VCE Chemistry 2013–2016

Written examination

Examination specifications

Overall conditions

The examination will be sat at a time and date to be set annually by the Victorian Curriculum and Assessment Authority.

There will be 15 minutes reading time and 2 hours 30 minutes writing time.

VCAA examination rules will apply. Details of these rules are published annually in the *VCE and VCAL Administrative Handbook.*

The examination will be marked by a panel appointed by the VCAA.

The examination will contribute 60 per cent to the Study Score.

Content

All outcomes in Units 3 and 4 will be examined. All of the key knowledge that underpins the outcomes in Units 3 and 4, and the set of key skills listed on page 12 of the study design are examinable except

- specific details related to the study of a selected chemical (one of: ammonia, sulfuric acid or nitric acid).

The underlying principles related to factors that affect the rate of chemical reactions and the position of equilibrium are examinable.

Each outcome will be approximately equally weighted.

Format

The examination paper will be in the form of a question and answer book. A data book will be supplied with the examination.

The total marks available for the examination will be 120–130.

The examination will consist of two sections.

Section A will contain 30 multiple-choice questions. Each question in Section A will be worth one mark.

Section B will contain mainly short answer questions. There will be a variety of question types in Section B, including questions that require calculations, descriptions and explanations. All questions will be compulsory.

Section B will be worth a total of 90–100 marks.

Approved materials and equipment

A scientific calculator is allowed.

Advice

The examination will be prepared according to the examination specifications above. The examination will conform to these specifications and will test a representative sample of the key knowledge and skills.

Version 3 – July 2013

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

Victorian Certificate of Education Year

SUPERVISOR TO ATTACH PROCESSING LABEL HERE

STUDENT NUMBER

Figures									Letter
Words									

CHEMISTRY

Written examination

Day Date

Reading time: *. ** to *.** ** (15 minutes)**
Writing time: *. ** to *.** ** (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	13	13	95
			Total 125

- 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 white out liquid/tape.

Materials supplied
- Question and answer book of 37 pages.
- A 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.
- 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.

Version 3 – July 2013

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.

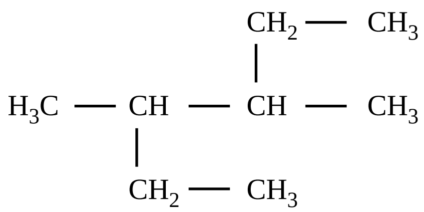
A correct answer scores 1, an incorrect answer scores 0.

Marks will **not** be deducted for incorrect answers.

No marks will be given if more than one answer is completed for any question.

Question 1

What is the correct systematic name for the following compound?

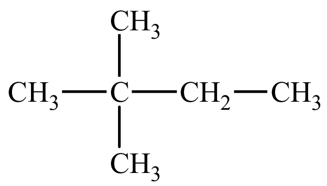


A. 2-ethyl-3-methylpentane
B. 3-methyl-4-ethylpentane
C. 3,4-dimethylhexane
D. 2,3-diethylbutane

Question 2

In a particular chlorination reaction, a single hydrogen atom of 2,2-dimethylbutane, C_6H_{14}, is replaced by one chlorine atom. More than one compound of formula $C_6H_{13}Cl$ will be formed.

A structure of 2,2-dimethylbutane is provided below.



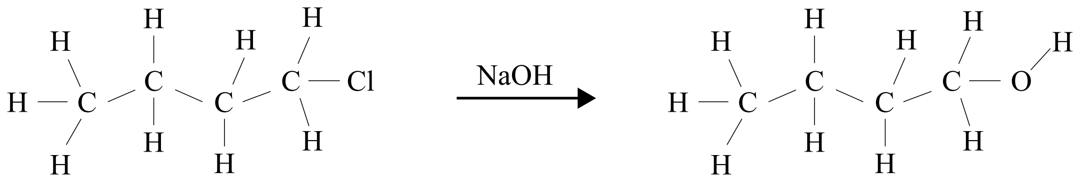
The number of different carbon compounds that could be formed in this monosubstitution reaction is

A. 2
B. 3
C. 4
D. 5

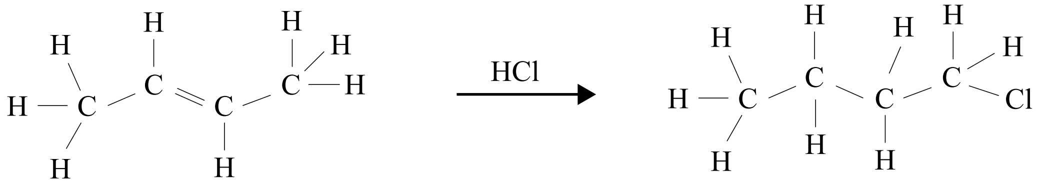
Question 3

Which one of the following organic reactions does **not** result in the product shown on the right-hand side of the reaction?

A.



B.



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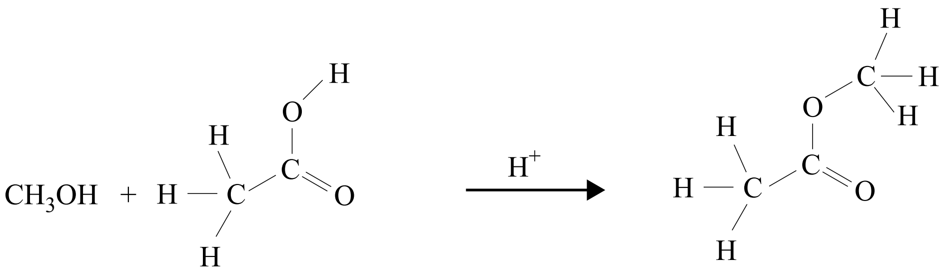

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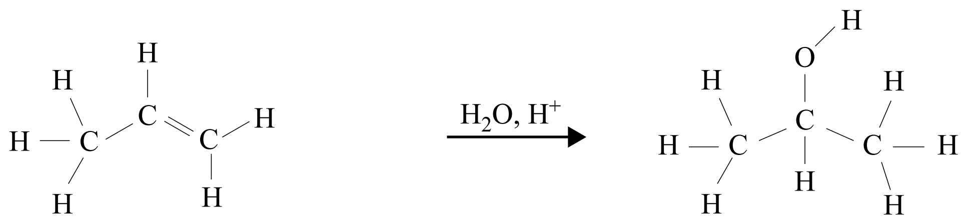
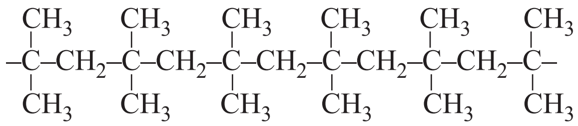


Question 4

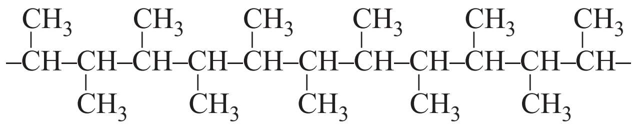
Consider the addition polymerisation of $CH_3CH = CHCH_3$.

The structure of the resulting polymer would be

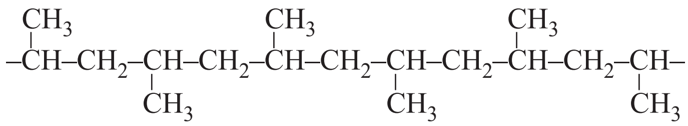
A.



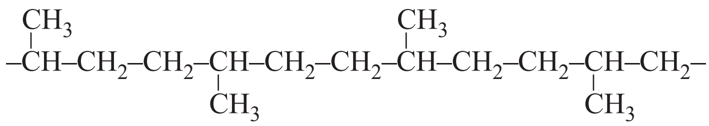
B.



C.



D.



Question 5

A biomolecule is chemically analysed and found to contain only the elements carbon, hydrogen, oxygen, nitrogen and phosphorus.

