generated by the station's solar arrays were replaced by lighter and more efficient lithium-ion batteries.

Ni-H₂ cells using 26 % potassium hydroxide (KOH) as an electrolyte were able to last up to seven years on the space station before being replaced.

One electrode is made up of porous nickel plaque, which contains nickel oxide hydroxide, NiO(OH); the other includes a Teflon-bonded platinum black catalyst.

The half-equation for the reaction occurring at the (+) electrode when this battery is delivering energy is $\text{NiOOH(s)} + \text{H}_2\text{O(l)} + \text{e}^- \rightarrow \text{Ni(OH)}_2\text{(s)} + \text{OH}^-\text{(aq)}$.

The reaction at the (-) electrode is most likely to be

- A. $2\text{H}_2\text{O(l)} + 2\text{e}^- \rightarrow \text{H}_2\text{(g)} + 2\text{OH}^-$
- B. $2\text{H}^+\text{(aq)} + 2\text{e}^- \rightarrow \text{H}_2\text{(g)}$
- C. $\text{H}_2\text{(g)} \rightarrow 2\text{H}^+\text{(aq)} + 2\text{e}^-$
- D. $\text{H}_2\text{(g)} + 2\text{OH}^-\text{(aq)} \rightarrow 2\text{H}_2\text{O(l)} + 2\text{e}^-$

Question 15

First generation biofuels can be described as FAMES (fatty acid methyl esters). Second generation biofuels include a renewable diesel, known as green diesel, formed by hydrotreating biological feedstocks such as oils and animal fats. In the process, the feedstock is deoxygenated and hydrogenated to form products with similar composition to petrodiesel. Compared to FAME biodiesel, green diesel would

- A. have a lower energy content per gram of fuel.
- B. be more viscous.
- C. have better cold flow properties.
- D. be more likely to absorb water.

Question 16

A sample of natural gas is 80 % methane, by volume.

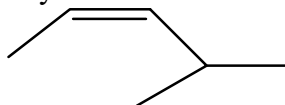
A 2.0 L sample of the natural gas is mixed with excess oxygen and sparked to react to completion.

Assuming all reactant and product volumes are measured at the same temperature and pressure, what is the change in the total volume of greenhouse gases as a result of the combustion reaction?

- A. 1.6 L
- B. 3.2 L
- C. 4.8 L
- D. 6.0 L

Question 17

Which compound is best represented by the structure below?



- A. *trans*-2-methylpent-3-ene.
- B. *cis*-4-methylpent-2-ene.
- C. *trans*-4-methylpent-2-ene.
- D. *cis*-2-methylpent-3-ene.

Question 18

A student's report on the electrolysis of an aqueous solution of copper(II) sulfate under standard conditions includes the following

'A flow of electricity passed through a solution of copper sulfate in water causes

- 1. the formation of negatively charged sulfate ions and positively charged copper ions;*
- 2. a metal deposit on the positively charged electrode;*
- 3. water to ionise into positively charged hydrogen ions and negatively charged oxygen ions;*
- 4. oxygen gas to be released into the air.'*

Which of the student's four statements about the effect of a 'flow of electricity passed through an aqueous solution of copper sulfate' is the **most** accurate?

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

Question 19

Shown below in **Figure 6** are Maxwell-Boltzmann curves for four different reactions, all occurring at the same temperature.

The activation energies of the four reactions are represented by the symbols E_{a1} , E_{a2} , E_{a3} and E_{a4} respectively.

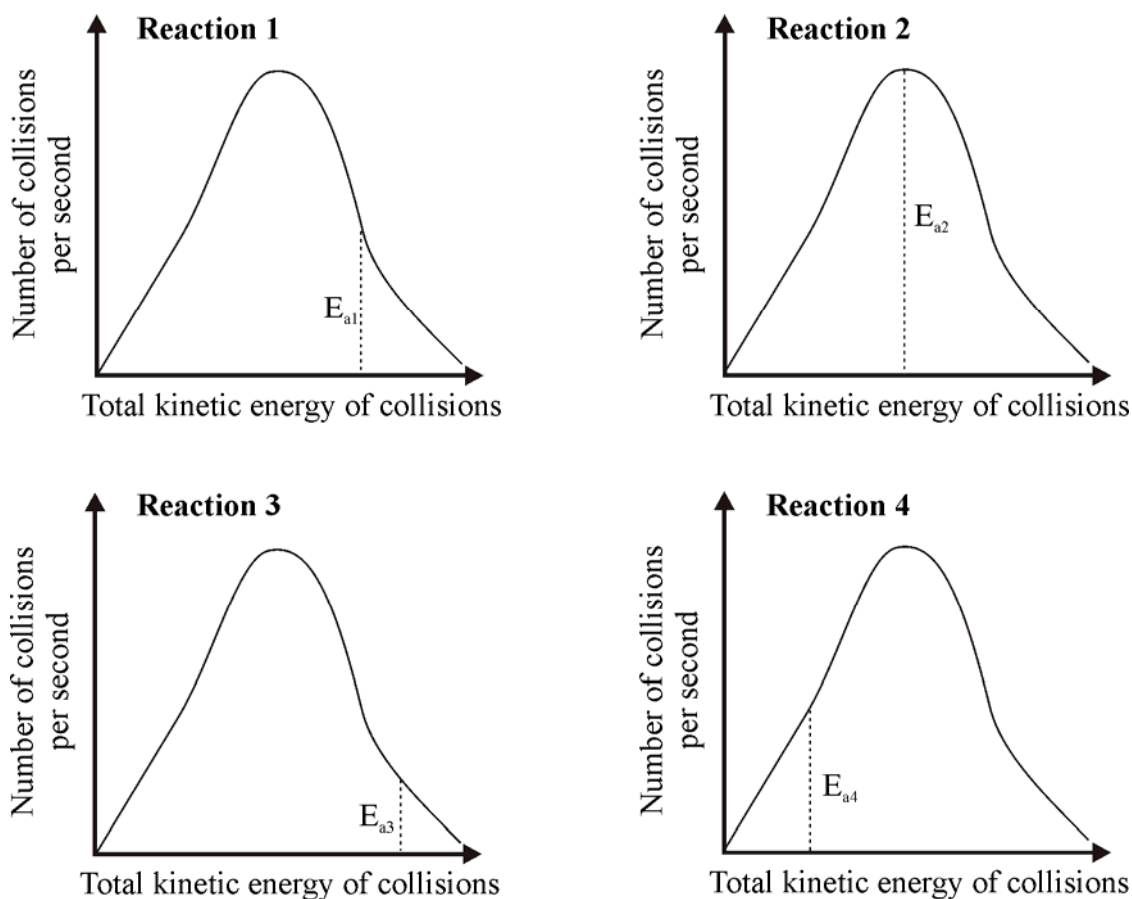


Figure 6

The order of reaction rates from slowest to fastest is

- A. Reaction 1 < Reaction 2 < Reaction 3 < Reaction 4.
- B. Reaction 3 < Reaction 1 < Reaction 4 < Reaction 2.
- C. Reaction 4 < Reaction 2 < Reaction 1 < Reaction 3.
- D. Reaction 3 < Reaction 1 < Reaction 2 < Reaction 4.

Question 20

Which of the following statements about enzymes is correct?

- A. Some substrates can cause the shape of the active site to change.
- B. The active sites of all enzymes have the same 3-dimensional shape.
- C. Coenzymes have a greater effect on reaction rate than enzymes.
- D. Enzyme activity is increased as pH decreases.

Question 21

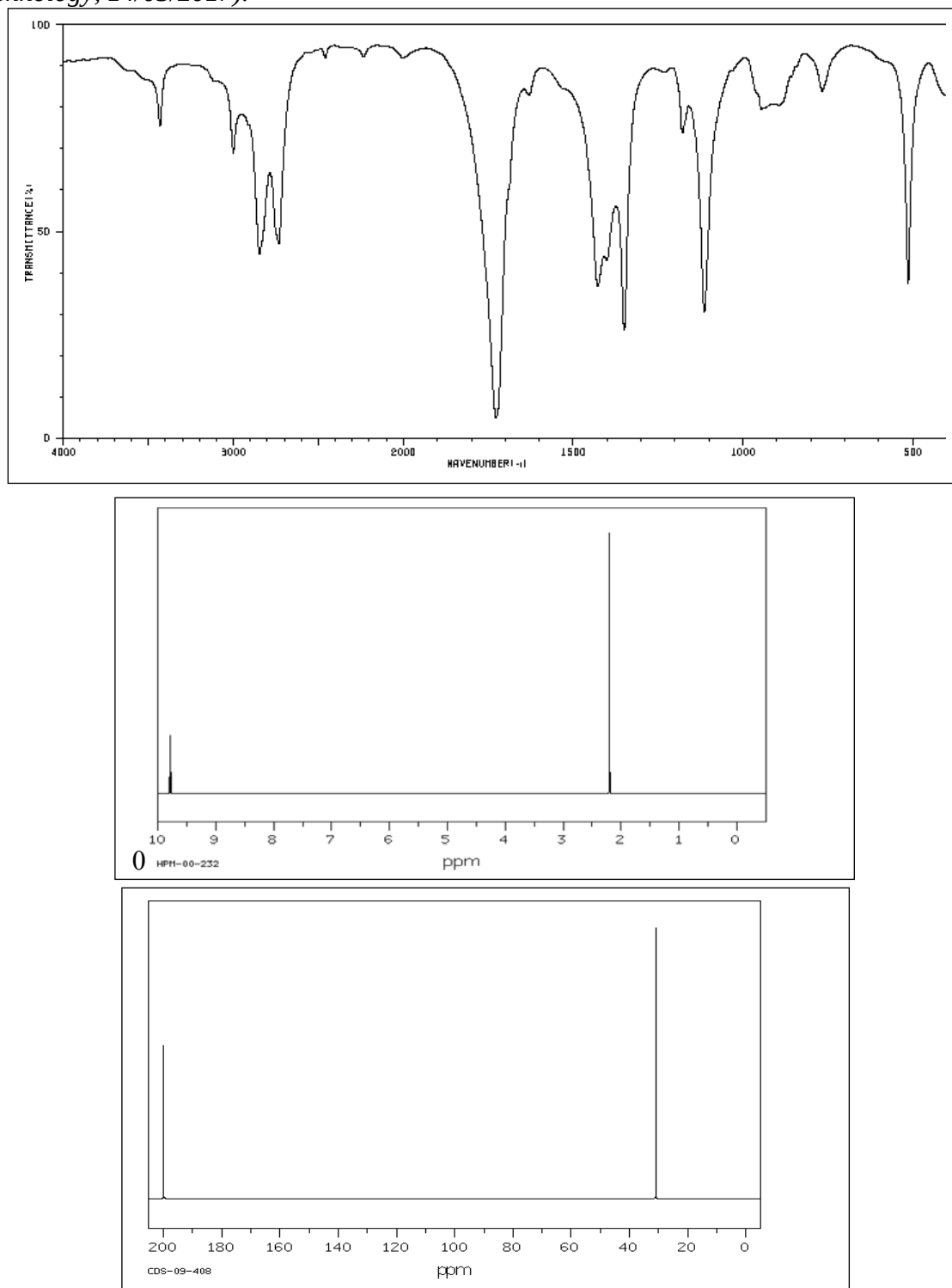
The longevity of a good wine is related to its acid content. Wines which age well show an increase in pH over time. Such wines will have a higher acid content, when bottled, than wines produced for immediate consumption. Whilst adding ascorbic acid to white wines increases their acid content, that is not the role it plays in ensuring the longevity of the wine. The likely role of ascorbic acid in wine is to act as

- A. a source of Vitamin C to reduce the effect of alcohol on the liver.
- B. an emulsifier and draw all the sediment in the wine to the bottom of the bottle.
- C. a reductant and so reduce the chance of the wine deteriorating due to the impact of free radicals.
- D. bactericide to kill any bacteria that might be present in the bottle closure (cork or screw top).

Question 22

The three spectra below relate to the same organic compound.

SDBSWeb: <http://sdb.s.db.aist.go.jp> (National Institute of Advanced Industrial Science and Technology, 14/03/2017).



According to this information the semi-structural formula of the compound is most likely to be

- A. CH_3COOH
- B. CH_3COCH_3
- C. CH_3CHO
- D. $\text{CH}_3\text{CH}_2\text{OH}$

Question 23

Graphical representation of data and concepts is an important component of chemistry. Consider the graphs below on which the Y-axis is unlabelled.

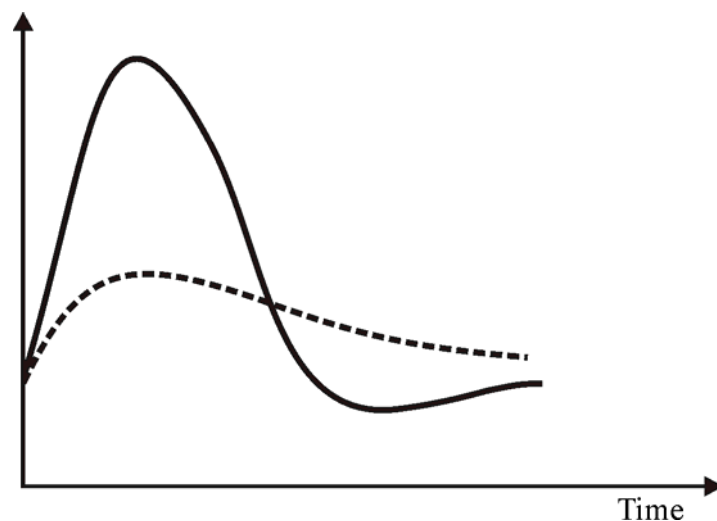


Figure 7

Which of the following options do the graphs in **Figure 7** best represent?

- A. The effect of temperature on particle collisions.
- B. The change in blood glucose levels during digestion.
- C. The effect of a catalyst on activation energy.
- D. Energy profiles for exothermic and endothermic reactions.

Question 24

Hazelwood Power station was a 1600 MW (megawatt – 1 MW = 1000 kJ s⁻¹) Victorian brown-coal fired power station that was decommissioned in the first half of 2017.

If a methane-fired gas power station, operating at 60 per cent efficiency, produced electrical energy at the same rate, the volume of CH₄, measured in ML at 30°C and 150 kPa, used in one hour would be

- A. 64.8
- B. 1.08×10^2
- C. 1.81×10^2
- D. 5.76×10^3

Question 25

Many of the venoms injected by spiders such as redbacks are cocktails of proteins that interfere with nerve transmission and cellular function. Snake venoms and box jellyfish stinging elements contain potent mixes of poisonous proteins, enzymes and polypeptides. Whilst antivenoms exist for most snake venoms, no such option is available for jellyfish stings.

Which of the following treatments would be **least** effective in reducing the impact of jellyfish stings?

- A. Bathing the affected area with a concentrated solution of inorganic ions.
- B. Bathing the affected with vinegar solution.
- C. Applying hot water, as hot as the victim can tolerate.
- D. Applying ice packs.

Question 26

As part of an analysis of a mixture of vitamins D₂ and D₃ by HPLC, the following chromatogram was recorded.

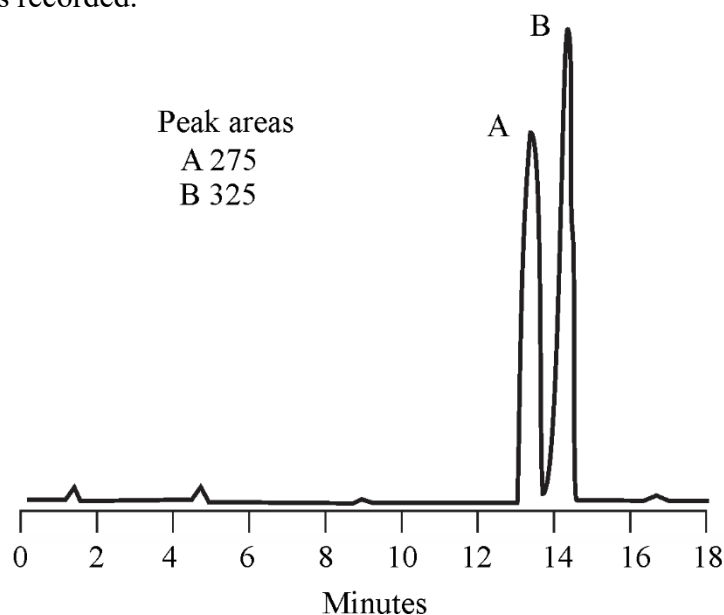


Figure 8

Tests showed that vitamin D₃ had the higher retention time.

