VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education 2016

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER Letter

CHEMISTRY

Written examination

Tuesday 8 November 2016

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	11	11	90
			Total 120

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or correction fluid/tape.

Materials supplied
- Question and answer book of 44 pages.
- Data book.
- Answer sheet for multiple-choice questions.

Instructions
- Write your **student number** in the space provided above on this page.
- Check that your **name** and **student number** as printed on your answer sheet for multiple-choice questions are correct, **and** sign your name in the space provided to verify this.
- Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.
- All written responses must be in English.

At the end of the examination
- Place the answer sheet for multiple-choice questions inside the front cover of this book.
- You may keep the data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

SECTION A – Multiple-choice questions

Instructions for Section A

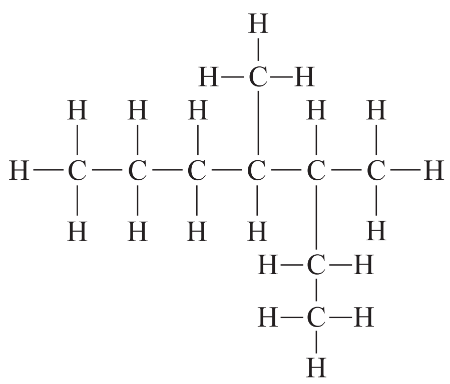
Answer **all** questions in pencil on the answer sheet provided for multiple-choice questions.
Choose the response that is **correct** or that **best answers** the question.
A correct answer scores 1; an incorrect answer scores 0.
Marks will **not** be deducted for incorrect answers.
No marks will be given if more than one answer is completed for any question.
Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1

Which one of the following lists contains only analytical techniques that can be used to determine the concentration of a substance?

A. AAS, GC and HPLC
B. HPLC, GC and TLC
C. UV-vis and ^{1}H NMR
D. UV-vis, AAS and TLC

Question 2



What is the correct systematic name for the compound shown above?

A. 4-methyl-5-ethylhexane
B. 2-ethyl-3-methylhexane
C. 4,5-dimethylheptane
D. 3,4-dimethylheptane

DO NOT WRITE IN THIS AREA

Question 3

Hydrogen peroxide solutions are commercially available and have a range of uses. The active ingredient, hydrogen peroxide, H_2O_2, undergoes decomposition in the presence of a suitable catalyst according to the reaction

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$

In this reaction, oxygen

A. only undergoes oxidation.

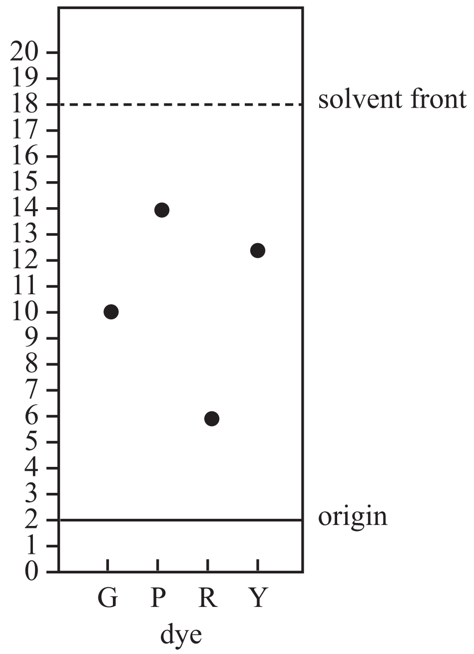
B. only undergoes reduction.

C. undergoes both oxidation and reduction.

D. undergoes neither oxidation nor reduction.

Question 4

A paper chromatograph of four dyes, G, P, R and Y, is shown below.



The R_f value of the dye most strongly adsorbed onto the stationary phase is

A. 0.25

B. 0.33

C. 0.75

D. 0.78

Question 5

A piece of double-stranded DNA is 300 base pairs in length. It contains 180 guanine bases.

The number of thymine and cytosine bases, respectively, is

A. 120 and 120

B. 120 and 180

C. 180 and 120

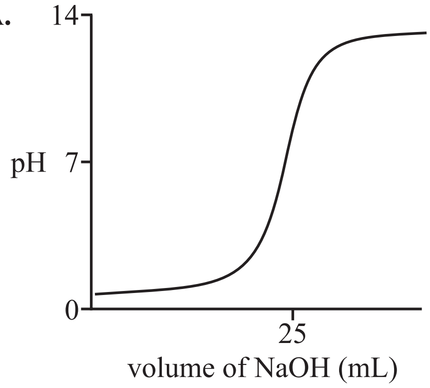
D. 180 and 180

Question 6

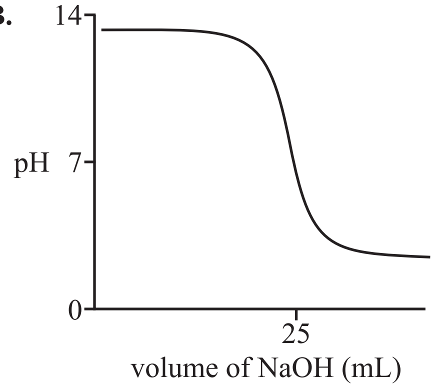
A solution of approximately 0.1 M benzoic acid, C_6H_5COOH, is titrated against a 0.1004 M solution of sodium hydroxide, NaOH.

Which one of the following pH curves represents this titration?

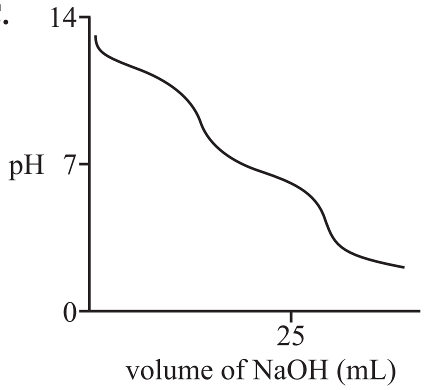
A.



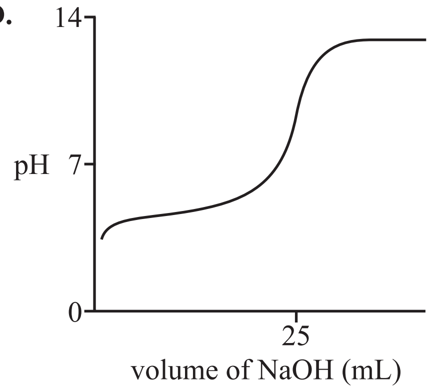
B.



C.



D.



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Use the following information to answer Questions 7 and 8.

A group of students was required to determine the concentration of a solution of hydrochloric acid, HCl, provided for a titration competition. In each titration, a 25.00 mL aliquot of a freshly standardised solution of 0.2450 M sodium hydroxide, NaOH, was pipetted into a conical flask and titrated against the HCl solution. An appropriate indicator was added. The experiment was repeated until three concordant results were obtained.

The data for these titrations is shown in the following table.

volume of aliquot of NaOH	25.00 mL
concentration of NaOH solution	0.2450 M
mean titre of HCl solution	13.49 mL

Question 7

Based on these results, the concentration of HCl is

A. 0.1322 M
B. 0.4540 M
C. 1.322 M
D. 2.202 M

Question 8

The experimental value of the concentration of HCl obtained from these titrations was less than the actual value. Which one of these actions by the students most likely accounts for the lower than expected result?

A. rinsing the burette with water
B. rinsing the pipette with water
C. rinsing the conical flask with water
D. leaving the funnel in the top of the burette

Question 9

The **most** suitable indicator for a titration of NaOH against benzoic acid, C_6H_5COOH, is

A. bromophenol blue.
B. methyl orange.
C. thymol blue.
D. phenol red.

Question 10

A student calibrated a calorimeter using an electric heating coil. A current of 1.50 A with a potential difference of 4.50 V was applied for two-and-a-half minutes. A digital probe recorded a temperature rise of 5.35 °C.

The value of the calibration factor, in J $°C^{-1}$, is

A. 189

B. 42.1

C. 3.15

D. 0.317

Question 11

Met-enkephalin (Tyr–Gly–Gly–Phe–Met) is a peptide found in the central nervous system and the gastrointestinal tract of the human body.

Which of the following are the correct structures for the two terminal ends of met-enkephalin at a very low pH?

A.	$-NH_2$	–COOH
B.	$-NH_2$	$-COO^-$
C.	$-NH_3^+$	$-COO^-$
D.	$-NH_3^+$	–COOH

Question 12

A condensation reaction involving 200 glucose molecules, $C_6H_{12}O_6$, results in a polysaccharide.

The molar mass, in g mol^{-1}, of the polysaccharide is

A. 36 000

B. 35 982

C. 32 418

D. 32 400

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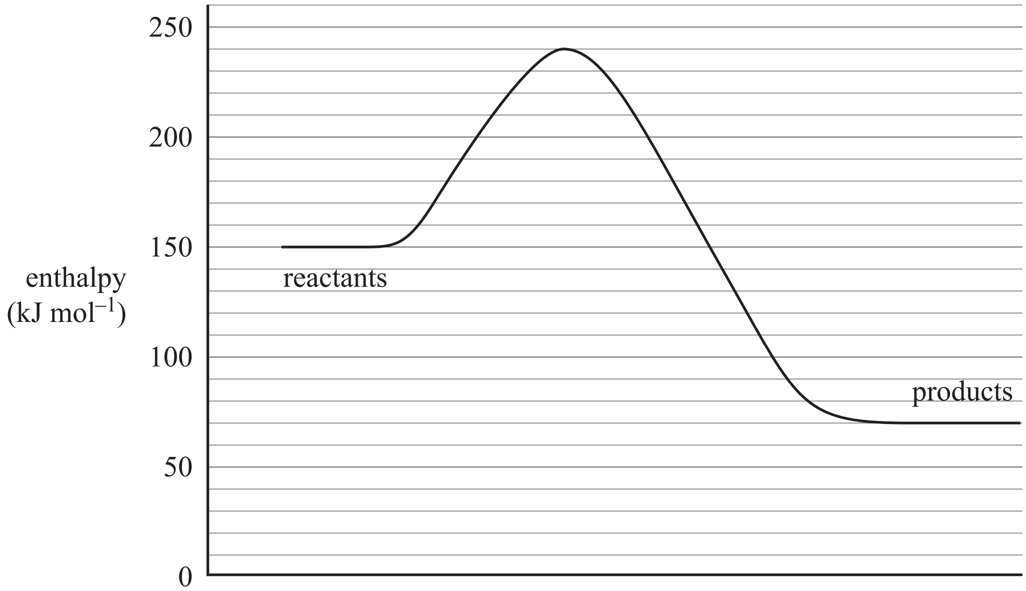
Question 13

A chemical reaction has the following energy profile.



