Learning Materials
by Lisachem

VCE CHEMISTRY 2013

YEAR 12 TRIAL EXAM

Unit 3 & Unit 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	8	8	105
			Total 135

To download the Chemistry Data Book please visit the VCAA website:
http://www.vcaa.vic.edu.au/Documents/exams/chemistry/2012/2012chem1-w.pdf *Page 28*

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STUDENT NUMBER

										Letter
Figures										
Words										

Student Name...……………………..

VCE Chemistry 2013 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.

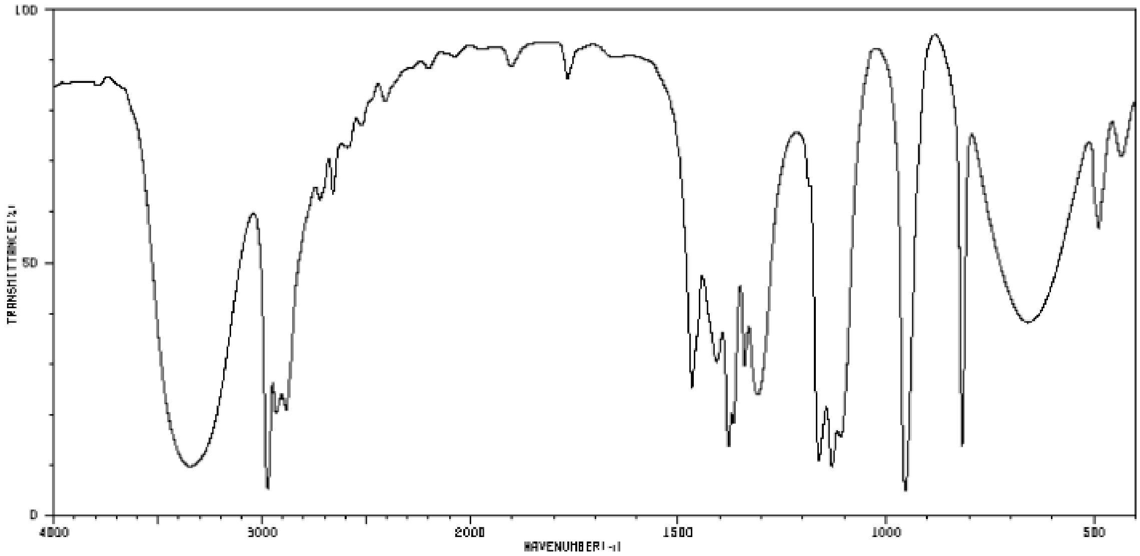
Question 1	A	B	C	D	*Question 2*	A	B	C	D
Question 3	A	B	C	D	*Question 4*	A	B	C	D
Question 5	A	B	C	D	*Question 6*	A	B	C	D
Question 7	A	B	C	D	*Question 8*	A	B	C	D
Question 9	A	B	C	D	*Question 10*	A	B	C	D
Question 11	A	B	C	D	*Question 12*	A	B	C	D
Question 13	A	B	C	D	*Question 14*	A	B	C	D
Question 15	A	B	C	D	*Question 16*	A	B	C	D
Question 17	A	B	C	D	*Question 18*	A	B	C	D
Question 19	A	B	C	D	*Question 20*	A	B	C	D
Question 21	A	B	C	D	*Question 22*	A	B	C	D
Question 23	A	B	C	D	*Question 24*	A	B	C	D
Question 25	A	B	C	D	*Question 26*	A	B	C	D
Question 27	A	B	C	D	*Question 28*	A	B	C	D
Question 29	A	B	C	D	*Question 30*	A	B	C	D

VCE Chemistry 2013 Year 12 Trial Exam Unit 3/4

SECTION A – Multiple Choice Section

Section A consists of 30 multiple-choice questions.
Section A is worth approximately 22 per cent of the marks available.
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
Analysis of an organic compound produces the IR and ^{13}C NMR spectra shown below.



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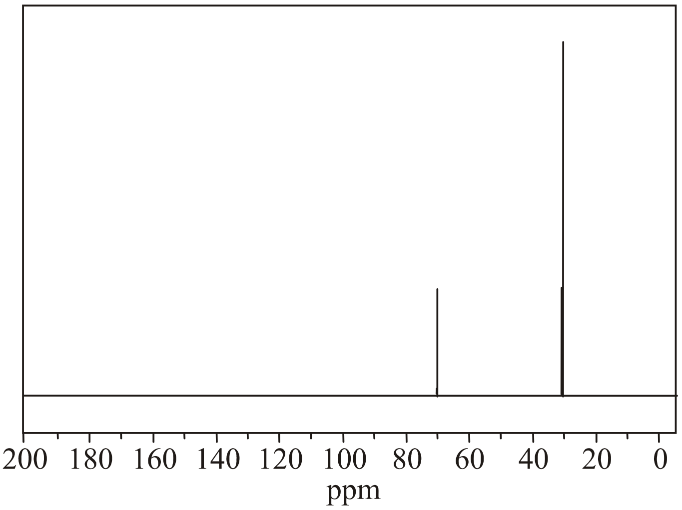


The compound could be
A. 2-butanol.
B. 1-propanol.
C. Ethanoic acid.
D. 2-methylpropan-2-ol.

Question 2

Sodium hydrogen carbonate decomposes on heating according to

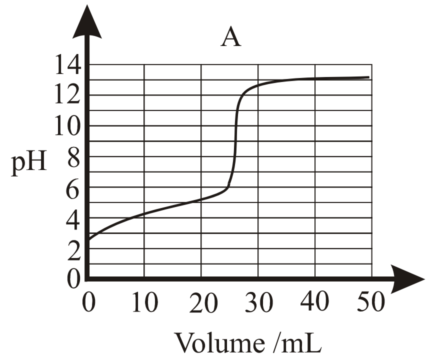
$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

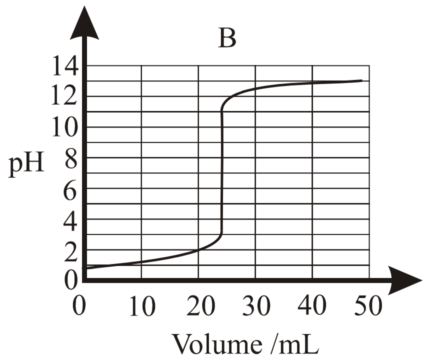
Decomposition of 1.275 g of a moist sample of $NaHCO_3$ yields a solid residue of 0.528 g. The mass of water present in the moist sample was

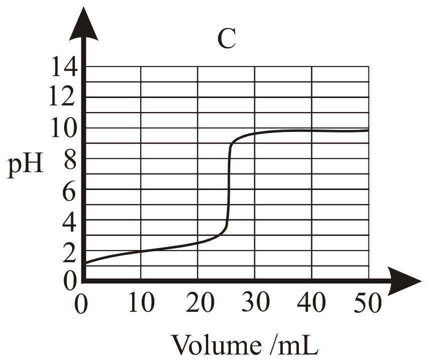
A. 0.090 g.
B. 0.137 g.
C. 0.438 g.
D. 0.837 g.

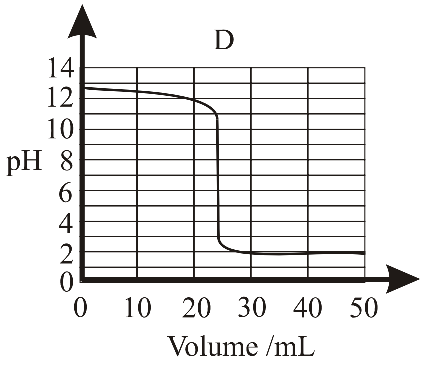
Questions 3 and 4 refer to the four titration curves below.

In all the cases the initial concentrations of the acids and bases involved in the titrations were 0.10 M









Question 3

Which of the titration curves best applies to reaction between 0.10 M HCl(aq) and 0.10 M NH_3(aq)?

A. Curve A.
B. Curve B.
C. Curve C.
D. Curve D.

Question 4
Which of the indicators listed would be the **least suitable** choice for any of the four titrations?

A. Methyl orange.
B. Methyl red.
C. Bromothymol blue.
D. Phenolphthalein.

Question 5
In electrochemistry, a 'gas electrode' contains a conducting material over which a gas is bubbled or collected.

A galvanic cell, constructed at standard conditions, contains two different gas electrodes. The operating cell voltage is 1.22 V.

Which of the following observations, made when the cell was operating, is most likely to be accurate?

A. A solid is produced at the anode.
B. Gas is produced at the cathode.
C. pH increases at the anode.
D. pH increases at the cathode.

Question 6
Perchloric acid, $HClO_4$, is an extremely strong acid and a very powerful oxidising agent.

Which of the following formulae represents the substance **least likely** to be produced when perchloric acid acts as the oxidant in a redox reaction?

A. Cl_2
B. Cl_2O
C. ClO_2
D. Cl_2O_7

Question 7
Lithium hydride, LiH, is an ionic compound but its solubility in water, is due to its ability to react with water. This reaction has been considered as a source of hydrogen for hydrogen-oxygen fuel cells.

When solid lithium hydride, LiH, is added to water, the overall reaction that occurs is represented by the equation

$$LiH(s) + H_2O(aq) \rightarrow Li^+(aq) + H_2(g) + OH^-(aq)$$

This reaction is most accurately described as

A. an hydrolysis reaction.
B. an acid-base reaction.
C. a redox reaction.
D. both an acid-base reaction and a redox reaction.

Question 8
1.05 g of glucose, in the presence of excess oxygen, in a bomb calorimeter was completely oxidised.

The calibration factor of the calorimeter (calorimeter constant) was 2.35 kJ °C.

The temperature in the calorimeter before reaction was 22.7 °C.

What was the highest possible temperature, in °C, of the calorimeter after reaction?

A. 7.0
B. 29.7
C. 15.7
D. 53.3

Question 9

The vanadium redox battery is a rechargeable battery that exploits the ability of vanadium to exist in solution in four different oxidation states. The species which can exist in solution appear in the standard half-cell potentials below

$VO_3^-(aq) + 4H^+(aq) + e^- \rightarrow VO^{2+}(aq) + 2H_2O(l)$ $E° = +1.00$ V

$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$ $E° = +0.32$ V

$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$ $E° = -0.26$ V

The cells in this battery have different electrolytes around the positive (+) and negative (-) electrodes. When the battery is delivering energy or being recharged, the electrolyte at one electrode contains species with +5 and +4 oxidation states and the electrolyte at the other electrode contains species with the +3 and +2 oxidation states.

The half-equation for the reaction occurring at the (+) electrode when recharging the cells in the vanadium redox battery would be

A. $VO^{2+}(aq) + 2H_2O(l) \rightarrow VO_3^-(aq) + 4H^+(aq) + e^-$
B. $V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$
C. $VO_3^-(aq) + 4H^+(aq) + e^- \rightarrow VO^{2+}(aq) + 2H_2O(l)$
D. $V^{3+}(aq) + H_2O(l) \rightarrow VO^{2+}(aq) + 2H^+(aq) + e^-$

Question 10

The data shown in the table below, were recorded during an investigation of the effect of changes in condition on the equilibrium reaction involved in the production of a particular chemical.

Investigation	Temperature - °C	Pressure - kPa	Percentage yield
1	200	1500	52
2	200	2000	65
3	300	2000	48
4	300	2500	56

On the basis of this information, the reaction equation has

A. more particles on the right hand side and the reaction is endothermic.
B. fewer particles on the right hand side and the reaction is endothermic.
C. more particles on the right hand side and the reaction is exothermic.
D. fewer particles on the right hand side and the reaction is exothermic.

Question 11

Which of the following statements about fuel cells is most accurate?

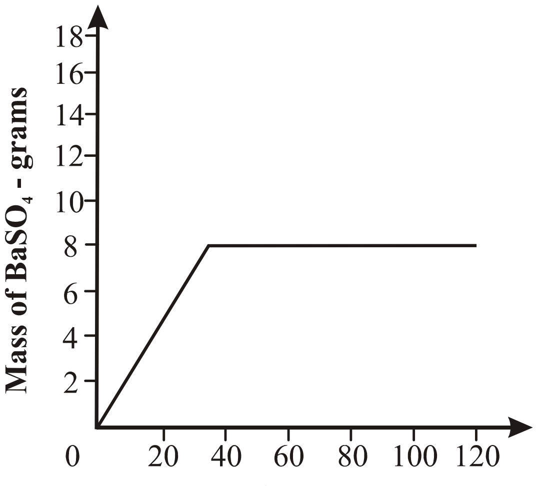
A. Fuel cells only convert chemical energy to electrical energy.
B. Fuel cells utilise only acid electrolytes.
C. Fuel cells indirectly involve combustion reactions.
D. Fuel cells are rechargeable.

Questions 12 and 13 refer to the following information.

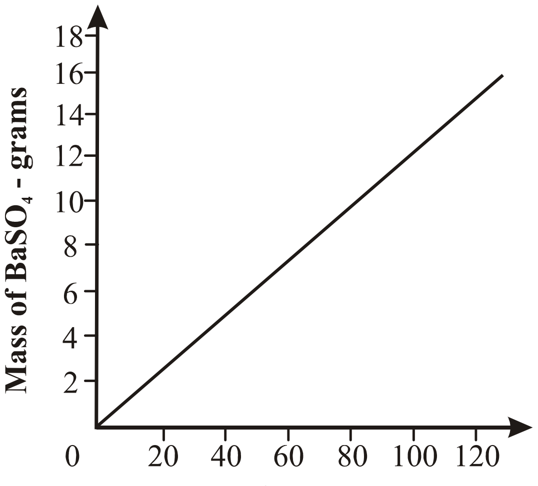
Four students investigating the stoichiometry of the reaction between aqueous solutions of barium chloride, $BaCl_2(aq)$, and sodium sulfate, $Na_2SO_4(aq)$, produced graphs on which the mass of precipitate that could be formed was plotted against the volume of $BaCl_2(aq)$ added to 100 mL of 0.34 M $Na_2SO_4(aq)$.

All students were assigned one of 0.50 M or 1.0 M $BaCl_2(aq)$.