Two sets of standards of known concentration of each of the vitamin D forms present were prepared and run through the same chromatograph. The calibration curves below were established from the data.

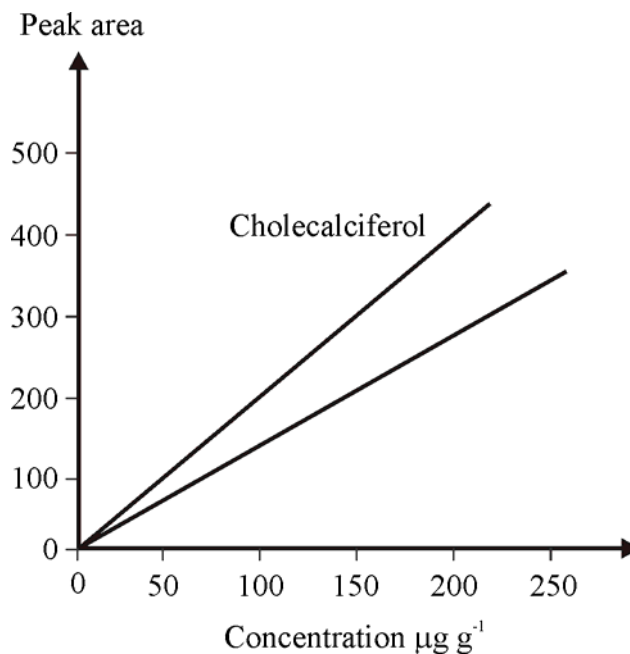


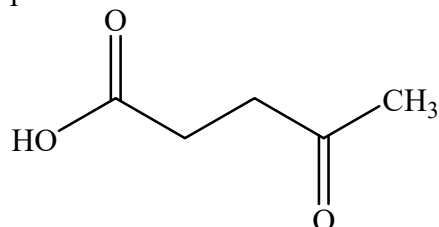
Figure 9

Based on the information in **Figure 9**, the mass of vitamin D₂ in 50 g of the mixture would be closest to

- A. 6 mg
- B. 7 mg
- C. 9 mg
- D. 10 mg

Question 27

Combustion is not an immediate process after fuel injection in a diesel engine leading to ignition delay. Cetane number is used to represent the combustion quality of diesel fuel during compression ignition. Increased cetane number reduces ignition delay. Fuel additives based on levulinic acid can be used to replace current unsustainable cetane improvers. Levulinic acid is a sustainable 'platform chemical' because it can be produced from wood chips, straw and plant waste, and used to make a variety of other valuable products. The structure of levulinic acid is represented below.



Levulinic acid can be produced by heating fructose in dilute sulfuric acid. The overall reaction may be summarised as

Fructose → Levulinic acid + Compound X + H₂O

The atom economy for the production of levulinic acid based on this chemical equation is closest to

- A. 48 per cent.
- B. 64 per cent.
- C. 74 per cent.
- D. 83 per cent.

Question 28

Lactic acid, C₃H₆O₃, is formed from the incomplete oxidation of glucose during anaerobic activity. Whilst lactic acid has the same proportion of C, H and O as many carbohydrates, it is technically not a carbohydrate. Its heat of combustion to 2 significant figures is 15 kJ g⁻¹.

A bomb calorimeter was used to investigate the energy content of lactic acid.

The following procedure was followed:

1. The calorimeter was calibrated by allowing a sample of ethanol to react completely with oxygen in the calorimeter. The energy released caused the temperature of the water surrounding the reaction bomb to change from 23.1°C to 35.4°C.
2. A 5.865 sample of pure lactic acid was later reacted completely with oxygen in the same calorimeter. The energy released caused the temperature of the water to change from 28.7°C to 39.2°C.

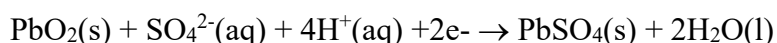
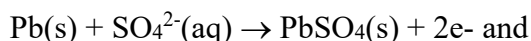
Assuming the calorimeter was 100 per cent efficient, which of the following would be closest to the mass of ethanol consumed during calibration?

- A. 2.5 g
- B. 3.5 g
- C. 4.8 g
- D. 5.6 g

Question 29

As well as providing energy for ignition, engine starting and lighting, the modern automobile battery also provides energy for power steering and windows, entertainment and GPS units, anti-lock brakes, cruise control, airbag sensors, air conditioning and demisters. It must recharge when the automobile is being driven.

The common 12 V lead acid car battery makes up around 40 per cent of worldwide annual battery sales. These batteries each contain 6 lead-acid cells, in which, during discharge, the following half-reactions occur.



When a car battery is recharging,

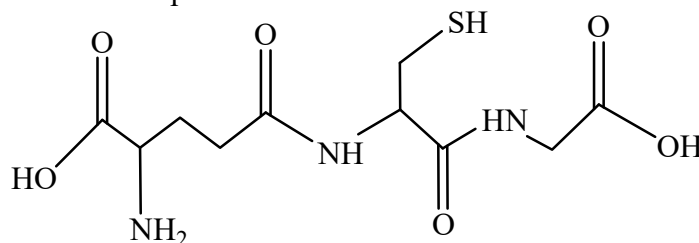
- A. Pb is produced at the negative electrode of each cell.
- B. the pH in each cell increases.
- C. PbSO_4 is produced at the positive electrode in each cell.
- D. the changes in the oxidation numbers of lead are from 0 to +2 and +4 to +2.

Question 30

Glutathione, common in animals and bacteria, is a natural scavenger of free radicals. As such it is part of the body's natural defence system. Viruses, bacteria, heavy metal toxicity, radiation, certain medications, and even the normal process of aging can all cause free-radical damage to healthy cells and deplete glutathione. Glutathione depletion has been linked with lower immune function and infection resistance.

Glutathione levels in humans tend to peak around the age of twenty, however foods such as avocados, broccoli, tomatoes, garlic and many others are natural sources.

The structure of glutathione is represented below.



Which of the following statements about glutathione is **least** accurate?

- A. Glutathione is an antioxidant.
- B. Glutathione is a tripeptide.
- C. Glutathione molecules contain four different functional groups.
- D. Glutathione molecules are formed from only two 2-amino acids.

End of Section A

VCE Chemistry 2017 Year 12 Trial Exam Unit 3/4

SECTION B – Short Answer Questions

(90 marks)

*Section B consists of 9 short answer questions.
You should answer all of these questions in the spaces provided.
The allotted **marks** are shown at the end of each part of each question.*

Question 1 (11 marks)

Methanol is a reactant in the production of biodiesel by transesterification. It can also be used to improve combustion quality of petrodiesel and reduce ignition delay. Methanol is also an effective fuel in its own right.

a. Write a balanced thermochemical equation for the combustion of methanol. **1 mark**

b. A laboratory experiment was set up to determine the heat of combustion of methanol. Methanol was burned in a ‘spirit burner’ and heat released was used to heat 200 mL of water. The apparatus was set up as shown in **Figure 10**.

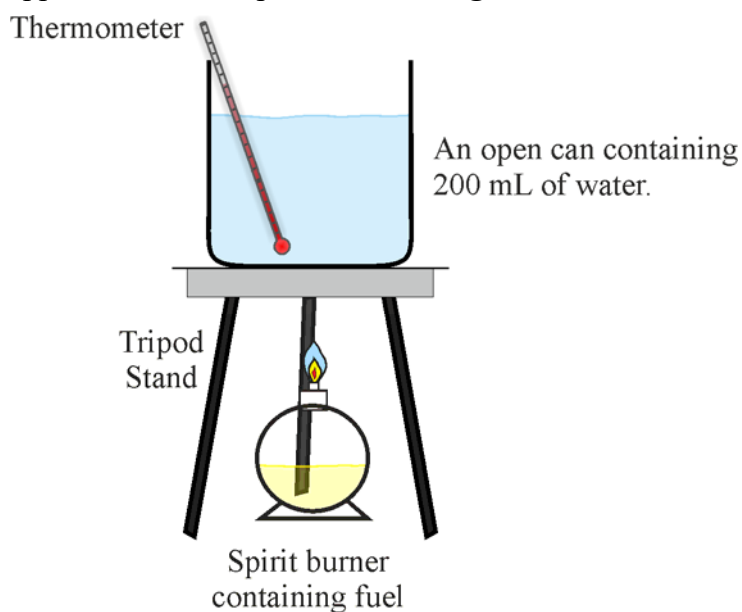


Figure 10

The following data were recorded:

Mass of spirit burner before heating: 125.62 g

Mass of spirit burner after heating: 121.56 g

Temperature of water before heating: 23.5°C

Temperature of water after heating: 54.7°C

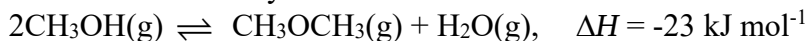
- i. Calculate the percentage of the energy released during the burning of the methanol that was transferred to the water in the can. **3 marks**
- ii. Describe and explain one modification that could improve the overall efficiency of the energy transfer to the water in the can. **1 mark**
- c. Methanol can also be used as the ‘fuel’ in a fuel cell using hydrochloric acid as an electrolyte. The overall equation for the fuel cell is the same as the combustion equation.
- i. Write balanced half-equations for the reactions occurring at **2 marks**
- (-) electrode.
- (+) electrode.
- ii. State an advantage of the use of porous electrodes in fuel cells, and identify one other factor that influences the choice of electrode. **1 mark**

- d.** BioDME (dimethyl ether) - CH_3OCH_3 - can be produced by first converting biomass to syngas, a mixture of CO and H_2 , followed by a two-step process.

The syngas is converted to methanol



and methanol is dehydrated to DME



- i.** Explain why the use of a catalyst is particularly beneficial in both steps.

2 marks

- ii.** BioDME, a second-generation biofuel, has been shown to have better ignitability in compression ignition engines and is considered to be a feasible alternative to petrodiesel and some other biodiesels. A significant problem encountered when engines are fuelled with DME is that the injection equipment breaks down prematurely due to extensive wear. This behaviour can be explained by the low viscosity of DME.
Explain why bioDME has much lower viscosity than a biofuel such as methyl stearate ($\text{C}_{17}\text{H}_{35}\text{COOCH}_3$).

1 mark

Question 2 (8 marks)

In an experimental study of the reaction between marble chips (calcium carbonate) and hydrochloric acid, the following data in **Table 1** were recorded.

Reaction time min : sec	Mass loss during reaction (grams)		
	Investigation 1	Investigation 2	Investigation 3
0	0.000	0.000	0.000
0 : 30	0.457	0.797	0.157
1 : 00	0.702	0.925	0.292
1 : 30	0.822	0.951	0.369
2 : 00	0.880	0.963	0.410
2 : 30	0.913	0.970	0.433
3 : 00	0.932	0.975	0.446
4 : 00	0.953	0.984	0.467
5 : 00	0.965	0.991	0.482
6 : 00	0.975	0.998	0.493
7 : 00	0.983	1.003	0.502
8 : 00	0.990	1.009	0.511
9 : 00	0.996	1.014	0.519
10 : 00	1.001	1.018	0.525

Table 1

In all three investigations

- 20.0 g of marble chips and 25 mL of hydrochloric acid were used and no catalyst was added.
- the reactants were at the same temperature.
- hydrochloric acid was the limiting reactant.

- a. Write a balanced equation for the reaction between calcium carbonate and hydrochloric acid.

1 mark

- b. The recorded data are represented on the graphs in **Figure 11**.

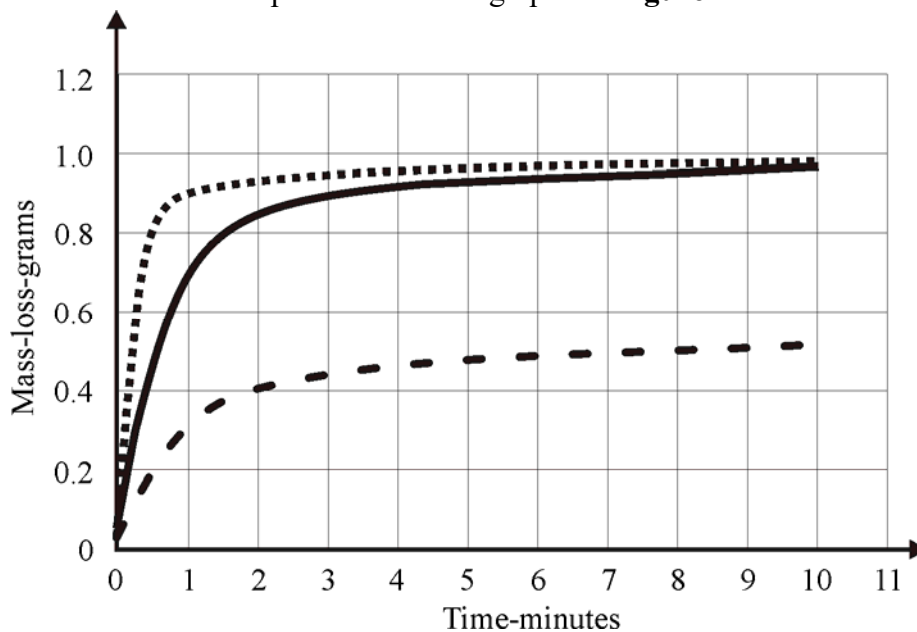


Figure 11

- i. Overall, what do the data for all three investigations indicate about the relationship between reaction rate and time? **1 mark**
- ii. Explain this relationship in terms of collision theory. **1 mark**
- c. In investigations 2 and 3, one factor impacting the initial rate of reaction – a different one for each investigation – was changed compared to Investigation 1.
- i. Identify the factor that was changed for Investigation 2 and explain how this was deduced from the information and data supplied. **2 marks**

- ii. Identify the factor that was changed for Investigation 3 and explain why the data for this investigation are significantly different to the data for the other two investigations.

1 mark

- d. For the two pairs of investigations, '1 and 2' and '1 and 3', identify the Controlled, Independent and Dependent variables and list them in **Table 2**.

2 marks

Investigations	Independent variables	Dependent variables	Controlled variables
1 and 2			
1 and 3			

Table 2

Question 3 (7 marks)

Figure 12 below represents an ‘idealised’ outcome at one electrode of the extended electrolysis, using graphite electrodes, of an aqueous solution containing $\text{Cu}(\text{NO}_3)_2$, AgNO_3 and KNO_3 which is 0.100 M for all three compounds.

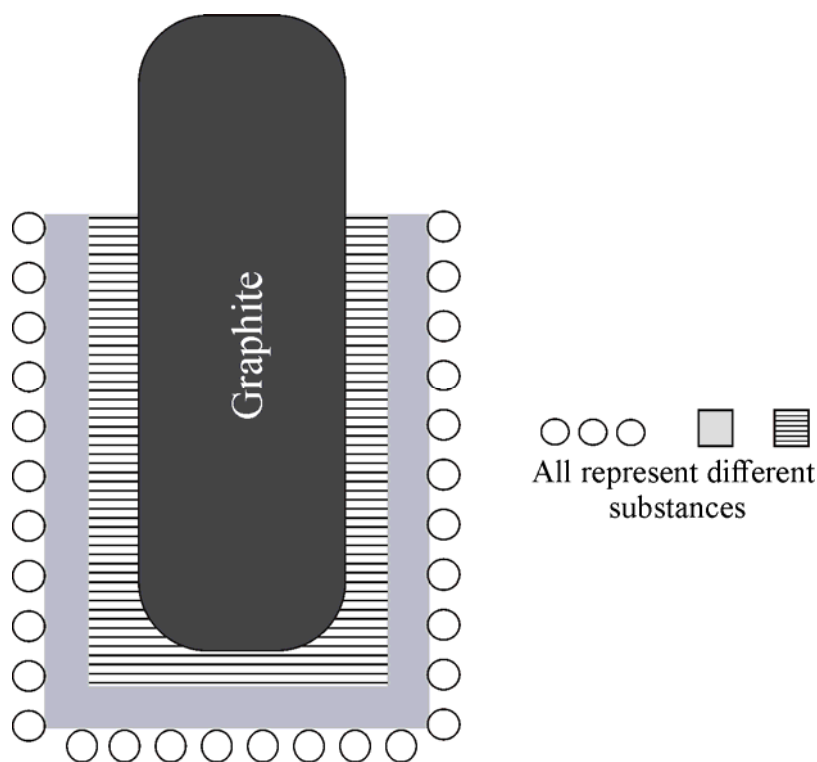


Figure 12

- a. Is this graphite electrode the anode or the cathode? Explain how you identified the function of this electrode.

