Learning Materials
by Lisachem

VCE CHEMISTRY 2014

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	112
			Total 142

To download the Chemistry Data Book please visit the VCAA website:
http://www.vcaa.vic.edu.au/Documents/exams/chemistry/chemdata_2012-w.pdf

Learning Materials *by Lisachem*
PO Box 2018, Hampton East, Victoria, 3188
Ph: (03) 9598 4564 Fax: (03) 8677 1725
Email: orders@learningmaterials.com.au or orders@lisachem.com.au
Website: www.learningmaterials.com.au

STUDENT NUMBER Letter

Figures									
Words									

Student Name...………………………**...**

VCE Chemistry 2014 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 2014 Year 12 Trial Exam Unit 3/4

SECTION A – Multiple Choice Questions

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
The systematic name 2-amino-3-methyl butanoic acid applies to

A. glycine.
B. alanine.
C. leucine.
D. valine.

Question 2
One method of extracting copper from copper(II) oxide is heating the CuO in the presence of carbon monoxide. The reaction occurring is described by the equation.

$$CuO(s) + CO(g) \rightarrow Cu(s) + CO_2(g)$$

Use the thermochemical equations below to determine ΔH for this reaction between CuO and CO.

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g);\ \Delta H = -566 \text{ kJ mol}^{-1}$$
$$2Cu(s) + O_2(g) \rightarrow 2CuO(s);\ \Delta H = -311 \text{ kJ mol}^{-1}$$

A. $\Delta H = -128$ kJ mol^{-1}
B. $\Delta H = -255$ kJ mol^{-1}
C. $\Delta H = +255$ kJ mol^{-1}
D. $\Delta H = -877$ kJ mol^{-1}

Question 3
It is possible to produce an ester starting with an alkene as the only organic compound. Which one of the following types of chemical reaction does not **need** to be part of the simplest reaction pathway?

A. Reduction.
B. Substitution.
C. Condensation.
D. Addition.

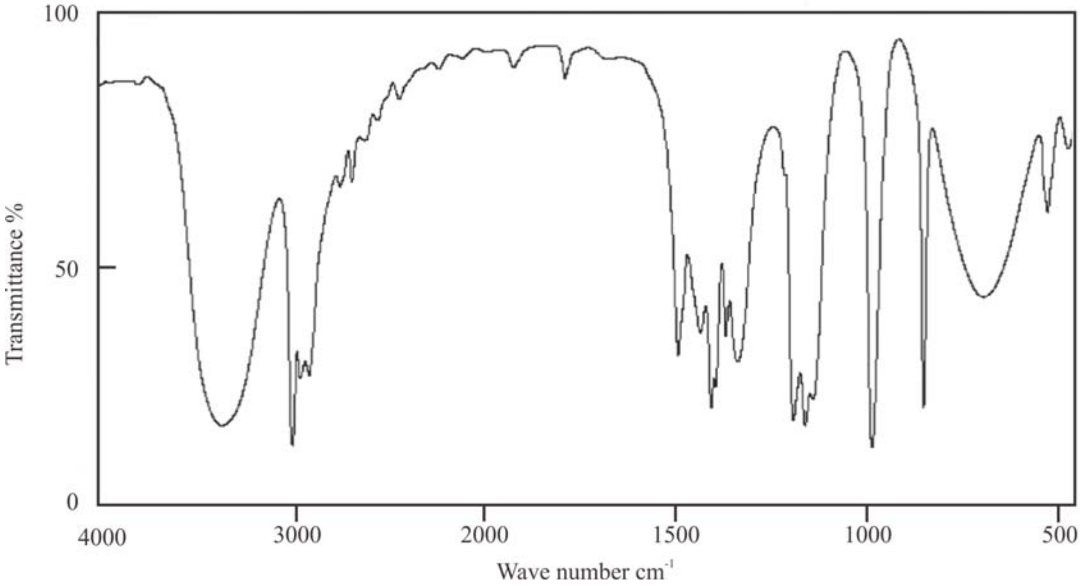
Question 4

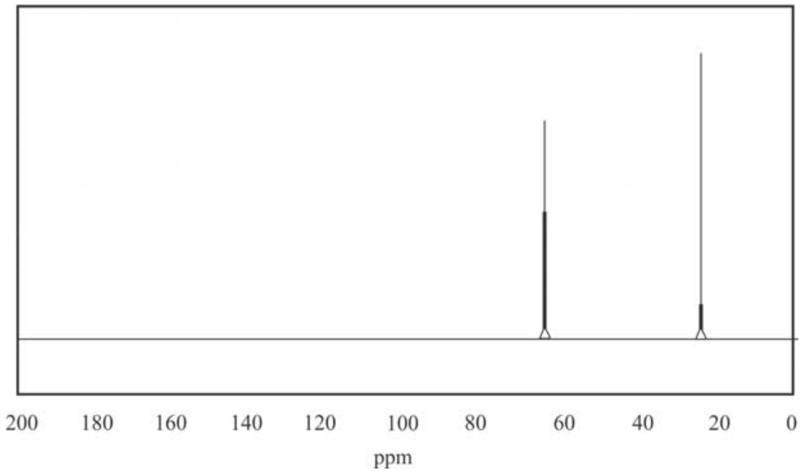
Which of the following biomolecules has the highest percentage, by mass, of carbon?

A. Glucose.
B. Glycerol.
C. Sucrose.
D. Glycine.

Question 5

The spectra below are of a compound of carbon, hydrogen and oxygen that contains 60.0 percent by mass carbon.





The compound is most likely to be

A. ethanol.
B. ethanoic acid.
C. methyl methanoate.
D. 2-propanol.

Question 6

In a determination of the SO_2 content of wine, a treated wine sample was titrated with 0.00525 M $I_2(aq)$.

The reaction occurring during the titration was

$I_2(aq) + SO_2(g) + 2H_2O(l) \rightarrow 2I^-(aq) + HSO_4^-(aq) + 3H^+(aq)$.

The following titration data were recorded.

Titration	Initial Reading (mL)	Final Reading (mL)
1.	2.50	19.25
2.	19.25	30.40
3.	1.45	12.65
4.	12.65	23.75

The mass of SO_2 present in the treated wine sample was

A. 3.75 mg.
B. 4.22 mg.
C. 3.75 g.
D. 4.22 g.

Question 7

When a 0.62 g sample of element X is allowed to react completely with oxygen, 1.10 g of an oxide of formula X_2O_3 is produced.

Element X is

A. aluminium.
B. chromium.
C. phosphorus.
D. iron.

Question 8

Molybdenum-air batteries are efficient with both acidic and alkaline electrolytes.

The relative reduction half-equations and electrode potentials at 25°C for 1 M solutions are

$H_2MoO_4(aq) + 6H^+(aq) + 6e^- \rightleftharpoons Mo(s) + 4H_2O(l) \qquad E° = -0.11\ V$

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

The expected operating voltage of a molybdenum-air using an alkaline electrolyte at standard conditions would be

A. 0.80 V.
B. 1.31 V.
C. 1.02 V.
D. 0.51 V.

Question 9

In an investigation to explore the effect of rinsing procedures in volumetric analysis, the concentration of an approximately 0.1 M solution of hydrochloric acid was determined by titrating an aliquot of a standard solution of sodium carbonate with the hydrochloric acid to the methyl orange endpoint.

The reaction occurring was:

$$Na_2CO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

Four groups completed the investigation using the same procedure and same solutions but with each group following specific rinsing instructions. Each group then calculated the *c*(HCl) based on their collected data.

The rinsing instructions are shown in the table below.

	Burette	Pipette	Titration flask
Group I	HCl(aq)	Na_2CO_3(aq)	Water
Group II	Water	Na_2CO_3(aq)	Water
Group III	Na_2CO_3(aq)	Na_2CO_3(aq)	Water
Group IV	HCl(aq)	Water	Water

The hydrochloric acid concentrations calculated by the four groups were 0.094 M, 0.095 M, 0.098 M, and 0.103 M.

The concentration of the acid according to Group I was most likely

A. 0.103 M.
B. 0.098 M.
C. 0.095 M.
D. 0.094 M.

Question 10

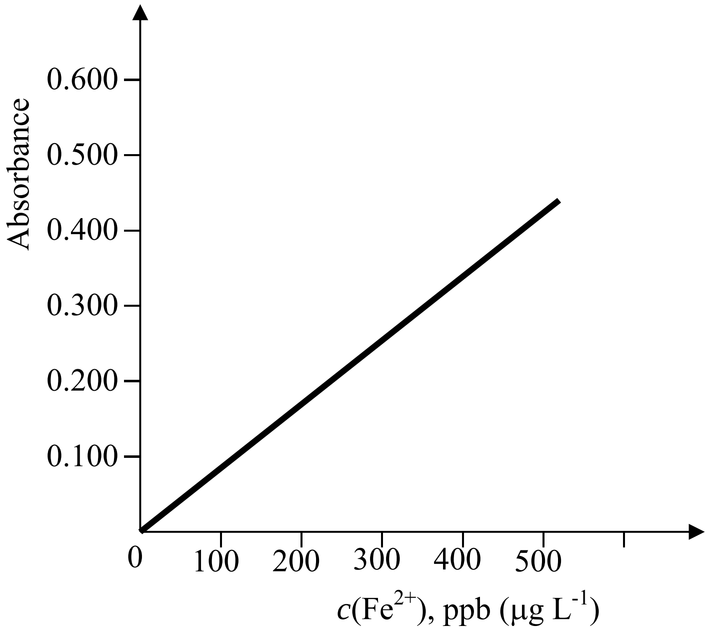
GC/MS (Gas Chromatography / Mass Spectrometry) was used to identify different alcohols present in an unidentified beverage. The most abundant alcohol present was ethanol with traces of butan-1-ol, methanol, and methylpropan-2-ol present.

The alcohol that would be expected to exit the gas chromatograph and enter the mass spectrometer first would be

A. ethanol.
B. methanol.
C. methylpropan-2-ol.
D. butan-1-ol.

Question 11
Levels of iron in solution can be determined by UV-Visible spectroscopy. In such an analysis all the iron present is converted to Fe^{2+}(aq) and the spectrophotometric agent ferrozine is added. Ferrozine combines with Fe^{2+}(aq) to produce an intense red solution. The complex species formed between Fe^{2+}(aq) and ferrozine absorbs strongly at around 510 nm.

A series of Fe^{2+}(aq) standards were prepared, treated with ferrozine, and their absorbances measured to produce the calibration graph below.



To calculate the mass of iron present in a 250 mL sample of a test solution, 5.0 mL of the solution was added to 145 mL water. This diluted solution was then treated with ferrozine and its absorbance measured at the wavelength used in establishing the calibration graph. The absorbance was 0.250.

The mass, in mg of iron, present in the test solution was closest to

A. 0.300 mg.
B. 2.25 mg.
C. 9.00 mg.
D. 225 mg.

Question 12

Copper reacts with dilute nitric acid to produce nitrogen(II) oxide according to the equation

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

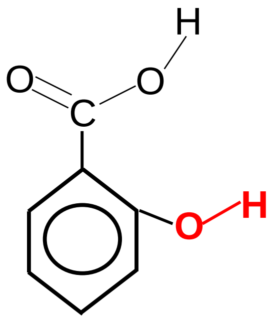
When 6.75 g of Cu is added to excess nitric acid and the reaction allowed to proceed to completion, 630 mL of NO is collected at STP.

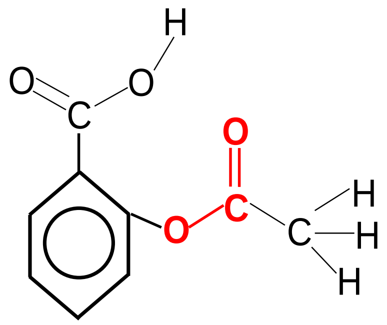
Which of the following is closest to the percentage of the NO produced in the reaction that was actually collected?

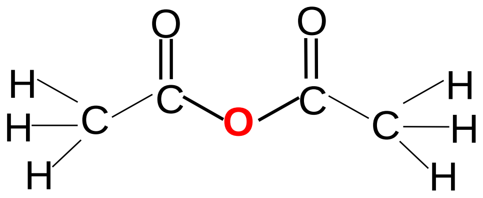
A. 27
B. 40
C. 60
D. 100

Question 13

The structures of some of the compounds associated with the production of aspirin are shown below.







The substance with the fewest peaks on its low resolution ^{1}H NMR spectrum is

A. ethanoic anhydride.
B. aspirin.
C. salicyl alcohol.
D. salicylic acid.

Question 14

A sample of bath salts contains a mixture of sodium carbonate, Na_2CO_3 and sodium hydrogen carbonate, $NaHCO_3$.

In a volumetric analysis to determine the amounts of both Na_2CO_3 and $NaHCO_3$ present in a sample of bath salts, a 50.00 mL aliquot of an aqueous solution of the bath salts was titrated with 0.1020 M hydrochloric acid solution using phenolphthalein to indicate the endpoint. Methyl orange indicator was then added to the resulting solution and this was titrated with the same acid to a second end point.

The reactions occurring during the titration are:

$HCl(aq) + Na_2CO_3(aq) \rightarrow NaHCO_3(aq) + NaCl(aq)$ – phenolphthalein end point and then

$HCl(aq) + NaHCO_3(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$ – methyl orange end point

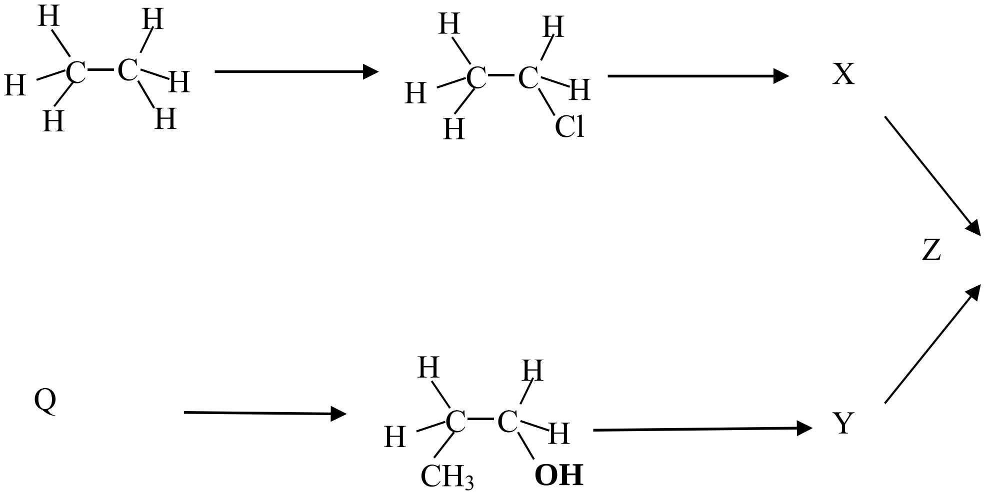
10.25 mL of the HCl(aq) was used to reach the phenolphthalein endpoint and a further 25.35 mL was used to reach the methyl orange endpoint.

