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

Figures									Letter
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.

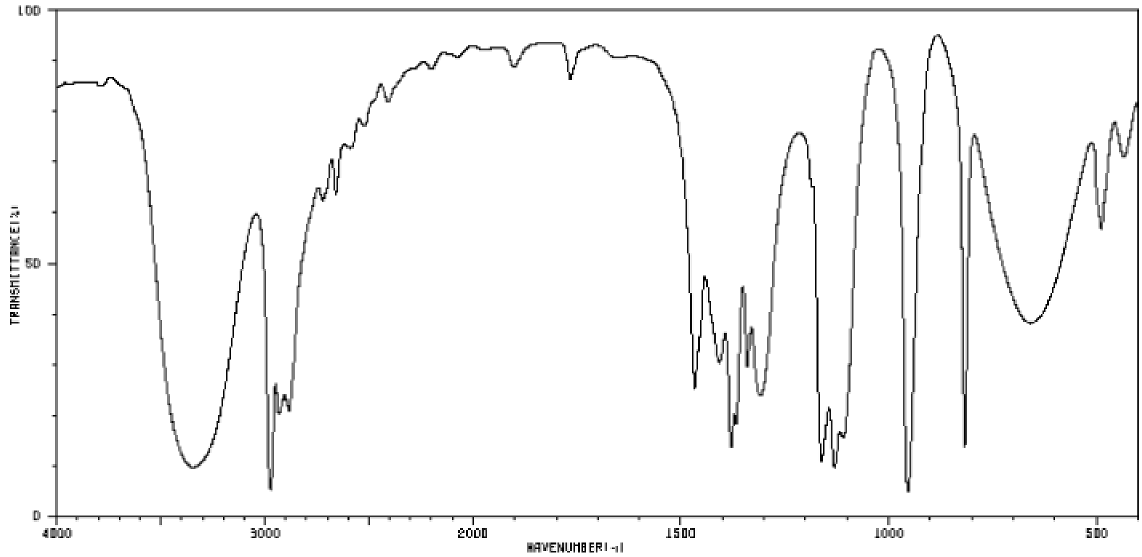
Question 1	A	B	C	D	*Question 2*	A	B	C	D
Question 3	A	B	C	D	*Question 4*	A	B	C	D
Question 5	A	B	C	D	*Question 6*	A	B	C	D
Question 7	A	B	C	D	*Question 8*	A	B	C	D
Question 9	A	B	C	D	*Question 10*	A	B	C	D
Question 11	A	B	C	D	*Question 12*	A	B	C	D
Question 13	A	B	C	D	*Question 14*	A	B	C	D
Question 15	A	B	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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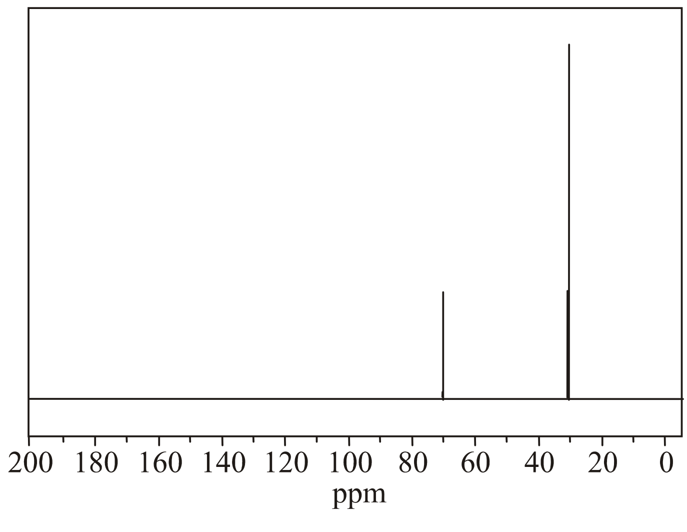


The compound could be
A. 2-butanol.
B. 1-propanol.
C. Ethanoic acid.
D. 2-methylpropan-2-ol.