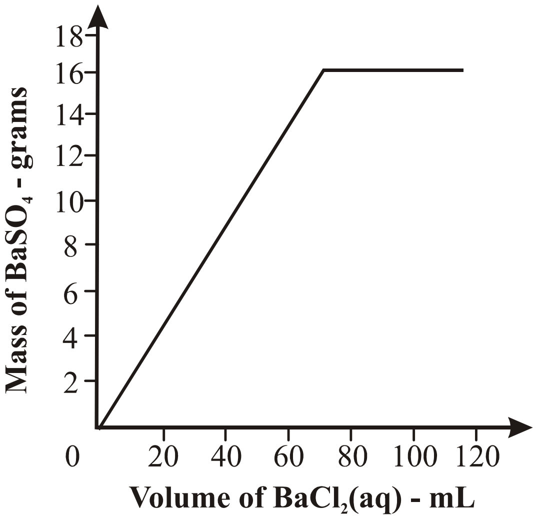
The graphs produced by the four students were:



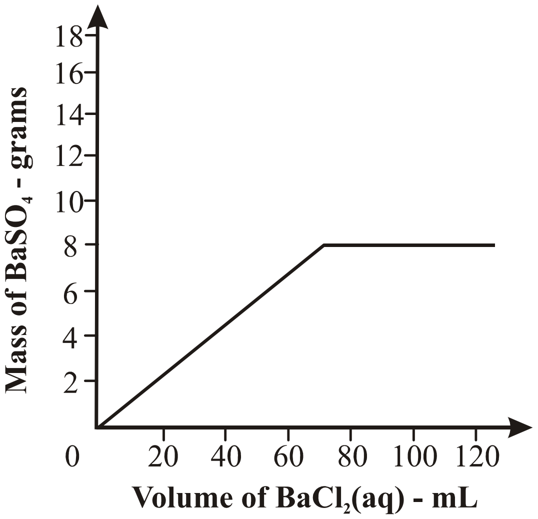
Graph 1



Graph 2



Graph 3



Graph 4

Question 12

Which graph best represents the use of 0.50 M $BaCl_2(aq)$?

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

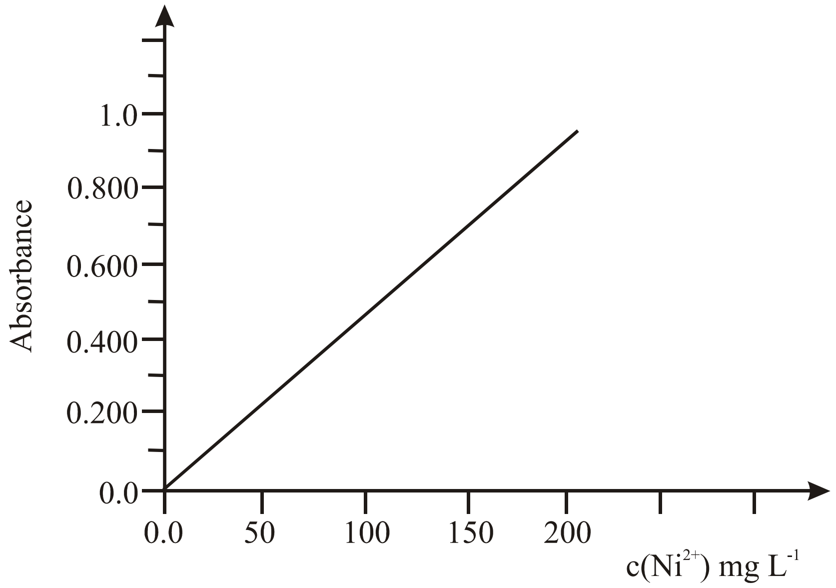
Question 13

Which graph best represents the use of 1.0 M $BaCl_2(aq)$?

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

Question 14

The nickel content of a sample of ore is analysed by atomic absorption spectroscopy. A set of $Ni^{2+}(aq)$ standard solutions was prepared, their absorbances measured and the calibration curve below plotted.



5.0 g of the ore was added to 200 mL of concentrated hydrochloric acid to extract all the nickel as $Ni^{2+}(aq)$ ions. Two 25.0 mL aliquots of this solution were taken and their absorbances measured under the same conditions as used for the standards.

The average absorbance was 0.66.

The percentage by mass of nickel in the ore is closest to

A. 0.1
B. 0.6
C. 22
D. 70

Question 15

The mass, in picograms (pg), of carbon atoms in one molecule of 2-methylbutanoic acid is

A. 8.31×10^{-12}
B. 9.97×10^{-11}
C. 8.31×10^{-36}
D. 9.97×10^{-35}

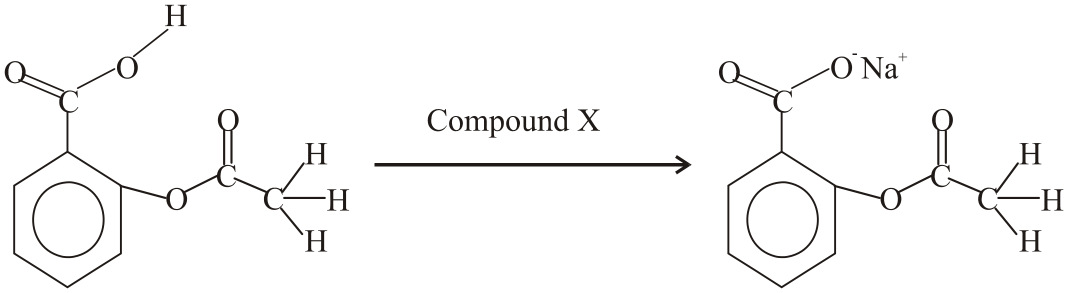
Question 16

When potassium permanganate, $KMnO_4$, was used as an oxidising agent in a galvanic cell, the cell produced a current of 2290 C of electricity when 1.25 gram of $KMnO_4$ was consumed in the cell. Assuming the conversion of chemical energy to electrical energy is 100 per cent efficient, which of the following is the chemical formula for the product of the reduction of the $KMnO_4$?

A. MnO.
B. Mn_2O_3.
C. MnO_2.
D. K_2MnO_4.

Question 17

The solubility of acetyl salicylic acid in water can be increased by converting it to sodium acetyl salicylate, as indicated below.



Acetyl salicylic acid and compound X react in a 1:1 mole ratio. During the conversion, carbon dioxide and water are also produced.

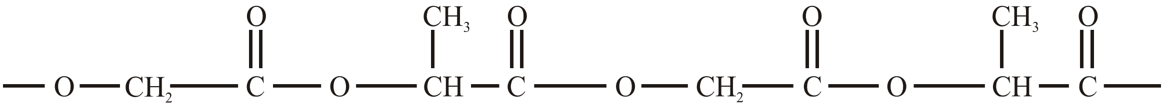
Compound X is

A. sodium hydroxide.
B. sodium carbonate.
C. sodium chloride.
D. sodium hydrogen carbonate.

Question 18

Polylactic glycolic acid (PLGA) is a biodegradable and biocompatible polymer used in the production of biomedical devices. PLGA can undergo hydrolysis in the body to produce its original monomers, lactic acid and glycolic acid.

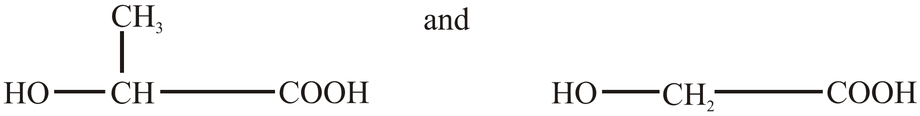
PLGA 50:50 contains equal numbers of both monomers. A section of PLGA 50:50 is represented below.



$$-O-CH_2-\overset{\overset{O}{\parallel}}{C}-O-\overset{\overset{CH_3}{|}}{CH}-\overset{\overset{O}{\parallel}}{C}-O-CH_2-\overset{\overset{O}{\parallel}}{C}-O-\overset{\overset{CH_3}{|}}{CH}-\overset{\overset{O}{\parallel}}{C}-$$

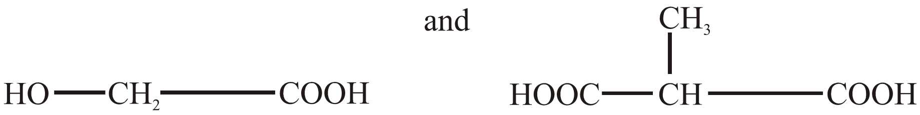
Which of the following alternatives **A. – D.** shows the correct structures of both lactic acid and glycolic acid?

A.



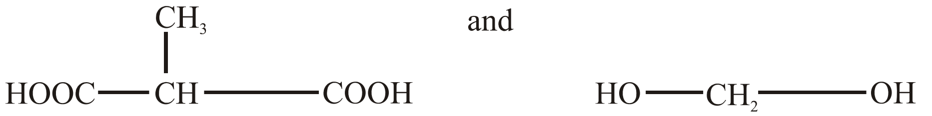
$HO-\overset{\overset{CH_3}{|}}{CH}-COOH$ and $HO-CH_2-COOH$

B.



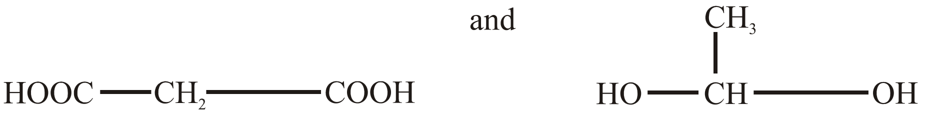
$HO-CH_2-COOH$ and $HOOC-\overset{\overset{CH_3}{|}}{CH}-COOH$

C.



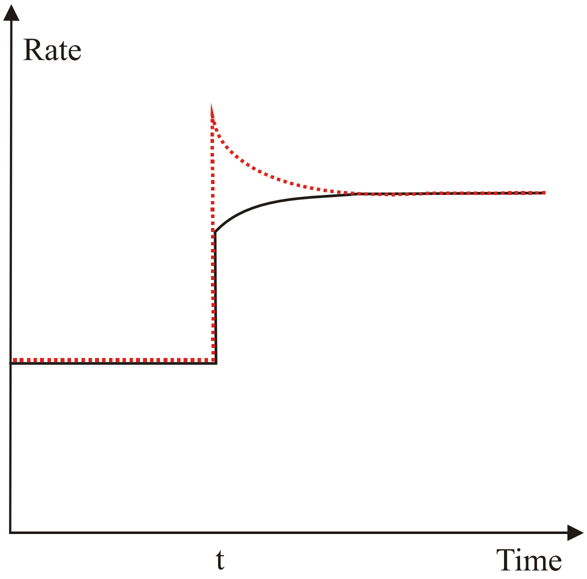
$HOOC-\overset{\overset{CH_3}{|}}{CH}-COOH$ and $HO-CH_2-OH$

D.



$HOOC-CH_2-COOH$ and $HO-\overset{\overset{CH_3}{|}}{CH}-OH$

Question 19
The impact of a change imposed, at time **t**, on an $2NO_2(g) \rightleftharpoons N_2O_4(g)$ equilibrium mixture is shown on the rate-time graph below.



The change imposed on the system was
A. addition of $NO_2(g)$.
B. addition of $N_2O_4(g)$.
C. increase of container volume.
D. decrease of container volume.

Question 20
A 0.100 M solution of a monoprotic weak acid has a pH of 2.60 at 25°C.
A 10.0 aliquot of that weak acid solution is diluted to 250 mL with water.
The pH of the diluted solution at 25°C would be expected to be
A. 2.40
B. 3.30
C. 1.60
D. 3.90

Question 21
In a gas-fired power station, some of the energy available from the combustion of methane is used to convert water in a boiler from liquid water to steam according to

$$H_2O(l) \rightarrow H_2O(g); \ \Delta H = +44.0 \text{ kJ mol}^{-1}$$

If the transfer of energy from the combustion to water in the boiler is 40 per cent efficient, what mass of methane would be consumed in producing 1.00 kg of steam from liquid water?
A. 17.6 g.
B. 44.0 g.
C. 110 g.
D. 323 g.

Question 22

The edited passage below, which appeared in a publicity brochure for a 2012 publication on Food Analysis, identifies a key analytical technique used. The name of the technique has been left blank.

For food scientists, ________________________________ *is a powerful tool for product composition testing and assuring product quality. Since the last edition of this volume was published, great strides have been taken in* ________________________________ *analysis techniques with particular attention to miniaturisation, automisation, and green chemistry.*

Considering the nature of the major components in foods, what is the ‘missing’ technique?

A. Atomic absorption spectrometry.
B. UV-visible spectrophotometry.
C. Gas chromatography.
D. High performance liquid chromatography.

Question 23

In an analysis to determine the concentration of hydrochloric acid in brick cleaner, 10 mL of brick cleaner was diluted to 250 mL with water, and 20.0 mL aliquots of 0.100 M $Na_2CO_3(aq)$ were titrated to the methyl orange endpoint with diluted brick cleaner.

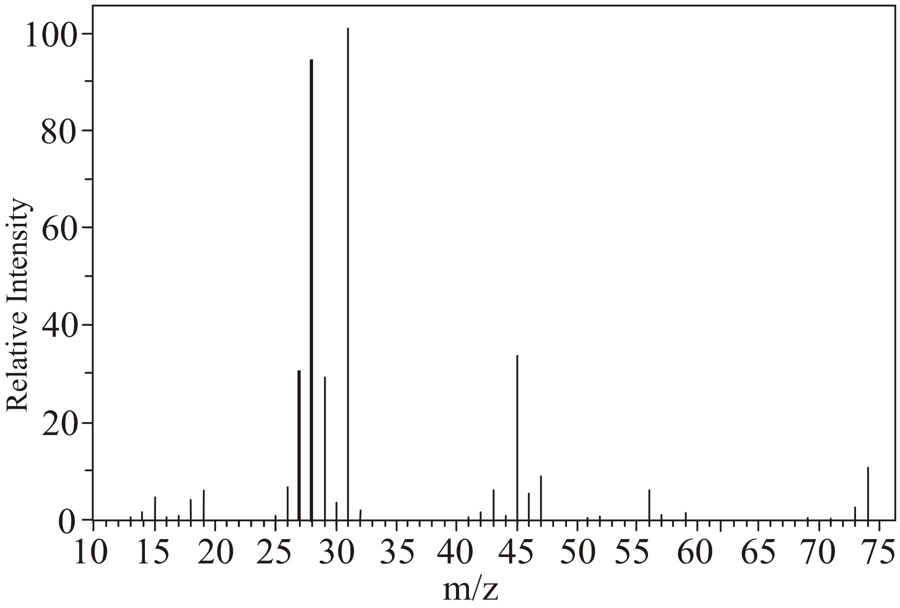
The titration reaction is $Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$

Which one of the following equipment rinsing techniques would result in a lower than true calculation of the concentration of hydrochloric acid in the brick cleaner?