The biomolecule is most likely to be

A. DNA.

B. a protein.

C. a triglyceride.

D. a polysaccharide.

Question 6

The reaction between a glycerol molecule and three long-chain carboxylic acid molecules is a

A. condensation reaction and the product contains a $-\underset{\underset{\displaystyle O}{\|}}{C}-O-C-$ group.

B. hydrolysis reaction and the product contains a $-\underset{\underset{\displaystyle O}{\|}}{C}-O-C-$ group.

C. condensation reaction and the product contains a $-C-O-O-C-$ group.

D. hydrolysis reaction and the product contains a $-C-O-O-C-$ group.

Question 7

The function of a protein is dependent on its three-dimensional structure. This structure can be disrupted, denaturing the protein.

Which of the following changes could cause denaturing?

I the addition of a strong acid

II the addition of a strong base

III a significant increase in temperature

A. I only

B. I and II only

C. III only

D. I, II and III

Question 8

The fatty acid with the greatest number of double bonds is

A. $C_{18}H_{34}O_2$

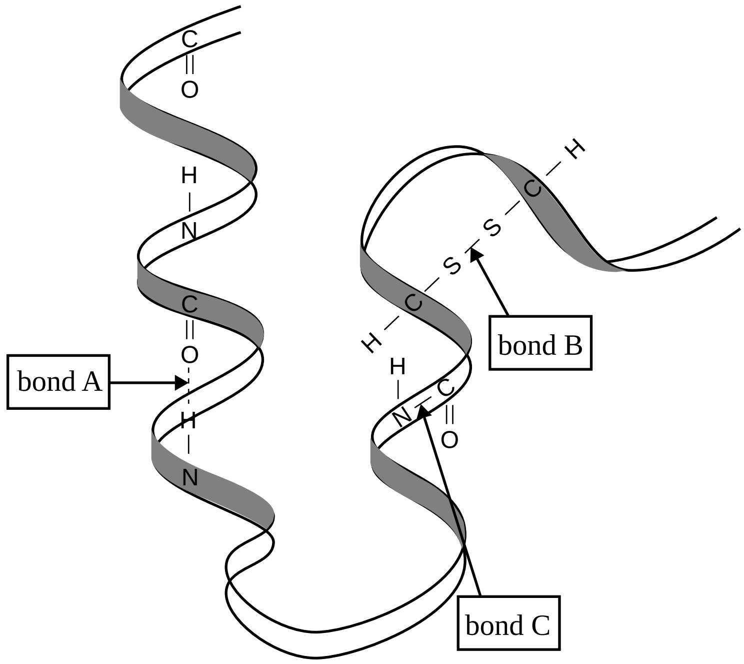
B. $C_{24}H_{48}O_2$

C. $C_{18}H_{32}O_2$

D. $C_{20}H_{32}O_2$

Question 9

Enzymes, which are composed mostly of protein, catalyse many chemical reactions. The structure of a portion of an enzyme, with some of its constituent atoms shown, is represented below.



Which level of protein structure is each of the chemical bonds labelled involved in?

	Bond A	Bond B	Bond C
A.	primary	tertiary	secondary
B.	secondary	tertiary	primary
C.	tertiary	primary	secondary
D.	primary	secondary	tertiary

Question 10

Consider the following statements about enzymes.

I Enzymes are proteins.

II Enzymes increase the rate of biochemical reactions.

III Enzymes increase the equilibrium constant of biochemical reactions.

Which of the above statements are correct?

A. I and II only

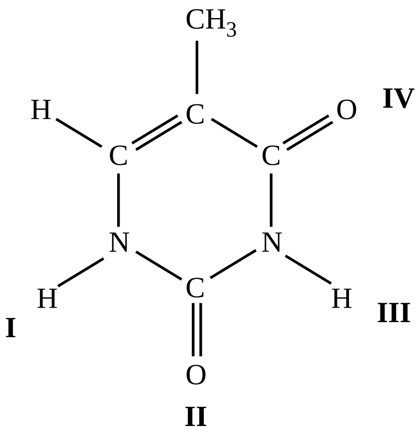
B. I and III only

C. II and III only

D. I, II and III

Question 11

The following is the structure of the DNA base, thymine.



At which points does thymine form hydrogen bonds with its complimentary base?

A. I, II and III only

B. II and III only

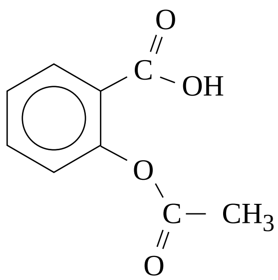
C. III and IV only

D. II, III and IV only

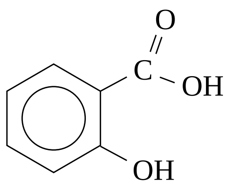
Question 12

Aspirin is a compound widely used as a painkiller and to relieve the symptoms of fever. It can be produced by means of a reaction in which salicylic acid is one of the reagents.

The structures of aspirin and salicylic acid are shown below.



aspirin



salicylic acid

Which one of the following statements about aspirin is **not** correct?

A. Aspirin may be prepared by reaction between salicylic acid and CH_3OH.

B. Aspirin contains both an ester and a carboxylic acid functional group.

C. Aspirin can undergo an acid-base reaction with $NaHCO_3$.

D. Aspirin may be prepared by reaction between salicylic acid and CH_3COOH.

Question 13

Which of the following would be the most suitable analytical technique to determine the isotope ratio of ^{235}U to ^{238}U in a sample of uranium metal?

A. mass spectroscopy

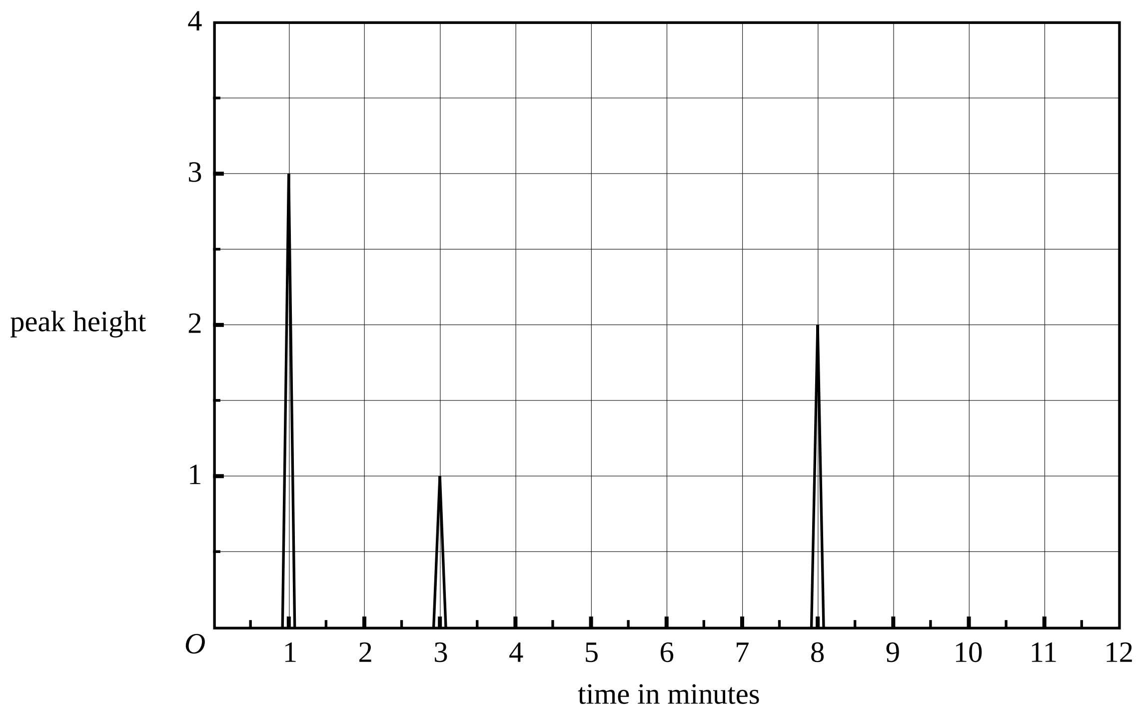
B. gas-liquid chromatography

C. atomic absorption spectroscopy

D. nuclear magnetic resonance spectroscopy

Question 14

A mixture of butane (C_4H_{10}), pentane (C_5H_{12}) and hexane (C_6H_{14}) was analysed in a gas-liquid chromatography column. The following output was obtained.