Question 2

Sodium hydrogen carbonate decomposes on heating according to

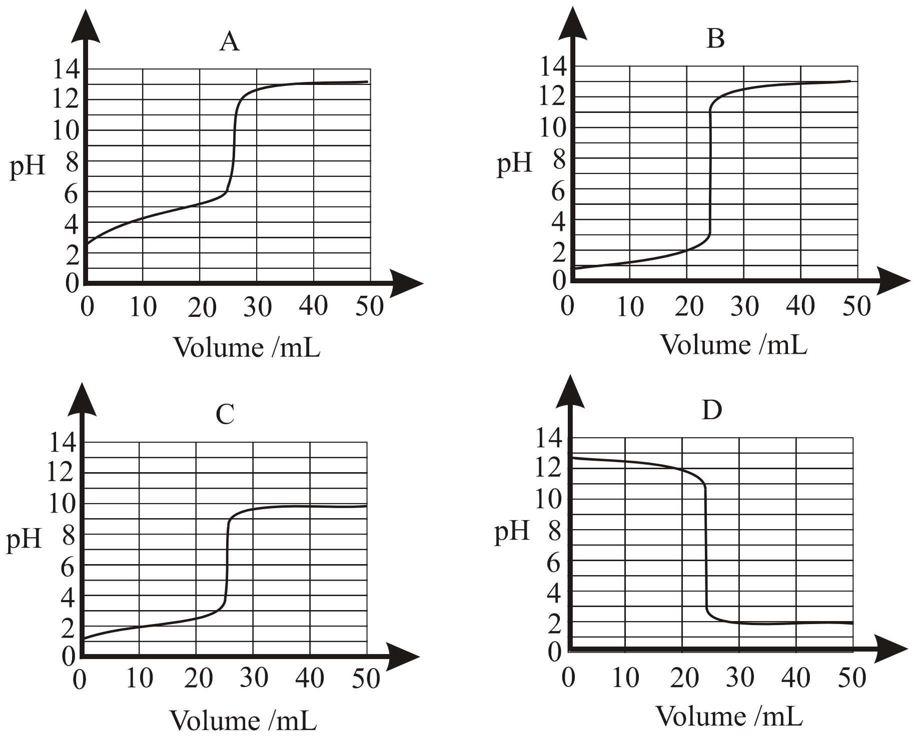
$$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$$

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.

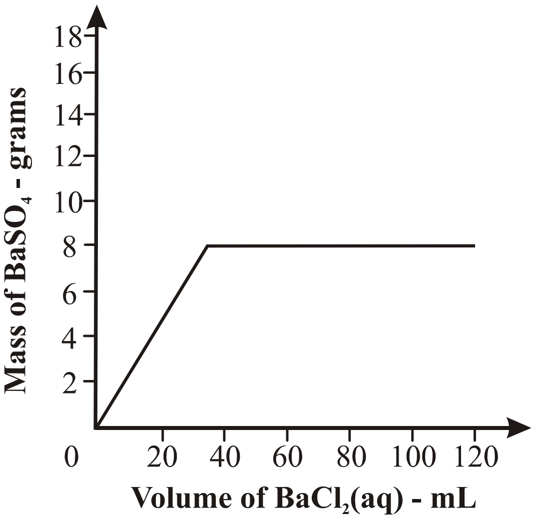
Question 11
Which of the following statements about fuel cells is most accurate?
A. Fuel cells only convert chemical energy to electrical energy.
B. Fuel cells utilise only acid electrolytes.
C. Fuel cells indirectly involve combustion reactions.
D. Fuel cells are rechargeable.

Questions 12 and 13 refer to the following information.

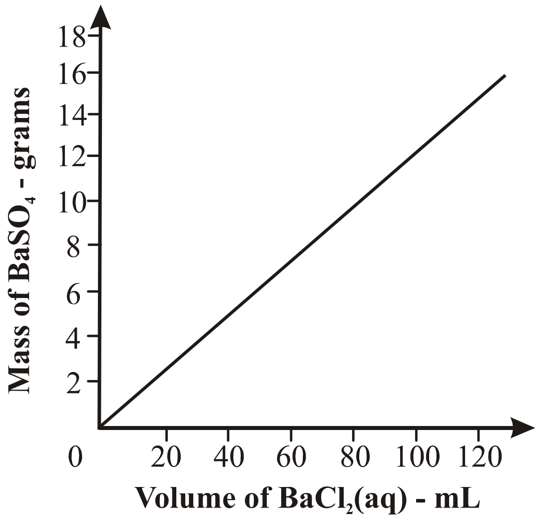
Four students investigating the stoichiometry of the reaction between aqueous solutions of barium chloride, $BaCl_2(aq)$, and sodium sulfate, $Na_2SO_4(aq)$, produced graphs on which the mass of precipitate that could be formed was plotted against the volume of $BaCl_2(aq)$ added to 100 mL of 0.34 M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