What was the amount, in mol, of sodium hydrogen carbonate in the 50.00 mL aliquot of bath salts solution?

A. 1.046×10^{-3}
B. 1.540×10^{-3}
C. 2.586×10^{-3}
D. 3.632×10^{-3}

Question 15

The diagram below shows a reaction pathway consistent with the designated content of Unit 3.



Which of the following correctly identifies compounds Q and Z?

A. Ethene, ethyl ethanoate.
B. Propane, propanoic acid.
C. Ethane, propyl ethanoate.
D. Propene, ethyl propanoate.

Question 16

The following statement describes an aspect of the operation of a type of modern analytical instrument:

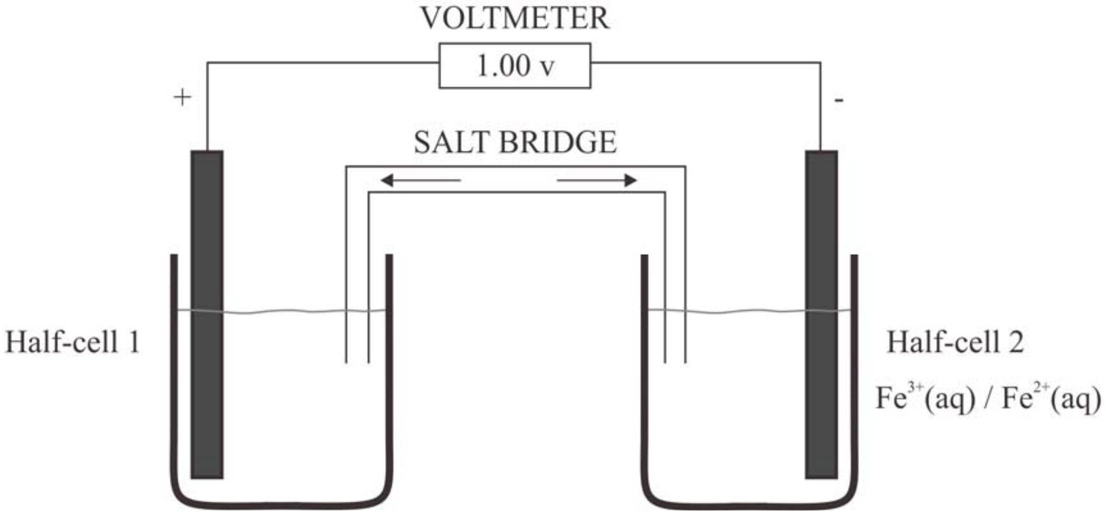
……… e.g. the electron in the third shell of a sodium atom will absorb energy at 589.0 nm wavelength. Only ground state atoms can absorb energy at this wavelength, and a hollow cathode lamp supplies the energy ………

Which of the following analyses could be performed using this instrument?

A. Determining the amount of potassium in a sports drink.
B. Identifying the functional groups present in a compound.
C. Determining the number of 'different' carbon atoms in a molecule.
D. Determining the alcohol content of wine.

Question 17

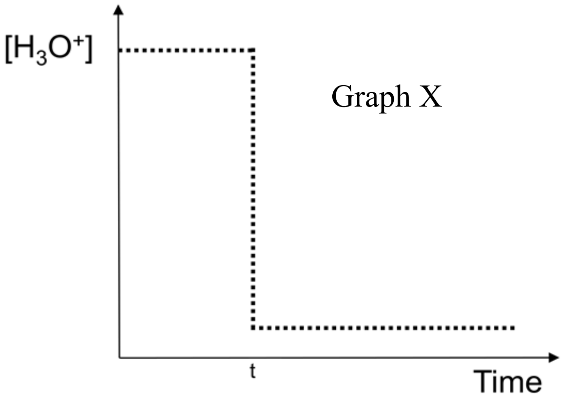
Consider the galvanic cell, represented below, operating at 25°C, 101.3 kPa and using 1 M solutions.

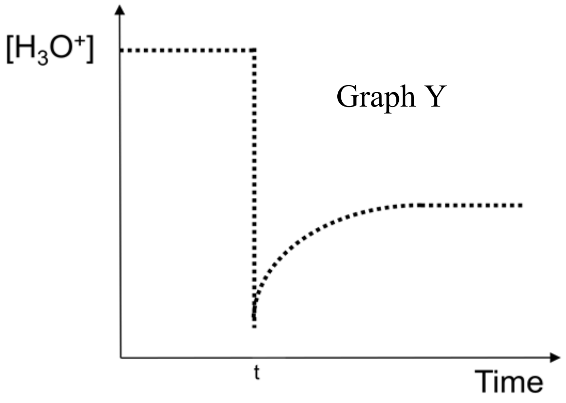


The product(s) of the half-reaction occurring in half-cell 1 is (are)

A. Ni(s).
B. $Ni^{2+}(aq)$.
C. $H_2O_2(aq)/H^+(aq)$.
D. $H_2O(l)$.

Question 18
The graphs below show the impact on the $c(H_3O^+)$ of diluting 10 mL solutions of two acids X and Y, both with initial pH 3.00, to 100 mL at time ‘t’, at 25 °C.





Which of the following statements is consistent with this information?

A. X is hydrochloric acid and has the higher initial concentration.
B. Y is methanoic acid and has the higher initial concentration.
C. X is methanoic acid and has the lower initial concentration.
D. Y is hydrochloric acid and has the lower initial concentration.

The following information applies to Questions 19 and 20.
The first nickel-cadmium storage battery, or NiCad battery, was created in 1899 in Sweden by Waldemar Jungner. NiCad batteries can be produced in a variety of sizes and are extremely durable, enabling a wide range of uses, including toys, power tools and industrial applications. Each rechargeable cell produces about 1.3-1.4 V on discharge. Prior to discharge, a NiCad cell contains NiO(OH)(s) and Cd(s) with an alkaline electrolyte.
The overall reaction occurring in a NiCad cell during **recharging** is

$$Cd(OH)_2(s) + 2Ni(OH)_2(s) \rightarrow 2NiO(OH)(s) + 2H_2O(l) + Cd(s)$$

Question 19
The half-reaction occurring at the anode when a NiCad battery is discharging will be

A. $Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-(aq)$
B. $2Ni(OH)_2(s) + 2OH^-(aq) \rightarrow 2NiO(OH)(s) + 2H_2O(l) + 2e^-$
C. $Cd(s) + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$
D. $2NiO(OH)(s) + 2H_2O(l) + 2e^- \rightarrow 2Ni(OH)_2(s) + 2OH^-(aq)$

Question 20
When a NiCad battery is being recharged, the negative terminal of the external power supply

A. should be connected to the electrode containing $Ni(OH)_2$ and a voltage of 1.35 V applied.
B. should be connected to the electrode containing $Ni(OH)_2$ and a voltage greater than 1.4 V applied.
C. should be connected to the electrode containing $Cd(OH)_2$ and a voltage of 1.35 V applied.
D. should be connected to the electrode containing $Cd(OH)_2$ and a voltage greater than 1.4 V applied.

Question 21

Nitrogen dioxide, NO_2, and dinitrogen tetroxide, N_2O_4, are compounds in which nitrogen has the same oxidation number.

Both compounds can be formed from reactions between nitrogen and oxygen according to the thermochemical equations

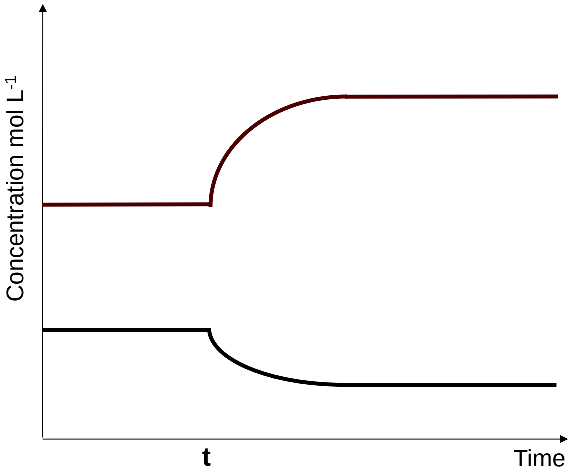
$$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g) \quad \Delta H = +90.4 \text{ kJ mol}^{-1}$$

$$N_2(g) + 2O_2(g) \rightarrow N_2O_4(g) \quad \Delta H = +9.7 \text{ kJ mol}^{-1}$$

A sample of pure $NO_2(g)$ collected in a sealed container quickly establishes an equilibrium with $N_2O_4(g)$, according to

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

The concentration-time graph below shows the effect of a change imposed at time ‘t’ on this equilibrium.



The change imposed was most likely to have been a

A. temperature increase.
B. volume increase.
C. temperature decrease.
D. volume decrease.

Question 22

The value of the equilibrium constant, K_c, for the equilibrium $2NO_2(g) \rightleftharpoons N_2O_4(g)$ at 100 °C is 2.04 M.

Some pure NO_2 is added to a 500 mL vessel and allowed to come to equilibrium at 100 °C.

The $[NO_2]$ at equilibrium was 0.310 M.

What mass, in g, of NO_2 was added to the 500 mL vessel?

A. 7.13 g.
B. 11.6 g.
C. 14.3 g.
D. 16.1 g.

Question 23

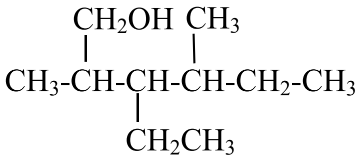
Disproportionation reactions are chemical reactions in which the same species acts as both the oxidant and the reductant.

Which of the species below is **least** likely to be involved in a disproportionation reaction?

A. H_2O
B. Cu^{2+}
C. Sn^{2+}
D. H_2O_2

Question 24

What is the systematic name of the compound which has the semi-structural formula shown below?



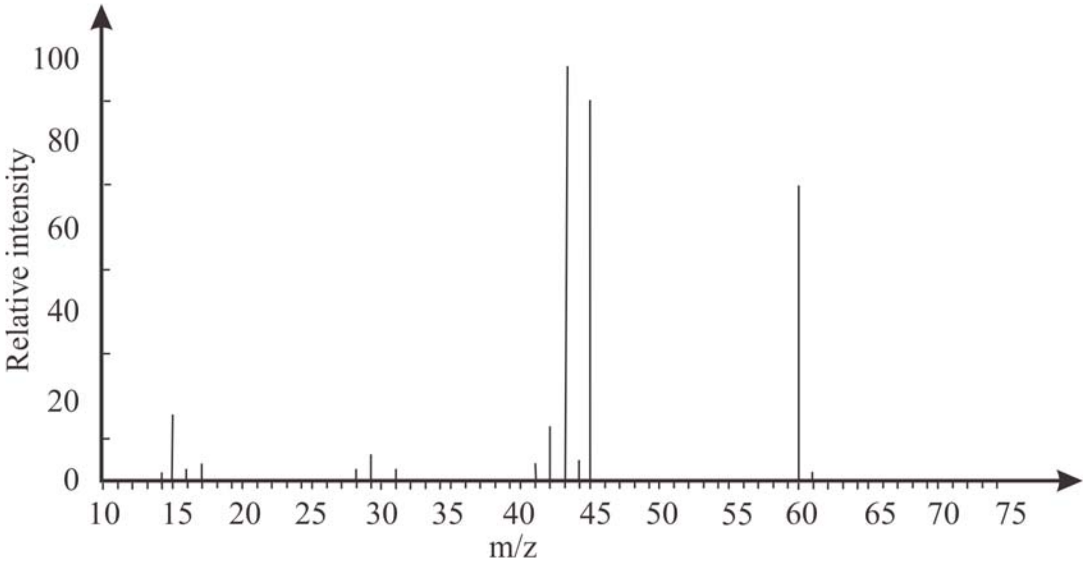
$$CH_3\text{-}CH(CH_2OH)\text{-}CH(CH_2CH_3)\text{-}CH(CH_3)\text{-}CH_2\text{-}CH_3$$

A. 2-methyl-3,5-diethylhexan-1-ol.
B. 3,5-dimethyl-2ethylheptan-1-ol.
C. 3,5-dimethyl-4-ethylhexan-6-ol.
D. 2,4-dimethyl-3-ethylhexan-1-ol.

Question 25

A measured sample of a pure monoprotic acid is dissolved in water and made up to 200 mL of solution. When 25.00 mL aliquots of this solution are then titrated with 1.000 M sodium hydroxide solution, the average titre required to reach the endpoint is 27.48 mL.

The mass spectrum for the acid is shown below:



What was the mass of the pure acid sample?

A. 1.65 g.
B. 13.2 g.
C. 9.46 g.
D. 8.03 g.

Question 26
An analysis of a sample of vinegar for ethanoic acid content involved a sequence of three titrations. The equations and data associated with these titrations are given below.

$Na_2CO_3(aq)$ +	$2HCl(aq)$	→ $2NaCl(aq) + CO_2(g) + H_2O(l)$
20.00 mL	*20.30 mL*	
from 250.0 mL	*of* ***'x'*** *M*	
containing		
1.330 g Na_2CO_3		

$HCl(aq)$ +	$NaOH(aq)$	→ $NaCl(aq) + H_2O(l)$
20.00 mL	*29.85 mL*	
of ***'x'*** *M*	*of* ***'y'*** *M*	

$CH_3COOH(aq)$ +	$NaOH(aq)$	→ $CH_3COONa(aq) + H_2O(l)$
in 20.00 mL	*19.00 mL*	
from 250.0 mL	*of* ***'y'*** *M*	
containing		
20.00 mL (19.95 g)		
of vinegar		

The most likely reason for using the sequence of three titrations would have been

A. sodium carbonate is a primary standard.
B. ethanoic acid is a weak acid.
C. sodium hydroxide is not a primary standard.
D. the analysis is more accurate if back titration is used.