A. Rinsing the pipette used to transfer the $Na_2CO_3(aq)$ aliquot only with water.
B. Rinsing the titration flask with the diluted brick cleaner.
C. Having water in the titration flask before the acid is added.
D. Rinsing the burette only with water.

Question 24

The mass spectrum of an organic compound is shown below.

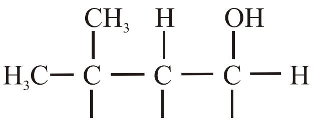


The IR spectrum of this compound shows a narrow absorption peak in the 1670-1750 cm^{-1} range.
The ^{13}C NMR spectrum of the compound shows 3 signals.
The high resolution ^{1}H NMR spectrum of the compound shows a quartet at chemical shift 4.1.
The compound is

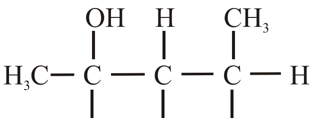
A. ethyl methanoate.
B. ethyl ethanoate.
C. propanoic acid.
D. methyl ethanoate.

Question 25

Consider the semi-structural formulae of two alcohols shown below.



$H_3C-C(CH_3)_2-CH_2-CH_2-OH$



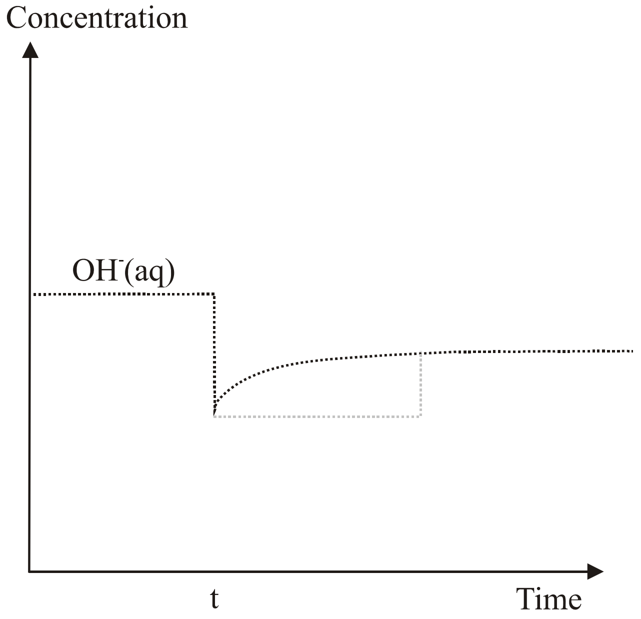
$H_3C-C(OH)(CH_3)-CH_2-CH_2-CH_3$

The two compounds represented would **not** have different

A. reactions with acidified $Cr_2O_7^{2-}(aq)$.
B. *m*/z values for their parent ion peaks on their mass spectra.
C. IR spectra below 1500 cm^{-1}.
D. numbers of peaks on their ^{13}C NMR spectra.

Question 26

The concentration-time graph below shows the impact of 50 mL of water being added to 50 mL of a 0.1 M aqueous solution at constant temperature at time **t.**



To which of the solutions below do the changes in concentration at time '**t**' best relate?

A. HCl(aq).
B. CH_3COOH(aq).
C. NH_3(aq).
D. NaCl(aq).

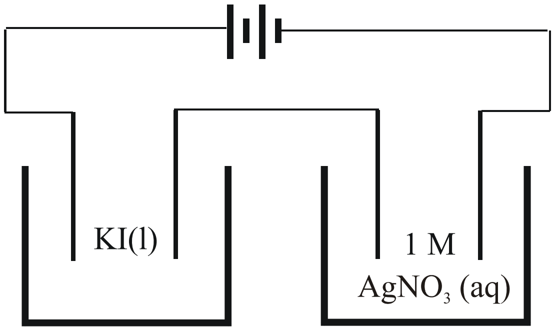
Question 27

Which one of the following statements best distinguishes fuel cells from electrolytic cells?

A. The supply of reactants from outside the cell.
B. The conversion of chemical energy to electrical energy.
C. The movement of electrons away from the anode.
D. The use of aqueous electrolytes.

Question 28

A current of 2.5 A is passed for 50 minutes through two cells connected in series. As indicated on the diagram below, these cells contained molten potassium iodide and a 1 M solution of silver nitrate respectively. Each cell also contains a pair of platinum electrodes.



Which of the following substances would be least likely to be produced during the electrolysis?

A. Hydrogen.
B. Silver.
C. Iodine.
D. Potassium.

Question 29

50.0 mL of 0.10 mol L^{-1} hydrochloric acid (HCl) is added to 50.0 mL of 0.30 M potassium hydroxide (KOH) solution and the reaction allowed to proceed to completion.
The concentration of potassium ions in the resulting solution, in mole per litre, is

A. 0.10
B. 0.15
C. 0.20
D. 0.30

Question 30

When 50 mL of 1.0 mol L^{-1} nitric acid, HNO_3(aq), is added to 50 mL of 1.0 mol L^{-1} potassium hydroxide solution, KOH (aq), the temperature of the mixture increases by 6.4 °C.
What should be the temperature change when 25 mL of each of these solutions are mixed together?

A. 1.6 °C.
B. 3.2 °C.
C. 6.4 °C.
D. 12.8 °C.

End of Section A

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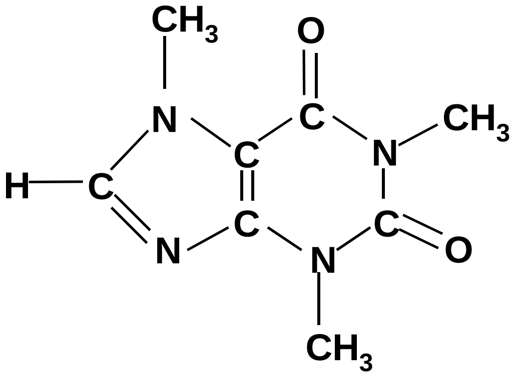
SECTION B – Short Answer Section

Section B consists of 8 short answer questions.
You should answer all of these questions in the spaces provided.
This section is worth approximately 78 per cent of the total marks available.
The marks allotted are shown at the end of each part of each question.

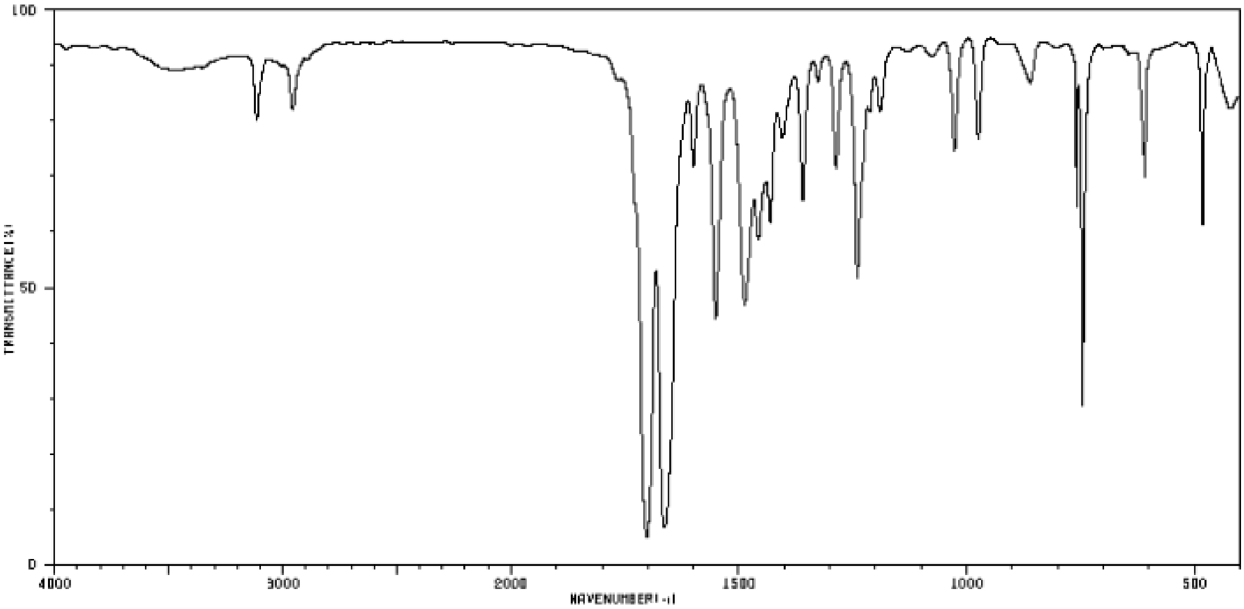
Question 1 (17 marks)
The Oxford Dictionary defines alkaloids as 'any of a class of nitrogenous organic compounds of plant origin which have pronounced psychological actions on humans'. Caffeine, which acts as a central system stimulant, is an alkaloid.
The structure of caffeine molecules is represented below.



a. Write the empirical formula of caffeine. **1 mark**

b. The mass spectrum of caffeine shows that the parent ion produces the most intense peak. Write the formula of the parent ion. **1 mark**

c. The IR spectrum of caffeine is shown below.



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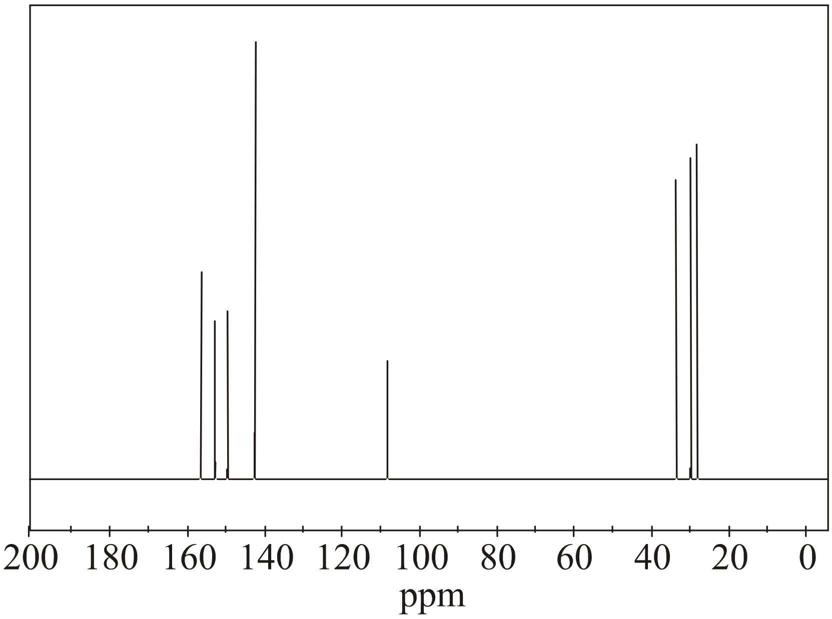
Explain the presence of **two** distinct strong peaks around 1650-1700 cm^{-1}. **2 marks**

d. The ^{13}C NMR spectrum of caffeine is shown below.



Explain the presence of eight peaks on the spectrum and why they all occur at different chemical shifts. **2 marks**

Decaffeination is the process of removing caffeine from coffee beans, cocoa, tea leaves and other caffeine containing materials.
In one method of decaffeination, coffee beans are steamed for 30 minutes and then rinsed with ethyl ethanoate for about 10 hours. The solvent is then drained away and the beans are steamed for another 10 hours to remove any remaining solvent.

e. The ethyl ethanoate used in this process is produced synthetically from ethene. Using semistructural formulae, use the boxes below to show an organic reaction pathway, including essential inorganic reactants and catalysts for the production of ethyl ethanoate from ethene. **5 marks**

f. Write a balanced chemical equation for the production of ethyl ethanoate. This is an equilibrium reaction. **1 mark**

g. The ΔH value for the correctly balanced equation for the production of ethyl ethanoate is +17.5 kJ mol^{-1}.

i. Give two advantages of heating the reaction mixture in a water bath. **2 marks**

ii. Why would the reaction mixture **not** be heated using a Bunsen burner? **1 mark**

h. One of the compounds involved in the production of ethyl ethanoate is also produced from biomass for use as a biofuel.
Write a balanced **thermochemica**l equation for the combustion of that biofuel. **2 marks**

Question 2 (14 marks)

The concentration of a solution of $CuSO_4(aq)$ was determined by electrogravimetric analysis. In this analysis a platinum electrode and a clean weighed copper electrode were placed in 100 mL of the solution and a current of 0.500 A was passed through the solution. Periodically the absorbance of the $CuSO_4(aq)$ is tested at a wavelength of 610 nm. The electrolysis was stopped when there was evidence that all the $Cu^{2+}(aq)$ had been converted to Cu(s). The copper electrode was removed from the solution, gently washed and dried.
The following data were recorded:

Mass of copper electrode before electrolysis = 11.27 g
Mass of copper electrode after electrolysis = 14.45 g

a. State the polarity of the electrodes. **1 mark**

copper –

platinum –

b. Write half-equations for the reactions most likely to be occurring at the electrodes during electrolysis. **2 marks**

copper –

platinum –

c. Assuming that the electrolysis was 100 per cent efficient, determine the concentration of the $CuSO_4(aq)$ solution. **2 marks**

d. What was the purpose of measuring the absorbance of the $CuSO_4$(aq) solution during the analysis? **1 mark**

e. Why was a wavelength of 610 nm used? **1 mark**

f. Assuming the electrolysis was continuous, what was the minimum time, in minutes, for which it should have run? **2 marks**

g. Give a reason why this was not a well-designed analytical method. **1 mark**

h. If the electrodes had been connected to the opposite terminals of the power supply, how would that have affected the $c(Cu^{2+})$ in the solution during the electrolysis? **1 mark**

i. The concentration of the $CuSO_4$(aq) could also have been determined by UV-Visible spectroscopy. State three key steps in that procedure. **3 marks**

Question 3 (14 marks)

Early in 2013 there was much discussion about the use of peptide supplements in sport in Australia. Some peptide supplements can work to help the body recover from strenuous activity and may be deemed usable. Others can encourage the body to release growth hormones and are generally banned.