Given that the sensitivity of the detector is the same per mole for all three substances, the mole percentage of hexane in the sample is closest to

A. 20

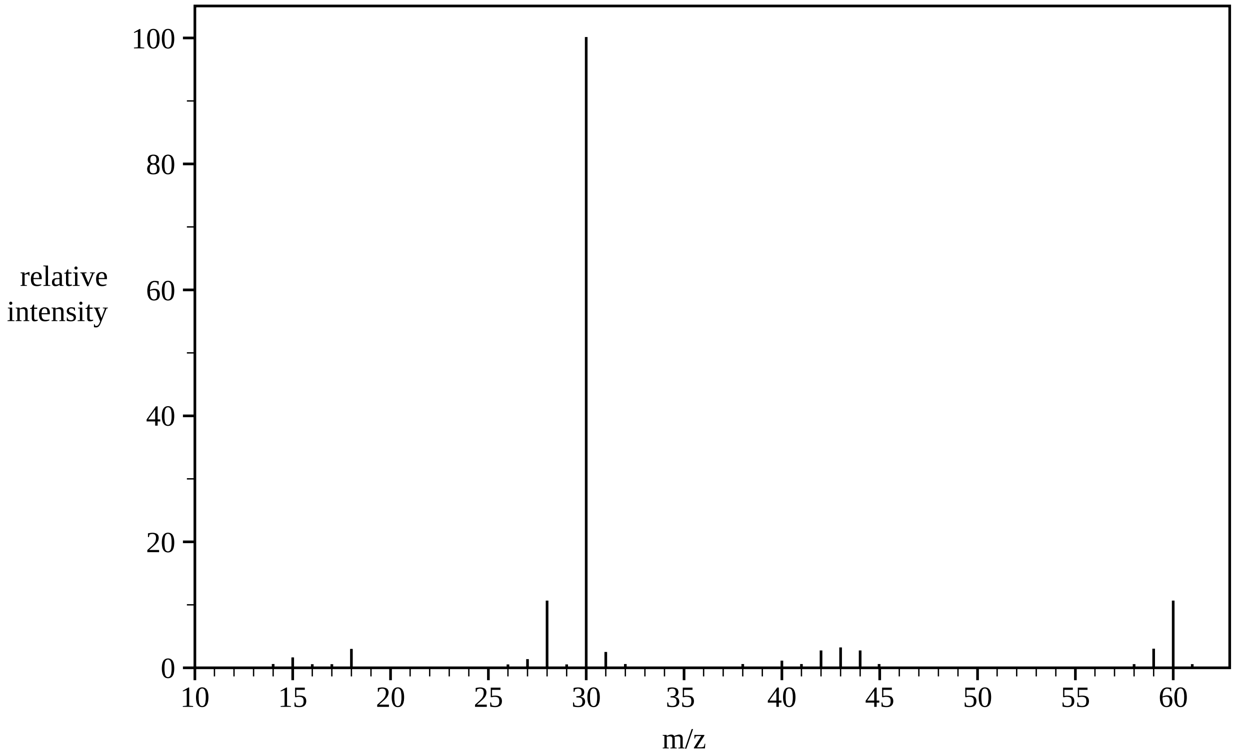
B. 30

C. 33

D. 50

Question 15

The mass spectrum of an unknown compound is given below. The empirical formula of this compound is CH_4N.



Source: Spectral Database for Organic Compounds SDBS

Which of the following correctly identifies the relative molecular mass and the formula of the molecular ion of this unknown compound?

	Relative molecular mass	Formula of the molecular ion
A.	60	$C_2H_8N_2^+$
B.	60	$C_2H_8N_2$
C.	30	CH_4N^+
D.	30	CH_4N

Question 16

The oxidation state of phosphorus in the pyrophosphate ion $P_2O_7^{4-}$ is

A. +3.5

B. +5

C. +7

D. +10

Question 17

Consider the following statements regarding the effect of temperature on the particles in a reaction mixture.

I At a higher temperature, particles move faster and the reactant particles collide more frequently.

II At a higher temperature, more particles have energy greater than the activation energy.

Which of the above statements provides an explanation as to why the observed reaction rate is greater at higher temperatures?

A. I only

B. II only

C. I and II to an equal extent

D. I and II, but II to a greater extent than I

Question 18

Methanol can be produced in a reaction between carbon monoxide and hydrogen according to the following equation.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g); \quad \Delta H = -90 \text{ kJ mol}^{-1}$$

Which one of the following changes would occur when a catalyst is added to an equilibrium mixture of carbon monoxide, hydrogen and methanol?

A. The value of ΔH would increase.

B. The amount of methanol would increase.

C. The temperature of the surroundings would increase.

D. The rates of both the forward and reverse reactions would increase.

Question 19

Consider the following combustion reactions for graphite and diamond.

$$C(\text{graphite}) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393 \text{ kJ mol}^{-1}$$

$$C(\text{diamond}) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -395 \text{ kJ mol}^{-1}$$

From the data provided it can be determined that the enthalpy change, ΔH, for the conversion of graphite to diamond

$$C(\text{graphite}) \rightarrow C(\text{diamond})$$

is

A. -2 kJ mol^{-1}

B. $+2$ kJ mol^{-1}

C. -788 kJ mol^{-1}

D. $+788$ kJ mol^{-1}

NO WRITING ALLOWED IN THIS AREA

Question 20

A chemist used bomb calorimetry to measure the enthalpy change (ΔH) for the combustion of butane.

The calibration factor (CF) of the calorimeter was determined by measuring the temperature rise (ΔT_1) that occurred when a known amount of charge (Q) was passed through the heating element in the calorimeter at a measured voltage (V).

The CF of this calorimeter can be calculated by using the expression

A. $\dfrac{Q}{V \times \Delta T_1}$

B. $\dfrac{\Delta T_1}{Q \times V}$

C. $V \times Q \times \Delta T_1$

D. $\dfrac{V \times Q}{\Delta T_1}$

Question 21

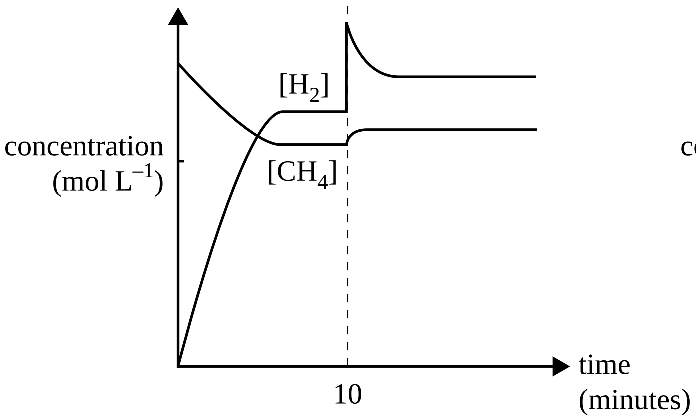
Water gas, a mixture of carbon monoxide and hydrogen, can be produced on an industrial scale by the following reaction.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + H_2(g) \qquad (\Delta H = +131 \text{ kJ/mol})$$

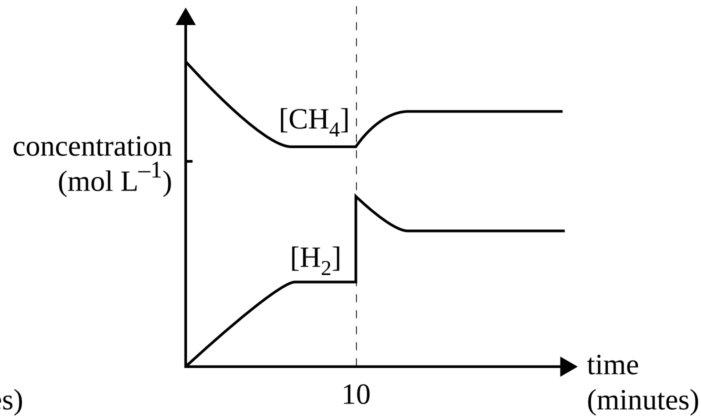
Equal amounts of $CH_4(g)$ and $H_2O(g)$ are added to a reaction vessel and allowed to react. After 10 minutes, equilibrium has been reached. At that time, some H_2 is added to the mixture and equilibrium is re-established.