The enthalpy change of the forward reaction, in kJ mol^{-1}, is

A. –170

B. –80

C. +70

D. +240

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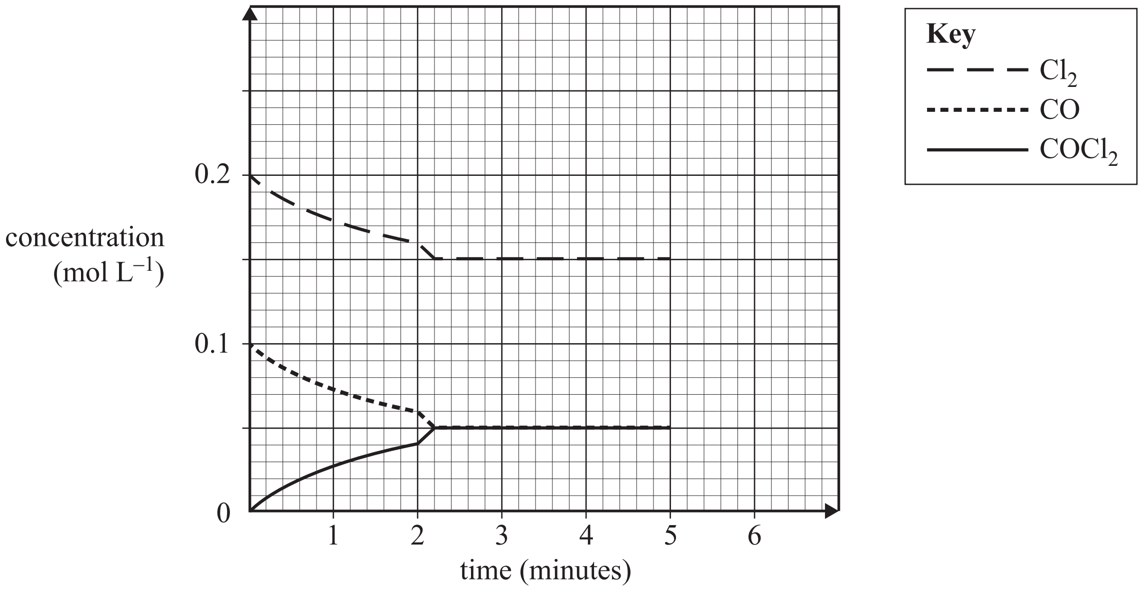
Use the following information to answer Questions 14–16.

A chemist injected 0.10 mol carbon monoxide gas, CO, and 0.20 mol chlorine gas, Cl_2, into a previously evacuated and sealed 1.0 L flask.

At that instant, the following reaction began to occur.

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \qquad \Delta H = -108 \text{ kJ mol}^{-1}$$

The concentrations of the three species present in the flask were monitored over time. The flask was held at a constant temperature. The following concentration–time graph was obtained.



Question 14

The most likely sudden change made to the system at the two-minute mark would be that

A. a catalyst was injected into the flask.

B. the volume of the flask was increased.

C. an inert gas was injected into the flask.

D. some of the gas mixture was removed from the flask.

Question 15

The magnitude of the equilibrium constant for the reaction at the temperature of the experiment is

A. 0.15

B. 1.4

C. 3.0

D. 6.7

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Question 16

If the equilibrium system were suddenly heated at constant volume at the five-minute mark, which one of the following changes would result?

A. The concentration of $COCl_2$ would increase.

B. The total gas pressure in the flask would decrease.

C. The equilibrium constant for the reaction would increase.

D. The total number of gas molecules in the flask would increase.

Question 17

The combustion of hexane takes place according to the equation

$$C_6H_{14}(g) + \frac{19}{2}O_2(g) \rightarrow 6CO_2(g) + 7H_2O(g) \qquad \Delta H = -4158 \text{ kJ mol}^{-1}$$

Consider the following reaction.

$$12CO_2(g) + 14H_2O(g) \rightarrow 2C_6H_{14}(g) + 19O_2(g)$$

The value of ΔH, in kJ mol^{-1}, for this reaction is

A. +8316

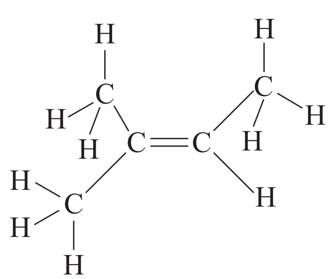
B. +4158

C. –2079

D. –3568

Question 18

The molecule with the structural formula shown below reacts with hydrogen bromide, HBr, to form $C_5H_{11}Br$.



The number of different structural isomers theoretically possible to be produced by this reaction is

A. 1

B. 2

C. 3

D. 4

Question 19

An electroplating process uses a solution of chromium(III) sulfate, $Cr_2(SO_4)_3$, to deposit a thin layer of chromium on the surface of an object. A current of 5.00 A is maintained.

How long does it take, in seconds, to deposit 0.0192 mol chromium onto the surface?

A. 371

B. 1110

C. 1860

D. 5570

Question 20

How does diluting a 0.1 M solution of lactic acid, $HC_3H_5O_3$, change its pH and percentage ionisation?

	pH	Percentage ionisation
A.	increase	decrease
B.	increase	increase
C.	decrease	increase
D.	decrease	decrease

Question 21

The ammonium ion NH_4^+ acts as a weak acid according to the equation

$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$$

The $[H_3O^+]$ of a 0.200 M ammonium chloride solution is closest to

A. 4.79×10^{-6} M

B. 9.55×10^{-6} M

C. 1.06×10^{-5} M

D. 1.51×10^{-5} M

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Question 22

When ethene is mixed with chlorine in the presence of UV light, the following reaction takes place.

$$CH_2CH_2(g) + Cl_2(g) \xrightarrow{\text{UV light}} CH_2ClCH_2Cl(l)$$

Reactions of organic compounds can be classified in a number of ways. The following list shows four possible classifications:

1. addition
2. substitution
3. redox
4. condensation

Which classification(s) applies to the reaction between ethene and chlorine?

A. 1

B. 1 and 2

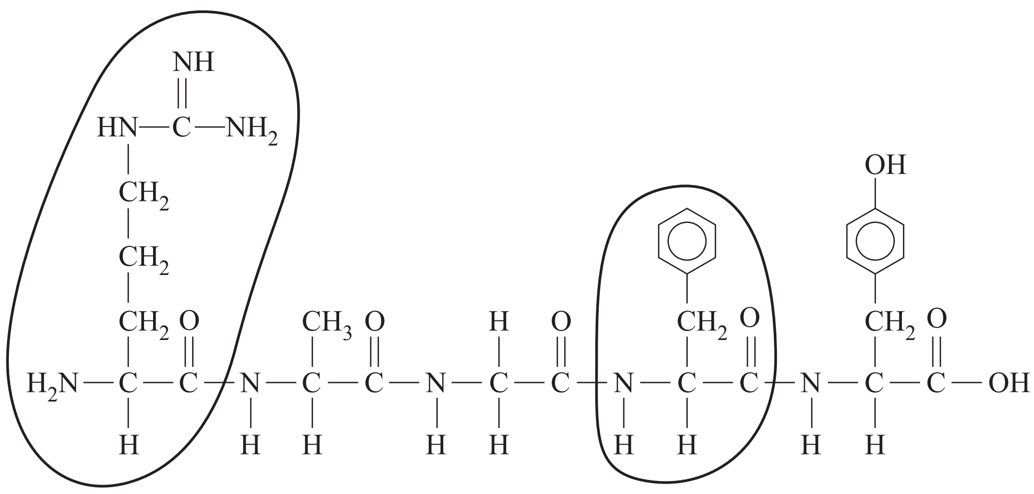
C. 1 and 3

D. 4

Question 23

Substance P is a peptide found in the human body, and it is associated with inflammation and pain.

The structure of Substance P is shown below.



What are the abbreviated names of the two circled amino acid residues?

A. Arg and Phe

B. Lys and Tyr

C. Phe and Tyr

D. Met and Arg

Question 24

Methanol is a liquid fuel that is often used in racing cars. The thermochemical equation for its complete combustion is

$$2CH_3OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(l) \qquad \Delta H = -1450 \text{ kJ mol}^{-1}$$

Octane is a principal constituent of petrol, which is used in many motor vehicles. The thermochemical equation for the complete combustion of octane is

$$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(l) \qquad \Delta H = -10\,900 \text{ kJ mol}^{-1}$$

The molar mass of methanol is 32 g mol^{-1} and the molar mass of octane is 114 g mol^{-1}.

Which one of the following statements is the **most** correct?

A. Burning just 1.0 g of octane releases almost 96 kJ of heat energy.

B. Burning just 1.0 g of methanol releases almost 23 kJ of heat energy.

C. Octane releases almost eight times more energy per kilogram than methanol.

D. The heat energy released by methanol will not be affected if the oxygen supply is limited.

Question 25

A class of Chemistry students investigated the reaction of copper metal and iodine solution. After making predictions about the reaction, they placed a copper strip into an iodine solution and compared their predictions with their observations.

A number of groups recorded the following.

Reactants	Prediction	Observation over 10 minutes
Cu metal + I_2 solution	A reaction should occur. The expected products are Cu^{2+} and I^-. The solution should turn from brown to blue as I_2 is consumed and Cu^{2+} is formed. The Cu metal should look corroded.	no apparent change

The predicted results were not observed. The class was asked to suggest some hypotheses to explain the unexpected result.

Which one of the following hypotheses could **not** explain the unexpected result?

A. The reaction rate might have been too slow for the time allowed.

B. An equilibrium was established and [Cu^{2+}] was too low to be visible.

C. A bromine solution was accidentally used in place of the iodine solution.

D. The surface of the copper metal was greasy.

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Question 26

Dilute nitric acid reacts with anhydrous sodium carbonate to produce carbon dioxide gas.

$$2HNO_3(aq) + Na_2CO_3(s) \rightarrow 2NaNO_3(aq) + CO_2(g) + H_2O(l)$$

In an experiment, 0.142 mol anhydrous Na_2CO_3 powder was added to excess HNO_3 in solution, in a 2.00 L reinforced, sealed, metal vessel. Pressure and temperature sensors were used to monitor the reaction.

The vessel was initially at 101.3 kPa and 22.0 °C. When the reaction was complete, the final temperature was 24.1 °C.

What is the **additional** pressure, in kPa, inside the vessel due to the carbon dioxide gas after the completion of the reaction? (Assume that the volume of the solution in the vessel is negligible.)

A. 349

B. 175

C. 28.3

D. 14.2

Question 27

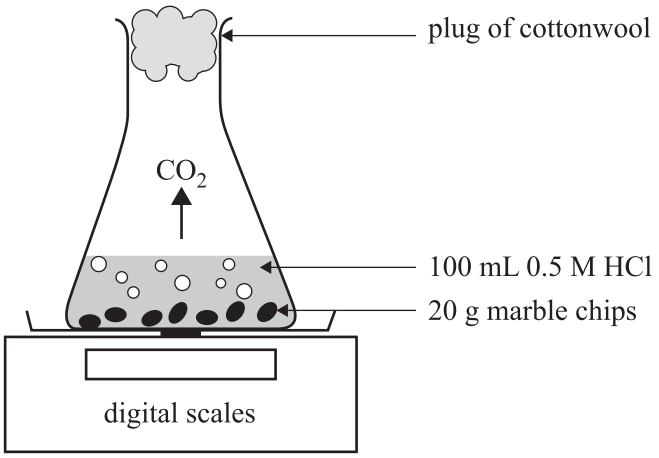
A student set up an experiment to test the effect of different factors on the rate and extent of the reaction between a strong acid and marble chips (calcium carbonate, $CaCO_3$). In each trial, the mass of the flask and its contents was measured every 30 seconds, from the instant the reactants were mixed.

Trial 1

The strong acid used was hydrochloric acid, HCl.

The equation for the reaction is as follows.