Question 27
Consider the equilibrium system $N_2O_4(g) \rightleftharpoons 2NO_2(g)$.
If the volume of a sample of this equilibrium mixture was halved and the temperature restored to its original value, it would be expected that, when equilibrium was established in the smaller volume, the

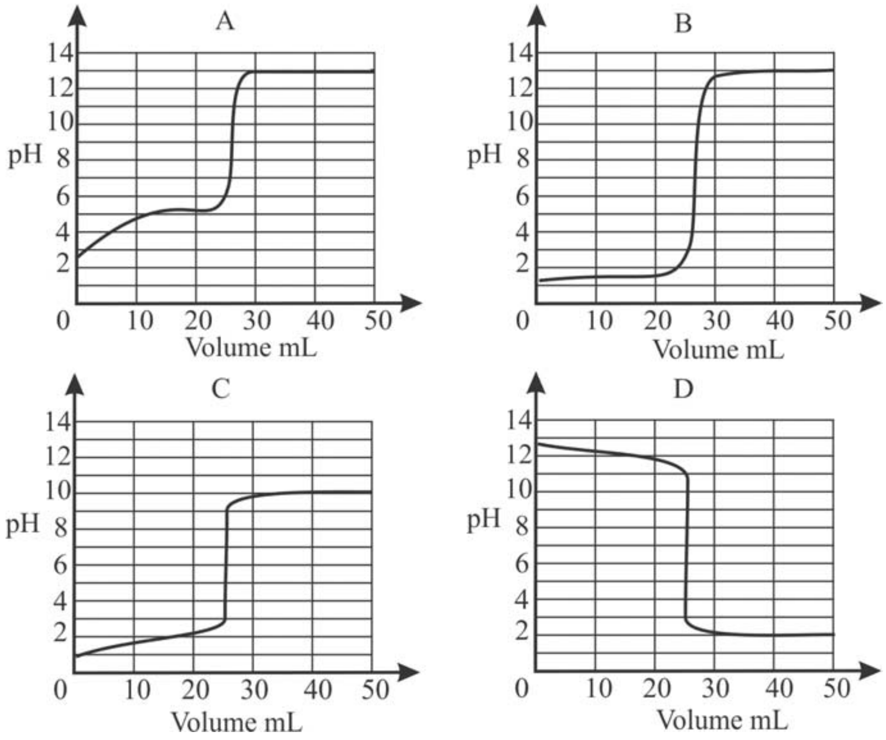
A. $[NO_2]$ would have increased and the $m(NO_2)$ would have increased.
B. $[NO_2]$ would have increased even though the $m(NO_2)$ would have decreased.
C. $[NO_2]$ would have decreased and the $m(NO_2)$ would have decreased.
D. $[NO_2]$ would have decreased even though the $m(NO_2)$ would have increased.

Question 28
The number of carbon atoms present in a 365 μg sample of methyl-2-propanamine is

A. 2.00×10^5
B. 9.00×10^{18}
C. 1.20×10^{19}
D. 4.80×10^{19}

Question 29

Shown below is a set of titration curves for reactions between approximately 0.10 M solutions of acids and bases.



Which of the following reactions is **not** associated with one of these titration curves.

A. $NH_3(aq) + HCl(aq) \rightarrow NH_4^+(aq) + Cl^-(aq)$

B. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

C. $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$

D. $NH_3(aq) + CH_3COOH(aq) \rightarrow NH_4^+(aq) + CH_3COO^-(aq)$

Question 30

In an experiment to determine the percentage by mass of sulfur in a fertiliser, all the sulfur in a known mass of fertiliser was converted to sulfate ions which were precipitated as barium sulfate. When calculating the percentage by mass of sulfur in the fertiliser sample from data collected in the experiment, the final answer was found to be over 100 per cent.
Which of the following errors would **not** have led to the calculated percentage being over 100 %?

A. Not rinsing the precipitate with water during collection.

B. Not drying the precipitate fully prior to weighing.

C. Incorrectly recording the weight of the fertiliser as 1.798 g rather than the correct 1.978.

D. Not converting all the sulfur in the sample to sulfate prior to precipitation.

End of Section A

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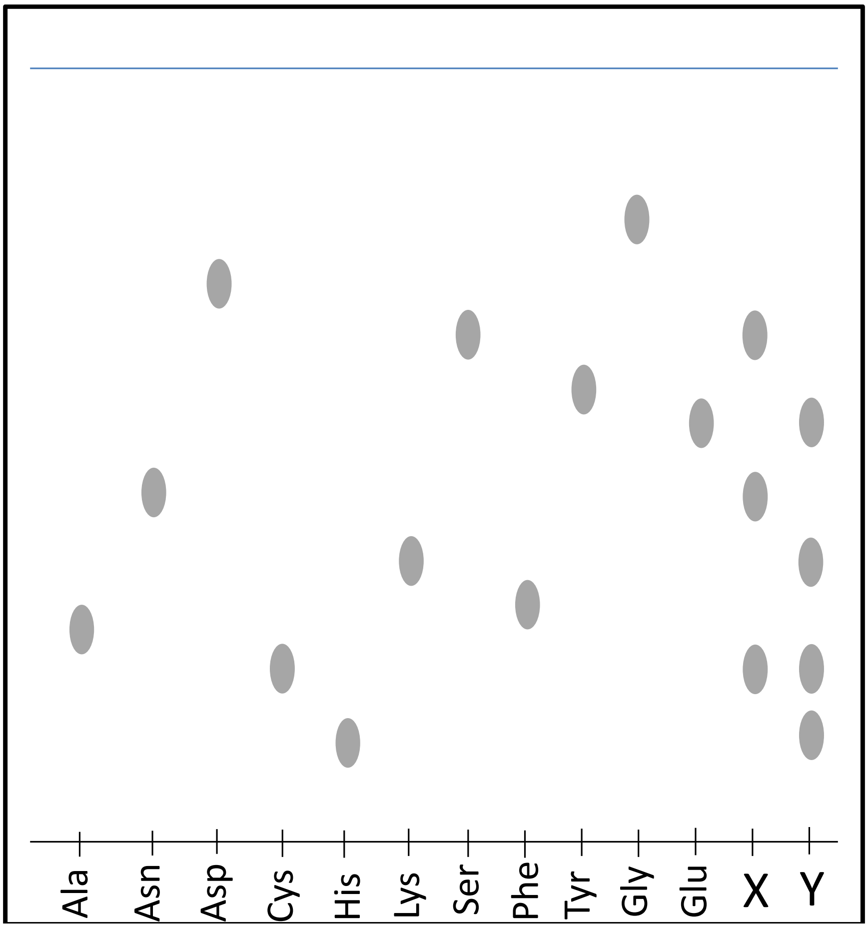
SECTION B – Short Answer Section

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 (16 marks)
The diagram below is a simulated TLC chromatogram for the separation of the amino acids produced from the hydrolysis of the compounds X and Y, together with some known amino acids.



a. Describe the reaction in which the individual amino acids were released from the compounds X and Y in terms of functional group changes. **2 marks**

b. Does the presence of three spots on the chromatogram of X mean that this was a tripeptide? Explain. **1 mark**

c. Draw the structure, showing all bonds on the side chains, of a dipeptide formed from valine and the sulfur containing amino acid present in both X and Y. On this structure circle the group of atoms associated with the peptide group. **2 marks**

d. One of the amino acids present in Y has a charge +2 in solution at pH 3. Give the name of this amino acid and explain why it has a charge of +2 under these conditions. **2 marks**

e. Chromatography involves separation of the compounds in a mixture. Referring to two amino acids on the TLC chromatogram image, describe the general principles of chromatography. **3 marks**

f. Proteins and nucleic acids both have distinct primary and secondary structures. Complete the following table covering associated types of bonding. **6 marks**

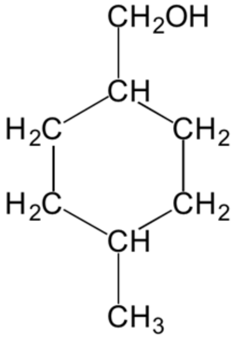
	Proteins	Nucleic acids
Type of bond associated with primary structure.		
Atoms between which primary structure bonds occur.		
Types of bonds associated with secondary structure.		
Atoms between which secondary structure bonds occur.		

Question 2 (16 marks)

On January 9, 2014, at least 28 000 L of a chemical known as MCHM leaked into the Elk River near Charleston, West Virginia (U.S.), near the intake for the local domestic water system. This prompted the declaration of a state of emergency with one quarter of West Virginia's population instructed not to drink or use tap water.

The systematic name of MCHM is 4-methylcyclohexylmethanol.

Its structure is shown below.



MCHM is used as a cleaning agent for coal, to reduce coal dust. The declared safe limit of MHCM for human ingestion was one ppm (m/V).

a. **i.** If the density of MHCM is 0.95 g mL^{-1}, into what volume of solution, in GL, would 28 000 L of MHCM need to be uniformly dispersed for the concentration to be reduced to one ppm (m/V). **2 marks**

ii. Determine the molar concentration of a 1.00 ppm (m/V) solution of MHCM. **1 mark**

b. Residents affected by this spill were advised that their water supply was usable after three days. However it was emphasised that they should thoroughly flush their pipes before using the water for cooking, washing or drinking. Why would this flushing have been necessary? **2 marks**

c. Consider the low resolution ^{1}H NMR spectrum of 4-methylcyclohexanemethanol. How many peaks would be present? **1 mark**

d. When 4-methylcyclohexanemethanol reacts with an acidified aqueous solution of dichromate ions, one organic compound is formed. $Cr^{3+}(aq)$ is another product.

i. Draw the structure showing all bonds of the organic compound formed. **1 mark**

ii. Write a balanced half-equation for the reduction part of the reaction. **1 mark**

e. Coal is a fossil fuel which, in Australia, is mined in both black and brown forms. Brown coal has higher moisture content than black coal.

i. A 1.00 kg sample of brown coal contains 40 per cent combustible material with the rest of the sample water.
Assuming that the combustible material is carbon and that the molar enthalpy of vaporisation for water is 41.0 kJ mol^{-1}, calculate the heat of combustion of the brown coal in kJ g^{-1}. **5 marks**

ii. A coal fired power station is currently '30 per cent efficient'. Explain the term '30 per cent efficient' and state **two** advantages – one economic and one environmental – which should be the result of improved efficiency. **2 marks**

iii. Coal fired power stations also emit SO_2. What is the link between that SO_2 and proteins? **1 mark**

Question 3 (9 marks)
In an investigation of electrolysis, an electric current was passed through a colourless one molar aqueous solution of a divalent metal nitrate at 25°C, using carbon electrodes.
It was observed that a gas was produced at one electrode and the metal was deposited on the other electrode.
The pH of the solution, near the electrode at which the gas was collected, was monitored during the process. Initially the pH was slightly below 7 and decreased as the electrolysis progressed.

The electrolysis was allowed to run for 5.30 minutes at a consistent current of 3.20 A.
At the conclusion of the electrolysis, the carbon electrode on which the metal had deposited was carefully washed, dried and weighed. Its mass had increased by 1.09 g.

a. **i.** State the name and give the sign of the electrode at which the metal was deposited. **1 mark**

ii. Why was the metal, rather than a gas, produced at this electrode? **2 marks**

b. **i.** Assuming the electrolysis process was 100 per cent efficient, calculate the molar mass of the metal deposited. **3 marks**

ii. Identify the metal deposited. **1 mark**

c. Another group carrying out the same investigation left the current running through the cell and noticed that after some time, bubbles of gas appeared at the electrode on which the metal had deposited. Explain this observation. **2 marks**

Question 4 (10 marks)

Consider the following statements relating to exothermic and endothermic reactions.

1. Exothermic reactions always start spontaneously whereas endothermic reactions require a source of energy to start.
2. In exothermic reactions, the release of heat energy causes the products to have a lower chemical energy content than the reactants.
3. On an energy profile for an endothermic reaction, the reactants are lower than products.
4. In the presence of catalyst the energy required to break reactant bonds is decreased but the energy released when product bonds form is not affected.
5. At higher temperature, both exothermic and endothermic reactions speed up.
6. At chemical equilibrium either an exothermic reaction **or** an endothermic reaction will be occurring.
7. The rate of an exothermic reaction increases as it proceeds but the rate of an endothermic reaction decreases as it proceeds.

a. Identify **two** of these statements which are **correct**. **1 mark**

b. Select **three** of the statements which are **incorrect** or partially correct and for each one explain why this is the case. **6 marks**

c. Two students investigated the reaction between zinc and 2.0 M hydrochloric acid. One used finely grained zinc powder, whilst the other one used lumps of zinc.

i. Write a balanced equation for the reaction. **1 mark**

ii. Explain, referring to collision theory, which reaction would be faster. **2 marks**

Question 5 (14 marks)

Because it inhibits the growth of mould and some bacteria, benzoic acid, C_6H_5COOH, along with its potassium, sodium and calcium salts, is used as a food preservative. It is a weak acid and is used to calibrate bomb calorimeters. Its molar enthalpy of combustion, (ΔH_c), is -3227 kJ mol^{-1}.

a. Write the chemical formula for the potassium salt of benzoic acid. **1 mark**

b. **i.** Write the equilibrium law expression for an aqueous solution of benzoic acid. **1 mark**

ii. Calculate the pH of a 0.100 M aqueous solution of benzoic acid. **3 marks**

c. A bomb calorimeter is calibrated by adding 1.56 g benzoic acid and excess oxygen to the reaction bomb and sparking the mixture. The temperature of the water surrounding the reaction bomb rises by 19.6 °C.

i. Determine the calibration factor of the calorimeter, in J °C^{-1}. **3 marks**

ii. If the calibration factor had been determined using the specific heat capacity of water **would** it differ from the value calculated in **i.**? Explain. **2 marks**

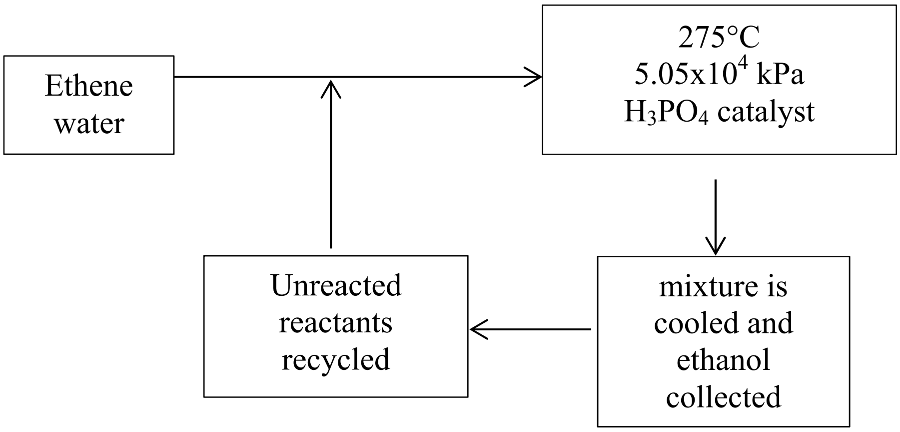
d. A different bomb calorimeter, with calibration factor 3.17 kJ $°C^{-1}$, is used to measure the heat of combustion of pentane. A weighed sample of the fuel was added to the reaction bomb along with oxygen and the mixture sparked. The temperature of the water surrounding the reaction bomb rose by 17.8°C.