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

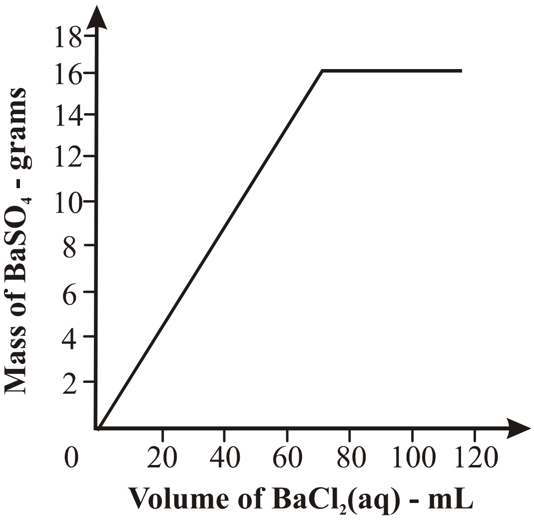
The graphs produced by the four students were:



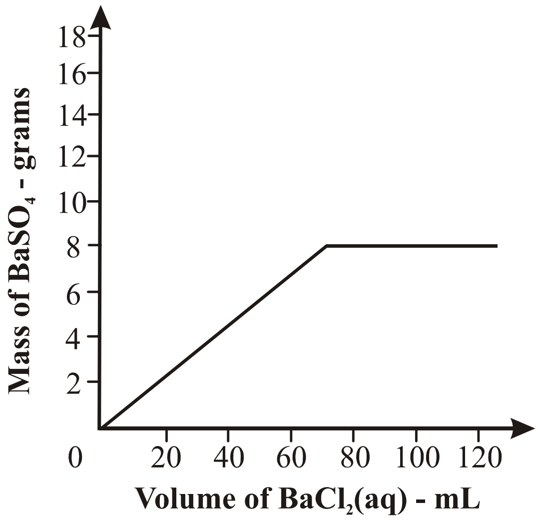
Graph 1



Graph 2



Graph 3



Graph 4

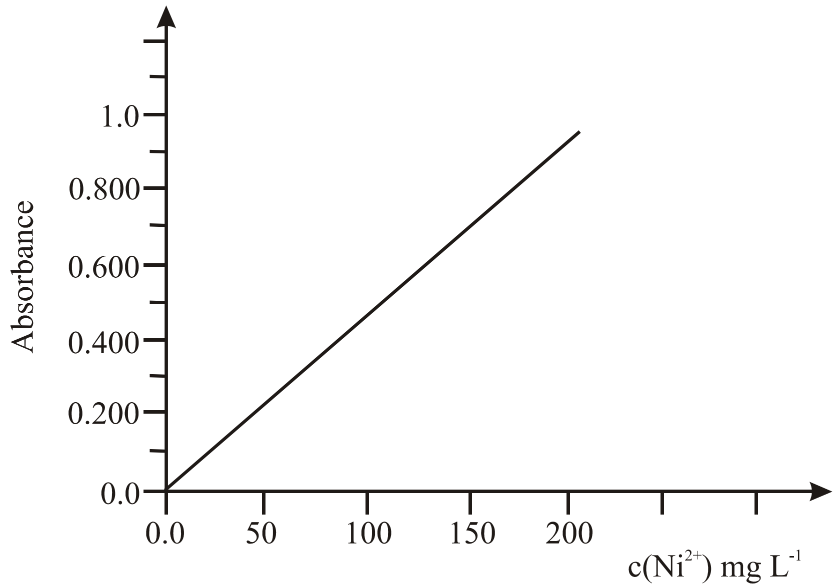
Question 12

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}

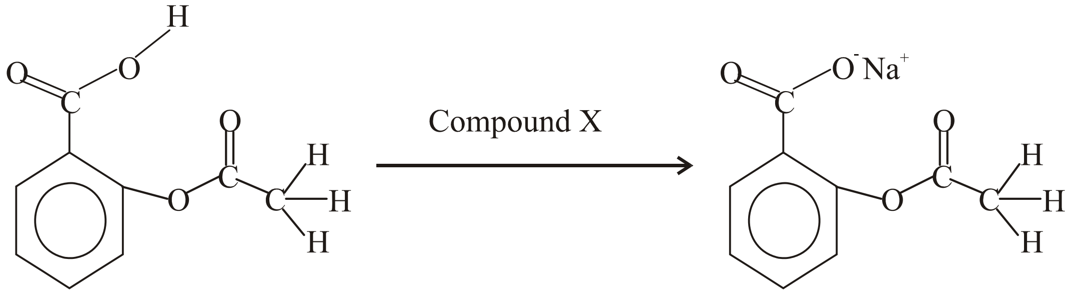
Question 16

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.

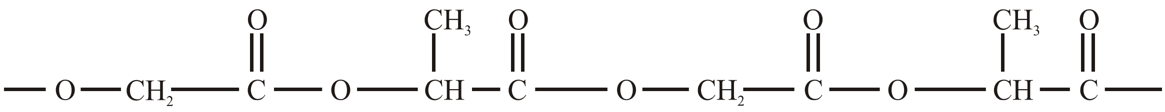
Compound X is

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

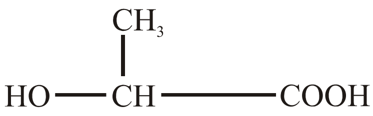
Question 18

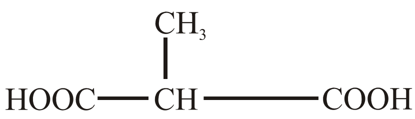
Polylactic glycolic acid (PLGA) is a biodegradable and biocompatible polymer used in the production of biomedical devices. PLGA can undergo hydrolysis in the body to produce its original monomers, lactic acid and glycolic acid.

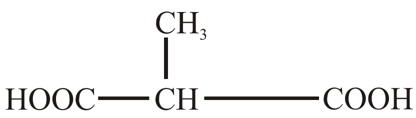
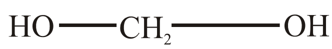
PLGA 50:50 contains equal numbers of both monomers. A section of PLGA 50:50 is represented below.

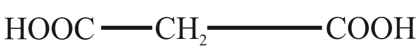
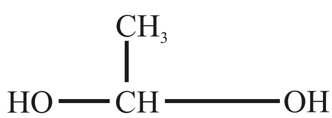


Which of the following alternatives **A. – D.** shows the correct structures of both lactic acid and glycolic acid?