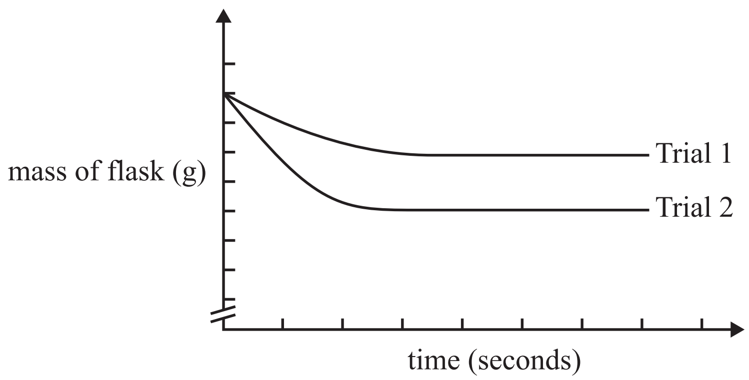
$$2HCl(aq) + CaCO_3(s) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$



Trial 2

One change to the reaction conditions was made and the experiment was repeated.

The results of the two trials were graphed on the same axes and are shown below.



In Trial 2, the student must have

A. heated the 0.5 M HCl before adding it to the flask.

B. doubled the volume of 0.5 M HCl added to the flask.

C. used 100 mL of 0.5 M H_2SO_4 instead of 100 mL of 0.5 M HCl.

D. used the same mass of marble but crushed it into a powder.

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Question 28

A team of chemists was investigating the following equilibrium reaction.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H \text{ is negative.}$$

Hydrogen gas, H_2, and iodine gas, I_2, were injected into a sealed container and the mixture was allowed to reach equilibrium.

The effect of the following changes on the amount of HI was measured:

1. More H_2 gas was injected into the container at a constant temperature and volume.
2. The temperature of the gases was decreased at a constant volume.
3. Some argon gas, Ar, was injected into the container at a constant temperature and volume.
4. The volume of the container was decreased at a constant temperature.

Which change(s) would have resulted in the formation of a greater amount, in mol, of HI?

A. 1 and 2 only

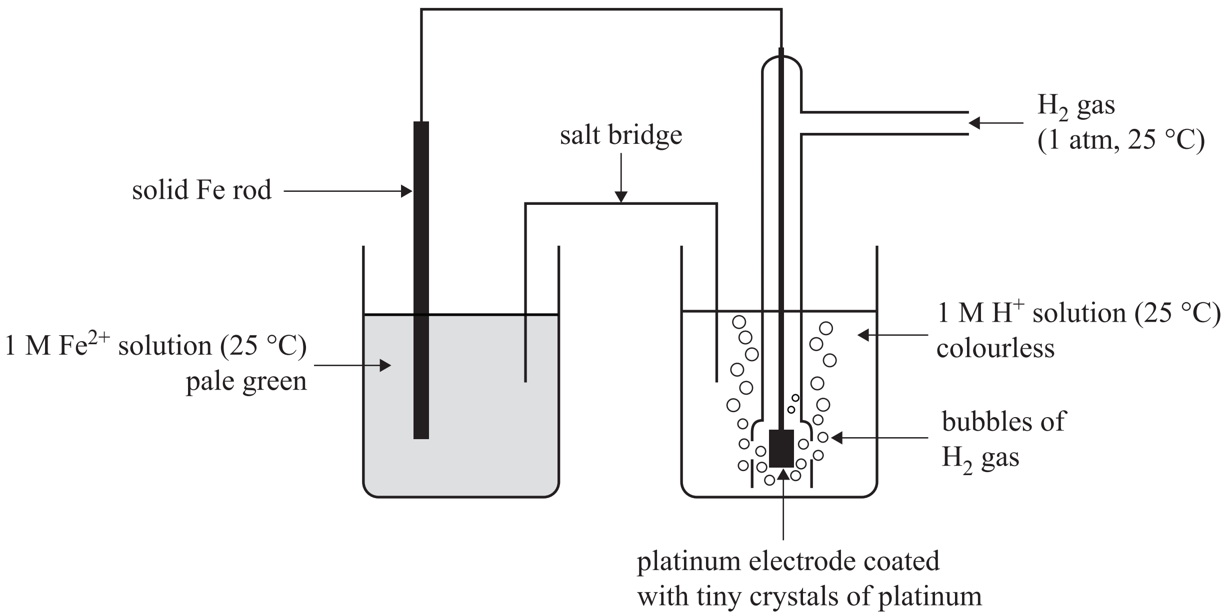
B. 1, 2 and 4 only

C. 3 only

D. 1 and 4 only

Use the following information to answer Questions 29 and 30.

The following diagram shows a galvanic cell that is set up in a university laboratory.



The half-cell on the right is called the standard hydrogen electrode (SHE). It is the standard against which all standard redox potentials are compared. Hydrogen gas, H_2, is continually bubbled into this half-cell.

Question 29

Which one of the following would occur at the platinum electrode when the cell discharges?

A. Electrons would move from the platinum electrode through the acid solution towards the salt bridge.

B. The platinum electrode would act as the anode in this cell and have positive polarity.

C. The pH of the solution surrounding the platinum electrode would increase.

D. The hydrogen gas would be oxidised at the platinum electrode's surface.

Question 30

What is one change that would be expected in the Fe^{2+}/Fe half-cell as the cell discharges?

A. Crystals of platinum would be deposited on the surface of the iron electrode.

B. The Fe^{2+} solution would start bubbling at the surface of the electrode.

C. Crystals of iron would be deposited on the surface of the iron electrode.

D. The Fe^{2+} solution would become a darker green colour.

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END OF SECTION A

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SECTION B

Instructions for Section B

Answer **all** questions in the spaces provided. Write using blue or black pen.

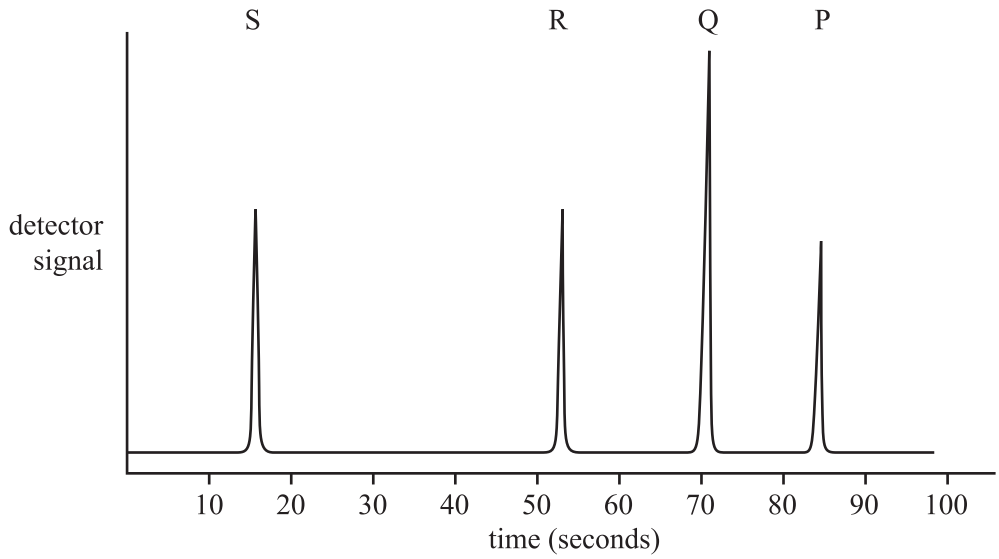
To obtain full marks for your responses, you should:

- give simplified answers, with an appropriate number of significant figures, to all numerical questions; unsimplified answers will not be given full marks
- show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working
- make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$, $NaCl(s)$.

Unless otherwise indicated, the diagrams in this book are **not** drawn to scale.

Question 1 (5 marks)

A perfume was analysed using a gas chromatograph. A simplified section of the resulting chromatogram is shown below. The four peaks correspond to compounds P, Q, R and S.



a. What is the retention time, R_t, of Compound Q? 1 mark

____

b. All four of the compounds, P, Q, R and S, are from the same family of organic compounds.

Which of these four compounds would have the highest molecular mass? State the evidence used. 2 marks

Compound ______________________________

Evidence ______________________________

____

c. Using the same instrument on another occasion, it was found that the chemical limonene had a retention time of 53 seconds.

Can it be concluded that limonene is one of the compounds in the perfume under analysis? Justify your answer. 2 marks

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Question 2 (6 marks)

A common iron ore, fool's gold, contains the mineral iron pyrite, FeS_2.

Typically, the percentage by mass of FeS_2 in a sample of fool's gold is between 90% and 95%. The actual percentage in a sample can be determined by gravimetric analysis.

The sulfur in FeS_2 is converted to sulfate ions, SO_4^{2-}. This is then mixed with an excess of barium chloride, $BaCl_2$, to form barium sulfate, $BaSO_4$, according to the equation

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$$

When the reaction has gone to completion, the $BaSO_4$ precipitate is collected in a filter paper and carefully washed. The filter paper and its contents are then transferred to a crucible. The crucible and its contents are heated until constant mass is achieved.

The data for an analysis of a mineral sample is as follows.

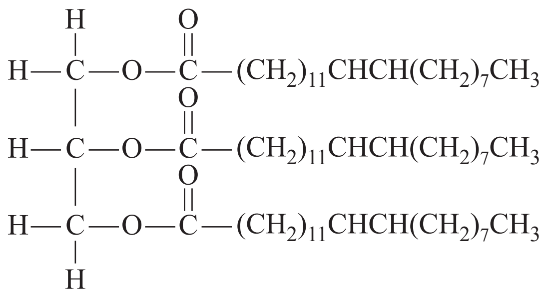
initial mass of mineral sample	14.3 g
mass of crucible and filter paper	123.40 g
mass of crucible, filter paper and dry $BaSO_4$	174.99 g
$M(FeS_2)$	120.0 g mol^{-1}
$M(BaCl_2)$	208.3 g mol^{-1}
$M(BaSO_4)$	233.4 g mol^{-1}

a. Calculate the percentage by mass of FeS_2 in this mineral sample. 5 marks

b. State **one** assumption that was made in completing the calculations for this analysis. 1 mark

Question 3 (9 marks)

The diagram below represents a certain biomolecule.



a. Name the class of organic biomolecules to which the biomolecule above belongs. 1 mark

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This biomolecule can be hydrolysed to form glycerol and erucic acid, a fatty acid. Erucic acid is classified as monounsaturated.

b. Explain why erucic acid is classified as monounsaturated. 1 mark

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Erucic acid can be extracted from plants. It can react with methanol to make methyl erucate, which can be used as the biofuel known as biodiesel.

c. Write the semi-structural formula of methyl erucate. 1 mark

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d. Describe **one** environmental advantage of using biodiesel as a fuel rather than petrodiesel, which is produced from crude oil. 2 marks

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DO NOT WRITE IN THIS AREA

e. Ethanol is another biofuel. It can be produced by the fermentation of sugars in plant material.

i. Write a balanced chemical equation for the fermentation of glucose. 1 mark

ii. The ethanol produced can be separated from the reaction mixture by distillation.

What would be the minimum mass of pure glucose needed to produce 1.00 L of pure ethanol from fermentation?