i. Assuming the calorimeter is 100 per cent efficient, calculate the mass of pentane added to the calorimeter. **3 marks**

ii. What could cause the calculated mass of pentane to be significantly less than the mass **actually** added to the calorimeter? **1 mark**

Question 6 (28 marks)

The diagram below is a simplified representation of the industrial production of ethanol via an equilibrium reaction between ethene and steam.



a. Write a balanced equation for the ethanol producing reaction consistent with the information supplied. **1 mark**

b. The production of 1.02 g of ethanol by this method releases 1.04 kJ of energy. Determine ΔH for your equation. **2 marks**

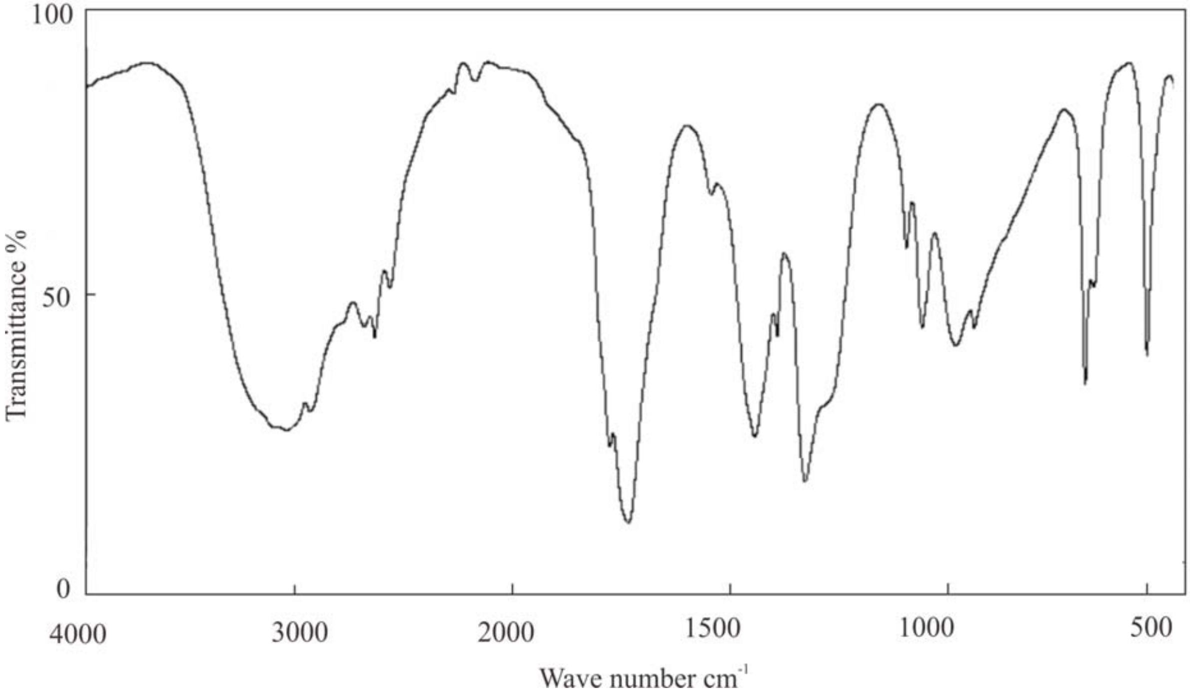
c. In an investigation of this production process, 44.6 g of ethene and 21.6 g of water were mixed in a 2.0 L container at 300°C and 4.75×10^4 kPa pressure. When equilibrium was established, 5.00 per cent of the ethene had been converted to ethanol. Calculate the value of the equilibrium constant under these conditions. **4 marks**

d. Explain why a slightly different yield of ethanol might be expected if the temperature and pressure conditions used in the investigation had been the same as those shown in the diagram for the industrial production. **3 marks**

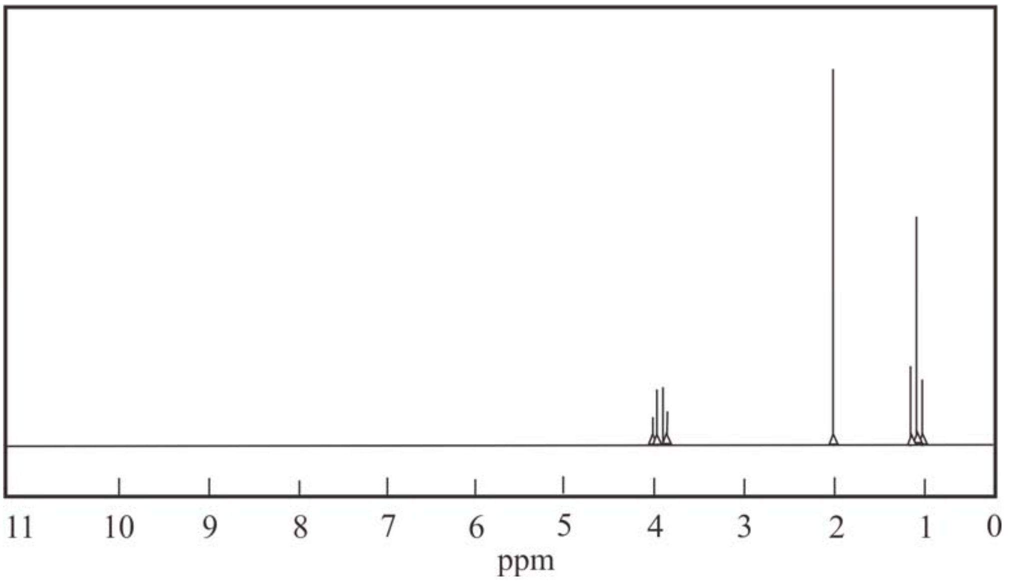
e. Explain, in terms of collision theory, how this system reaches equilibrium. **3 marks**

f. The spectra shown below are spectra of two organic compounds produced in a reaction pathway from ethanol where ethanol is the only starting organic compound.

Spectrum 1



Spectrum 2



i. Explain how these spectra can be used to identify the two compounds. Give the names and semistructural formulae of the two different compounds. **6 marks**

ii. What inorganic chemicals are commonly used in the production of the two different compounds from ethanol? **2 marks**

g. Ethanol is an important biofuel and is produced by fermentation.

i. Write a balanced equation for the fermentation reaction. **1 mark**

ii. Ethanol is added to petrol, mainly octane, to produce what is known as E10 blend. Ethanol is also the alcoholic component of alcoholic beverages which are aqueous solutions. Explain how ethanol dissolves in both water and octane. **3 marks**

iii. Write a balanced equation for the combustion of ethanol. **1 mark**

h. Ethanol is the fuel in ethanol-oxygen fuel cells.

i. State the name and sign of the electrode at which ethanol reacts. **1 mark**

ii. Write the half-equation for the reaction of ethanol in a fuel cell containing an acidic electrolyte. **1 mark**

Question 7 (8 marks)

An investigation to determine the reducing strength of four metals, represented by P, Q, R, and S, made use of the four metals, aqueous solutions of their cations and hydrochloric acid. All four metals existed as +2 ions in solution.

The following observations were recorded.

	P	**Q**	**R**	**S**
$P^{2+}(aq)$		reaction	no reaction	reaction
$Q^{2+}(aq)$	no reaction		no reaction	no reaction
$R^{2+}(aq)$	reaction	reaction		reaction
$S^{2+}(aq)$	no reaction	reaction	no reaction	
1 M HCl(aq)	no reaction			reaction

a. Explain how the recorded observations can be used to arrange the four metals in order of increasing reducing strength. **5 marks**

b. If all the solutions used were 1 M solutions at 25°C, identify which of the metals would have positive *E*° values on the electrochemical series and explain the reasoning behind your choice(s). **2 marks**

c. A student uses the electrochemical series to predict that when $Cl_2(g)$ at 25°C and 101.3 kPa is bubbled through 1 M $Fe^{2+}(aq)$ solution, $Fe^{3+}(aq)$ ions should be produced in the solution. However on adding KSCN(aq) to the solution, the dark red colour characteristic of $Fe(NCS)^{2+}(aq)$ is not produced. Suggest a reason why the 'expected' reaction between $Fe^{2+}(aq)$ and $Cl_2(g)$ is not observed. **1 mark**

Question 8 (11 marks)

'The Conversation' (http://theconversation.com/ipcc-report-biofuels-alone-are-unsustainable-but-can-still-help-combat-climate-change-25046) on April 1, 2014 included an article entitled 'IPCC report: biofuels alone are unsustainable, but can still help combat climate change'. The article discusses a report from the meeting of Working Group II of the International Panel on Climate Change (IPCC) in March 2014 that raised some issues about the extent to which biofuels may assist in reducing carbon dioxide emissions as part of an overall strategy in reducing the impact of climate change.

a. The article includes a statement 'If all went according to plan, the carbon cycle would be "closed" and there would be no (or very little) net release of carbon dioxide into the atmosphere from (the use of) biofuels.'

i. Using bioethanol as an example, explain why there should be little, if any, net release of CO_2 into the atmosphere from the use of biofuels. **1 mark**

ii. Many areas of the planet are regularly under the impact of drought. Give two reasons **why** biofuels are unlikely to be a sustainable fuel source in such areas. **1 mark**

b. Biodiesel is produced by transesterification, a process in which triglycerides are converted to methyl esters in a reaction catalysed by either an acid or a base. Research has shown that chicken fat is very suitable for the production of biodiesel. The transesterification of a triglyceride in chicken fat is represented by the incomplete equation below.

i. Write the name and give the semistructural formula of compound A. **1 mark**

ii. Give the name and molecular formula of compound B. **1 mark**

iii. Give the semistructural formula of the biodiesel produced which is monounsaturated. **2 marks**

c. Analysis of the combustion of a 0.631 g sample of methyl palmitate indicated the release of 23.5 kJ of energy.
Write a balanced thermochemical equation for the combustion of methyl palmitate. **3 marks**

d. Nuclear energy is often put forward as the best fuel source for reducing CO_2 emissions in power stations.

i. What is the **main** advantage of nuclear fuel as an energy source? **1 mark**

ii. What is the **main** disadvantage in the use of nuclear energy as a fuel source? **1 mark**

End of Section B

End of Trial Exam

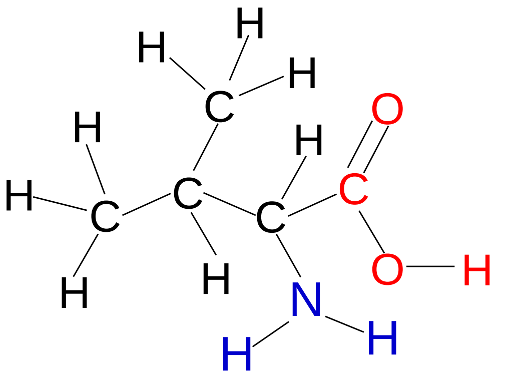
Suggested Answers

VCE Chemistry 2014 Year 12 Trial Exam Unit 3/4

SECTION A – Multiple Choice Answers

(1 mark per question)

Q1. D Quickly sketch the structure for 2-amino-3-methylbutanoic acid.



This is an amino acid with $(CH_3)_2CH$ as its Z-(side) group, i.e. **valine.** *(Table 8 of the Data Book).*
The systematic of the other amino acids listed are
glycine – 2-aminoethanoic acid.
alanine – 2-aminopropanoic acid.
leucine – 2-amino-4-methylpentanoic acid.

Q2. A $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$; $\Delta H = -566$ kJ mol^{-1} 1.
$2Cu(s) + O_2(g) \rightarrow 2CuO(s)$; $\Delta H = -311$ kJ mol^{-1} 2.
The required equation requires CuO on the left hand side, so reverse equation 2.
$2CuO(s) \rightarrow 2Cu(s) + O_2(g)$; $\Delta H = +311$ kJ mol^{-1} 2A.
Add equations 1. and 2A.
$2CO(g) + O_2(g) + 2CuO(s) \rightarrow 2CO_2(g) + 2Cu(s) + O_2(g)$; $\Delta H = -566$ kJ mol^{-1} + 311 kJ mol^{-1}
$2CO(g) + 2CuO(s) \rightarrow 2Cu(s) + 2CO_2(g)$; $\Delta H = -255$ kJ mol^{-1}
Divide through by 2 to get the required mole ratio
$CO(g) + CuO(s) \rightarrow Cu(s) + CO_2(g)$; $\mathbf{\Delta H = -128\ kJ\ mol^{-1}}$

Q3. B The **simplest** pathway from an alkene to an ester derived from that alkene is

1. alkene to alcohol – **addition** reaction with water (steam)
2. alcohol to carboxylic acid – redox reaction (oxidation of the alcohol, **reduction** of the oxidant).
3. alcohol + carboxylic acid to ester – **condensation** reaction.
   There is no need for a substitution reaction in this pathway.

Q4. C Semi-structural formulae of glycine (Table 8), and sucrose and glycerol (Table 10) of the Data Book.
Glucose, $C_6H_{12}O_6$, $M(C_6H_{12}O_6) = 180.0$ g mol^{-1}
% C = (72.0 / 180.0) x 100 = 40.0 %
Glycerol, $CH_2OHCHOHCH_2OH$, i.e. C_3H_8O, $M(C_3H_8O_2) = 92.0$ g mol^{-1}
% C = (36.0 / 92.0) x 100 = 39.1 %
Sucrose, $C_{12}H_{22}O_{11}$, $M(C_6H_{12}O_6) = 342.0$ g mol^{-1}
% C = (144.0/342.0) x 100 = **42.1** %
Glycine NH_2CH_2COOH, i.e. $C_2H_5NO_2$, $M(C_2H_5NO_2) = 75.0$ g mol^{-1}
% C = (24.0 / 75.0) x 100 = 32.0 %.