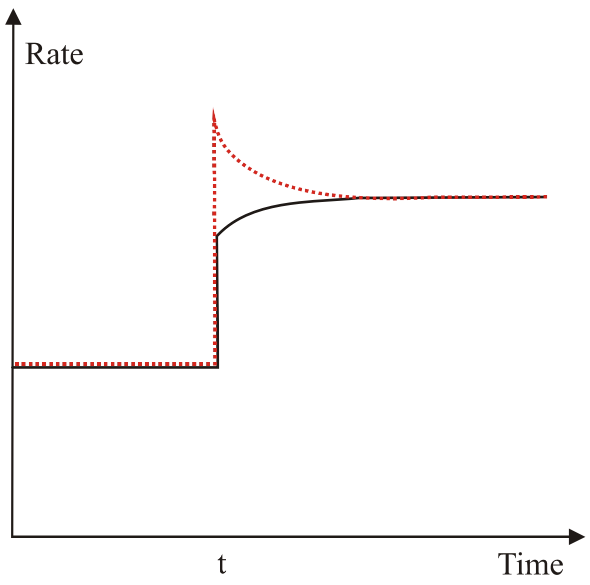
A.  and 

B.  and 

C.  and 

D.  and 

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

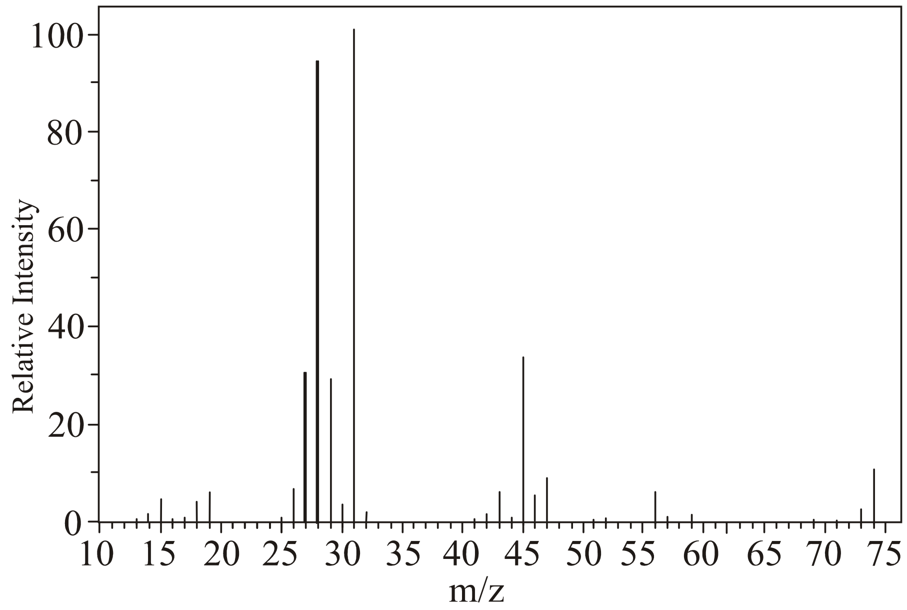
In an analysis to determine the concentration of hydrochloric acid in brick cleaner, 10 mL of brick cleaner was diluted to 250 mL with water, and 20.0 mL aliquots of 0.100 M $Na_2CO_3(aq)$ were titrated to the methyl orange endpoint with diluted brick cleaner.

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.

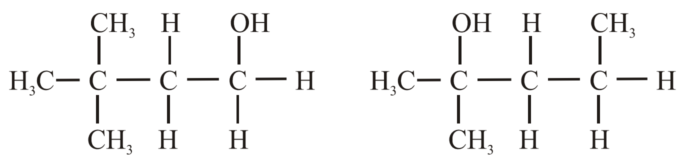
Question 24
The mass spectrum of an organic compound is shown below.



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.

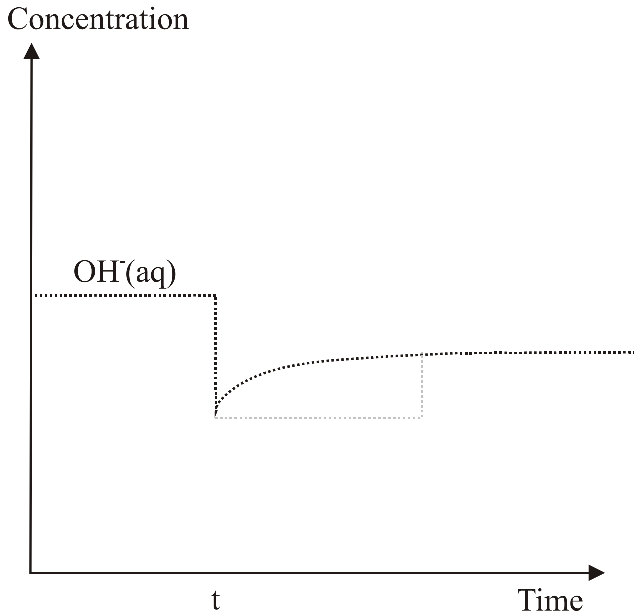
Question 25
Consider the semi-structural formulae of two alcohols shown below.