$d(C_2H_5OH) = 0.785\ g\ mL^{-1}$ 3 marks

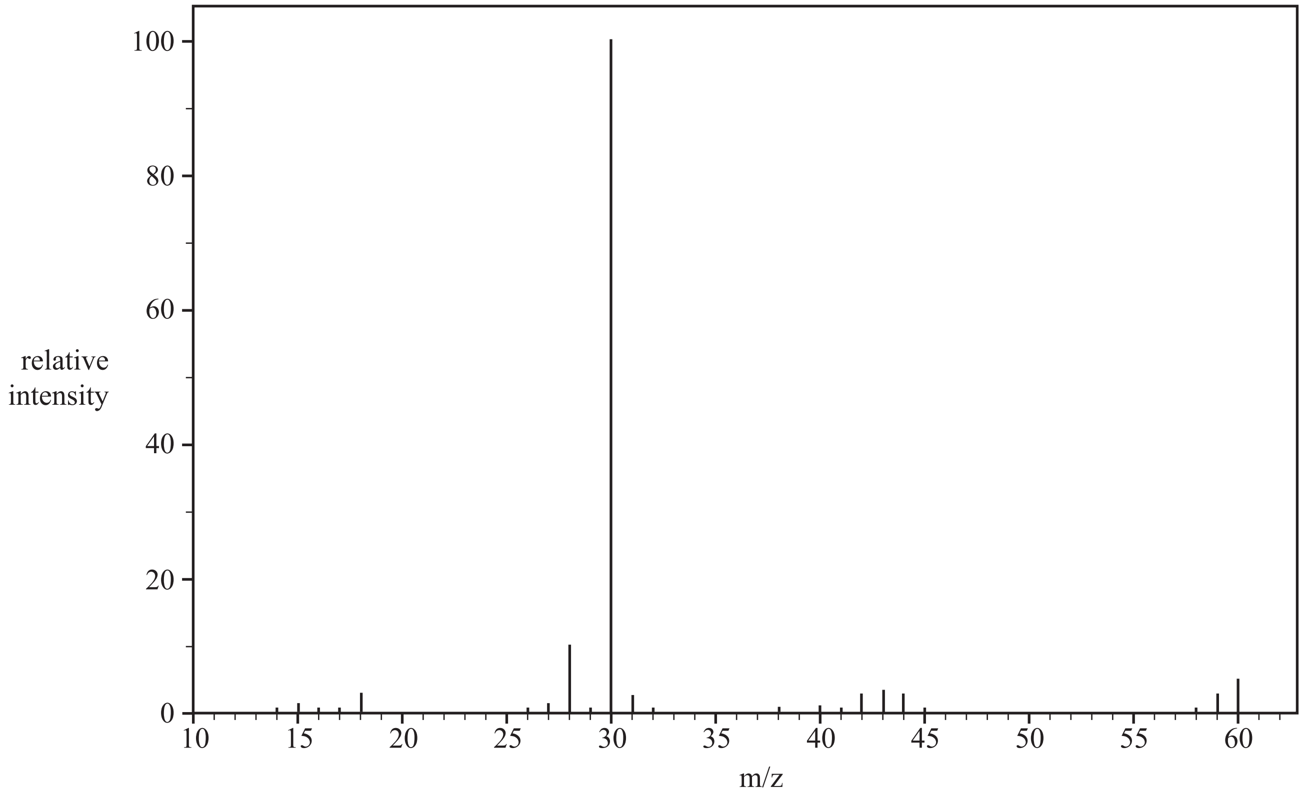
Question 4 (10 marks)

A bottle containing an unknown organic compound was examined in a university laboratory. There was an incomplete label on the bottle that gave only the empirical formula for the contents: CH_4N.

A chemist hypothesised that the unknown compound was 1,2-ethanediamine, $NH_2CH_2CH_2NH_2$.

a. Mass spectrometry produced the following spectral data.

Mass spectrum



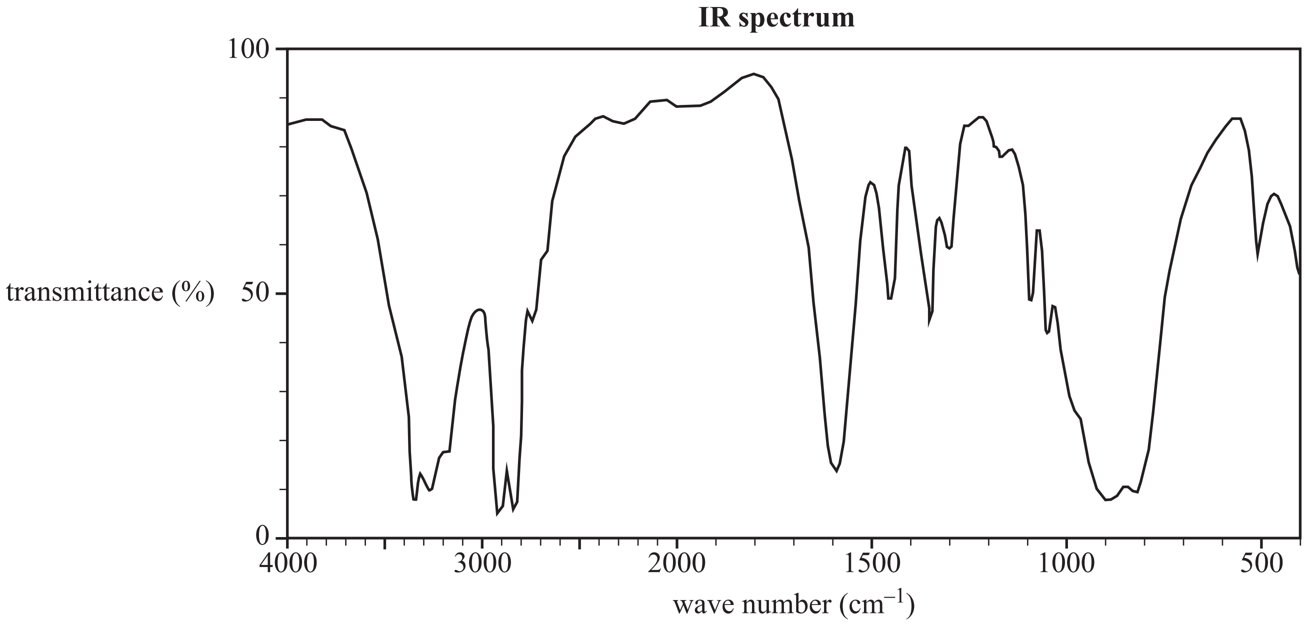
Data: SDBSWeb, http://sdbs.db.aist.go.jp, National Institute of Advanced Industrial Science and Technology

i. On the diagram above, circle the base peak. 1 mark

ii. At what m/z ratio is the principal peak that supports the chemist's hypothesis that the unknown compound has the formula $NH_2CH_2CH_2NH_2$? Justify your answer. 2 marks

iii. Write the semi-structural formula of the species that produces the peak at 30 m/z. 1 mark

Infrared (IR) spectroscopy was also used to analyse the sample. The spectrum is shown below.

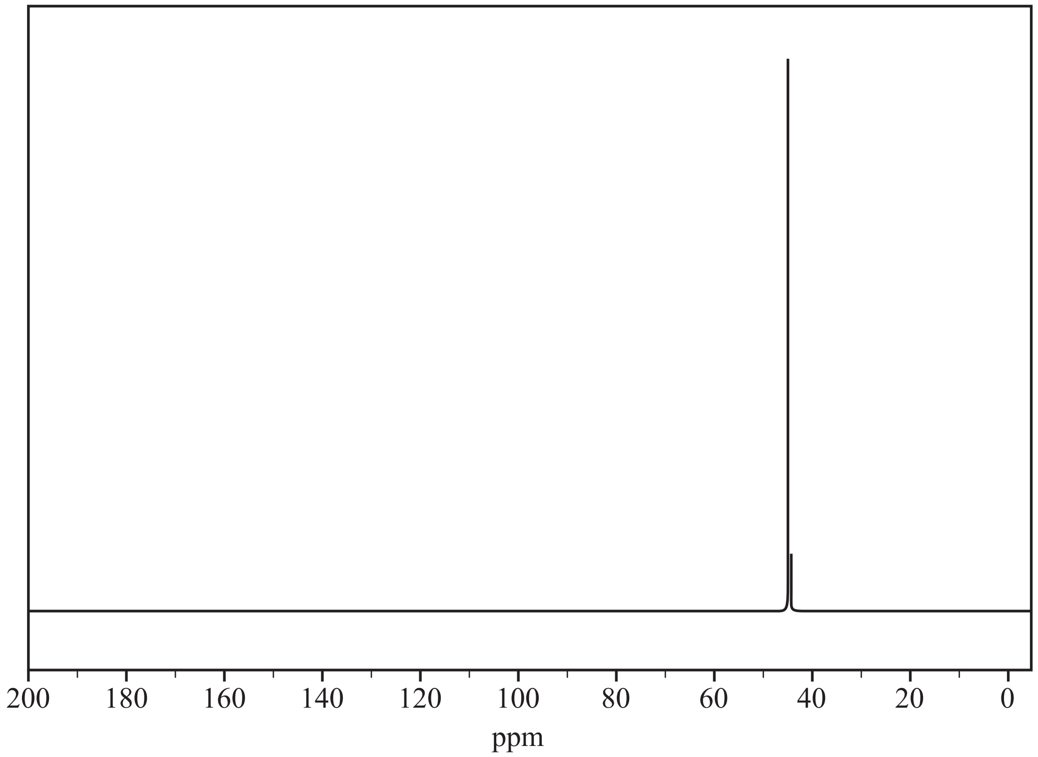


Data: SDBSWeb, http://sdbs.db.aist.go.jp,
National Institute of Advanced Industrial Science and Technology

b. Is this spectrum consistent with the unknown compound being $NH_2CH_2CH_2NH_2$? Use evidence from the IR spectrum in your response. 2 marks

The sample was also analysed using ^{13}C NMR. The spectrum is shown below.

^{13}C NMR spectrum



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

c. Is the ^{13}C NMR spectrum consistent with the structure of $NH_2CH_2CH_2NH_2$? Justify your answer. 2 marks

d. $NH_2CH_2CH_2NH_2$ forms a condensation polymer with butanedioic acid, $HOOCCH_2CH_2COOH$.

Draw the structure of the repeating unit on the copolymer that would be formed. 2 marks

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Question 5 (12 marks)

Bromomethane, CH_3Br, is a toxic, odourless and colourless gas. It is used by quarantine authorities to kill insect pests.