1 mark

- b. i. Identify the substance produced first at this electrode and explain why it is the first to be deposited.

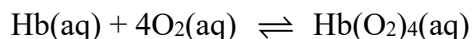
1 mark

- ii.** Identify the second substance produced at this electrode and explain when it is deposited and why it is the second substance deposited. **1 mark**
- iii.** Write a balanced half-equation for the production of the third substance formed at this electrode. **1 mark**
- c.** Explain why the diagram given is very much an ‘ideal’ representation of the reactions occurring at this electrode during the electrolysis. **1 mark**
- d.** Write a balanced half-equation(s) for the reaction(s) occurring at the other electrode during the electrolysis. **1 mark**
- e.** What effect does the electrolysis have on the total cation concentration in the solution? Explain. **1 mark**

Question 4 (7 marks)

Haemoglobin is a protein that is used to carry oxygen through the blood stream from the lungs to the tissues. Haemoglobin has a lower affinity for oxygen the lower the concentration of oxygen gets. **Haemoglobin** consists of four subunits, each with a cofactor called a heme group that has an iron atom center. The iron is the main component that actually binds to oxygen, thus each haemoglobin molecule is able to carry four molecules of O₂.

The haemoglobin-O₂ equilibrium in the blood may be represented by the simple equilibrium



Carbon monoxide, even in very low concentrations, is highly toxic because it blocks the transport of O₂ through the body.

- a. What is the most common source of carbon monoxide exposure? Write a supporting balanced equation.

2 marks

- b. In terms of competing equilibria, explain how carbon monoxide interacts with the haemoglobin-oxygen equilibrium given above.

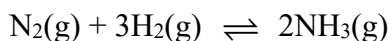
2 marks

- c. Use equilibrium principles to explain why 100 per cent oxygen therapy is used to treat carbon-monoxide poisoning. **1 mark**
- d. Explain why haemoglobin is described as a quaternary protein. **1 mark**
- e. Carbon dioxide plays a more productive role than CO in the body via the equilibrium sequence
$$\text{CO}_2(\text{g}) \rightleftharpoons \text{CO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{CO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$$

which is important in maintaining blood pH within healthy limits.
Explain how the system adjusting to blood pH that is too low will impact on the amount of $\text{CO}_2(\text{g})$ exhaled. **1 mark**

Question 5 (8 marks)

Ammonia, NH_3 , is manufactured from nitrogen and hydrogen by the Haber process according to the following equilibrium



The data in **Table 3** give approximate values for the percentage yield of ammonia at various temperatures and pressures.

Temperature ($^{\circ}\text{C}$)	Pressure (kPa)	% of NH_3 at equilibrium
400	2.00×10^5	36.3
400	3.00×10^5	49.2
400	4.00×10^5	56.5
300	2.00×10^5	62.8
500	2.00×10^5	17.6

Table 3

Use the data in **Table 3** to help you answer the following questions:

- a. Explain why the observed effect of pressure upon the yield of ammonia is consistent with Le Chatelier's principle. **2 marks**
- b. Write the equilibrium constant expression, K_c , for the formation of ammonia. **1 mark**
- c. What is the thermochemical nature of the ammonia producing reaction? Explain. **1 mark**
- d. Explain how the introduction of a catalyst would impact on the equilibrium yield of NH_3 . **1 mark**

The rate-time graphs shown in **Figure 13** are related to the impact of an instantaneous volume decrease, at time 't' on the Haber process equilibrium.

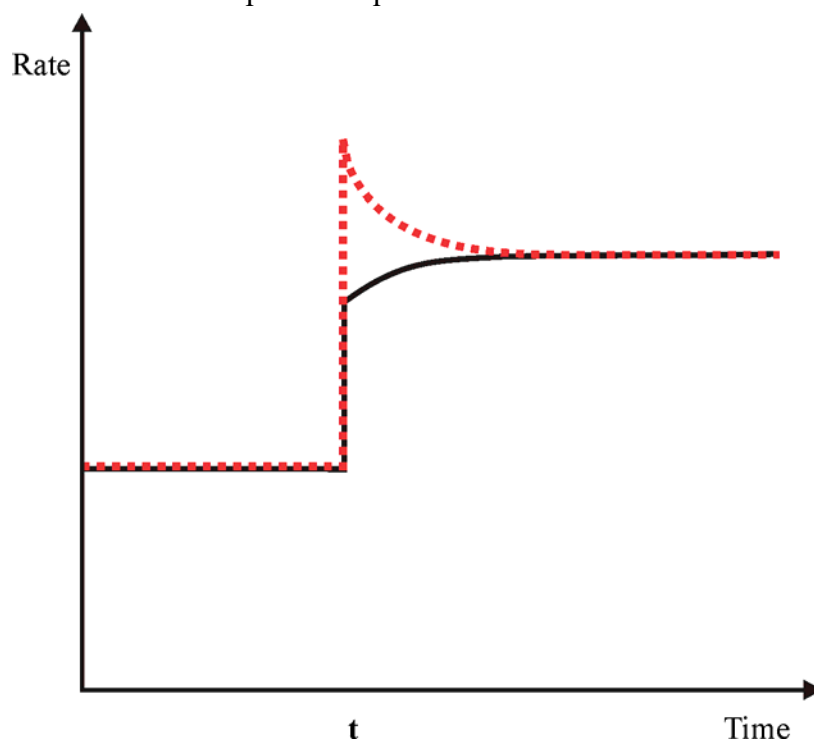


Figure 13

- e. Explain the shapes of these graphs in **Figure 13** and indicate which of the two graphs represent the forward and reverse reactions respectively.

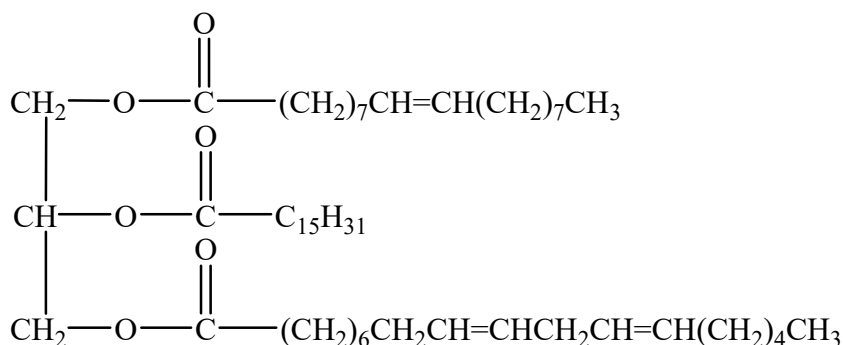
3 marks

Question 6 (17 marks)

Olive oil is a pale yellow or greenish liquid extracted from the fruit of the olive tree *Olea Europaea*. The nutrition information label on a 750 mL bottle of ‘Cobram Estate’ Australian Extra Virgin Olive oil includes the following data applying to a 15 mL serving

Energy	517 kJ
Fat total	13.7 g
Saturated	2.1 g
Monounsaturated	10.2 g
Polyunsaturated	1.4 g
Total polyphenols	8 mg

Consider the fat represented by the structure below.



a. i. Explain how such molecules are digested.

2 marks

ii. Name **two** of the initial products of the digestion of the molecule shown and indicate how these products relate to the information shown on the nutrition information label.

2 marks

iii. Explain why the term omega-6 applies to one of the digestion products.

1 mark

- iv. Name, and give the semistructural formula of a similar compound to which the term omega-3 applies.

1 mark

- b. Write a balanced equation describing the complete combustion of the fat represented in Question 6ai.

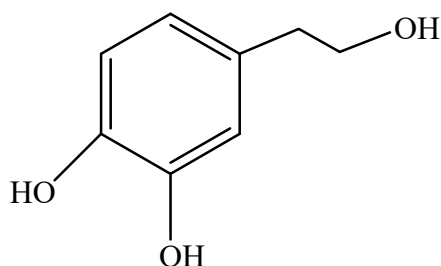
2 marks

- c. High quality extra virgin olive oils have a slightly bitter spicy taste associated with antioxidant polyphenols.

- i. Why are antioxidants added to olive oils?

2 marks

Hydroxytyrosol, a polyphenol present in olive oil as shown below, does not have optical isomers.



- ii. Vitamin C, also an antioxidant, is an enantiomer of ascorbic acid. Use the structures of the two compounds to explain this difference.

2 marks

- d. If 7.5 mL of ‘*Cobram Estate*’ Australian Extra Virgin Olive oil is used to heat 500 mL of water, and the transfer of thermal energy to the water is 40 % efficient, what will be the temperature change in the water? **3 marks**
- e. Calculate the density, in g mL^{-1} of ‘*Cobram Estate*’ Australian Extra Virgin Olive oil utilising relevant information supplied in the **VCE Data Book** in your calculation. **2 marks**

Question 7 (10 marks)

Two organic reaction pathways are shown in **Figure 14**.

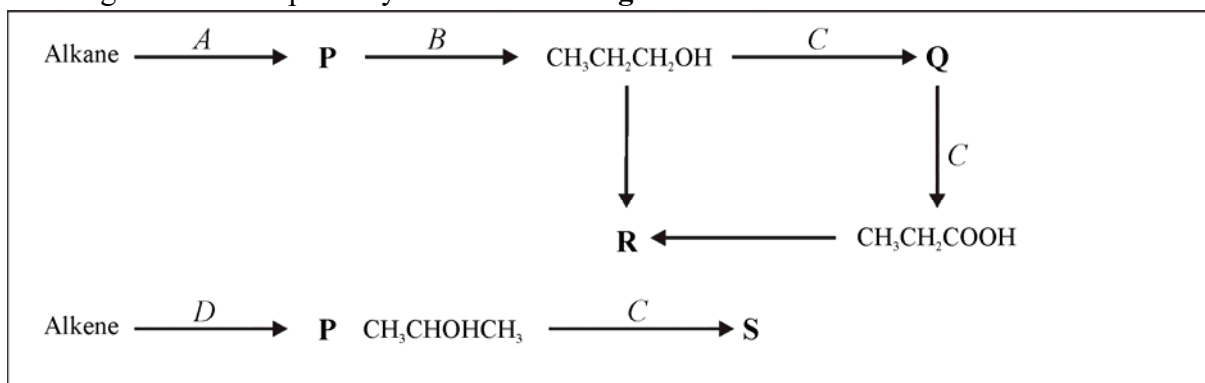


Figure 14

- a. Write the semi structural formulae of compounds represented by **Q**, **R** and **S**. **3 marks**

Q

R

S

- b. Give the chemical formulae of the reagents represented by **B**, **C** and **D**. **3 marks**

B

C

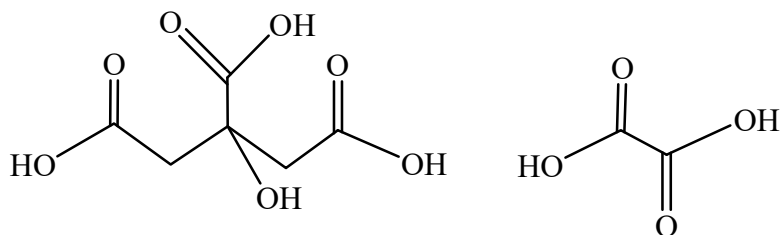
D

- c. Write balanced half-equations describing the production of **S**. **2 marks**

- d. In an investigation of the reaction to produce compound R using equal chemical amounts of each reactant, equilibrium was achieved when 75 per cent of the reactants were consumed. Determine the associated equilibrium constant. **2 marks**

Question 8 (11 marks)

The structures below represent citric acid and oxalic acid. Citric acid is triprotic and oxalic acid is diprotic.



Asked to design an analysis technique for the citric acid content of designated fruit juice, a group of chemistry students present the following summary of a procedure:

1. Make up 500 mL of a 1.00 M solution of NaOH.
2. Weigh out three 2.50 g samples of oxalic acid and add each one to 50 mL of water in a 250 mL flask.
3. Titrate each of the three oxalic acid solutions with the NaOH(aq) solution to the phenolphthalein endpoint.
4. Add a 50.0 mL sample of the fruit juice to each of three 250 mL flasks.
5. Titrate each of the three fruit samples to the phenolphthalein end point with the NaOH solution prepared in 1.
6. Calculate the citric acid content of the fruit juice in g L⁻¹.

The procedure as described was followed and **Table 4** displays the data recorded.

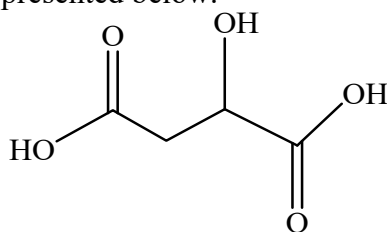
$m(\text{C}_2\text{H}_2\text{O}_4)$	$V(\text{NaOH})$ for oxalic acid samples	$V(\text{NaOH})$ required for juice samples
1.25 g	27.6 mL	33.6 mL
1.23 g	27.1 mL	33.4 mL
1.26 g	27.4 mL	33.9 mL

Table 4

- a. Write balanced equations using molecular formulae for the reactions between:
- i. Oxalic acid and the sodium hydroxide solution. **1 mark**
 - ii. Citric acid and the sodium hydroxide solution. **1 mark**
- b. Are the recorded data appropriately presented? Explain. **1 mark**

- c. Given that oxalic acid is not present in the fruit juice, why would it have been used in the analytical procedure? **1 mark**
- d. Calculate the accurate molar concentration of the NaOH(aq) used in the titration. **3 marks**
- e. Calculate the concentration of citric acid content of the fruit juice, in g L⁻¹. **3 marks**

Further analysis of the fruit juice used shows it to contain significant amounts of malic acid. The structure of malic acid is represented below.