One supplement, not a peptide, on the WADA (Word Anti-Doping Authority) list of prohibited supplements, is known by a variety of names including DMAA and Geranamine. Its systematic name is 4-methylhexan-2-amine. It is banned because of potential serious health risks.

a. Draw the structural formula, showing all bonds, of molecules of this compound. **1 mark**

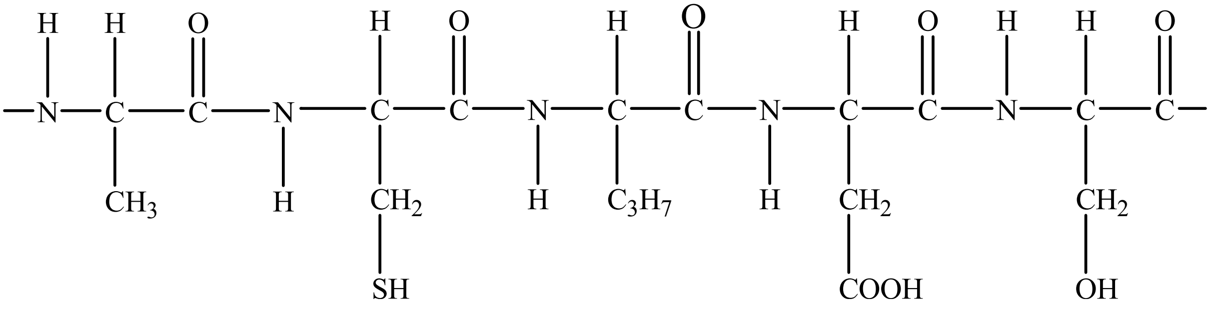
b. In some reports, DMAA has also been called 2-amino-4-methylhexane and incorrectly described as an amino acid supplement. Explain why DMMA is not an amino acid. **1 mark**

c. Give the systematic name of the amino acid, alanine. **1 mark**

d. Give the structural formula, showing all bonds, of the amino acid, aspartic acid, in solution at pH 11. **1 mark**

e. How is a tripeptide formed from its smaller units? **2 marks**

f. A section of a polypeptide is represented below

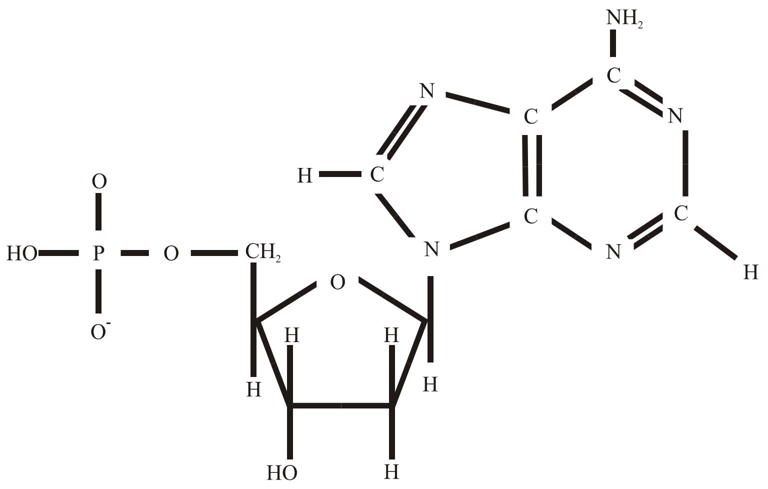


i. Circle a bond which maintains the primary structure of a protein. **1 mark**

ii. Place a hash sign (#) next to two 'different' atoms between which bonding responsible for maintaining the secondary structure of a protein occurs. **1 mark**

iii. Draw a rectangle around the atom commonly associated with the tertiary structure of a protein. **1 mark**

g. The structure of a nucleotide is represented below



i. Name the three species which combined to form this nucleotide. **2 marks**

ii. Circle the groups of atoms where reaction occurs when this nucleotide becomes part of the primary structure of DNA. **1 mark**

iii. Use hash signs (#) to show where bonding occurs between this nucleotide and its complement in the secondary structure of DNA. **1 mark**

h. Other than the total number of nucleotides in each strand of the double helix of DNA, what is the key factor in the overall strength of attraction between the strands? Explain your answer. **1 mark**

Question 4 (16 marks)

Annual global methanol production exceeds 50 million tonnes. Each day well over 100 000 tonnes of methanol are used as either chemical feedstock or fuel.

Methanol is produced from a variety of feedstocks, including natural gas, coal and biomass.

a. Production of methanol from natural gas requires the production of synthesis gas (a mixture of carbon monoxide and hydrogen). Methanol is produced from synthesis gas according to the equilibrium

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g); \quad \Delta H = -91 \text{ kJ mol}^{-1}$$

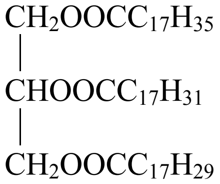
The catalyst used is a mixture of copper, zinc oxide and alumina.

i. What are two advantages arising from the use of the catalyst in methanol production? **2 marks**

ii. A sample of synthesis gas containing 0.240 mol of carbon monoxide and 0.380 mol of hydrogen was allowed to come to equilibrium in a 5.00 L reaction vessel. At equilibrium 0.170 mol of carbon monoxide was present. Determine the value of the equilibrium constant at the temperature of the equilibrium. **3 marks**

iii. When the temperature of the equilibrium established in **(ii.)** was altered, the value of the equilibrium constant was found to increase. Was the temperature increased or decreased? Explain your choice. **1 mark**

b. One industrial use of methanol is in the production of biofuels from vegetable oils such as

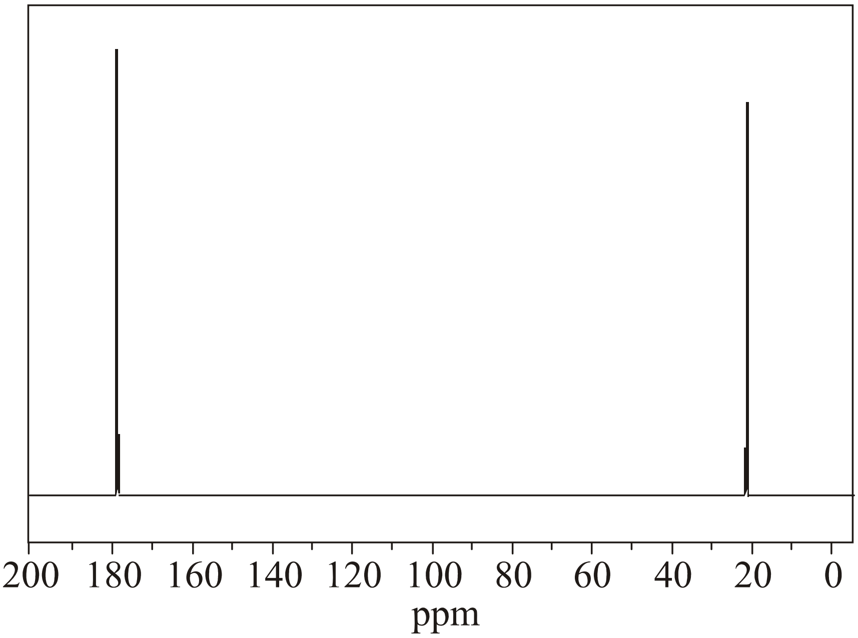


$$\begin{array}{l} CH_2OOCC_{17}H_{35} \\ | \\ CHOOCC_{17}H_{31} \\ | \\ CH_2OOCC_{17}H_{29} \end{array}$$

i. Give the molecular formula of the most common by-product of biodiesel production. **1 mark**

ii. 0.010 mol of one of the fatty acids available from the vegetable oil requires 7.61 g I_2 for complete reaction.
Identify the fatty acid and write a balanced equation for the production of methylester biodiesel from this fatty acid. **3 marks**

c. Another industrial use of methanol is the production of a carboxylic acid by reaction between methanol and carbon monoxide in the process known as methanol carbonylation.
Shown below is the ^{13}C NMR spectrum of the carboxylic acid.



i. Write a balanced equation for methanol carbonylation. **1 mark**

ii. This carboxylic acid can also be produced from another alcohol. Give the semi-structural formula of this other alcohol, describe the peaks you would expect to see on its high resolution ^{1}H NMR spectrum and identify the H atoms associated with each peak. **2 marks**

d. Methanol can be used as a fuel in two ways – by direct combustion or in a fuel cell.

i. What chemical property is methanol displaying when used as a fuel? **1 mark**

ii. Write balanced half-equations for the reactions occurring at the electrodes in a methanol-oxygen fuel cell with an acid electrolyte. **2 marks**

Question 5 (10 marks)

US Patent Number 81488020 issued in 2012 deals with the invention of a 'molybdenum-air' battery. The description of the invention includes the statement 'in accord with the present invention, the anode of a metal-air battery system includes an electrochemically active metal'. Metal-air batteries are typically lighter and provide more energy than ordinary primary batteries because of the use of air. The most commonly used metal-air battery is the zinc-battery, but molybdenum-air batteries have a higher energy density. Molybdenum-air batteries are efficient with both acid and alkaline electrolytes.

$H_2MoO_4(aq) + 6H^+(aq) + 6e^- \rightleftharpoons Mo(s) + 4H_2O(l)$ $E° = -0.11$ V
$MoO_4^{2-}(aq) + 4H_2O(l) + 6e^- \rightleftharpoons Mo(s) + 8OH^-(aq)$ $E^0 = -0.91$ V

a. **i.** Write the half-equation for the reaction at the cathode in an operating alkaline molybdenum-air battery. **1 mark**

ii. Write the overall equation for an operating alkaline molybdenum-air battery. **1 mark**

iii. What would be the expected operating voltage, at standard conditions, of an alkaline molybdenum-air cell? **1 mark**

b. Why can batteries such as the molybdenum-air battery contain a much greater proportion, by mass, of reductant than conventional primary cells? **1 mark**

c. In a zinc-air cell, the anode reaction is represented by the half-equation

$$Zn(s) + 2OH^{-}(aq) \rightarrow Zn(OH)_2(s) + 2e^{-}$$

The maximum operating cell voltage under standard conditions is 1.65 V.

i. Calculate the maximum amount, in kJ, of electrical energy available from the consumption of one mol Zn in an alkaline Zn-air battery. **1 mark**

ii. Calculate the maximum amount, in kJ, of electrical energy available from the consumption of one mol of Mo in an alkaline Mo-air battery. **1 mark**

iii. Energy density is the energy available per gram of reductant. Show that despite having a lower molar mass and higher cell voltage, the energy density of an alkaline Zn-air cell is smaller than the energy density of an alkaline Mo-air cell. **2 marks**

d. Lithium ion cells are secondary cells and so rechargeable. They have operating voltages up to 3.7 V. What are the two key requirements for correct recharging of a lithium ion cell? **2 marks**

Question 6 (14 marks)

Aqueous solutions of sodium thiosulfate, $Na_2S_2O_3(aq)$, and hydrochloric acid, $HCl(aq)$, react according to the equation.

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + SO_2(g) + S(s) + H_2O(l)$$

The production of solid sulfur makes the solution cloudy and provides a way to investigate the effect of various factors on the rate of the reaction.

a. Identify three factors that affect the rate of reaction, which could be investigated by measuring the change in turbidity (cloudiness) of the reaction mixture, with time. **1 mark**

b. A student decides to investigate the effect of concentration of sodium thiosulfate on the rate of this reaction by measuring the time it takes for a black cross, placed under the reaction beaker, to fully disappear when looking down through the solution. Identify three properties that should be kept constant during the investigation. **2 marks**

c. The student investigates the following reaction mixtures at room temperature.

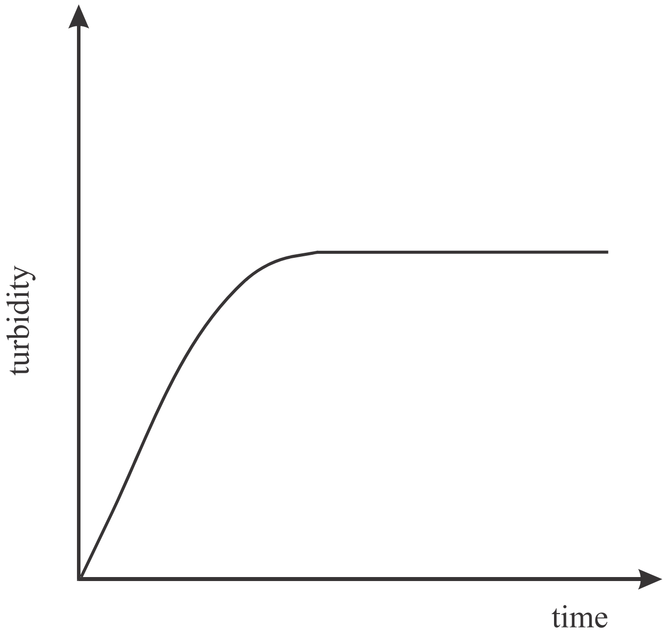
Investigation Number	$Na_2S_2O_3(aq)$	$HCl(aq)$	Water
1	10 mL of 0.25 M	5.0 mL of 2.0 M	35 mL
2	25 mL of 0.25 M	5.0 mL of 2.0 M	20 mL
3	40 mL of 0.25 M	5.0 mL of 2.0 M	5.0 mL

i. Discuss how these reaction mixtures would provide evidence of the effect of changes in the $c(Na_2S_2O_3)$ on the rate of the reaction. **2 marks**

ii. What is the concentration of $Na_2S_2O_3(aq)$ in the reaction mixture at the **start of the reaction** in Investigation 2? **1 mark**

iii. What should be the concentration of $Cl^-(aq)$ in the reaction mixture when the reaction in Investigation 2 is complete? **1 mark**

d. The diagram below represents a graph of turbidity (cloudiness) against time for Investigation 2.



i. Why does the turbidity eventually become constant? **1 mark**

ii. On the same diagram, draw a graph representing Investigation 3. **2 marks**

e. In another investigation of factors affecting the rate of reaction between $Na_2S_2O_3(s)$ and 2.0 MHCl(aq), the following data were recorded.