Which one of the following graphs best represents the concentrations in the amounts of CH_4 and H_2 in the reaction mixture?

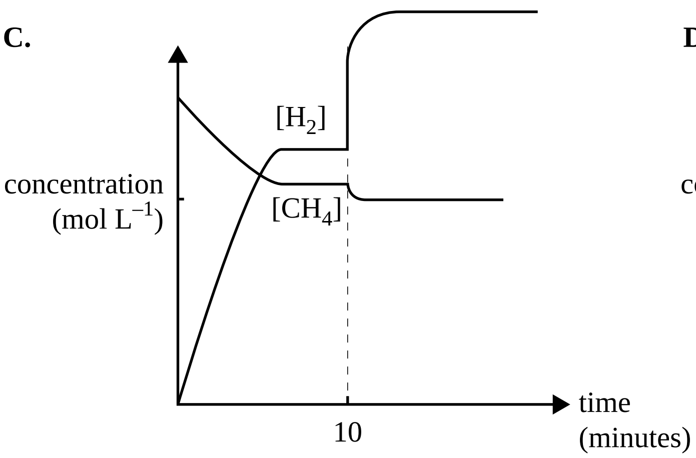
A.



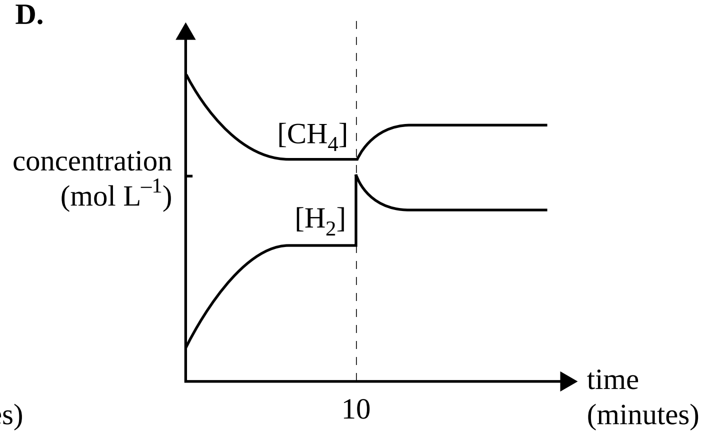
B.



C.



D.



Question 22

Ethanol can be manufactured by the reaction between ethene and water. This is represented by the equation

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \quad \Delta H = -46 \text{ kJ mol}^{-1}$$

Which conditions would produce the highest percentage yield of ethanol at equilibrium?

A. low pressure and low temperature

B. high pressure and low temperature

C. low pressure and high temperature

D. high pressure and high temperature

Question 23

At 25 ºC, the pH of 0.0050 M $Ba(OH)_2$ is

A. 2.0

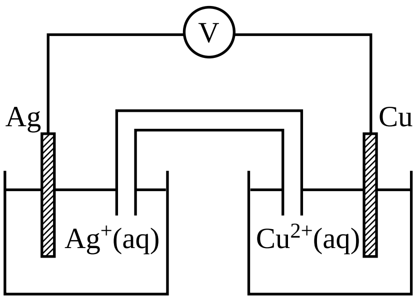
B. 2.3

C. 11.7

D. 12.0

Use the following information to answer Questions 24 and 25.

The following galvanic cell was set up under standard conditions.



Question 24

The overall equation for the reaction occurring in this galvanic cell is

A. $Ag^+(aq) + Cu(s) \rightarrow Ag(s) + Cu^{2+}(aq)$

B. $Ag(s) + Cu^{2+}(aq) \rightarrow Ag^+(aq) + Cu(s)$

C. $2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$

D. $2Ag(s) + Cu^{2+}(aq) \rightarrow 2Ag^+(aq) + Cu(s)$

Question 25

The predicted maximum voltage produced by this cell under standard conditions is

A. 0.46 V

B. 1.14 V

C. 1.26 V

D. 1.94 V

Use the following information to answer Questions 26–28.

The oxidation of methane (natural gas) can be used to produce electricity in a gas-fired power station. Methane can also be oxidised to produce electricity in a fuel cell. The overall equation for the oxidation of methane is

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \qquad \Delta H = -900 \text{ kJ mol}^{-1}$$

Question 26

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

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

The maximum mass of water, in grams, that could be converted from liquid water to steam by the complete oxidation of one mole of methane is

A. 20.5

B. 61.8

C. 184

D. 368

Use the following additional information to answer Questions 27 and 28.

In a fuel cell based on the oxidation of methane, the equation for the anode half reaction is

$$CH_4(g) + 2H_2O(l) \rightarrow CO_2(g) + 8H^+(aq) + 8e^-$$

Question 27

The corresponding equation for the half reaction at the cathode is

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

B. $4H^+(aq) + O_2(g) \rightarrow 2H_2O(l)$

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

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

Question 28

Assuming that all the energy of the oxidation reaction is converted to electricity, the amount of electric charge, in coulomb, obtained from the oxidation of one mole of methane is closest to

A. 8×10^2

B. 1×10^3

C. 8×10^5

D. 1×10^6

Question 29

The cell reaction when a car battery releases energy is given by the equation below.

$$Pb(s) + PbO_2(s) + 4H^+(aq) + 2SO_4^{2-}(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$

When the battery is being **recharged**, the reaction that occurs at the negative electrode is

A. $Pb(s) + SO_4^{2-}(aq) \rightarrow PbSO_4(s) + 2e^-$

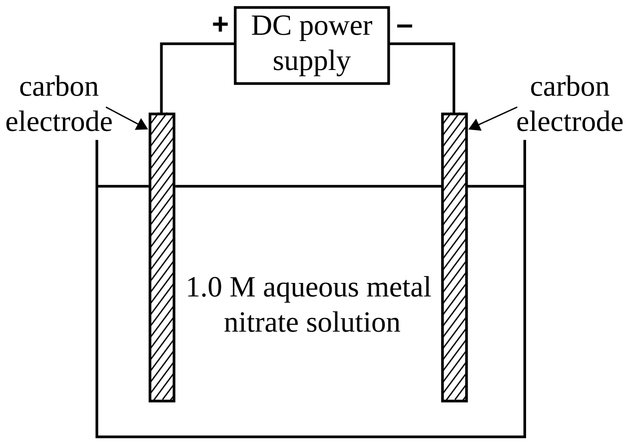
B. $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

C. $PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

D. $PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$

Question 30

A series of electrolysis experiments is conducted using the apparatus shown below.



An electric charge of 0.030 faraday was passed through separate solutions of 1.0 M $Cr(NO_3)_3$, 1.0 M $Cu(NO_3)_2$ and 1.0 M $AgNO_3$. In each case the corresponding metal was deposited on the negative electrode.

The amount, in mol, of each metal deposited is

	Amount, in mol, of chromium deposited	Amount, in mol, of copper deposited	Amount, in mol, of silver deposited
A.	0.030	0.030	0.030
B.	0.010	0.015	0.030
C.	0.090	0.060	0.030
D.	0.030	0.020	0.010

END OF SECTION A

TURN OVER

SECTION B

Instructions for Section B

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

To obtain full marks for your responses you should

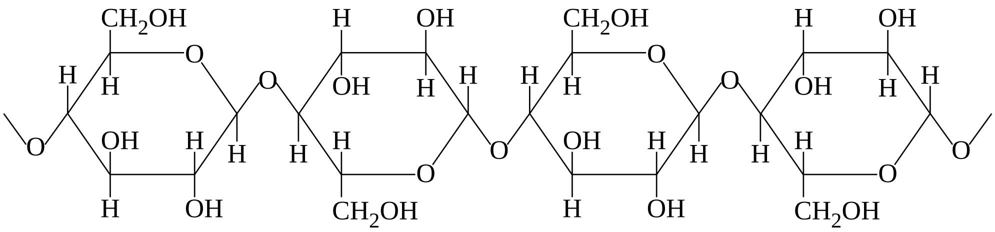
- give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of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

Question 1 (11 marks)

Biochemical fuels, such as bioethanol, can be produced using plant material.