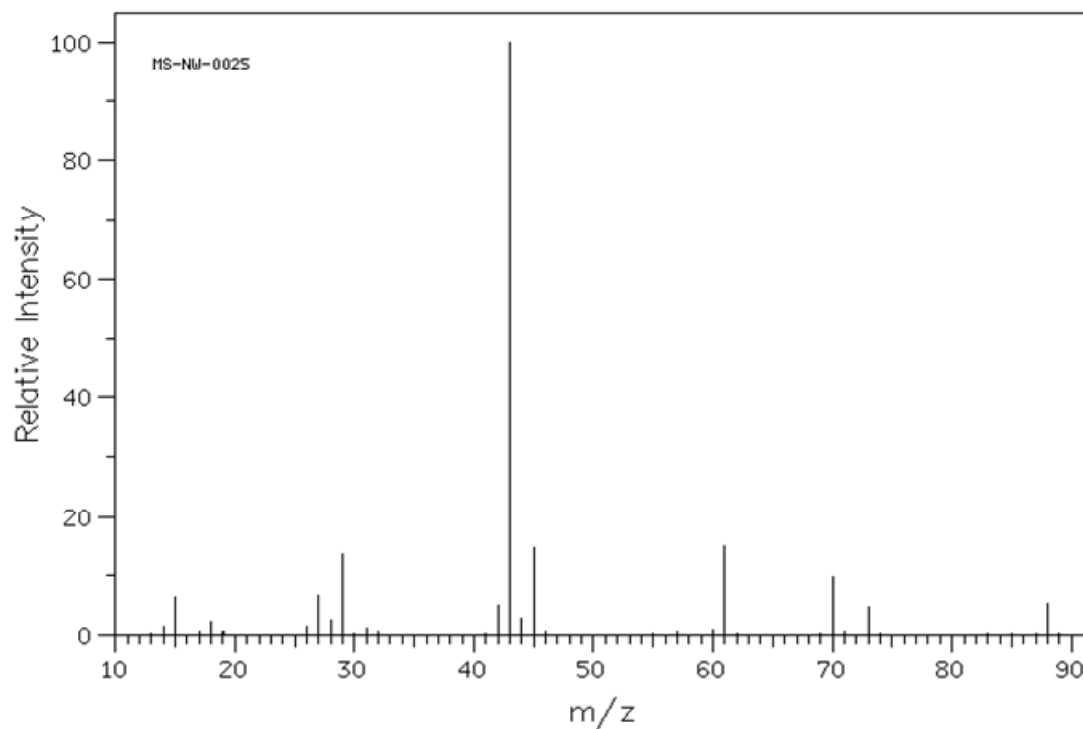


- f. Explain how the presence of significant amounts of malic acid in the fruit juice would affect the calculated concentration of citric acid? **1 mark**

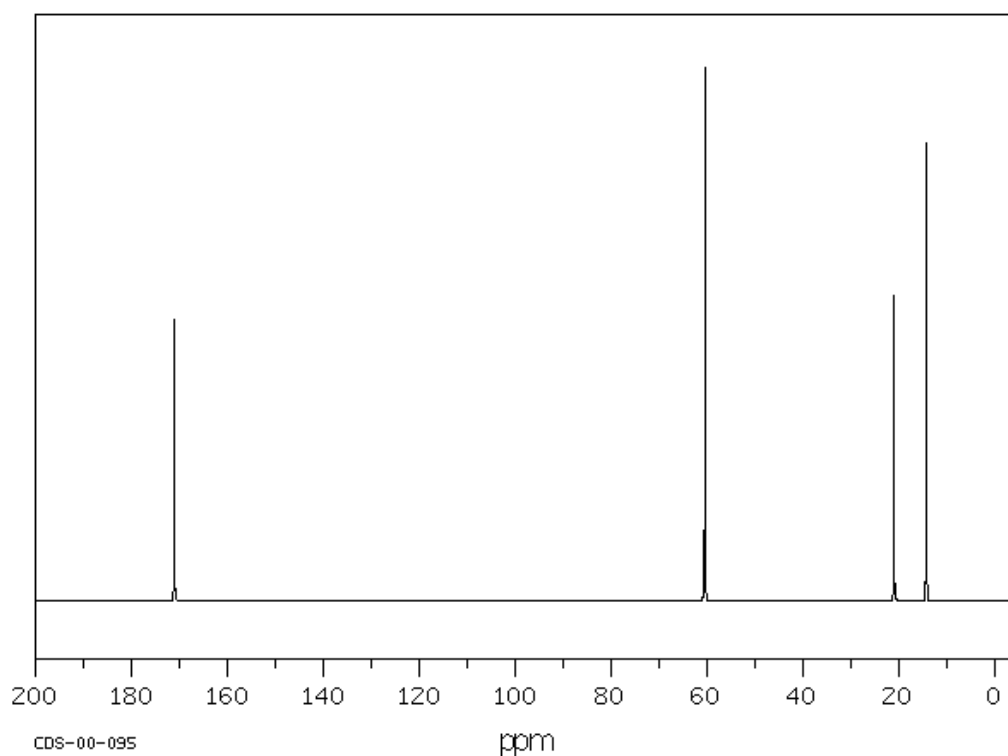
Question 9 (11 marks)

The three spectra shown below were an integral part of an analysis exercise to verify the structure of an organic compound. *SDBSWeb*: <http://sdb.sdb.aist.go.jp> (National Institute of Advanced Industrial Science and Technology, May 2, 2017).

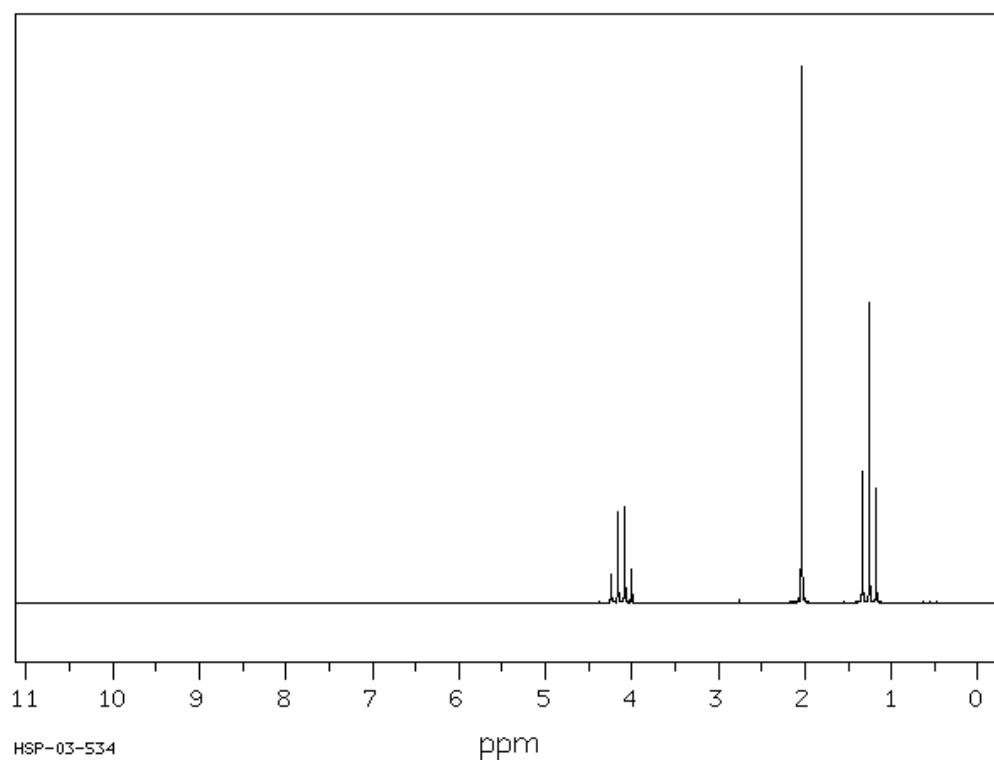
Mass Spectrum



^{13}C Spectrum



^1H NMR Spectrum



- a. Give the two most significant pieces of data that may be deduced about the compound from the mass spectrum. **2 marks**
- b. What does the ^{13}C spectrum indicate about the compound? **1 mark**
- c. Identify all the useful information about the structure of the compound that may be deduced from the ^1H NMR spectrum. **3 marks**

- d.** Molecules of the compound contain three different elements. Using all the available information, determine a semi-structural formula for the compound. **2 marks**
- e.** Give the wave-number bands of two significant peaks that should appear on the IR spectrum of this compound. **1 mark**
- f.** The compound has at least one structural isomer containing a different functional group. Identify one of these isomers and describe how the ^1H NMR spectrum of the isomer would differ from the ^1H NMR spectrum of the compound. **2 marks**

End of Section B

End of Trial Exam

Question 10 (13 marks) – BONUS QUESTION

The artificial sweetener Aspartame has two enantiomers, one of which, L-aspartame, tastes sweet whilst the other, D-aspartame, is tasteless.

- a. How many chiral carbons are present on an aspartame molecule? **1 mark**
- b. Describe the structural change that occurs when the pH of an aqueous solution of aspartame changes from 10 to 4. **2 marks**
- c. Comment on the relative interactions of the two aspartame enantiomers with our taste buds. **1 mark**
- d. Both aspartame and sucrose (common sugar) undergo hydrolysis reactions in the body.
- i. Describe the functional group changes that occur during these hydrolyses. **2 marks**
- ii. Name the products of the hydrolysis of aspartame. **2 marks**
- iii. Name the products of hydrolysis of sucrose. **2 marks**
- iv. One of the products of the hydrolysis of sucrose is also a product of the hydrolysis of starch. Explain the link between the glycaemic index (GI) of foods and the structure of starch. **3 marks**

End of Bonus Question

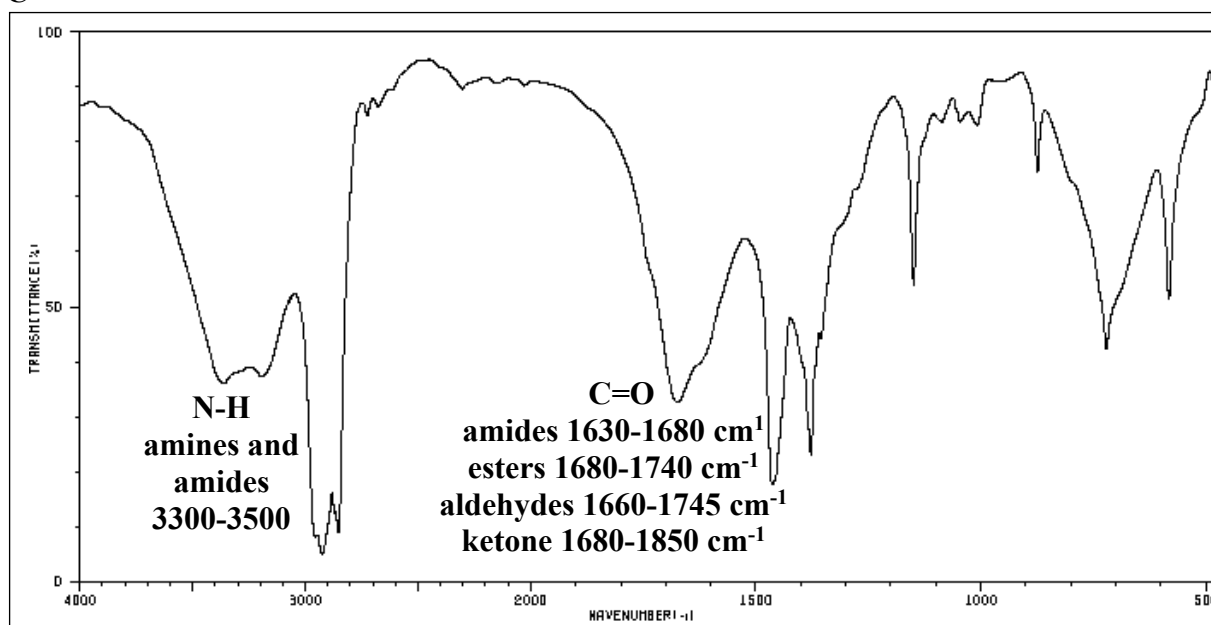
Suggested Answers

VCE Chemistry 2017 Year 12 Trial Exam Unit 3/4

SECTION A – Multiple Choice Answers

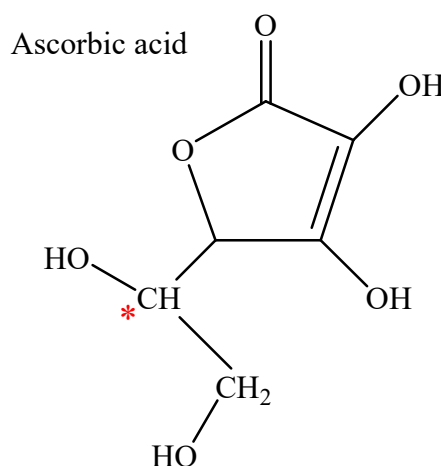
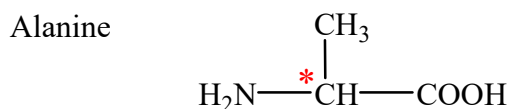
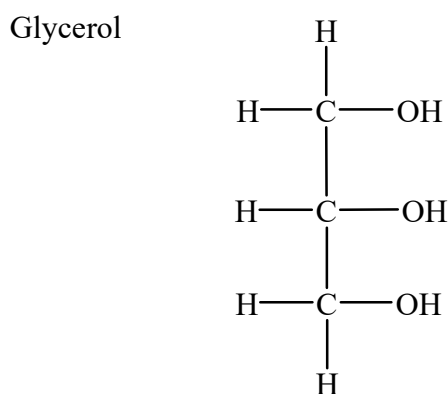
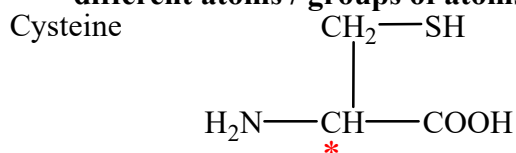
- Q1. B** Need to use the data to calculate the reaction quotient (concentration fraction), Q , (CF).
$$Q = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]}$$
$$= \frac{(4.2 \times 10^{-3})^2}{\{0.50 \times 0.25\}}$$
$$= 1.41 \times 10^{-4}$$
 $Q < K (1.7 \times 10^{-3})$, so system is not at equilibrium and moves to increase Q to get there. The **forward reaction is favoured and proceeds faster than the reverse reaction** as the position of equilibrium shifts to the right.

- Q2. C**



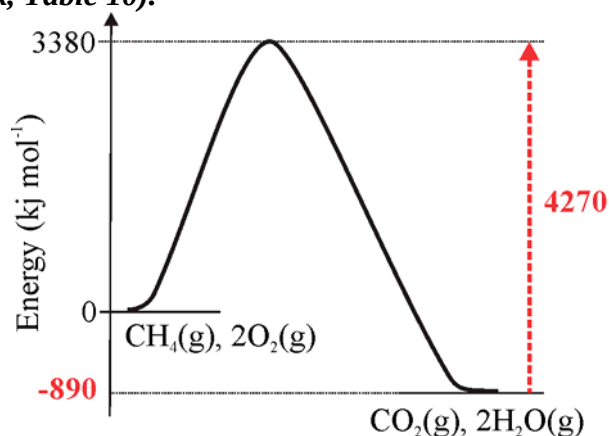
The two significant peaks on the spectrum are at about 1680 cm^{-1} and 3300 cm^{-1} . The carbonyl group at 1680 cm^{-1} , could be part of an amide, an ester or an aldehyde (ketone is less likely according to its absorption band). At 3300 cm^{-1} the lack of a broad band overlapping C-H ($2850\text{-}3900 \text{ cm}^{-1}$) rules out O-H acid ($2500\text{-}3300 \text{ cm}^{-1}$).

- Q3. D** Some 'garbage' in landfill that provides a source of methane is from food waste and garden waste. On this basis, the methane can be classified as biogas and renewable. The methane in coal seam gas is not renewable because of its relationship with fossil-fuels. So, depending on the source, methane may be classified as **both renewable and non-renewable**.
- Q4. B** Since only spirit burners containing methanol, not the required ethanol, were supplied, a **systematic error** has occurred. This was not a random selection of the incorrect fuel by the student.
Because methanol (22.7 kJ g^{-1}) has a lower heat of combustion than ethanol (29.6 kJ g^{-1}), **more ethanol will need to react** to provide the energy needed to increase the temperature of the water by 20°C .
- Q5. C** Chiral molecules have enantiomers, optical isomers which are non-superimposable images. To be chiral a molecule must have a chiral centre, indicated with an asterisk * on the structures below, which has a C atom attached to four different atoms or groups of atoms.
Glycerol is not chiral because none of the C atoms is attached to four different atoms / groups of atoms.

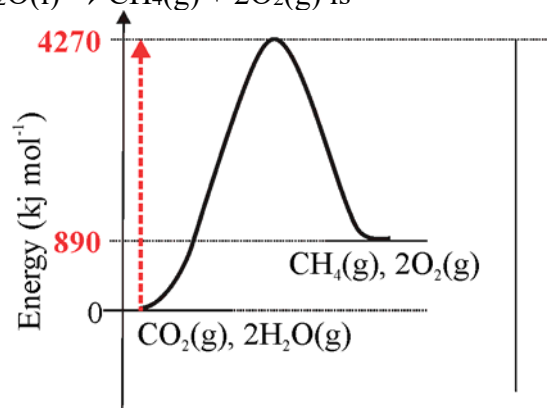


- Q6. C** Since $d = m / V$
 $m(\text{C}_{16}\text{H}_{34}) = d \times V$
 $= 0.775 \text{ g mL}^{-1} \times 20.0 \times 10^3 \text{ mL}$
 $= 1.55 \times 10^4 \text{ g}$
 $n(\text{C}_{16}\text{H}_{34}) \text{ reacting} = 1.55 \times 10^4 / 226.0$
 $= 68.6 \text{ mol}$
 $n(\text{CO}_2) \text{ produced} = 16 \times n(\text{C}_{16}\text{H}_{34})$
 $= 16 \times 68.6$
 $= 1.10 \times 10^3 \text{ mol}$
 $V(\text{CO}_2) = 1.10 \times 10^3 \text{ mol} \times 24.8 \text{ L mol}^{-1}$
 $= 2.72 \times 10^4 \text{ L}$
 $= \mathbf{27.2 \text{ ML}}$

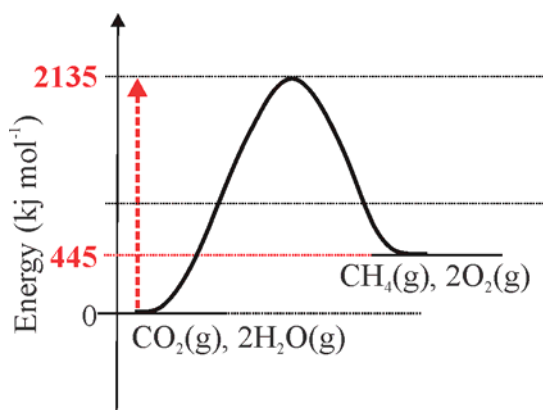
- Q7. B** $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}); \Delta H = -889 \text{ kJ mol}^{-1}$.
(Data Book, Table 10).