A simplified reaction for its synthesis is

$$CH_3OH(g) + HBr(g) \rightleftharpoons CH_3Br(g) + H_2O(g) \qquad \Delta H = -37.2 \text{ kJ mol}^{-1} \text{ at } 298 \text{ K}$$

The manufacturer of this chemical investigates reaction conditions that could affect the time the process takes and the percentage yield.

a. Predict the effect of each change given below on the rate of production of bromomethane and circle your prediction (increase, no change or decrease). Give your reasoning. 4 marks

- Increasing temperature (constant volume)

  increase no change decrease

Reasoning ____________________

- Increasing pressure (constant temperature)

  increase no change decrease

Reasoning ____________________

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b. Considering the system at equilibrium, predict the effect of each change given below on the percentage yield of bromomethane and circle your prediction (increase, no change or decrease). Give your reasoning. 4 marks

- Increasing pressure (constant temperature)

increase no change decrease

Reasoning ____

____

____

____

____

- Continuously removing the product CH_3Br (constant volume and temperature)

increase no change decrease

Reasoning ____

____

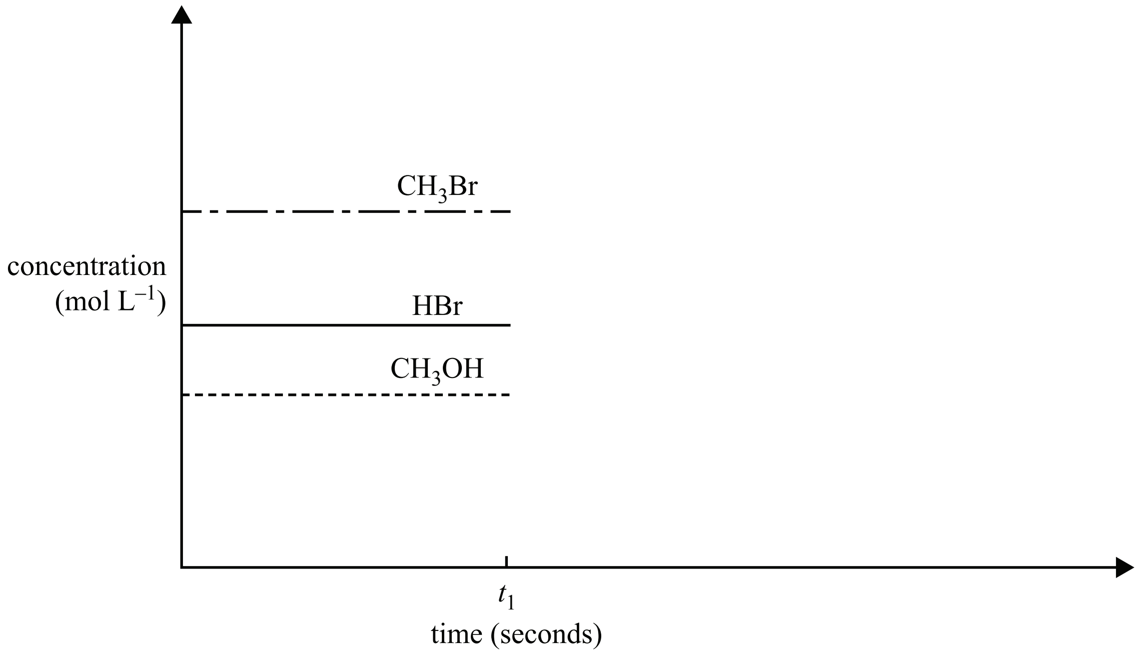
____

____

____

c. The graph below represents the concentration of three of the species involved in the production of CH_3Br when they are at equilibrium at constant temperature. At time t_1, a small amount of HBr was suddenly added to the equilibrium mixture.

Complete the graph after t_1, showing the changes in concentration for each of the three species. 3 marks



d. When bromomethane is used by quarantine officers, it is pumped into a sealed room that contains the items to be treated.

Describe **one** safety precaution that quarantine officers would need to consider when using bromomethane. 1 mark

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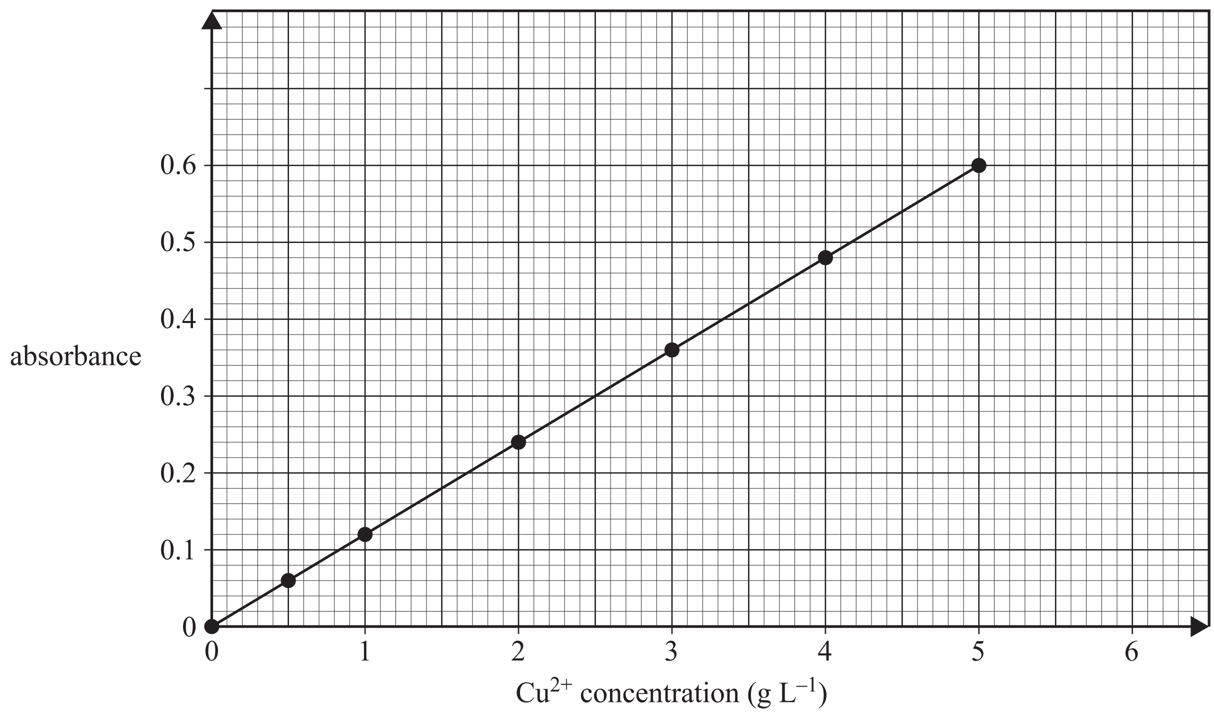
Question 6 (6 marks)

Brass is an alloy of copper and zinc.

To determine the percentage of copper in a particular sample of brass, an analyst prepared a number of standard solutions of copper(II) ions and measured their absorbance using an atomic absorption spectrometer (AAS).

The calibration curve obtained is shown below.



a. A 0.198 g sample of the brass was dissolved in acid and the solution was made up to 100.00 mL in a volumetric flask. The absorbance of this test solution was found to be 0.13

Calculate the percentage by mass of copper in the brass sample. 3 marks

b. If the analyst had made up the solution of the brass sample to 20.00 mL instead of 100.00 mL, would the result of the analysis have been equally reliable? Why? 2 marks

c. Name another analytical technique that could be used to verify the result from **part a.** 1 mark

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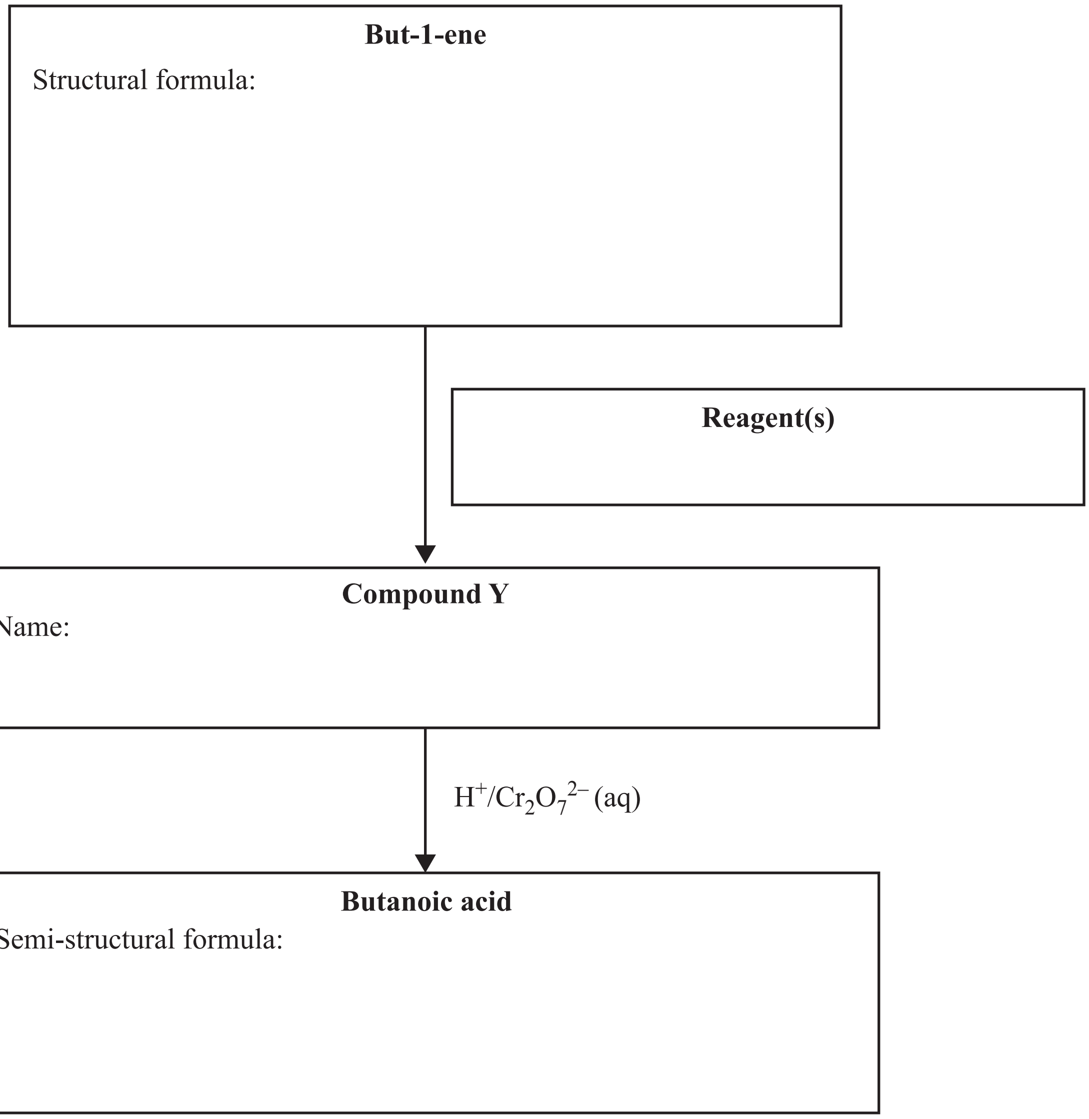
Question 7 (8 marks)

a. Butanoic acid is the simplest carboxylic acid that is also classified as a fatty acid. Butanoic acid may be synthesised as outlined in the following reaction flow chart.



i. Draw the structural formula of but-1-ene in the box provided. 1 mark

ii. State the reagent(s) needed to convert but-1-ene to Compound Y in the box provided. 1 mark

iii. Write the systematic name of Compound Y in the box provided. 1 mark

iv. Write the semi-structural formula of butanoic acid in the box provided. 1 mark