Na_2SO_3 description	*n*($Na_2S_2O_3$)	*V*(HCl)	Reaction time
Pellets	2.0 g	25 mL	57 seconds
Powder	2.0 g	25 mL	6.5 seconds

What factor was being investigated and are the results consistent with collision theory? Explain. **2 marks**

f. Discuss the validity of the following statement *'catalysts and higher temperatures increase reaction rate by increasing the proportion of successful collisions'*. **2 marks**

Question 7 (9 marks)

The Kjeldahl method in analytical chemistry is a method for the determination of the nitrogen content of substances. It was developed by Johan Kjedahl in 1883 and 130 years later is still an official standard method for the determination of nitrogen in all kinds of food samples. It is also used in environmental analysis and in agriculture for determining nitrates and ammonium content.

In an analysis of a food sample for nitrogen content, the following steps were followed.

1. The sample was digested in sulfuric acid to convert all the nitrogen to $NH_4^+(aq)$
   N containing compound $\rightarrow NH_4^+(aq)$.
2. NaOH(aq) is then added to the mixture to convert all the $NH_4^+(aq)$ ions to $NH_3(g)$
   $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$.
   The solution is heated to ensure that all the $NH_3(g)$ is liberated.
3. The liberated $NH_3(g)$ is then passed into 100.0 mL of 0.100 M HCl(aq).
4. When all the $NH_3(g)$ has been absorbed, the solution from (3.) is titrated with 0.200 M NaOH.
   The following data were recorded:
   Mass of food sample: 5.152 g
   Average titre volume: 31.4 mL

a. Write balanced equations for the reactions occurring in Steps 3 and 4. **2 marks**

b. Calculate the *n*(HCl) which reacted with the $NH_3(g)$ produced from the food sample. **2 marks**

c. Calculate the mass of nitrogen present in the food sample. **1 mark**

d. Determine the %, by mass, of nitrogen in the food sample. **1 mark**

e. In an alternative version of the Kjeldahl process, the $NH_3(g)$ produced is absorbed into boric acid solution, $H_3BO_3(aq)$.
Boric acid is a weak acid. Its hydrolysis may be represented by the equilibrium

$$H_3BO_3(aq) + H_2O(l) \rightleftharpoons B(OH)_4^-(aq) + H^+(aq)$$

What would be the pH, at 25°C of a 0.647 M aqueous solution of boric acid? **3 marks**

Question 8 (11 marks)
When 0.444 g sample of sucrose ($C_{12}H_{22}O_{11}$) undergoes complete combustion in a bomb calorimeter, the temperature increases from 20.00 °C to 22.06 °C.
The calorimeter contains 748 mL of water.
420 J is required to raise the temperature of the bomb and other **non-aqueous** internal calorimeter components by 1°C.

a. Calculate the molar enthalpy of combustion of sucrose. **4 marks**

b. Write a balanced equation for the combustion of sucrose. **1 mark**

c. Maltose, $C_{12}H_{22}O_{11}$, is a disaccharide which can be a source of the biofuel, ethanol. During hydrolysis it is converted to glucose, $C_6H_{12}O_6$, which is then converted to ethanol during fermentation.

- **i.** Write a balanced equation for the conversion of maltose to glucose. **1 mark**

- **ii.** Write a balanced equation for the fermentation of glucose. **1 mark**

d. 2.00 g of ethanol undergoes complete combustion in a bomb calorimeter with a total calorimeter constant of 1.32 kJ °C^{-1}.

i. What is the maximum possible change in temperature? **3 marks**

ii. Give one reason why the actual temperature change might fall short of the maximum possible temperature change. **1 mark**

End of Section B

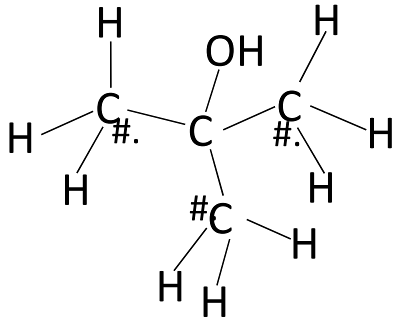
End of Trial Exam

Suggested Answers

VCE Chemistry 2013 Year 12 Trial Exam Unit 3/4

SECTION A – Multiple Choice Answers

Q1 D The compound is an alcohol because the IR spectrum shows a distinct O-H (**alcohols**) absorption in the 3200-3550 cm^{-1} band and a separate C-H absorption in the 2850-3300 cm^{-1} band.
The ^{13}C NMR spectrum shows two peaks indicating two different carbon environments.
2-butanol, $CH_3CH_2CHOHCH_3$ has 4 different carbon environments.
1-propanol, $CH_3CH_2CH_2OH$ has 3 different carbon environments.
Ethanoic acid, CH_3COOH, has 2 different carbon environments but is **not an alcohol.**
2-methylpropan-2-ol, $(CH_3)_3COH$, has 2 different carbon environments, all the asterisked (#) C atoms in the structure shown below have the same bonding environment.



Q2 C The H_2O present in the moist sample is **not** represented in the equation for the decomposition of $NaHCO_3$.
Use the mass of solid product, Na_2CO_3, and the equation to calculate the $m(NaHCO_3)$ present in the moist sample. Then subtract the calculated $m(NaHCO_3)$ from the mass of the most sample.
$n(Na_2CO_3)$ produced $= 0.528$ g / 106.0 g mol^{-1}
$= 0.00498$ mol
$n(NaHCO_3)$ reacting $= 2 \times 0.00498$
$= 0.00996$
$m(NaHCO_3)$ in moist sample $= 0.00996$ mol x 84.0 g mol^{-1}
$= 0.837$ g
$m(H_2O)$ in moist sample $= m(\text{sample}) - m(NaHCO_3)$
$= 1.275 - 0.837$
$= \mathbf{0.438\ g}$

Q3 C 0.10 M solutions of strong monoprotic acids have pH =1 at 25°C
0.10 M solutions of weak acids have pH > 1 at 25°C
0.10 M solutions of strong bases have pH =13 at 25°C
0.10 M solutions of weak bases have pH < 13 at 25°C
Only titration curve D is for a reaction in which an acid is added to a base, but it is for a strong acid reacting with a strong base. The other three curves are for the addition of a base to an acid.
NH_3(aq) is a **weak base**, **HCl(aq)** is **strong acid**.
Titration curve C represents **the titration of 0.10 M HCl(aq) by 0.10 M NH_3(aq).**
The reaction occurring is **$NH_3(aq) + HCl(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$.**
At the **equivalence point,** the pH of the solution is determined by the products of the reaction. Since **NH_4^+(aq)** is a **weak acid**, the **pH** will be **less than 7** (**about 5.3**).

Q4 A The choice of indicator is determined by the expected pH at the equivalence point. The approximate pH values at the equivalence point on the titration curves, and appropriate indicators *(Data Book Table 11)* are
Curve A: 9; **phenolphthalein**
Curve B: 7; **bromothymol blue** (phenol red, methyl red could also be effective)
Curve C: 5; **methyl red**
Curve D: 7; **bromothymol blue** (phenol red, phenolphthalein could also be effective)
Methyl orange, pH range 3.1-4.4 would be the **least suitable** choice of indicator.

Q5 A In the electrochemical series (*Data Book Table 2)* the *E*° values for half-cells which involve a gas are
+2.87, +1.36, +1.23, +0.68, +0.40, +0.14, 0.00, -0.83.
The cell voltage of 1.22 V reflects the difference between the *E*° values of the two half-cells.

$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	1.36 V
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$	0.14 V

Cell half-equations
Anode (-): $H_2S(g) \rightarrow S(s) + 2H^+(aq) + 2e^-$
Cathode (+): $Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$
At the **anode**: pH decreases and a **solid** (sulfur) **is produced**.
At the cathode: gas is consumed.

Q6 D When $HClO_4$ acts as an oxidant, the oxidation number of chlorine changes. Since $HClO_4$ is the oxidant, it causes oxidation and as a consequence is itself reduced. Hence the oxidation number of Cl should decrease.
Applying the general rules of oxidation numbers, the oxidation numbers of Cl in the four alternatives are
Cl_2: 0
Cl_2O: +1
ClO_2: +4
Cl_2O_7: +7
The oxidation number of Cl in $HClO_4$ is +7.
Cl_2O_7 will not be a reduction product of $HClO_4$ because the oxidation number of Cl is +7 in both.

Q7 D $LiH(s) + H_2O(aq) \rightarrow Li^+(aq) + H_2(g) + OH^-(aq)$

Whilst the reaction is an **hydrolysis reaction** – i.e. the LiH reacts with rather than dissolves in water – this description **does not reflect all the chemistry** involved in the reaction.

Consider the oxidation numbers of H

LiH: -1, H_2O: +1; H_2: 0; OH^-: +1

The H^- (hydride) ion in LiH has been oxidised; oxidation number of H increases from -1 in LiH to 0 in H_2

H_2O has been reduced; oxidation number of H decrease from +1 in H_2O to 0 in H_2

This reaction is a **redox reaction**.

The presence of $OH^-(aq)$ as a product suggests that **water has acted as an acid** and donated H^+ (a proton) to a base. But what was the base?

The H^- which is present in LiH(s) has been converted to $H_2(g)$, i.e. **H^- has acted as the base** and accepted $H^+(aq)$ in forming $H_2(g)$.

This reaction is an **acid-base** reaction.

Q8 B The combustion of glucose is exothermic, so the temperature in the calorimeter will rise.

According to Data Book; $\Delta H_c(C_6H_{12}O_6) = -2816\ kJ\ mol^{-1}$

$n(C_6H_{12}O_6) = 1.05 / 180.0$

$= 5.83 \times 10^{-3}$ mol

E released by 1.05 g $C_6H_{12}O_6$ $= 5.83 \times 10^{-3}$ mol x 2816 kJ mol^{-1}

$= 16.4$ kJ

Since $E = CF \times \Delta T$ then $\Delta T = E / CF$

$= 16.4$ kJ / 2.35 kJ °C^{-1}

$= 6.99$ °C

Final temperature = 22.7 + 6.99 = **29.7°C**

This is the maximum temperature reached if there is no loss of heat to the atmosphere.

Q9 A The vanadium species with the four oxidation states are

+5 – VO_3^-

+4 – VO^{2+}

+3 – V^{3+}

+2 – V^{2+}

So the electrolytes around the electrodes contain $VO_3^-(aq)/VO^{2+}(aq)$ and $V^{3+}(aq)/V^{2+}(aq)$ respectively.

When the battery discharges, i.e. converts chemical energy to electrical energy, electrons move from the (-) electrode to the (+) electrode. Discharge involves the reaction between the strongest reductant present (V^{2+}) and the strongest oxidant present (VO_3^-).

Discharge half-equations.

(-) electrode: $V^{2+}(aq) \rightarrow V^{3+}(aq) + e^-$

(+) electrode: $VO_3^-(aq) + 4H^+(aq) + e^- \rightarrow VO^{2+}(aq) + 2H_2O(l)$

During recharging, the half-equations at the electrodes are reversed as electrons are forced to flow from the (+) electrode to the (-) electrode.

Recharging half-equations.

(-) electrode: $V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$

(+) electrode: $\mathbf{VO^{2+}(aq) + 2H_2O(l) \rightarrow VO_3^-(aq) + 4H^+(aq) + e^-}$

Q10 D Investigations 1 and 2 showed the effect of a change in pressure at constant temperature. The data show that the yield of product is greater at higher pressure. This is also shown from the data for Investigations 3 and 4.
According to Le Chatelier's principle, an equilibrium system will partially oppose an increase in pressure by favouring the side of the equilibrium reaction with fewer particles. Since the yield of product is higher, there are **fewer particles on the right hand side**.
Investigations 2 and 3 showed the effect of a change in temperature at constant pressure. They showed that the yield decreased when the temperature was increased. An increase in temperature favours the endothermic reaction which, since the yield decreased, must be the reverse reaction. Hence the **forward reaction is exothermic**.

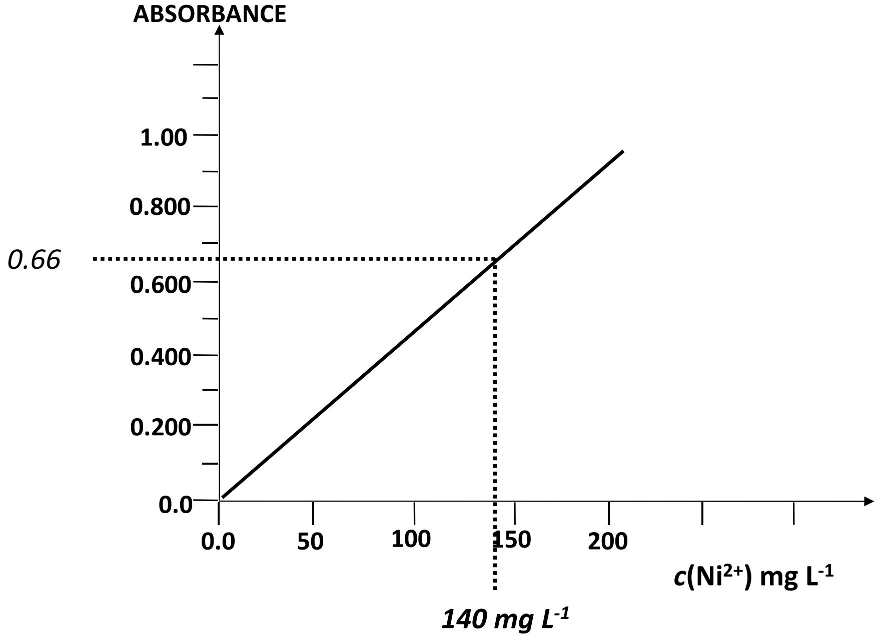
Q11 C Consider the alternatives.