The energy profile for the reverse reaction
 $\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{CH}_4(\text{g}) + 2\text{O}_2(\text{g})$ is



The energy profile for the reverse reaction
 $\frac{1}{2}\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \frac{1}{2}\text{CH}_4(\text{g}) + \text{O}_2(\text{g})$ is

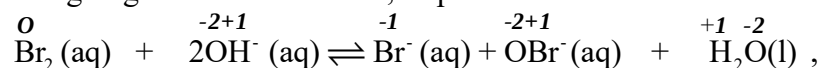


This shows the activation energy to be 2135 kJ mol^{-1} .

Q8. B The $c(\text{CH}_3\text{COOH})$ values, as calculated from the five investigations are **quite consistent** and so reflect **low random error** effect.
 However, all the values are **below the true value**, suggesting a **significant systematic error**, such as the use of an incorrectly calibrated pipette, incorrectly calibrated burette or even incorrect indicator
 In combination, the results show **low random error** and **high systematic error**.

Q9. A $\text{Br}_2(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightleftharpoons \text{Br}^-(\text{aq}) + \text{OBr}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}), \quad \Delta H = 15 \text{ kJ mol}^{-1}$

Assigning oxidation numbers, as per standard rules.



Since the forward reaction is endothermic, when temperature of the equilibrium solution is decreased, the **reverse exothermic reaction is favoured**. Therefore

- the **number of atoms with oxidation number +1 decreases**; there are three atoms on the right (Br in BrO^- and 2H in H_2O) but only two - 2H atoms - on the left (in the 2OH^-).
- the number of atoms with oxidation number -2 does not change; there are two atoms on the right and two atoms on the left (in the 2OH^-).
- the number of atoms with oxidation number -1 decreases from one (Br^-) to zero.
- the number of atoms with oxidation number zero increases from zero to one (Br_2).

Q10. A From the electrochemical series $E^\circ (\text{Fe}^{2+}(\text{aq})/\text{Fe}(\text{s})) = -0.44 \text{ V}$.

The cell voltage of 1.21 V is the difference between the E° values of the two half cells, so half-cell one must contain a redox pair with E° either 1.21 V higher or 1.21 V lower than $E^\circ (\text{Fe}^{2+}(\text{aq})/\text{Fe}(\text{s}))$.

$$E^\circ(\text{half-cell 1}) = -0.44 + 1.21 = +0.77 \text{ V}$$

or

$$E^\circ(\text{half-cell 1}) = -0.44 - 1.21 = -1.65 \text{ V}$$

According to the electrochemical series

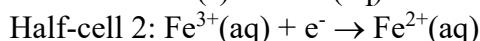
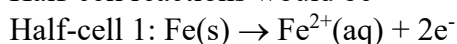
$$E^\circ (\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})) = +0.77 \text{ V}$$

$$E^\circ (\text{Al}^{3+}(\text{aq})/\text{Al}(\text{s})) = -1.66 \text{ V}$$

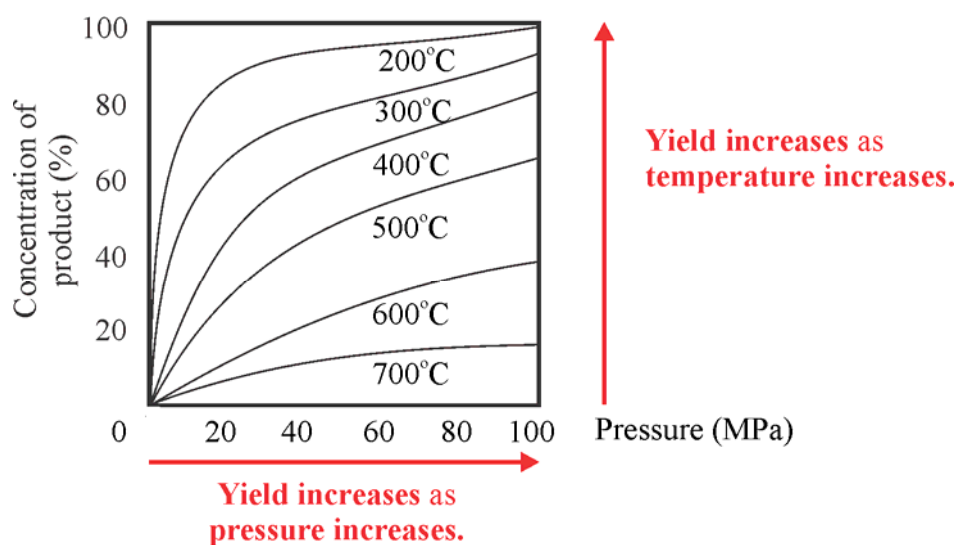
It is a close call, but $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$ is the more accurate option.

In the $\text{Fe}^{3+}(\text{aq})/\text{Fe}^{2+}(\text{aq})$, the electrode must be non-reactive, so it cannot be Fe since it could react with $\text{Fe}^{2+}(\text{aq})$. So, either a **platinum (Pt) or graphite (C)** electrode would be used.

Half-cell reactions would be



Q11. A



Since the yield increases as the temperature decreases, the **forward reaction** is favoured by low temperature, i.e. is **exothermic**.

Since the yield is increasing as the pressure increases, and the equilibrium system responds to partially oppose the pressure increase by moving to **reduce the number of particles** in the system, the **product must on the side of the equilibrium with fewer particles**.

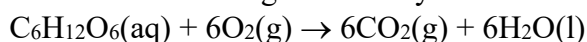
This behaviour is consistent with the equilibrium involved in ammonia production, i.e.



Q12. D

The reactions represented by **1.** are all **hydrolysis** (hydrolytic) reactions which occur during the digestion of the major food groups. Proteins are broken down into amino acids, fats into fatty acids and glycerol, and carbohydrates into monosaccharides.

The reaction represented by **2.** is **respiration** where energy required for the effective functioning of the body is released via the reaction



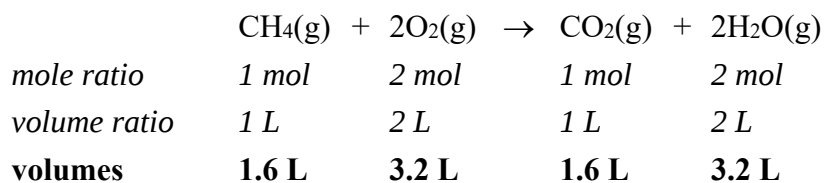
The reactions represented by **3.** are all **condensation** reactions that occur as proteins, fats and glycogen are formed in cells of the body.

- Q13. A** To answer this question it is necessary to first deduce that **X** represents amino acids, **Z** represents proteins, **Q** represents glycerol and **Y** represents glycogen.
- Q** – formula $\text{CH}_2\text{OHCHOHCH}_2\text{OH}$ or $\text{C}_3\text{H}_8\text{O}_3$
 1 mol (92.0 g) $\text{C}_3\text{H}_8\text{O}_3$ contains $3 \times 16.0 = 48.0$ g of O atoms
 $\% \text{ O} = (48.0 / 92.0) \times 100$
 $= 52.2 \%$
- X** – general amino acid formula is $\text{NH}_2\text{CH}(\text{Z})\text{COOH}$
 Consider glycine $\text{NH}_2\text{CH}_2\text{COOH}$, the amino acid with the lowest molar mass
 1 mol (75.0 g) $\text{NH}_2\text{CH}_2\text{COOH}$ contains $2 \times 16.0 = 32.0$ g of O atoms
 $\% \text{ O} = (32.0 / 75.0) \times 100$
 $= 42.7 \%$
Aspartic acid $\text{NH}_2\text{CH}(\text{CH}_2\text{COOH})\text{COOH}$, the amino acid with the largest mass of oxygen, has 64.0 g of O atoms in 1 mole (133 g)
 $\% \text{ O} = (64.0 / 133) \times 100$
 $= 48.1 \%$
- Z** – since proteins are formed from amino acids, and oxygen is released as water in the condensation process, the percentage, by mass, of oxygen in protein is going to be less than 48.1 %.
- Y** – glycogen is formed from the condensation polymerisation of glucose and can be represented by $n\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow -(\text{C}_6\text{H}_{10}\text{O}_5)_n- + n-1 \text{H}_2\text{O}$, where n is a very large number.
 So, the percentage, by mass, of O in glycogen is effectively the same as the % in $\text{C}_6\text{H}_{10}\text{O}_5$
 1 mol (162 g) $\text{C}_6\text{H}_{10}\text{O}_5$ contains $5 \times 16.0 = 80.0$ g O atoms
 $\% \text{ O} = (80.0 / 162) \times 100$
 $= 49.4 \%$
- Q14. D** Since NiOOH (nickel oxide hydroxide) is reduced, it must be the oxidant. This suggests that H_2 must be the reductant.
 As the **reductant**, H_2 causes the reduction of NiOOH to $\text{Ni}(\text{OH})_2$ and is itself **oxidised**.
 Since the electrolyte is alkaline, i.e. contains $\text{OH}^-(\text{aq})$, the oxidation half-equation must contain $\text{OH}^-(\text{aq})$ ions and may be obtained from the electrochemical series in the **Data Book**.
 $\text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^-$
- Q15. C** Green diesel will exhibit similar properties to petrodiesel and so, compared to FAME biofuel will
- have higher energy content per gram due to lack of oxygen in the molecules.
 - be less viscous due to weaker intermolecular attraction.
 - **have better cold flow properties** – determined by weaker intermolecular attraction.
 - be less likely to absorb water because it lacks the polar sites present on ester groups in FAME biodiesel.

- Q16. B** When all gases are measured at the same temperature, the ratios by volume of the reactants and products are the same as the ratio by mole amount as indicated in the balanced equation.

$$V(\text{methane}) \text{ reacting} = 0.80 \times 2.0 = 1.6 \text{ L}$$

The balanced equation for the combustion of methane is



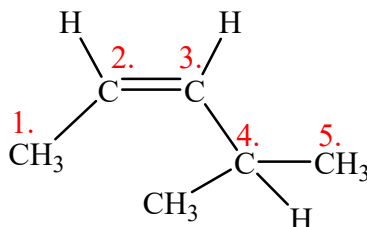
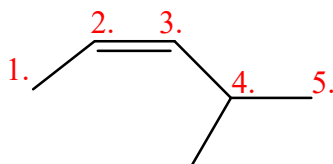
Greenhouse gases

Initially – 1.6 L $\text{CH}_4(\text{g})$

Finally – 1.6 L $\text{CO}_2(\text{g})$ and 3.2 L of $\text{H}_2\text{O}(\text{g})$ = **4.8 L**

Change in volume of greenhouse gases = $4.8 - 1.6$
= **3.2 L**

- Q17. B** The C atoms on the structure are numbered so the alkene $\text{C}=\text{C}$ double bond starts on the lowest possible numbered C atom.



pent-2-ene five C atoms with $\text{C}=\text{C}$ between C2 and C3

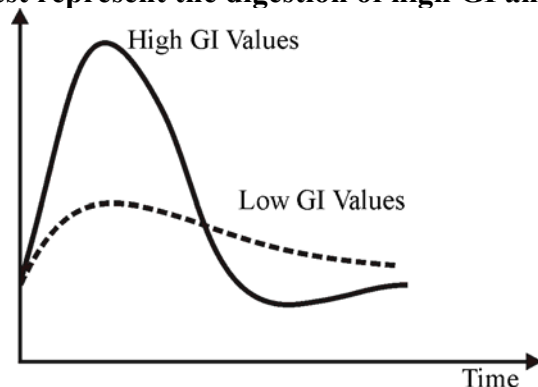
4-methylpent-2-ene methyl group attached to C4

cis-4-methylpent-2-ene the C atoms attached to the $\text{C}=\text{C}$ double bond are on the same side of the $\text{C}=\text{C}$ double bond.

- Q18. D** The species $\text{Cu}^{2+}(\text{aq})$ and $\text{H}_2\text{O}(\text{l})$ appear on the electrochemical series (**Data Book**) according to
- $$\begin{array}{llll} \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- & \rightleftharpoons & 2\text{H}_2\text{O}(\text{l}) & +1.77 \text{ V} \\ \text{Cu}^{2+}(\text{aq}) + 2\text{e}^- & \rightleftharpoons & \text{Cu}(\text{s}) & +0.34 \text{ V} \\ 2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- & \rightleftharpoons & \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq}) & -0.83 \text{ V} \end{array}$$
- The electrolysis involves the strongest oxidant, $\text{Cu}^{2+}(\text{aq})$, and strongest reductant, $\text{H}_2\text{O}(\text{l})$. The half-equations for the reactions at the electrodes are
- Anode (+) $2\text{H}_2\text{O}(\text{l}) \rightarrow \text{O}_2 + 4\text{H}^+(\text{aq}) + 4\text{e}^-$
- Cathode (-) $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$
- Consider the four statements
1. Incorrect, the **ions are present in solution** prior to the passing of the electric current.
 2. Incorrect, Cu is deposited on the cathode, which is the **(-) electrode** in electrolysis.
 3. Incorrect, whilst $\text{H}^+(\text{aq})$ ions are produced at the anode, **no $\text{O}^{2-}(\text{aq})$ ions** are formed.
 4. **Correct, $\text{O}_2(\text{g})$ is produced in the oxidation of $\text{H}_2\text{O}(\text{l})$ at the anode.**
- Q19. D** The rate of a chemical reaction is determined by the **proportion of reactant molecule collisions that have energy greater than the activation energy for the reaction**.
- This proportion is reflected, on a Maxwell-Boltzmann kinetic energy distribution curve, as the **area under the curve to the right of the activation energy**. This area, and hence the **rate of reaction, increases in order of**
- Reaction 3 < Reaction 1 < Reaction 2 < Reaction 4**
- Q20. A** The two main models of enzyme function are the lock-and-key model and the induced fit model.
- In the lock and key model, the shape of the enzyme active site (the lock) is such that only a specifically shaped substrate (the key) fits.
- In the **induced fit model**, the shape of the **active site** is **temporarily modified** as it interacts with the substrate molecules to provide a better fit for the substrate. The active site resumes its normal shape as the product of the reaction leaves.
- The **shape of the active site is unique to each enzyme**.
- Coenzymes are not enzymes, rather they are a cofactor (metal ion or non-protein organic compound) which enable some enzymes to catalyse reactions; without the coenzyme, the catalysis would not occur. However, a **coenzyme in isolation does not have catalytic properties** and, in isolation, does not affect reaction rate.
- Enzyme activity occurs in a narrow pH range** and is **significantly decreased by any change to a pH outside that range**. Some enzymes are active in alkaline solutions – higher pH, whilst others are active in acidic solutions – lower pH.