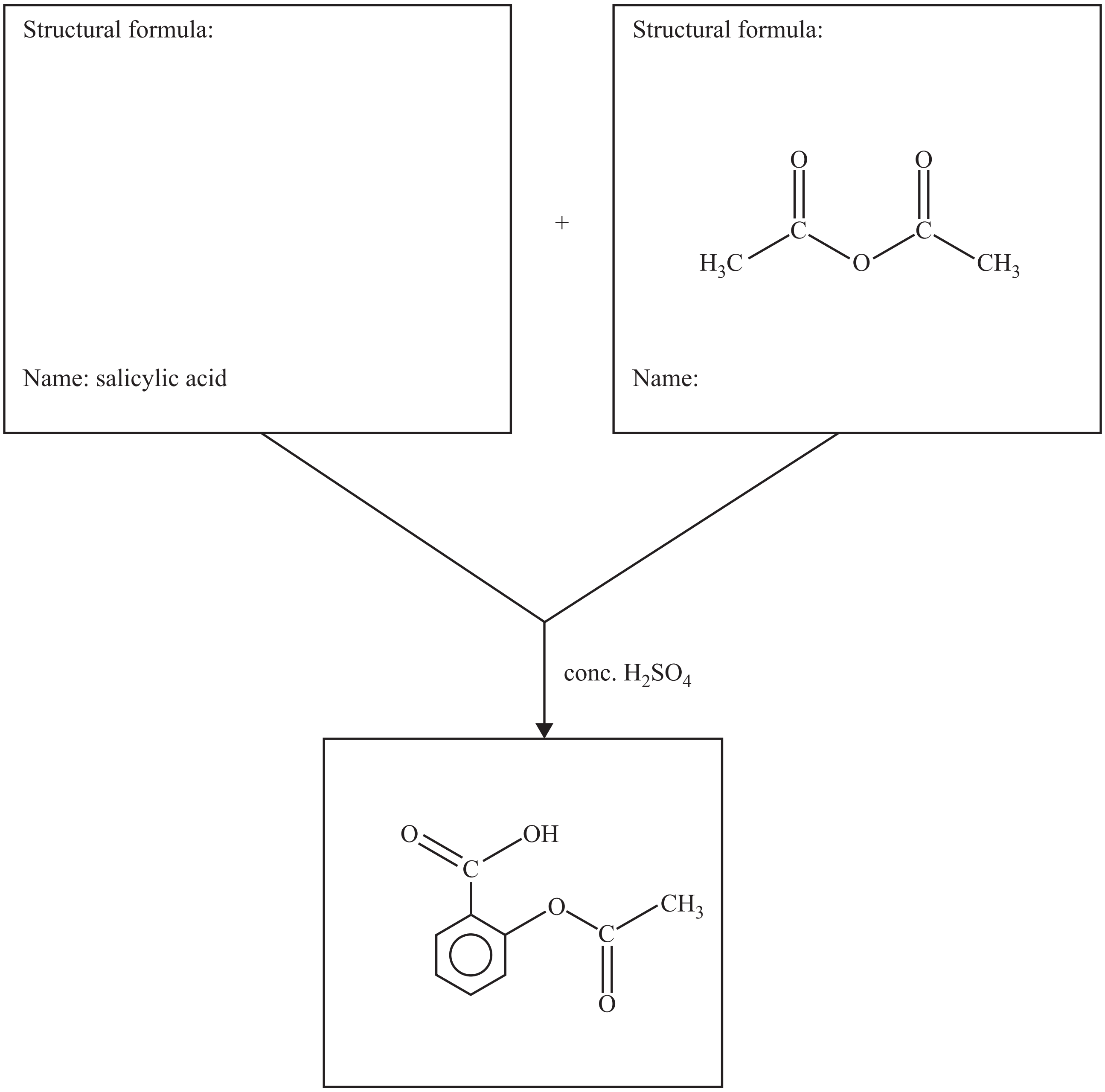
v. Write a balanced half-equation for the conversion of $Cr_2O_7^{2-}$ to Cr^{3+}. 2 marks

b. An incomplete reaction pathway for the synthesis of aspirin is given below.

i. Draw the structural formula of salicylic acid in the box provided. 1 mark

ii. The structural formula of the other reactant is provided.

State its systematic name in the box provided. 1 mark



Aspirin

Question 8 (7 marks)

The lithium-ion battery is a secondary cell that is now widely used in portable electronic devices.

In these batteries, lithium ions, Li^+, move through a special non-aqueous electrolyte between the two electrodes. The batteries are housed in sealed containers to ensure that no moisture can enter them.

Both electrodes are made up of materials that allow the lithium ions to move into and out of their structures. The anode consists of LiC_6, where lithium is embedded in the graphite structure. Lithium cobalt oxide, $LiCoO_2$, is commonly used as the material in the cathode. The reaction at the cathode is quite complex. When the cell discharges, Li^+ ions move out of the anode and enter the cathode.

During discharge, the half-cell reaction at the anode is

$$LiC_6 \rightarrow Li^+ + e^- + C_6$$

a. During discharge, what is the polarity of the graphite electrode? 1 mark

---

b. Write the half-equation for the reaction that occurs at the cathode of a lithium-ion battery when it is recharged. 1 mark

---

c. In a lithium-ion battery, lithium metal must not be in contact with water.

Explain why and justify your answer with the use of appropriate equations. 3 marks

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d. Identify **one** design feature of the lithium-ion battery that enables it to be recharged. 1 mark

e. What is **one** advantage of using a secondary cell compared to using a fuel cell? 1 mark

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Question 9 (8 marks)

Standard solutions of sodium hydroxide, NaOH, must be kept in airtight containers. This is because NaOH is a strong base and absorbs acidic oxides, such as carbon dioxide, CO_2, from the air and reacts with them. As a result, the concentration of NaOH is changed to an unknown extent.

a. CO_2 in the air reacts with water to form carbonic acid, H_2CO_3. This can react with NaOH to form sodium carbonate, Na_2CO_3.

i. Write a balanced overall equation for the reaction between CO_2 gas and water to form H_2CO_3. 1 mark

____

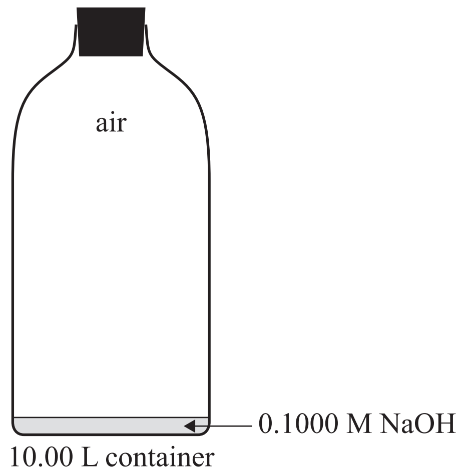
ii. Write a balanced equation for the complete reaction between H_2CO_3 and NaOH to form Na_2CO_3. 1 mark

____

b. A 10.00 L container is completely filled with a freshly made 0.1000 M NaOH solution.

During a Chemistry class, 9.90 L of the solution is used and air enters the empty space above the remaining solution before the container is completely sealed off from the outside air.

The container is then opened. Air enters the container at 101.3 kPa and 21.5 °C. Assume that the concentration of CO_2 in the air is 0.0400 %(v/v).



i. Calculate the amount of CO_2, in mol, that entered the container. 2 marks

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____

____

____

SECTION B – Question 9 – continued

ii. Calculate the amount of NaOH, in mol, that would be present in the solution that remains in the container. Assume that the NaOH did not react with the CO_2 in the air that entered when the container was opened. 1 mark

iii. The container is then shaken thoroughly, ensuring that all the CO_2 in the air is absorbed into the solution.

Calculate the resulting concentration of NaOH in the solution in the container. 3 marks

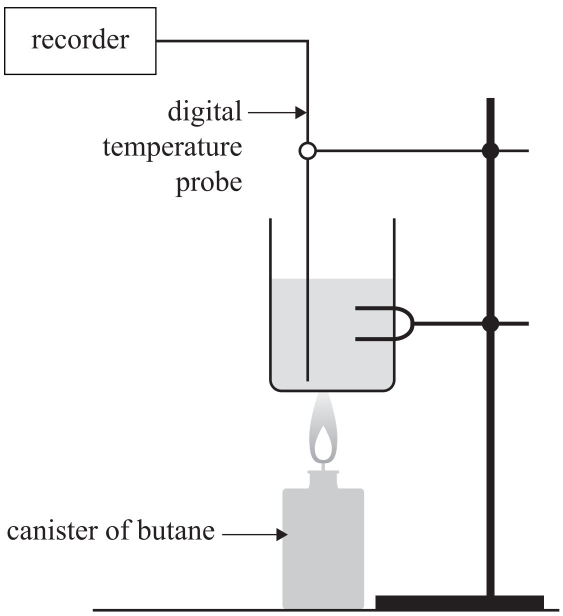
Question 10 (12 marks)

A senior Chemistry student bought a packet of Krispy Krackers from the local farmers' market. The label on the packet had no information on the energy content of the biscuits.

The student decided that he would measure the energy content of a Krispy Krackers biscuit by burning it under a can of water and measuring the temperature rise of the water.

Having performed a similar experiment in class, he knew that when the biscuit was burnt, heat energy would be lost to the environment. To increase the accuracy of the result, some butane gas from a butane canister was first burnt and the temperature rise of the water from that was measured. The heat energy released by burning butane was known, and the percentage energy loss using the equipment could be determined and adjusted to get the result for the biscuit.

The experimental set-up and the results for Part 1 of the experiment are shown below.



Part 1

Part 1 – The heat content of butane

1. Measure the initial mass of a butane canister.
2. Measure the mass of a metal can, add 250 mL of water and re-weigh.
3. Set up the apparatus as in the diagram and measure the initial temperature of the water.
4. Burn the butane gas for five minutes.
5. Immediately measure the final temperature of the water.
6. Measure the final mass of the butane canister when cool.

Results table for Part 1

Quantity	Measurement
mass of empty can	52.14 g
mass of can + water before combustion	303.37 g
mass of butane canister before heating	260.15 g
mass of butane canister after heating	259.79 g
initial temperature of water	22.1 °C
final temperature of water	32.7 °C

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a. **i.** Write the balanced thermochemical equation for the complete combustion of butane. 2 marks

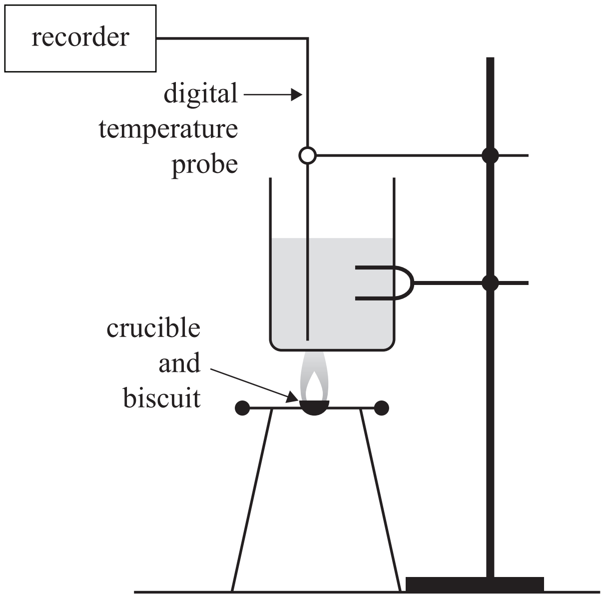
ii. Calculate the amount of heat energy absorbed by the water when it was heated by burning the butane. Give your answer in kilojoules. 2 marks

iii. Calculate the experimental value of the molar heat of combustion of butane. Give your answer in kJ mol^{-1}. 2 marks

iv. Use the known enthalpy change for butane to calculate the percentage energy loss to the environment using the following relationship. 1 mark

$$\text{percentage energy loss} = \frac{(\text{theoretical value of } \Delta H - \text{experimental value of } \Delta H)}{\text{theoretical value of } \Delta H} \times \frac{100}{1}$$

The experimental set-up and the results for Part 2 of the experiment are shown below.