Consider the following biochemical pathway which converts substances available in pulped plant material to ethanol.

molecule A



hydrolysis ↓ H_2O

molecule B

fermentation ↓

ethanol and carbon dioxide

a. Molecule A is a large biomolecule. Name the group of biomolecules to which molecule A belongs. 1 mark

____

b. Write the chemical formula for molecule B. 1 mark

____

c. It is argued that ethanol produced in this way could be considered renewable compared to other fuels such as petroleum.

Explain why this is so and discuss the advantages and disadvantages of using energy resources such as bioethanol. 4 marks

1.50 kg of wood pulp is used in the process and 438 mL of liquid ethanol is collected. 4.38 mL (1%) of this ethanol is then completely combusted in a bomb calorimeter. The calibration factor for this calorimeter is 12.5 kJ ºC^{-1}.

The complete combustion of the ethanol resulted in a temperature increase of 13.75 ºC.

d. Use the following equation to calculate the mass of ethanol completely combusted in the bomb calorimeter.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2\,(g) + 3H_2O(l)$$

3 marks

e. Would the percentage yield of ethanol be higher, lower or stay the same if the ethanol collected from this process is contaminated with water? Explain. 2 marks

Question 2 (8 marks)

A chemical engineer designs a pilot plant to determine the conditions that will give the best results for copper plating different objects.

A range of experiments indicates that an electroplating cell with an aqueous electrolyte containing copper(I) cyanide, CuCN, potassium cyanide, KCN, and potassium hydroxide, KOH, will produce a uniform copper coating.

a. Write a balanced half-equation for the cathode reaction in this electrolytic cell. 1 mark

____

b. In one trial, a medal is copper plated in the cell. The experimental data is given below.

time = 315 minutes

current = 0.900 A

Calculate the mass of copper plated on to the medal. 4 marks

____

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____

____

____

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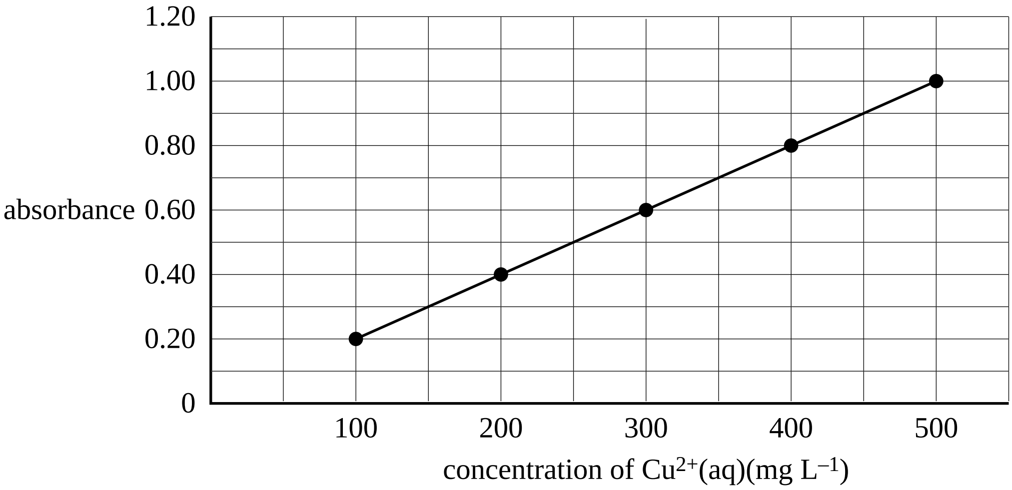
An experiment was carried out to determine the purity of the copper anode that had been used in the electroplating cell. A 0.855g sample of copper plate is removed from the medal and dissolved in nitric acid, producing a solution of copper(II) ions, $Cu^{2+}(aq)$.

The solution containing the $Cu^{2+}(aq)$ ions was filtered and made up to a volume of 500.0 mL.

25.0 mL of this solution was then further diluted to 100.0 mL in a volumetric flask. This solution was then analysed using atomic absorption spectroscopy (AAS). The absorbance of this solution was 0.80.

The absorbance of a series of solutions of $Cu^{2+}(aq)$ ions of known concentration was then prepared and the following calibration graph was drawn.

Calibration graph



c. **i.** What is the concentration, in mg L^{-1}, of $Cu^{2+}(aq)$ ions in the diluted solution in the volumetric flask? 1 mark

___

ii. Calculate the percentage purity of copper in the anode. 2 marks

___

___

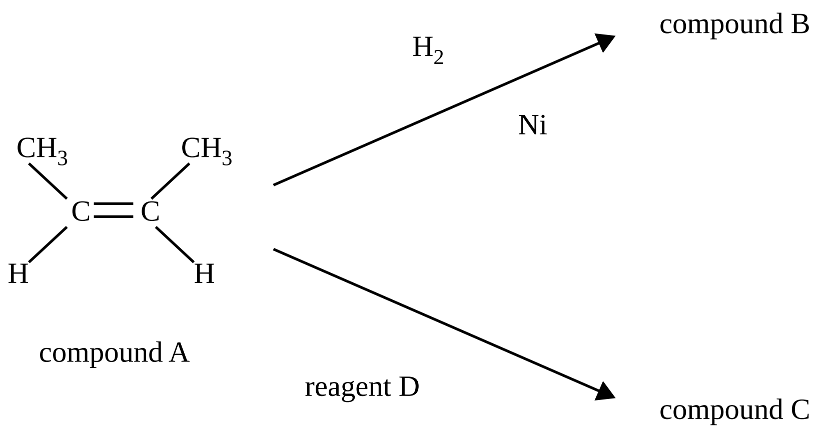
___

___

___

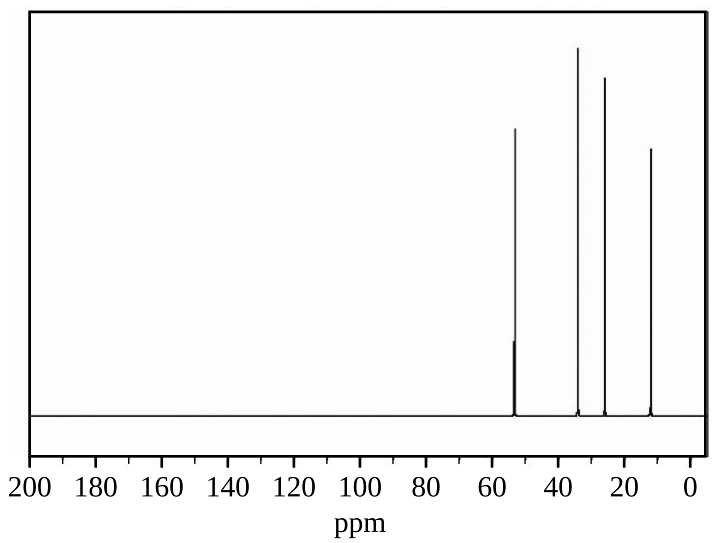
Question 3 (8 marks)

Two reactions of compound A are shown below.



a. Give the systematic name for compound A. 1 mark

Compound C is known to contain the elements C, H and Br.
Below is the ^{13}C NMR spectrum of compound C.



b. **i.** Use this information to explain why compound C cannot be 2,3-dibromobutane. 2 marks

Compound C is 2-bromobutane.