- Q21. C** Ascorbic acid, also known as Vitamin C, is an **antioxidant**, thus it reduces the impact of free radicals by donating electrons in its role as a water soluble free radical scavenger. A key chemical property of antioxidants is they act as **reductants**. Reductants are oxidised (donate electrons) in chemical reactions.
- Q22. C** In conjunction with the information supplied in Tables 14, 15 and 16 of the **VCE Chemistry Data Book**:
 The IR spectrum provides evidence of the **presence of** the carbonyl (**C=O**) functional group.
C=O (aldehydes); absorption band 1670-1745 cm^{-1} , or **C=O (ketones)**; absorption band 1680-1850 cm^{-1}
lack of O-H acids, no broad absorption band in absorption band 2500-3500 cm^{-1}
lack of O-H alcohols no characteristic absorption in absorption band 3200-3600 cm^{-1}
 The ^1H NMR spectrum provides evidence of
H attached to a carbonyl group as in RCHO , peak at **9.8 ppm** (in the range 9.4-10.0 ppm),
H in a CH_3 attached to a carbonyl group as in RCOCH_3 , peak at 2.2 ppm (in the range 2.1-2.7).
 This evidence suggests the **most likely compound** was the **aldehyde CH_3CHO** (ethanal). This is further supported by the ^{13}C NMR spectrum which provides evidence of **H** attached to a carbonyl group as in RCHO , peak at **200 ppm** (in the range 205-220 ppm).

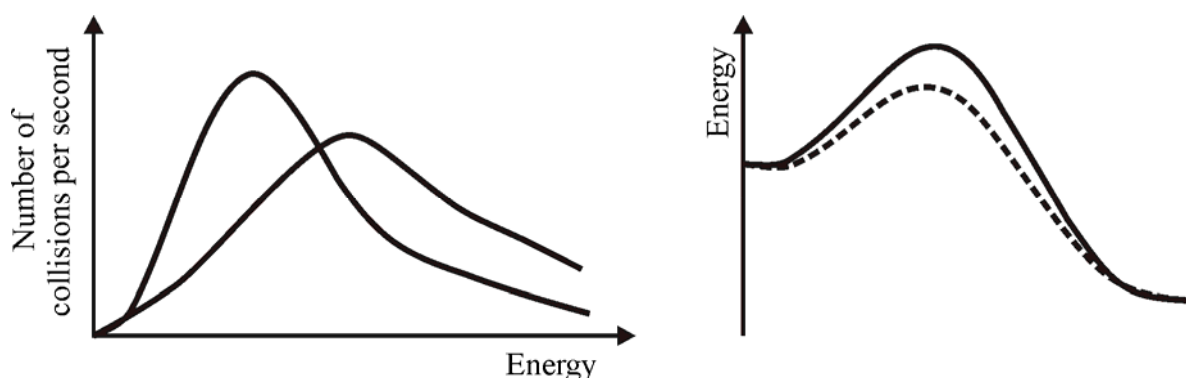
Q23. B The graphs **best represent the digestion of high GI and low GI carbohydrates.**



High GI carbohydrates contain a **greater proportion of amylopectin**, the more easily digestible branched component of starch, and **so release glucose more rapidly** than **low GI carbohydrates**, which contain a **greater proportion of amylose**, the less branched component. The graphs represent the change in blood glucose levels after digestion.

The “0” hour on the horizontal axis represents the time at which one eats. The unbroken curve shows the rise in blood sugar following a high glycaemic index meal. Rapid blood glucose rise in the first hour causes a high insulin output to lower blood glucose. Since cell requirements are not this great in the first hour, much of that glucose is sent to the liver and, if not converted to glycogen, may be converted to triglyceride for fat storage. This happens aggressively in the presence of high insulin, resulting in the blood glucose dropping rapidly by about 2 hours after digestion. This can stimulate hunger and further intake of food. The dashed curve represents the digestion of a low GI index meal and reflects the slower digestion of amylose relative to amylopectin.

This was the only alternative for which ‘Time’ was a valid axis. The Boltzmann distribution curve showing the effect of temperature on particle collision has ‘Energy’ as the horizontal axis. Energy profiles do not need horizontal axes. The diagrams below represent **A** (the effect of temperature on particle collision) and **C** (the effect of a catalyst on activation energy).



The diagrams below represent **D** (energy profiles for exothermic and endothermic reactions).



Q24. C Energy released = $1600 \times 1000 \text{ kJ s}^{-1} \times (60 \times 60) \text{ s}$
 $= 5.76 \times 10^9 \text{ kJ}$

$$n(\text{CH}_4) = 5.76 \times 10^9 \text{ kJ} / 890 \text{ kJ mol}^{-1}$$

$$= 6.48 \times 10^6 \text{ mol}$$

$$V(\text{CH}_4) = nRT/PV$$

$$= 6.48 \times 10^6 \times 8.31 \times 303 / 150$$

$$= 1.08 \times 10^8 \text{ L}$$

However, since the energy conversion is only 60 per cent efficient,

$$1.08 \times 10^8 \text{ L} = 0.60 \times V(\text{CH}_4) \text{ needed}$$

$$V(\text{CH}_4) \text{ needed} = 1.08 \times 10^8 / 0.60$$

$$= 1.81 \times 10^8 \text{ L}$$

$$= 1.81 \times 10^5 \text{ kL}$$

$$= \mathbf{1.81 \times 10^2 \text{ ML}}$$

Alternatively:

$$E = 1600 \times 1000 \times 3600$$

$$= 5.76 \times 10^9 \text{ kJ}$$

60 % efficiency

$$E \text{ required} = 5.76 \times 10^9 / (60/100)$$

$$= 9.6 \times 10^9 \text{ kJ}$$

$$\Delta H_c(\text{CH}_4) = -890 \text{ kJ mol}^{-1}$$

$$n(\text{CH}_4) = 9.6 \times 10^9 / 890 = 1.08 \times 10^7 \text{ mol}$$

$$V = nRT/P$$

$$= 1.08 \times 10^7 \times 8.31 \times 303 / 150$$

$$= 1.81 \times 10^8 \text{ L}$$

$$= \mathbf{1.81 \times 10^2 \text{ ML}}$$

Q25. D Proteins, enzymes and polypeptides must retain secondary, tertiary and, in many cases quaternary structures to maintain their activity. So, anything that will disrupt the structure of these species in the toxin will reduce the impact of the jellyfish sting.

Inorganic ions, acid and hot water can all denature protein structures.

Solution of **inorganic ions will disrupt ion-ion interactions** in the tertiary structure.

Treating with **acidic solution will decrease the pH** and so disrupt tertiary structure.

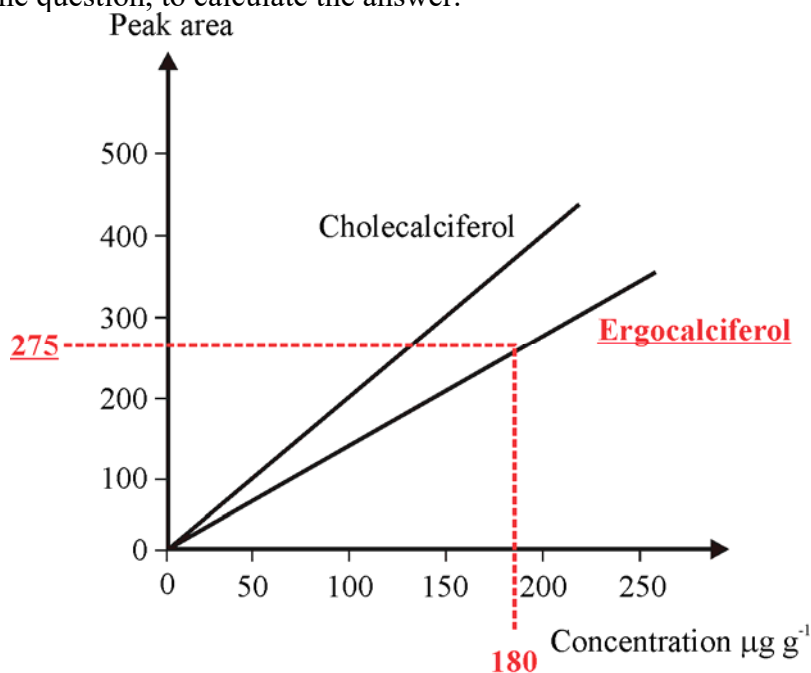
The **higher temperature** of hot water will disrupt secondary, tertiary and quaternary structures.

The treatment least likely to impact on protein structure is cold water.

Q26. C Vitamin D₃ (cholecalciferol) has the **higher retention time**.

So the peak area of vitamin D₂ (ergocalciferol) was 275.

Use the calibration graph for ergocalciferol, i.e. the one unlabelled on the diagram in the question, to calculate the answer.



$$c(\text{ergocalciferol}) = 180 \mu\text{g g}^{-1}$$

$$\begin{aligned}\text{So, } m(\text{vitamin D}_2) \text{ in } 50 \text{ g sample} &= 50 \times 180 \\ &= 9000 \mu\text{g} \\ &= \mathbf{9 \text{ mg}}\end{aligned}$$

Q27. B The semi-structural formula of **Levulinic acid** is $\text{CH}_3\text{COCH}_2\text{CH}_2\text{COOH}$, so its molecular formula is **C₅H₈O₃**.

Fructose is structural isomer of glucose and so its molecular formula is **C₆H₁₂O₆**

$$\text{Atom economy} = (\text{mass of desired product} / \text{mass of reactants}) \times 100$$

$$= [M(\text{C}_5\text{H}_8\text{O}_3) / M(\text{C}_6\text{H}_{12}\text{O}_6)] \times 100$$

$$= (116 / 180) \times 100$$

$$= \mathbf{64 \%}$$

Alternatively:

A simple atom balance indicates compound X must be CH_2O_2 (actually methanoic acid – HCOOH)



$$\text{Atom economy} = (\text{mass of desired product} / \text{total mass of products}) \times 100$$

$$= [M(\text{C}_5\text{H}_8\text{O}_3) / [M(\text{C}_6\text{H}_{12}\text{O}_6) + M(\text{HCOOH}) + M(\text{H}_2\text{O})]] \times 100$$

$$= (116 / [116 + 46 + 18]) \times 100$$

$$= \mathbf{64 \%}$$

Q28. B Since lactic acid, $\text{C}_3\text{H}_6\text{O}_3$, is a carbohydrate, the energy released during the combustion of the lactic acid may be estimated.

$$\begin{aligned}\text{Energy from 5.865 g lactic acid} &= 5.865 \times 15 \\ &= 88.0 \text{ kJ}\end{aligned}$$

$$\begin{aligned}\text{Lactic acid combustion: } \Delta T &= 39.2 - 28.7 \\ &= 10.5^\circ\text{C}\end{aligned}$$

$$\text{Energy released} = \text{Calorimeter constant} \times \Delta T$$

$$\begin{aligned}\text{Calorimeter constant} &= 88.0 \text{ kJ} / 10.5^\circ\text{C} \\ &= 8.38 \text{ kJ}^\circ\text{C}^{-1}\end{aligned}$$

$$\begin{aligned}\text{Ethanol combustion: } \Delta T &= 35.4 - 23.1 \\ &= 12.3^\circ\text{C}\end{aligned}$$

$$\begin{aligned}\text{Energy released during ethanol combustion} &= 8.38 \text{ kJ }^\circ\text{C}^{-1} \times 12.3^\circ\text{C} \\ &= 103 \text{ kJ}.\end{aligned}$$

$$\text{Heat of combustion of ethanol} = 29.6 \text{ kJ g}^{-1} - \text{Data Book Table 11.}$$

$$\begin{aligned}m(\text{ethanol}) \text{ used} &= 103 \text{ kJ} / 29.6 \text{ kJ g}^{-1} \\ &= 3.5 \text{ g}\end{aligned}$$

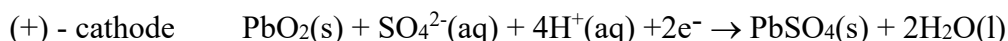
Alternatively:

The ratio of the energies released by ethanol and lactic acid is equal to the ratio of the temperature changes.

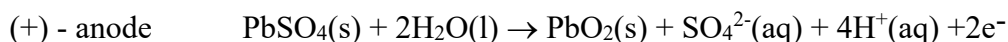
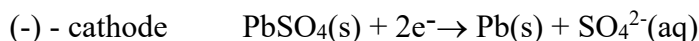
$$\begin{aligned}\text{Energy from } \text{CH}_3\text{CH}_2\text{OH} / 88.0 &= 12.3 / 10.5 \\ &= (12.3 / 10.5) \times 88.0 \\ &= 103 \text{ kJ}\end{aligned}$$

$$\begin{aligned}m(\text{CH}_3\text{CH}_2\text{OH}) &= 103 / 29.6 \\ &= 3.5 \text{ g}\end{aligned}$$

Q29. A In discharging reactions, which convert chemical energy to electrical energy, electrons move from the (-) electrode to the (+) electrode. Electrons always move from the site of oxidation (anode) to the site of reduction (cathode).



So, recharging reactions occurring at these electrodes are the reverse of the discharging reactions.



Checking the four alternatives

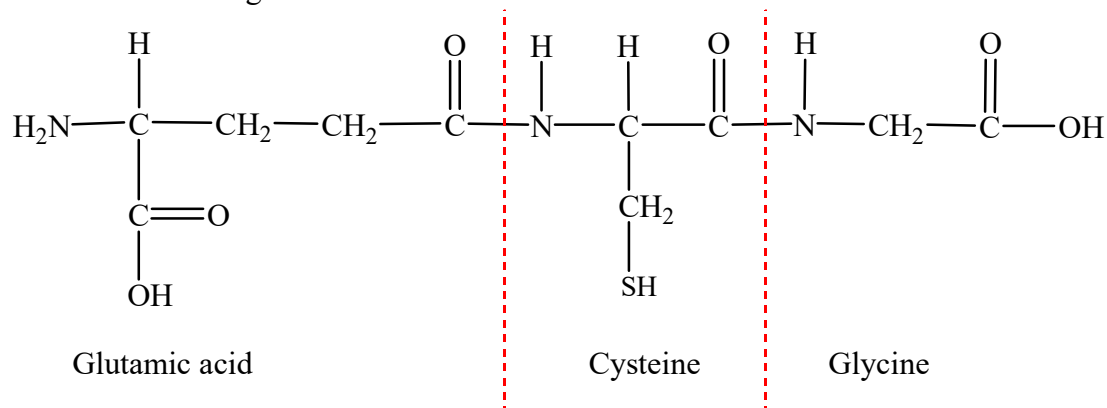
A. Pb is produced at the (-) electrode.

B. pH will decrease as H^+ ions are produced at (+) electrode.

C. PbSO_4 is consumed NOT produced.

D. Oxidation numbers of Pb change from +2 to +4 at the anode, and +2 to 0 at the cathode.

Q30. D The expanded structure of **glutathione** shown below may be used to show that **three 2-amino acids** may be identified (using *Table 17 in the Data Book*) as contributing to the structure.



Hence alternative **D** is **incorrect**.

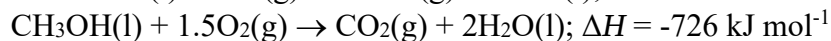
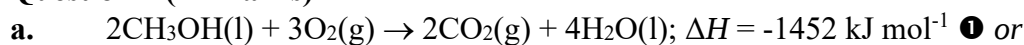
As a free radical scavenger, **glutathione is an antioxidant**.

Glutathione is a tripeptide, because it contains three amino acid residues.

The **four functional groups** present are -NH_2 (amino), -COOH (carboxyl), -CONH- (peptide), -SH (thiol).