Q5. D The two spectra shown are the IR spectrum and the ^{13}C NMR spectrum.
The IR spectrum shows distinct absorptions around 3300 cm^{-1}, characteristic of O-H alcohols (3200-3550 cm^{-1}) and 3000 cm^{-1}, C-H (2850-3300 cm^{-1})
Hence the compound is most likely an **alcohol**.
The lack of absorption in the 1670-1750 cm^{-1} band eliminates B and C as possibility answers since the C=O group is not present.
The second spectrum, a ^{13}C NMR spectrum, indicates that the molecules have **two different carbon environments**.
However both alcohols given have two different carbon hydrogen environments, i.e. Ethanol, CH_3CH_2OH, 2-propanol, $(CH_3)_2CHOH$.
The compound contains 60.0 per cent C
Ethanol, C_2H_6O; % C = (24.0 / 46.0) x 100 = 52.0 %
2-propanol, C_3H_8O; **% C** = (36.0 / 60.0) x 100 = **60.0 %**
The compound was most likely to be 2-propanol.

Q6. A Titre volumes:
(19.25 – 2.50) 16.75 mL, (30.40 – 19.25) 11.15 mL, (12.65 – 1.45) 11.20 mL, (23.75 – 12.65) 11.10 mL
Using concordant titres (those within 0.1 mL)
Average $V(I_2)$ used = (11.15 + 11.20 + 11.10) / 3
= **11.15 mL**
$n(SO_2)$ in sample = $n(I_2)$ used
= 0.00525 x 11.15x10^{-3}
= 5.85x10^{-5} mol
$m(SO_2)$ in sample = 5.85x10^{-5} mol x 64.1 g mol^{-1}
= 3.75x10^{-3} g
= **3.75 mg**

Q7. C m(O) in sample = $m(X_2O_3)$ produced – m(X)
= 1.10 – 0.62
= 0.48 g
n(O) in sample = 0.48 g / 16.0 g mol^{-1}
= 0.030 mol
Since there are 3 mol O atoms for every 2 mol X atoms in the oxide
n(X) = $^2/_3$ x n(O) = $^2/_3$ x 0.30
= 0.020 mol
M(X) = m(X) / n(X)
= 0.62 g / 0.020 mol
= 31 g mol^{-1}
According to the Periodic Table (Data Book Table 1), the element is **Phosphorus**

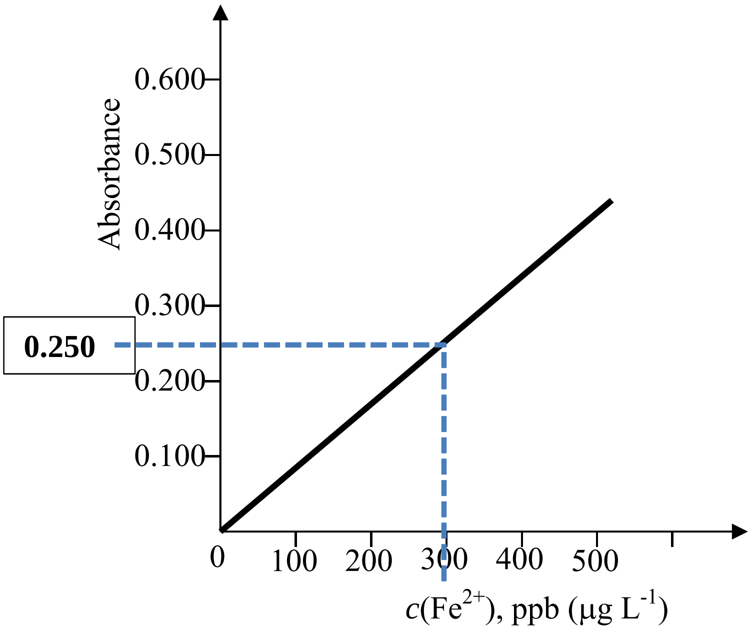
Q8. B In the molybdenum-air cells the oxidant is $O_2(g)$.
According to the electrochemical series (Data Book Table 2), in an alkaline electrolyte.
$\mathbf{O_2}(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$; $E^o = +0.40$ V
For the reductant, Mo, in alkaline solution
$MoO_4^{2-}(aq) + 4H_2O(l) + 6e^- \rightleftharpoons \mathbf{Mo}(s) + 8OH^-(aq)$ $E^o = -0.91$ V
The cell operating voltage = E^o(oxidant half-cell) - $E°$(reductant half-cell)
= +0.40 – (-0.91)
= **1.31 V**

Q9. B In this exercise the Na_2CO_3 aliquot was titrated with HCl(aq), the pipette should have been rinsed with the Na_2CO_3(aq) and burette with the HCl(aq). Titration flasks should be rinsed with water. In the ensuing calculation the only variable between the four groups should have been the V(HCl) used in the titration.
The impact of the differing volumes of HCl will impact in c(HCl) = n(HCl) / V(HCl).
Group I followed the correct rinsing procedures so should have calculated the **correct *c*(HCl).**
Group II – rinsing the burette with water will leave traces of water which will decrease the concentration of the HCl(aq) then added to the burette and lead to a larger titre. So a larger volume of HCl(aq) will be required to provide the n(HCl) to react completely with the Na_2CO_3. Since c(HCl) is calculated from n(HCl) / V(titre), the **calculated *c*(HCl) will be lower than the correct value.**
Group III – the effect of rinsing the burette with Na_2CO_3(aq) will be to reduce the concentration of the HCl(aq) then added again leading to a larger titre and a **lower than correct calculated *c*(HCl).**
Group IV – rinsing the pipette with water will leave traces of water and will cause the amount of Na_2CO_3 present in the aliquot then taken using the pipette to be less than it should be. Less HCl(aq) will be needed to get to the equivalence point, so a lower titre volume will be recorded leading to a **higher than correct calculated *c*(HCl).**
With two groups calculating concentrations lower than the true value and one group calculating a concentration higher than the true value, the **correct *c*(HCl) is most likely to be 0.098 M.**

Q10. B CH_3OH - methanol, CH_3CH_2OH - ethanol, $CH_3CH_2CH_2OH$ – propan-1-ol, $CH_3CH_2CH_2OH$ – butan-1-ol and $(CH_3)_3COH$ – methylpropane-2ol all have a single hydroxyl group so their **relative attractions to the stationary phase will depend on the attraction of their non-polar hydrocarbon sections with a non-polar stationary phase**.

Methanol - CH_3OH will have the weakest attraction to the stationary phase and so exit the gas chromatograph and pass into the mass spectrometer first.

Q11. B



Absorbance 0.250 → $c(Fe^{2+})$ in 150 mL diluted solution = 300 µg L^{-1}
5.0 mL of the original 250 mL test solution had been diluted to 150 mL, i.e. diluted by a factor of 30.
Hence $c(Fe^{2+})$ in original 250 mL of solution = 30 x 300
= 9.00×10^3 µg L^{-1}
$m(Fe^{2+})$ in test solution = 9.00×10^3 µg L^{-1} x 250×10^{-3} L
= 2.25×10^3 µg
To convert µg to mg divide by 1000 (Data Book Table 4)
$m(Fe^{2+})$ in test solution = 2.25×10^3 / 1000
= **2.25 mg**

Alternatively:
$m(Fe^{2+})$ in 150 mL of diluted solution = 300 x (150/1000) = 45.0 µg
$m(Fe^{2+})$ in 5 mL of original solution = 45.0 µg
$m(Fe^{2+})$ in 250 mL of original solution = 45.0 x (250/5) = 2.25×10^3 µg
Since 1000 µg = 1 mg
$m(Fe^{2+})$ in 250 mL of original solution =) = 2.25×10^3 / 1000 = 2.25 mg

Q12. B $3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$

6.75 g *xs* *at STP*

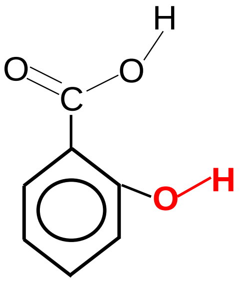
n(Cu) added = 6.75 g / 63.5 g mol^{-1}
= 0.106 mol

n(NO) produced = $^2/_3$ x n(Cu)
= $^2/_3$ x 0.106
= 0.0707 mol

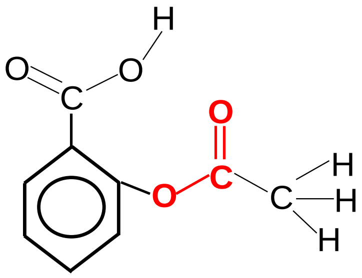
n(NO) collected = V(NO) collected / V_m(STP)
= 630×10^{-3} L / 22.4 L mol^{-1}
= 0.0281 mol

% NO collected = [n(NO) collected / n(NO) produced] x 100
= [0.0281 / 0.0707] x 100
= **39.7 %**

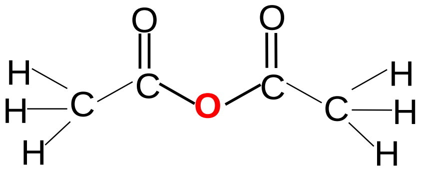
Q13. A The compounds shown in the question are



Salicylic acid



Aspirin (acetylsalicylic acid)



Ethanoic anhydride

Salicyl alcohol is not shown – its structure is like salicylic acid but with $–CH_2OH$ instead of -COOH

The benzene ring in salicylic acid and aspirin contains 4 H atoms, all of which are ‘different’ bonding environments. The bond environment must consider the whole molecule not just the atoms involved in a specific bond.

Salicylic acid: 6 different H environments → 6 peaks

Aspirin: 6 different H environments → 6 peaks

Ethanoic anhydride has only one H environment, with respect to the rest of the molecule all 6 H atoms are chemically equivalent. It would have only one peak (other than TMS) on its ^{1} H NMR spectrum.

Q14. B 10.25 mL of 0.1020 M HCl(aq) was used to convert Na_2CO_3 to $NaHCO_3$

$HCl(aq) + Na_2CO_3(aq) \rightarrow NaHCO_3(aq) + NaCl(aq)$

n(Na_2CO_3) present = *n*(HCl) required to reach phenolphthalein endpoint.
= *c*(HCl) x *V*(HCl)
= 0.1020 mol L^{-1} x 10.25x10^{-3} L
= 1.046x10^{-3} mol

***n*($NaHCO_3$) produced from Na_2CO_3 = *n*(Na_2CO_3)**
= 1.046x10^{-3} mol

25.25 mL of 0.1020 M HCl(aq) was required to react with all the $NaHCO_3$ – that initially present and that produced from Na_2CO_3.

$HCl(aq) + NaHCO_3(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$

n($NaHCO_3$) reacting = *n*(HCl) added between endpoints.
= 0.1020 x 25.35x10^{-3}
= **2.586x10^{-3} mol**

$NaHCO_3$ in bath salts is the difference between the amount reacting in the second titration and the amount produced from Na_2CO_3.

n($NaHCO_3$) in 50 mL bath salts = *n*($NaHCO_3$) reacting – *n*($NaHCO_3$) from Na_2CO_3
= 2.586x10^{-3} – 1.046x10^{-3}
= **1.540x10^{-3} mol**

Alternatively

10.25 mL of 0.1020 HCl(aq) was required in the phenolphthalein titration to convert the Na_2CO_3 initially present the aliquot of bath salts solution to $NaHCO_3$. This means that in the methyl orange titration, 10.25 mL of the added 0.1020 M HCl(aq) reacted with the $NaHCO_3$ produced from Na_2CO_3.

The remainder of the second titre, i.e. 25.35 – 10.25 = **15.10 mL of 0.1020 M HCl(aq) reacted with the $NaHCO_3$ initially present in the aliquot of bath salts solution**.

***n*($NaHCO_3$) in aliquot of bath salts solution** = *n*(HCl) reacting with that $NaHCO_3$
= 0.1020 x 15.10x10^{-3}
= **1.540X10^{-3} mol**

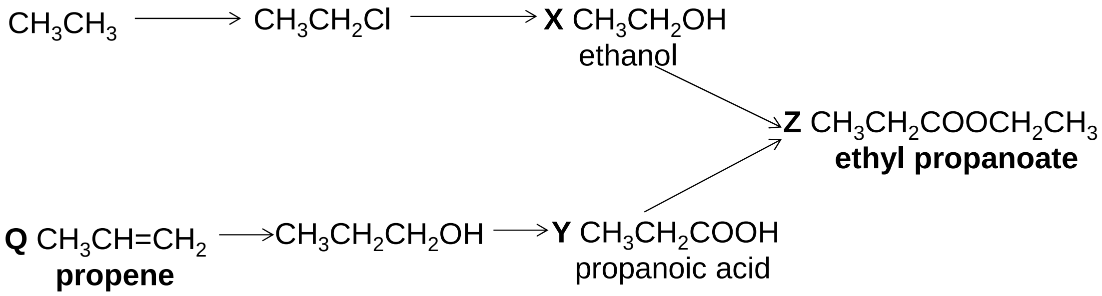
Q15. D X and Y are both organic compounds used to produce another organic compound Z. The pathway can be consistent with the production of an ester, Z, from an alcohol, X, and a carboxylic acid, Y.

X – **ethanol** produced from the reaction of CH_3CH_2Cl with $OH^-(aq)$ - (substitution).

Y – **propanoic acid** from the oxidation of $CH_3CH_2CH_2OH$ and acidified $Cr_2O_7^{2-}(aq)$ – (oxidation/redox).

Z – **ethyl propanoate** from the reaction between CH_3CH_2OH and CH_3CH_2COOH – (condensation).

Q – **propene**, since $CH_3CH_2CH_2OH$ is produced directly from $CH_3CH=CH_2$ by reaction with H_2O in the presence of H_3PO_4 catalyst – (addition)



Q16. A The analytical process referred to is Atomic Absorption Spectroscopy (AAS), which is most suitable for measuring amounts of metals extracted into or present in solution, hence could be used in the determination of the amount of potassium in a sports drink.

The analytical techniques used in the other options would be.

B. IR spectroscopy

C. ^{13}C NMR spectroscopy

D. Gas chromatography or redox titration.

Q17. D In order for the cell to generate 1.0 V at 25°C, 101.3 kPa and for 1 M solutions, the difference between the E^{o} values of the two half-cells must be 1.00 V.
Since the $Fe^{3+}(aq)/Fe^{2+}(aq)$ half-cell has an E^{o} value of +0.77 V, the other half cell must have an E^{o} value either 1.00 V greater than +0.77 V, i.e. +1.77 V, or 1.00 V less than +0.77 V, i.e. -0.23 V.