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.**

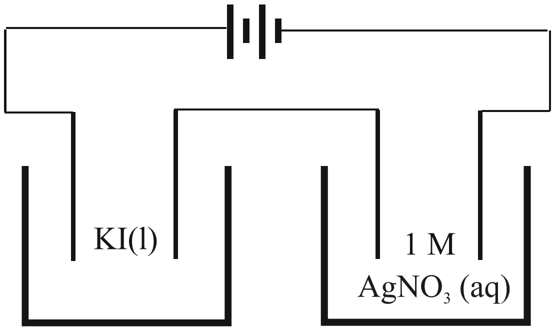


To which of the solutions below do the changes in concentration at time '**t**' best relate?
A. HCl(aq).
B. CH_3COOH(aq).
C. NH_3(aq).
D. NaCl(aq).

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

VCE Chemistry 2013 Year 12 Trial Exam Unit 3/4

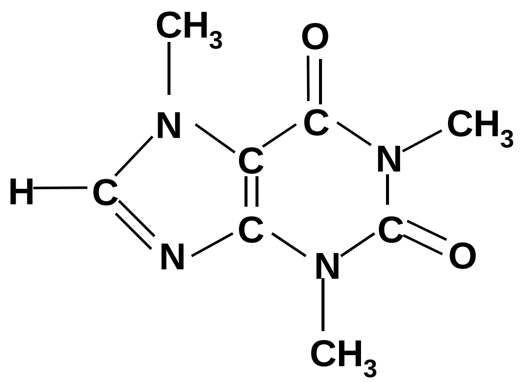
SECTION B – Short Answer Section

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.

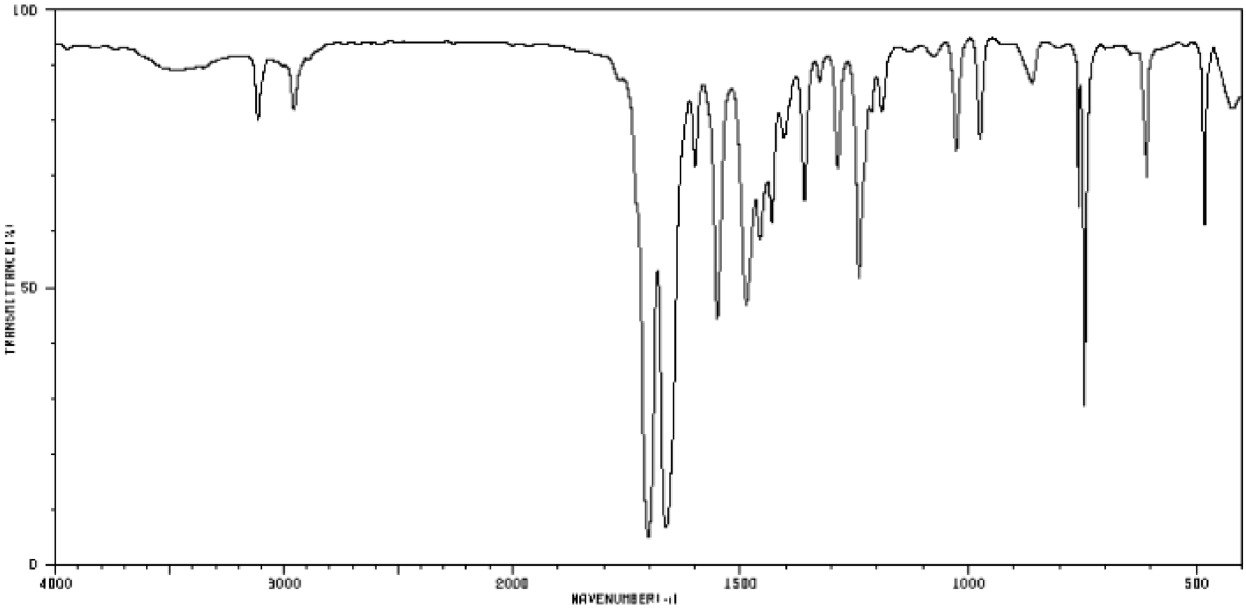
The structure of caffeine molecules is represented below.