ii. Draw the structure of 2-bromobutane, showing all bonds. 1 mark

iii. Name reagent D 1 mark

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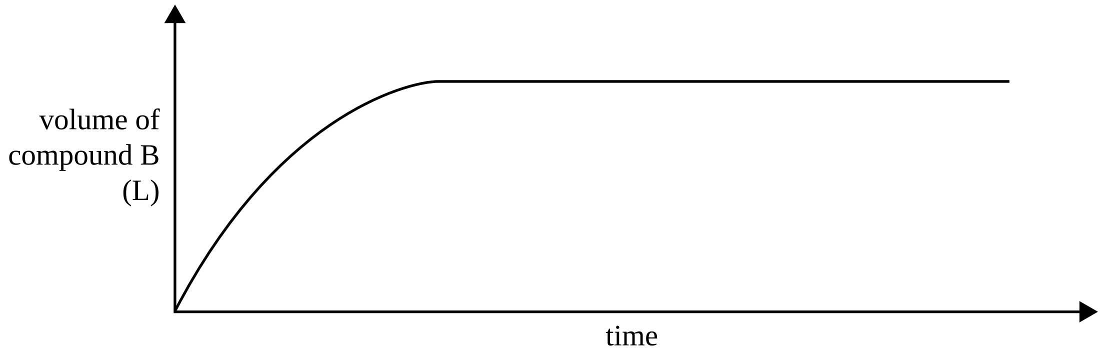
The graph below shows the volume of compound B formed over time **without** the nickel catalyst present.



c. **i.** On the axes above, sketch the expected graph of volume of compound B against time **with** the nickel catalyst present. Assume that the temperature is kept constant. 1 mark

ii. Describe how a catalyst is able to change the rate of a reaction. 2 marks

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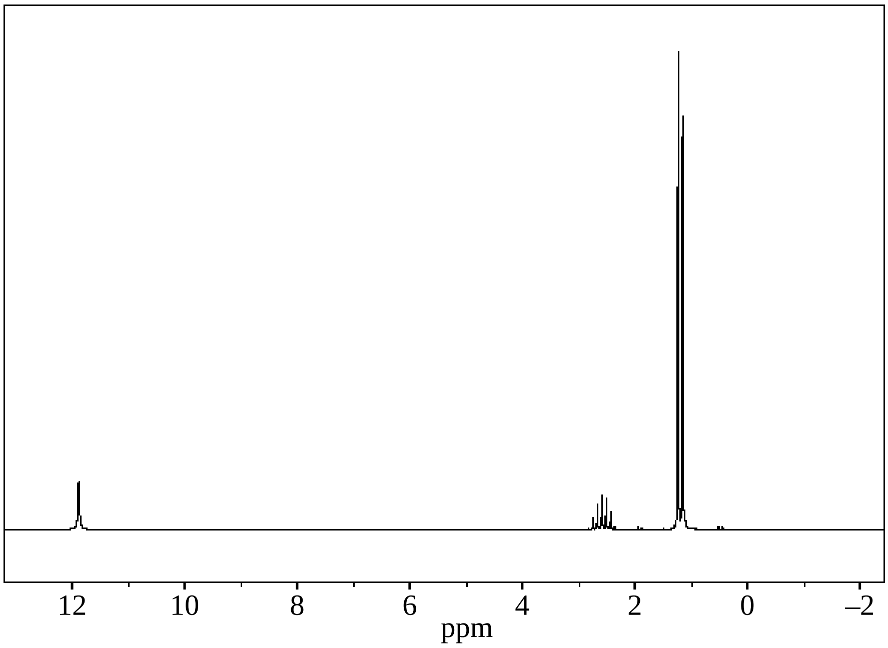
Question 4 (18 marks)

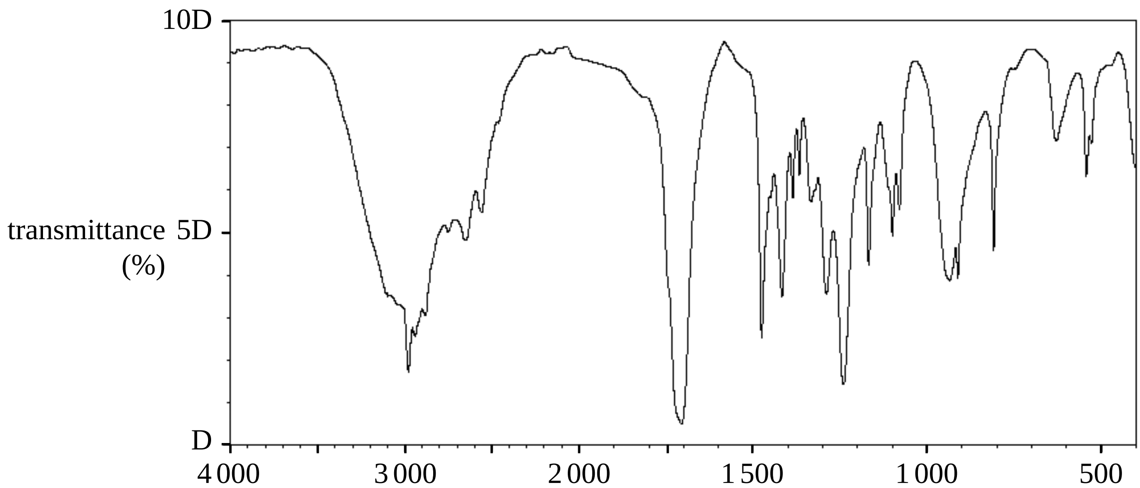
A student is to determine the identity and concentration of a solution of a weak, monoprotic acid, HA, with molecular formula $C_4H_8O_2$.

The proton NMR and IR spectra for HA are provided below.

Proton NMR spectrum



IR spectrum



a. Use this data to determine the number of hydrogen environments in HA. 1 mark

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b. The H-1 NMR signal at 2.6 ppm is split into a septuplet (7 peaks).
What information does this provide about the structure of HA? 1 mark

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c. Identify the group of atoms responsible for the following absorptions on the IR spectrum. 2 marks

i. 3000 cm^{-1} ______________________________

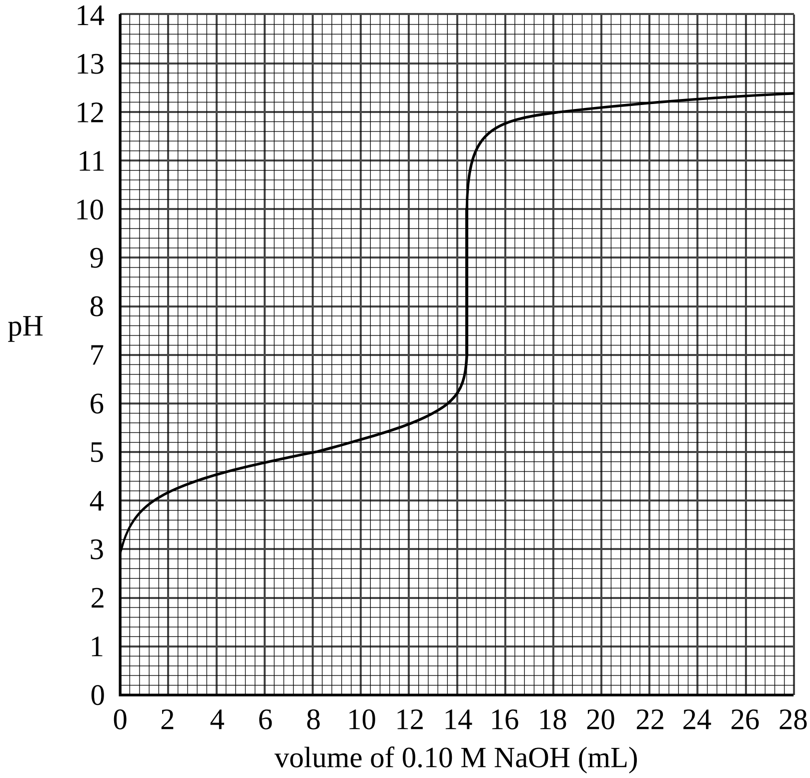
ii. 1700 cm^{-1} ______________________________

d. Propose a structure for HA that is consistent with all the evidence provided. 2 marks

e. A ^{13}C NMR spectrum of this acid could also have been obtained.
Explain what information about the structure of HA would be provided by a ^{13}C NMR spectrum.
Your answer should include

- why ^{13}C is used for analysis and not ^{12}C, the more abundant isotope of carbon
- the number of peaks that would be expected in the spectrum
- the information the number of peaks would provide
- a conclusion as to whether a ^{13}C NMR spectrum could replace a ^{1}H NMR spectrum in order to successfully identify HA (or any information that can be gained from a ^{1}H NMR spectrum that is not provided by a ^{13}C NMR spectrum). 4 marks

f. In order to determine the concentration of the solution of HA, the student titrates a 20.0 mL aliquot of HA with a 0.100 M sodium hydroxide solution, NaOH (aq). The following graph shows how the pH changes during this titration.