A. Fuel cells are **not 100 % efficient in the conversion of chemical energy to electrical energy**. Chemical energy is also converted to heat energy.
B. Fuel cells utilise both acid and **alkaline electrolytes**.
C. The **overall chemical equation for a fuel cell is the same as the equation for the combustion of the fuel** used. In direct combustion, the fuel and oxygen are in direct contact and so chemical energy is converted to thermal energy. In fuel cells the fuel and oxygen do not come in contact, and the flow of electrons from the anode (oxidation of the fuel) to the cathode (reduction of oxygen) is indicative of the conversion of chemical energy to electrical energy.
D. Fuel cells are **not rechargeable**, they require a continuous supply of fuel and oxygen to operate.

Q12 D The reaction occurring was
$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$.
Addition of increasing volumes of $BaCl_2(aq)$ will at some point make $Na_2SO_4(aq)$ the limiting reagent, and at that point the maximum mass of $BaSO_4$ will have precipitated.
All students used 100 mL of 0.34 M $Na_2SO_4(aq)$.
$n(Na_2SO_4) = 0.34 \text{ mol L}^{-1} \times 100\times10^{-3}\text{L}$
$= 0.034$ mol
Maximum $n(BaSO_4)$ that could be produced = 0.034 mol
Maximum $m(BaSO_4)$ $= 0.034 \text{ mol} \times 233.4 \text{ g mol}^{-1}$
= **7.9 g**
$n(BaCl_2)$ required to produce 7.9 g $BaSO_4$ = $n(BaSO_4)$ = 0.034 mol
$V(BaCl_2)$ required $= n(BaCl_2) / c(BaCl_2)$
$= 0.034 \text{ mol} / 0.50 \text{ mol L}^{-1}$
= 0.068 L
= **68 mL**
This is consistent with **Graph D**.

Q13 A Using 1.0 M $BaCl_2(aq)$, i.e. twice as concentrated as 0.50 M, means that only half as much, i.e. 34 mL, will be required to precipitate the maximum amount of $BaSO_4$.
Maximum mass $BaSO_4$ = 7.9 g
$V(BaCl_2)$ required = 34 mL
This is consistent with **Graph A.**

Q14 **B** Use the calibration curve to determine the $c(\text{Ni}^{2+})$ in the 25.0 mL aliquots.



140 mg L^{-1} Ni $\rightarrow$ (140 / 1000) x 25 mg Ni in 25 mL aliquot
$\rightarrow$ 3.5 mg Ni in 25 mL aliquot
All the Ni from 5.00 g of the ore was in the original 200 mL of solution.
m(Ni) in 5.00 g ore = m(Ni) in 200 mL solution
= (3.5 / 25) x 200
= 28 mg
% Ni in ore = (m(Ni) g / m(ore) g) x 100
= $(28\text{x}10^{-3} / 5.0)$ x 100
= **0.56 %**

Q15 **B** 2-methyl butanoic acid
- semi-structural formula: $CH_3CH_2CH(CH_3)COOH$
- molecular formula: $C_5H_{10}O_2$
- alternatively, since carboxylic acids have the molecular formula $C_nH_{2n}O_2$, and 2-each methyl butanoic acid molecule has 5 C atoms, its molecular formula must be $C_5H_{10}O_2$.

$n(C_5H_{10}O_2) = N(C_5H_{10}O_2) / N_A$
$= 1 / 6.02\text{x}10^{23}$
$= 1.66\text{x}10^{-24}$ mol
$n(\text{C}) = 5 \text{ x } 1.66\text{x}10^{-24}$
$= 8.31\text{x}10^{-24}$ mol
$m(\text{C}) = 8.31\text{x}10^{-24}$ mol x 12.0 g mol^{-1}
$= 9.97\text{x}10^{-23}$ g
$= 9.97\text{x}10^{-23} \text{ x } 10^{12}$ (1 g = 10^{12} pg)
= **$9.97\text{x}10^{-11}$ pg**

Q16 C $n(KMnO_4)$ consumed = 1.25 / (39.1 + 54.9 + 4x16.0)
= 0.00791 mol

$n(e^-)$ transferred = Q / F
= 2290 C / 96500 C mol^{-1}
= 0.02373 mol

Ratio $n(e^-) / n(KMnO_4)$ = 0.02373 / 0.00791 = 3

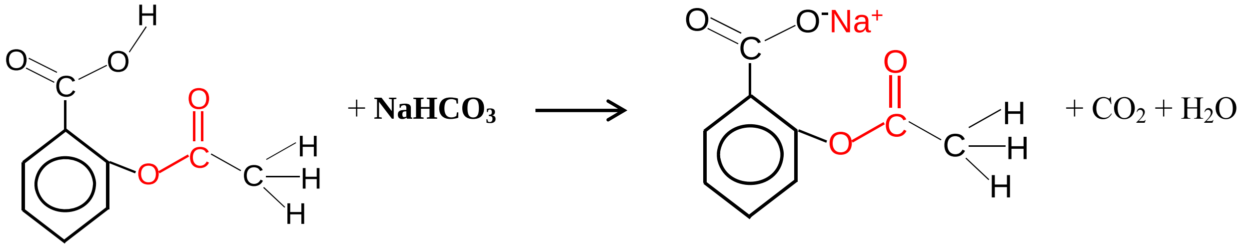
So the oxidation number of Mn has decreased by 3 as the MnO_4^- causes oxidation and is itself reduced.

Final oxidation number of Mn is +4 (decreased from +7 in $KMnO_4$).

The oxidation product in which Mn may be assigned +4 as its oxidation number is **MnO_2**. It would be produced according to the half-equation

$MnO_4^-(aq) + 4H^+(aq) + 3e^- \rightarrow MnO_2(s) + 2H_2O(l)$

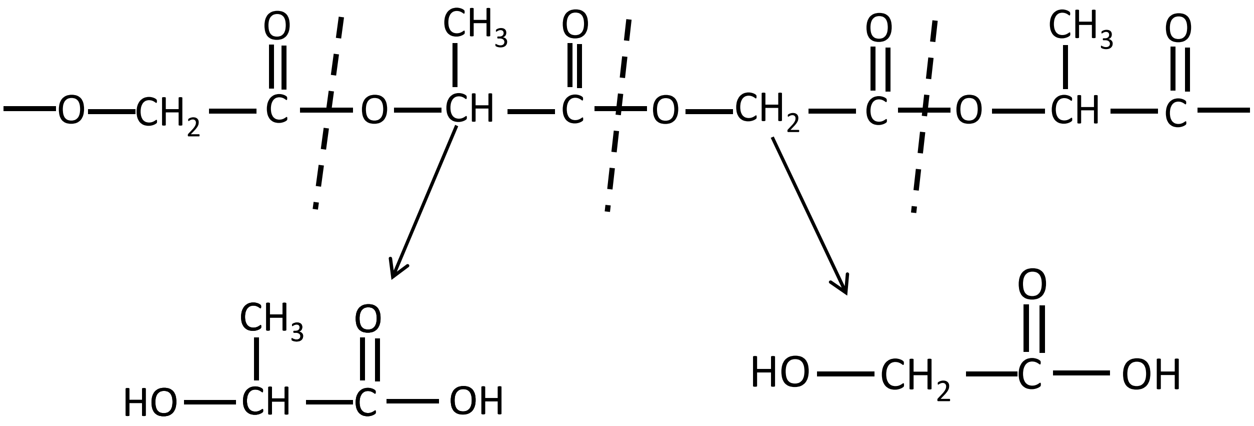
Q17 D The balanced equation for the reaction is



Compound X was **sodium hydrogen carbonate**

Sodium carbonate could also be used but one mol Na_2CO_3 would react with two mol of acetyl salicylic acid.

Q18 A PLGA is a polyester. During hydrolysis, **water reacts with the ester groups to convert them back to carboxyl, -COOH, and hydroxyl, -OH, groups**.



Q19 D At time **t,** the rates of both the forward and reverse reactions instantaneously increase. This can only happen if the concentrations of $NO_2(g)$ and $N_2O_4(g)$ both increase. This would happen if the **volume of the container was decreased** at time **t**.

The subsequent changes in the rates are consistent with this change. When the volume is decreased, the pressure increases and so the reaction producing fewer particles is favoured as the system moves to partially compensate for the pressure increase.

As the system moves to produce fewer particles the $[NO_2]$ decreases and the $[N_2O_4]$ increases, hence the rate of the forward reaction decreases and the rate of the reverse reaction continues to increase. This continues until both rates are equal when equilibrium is re-established, but the rates will be higher than initially because of the increased concentrations.

Q20 B The General equation for the ionisation of a weak acid is

$HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$, for which

$K_a = [H_3O^+][A^-] / [HA]$

Applying the standard weak acid assumptions:

Insignificant contribution to the [H3O+] from the self-ionisation of water

Minimal ionisation of the acid, i.e. [HA]equilibrium = [HA]initially

the equilibrium law simplifies to

$K_a = [H_3O^+]^2 / [HA]$

For 0.10 M solution

$pH = 2.6 \rightarrow [H_3O^+] = 10^{-2.6}$ M (0.0025 M)

$K_a = (10^{-2.6})^2 / 0.10$

$= 6.31 \times 10^{-5}$ ….. *benzoic acid, C_6H_5COOH - Data Book Table 12*

When the solution is diluted, the same K_a applies because the temperature is still 25°C.

The original solution was diluted by a factor of 25 (10 mL to 250 mL)

After dilution $[HA] = 0.10 / 25$

$= 0.0040$ M

$K_a = [H_3O^+]^2 / [HA]$

$6.31 \times 10^{-5} = [H_3O^+]^2 / 0.0040$

$[H_3O^+]^2 = 0.0040 \times 6.31 \times 10^{-5}$

$[H_3O^+] = \sqrt{(0.0040 \times 6.31 \times 10^{-5})}$

$= 5.02 \times 10^{-4}$

$pH = -\log_{10}(5.02 \times 10^{-4})$

= 3.30

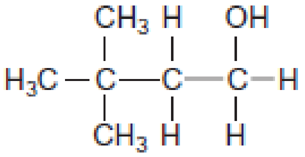
Q21 C $n(H_2O)$ converted to steam = 1.00×10^3 g / 18.0 g mol^{-1}
= 55.6 mol
Energy required to produce steam = $n(H_2O)$ x Energy per mol H_2O
= 55.6 mol x 44.0 kJ mol^{-1}
= 2.44×10^3 kJ
Since 40 % of the energy released in the combustion of methane is transferred to $H_2O(l)$.
2.44×10^3 kJ = 0.40 x Energy released from combustion of CH_4
Energy from CH_4 = 2.44×10^3 / 0.40
= 6.11×10^3 kJ
$n(CH_4)$ required = Energy from CH_4 / Energy released per mol CH_4
= 6.11×10^3 kJ / 889 kJ mol^{-1} [Data Book Table 12]
= 6.87 mol
$m(CH_4)$ required = 6.87 mol x 16.0 g mol^{-1}
= 110 g

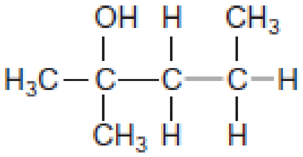
Q22 D The major components in foods are proteins, fats and carbohydrates. These are analysed using chromatography. However the large size of the molecules and temperature sensitivity, i.e. sugars decomposing, and proteins denaturing on heating means that HPLC is a better option than GC.

Q23 D The calculations associated with this analysis would proceed along the lines of
$n(Na_2CO_3)$ in 20.0 mL aliquot
$n(HCl)$ added from burette = 2 x $n(Na_2CO_3)$
$c(HCl)$ in diluted brick cleaner = $n(HCl)$ / ***V*(titre)**
$c(HCl)$ in brick cleaner = $c(HCl)$ in diluted brick cleaner x dilution factor**.**
The only variable in this calculation sequence is the volume of diluted brick cleaner added from the burette. Since the calculations involve dividing by the titre volume, a larger volume will lead to a lower calculated $c(HCl)$ in the brick cleaner, whilst a lower volume will lead to a higher calculated concentration.
Consider the alternatives.
If the pipette used to transfer to $Na_2CO_3(aq)$ aliquot is rinsed only with water, there will be slightly less Na_2CO_3 present in the aliquot and so a smaller titre volume will be required → higher than true calculated c(HCl).
If the titration flask is rinsed with diluted brick cleaner, some of the added $Na_2CO_3(aq)$ in the 20.0 mL aliquot will react with the HCl in the traces of diluted brick cleaner remaining. There will be less Na_2CO_3 to react during the titration, so a smaller titre volume will be required → higher than true calculated c(HCl).
Water in the titration flask will have no effect on the titre volume used because it does not affect the $n(Na_2CO_3)$ available to react with HCl(aq) in the diluted brick cleaner.
If the burette is rinsed only with water, the traces remaining will further dilute the added dilute brick cleaner. Hence a larger titre will be required to provide the n(HCl) needed to react with the $Na_2CO_3(aq)$ → lower than true calculated c(HCl).

Q24 A The mass spectrum suggests that the parent ion has a relative mass of 74.
The IR spectrum information suggests the presence of C=O.
Both carboxylic acids and esters contain a C=O bond.
The ^{13}C NMR spectrum suggests 3 different carbon environments.
Both acids and esters have molecular formula $C_nH_{2n}O_2$, which for 3 C is $C_3H_6O_2$
$M_r(C_3H_6O_2) = 74$
Substance could be
propanoic acid, CH_3CH_2COOH *or*
ethyl methanoate, $HCOOCH_2CH_3$ *or*
methyl ethanoate, CH_3COOCH_3.
Both ethyl methanoate and propanoic have CH_3CH_2- hence will show a **quartet** (for H on CH_2) and a **triplet** (for H on CH_3), as per the n+1 rule for splitting of signals for H on adjacent C atoms.
However the quartet at chemical shift 4.1 *(Data Book Table 5)* suggests that the compound has an ethyl group bonded the second O of the ester group.
Compound is **ethyl methanoate,** $HCOOCH_2CH_3$.