According to the electrochemical series this is consistent with

$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$ 1.77 V

$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$ *0.77 V*

$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$ *-0.23 V*

In a galvanic cell, electrons move spontaneously from the anode (-) to the cathode (+).
So the electrode signs indicate that oxidation is occurring in the $Fe^{3+}(aq)/Fe^{2+}(aq)$ half-cell i.e.
$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$
Since electrons leave the site of oxidation and go to the site of reduction, the left-hand half-cell must contain the oxidant, in this case $H_2O_2(aq)$,$H^+(aq)$, i.e. 1.00 V higher up on the electrochemical series than the reductant $Fe^{2+}(aq)$.
$H_2O(l)$ is the **product of the half-reaction in half-cell 1,** because the oxidant $H_2O_2(aq)$ is reduced to $H_2O(l)$ according to $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H2O(l)$.

Alternatively:
Since E(cell) = E^{o}(oxidant half-cell) - E^{o}(reductant half-cell)
1.00 V = E^{o}(oxidant) - E^{o}($Fe^{3+}(aq)/Fe^{2+}(aq)$)
= E^{o}(oxidant) - (0.77 V)
Hence E^{o}(oxidant) = 1.00 + 0.77
= +1.77 V
From the electrochemical series $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow {}_2\boldsymbol{H_2O}(l)$; E^{o} = +1.77 V

Q18. B For both X and Y the $[H_3O^+]$ decreases at time 't' because of the increase in volume.
The fact that for **X** the $[H_3O^+]$ stays constant after dilution suggests that it is **a strong acid** and was **fully ionised** in solution prior to dilution.
For **Y** the rise in $[H_3O^+]$ after dilution suggests that it is a **weak acid**. As a weak acid, HA (aq), **only a small amount has ionised prior to dilution**. Whilst the concentrations of $A^-(aq)$ and HA(aq) also decrease **on dilution**, the concentration fraction $\{[A^-][H_3O^+] / [HA]\}$ becomes $< K$.
To get back to equilibrium, **ionisation of the acid increases, causing the $[H_3O^+]$ to increase until equilibrium is again established**.
X - Hydrochloric acid, HCl(aq), is a strong acid.
Y - Methanoic acid, HCOOH(aq), is a weak acid. ($K_a = 1.8\text{x}10^{-4}$)
Since both acids have the same initial pH, hence $[H_3O^+]$, and HCl(aq) is fully ionised but HCOOH(aq) is only partially ionised, **HCOOH(aq) will have the higher initial concentration**.
pH 3.00 → c(HCl) = 0.0010 M
pH 3.00 → $c(HCOOH) = \{[H_3O^+]^2/K_a\} = \{[0.0010]^2/1.8\text{x}10^{-4}\} = 0.0056$ M
Correct Answer B

Q19. C Given the overall recharging reaction

$$Cd(OH)_2(s) + 2Ni(OH)_2(s) \rightarrow 2NiO(OH)(s) + 2H_2O(l) + Cd(s)$$

The overall discharging reaction must be

$$2\overset{+3}{Ni}O(OH)(s) + 2H_2O(l) + \overset{0}{Cd}(s) \rightarrow \overset{+2}{Cd}(OH)_2(s) + 2\overset{+2}{Ni}(OH)_2(s)$$

Since oxidation occurs at the anode and, according to the oxidation numbers Cd is oxidised to $Cd(OH)_2$, the oxidation half-equation during discharging must be $Cd(s) + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$.

Q20. D During recharging, according to the oxidation numbers

$$\overset{+2}{Cd}(OH)_2(s) + 2\overset{+2}{Ni}(OH)_2(s) \rightarrow 2\overset{+3}{Ni}O(OH)(s) + 2H_2O(l) + \overset{0}{Cd}(s)$$

$Cd(OH)_2$ is reduced and during recharging (electrolysis) reduction occurs **at the (-) electrode**.

Since the **negative terminal of power supply must be attached to the (-) terminal of the battery** it must be **connected to the electrode containing $Cd(OH)_2$.**

During recharging a voltage greater than that generated during discharging must be applied to the cell to force the electrons to flow in the opposite direction.

Hence a **voltage greater than 1.4 V** must be applied.

Q21. A From time t, the concentration of one species gradually increases and the concentration of the other species gradually decreases until equilibrium is reached again. This indicates the change was not a change in volume since that would cause an instantaneous concentration increase or decrease for both species prior to the gradual adjustments back to equilibrium.

The gradual changes in concentration of both species after time t suggest **a change in temperature** was imposed.

The change in concentration for the **top curve** is significantly greater, implying that was the **species is on the side with more particles**, i.e. the top curve is for NO_2.

The amount of NO_2 has increased, as a result of the imposed change, **whilst the amount of N_2O_4 has decreased.**

According to the supplied thermochemical information

$N_2(g) + 2O_2(g) \rightarrow 2NO_2(g) \quad \Delta H = +90.4 \text{ kJ mol}^{-1}$

$N_2(g) + 2O_2(g) \rightarrow N_2O_4(g) \quad \Delta H = +9.7 \text{ kJ mol}^{-1}$

Reversing the first equation (also changing sign of ΔH) and adding it to the second one gives

$$2NO_2(g) \rightarrow N_2O_4(g); \ \Delta H = -90.4 + 9.7 \text{ kJ mol}^{-1}$$
$$= -80.7 \text{ kJ mol}^{-1}$$

So in the equilibrium $2NO_2(g) \rightleftharpoons N_2O_4(g)$ the forward reaction is exothermic.

Since the **temperature change favours the reverse endothermic reaction** it must have been a **temperature increase**.

Q22. D $[NO_2]$ initially = ?

$[NO_2]$ equilibrium = 0.310 M

$K_c = [N_2O_4] / [NO_2]^2$

$2.04 = [N_2O_4] / 0.310^2$

$[N_2O_4]$ equilibrium $= 2.04 \times 0.310^2$

$= 0.196$ M

$n(NO_2)$ equilibrium $= 0.310 \text{ mol L}^{-1} \times 0.500$ L

= **0.155 mol**

$n(N_2O_4)$ at equilibrium = **0.196** mol $L^{-1} \times 0.500$ L

= 0.0980 mol

$n(NO_2)$ reacted = 2 x $n(N_2O_4)$ at equilibrium

= 2 x 0.0980

= **0.196 mol**

$n(NO_2)$ added to container = 0.155 + 0.196

= 0.351 mol

$m(NO_2)$ = 0.351 mol x 46.0 g mol^{-1}

= **16.1 g**

Q23. B Species which can act as both oxidants and reductants can be identified on the electrochemical series. (Data Book Table 2).

This shows that **H_2O, H_2O_2 and Sn^{2+} can all act as both oxidants and reductants**

H_2O – reduced to H_2, oxidised to O_2

$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2\mathbf{H_2O}(l)$ $E° = +1.23$ V

$2\mathbf{H_2O}(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$ $E° = –0.83$

H_2O_2 – reduced to H_2O, oxidised to O_2

$\mathbf{H_2O_2}(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O_2(l)$ $E° = +1.77$ V

$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons 2\mathbf{H_2O_2}(l)$ $E° = +0.68$ V

Sn^{2+} – reduced to Sn, oxidised to Sn^{4+}

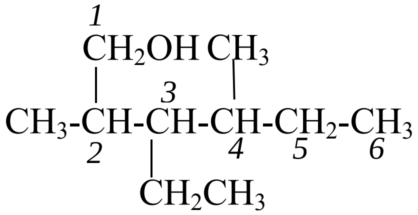
$Sn^{4+}(aq) + 2e^- \rightleftharpoons \mathbf{Sn^{2+}}(aq)$ $E° = +0.15$ V

$\mathbf{Sn^{2+}}(aq) + 2e^- \rightleftharpoons Sn(s)$ $E° = -0.14$ V

Cu^{2+} appears only as an oxidant, reduced to Cu.

$\mathbf{Cu^{2+}}(aq) + 2e^- \rightleftharpoons Cu(s)$ $E° = +0.34$ V

Q24. D Identify the longest continuous run of C atoms numbered so that the hydroxyl, -OH group has the lowest possible number



$$CH_3\text{-}\underset{2}{\overset{\overset{1}{CH_2OH}}{\overset{|}{C}H}}\text{-}\underset{\underset{CH_2CH_3}{|}}{\overset{3}{C}H}\text{-}\underset{4}{\overset{\overset{CH_3}{|}}{C}H}\text{-}\underset{5}{CH_2}\text{-}\underset{6}{CH_3}$$

6 carbons in a continuous run → hex**an** .. since all C-C bonds are single bonds

Hydroxyl –OH group on C-1

2 methyl $–CH_3$ groups at C-2 and C-4

1 ethyl $–CH_2CH_3$ group at C-3

Hence **2,4-dimethyl-3-ethylhexan-1-ol**

Q25. B The monoprotic acid may be represented by HA, so the reaction with NaOH is

$HA(aq) + NaOH(aq) \rightarrow NaA(aq) + H_2O(l)$

n(NaOH) used = *c*(NaOH) x *V*(NaOH)
= $1.000 \times 27.48 \times 10^{-3}$
= 2.748×10^{-2} mol

n(HA) in 25.0 mL aliquot = *n*(NaOH)
= 2.748×10^{-2} mol ❶

n(HA) in sample = $(2.748 \times 10^{-2} / 25) \times 200$
= 0.2198 mol

According to the mass spectrum M(HA) = 60.0 g mol^{-1}

m(HA) = *n*(HA) x M(HA)
= 0.2198 x 60.0
= **13.2 g**

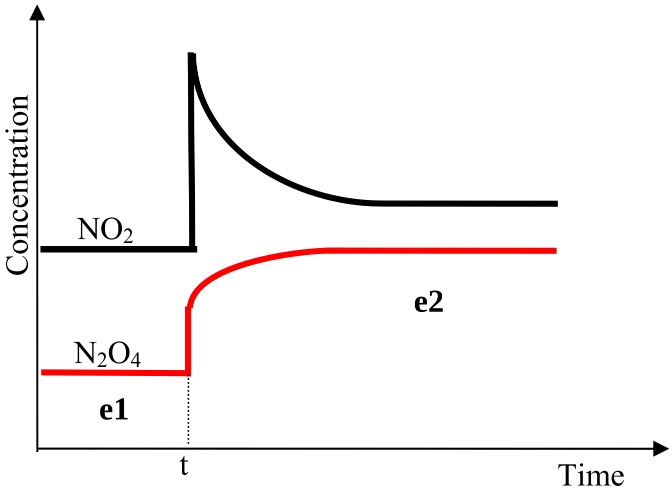
Q26. C Because **solid NaOH is not a primary standard**, the concentration of aqueous solutions of NaOH cannot be accurately determined from the mass dissolved. Aqueous solutions of NaOH can be standardised against standard solutions of hydrochloric acid. The HCl(aq) is itself standardised by titration against an aqueous solution of a primary standard, in this case Na_2CO_3.

The reaction sequence was:

1. a solution of the primary standard Na_2CO_3 was made and used to standardise the '**x**' M HCl(aq)
2. the standardised HCl(aq) was used it standardise the '**y**' M NaOH(aq)
3. aliquots of the diluted vinegar sample were titrated with the standardised NaOH(aq)

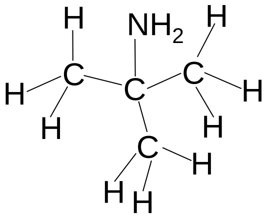
Alternatives A, B and C are all chemically correct statements but the **most relevant** to this analysis was **C – sodium hydroxide is not a primary standard**. This analysis did NOT involve back titration which usually involves titration to determine the amount of 'excess' reactant.

Q27. B When the volume of the equilibrium mixture was halved, the pressure and concentration of each species immediately doubles. The effect of this change is represented on the concentration-time diagram below, consistent with Le Chatelier's principle that the system will compensate for the pressure increase by moving to compensate for the change by favouring the side with fewer particles.



Compare the amounts and concentrations of NO_2 and N_2O_4 present at the equilibrium positions **e1** - before the volume change, and **e2** - after the volume change is interesting.
The concentration-time graph shows clearly that $\mathbf{[NO_2]_{e2}} > \mathbf{[NO_2]_{e1}}$, overall the $\mathbf{[NO_2]}$ **increases**. After the change the system returns to equilibrium but the $[NO_2]$ does **not** drop to its value prior to the imposed changed.
As the system returns to equilibrium NO_2 is converted into N_2O_4, i.e. the mass of NO_2 decreases so it follows that $\boldsymbol{m}\mathbf{(NO_2)_{e2}} < \boldsymbol{m}\mathbf{(NO_2)_{e1}}$; overall the $\boldsymbol{m}\mathbf{(NO_2)}$ **decreases**.

Q28. C methyl-2-propanamine



– semistructural formula $(CH_3)_3CNH_2$
– molecular formula: $C_4H_{11}N$

$n(C_4H_{11}N) = 365\text{x}10^{-6}$ g / 73.0 g mol^{-1} ……. to covert μg to g divide by 10^6
$= 5.00\text{x}10^{-6}$ mol
$n(C) = 4 \text{ x}5.00\text{x}10^{-6}$
$= 2.00\text{x}10^{-5}$ mol
$N(C) = 2.00\text{x}10^{-5} \text{ x } 6.02\text{x}10^{23}$
$= \mathbf{1.20x10^{19}}$ atoms

Q29. D With all initial concentrations at 0.1 M, the starting pH in the titration curves should be

- very close to 1 for HCl(aq), a strong acid
- significantly higher than 1 but less than 7 for CH_3COOH(aq), a weak acid base.
- very close to 13 for NaOH(aq), a strong base
- significantly less than 13 but greater than 7 for NH_3(aq), a weak acid base.

Finishing pH values close to 1 and 13 reflect titration with a strong acid and a weak base respectively.

Finishing pH values less than 13 but greater than 7, and greater than 1 but less than 7, reflect titration with a weak base and a weak acid respectively.

Titration curve A shows the titration of a weak acid by a strong base – alternative C.

Titration curve B shows the titration of a strong acid by a strong base – alternative B.

Titration curve C shows the titration of a strong acid by a weak base – alternative A.

Titration curve D shows the titration of a strong base by a strong acid – alternative B.

Reaction between NH_3(aq) and CH_3COOH(aq) i.e. between a weak base and a weak acid is not represented in the titration curves shown.

Q30. D Consider the alternatives

A. *not rinsing the precipitate with water during collection.* This means that **some soluble species may be caught in the precipitate and not flushed** out leading to a **higher than true measured *m*(precipitate)** and **calculated percentage over 100**.

B. *not drying the precipitate fully prior to weighing.* This means that **water will remain in the precipitate** leading to a **higher than true measured *m*(precipitate)** and **calculated percentage over 100**.

C. *incorrectly recording the weight of the fertiliser as 1.798 g rather than the correct 1.978.* This means that when calculating % sulfur = [*m*(sulfur) / *m*(sample)] x 100, **dividing by 1.798 rather than the correct 1.978** will produce a **calculate percentage over 100**.