Use the information in this graph to determine

i. the volume of NaOH used to neutralise the solution of HA 1 mark

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ii. the concentration of HA 3 marks

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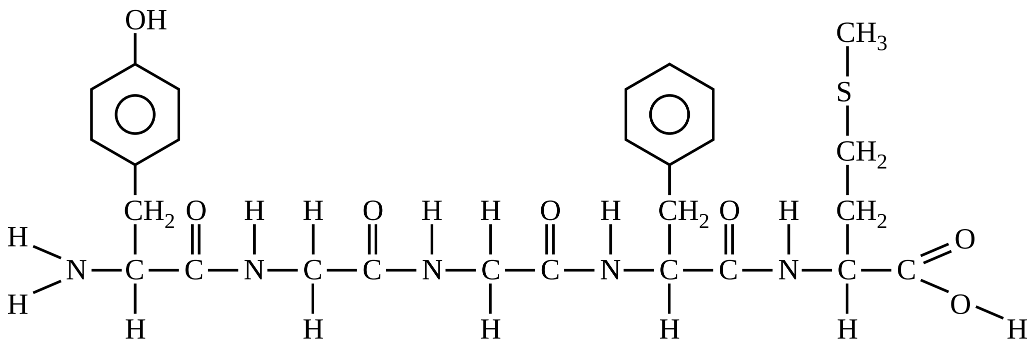
iii. the concentration of hydronium ions, H_3O^+, in the solution of HA before it was reacted with NaOH 2 marks

iv. the value of the acidity constant, K_a, for the weak acid HA. 2 marks

Question 5 (6 marks)

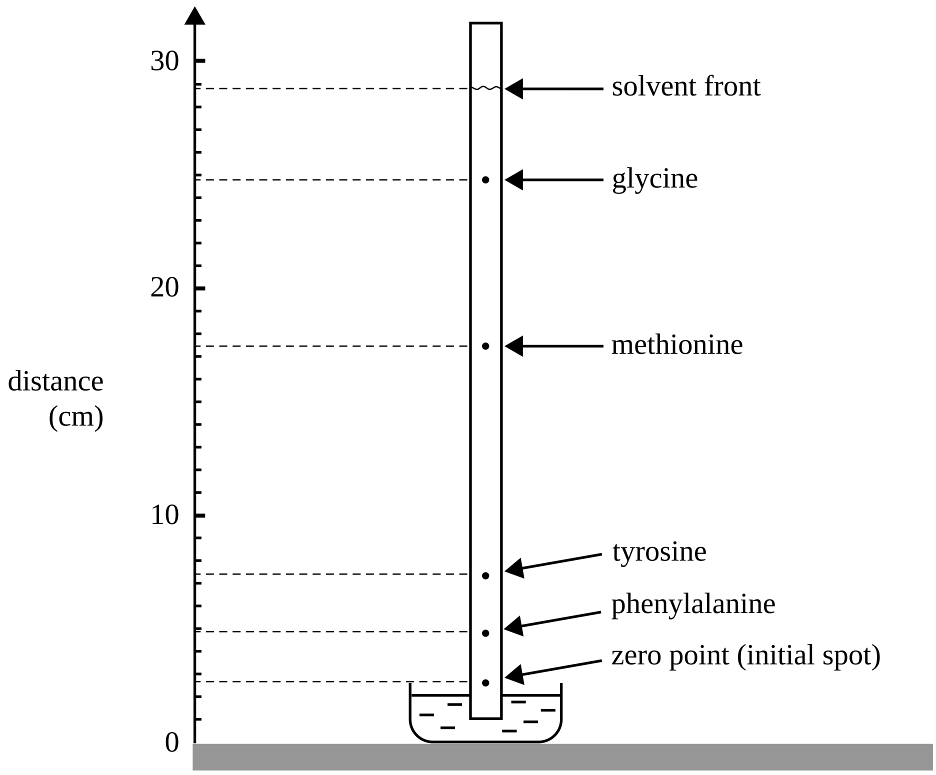
Chromatography is often used for the analysis of the mixture of amino acids that is formed when proteins are broken down. The small protein methionine enkephalin has some painkilling activity. The amino acids that make up this protein include methionine, phenylalanine, tyrosine and glycine.

The structure of the protein methionine enkephalin is given below.



a. Circle the methionine residue on the diagram above. 1 mark

An aqueous solution of methionine enkephalin is broken down into its constituent amino acids and the resultant solution of amino acids is subjected to paper chromatography. A strip from such a chromatogram is shown below.



Amino acids are colourless, but the position of an amino acid spot on the strip can be seen by spraying the strip with a solution of ninhydrin, a substance that reacts with amino acids to produce an intense purple colour.

b. This chromatogram shows a spot of methionine at 17.5 cm on this scale.

Under these same conditions, where would the methionine spot be if the solvent had only reached the 20 cm mark on this scale? 2 marks

c. Explain the principles of the chromatographic technique that enables these amino acids to be separated. 2 marks

d. The mobile phase used in this chromatographic analysis has a low pH.

Draw the structure of glycine when it is dissolved in this mobile phase. 1 mark

Question 6 (7 marks)

Dimethyl ether, CH_3OCH_3, is used as an environmentally friendly propellant in spray cans. It can be synthesised from methanol according to the following equation.

$$2CH_3OH(g) \rightleftharpoons CH_3OCH_3(g) + H_2O(g); \qquad \Delta H = -24 \text{ kJ mol}^{-1}$$

The equilibrium constant, *K*, for this reaction at 350 °C is 5.74.

a. Write an expression for *K* for this reaction. 1 mark

b. Calculate the value of *K* at 350 °C for the following reaction.

$$CH_3OCH_3(g) + H_2O(g) \rightleftharpoons 2CH_3OH(g)$$

1 mark

c. Methanol is pumped into an empty 20.0 L reactor vessel. At equilibrium the vessel contains 0.340 mol of methanol at 350 °C.

i. Calculate the concentration, in mol L^{-1}, of methanol at equilibrium. 1 mark

ii. Calculate the amount, in mol, of dimethyl ether present at equilibrium. 2 marks

iii. Calculate the amount, in mol, of methanol initially pumped into the reaction vessel. 2 marks

Question 7 (3 marks)

a. Use information from the electrochemical series in the Data Book to write a balanced overall equation that shows hydrogen peroxide, H_2O_2, reacting as a reductant. 2 marks

b. Using data from the electrochemical series, a student predicts that a reaction will occur between Cu^{2+} ions and H_2 gas. To test this prediction, hydrogen gas was bubbled into an aqueous solution of copper(II) sulfate, $CuSO_4$. No reaction was observed after 5 minutes.

Provide one possible chemical reason that explains why the predicted reaction was not observed. 1 mark

Question 8 (6 marks)

The **lithium button cell**, used to power watches and calculators, is a primary cell containing lithium metal. The **lithium ion cell** is a secondary cell that is used to power laptop computers.

a. What is the difference between a primary and a secondary cell? 1 mark

b. By referring to information provided in the Data Book, give one reason why lithium is used as a reactant in these galvanic cells. 1 mark

Some early lithium metal batteries exploded when exposed to water. The following reaction occurs when lithium reacts with water.

$$2Li(s) + 2H_2O(l) \rightarrow H_2(g) + 2LiOH(aq)$$

c. What volume, in L, of hydrogen gas at 20.0 °C and 950 mm Hg pressure is produced by the reaction of 1.00 g lithium with excess water? 3 marks

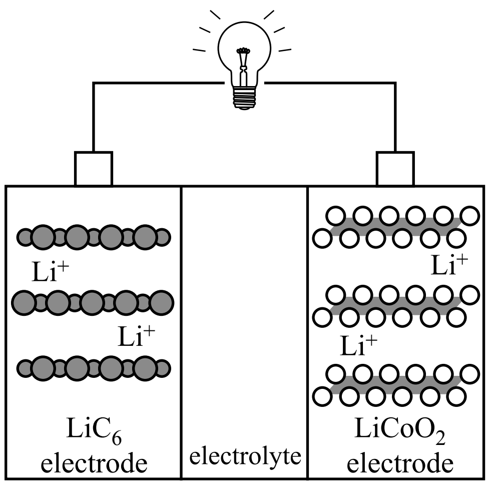
In lithium ion cells, lithium ions move between the electrodes as the cell is discharged and recharged. The negative electrode consists of lithiated graphite, LiC_6, and the positive electrode consists of lithium cobalt oxide, $LiCoO_2$.