Q25 B The two compounds are structural isomers and have the molecular formula, $C_6H_{14}O$.
The compounds are





3,3-dimethylbutan-2-ol	2-methyl-pentan-2-ol
A. oxidised to the acid	oxidised but NOT to the acid
B. parent ion *m*/*z* = 102	parent ion *m*/*z* = 102
C. fingerprint region	fingerprint region
D. ^{13}C NMR – 4 peaks	^{13}C NMR – 5 peaks

Only alcohols with the hydroxyl –OH group bonded to C-1, i.e. the end carbon, can be oxidised to a carboxylic acid.
Since all compounds have unique fingerprint regions, the only one of the listed characteristics in which they did **not differ** was the ***m*/z value of the parent ion peak**.

Q26 C The nature of the aqueous solutions is represented in the equations below.
$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$
$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$
$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
$NaCl(aq) \rightarrow Na^+(aq) + Cl^-(aq)$
The $[OH^-]$ is most significant in $NH_3(aq)$. Doubling the volume by **adding 50 mL of water instantaneously halves concentrations**.
However the impact is an increase in the extent of ionisation of aqueous solutions of weak acids and weak bases. For both $CH_3COOH(aq)$ and $NH_3(aq)$, the volume increases, and concentration decreases, causing the concentration fraction to become less than *K*. As the systems move to return to equilibrium, the forward reaction is favoured. It is in **$NH_3(aq)$** that this causes an **increase in $[OH^-]$ as the system returns to equilibrium**.

Q27 B The most **fundamental difference** between fuel cells and electrolytic cells is the **dominant energy conversion** occurring in the cells.

In all **fuel cells, chemical energy is converted to electrical energy** BUT in **electrolytic cells, electrical energy is converted to chemical energy**.

With respect to the ‘supply of reactants from outside the cell’, this does happen in all fuel cells but also happens in some electrolytic cells, so it is not the ‘best’ distinguishing feature.

Electrons leave the anode – the site of oxidation – in all electrochemical cells.

Aqueous electrolytes are present in many fuel cells and many electrolytic cells.

Q28 A **KI(l)** contains $K^+(l)$ – oxidant , and $I^-(l)$ – reductant ions

Half-equations occurring during electrolysis (*referring to Data Book – Table 2 Electrochemical series*)

Anode (+); $2I^-(l) \rightarrow \mathbf{I_2}(s) + 2e^-$

Cathode (-); $K^+(l) + e^- \rightarrow \mathbf{K}(s)$

$AgNO_3$(aq) contains $Ag^+(aq)$, $H_2O(l)$ – oxidants, and $H_2O(l)$ – reductants.

$NO_3^-(aq)$ is not included in the electrochemical series in the Data Book and can be ignored.

The stronger oxidant is $Ag^+(aq)$.

Half-equations occurring during electrolysis (*referring to Data Book – Table 2 Electrochemical series*)

Anode (+); $2H_2O(l) \rightarrow \mathbf{O_2}(g) + 4H^+(aq) + 4e^-$

Cathode (-); $Ag^+(aq) + e^- \rightarrow \mathbf{Ag}(s)$

Because $Ag^+(aq)$ is reduced in preference to H_2O, $H_2(g)$ is least likely to be produced.

Q29 B $KOH(aq)$ contains $K^+(aq)$ and $OH^-(aq)$ ions. The $K^+(aq)$ ions are not involved in the neutralisation reaction.

$KOH(aq) + HCl(aq) \rightarrow KCl(aq) + H_2O(l)$

Since the $K^+(aq)$ ions that were initially in 50.0 mL of 0.30 M KOH(aq) finish up in 100 mL of solution after the addition of 50.0 mL of 0.10 M HCl(aq), i.e. the volume occupied has doubled, the $[K^+]$ halves from 0.30 M to **0.15 M.**

If you did not pick up on the ‘spectator ion’ nature of the $K^+(aq)$ *and base your calculation on the n(KOH) in excess – incorrect because it assumes* K^+ *as well* OH^- *reacts, you would get 0.10 M or 0.20 M depending on whether you use 100 mL or 500 mL as your total volume.*

Q30 C The reaction occurring is the exothermic neutralisation reaction

$HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + HCl(aq)$

25.0 mL 1.0 M $HNO_3(aq)$ reacting with 25.0 mL of 1.0 M KOH(aq) will release half as much thermal energy as 50.0 mL 1.0 M $HNO_3(aq)$ reacting with 50.0 mL of 1.0 M KOH(aq).

However, half as much energy is being released into half the total volume, i.e. 50 mL rather than 100 mL.

So the temperature change will be the same, i.e. **6.4 °C.**

SECTION B – Short Answer (Answers)

Question 1

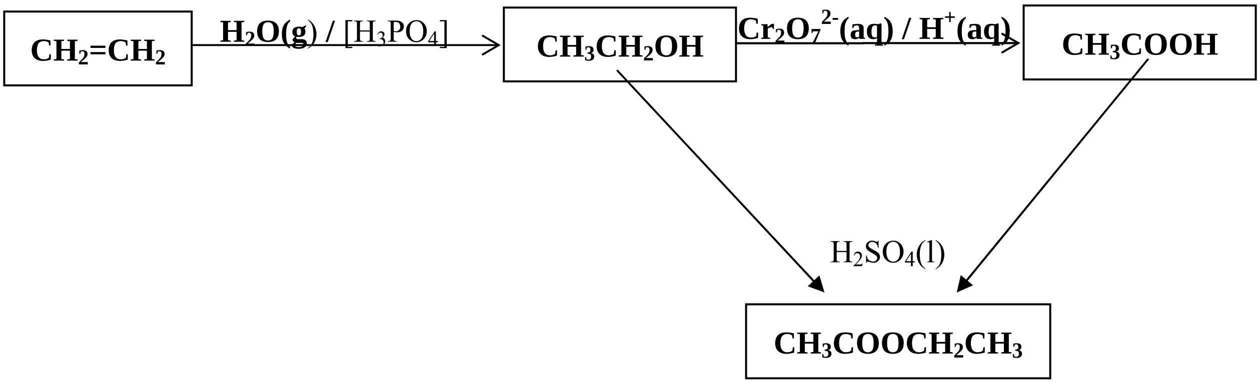
a. The molecular formula, deduced from the structure given, is $C_8H_{10}N_4O_2$, hence the empirical formula is $C_4H_5N_4O_2$ ❶

b. $[C_8H_{10}N_4O_2]^+$ ❶

c. The two peaks are in the absorption band 1670-1750 cm^{-1} (Data Book) and are caused by the two C=O groups ❶ in the molecule.
The peaks are centred at slightly different wavenumbers because of the different bonding environments in the caffeine molecule; one C=O is between two N atoms whilst the other C=O is between one C and one N atom. ❶

d. There are eight peaks and there are 8 'different' carbon atoms ❶ in the caffeine molecule. Each C atom has a different bonding environment (looking through the whole molecule) ❶. This means each C nucleus has different exposure to the external magnetic field and so requires a different amount of energy to change its nuclear spin state.

e.



Two marks ❶❶ for the four semi-structural formulae correct; one mark if two or three correct.
One mark ❶ for **$H_2O(g)$** / $[H_3PO_4]$
One mark ❶ **$Cr_2O_7^{2-}(aq)$ / $H^+(aq)$**
One mark ❶ **$[H_2SO_4(l)]$**
The use of [] here is simply to remind students these substances act as catalysts in this pathway.

f. $CH_3CH_2OH(l) + CH_3COOH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$ ❶
NB Correct states and equilibrium arrows necessary for the mark.

g. **i.** Because the forward reaction is endothermic, the **yield of ethyl ethanoate will be increased.** ❶
The higher temperature will **increase the rate of reaction.** ❶
ii. Ethanol is volatile and very flammable and should not be used near a naked flame. There would be a high risk of explosion. ❶
Ethanoic acid is also flammable - it has a flash point of about 44 °C, (ethanol 15 °C)

h. **$CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ ❶, ΔH = -1364 kJ mol^{-1} ❶**
[Data Book Table 13]

Question 2

a. copper **(-)**, platinum **(+)** ❶

b. (-) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ ❶

(+) $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$ ❶

c. $m(Cu)$ produced during electrolysis = 14.45 – 11.27

= 3.18 g

$n(CuSO_4)$ in 100 mL solution = $n(Cu)$ produced

= 3.18 g / 63.5 g mol^{-1}

= 0.0501 mol ❶

$c(CuSO_4)$ = 0.0501 / 100×10^{-3}

= **0.501 mol L^{-1}** ❶

d. The absorbance was measured to determine when to stop the electrolysis. When the absorbance reading was zero, or constant close to zero, the all Cu^{2+} ions would have been reduced and deposited as Cu on the cathode. ❶

e. 610 nm would have been identified as a wavelength at which $Cu^{2+}(aq)$ absorb strongly but other species in the solution do not. ❶

f. Q = It; to determine Q and I are needed

Q = n(e-) x F = 2 x n(Cu) x F

= 2 x 0.0501 x 96500

= 9.70×10^3 C ❶

t = Q / I

= 9.70×10^3/ 0.500

= 1.93x104 seconds

= 322 minutes ❶

g. The time taken for the analysis, over 5 hours, is excessive given that the analysis is simply to determine the concentration of a solution. ❶ or

Predicted reactions, based on the electrochemical series are only accurate for 1 M solutions. Since the $c(Cu^{2+})$ is below 1 M initially, and decreases as the electrolysis proceeds, other reactions may be occurring ***or***

maintaining a current of 0.500 A over this time period would be difficult.

h. The $c(Cu^{2+})$ would stay constant during the electrolysis. ❶

The (+) Cu electrode would be site of oxidation where Cu(s) is oxidised to $Cu^{2+}(aq)$.

The (-) Pt electrode would be the site of reduction where $Cu^{2+}(aq)$ is reduced to Cu(s).

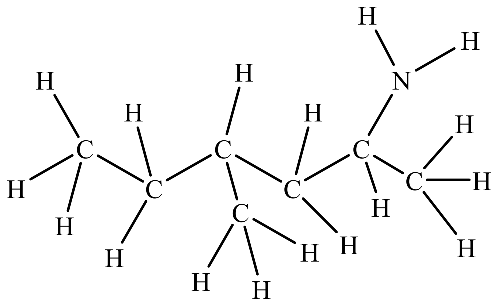
i. Make up a set of standard $Cu^{2+}(aq)$ solutions and measure their absorbance at 610 nm. ❶

Plot a calibration curve to establish the relationship between absorbance and $c(Cu^{2+})$. ❶

Measure the absorbance of $CuSO_4(aq)$ solution being analysed at 610 nm and use the calibration curve to determine the $c(Cu^{2+})$ in the solution. ❶

Question 3

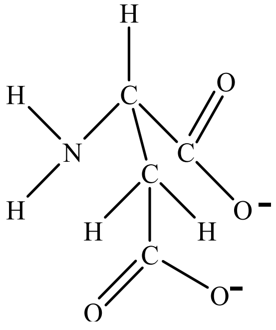
a. ❶



b. Amino acids contain a carboxyl –COOH functional group as well as an amino group. DMMA molecules do not have carboxyl groups. ❶

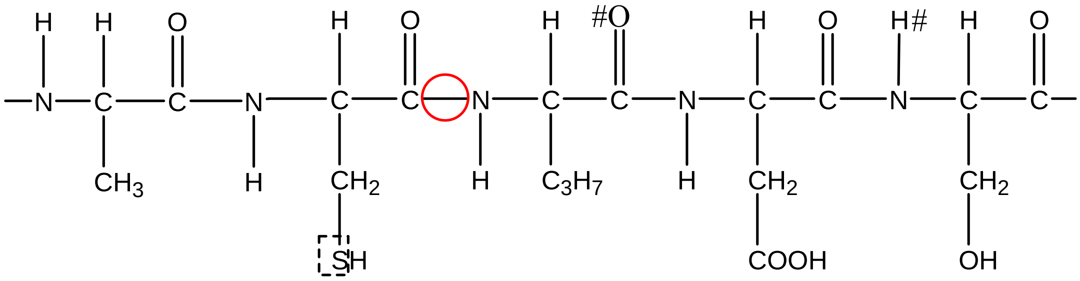
c. **2-aminopropanoic acid.** ❶

d. ❶



e. A tripeptide is formed when **three amino acid molecules react together in a condensation reaction.** ❶
The **–COOH group on one amino acid reacts with the $–NH_2$ group, its adjacent amino acid, to form a peptide –CONH- link**. ❶ A tripeptide contains two peptide links.

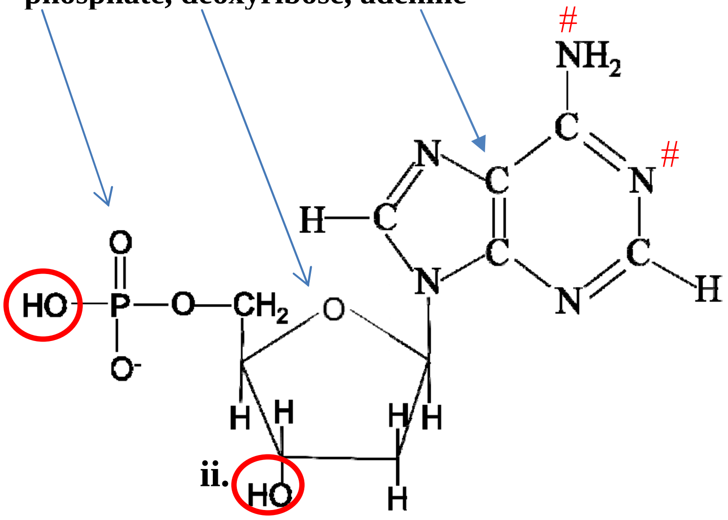
f.



i. ❶ for any C-N bond.
ii. ❶ for an 'O' on one peptide group AND an 'H' on a different peptide group.
iii. ❶ for the 'S' atom.

g. **i.** **phosphate, deoxyribose, adenine**

ii.



i. ❶❶ for all three correct, [❶ for two correct]

ii. ❶ for both ‘OH’ groups circled. Also accept POOH.

iii. ❶ for both the N and the NH_2 on the right hand side of the nitrogen base (adenine). No marks if the H on the C-H is asterisked.

h. **Hydrogen bonding between complementary nitrogen bases on adjacent strands. Cytosine-Guanine (C-G) pairs** have **three sites for hydrogen bonding,** whereas **Adenine-Thymine (A-T) pairs** have only **two sites for hydrogen bonding**. ❶ The greater the proportion of C-G (cytosine-guanine) base pairs, the stronger the attraction between the strands.