D. *not converting all the sulfur in the sample to sulfate prior to precipitation.* This means that the amount of sulfate produced hence ***m*(precipitate) collected will be lower than it should be** leading to a **calculated percentage less than 100.**

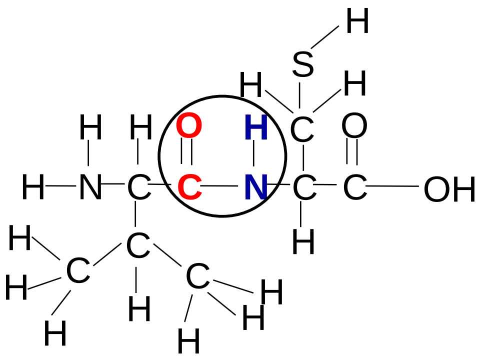
SECTION B - Short Answer (Answers)

Question 1 (16 marks)

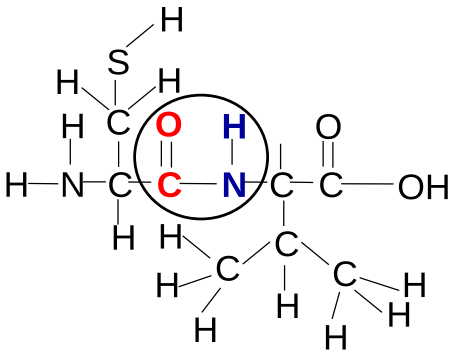
a. In the hydrolysis reaction **water reacted with the peptide groups, CO-NH ❶**, which were converted into **carboxyl, COOH, and amino, NH_2 groups ❶**

b. A tripeptide is formed from three amino acid residues. If each of the three amino acids was present only once in each molecule of X, it would be a tripeptide, however the **chromatogram does not indicate the relative number of each of the three amino acids in the molecule hence it may or may not be a tripeptide. ❶** Also a tripeptide need not give three spots on the chromatogram since it can be formed from a single amino acid or from two amino acids.

c. The sulfur containing amino acid in X and Y is cysteine (cys) – (Data Book Table 8 for structure). Two dipeptides are possible: from reaction between –COOH on valine and –NH_2on cysteine, or between –COOH on cysteine and –NH_2 on valine.

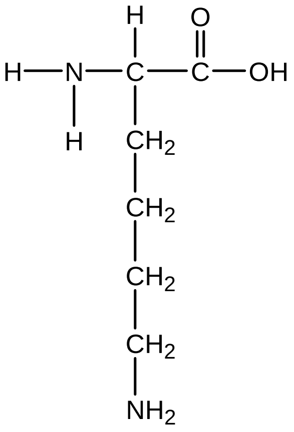


or

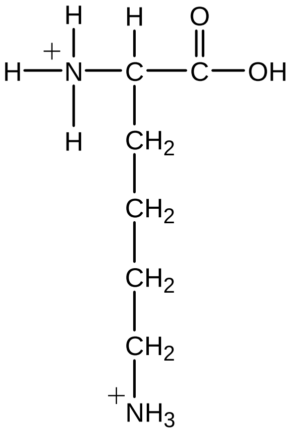


❶ *for –CH_2SH (cysteine) and –$CH(CH_3)_2$ (valine) side groups with all bonds shown.*
❶ *for correct overall structure and peptide group correctly circled.*

d. To have a charge of +2 in solution at pH 3, the **amino acid must have two groups that can be protonated (accept H^+(aq)) in acidic solution**. **Lysine ❶**, has **two basic NH_2 groups both of which will be protonated to – $^+NH_3$ ❶** giving an overall charge of +2.



Lysine



Lysine at pH 3

e. In chromatography the **mobile phase carries the components in a mixture over the stationary phase. Components are separated according to the relative attractions to the stationary and mobile phases.** ❶ The **component most strongly attracted to stationary phase, in this case histidine, moves the least distance** (slowest) ❶. The **component least strongly attracted to the stationary phase, in this case glycine, moves the greatest distance** (fastest) ❶.
❶ *for appropriate mention of mobile and stationary phases.*
❶ *for identification of glycine as being least strongly attracted to the stationary phase.*
❶ *for identification of histidine as being most strongly attracted to the stationary phase.*
The second and third marks can be awarded for accurate comparison of any two amino acids in the chromatogram.

f.

	Proteins	Nucleic acids
Type of bond associated with primary structure. ❶ *for both correct*	**Covalent**	**Covalent**
Atoms between which primary structure bonds occur.	**C and N** in peptide link ❶	**C** on one nucleotide **to O to P** on adjacent nucleotide ❶
Types of bonds associated with secondary structure. ❶ *for both correct*	**Hydrogen bonding**	**Hydrogen bonding**
Atoms between which secondary structure bonds occur.	**O on one peptide group** and **H on a different peptide group.** ❶	**H and N, and H and O** on **complementary nitrogen bases.** ❶

Question 2 (16 marks)

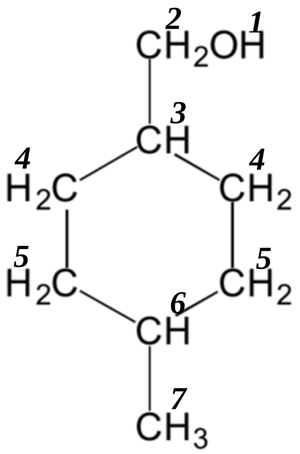
a. **i.** $m(\text{MHCM}) = 0.95 \text{ x } 28000\text{x}10^3$
$= 2.66 \text{ x}10^7$ ❶
The unit ppm(m/V)is equivalent to mg L^{-1}
$c(\text{in mg L}^{-1}) = m(\text{in mg}) / V(\text{in L})$, hence
$V(\text{solution}) = m(\text{mg}) / c(\text{mg L}^{-1})$
$= 2.66 \text{ x}10^7 \text{ x } 10^3 / 1$
$= 2.66 \text{ x}10^{10}$ L ……. *to convert L to GL divide by* 10^9 *(Data Book Table 4)*
= 27 GL ❶ (2 sig figs)

ii. 1.00 ppm = 1.00 mg $C_8H_{16}O$ in one litre of solution
$M(C_8H_{16}O) = 128.0 \text{ g mol}^{-1}$
$n(C_8H_{18}O)$ *in one L* $= 1.00\text{x}10^{-3} \text{ g} / 128.0 \text{ g mol}^{-1}$
$= 7.8\text{x}10^{-6}\text{mol}$
$c(C_8H_{16}O)$ **=** $\mathbf{7.8x10^{-6}}$ **mol** $\mathbf{L^{-1}}$ ❶ *or* $7.8\text{x}10^{-6}$ M

b. In the **initial stages** of the spill, the levels of MCHM in the water would have been very high and some of this **highly concentrated solution may have entered the domestic water supply** ❶. **Flushing thoroughly would effectively wash this through the pipes and ensure that the water was diluted below dangerous levels of MCHM and safe for domestic use.** ❶

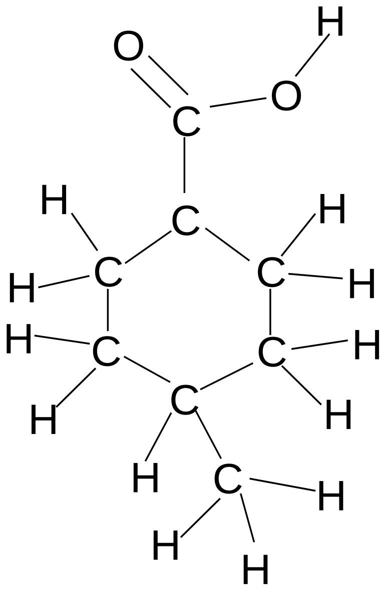
c. **7 peaks** ❶

The seven different H environments are indicated on the diagram below.



A quick check to show that the H atoms labelled 4 and 5 are in different chemical environments is their relative distances from the –OH functional group.

d. **i.**



❶ *for overall structure showing all bonds.*

ii. When MHCM is oxidised, acidified $Cr_2O_7^{2-}(aq)$ is reduced to $Cr^{3+}(aq)$. The half-equation for this reaction is

$$\mathbf{Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)}$$ ❶

e. **i.** $m(\text{C}) = 40.0/100 \times 1000$
$= 400$ g
$m(\text{H}_2\text{O}) = 1000 – 400$
$= 600$ g
According to Table 13 of the Data Book, $\Delta H_c(\text{C}) = 394$ kJ mol^{-1}
$n(\text{C}) = 400 / 12.0$
$= 33.3$ mol ❶
Energy released from coal = energy available from C content – energy required to vaporise H_2O
Energy available from C = 33. 3 mol x 394 kJ mol^{-1}
$= 1.31\text{x}10^4$ kJ ❶
$n(\text{H}_2\text{O}) = 600 / 18.0$
$= 33.3$ mol ❶
Energy required to vaporise water = 33.3 mol x 41.0 kJ mol^{-1}
$= 1.37\text{x}10^3$ kJ ❶
Energy released by 1.0 kg of brown coal = $1.31\text{x}10^4 – 1.37\text{x}10^3$
$= 1.18\text{x}10^4$ kJ
Heat of combustion = $1.18\text{x}10^4$ kJ / 1000 g
= **11.8 kJ g^{-1}** ❶

ii. Only around 30 per cent of the chemical energy of the coal is converted to electrical energy. The rest is lost, mainly as heat energy, in the energy conversions in the power station.
Economic advantage – **less coal needed for the production of electrical energy hence electricity should be cheaper for consumers.** ❶
Environmental advantage – **reduced emissions of the greenhouse gas CO_2.** ❶

iii. Plant material from which coal was formed (over millions of years) contained **proteins**, some of which were formed from **amino acids with side-chains containing sulfur** ❶, e.g. cysteine, methionine. Sulfur burns in air to produce SO_2.

Question 3 (9 marks)

a. **i.** **Cathode; Negative(-)** ❶

ii. The **strongest oxidant** present in the half-cell was the **metal cations** ❶, and hence they **reduced** in **preference to water** at the cathode. ❶

b. **i.** $Q = It = 3.20 \times 5.30 \times 60$
$= 1.02\text{x}10^3$ C
$n(\text{e}^-) = \text{Q} / \text{F} = 1.02\text{x}10^3 / 96500$
$= 0.0105$ mol ❶
Divalent metal $\rightarrow$ $X^{2+}(aq)$ ions.
Reduction half-equation is $X^{2+}(aq) + 2e^- \rightarrow X(s)$
$n(\text{X}) = n(\text{e}^-) / 2 = 0.0105 / 2$
$= 5.27\text{x}10^{-3}$ mol ❶
$M(\text{X}) = m(\text{X}) / n(\text{X})$
$= 1.09 / 5.27\text{x}10^{-3}$
$= 207$ g mol^{-1} ❶

ii. **Lead** ❶ *According to Date Book Table 1 (periodic table), $A_r(Pb) = 207.2$*

c. $Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$

$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$

During electrolysis, the stronger reductant $Pb^{2+}(aq)$ is preferentially reduced and Pb is deposited at the cathode. However if the electrolysis was allowed to run for an extended time, the **concentration of $Pb^{2+}(aq)$ will eventually drop to a level** ❶such that **H_2O is preferentially reduced and $H_2(g)$ is produced** at the cathode. ❶

Question 4 (10 marks)

a. ❶ **for two of statements 2., 3., and 5.** all of which are correct.

2. *The products of an exothermic reaction have a lower chemical energy content because chemical energy is converted into thermal energy*
3. *Since thermal energy is converted to chemical energy in an endothermic reaction, the products have a higher chemical energy content and are higher than the reactants on an energy profile.*
5. *Increasing temperature increases the kinetic energy of all particles and so increases the proportion of fruitful collisions, hence increasing the rate of reaction.*

b. ❶❶ **x 3** for a **clear explanation** of **why each of the <u>three</u> identified statements is incorrect.**

1. *Exothermic reactions always start spontaneously whereas endothermic reactions require a source of energy to start.*
   All chemical reactions require a source of energy to start. The **reactant molecules must have energy greater than the activation energy to enable the bonds in the reactant particles to break** ❶. If a **reaction** is **spontaneous** it means that the **prevailing conditions provide energy greater than the activation energy for that reaction.** ❶
4. *In the presence of catalyst the energy required to break reactant bonds is decreased but the energy released when product bonds form is not affected.*
   A **catalyst lowers the activation energy of a reaction but does not change the ΔH.** ❶ Since ΔH reflects the difference between the energy released when product bonds are formed and the energy used to break reactant bonds, the **presence of a catalyst decreases both energies – required for bond breaking, released in bond making- equally**. ❶
6. *At chemical equilibrium either an exothermic reaction* ***or*** *an endothermic reaction will be occurring.*
   At **equilibrium the rates of the forward and reverse reactions are occurring at the same rate**. ❶ **If the forward reaction is exothermic, the reverse reaction must be endothermic**, so at equilibrium BOTH **an exothermic and a reverse reaction are occurring**. ❶
7. *The rate of an exothermic reaction increases as it proceeds but the rate of an endothermic reaction decreases as it proceeds.*
   As reaction proceeds, reactant concentration decreases. This means that the **number of fruitful collisions decreases and the reaction slows down**. ❶ This **happens in both exothermic and endothermic reactions.** ❶

c. **i.** **$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$ …. or**

$Zn(s) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$ ❶

ii. The reaction using **zinc powder** ❶ would be faster since this will provide a **greater surface area for reaction** and **more successful collisions (**collisions with energy greater than the activation energy) **between Zn and $H^+(aq)$ ions**. ❶

Question 5 (14 marks)

a. **C_6H_5COOK ❶** ($C_6H_5COO^-K^+$)

b. i. Equilibrium equation is $C_6H_5COOH(aq) + H_2O(l) \rightleftharpoons C_6H_5COO^-(aq) + H_3O^+(aq)$

or

$C_6H_5COOH(aq) \rightleftharpoons C_6H_5COO^-(aq) + H^+(aq)$

$K_a = [C_6H_5COO^-][H_3O^+] / [C_6H_5COOH]$ ❶ *or*

$K_a = [C_6H_5COO^-][H^+] / [C_6H_5COOH]$ *or*

$6.4 x 10^{-3} = [C_6H_5COO^-][H_3O^+] / 0.100$ *Since $K_a(C_6H_5COOH) = 6.4x10^{-5}$ (Data Book, Table 12)*

ii. Apply the standard weak acid assumptions – minimal ionisation of the acid, hence $[C_6H_5COOH]_{eqm} = 0.100$ M – minimal effect from the self-ionisation of water, hence $[C_6H_5COO^-]_{eqm} = [H_3O^+]_{eqm}$