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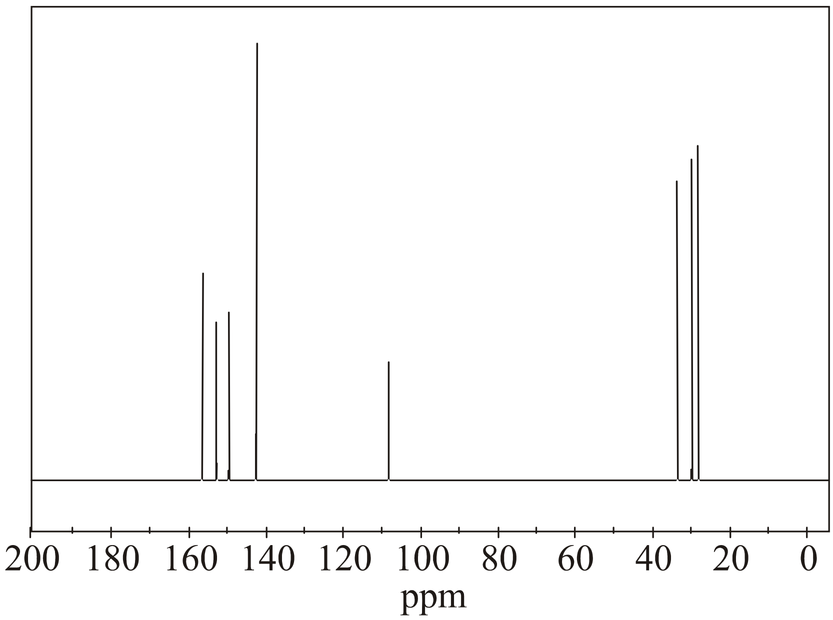
Explain the presence of **two** distinct strong peaks around 1650-1700 cm^{-1}. **2 marks**

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**

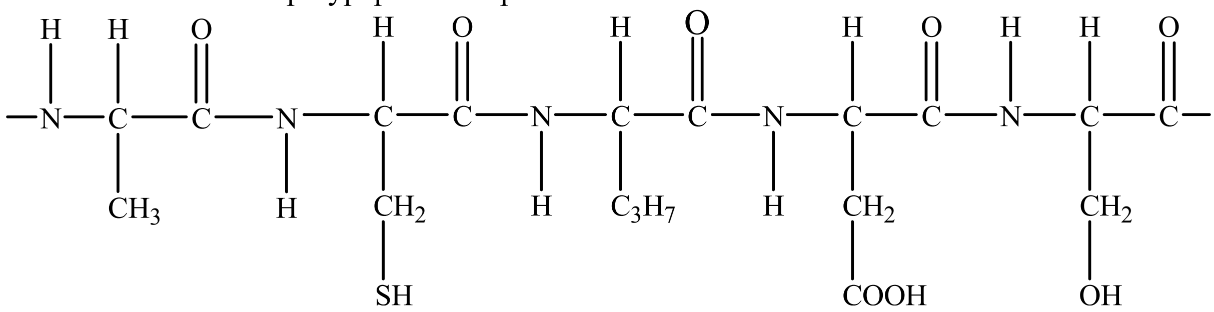
b. In some reports, DMAA has also been called 2-amino-4-methylhexane and incorrectly described as an amino acid supplement. Explain why DMMA is not an amino acid. **1 mark**