SECTION B – Short Answer (Answers)

Question 1 (11 marks)



b. i. Energy added to water $= 4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1} \times m(\text{H}_2\text{O}) \times \Delta T$
 $= 4.18 \times 200 \times (54.7 - 23.5)$
 $= 4.18 \times 200 \times 31.2$
 $= 2.61 \times 10^4 \text{ J}$
 $= \mathbf{26.1 \text{ kJ}}$ ❶

$m(\text{CH}_3\text{OH}) \text{ used} = 125.62 - 121.56$
 $= 4.06 \text{ g}$

Energy released by $\text{CH}_3\text{OH} = m(\text{CH}_3\text{OH}) \times \text{Energy released per gram CH}_3\text{OH}$

According to the **Data Book**, Heat of combustion $= 22.7 \text{ kJ g}^{-1}$

$= 4.06 \text{ g} \times 22.7 \text{ kJ g}^{-1}$

$= \mathbf{92.2 \text{ kJ}}$ ❶

% energy transferred to water $= (\text{energy added to water} / \text{energy released by CH}_3\text{OH}) \times 100$
 $= (26.1 / 92.2) \times 100$
 $= \mathbf{28.3 \%}$ ❶

Alternatively – for the second mark:

$n(\text{CH}_3\text{OH}) \text{ used} = 4.06 / 32.0$

$= 0.127 \text{ mol}$

Energy released by $\text{CH}_3\text{OH} = n(\text{CH}_3\text{OH}) \times \text{Energy released per mole CH}_3\text{OH}$

According to the **Data Book**, $1 \text{ mol CH}_3\text{OH} \rightarrow 726 \text{ kJ}$

$= 0.127 \text{ mol} \times 726 \text{ kJ mol}^{-1}$

$= \mathbf{92.1 \text{ kJ}}$

ii. Possible answers include:

1. Put a lid on the can – this reduces heat escaping from the water to the atmosphere.
2. Move the flame closer to the can – this reduces heat loss to the surrounding atmosphere.
3. Place a reflective shield around the burner and flame – this reduces heat loss to the atmosphere and the impact of air currents on the flame.

❶ mark for an appropriate answer.

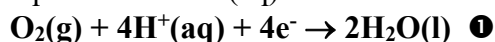
c. i. (-) electrode

The fuel, CH_3OH , is oxidised to CO_2



(+) electrode

Oxygen is reduced, since the electrolyte is acid, the reduction half-equation is obtained from the electrochemical series by looking for O_2 – the oxidant – in a half-equation with $\text{H}^+(\text{aq})$

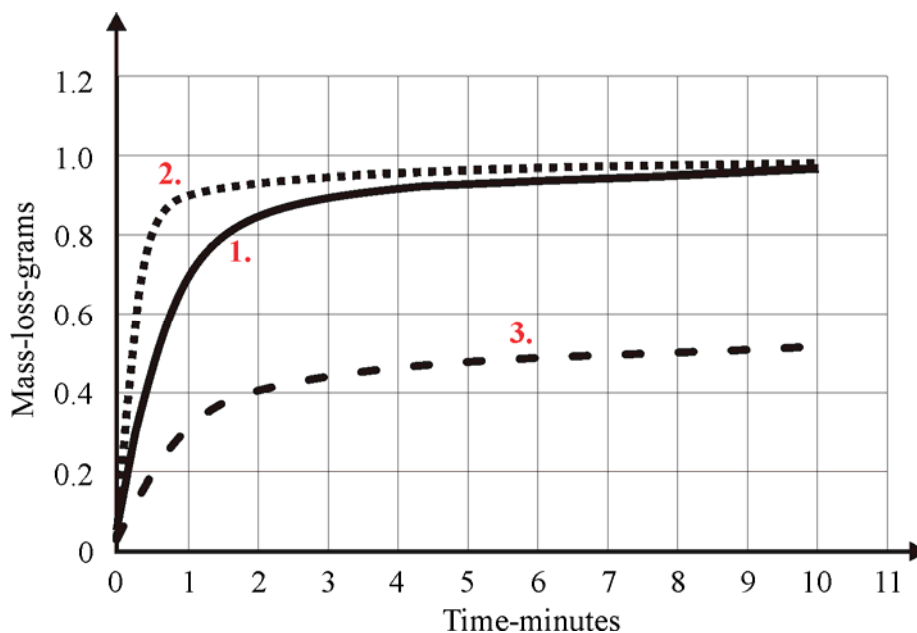


- ii. Porous electrodes **allow for better contact between the fuel and the electrolyte**, and with oxygen and the electrolyte thereby **increasing the reaction rate**. ① They can also be impregnated with catalyst.
Electrodes in a fuel cell must:
 - **conduct electricity**.
 - **not react** with the fuel, oxygen or electrolyte.
- d. i. Both steps involve equilibria with exothermic reactions. To **maximise yield, low temperatures should be used**. However, the **reaction rate decreases at lower temperatures**. ① Using a catalyst means that both a good yield and a good reaction rate can be achieved. ①
- ii. The **much smaller bioDME molecules have less intermolecular attraction**, so bioDME is less viscous than methyl stearate. The **low viscosity means the bioDME is a poor lubricant**. ①

Question 2 (8 marks)

- a. $\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$ ① *or*
 $\text{CaCO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$

b.



- i. Since the **gradients of all three graphs decrease**, reaction rate decreases ① as the reaction proceeds (time increases).
- ii. As the reaction proceeds, **reactant concentration** – in this case $c(\text{HCl}(\text{aq}))$ – **decreases**. This **reduces the number of collisions**, and the number of successful collisions. ①
- c. i. **Increase in surface area.**
The initial reaction rate is higher. This could be caused by a temperature increase, higher $c(\text{HCl})$, addition of a catalyst, or increased surface area. Since it was **clearly stated the starting temperature was the same and no catalyst was used for all three investigations**, either the surface area was larger – smaller marble chips used or a higher $c(\text{HCl})$ was used. ① However, since the CaCO_3 was in excess (HCl was the limiting reactant), a higher $c(\text{HCl})$ would produce a greater overall mass loss. ①

ii. Lower $c(\text{HCl})$

The initial reaction rate is lower and the overall mass loss in investigation 3 is half of that for investigation 1 both observations are consistent with using a lower $c(\text{HCl})$ – most likely half the $c(\text{HCl})$ used in investigation 1. ❶

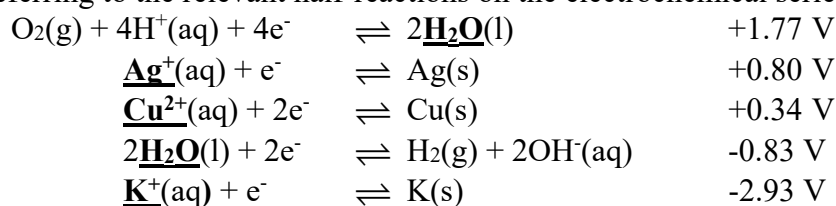
d.

Investigations	Independent variables	Dependent variables	Controlled variables
1 and 2 ❶	Surface area (particle size) of CaCO_3	$m(\text{CO}_2)$ / mass loss / reaction rate	Temperature $V(\text{HCl})$ $c(\text{HCl})$
1 and 3 ❶	Concentration of $\text{HCl}(\text{aq})$	$m(\text{CO}_2)$ / mass loss / reaction rate	Temperature $V(\text{HCl})$ Surface area CaCO_3

Question 3 (7 marks)

a. Cathode. There are 4 oxidants present in the cell – $\text{Cu}^{2+}(\text{aq})$, $\text{Ag}^+(\text{aq})$, $\text{K}^+(\text{aq})$ and $\text{H}_2\text{O}(\text{l})$, but only 1 reductant – $\text{H}_2\text{O}(\text{l})$, so multiple products are only possible at the cathode (where oxidants are reduced). ❶

b. Referring to the relevant half-reactions on the electrochemical series.



i. Ag, silver – the strongest oxidant, $\text{Ag}^+(\text{aq})$ is the first to be reduced. ❶

ii. Cu, copper – as the $c(\text{Ag}^{2+})$ decreases, a point will be reached where the next strongest oxidant, $\text{Cu}^{2+}(\text{aq})$ will be reduced at the cathode. ❶

iii. $2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$ ❶

H_2 , hydrogen is the third substance formed – as the $c(\text{Cu}^{2+})$ decreases, a point will be reached where the next strongest oxidant, $\text{H}_2\text{O}(\text{l})$ will be reduced at the cathode. NB. $\text{K}(\text{s})$ will not be produced because $\text{H}_2\text{O}(\text{l})$ is a much stronger oxidant and is reduced preferentially to $\text{K}^+(\text{aq})$.

c. The layers of Ag and Cu deposited would be far more irregular and we are assuming that the behaviour predicted by standard conditions, 1 M solutions, 25°C and 100 kPa will be followed. ❶ or

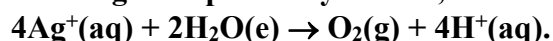
There may be areas – depending on concentration - where both $\text{Ag}(\text{s})$ and $\text{Cu}(\text{s})$ or $\text{Cu}(\text{s})$ and $\text{H}_2(\text{g})$ are produced simultaneously.

d. $2\text{H}_2\text{O}(\text{l}) \rightarrow \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^-$ ❶

e. Total cation concentration is increased.

Cations consumed as $\text{Ag}^+(\text{aq})$ and $\text{Cu}^{2+}(\text{aq})$ are reduced and replaced by $\text{H}^+(\text{aq})$ ions from the oxidation half-equation $2\text{H}_2\text{O}(\text{l}) \rightarrow \text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^-$.

Each Ag^+ is replaced by one H^+ ,



Each Cu^{2+} is replaced by 2 H^+ ,



Overall, the number of cations increases.

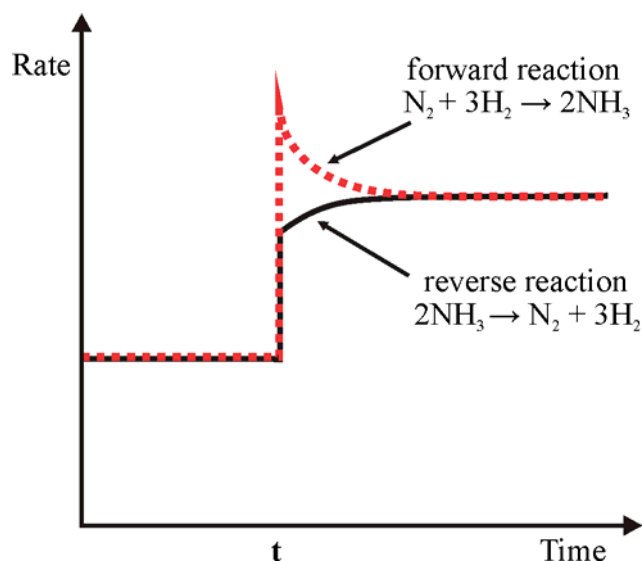
Question 4 (7 marks)

- a. **Incomplete combustion of carbon containing fuels. 1**
Any **balanced combustion equation of a fuel showing CO as a product, e.g. 1**
 $2\text{CH}_4(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}(\text{g}) + 4\text{H}_2\text{O}(\text{g})$
- b. **Haemoglobin has a greater affinity for CO(g) than O₂(g), so in the presence of CO the equilibrium**
Hb(aq) + 4CO(aq) $\rightleftharpoons$ Hb(CO)₄(aq) is established. 1 This impacts on the haemoglobin-oxygen equilibrium as **the decrease in [Hb] causes the equilibrium**
Hb(aq) + 4O₂(aq) $\rightleftharpoons$ Hb(O₂)₄(aq) to shift to the left 1 to compensate.
Consequently, **CO is carried round the body rather than O₂.**
- c. The presence of CO in the air effectively establishes the equilibrium
 $\text{Hb}(\text{O}_2)_4(\text{aq}) + 4\text{CO}(\text{g}) \rightleftharpoons \text{Hb}(\text{CO})_4(\text{aq}) + 4\text{O}_2(\text{g})$
This **equilibrium lies far to the right and so treatment of CO poisoning must involve intervention that will push the equilibrium to the left to allow more Hb(O₂)₄ to form.**
Since **O₂(g) is a product in this equilibrium, pure oxygen therapy will achieve this goal as the system moves to compensate for the increased oxygen concentration. 1**
- d. **Haemoglobin has a quaternary structure, i.e. contains two or more protein (polypeptide) chains clustered into a specific shape. 1** Haemoglobin has **four heme units** each containing an Fe²⁺ ion (a cofactor) and **each haemoglobin molecule can carry four O₂ molecules.**
- e. **Low blood pH is due to the [H₃O⁺] being too high.** The system compensates by using up some of the H₃O⁺(aq) thereby **pushing all the linked equilibria to the left. 1** This **increases the amount of CO₂(g) released in the lungs to be exhaled.**

Question 5 (8 marks)

- a. The data show that, at constant temperature, the **yield of NH₃ increases as the pressure increases. 1** This is consistent with Le Chatelier's principle which suggests that the **system strives to partially oppose a pressure increase by favouring the side of the reaction with fewer particles and so favours the NH₃ producing a forward reaction. 1**
- b. $K_c = [\text{NH}_3]^2 / \{[\text{N}_2] [\text{H}_2]^3\} \text{ M}^{-2}$ **1**
- c. **Exothermic.**
The data show that at constant pressure ($2.00 \times 10^5 \text{ kPa}$), the **yield of NH₃ decreases as the temperature increases. 1**
- d. **No effect.** A catalyst would increase the rate of production of NH₃ but since it **would not change the position of equilibrium, it would not affect the equilibrium yield. 1**

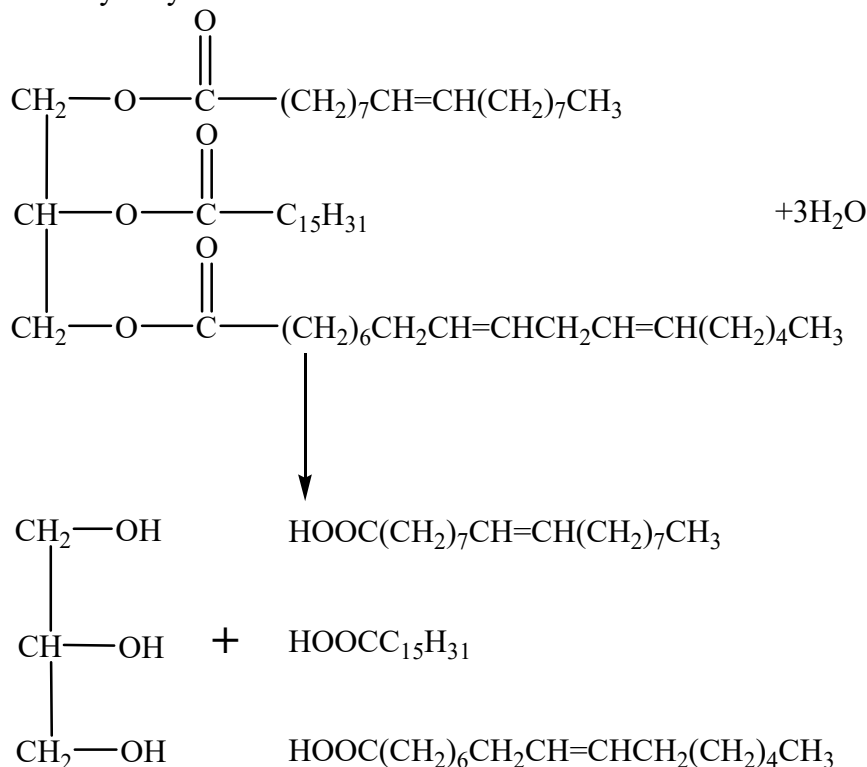
e.