Question 4

a. **i.** The main function and role of the catalyst is to increase the rate of reaction. ❶This then allows the use of lower temperature for the reaction which, from an equilibrium perspective, increases the yield of methanol ❶ because the forward reaction is exothermic.

NB The catalyst itself does NOT affect the yield of the reaction. The increase in yield is due to the ability to use a lower temperature because of the effect of the catalyst on reaction rate.

ii. $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$;

	CO	H_2		CH_3OH	
Initially	0.240	0.380		-	mol
Reacting	0.070	0.140	→	0.070	mol
Equilibrium	**0.170**	**0.240**		**0.070**	mol ❶

At equilibrium: [CO] = 0.170 mol / 5.00 L = 0.0340 M

$[H_2]$ = 0.240 / 5.00 = 0.0480 M

$[CH_3OH]$ = 0.070 / 5.00 = 0.014 M ❶

$K = [CH_3OH] / [CO][H_2]^2$

$= 0.014 / \{0.034 \times 0.0480^2\}$

= 178 ❶ (M^{-2})

iii. For the equilibrium constant to increase, the **forward reaction** must be **favoured**. Since the **forward reaction** is **exothermic,** the **temperature** must have **decreased.** ❶

b. **i.** $\mathbf{C_3H_8O_3}$ ❶ - glycerol (*Data Book Table 10)*

ii. I_2 reacts in an addition reaction across the C=C double bond.

$n(I_2) = 7.61 \text{ g} / 253.8 \text{ g mol}^{-1}$

$= 0.0300$ mol

Ratio $n(I_2) / n(\text{fatty acid}) = 0.0300 / 0.010$

$= 3$ ❶

Hence the fatty acid molecule has 3 C=C double bonds, i.e. 6 H atoms less than the saturated fatty acid with the same number of C atoms

Acid is linolenic acid – $\mathbf{C_{17}H_{29}COOH}$ ❶

To produce the methyl ester, linolenic acid reacts with methanol according to

$\mathbf{C_{17}H_{29}COOH(l) + CH_3OH(l) \rightarrow C_{17}H_{29}COOCH_3(l) + H_2O(l)}$

❶ for correctly balanced equation, including states.

c. **i.** The ^{13}C NMR spectrum shows 2 peaks, indicating two different carbon bonding environments in the molecule, i.e. ethanoic acid, CH_3COOH.

$\mathbf{CH_3OH(l) + CO(g) \rightarrow CH_3COOH(l)}$ ❶

ii. CH_3CH_2OH

Three sets of peaks

Singlet – for the **OH** hydrogen

Triplet – for the CH_3 hydrogens

Quartet – for the CH_2 hydrogens

❶❶ for all three correct; ❶ for any two correct

d. **i.** Methanol is acting as a **reductant** ❶. It is being oxidised.

ii. $CH_3OH(l)$ is oxidised to $CO_2(g)$ at the anode. The half-equation is developed by using the half-equation balancing principles.

Half-equations

Anode – $\mathbf{CH_3OH(l) + H_2O(l) \rightarrow CO_2(g) + 6H^+(aq) + 6e^-}$ ❶

Cathode – $\mathbf{O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)}$ ❶ ….*from Data Book Table 2.*

Question 5

a. **i.** The oxidant in air is O_2, which is reduced at the cathode *Data Book Table 2*

$\mathbf{O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq).}$ ❶

ii. Mo is oxidised at the anode, O_2 is reduced at the cathode.

Oxidation: $Mo(s) + 8OH^-(aq) \rightarrow MoO_4^{2-}(aq) + 4H_2O(l) + 6e^-$ ….*from supplied information.*

Reduction: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ ..*from (a. i.).*

Overall equation: multiply oxidation half-equation by 2 and reduction half-equation by 3, then add. Cancelling down species that appear on both sides.

$\mathbf{2Mo(s) + 4OH^-(aq) + 3O_2(g) \rightarrow 2MoO_4^{2-}(aq) + 2H_2O(l)}$ ❶

iii. $O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$ $E° = +0.40$ V

$MoO_4^{2-}(aq) + 4H_2O(l) + 6e^- \rightleftharpoons Mo(s) + 8OH^-(aq)$ $E^0 = -0.91$ V

Cell voltage alkaline version = 0.40 – (-0.91)

= **1.31 V** ❶

b. Since the **oxidant** is supplied as needed from **air** it does **not** need to be **stored in the battery**. ❶

c. **i.** Electrical energy = $VIt = V \times n(e) \times Q$

Oxidation of 1 mol Zn → 2 mol e^-

E from 1 mol Zn = 1.65 x 2 x 96500

= 3.18×10^5 J

= **318 kJ** ❶

ii. Oxidation of 1 mol Mo → 6 mol e^-

E from 1 mol Mo = 1.31 x 6 x 96500

= 7.58×10^5 J

= **758 kJ** ❶

iii. M(Zn) = 65.4 g mol L^{-1}

Energy per gram of **Zn** = 318 kJ mol^{-1} / 65.4 g mol^{-1}

= **4.86 kJ g^{-1}** ❶

M(Mo) = 95.9

Energy per gram of **Mo** = 758 /95.9

= **7.90 kJ g^{-1}** ❶

d. The **(-) negative terminal** of the power supply (recharger) must be attached **to the (-) electrode** of the cell, and the **(+) positive terminal** of the recharger **to the (+) electrode** of the cell. ❶

The recharger must supply a **voltage greater than 3.7 V** per cell.❶

Question 6

a. **Temperature**, **Concentration** and the use of a **Catalyst.** ❶

b. **Three** of:
HCl(aq) concentration.
Total volume of solution.
Temperature.
Diameter of reaction beaker.
❶❶ for three; ❶ for two

c. **i.** Because the total volume of the reaction mixture remains the same (50 mL), but the volume of 0.25 M $Na_2S_2O_3$(aq) used varies, the actual ***c*($Na_2S_2O_3$) at the start of the reaction is different in each investigation**. The ***c*(HCl) is the same in all three reaction mixtures** ❶

With all three investigations at room temperature the **only variable is *c*($Na_2S_2O_3$)**. ❶

ii. **0.125 M** ❶

Total volume of solution is double that used of $Na_2S_2O_3$ (25 mL to 50 mL). Hence the concentration of $Na_2S_2O_3$ is halved at the instant before the reaction begins.

iii. **0.20 M** ❶

Cl^- (aq) is a spectator ion so the n(Cl^-) does not change. Since the volume increases by a factor of 10 (5 mL to 50 mL), the concentration decreases by a factor of 10, from 2.0 M to 0.20 M.

d. **i.** Since the equation for the reaction was not an equilibrium equation, the reaction may be assumed to go to completion, at which point the **amount of sulfur present is constant**. ❶

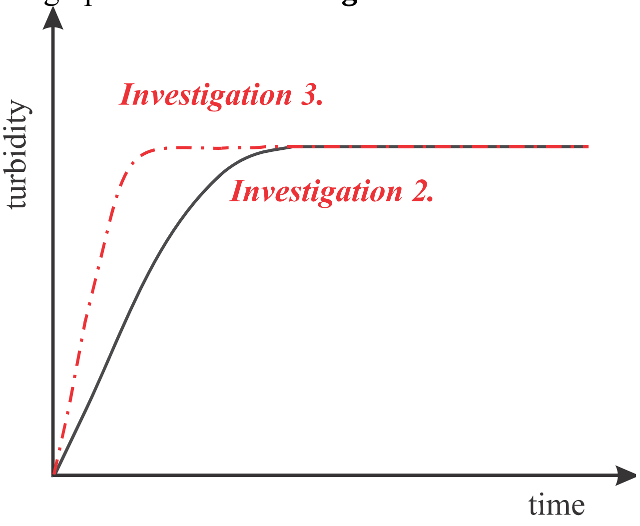
ii. The initial rate of reaction in Investigation 3 is higher because the *c*($Na_2S_2O_3$) is higher.

The relative turbidity depends on the relative amounts of S(s) produced

Investigation 2. : *n*($Na_2S_2O_3$) = 0.25 x $25x10^{-3}$ = 0.00625 mol;
n(HCl) = 2.0 x $5.0x10^{-3}$ = 0.010 mol
Since $Na_2S_2O_3$ is in excess, ***n*(S)** produced = ½ x *n*(HCl) = **0.0050 mol**

Investigation 3. : *n*($Na_2S_2O_3$) = 0.25 x $40x10^{-3}$ = 0.010 mol;
n(HCl) = 2.0 x $5.0x10^{-3}$ = 0.010 mol
Since $Na_2S_2O_3$ is in excess, ***n*(S)** produced = ½ x *n*(HCl) = **0.0050 mol**

Hence the graphs for **both investigations level off at the same turbidity**.



❶ for steeper gradient for Investigation 3.
❶ for graph levelling off earlier but at the same turbidity for Investigation 3.

e. **Surface area.** ❶
The **shorter reaction time (faster rate) for $Na_2S_2O_3$ powder** is consistent with the **greater surface area** allowing for more collisions between reactant particles and hence **more collisions with energy greater than the activation energy**. ❶

f. The **proportion of collisions with energy greater than the activation energy** is increased by an increase in temperature or the introduction of a catalyst.
An **increase in temperature** increases the **average kinetic energy** of the colliding particles. ❶
A **catalyst** has **no effect on the average kinetic energy** of the colliding particles but does **lower the activation energy** by providing an alternative reaction pathway. ❶

Question 7

a. Step 3: **$NH_3(g) + HCl(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$** ❶
Or **$NH_3(g) + H^+(aq) \rightarrow NH_4^+(aq)$**
Step 4: **$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$** ❶
Or **$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$**

b. n(HCl) reacted with NH_3(g) = n(HCl) supplied – n(HCl) in excess
= n(HCl) supplied – n(NaOH)
= **$0.100 \times 100 \times 10^{-3} - 0.200 \times 31.4 \times 10^{-3}$** ❶
= 0.0100 – 0.00628
= **0.0037 mol** ❶ (0.003720)

c. n(N) in sample = $n(NH_3)$ produced
= n(HCl) reacting with NH_3
= 0.0037 mol
m(N) in sample = 0.0037 x 14.0
= **0.052 g** ❶

d. % N = [m(N) / m(sample)] x 100
= (0.052 / 5.152) x 100
= **1.01 %** ❶

e. $H_3BO_3(aq) + H_2O(l) \rightleftharpoons B(OH)_4^-(aq) + H^+(aq)$; $K_a = 5.8 \times 10^{-10}$ - *Data Book Table 12*
$K_a = [B(OH)_4^-][H^+] / [H_3BO_3]$
Standard weak acid assumptions may be made,
i.e. (i) negligible contribution to $[H^+]$ from self-ionisation of water so $[B(OH)_4^-] = [H^+]$
(ii) very small extent of reaction so equilibrium $[H_3BO_3]$is the same as the initial concentration.
$5.8 \times 10^{-10} = [H^+]^2 / 0.647$
$[H^+]^2 = 5.8 \times 10^{-10} \times 0.647$ ❶
$[H^+] = \sqrt{(5.8 \times 10^{-10} \times 0.647)}$
$= 1.94 \times 10^{-5}$ M ❶
pH $= -\log_{10}(1.94 \times 10^{-5})$
= 4.7 ❶

Question 8

a. $n(C_{12}H_{22}O_{11})$ reacting = 0.444 g / 342.0 g mol^{-1}
= 1.30×10^{-3} mol ❶
Energy absorbed by water = Heat capacity x $m(H_2O)$ x ΔT
= 4.18 J K^{-1} g^{-1} x 748 g x 2.06 K
= 6.44×10^{3}J ❶
Energy absorbed by calorimeter components = 420 J K^{-1} x 2.06 K
= 865 J
Energy released in combustion of sucrose = 6.44×10^{3} + 865 J
= 7.31×10^{3} J ❶
Energy per mol $C_{12}H_{22}O_{11}$ = 7.31×10^{3} / 1.30×10^{-3}
= 5.62×10^{6} J mol^{-1}
= 5.62×10^{3} kJ mol^{-1}
$\Delta H_c(C_{12}H_{22}O_{11})$ = **-5.62×10^{3} kJ mol^{-1}** ❶

b. **$C_{12}H_{22}O_{11}(s) + 12O_2(g) \rightarrow 12CO_2(g) + 11H_2O(l)$** ❶

c. i. **$C_{12}H_{22}O_{11}(aq) + H_2O(l) \rightarrow 2C_6H_{12}O_6(aq)$** ❶

ii. **$C_6H_{12}O_6(aq) \rightarrow 2CH_3CH_2OH(aq) + 2CO_2(g)$** ❶

d. **i.** $n(CH_3CH_2OH)$ reacting = 2.0 / 46.0
= 0.0435 mol ❶
Energy released = $n(CH_3CH_2OH)$ x energy available per mol CH_3CH_2OH
(from ΔH_c – Data Book Table 13)
= 0.0435 mol x 1364 kJ mol^{-1}
= 59.3 kJ ❶
Maximum ΔT = Energy released / Calibration Factor
= 59.3 kJ / 1.32 kJ °C^{-1}
= **44.9 °C** ❶

ii. Some of the **energy** released from the ethanol may have been **lost to the surrounding environment.** ❶

End of Suggested Answers