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

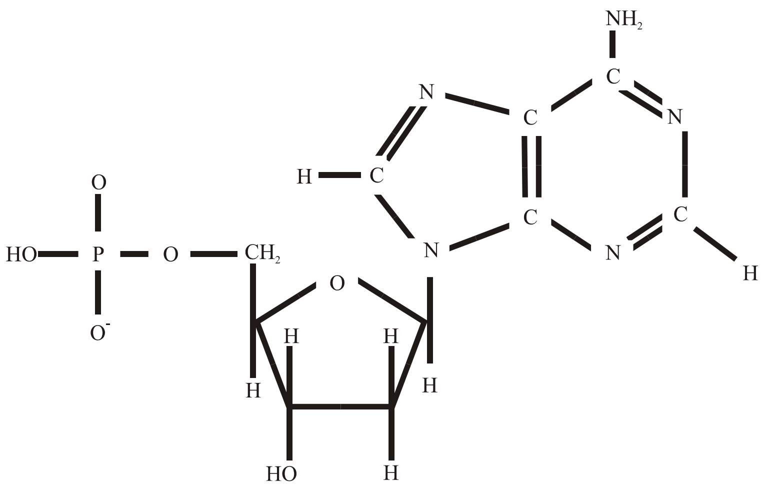


i. Circle a bond which maintains the primary structure of a protein. **1 mark**

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**

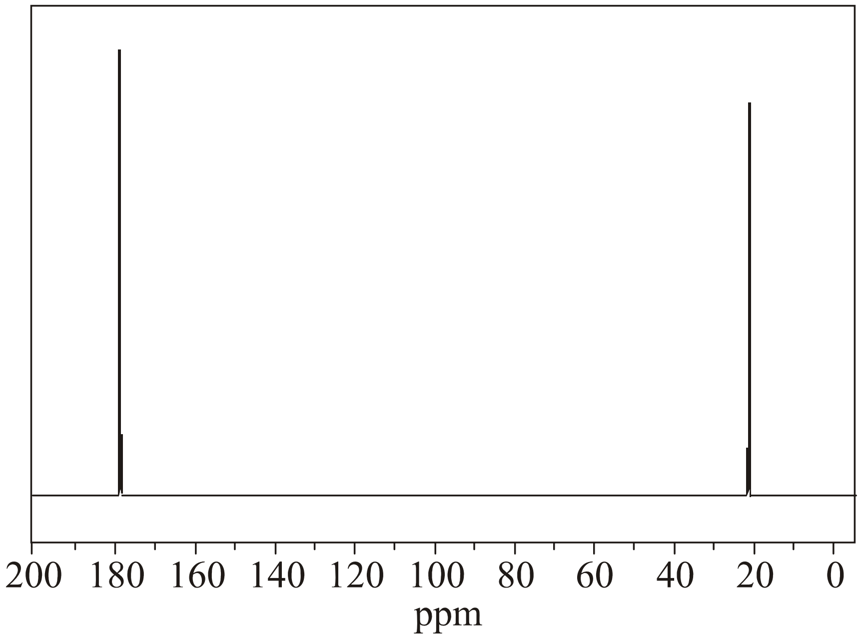
b. One industrial use of methanol is in the production of biofuels from vegetable oils such as

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

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.

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

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

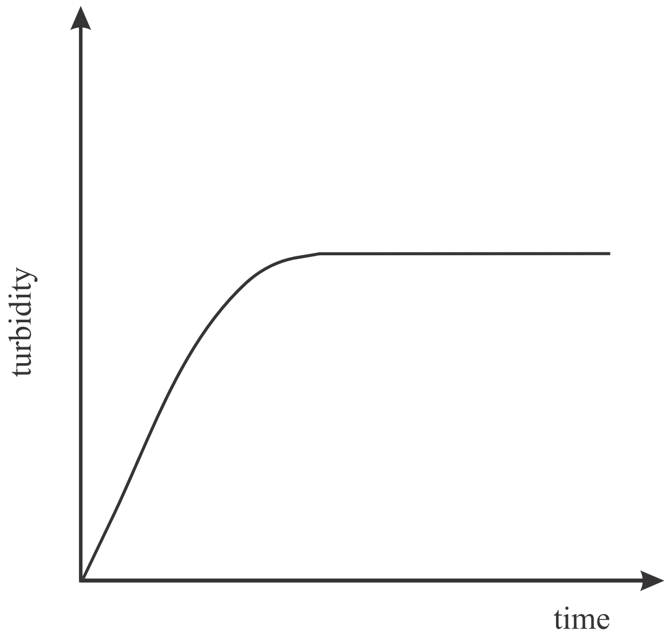
Investigation Number	$Na_2S_2O_3(aq)$	$HCl(aq)$	Water
1	10 mL of 0.25 M	5.0 mL of 2.0 M	35 mL
2	25 mL of 0.25 M	5.0 mL of 2.0 M	20 mL
3	40 mL of 0.25 M	5.0 mL of 2.0 M	5.0 mL

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