Initially the system is at equilibrium and the rates of forward and reverse reactions are equal. The **volume decrease instantaneously increases reactant and product concentrations** and so the **rates of the forward and reverse reactions increase**. ❶ The forward rate increases more because of the greater number of reactant particles in the equation. As **the system moves to counteract the volume decrease** (concentration increase), the reactant that produces **fewer particles** is favoured, i.e. the forward reaction. ❶ As the **forward reaction** proceeds, its **rate drops** as $[\text{N}_2]$ and $[\text{H}_2]$ (reactants) decrease, and the **rate of the reverse reaction increases** as the $[\text{NH}_3]$ (product) increases. Eventually **equilibrium is established again** and the **rates of the forward and reverse reactions are again equal**. ❶

Question 6 (17 marks)

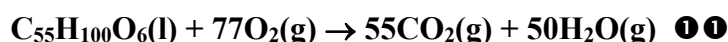
- a. i. The key process in triglyceride digestion is **lipase catalysed hydrolysis**, in which **water acts across the ester groups each of which is thus converted to a carboxyl and a hydroxyl group**. However, since **fats are effectively insoluble in water and lipase is a water-soluble protein**, **bile is used to emulsify the triglyceride**. ❶❶
The overall hydrolysis reaction is



- ii. Two ❶❶ of the following:
Oleic acid $[\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{COOH}]$ – **monounsaturated** fatty acid.
Palmitic acid $[\text{C}_{15}\text{H}_{31}\text{COOH}]$ – **saturated** fatty acid.
Linoleic acid $[\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2(\text{CH}_2)_6\text{COOH}]$ – **polyunsaturated** fatty acid.
- iii. An **omega-6 unsaturated fatty acid** has its **first C=C double bond beginning with the sixth carbon** from the beginning of the hydrocarbon chain. **Linoleic acid**, ❶ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2(\text{CH}_2)_6\text{COOH}$, is an omega-6 fatty acid.
- iv. **Linolenic acid**,
 $\text{CH}_3(\text{CH}_2)_4\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2\text{CH}=\text{CHCH}_2(\text{CH}_2)_6\text{COOH}$ ❶

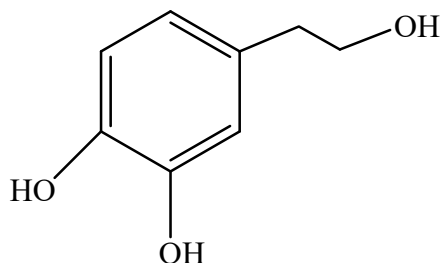
- b. The molecular formula of the triglyceride is **$\text{C}_{52}\text{H}_{98}\text{O}_6$**

- Skeleton equation $\text{C}_{55}\text{H}_{100}\text{O}_6(\text{l}) + ___\text{O}_2(\text{g}) \rightarrow ___\text{CO}_2(\text{g}) + ___\text{H}_2\text{O}(\text{g})$
- Balance C atoms $\text{C}_{55}\text{H}_{100}\text{O}_6(\text{l}) + ___\text{O}_2(\text{g}) \rightarrow 55\text{CO}_2(\text{g}) + ___\text{H}_2\text{O}(\text{g})$
- Balance H atoms $\text{C}_{55}\text{H}_{100}\text{O}_6(\text{l}) + ___\text{O}_2(\text{g}) \rightarrow 55\text{CO}_2(\text{g}) + 50\text{H}_2\text{O}(\text{g})$
- Balance O atoms, $110 + 50 = 160$ on right, 6 on left, need 154 O,
i.e. 77O_2 on left.

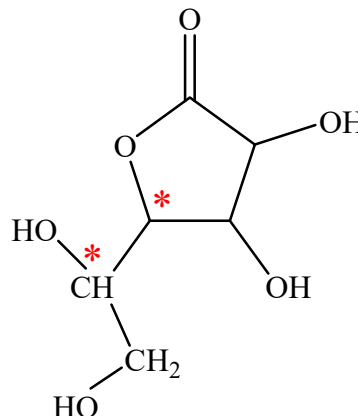


- c. i. The presence of **C=C bonds in unsaturated fatty acids in olive oil are very reactive**. ❶ Oxidative rancidity is associated with **autoxidation of fats** from which **foul smelling short chain aldehydes and ketones** can result. **Antioxidants** prevent this happening by **inhibiting the propagation of free radicals** ❶ associated with autoxidation.

ii.



Hydroxytyrosol



Ascorbic acid (from *Data Book*)

To have enantiomers, a **molecule must be chiral**, i.e. have a chiral centre. **Carbon atoms making single bonds to four different atoms or groups are chiral centres**. ❶

Hydroxytyrosol has no chiral centre, whereas ascorbic acid has two chiral centres, ❶ indicated by the asterisks (*).

- d. Energy released by oil = $(517 / 15) \times 7.5$
= 258.5 kJ

$$\text{Energy transferred to water} = 0.40 \times 258.5$$

$$= 103.4 \text{ kJ } \text{❶}$$

$$103.4 \times 10^3 \text{ J} = 4.18 \text{ J g}^{-1} \text{ }^\circ\text{C}^{-1} \times 500 \text{ g} \times \Delta T \text{ } \text{❶} \quad \text{assume } d(\text{H}_2\text{O}) = 1 \text{ g mL}^{-1}$$

$$\Delta T = 103.4 \times 10^3 / (4.18 \times 500)$$

$$= 49.5^\circ\text{C } \text{❶}$$

- e. According to *Data Book, Table 13*.

Energy content of fats and oils = 37 kJ g⁻¹

15 mL olive oil → 517 kJ

$$m(\text{olive oil}) \text{ for } 517 \text{ kJ} = 517 / 37$$

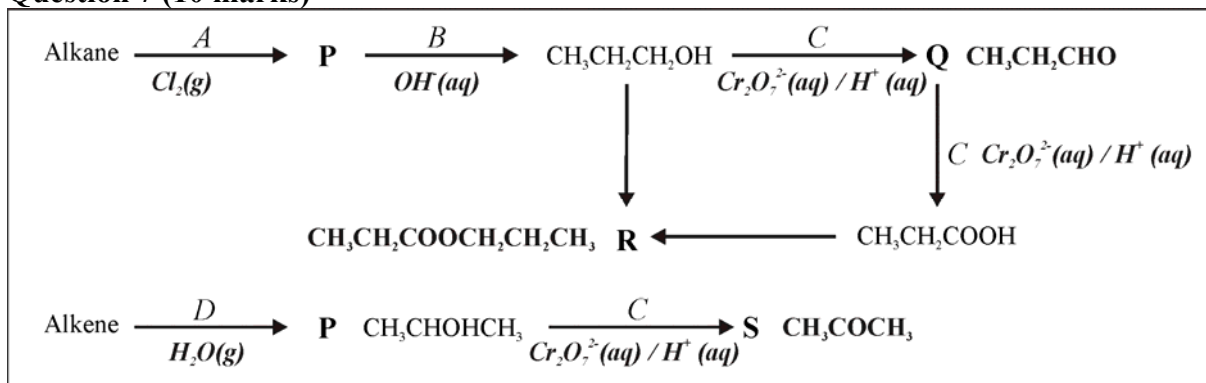
$$= 14 \text{ g } \text{❶}$$

So, 14 g olive oil is equivalent to 15 mL olive oil

$$d(\text{olive oil}) = 14 \text{ g} / 15 \text{ mL}$$

$$= 0.93 \text{ g mL}^{-1} \text{ } \text{❶}$$

Question 7 (10 marks)



- a. **Q – CH₃CH₂CHO 1**
R – CH₃CH₂COOCH₂CH₃ 1
S – CH₃COCH₃ 1
- b. **B – OH⁻(aq) / NaOH(aq) 1**
C – Cr₂O₇²⁻(aq) / H⁺(aq) 1
D – H₂O(g) 1
- c. Oxidation: **CH₃CHOHCH₃(aq) → CH₃COCH₃(l) + 2H⁺(aq) + 2e⁻ 1**
Reduction: **Cr₂O₇²⁻(aq) + 14H⁺(aq) + 6e⁻ → 2Cr³⁺(aq) + 7H₂O(l) 1**
- d. Compound R is propylpropanoate produced via the equilibrium
CH₃CH₂COOH(l) + CH₃CH₂CH₂OH(l) ⇌ CH₃CH₂COOCH₂CH₂CH₃(l) + H₂O(l)
Because equal chemical amounts of each reactant were used, the initial amount may be assumed to be, say 0.50 mol, of which 75 %, i.e. 0.375 mol (0.75 × 0.50) reacts as the system gets to equilibrium
- | | | | | |
|--------------------|--|--|---|--------------------------|
| | CH₃CH₂COOH(l) | CH₃CH₂CH₂OH(l) | CH₃CH₂COOCH₂CH₂CH₃(l) | H₂O(l) |
| Initially (mol) | 0.50 | 0.50 | - | - |
| Reacting (mol) | 0.375 | 0.375 | 0.375 | 0.375 |
| Equilibrium | 0.125 | 0.125 | 0.375 | 0.375 1 |

Because there are the same number of mol on both sides of the balanced equation, volume is not a significant issue in the calculation; it may be assumed to be 1 L

$$K_c = \frac{[\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3][\text{H}_2\text{O}]}{[\text{CH}_3\text{CH}_2\text{COOH}][\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}]}$$

$$= \frac{(0.375 \times 0.375)}{(0.125 \times 0.125)}$$

$$= \mathbf{9.0 \quad 1}$$

Alternatively:

Since 75 % percent of each of the reactants were consumed in getting to equilibrium, and equal mole amounts of reactants were initially present, the ratio of each of the products to each of the reactants at equilibrium will be 3 : 1.

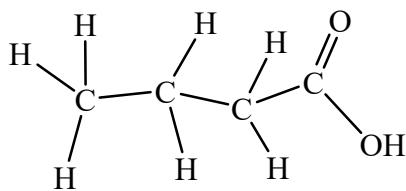
Hence, for this equilibrium, $K = 3 \times 3 / 1 \times 1 = \mathbf{9.0}$

Question 8 (11 marks)

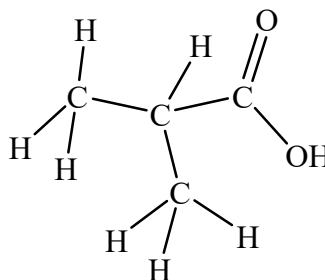
- a. i. $\text{C}_2\text{H}_2\text{O}_4(\text{aq}) + 2\text{NaOH}(\text{aq}) \rightarrow \text{C}_2\text{H}_2\text{O}_4^{2-}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ ❶
ii. $\text{C}_7\text{H}_8\text{O}_7(\text{aq}) + 3\text{NaOH}(\text{aq}) \rightarrow \text{C}_7\text{H}_5\text{O}_7^{3-}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$ ❶
- b. The data in the third column ($V(\text{NaOH})$ required to react with citric acid in the fruit juice) should have been presented separately to avoid confusion; these data are not linked to the individual amounts of oxalic used. ❶
- c. **Oxalic acid is a primary standard.** ❶ Sodium hydroxide absorbs water from the atmosphere and reacts with atmospheric CO_2 , hence the samples used are unlikely to be pure and the accurate concentration of the solution will not be 1.00 M.
By reacting the $\text{NaOH}(\text{aq})$ with oxalic acid, the accurate $c(\text{NaOH})$ can be determined.
- d. Average $m(\text{C}_2\text{H}_4\text{O}_4)$ used = $(1.25 + 1.23 + 1.26) / 3$
= 1.247 g
Average $V(\text{NaOH})$ used = $(27.6 + 27.1 + 27.4) / 3$
= 27.37 mL ❶
 $n(\text{C}_2\text{H}_4\text{O}_4)$ reacting = $1.247 / 90$
= 0.0139 mol ❶
 $n(\text{NaOH})$ required = $2 \times n(\text{C}_2\text{H}_4\text{O}_4)$
= 2×0.0139
= 0.0277 mol
 $c(\text{NaOH})$ = $0.0277 \text{ mol} / 0.0237 \text{ L}$
= **1.012 mol L⁻¹** ❶
- e. Average $V(\text{NaOH})$ used in titrating citric acid in fruit juice = $(33.6 + 33.4 + 33.9)$
= 33.63 mL
 $n(\text{NaOH})$ reacting with citric acid in juice sample = $1.012 \text{ mol L}^{-1} \times 33.63 \times 10^{-3} \text{ L}$
= 0.0340 mol ❶
 $n(\text{C}_7\text{H}_8\text{O}_7)$ reacting = $n(\text{NaOH}) / 3$
= $0.0340 / 3$
= 0.0113 mol ❶
 $m(\text{C}_7\text{H}_8\text{O}_6)$ in 50.0 sample of juice = $0.0113 \text{ mol} \times 204.0 \text{ g mol}^{-1}$
= 2.32 g
 $m(\text{C}_7\text{H}_8\text{O}_6)$ in one L of juice = $(2.32 / 50) \times 1000$
= **46.3 g L⁻¹** ❶
- f. The calculated concentration of citric acid will be higher than the true value because the total $V(\text{NaOH})$ added includes some that will have reacted with malic acid. ❶

Question 9 (11 marks)

- a. Parent-ion peak at $m/z = 88$, indicating that the **relative molecular mass** of the compound is **88**. ①
Reference peak at $m/z = 43$, indicating that the **relative mass of the most abundant fragment** is **43**. ①
- b. The compound has **4 different carbon environments**. ①
- c. The compound has **3 different hydrogen environments**. ①
The presence of a **quartet** and a **triplet** indicates the presence of a **CH_3CH_2 -** group. ①
The singlet at $\delta = 2.0$ ppm is consistent with **H on a carbon which is bonded to the carbon of an ester or amide group**, i.e. CH_3COOR , or CH_3COONHR . [Data Book, Table 16] ①
- d. All the information deduced so far indicates that the **compound could be either $\text{CH}_3\text{COOCH}_2\text{CH}_3$ or $\text{CH}_3\text{CONHCH}_2\text{CH}_3$** . ①
 $M_r(\text{CH}_3\text{COOCH}_2\text{CH}_3) = 88.0$
 $M_r(\text{CH}_3\text{CONHCH}_2\text{CH}_3) = 79.0$
Compound is **$\text{CH}_3\text{COOCH}_2\text{CH}_3$** ① – ethyl ethanoate.
- e. **$1720\text{--}1840\text{ cm}^{-1}$ C=O esters** and
 $2850\text{--}3090\text{ cm}^{-1}$ C-H ①
- f. **Carboxylic acids are structural isomers of esters with the same number of C atoms.**
There are two 4 C carboxylic acids.



Butanoic acid



Methylpropanoic acid

Differences in ^1H NMR spectra, from the spectrum for the compound would be
Butanoic acid ① - Peak at $\delta = 9.0\text{--}13.0$ for H in the carboxyl group -COOH ① or
Four hydrogen environments rather than three.

or

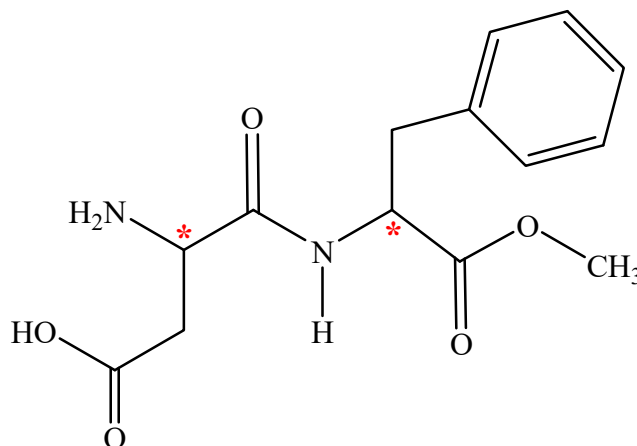
Methyl propanoic acid - Peak at $\delta = 9.0\text{--}13.0$ for H in the carboxyl group -COOH or
Singlet, doublet and septet, rather than singlet, triplet and quartet on its high resolution spectrum.

End of Suggested Answers

Question 10 (13 marks) BONUS QUESTION

a. Two. ①

The structure of aspartame was supplied in Table 10 in the *Data Book*. This is shown below with the two chiral carbons (those bonded to four different groups) indicated by an asterisk (*).



- b. At pH 10, the carboxyl group ($-\text{COOH}$) is deprotonated to COO^- , as aspartame acts as an acid in the alkaline solution and the molecules are negatively charged. ①
At pH 4, the amino ($-\text{NH}_2$) group is protonated to $^+\text{NH}_3$, as aspartame acts as a base in the acidic solution and the molecules are positively charged. ① (Also, NH in the amide group could be protonated to $^+\text{NH}_2$).
- c. The fact that we taste L-aspartame but not D-aspartame indicates that only the chiral molecules interact with our taste buds. ①
- d. i. Aspartame: peptide (amide) $\rightarrow$ carboxyl + amino ①
Sucrose: ether (glycoside) $\rightarrow$ hydroxyl ①
ii. Aspartic acid ①, phenylalanine ① – (from Table 17 in the Data Book)
iii. Glucose ①, Fructose ①
iv. The glycaemic index ranks carbohydrate-intense foods based on their effect on blood-sugar (glucose) levels ① (over a 2-hour period). Glucose is released during the hydrolysis of starch but the rate at which glucose is released into the blood depends on the relative amounts of amylose and amylopectin ① (polymers of glucose) present in the starch. Straight chain amylose is more difficult to digest than branched chain amylopectin, so a more rapid higher peak in blood glucose levels indicate a greater proportion of amylopectin in the starch. ①

End of Suggested Answers (Bonus Question)