Part 2

Part 2 – The heat content of a Krispy Kracker

1. Measure the mass of a crucible, add a biscuit and re-weigh.
2. Set up the apparatus as in the diagram, using the same can of water as used in Part 1, and measure the initial temperature of the water.
3. Burn the biscuit until the flame runs out.
4. Immediately measure the final temperature of the water.
5. Measure the final mass of the crucible when cool.

Results table for Part 2

Quantity	Measurement
mass of crucible	44.33 g
mass of biscuit + crucible before combustion	46.75 g
mass of crucible after combustion	44.34 g
mass of water (from Part 1)	251.23 g
initial temperature of water	28.5 °C
final temperature of water	34.9 °C

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b. **i.** Calculate the energy content of Krispy Krackers using the data in the results table for Part 2. Give your answer in kJ/100 g. 2 marks

ii. Explain why the energy content of a biscuit cannot be given in kJ mol^{-1}. 1 mark

c. Assume that the same percentage heat energy loss occurred when burning the Krispy Kracker as when the butane was burnt in Part 1.

Calculate a more accurate value of the energy content of Krispy Krackers in kJ/100 g. 2 marks

Question 11 (7 marks)

A student investigated the electroplating of a metal with nickel. The following is her report.

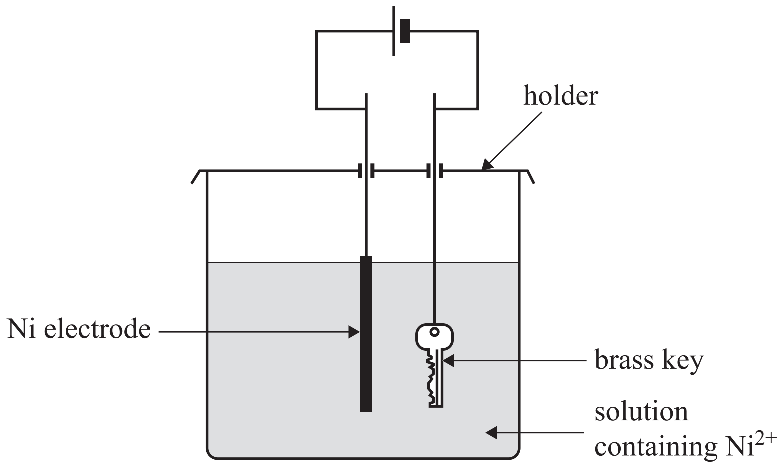
Electroplating a brass key with nickel

Aim

To investigate whether Faraday's laws apply to the electroplating of a brass key with nickel

Procedure

Step 1 – The apparatus was set up as in the diagram below. The electrolyte solution was supplied. The brass key was sanded, weighed and placed in the solution, as shown below.



Step 2 – The current was turned on for exactly 20 minutes. The current and voltage were measured when the power was turned on.

Step 3 – The key was removed from the solution, patted dry with a paper towel and weighed.
Steps 1–3 were repeated for two more keys.

Results

Three trials of the experiment were conducted, X, Y and Z.

Trial	Initial mass of brass key (g)	Final mass of brass key (g)	Mass of nickel deposit (g)	Current (A)	Voltage (V)
X	2.774	2.907	0.133	0.52	2.4
Y	3.068	3.269	0.201	0.54	2.2
Z	3.122	3.310	0.188	0.50	1.9

Predicted mass for Trial X using Faraday's laws

$$m(\text{Ni}) = \frac{0.52 \times 20 \times 60}{96\,500} \times \frac{58.7}{2} = 0.19 \text{ g}$$

Conclusion

Faraday's laws apply to the electroplating of a brass key with nickel.

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Evaluate the student's experimental design and report. In your response:

- identify and explain **one** strength of the experimental design
- suggest **two** improvements or modifications that you would make to the experimental design and justify your suggestions
- comment on the validity of the conclusion based on the results obtained.

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END OF QUESTION AND ANSWER BOOK

VICTORIAN CURRICULUM
AND ASSESSMENT AUTHORITY

Victorian Certificate of Education
2016

CHEMISTRY

Written examination

Tuesday 8 November 2016

Reading time: 9.00 am to 9.15 am (15 minutes)
Writing time: 9.15 am to 11.45 am (2 hours 30 minutes)

DATA BOOK

Instructions

• A question and answer book is provided with this data book.

Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic devices into the examination room.

Table of contents

1. Periodic table of the elements

1 **H** 1.0 hydrogen																	**2** **He** 4.0 helium
3 **Li** 6.9 lithium	**4** **Be** 9.0 beryllium											**5** **B** 10.8 boron	**6** **C** 12.0 carbon	**7** **N** 14.0 nitrogen	**8** **O** 16.0 oxygen	**9** **F** 19.0 fluorine	**10** **Ne** 20.2 neon
11 **Na** 23.0 sodium	**12** **Mg** 24.3 magnesium											**13** **Al** 27.0 aluminium	**14** **Si** 28.1 silicon	**15** **P** 31.0 phosphorus	**16** **S** 32.1 sulfur	**17** **Cl** 35.5 chlorine	**18** **Ar** 39.9 argon
19 **K** 39.1 potassium	**20** **Ca** 40.1 calcium	**21** **Sc** 45.0 scandium	**22** **Ti** 47.9 titanium	**23** **V** 50.9 vanadium	**24** **Cr** 52.0 chromium	**25** **Mn** 54.9 manganese	**26** **Fe** 55.8 iron	**27** **Co** 58.9 cobalt	**28** **Ni** 58.7 nickel	**29** **Cu** 63.5 copper	**30** **Zn** 65.4 zinc	**31** **Ga** 69.7 gallium	**32** **Ge** 72.6 germanium	**33** **As** 74.9 arsenic	**34** **Se** 79.0 selenium	**35** **Br** 79.9 bromine	**36** **Kr** 83.8 krypton
37 **Rb** 85.5 rubidium	**38** **Sr** 87.6 strontium	**39** **Y** 88.9 yttrium	**40** **Zr** 91.2 zirconium	**41** **Nb** 92.9 niobium	**42** **Mo** 96.0 molybdenum	**43** **Tc** (98) technetium	**44** **Ru** 101.1 ruthenium	**45** **Rh** 102.9 rhodium	**46** **Pd** 106.4 palladium	**47** **Ag** 107.9 silver	**48** **Cd** 112.4 cadmium	**49** **In** 114.8 indium	**50** **Sn** 118.7 tin	**51** **Sb** 121.8 antimony	**52** **Te** 127.6 tellurium	**53** **I** 126.9 iodine	**54** **Xe** 131.3 xenon
55 **Cs** 132.9 caesium	**56** **Ba** 137.3 barium	**57–71** lanthanoids	**72** **Hf** 178.5 hafnium	**73** **Ta** 180.9 tantalum	**74** **W** 183.8 tungsten	**75** **Re** 186.2 rhenium	**76** **Os** 190.2 osmium	**77** **Ir** 192.2 iridium	**78** **Pt** 195.1 platinum	**79** **Au** 197.0 gold	**80** **Hg** 200.6 mercury	**81** **Tl** 204.4 thallium	**82** **Pb** 207.2 lead	**83** **Bi** 209.0 bismuth	**84** **Po** (210) polonium	**85** **At** (210) astatine	**86** **Rn** (222) radon
87 **Fr** (223) francium	**88** **Ra** (226) radium	**89–103** actinoids	**104** **Rf** (261) rutherfordium	**105** **Db** (262) dubnium	**106** **Sg** (266) seaborgium	**107** **Bh** (264) bohrium	**108** **Hs** (267) hassium	**109** **Mt** (268) meitnerium	**110** **Ds** (271) darmstadtium	**111** **Rg** (272) roentgenium	**112** **Cn** (285) copernicium		**114** **Fl** (289) flerovium		**116** **Lv** (292) livermorium		

Key: **79** atomic number; **Au** symbol of element; 197.0 relative atomic mass; gold name of element

57 **La** 138.9 lanthanum	**58** **Ce** 140.1 cerium	**59** **Pr** 140.9 praseodymium	**60** **Nd** 144.2 neodymium	**61** **Pm** (145) promethium	**62** **Sm** 150.4 samarium	**63** **Eu** 152.0 europium	**64** **Gd** 157.3 gadolinium	**65** **Tb** 158.9 terbium	**66** **Dy** 162.5 dysprosium	**67** **Ho** 164.9 holmium	**68** **Er** 167.3 erbium	**69** **Tm** 168.9 thulium	**70** **Yb** 173.1 ytterbium	**71** **Lu** 175.0 lutetium
89 **Ac** (227) actinium	**90** **Th** 232.0 thorium	**91** **Pa** 231.0 protactinium	**92** **U** 238.0 uranium	**93** **Np** (237) neptunium	**94** **Pu** (244) plutonium	**95** **Am** (243) americium	**96** **Cm** (247) curium	**97** **Bk** (247) berkelium	**98** **Cf** (251) californium	**99** **Es** (252) einsteinium	**100** **Fm** (257) fermium	**101** **Md** (258) mendelevium	**102** **No** (259) nobelium	**103** **Lr** (262) lawrencium

The value in brackets indicates the mass number of the longest-lived isotope.

2. The electrochemical series

Reaction	Standard electrode potential (E^0) in volts at 25 °C
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	+2.87
$H_2O_2(aq) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$	+1.77
$Au^+(aq) + e^- \rightleftharpoons Au(s)$	+1.68
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$	+1.36
$O_2(g) + 4H^+(aq) + 4e^- \rightleftharpoons 2H_2O(1)$	+1.23
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	+1.09
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77
$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$	+0.68
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	+0.54
$O_2(g) + 2H_2O(l) + 4e^- \rightleftharpoons 4OH^-(aq)$	+0.40
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	+0.15
$S(s) + 2H^+(aq) + 2e^- \rightleftharpoons H_2S(g)$	+0.14
$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$	0.00
$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightleftharpoons Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s)$	–0.23
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	–0.28
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	–0.44
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	–0.76
$2H_2O(l) + 2e^- \rightleftharpoons H_2(g) + 2OH^-(aq)$	–0.83
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	–1.03
$Al^{3+}(aq) + 3e^- \rightleftharpoons Al(s)$	–1.67
$Mg^{2+}(aq) + 2e^- \rightleftharpoons Mg(s)$	–2.34
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	–2.71
$Ca^{2+}(aq) + 2e^- \rightleftharpoons Ca(s)$	–2.87
$K^+(aq) + e^- \rightleftharpoons K(s)$	–2.93
$Li^+(aq) + e^- \rightleftharpoons Li(s)$	–3.02

3. Physical constants

Avogadro's constant (N_A)	6.02×10^{23} mol^{-1}
charge on one electron	-1.60×10^{-19} C
Faraday constant (F)	96 500 C mol^{-1}
gas constant (R)	8.31 J K^{-1} mol^{-1}
ionic product (self-ionisation constant) for water (K_w) at 298 K	1.00×10^{-14} mol^2 L^{-2}
molar volume (V_m) of an ideal gas at 273 K, 101.3 kPa (STP)	22.4 L mol^{-1}
molar volume (V_m) of an ideal gas at 298 K, 101.3 kPa (SLC)	24.5 L mol^{-1}
specific heat capacity (c) of water	4.18 J g^{-1} K^{-1}
density (d) of water at 25 °C	1.00 g mL^{-1}
1 atm	101.3 kPa = 760 mm Hg
0 °C	273 K

4. SI prefixes, their symbols and values

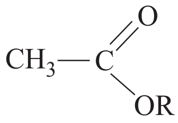
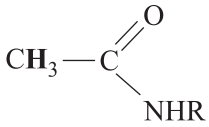
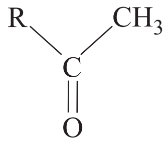
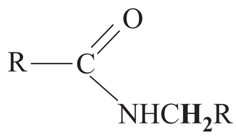
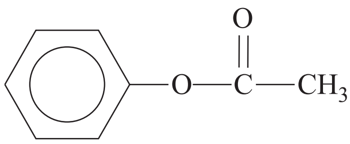
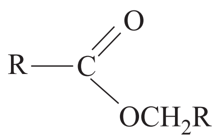
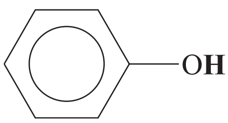
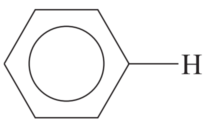
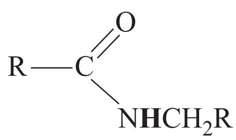
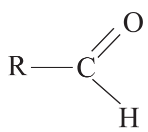
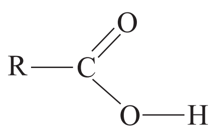
SI prefix	Symbol	Value
giga	G	10^9
mega	M	10^6
kilo	k	10^3
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}

5. ^{1}H NMR data

Typical proton shift values relative to TMS = 0

These can differ slightly in different solvents. Where more than one proton environment is shown in the formula, the shift refers to the ones in bold letters.