$6.4x10^{-5} = [H_3O^+]^2 / 0.100 \rightarrow [H_3O^+]^2 = 0.100 \text{ x } 6.4x10^{-5}$ ❶

$[H_3O^+] = \sqrt{(0.100x6.4x10^{-5})}$

$= 2.53x10^{-3}$ M ❶

pH $= -\log(2.53x10^{-3})$

= **2.60** ❶

c. i. $n(C_6H_5COOH)$ used = 1.56 g / 122.0 g mol^{-1}

$= 1.28x10^{-2}$ mol

Energy released $= 1.28x10^{-2}$ mol x 3227 kJ mol^{-1} ❶

= 41.3 kJ

$= 4.13x10^4$ J

Calibration factor $= 4.13x10^4$ J / 19.6°C

$= 2.11x10^3$ J °C^{-1} ❶❶

ii. The **calibration factor** calculated using the specific heat of water would be **lower** ❶ because it would **not account for the energy absorbed by the calorimeter components**. ❶

d. i. Energy released by fuel = Calibration factor x ΔT

= 3.17 kJ °C^{-1} x 17.8 °C

= 56.4 kJ ❶

According to Table 13 of the Data Book, $\Delta H_c(C_5H_{12}) = -3509$ kJ mol^{-1}

$n(C_5H_{12})$ = 56.4 kJ / 3509 kJ mol^{-1}

$= 1.61x10^{-2}$ mol ❶

$m(C_5H_{12})$ added to the calorimeter $= 1.61x10^{-2}$ mol x 72.0 g mol^{-1}

= **1.16 g** ❶

ii. **Incomplete combustion** of pentane due to not adding sufficient or excess oxygen to the calorimeter. ❶

Question 6 (28 marks)

a. **$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$** ❶

b. n(CH_3CH_2OH) = 1.02 / 46.0
= 0.0222 mol
Energy released per mol = 1.04 kJ / 0.0222 mol
= 46.9 kJ mol^{-1}
Since the reaction is exothermic **$\Delta H = -46.9$ kJ mol^{-1}**
❶ for correct numerical answer; ❶ for correct sign and units.

c. *n*($CH_2{=}CH_2$) initially = 44.6 g / 28.0 g mol-1
= 1.593 mol
n($CH_2{=}CH_2$) reacted in getting to equilibrium = (5.00/100) x 1.593
= 0.080 mol
n($CH_2{=}CH_2$) at equilibrium = 1.593 – 0.080
= 1.513 mol ❶
n(H_2O) initially = 21.6 g / 18.0 g mol^{-1}
= 1.20 mol
n(H_2O) reacted in getting to equilibrium = *n*($CH_2{=}CH_2$) reacted in getting to equilibrium
= 0.080 mol
n(H_2O) at equilibrium = 1.20 – 0.080
= 1.12 mol ❶
n(CH_3CH_2OH) at equilibrium = *n*(CH_2CH_2) reacted in getting to equilibrium
= 0.080 mol ❶
K = [CH_3CH_2OH] / {[$CH_2{=}CH_2$][H_2O]}
= (0.080/2.0) / {(1.513/2.0) x (1.120/2.0)}
= **0.094** ❶ (M^{-1})

d. The investigation conditions use a higher temperature (300 °C) and a lower pressure (4.75×10^4 kPa) than the industrial production (275 °C / 5.05×10^4).
Since the forward reaction is exothermic, the **lower temperature will favour the forward** reaction, thus giving a **higher yield of ethanol** ❶
The **lower pressure will favour the side with more particles**, i.e. the reactant side, thus giving **a lower yield of ethanol.** ❶
However since there is **not enough information to determine relative extents of the two effects**, it is **not possible to say whether the yield increases or decreases, just that is might be different.** ❶

e. Higher concentrations allow for more effective collisions (those with energy greater than the activation energy) between reacting particles. **Initially the forward reaction is at its maximum rate** and the reverse reaction has yet to begin. **As the forward reaction proceeds, its rate decreases as the concentrations of ethene and water decrease**. ❶As the **concentration of ethanol increases, the rate of the reverse reaction increases**. ❶ **Eventually** the **rates of the forward reaction and the reverse reaction are equal** and the system has reached equilibrium. ❶

f. **i.** Spectrum 1 – an **IR spectrum**.
It shows a **broad absorption band in the range 2500-3300 cm^{-1}**, characteristic of **O-H** in **carboxylic acids** ❶ and a **strong absorption in the range 1670-1750 cm^{-1}, characteristic of C=O**. ❶ (*Table 7 in Data Book gives absorption band wave numbers).*
The only carboxylic acid produced from ethanol is **ethanoic acid CH_3COOH** ❶
Spectrum 2 – a **high resolution ^{1}H NMR spectrum**.
It shows a quartet at **chemical shift 4.1 ppm** consistent with R**COO**CH_2R, i.e. an **ester**. ❶ The only ester than can be produced using ethanol as the only 'starting' organic compound is **ethyl ethanoate, $CH_3COOCH_2CH_3$.** ❶
(*Table 5 in Data Book) gives ^{1}H NMR chemical shifts.*
The **structure of $CH_3COOCH_2CH_3$** is consistent with the presence of a **singlet, quartet and triplet** in the high resolution ^{1}H NMR spectrum,
CH(singlet)$_3$**COOCH**(quartet)$_2$**CH**(triplet)$_3$**.** ❶

ii. **Dichromate ions, $Cr_2O_7^{2-}$(aq)** / potassium dichromate, K_2CrO_7(aq) ❶
Sulfuric acid, H_2SO_4(l) ❶
Acidified $Cr_2O_7^{2-}$(aq) is used to oxidise ethanol to ethanoic acid.
H_2SO_4(l) is used as a catalyst in the condensation reaction between CH_3CH_2OH(l) and CH_3COOH(l) to produce $CH_3COOCH_2CH_3$.

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

ii. Ethanol, CH_3CH_2OH, molecules contain a **polar hydroxyl group, -OH**, and a **non-polar ethyl group, -CH_2CH_3** ❶
The polar hydroxyl group allows them to form **hydrogen bonds with water molecules** and so dissolve in water. ❶
The non-polar ethyl group allows ethanol to dissolve in non-polar octane through **dispersion force attraction to the C_8H_{18} molecules**. ❶

iii. $CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ ❶
*NB (aq) is **not** an acceptable state for ethanol in a combustion reaction.*

h. **i** Ethanol is oxidised at the **anode** which is **negative (-)** in fuel cell. ❶

ii. $CH_3CH_2OH(l) + 3H_2O(l) \rightarrow 2CO_2(g) + 12H^+(aq) + 12e^-$ ❶
NB. Since the overall redox reaction for the fuel cell would be same as the combustion reaction, the fuel ethanol is oxidised to CO_2.

Question 7 (8 marks)

a. **1.** When one metal is added to an aqueous solution of the cations of another metal, the **likelihood of reaction depends on the relative reducing strengths of the two metals.**

2. When a **reaction does occur,** the **metal added is a stronger reductant than the metal associated with the cations in the aqueous solution used.**

3. When a **reaction does not occur**, the **metal added is a weaker reductant than the metal associated with the cations in the aqueous solution used.**
❶ for one of the above points 1, 2 or 3

4. **Q(s)** reacts with P^{2+}(aq), R^{2+}(aq) and S^{2+}(aq) hence it is the **strongest reductant**. ❶

5. **R(s)** does not react with any of P^{2+}(aq), Q^{2+}(aq) or S^{2-}(aq) hence it is the **weakest reductant**. ❶

6. **S(s)** reacts with P^{2+}(aq) and R^{2+}(aq) but not Q^{2+}(aq), hence **is a stronger reductant than P(s) and R(s) but a weaker reductant then Q(s)**.

7. **P(s)** reacts with R^{2+}(aq) but not Q^{2+}(aq) or S^{2+}(aq), hence it **is a stronger reductant than R, but a weaker reductant than Q(s) and S(s**).

8. **Order of increasing reducing strength is R, P, S, Q**

❶❶ for any ***two*** of points 6, 7 and 8.

b. **Two – R and P** – would have positive E° values ❶
Since **P does not react with 1 M HCl(aq),** the reductant is **above** **$2H^+(aq) + 2e^- \rightarrow H_2(g)$, E° = 0.0 V** on the electrochemical series and has a **positive E° value**. Since **R is a weaker reductant than P** it would also be not expected to react with 1 M HCl(aq) and **also have a positive E° value**. ❶ OR
Since **S reacts with 1 M HCl(aq),** the reductant is **below $2H^+(aq) + 2e^- \rightarrow H_2(g)$, E° = 0.0 V** on the electrochemical series and has a **negative E° value**. Since **Q is a stronger reductant than S** it would also be expected to react with 1 M HCl(aq) and also have a **negative E° value**. ❶
In terms of the electrochemical series the reduction half-equations would be in the order
$R^{2+}(aq) + 2e^- \rightleftharpoons R(s)$
$P^{2+}(aq) + 2e^- \rightleftharpoons P(s)$
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$
$S^{2+}(aq) + 2e^- \rightleftharpoons S(s)$
$Q^{2+}(aq) + 2e^- \rightleftharpoons Q(s)$

c. Because the conditions used, 25°C, 101.3 kPa and 1 M solutions, are those on which predictions based on the electrochemical series are most likely to occur, the most likely reason is the **rate of reaction between Cl_2(g) and Fe^{2+}(aq) was very slow.** ❶
Alternatively: Cl_2 may preferentially react with SCN^-(aq).

Question 8 (11 marks)

a. **i.** Bioethanol is produced by the fermentation of glucose obtained from sugar cane or other crops. The combined **amount CO_2 released in the combustion of ethanol, and fermentation of glucose, equates to the amount of CO_2 consumed in photosynthesis during the plant's growth**. ❶

This can be shown by adding together the equation for fermentation

$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$

and the equation for the combustion of ethanol doubled

$2CH_3CH_2OH + 6O_2 \rightarrow 4CO_2 + 6H_2O$

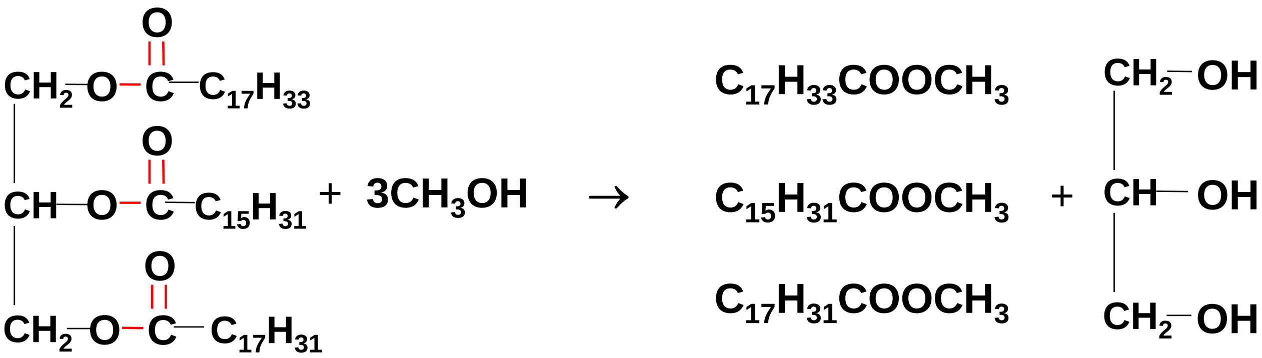
to give

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

which is the reverse of the equation for photosynthesis.

ii. Both land and water are required for the growth of crops for the production of biofuels. **Lack of water during drought and the need to use fertile land for food crops reduces the likelihood of sustainable biofuel production.** ❶

b. In transesterification 1 mol of the triglyceride reacts with 3 mol of the alcohol (methanol) to produce 3 mol of biodiesel (methyl esters) and 1 mol of glycerol.



i. **Methanol, CH_3OH** ❶

ii. **Glycerol, $C_3H_8O_3$** ❶

iii. Three different biodiesels were produced. These can be identified from hydrocarbon tails on the ester groups in the triglyceride, using Table 8 in the Data Book, because they are the same as the hydrocarbon tails on the associated fatty acids. The hydrocarbon tail on a saturated fatty acid in C_nH_{2n+1}, as in **$C_{17}H_{35}$** and for each C=C double bond on a saturated fatty acid 2 less H atoms will be present, e.g. for one C=C double bond, a monounsaturated compound, C_nH_{2n-1}, as in $C_{17}H_{33}$ ❶❶

So the monounsaturated biodiesel product is **$C_{17}H_{33}COOCH_3$**.

c. Since palmitic acid is $C_{15}H_{31}COOH$ (Table 9 Data Book), the formula for methyl palmitate is $C_{15}H_{31}COOCH_3$

$n(C_{15}H_{31}COOCH_3) = 0.631\text{ g} / 270.0\text{ g mol}^{-1}$
$= 2.34\text{x}10^{-3}\text{ mol}$

Energy released per mol $C_{15}H_{31}COOCH_3 = 23.5\text{ kJ} / 2.34\text{x}10^{-3}$
$= 1.01\text{x}10^{4}\text{ kJ mol}^{-1}$ ❶

Combustion equation – balance C, then H, then O (discounting for O in the fuel)

$C_{15}H_{31}COOCH_3(l) + \_\_\_O_2(g) \rightarrow 17CO_2(g) + 17H_2O(g)$

There are 51 ‘O’ on the right, on the left there are 2 ‘O’ in the fuel so 49 ‘O’ must come from O_2

$C_{15}H_{31}COOCH_3(l) + 24.5O_2(g) \rightarrow 17CO_2(g) + 17H_2O(g)$

Thermochemical equation:

$C_{15}H_{31}COOCH_3(l) + 24.5O_2(g) \rightarrow 17CO_2(g) + 17H_2O(g), \Delta H = -1.01\text{x}10^{4}\text{ kJ mol}^{-1}$

OR

$2C_{15}H_{31}COOCH_3(l) + 49O_2(g) \rightarrow 34CO_2(g) + 34H_2O(g), \Delta H = -2.02\text{x}10^{4}\text{ kJ mol}^{-1}$
❶❶

d. **i.** Nuclear fuels have **high energy densities**, i.e. significantly more energy per gram of fuel than other fuel sources. ❶

ii. **Radioactive waste** has long half-lives and needs to be **stored in secure leak-proof containers** for thousands of years. ❶

End of Suggested Answers