Type of proton	Chemical shift (ppm)
$R{-}CH_3$	0.8–1.0
$R{-}CH_2{-}R$	1.2–1.4
$RCH = CH{-}C\mathbf{H_3}$	1.6–1.9
$R_3{-}CH$	1.4–1.7

Type of proton	Chemical shift (ppm)
 or 	2.0
	2.1–2.7
$R–CH_2–X$ (X = F, Cl, Br or I)	3.0–4.5
$R–C\mathbf{H_2}–OH$, $R_2–C\mathbf{H}–OH$	3.3–4.5
	3.2
$R—O—CH_3$ or $R—O—CH_2R$	3.3
	2.3
	4.1
R–O–H	1–6 (varies considerably under different conditions)
$R–NH_2$	1–5
$RHC{=}C\mathbf{H_2}$	4.6–6.0
	7.0
	7.3
	8.1
	9–10
	9–13

6. ^{13}C NMR data

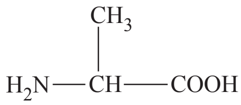
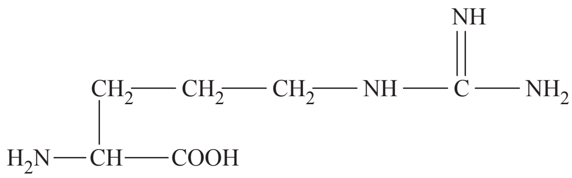
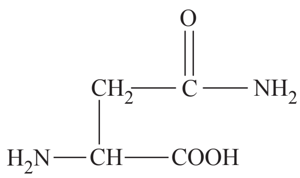
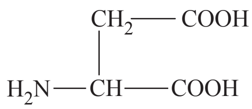
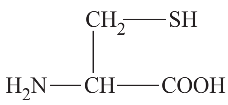
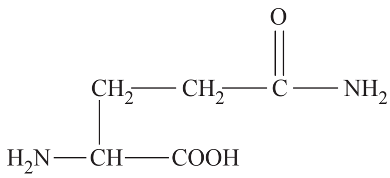
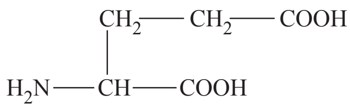
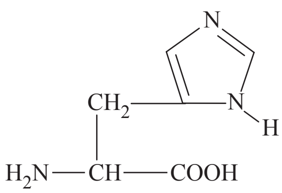
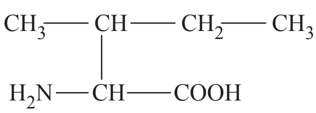
Type of carbon	Chemical shift (ppm)
$R–CH_3$	8–25
$R–CH_2–R$	20–45
$R_3–CH$	40–60
$R_4–C$	36–45
$R–CH_2–X$	15–80
$R_3C–NH_2$	35–70
$R–CH_2–OH$	50–90
RC≡CR	75–95
$R_2C=CR_2$	110–150
RCOOH	160–185

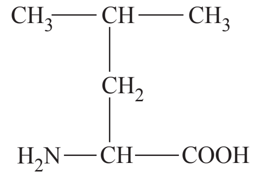
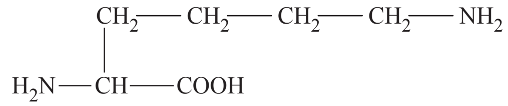
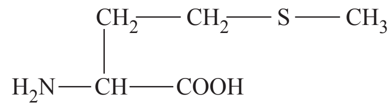
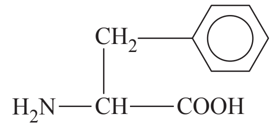
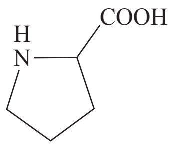
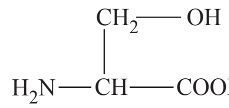
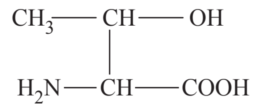
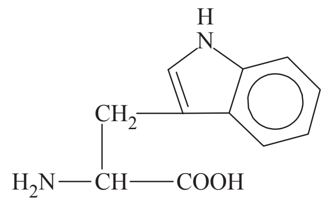
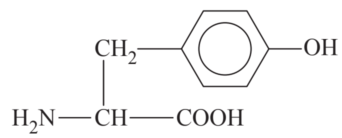
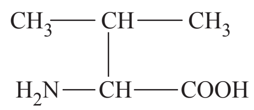
7. Infrared absorption data

Characteristic range for infrared absorption

Bond	Wave number (cm^{-1})
C–Cl	700–800
C–C	750–1100
C–O	1000–1300
C=C	1610–1680
C=O	1670–1750
O–H (acids)	2500–3300
C–H	2850–3300
O–H (alcohols)	3200–3550
N–H (primary amines)	3350–3500

8. 2-amino acids (α-amino acids)

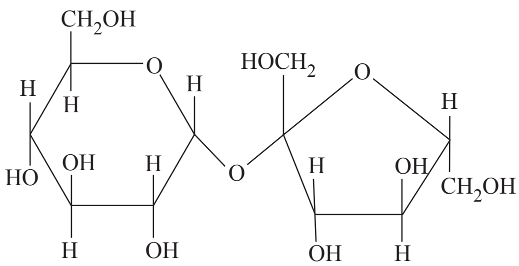
Name	Symbol	Structure
alanine	Ala	
arginine	Arg	
asparagine	Asn	
aspartic acid	Asp	
cysteine	Cys	
glutamine	Gln	
glutamic acid	Glu	
glycine	Gly	H_2N-CH_2-COOH
histidine	His	
isoleucine	Ile	

Name	Symbol	Structure
leucine	Leu	
lysine	Lys	
methionine	Met	
phenylalanine	Phe	
proline	Pro	
serine	Ser	
threonine	Thr	
tryptophan	Trp	
tyrosine	Tyr	
valine	Val	

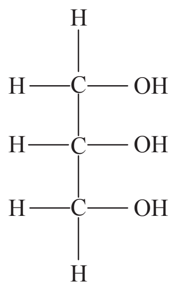
9. Formulas of some fatty acids

Name	Formula
lauric	$C_{11}H_{23}COOH$
myristic	$C_{13}H_{27}COOH$
palmitic	$C_{15}H_{31}COOH$
palmitoleic	$C_{15}H_{29}COOH$
stearic	$C_{17}H_{35}COOH$
oleic	$C_{17}H_{33}COOH$
linoleic	$C_{17}H_{31}COOH$
linolenic	$C_{17}H_{29}COOH$
arachidic	$C_{19}H_{39}COOH$
arachidonic	$C_{19}H_{31}COOH$

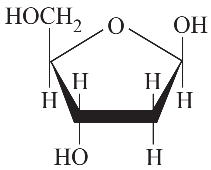
10. Structural formulas of some important biomolecules



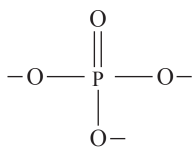
sucrose



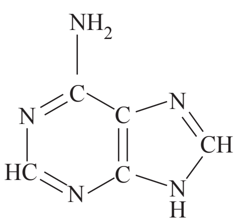
glycerol



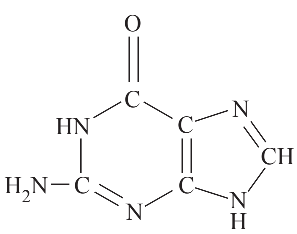
deoxyribose



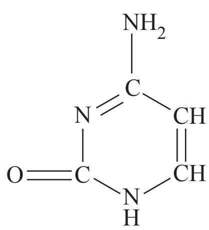
phosphate



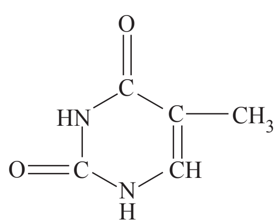
adenine



guanine



cytosine



thymine

11. Acid-base indicators

Name	pH range	Colour change		K_a
		Acid	Base	
thymol blue	1.2–2.8	red	yellow	2×10^{-2}
methyl orange	3.1–4.4	red	yellow	2×10^{-4}
bromophenol blue	3.0–4.6	yellow	blue	6×10^{-5}
methyl red	4.2–6.3	red	yellow	8×10^{-6}
bromothymol blue	6.0–7.6	yellow	blue	1×10^{-7}
phenol red	6.8–8.4	yellow	red	1×10^{-8}
phenolphthalein	8.3–10.0	colourless	red	5×10^{-10}

12. Acidity constants, K_a, of some weak acids at 25 °C

Name	Formula	K_a
ammonium ion	NH_4^+	5.6×10^{-10}
benzoic	C_6H_5COOH	6.4×10^{-5}
boric	H_3BO_3	5.8×10^{-10}
ethanoic	CH_3COOH	1.7×10^{-5}
hydrocyanic	HCN	6.3×10^{-10}
hydrofluoric	HF	7.6×10^{-4}
hypobromous	$HOBr$	2.4×10^{-9}
hypochlorous	$HOCl$	2.9×10^{-8}
lactic	$HC_3H_5O_3$	1.4×10^{-4}
methanoic	$HCOOH$	1.8×10^{-4}
nitrous	HNO_2	7.2×10^{-4}
propanoic	C_2H_5COOH	1.3×10^{-5}

13. Values of molar enthalpy of combustion of some common fuels at 298 K and 101.3 kPa

Substance	Formula	State	ΔH_c (kJ mol^{-1})
hydrogen	H_2	g	–286
carbon (graphite)	C	s	–394
methane	CH_4	g	–889
ethane	C_2H_6	g	–1557
propane	C_3H_8	g	–2217
butane	C_4H_{10}	g	–2874
pentane	C_5H_{12}	l	–3509
hexane	C_6H_{14}	l	–4158
octane	C_8H_{18}	l	–5464
ethene	C_2H_4	g	–1409
methanol	CH_3OH	l	–725
ethanol	C_2H_5OH	l	–1364
1-propanol	$CH_3CH_2CH_2OH$	l	–2016
2-propanol	$CH_3CHOHCH_3$	l	–2003
glucose	$C_6H_{12}O_6$	s	–2816

END OF DATA BOOK