The chemical reactions that take place in the lithium ion cell are complex. The following equations present a simplified description of the reactions that occur at the electrodes as the cell is **recharged**.

positive electrode $LiCoO_2 \rightarrow CoO_2 + Li^+ + e^-$

negative electrode $6C + Li^+ + e^- \rightarrow LiC_6$

d. On the diagram below, use arrows to indicate the directions of movement of electrons, e^-, and Li^+ ions as the lithium ion cell is **discharged**. 1 mark



Question 9 (6 marks)

Since the start of the industrial age, most of the energy used by humans has come from the burning of coal and oil. In that time the amount of CO_2 in the air has increased from approximately 0.42% by mass to 0.58% by mass.

a. Assume that the total mass of Earth's atmosphere is 5.15×10^{18} kg.

Calculate the additional mass of CO_2, in kg, that has been added to Earth's atmosphere since the start of the industrial age. 1 mark

b. Burning coal produces both CO_2 and energy.

If half of this additional CO_2 has come from the burning of this coal, calculate the total amount of energy, in kJ, that has been produced, given that

$$C(s) + O_2(g) \rightarrow CO_2(g); \quad \Delta H = -394 \text{ kJ mol}^{-1}$$

For the purposes of this calculation, assume that coal is pure carbon. 2 marks

c. Earth's oceans contain significant amounts of dissolved carbon dioxide. The dissolving process can be described by the following chemical equilibria.

$$CO_2(g) \rightleftharpoons CO_2(aq)$$

$$CO_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

Use this information to explain the likely effect of the increasing concentration of atmospheric CO_2 on the pH of seawater at the ocean surface. 3 marks

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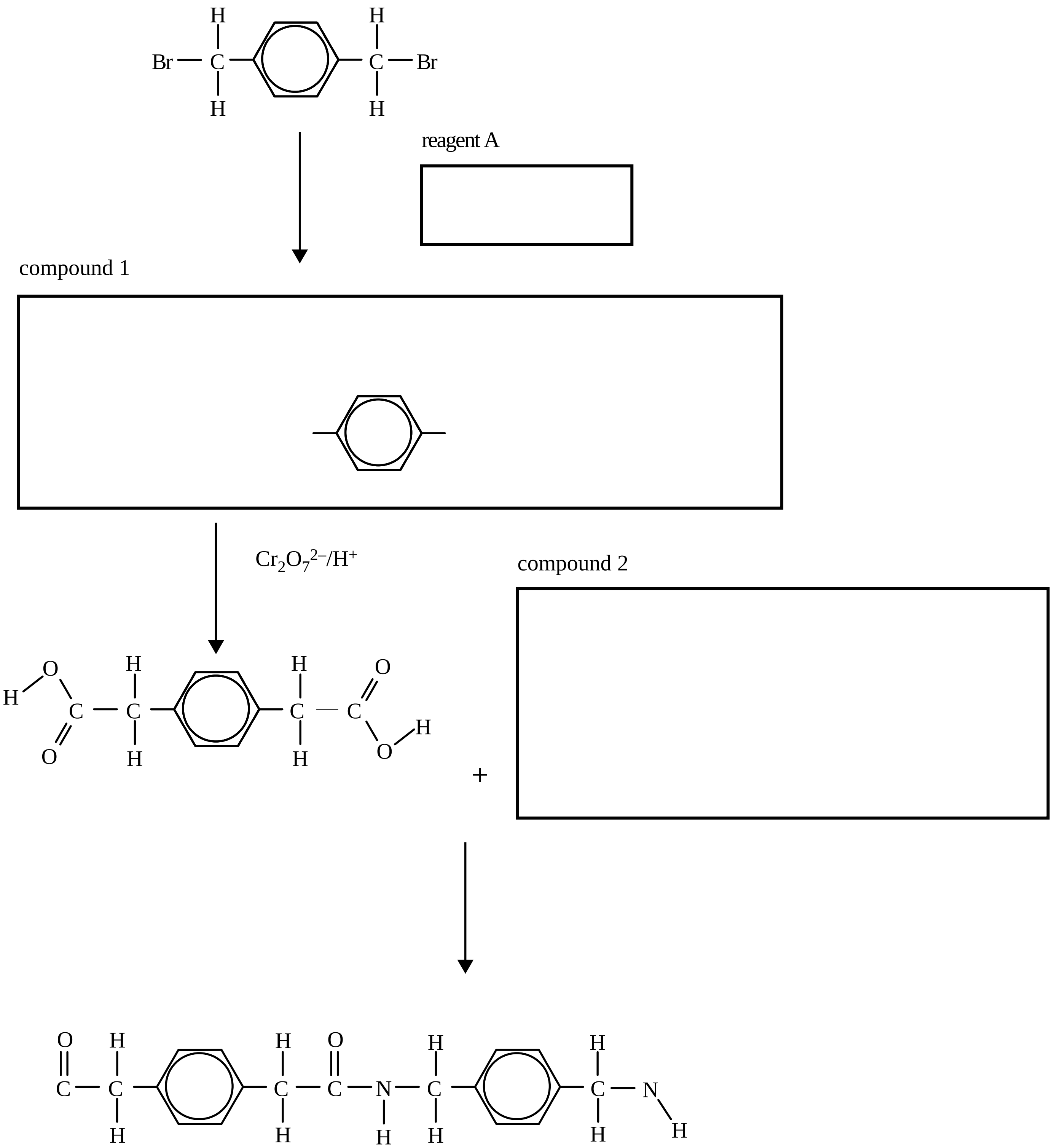
Question 10 (5 marks)

A student proposes a reaction pathway to produce a new polymer. The partially completed reaction pathway for this polymer is given below.



a. In the appropriate box, write the formula for reagent A. 1 mark

b. In the appropriate box, complete the structure for compound 1. 1 mark

SECTION B – Question 10 – continued

c. Write a balanced half-equation for the reduction of dichromate ions to Cr^{3+} ions in aqueous acid solution. 1 mark

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d. In the appropriate box, complete the structure of compound 2. 1 mark

e. Name the new functional group formed in the polymer. 1 mark

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Question 11 (4 marks)

Phosphorus is an essential ingredient in plant fertiliser. The phosphorus content in fertiliser can be determined as a percentage, by mass, of P_2O_5.

A 3.256 g sample of fertiliser is mixed with 40.0 mL of deionised water and the insoluble residue is then removed using vacuum filtration. 45.0 mL of 10% $MgSO_4.7H_2O$ solution is added to the filtrate followed by 150.0 mL of 2 M NH_3 solution. A white precipitate forms. This precipitate is filtered and washed with three 5 mL portions of deionised water. The final mass of the precipitate, once thoroughly dried, was 4.141 g. The formula of the precipitate is known to be $MgNH_4PO_4.6H_2O$. Assume that the experiment was conducted at 25 °C and that all the phosphorus had been precipitated as $MgNH_4PO_4.6H_2O$.

Calculate the mass of P_2O_5 in 1.00 kg of fertiliser.

(Molar mass of $MgNH_4PO_4.6H_2O$ = 245.3 g mol^{-1}. Molar mass of P_2O_5 = 142.0 g mol^{-1}.)

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Question 12 (7 marks)

When the substance CH_3CHO (substance X) is dissolved in water it reacts to form an equilibrium mixture with $CH_3CH(OH)_2$ (substance Y) according to the equation

$$X(aq) + H_2O(l) \rightleftharpoons Y(aq)$$

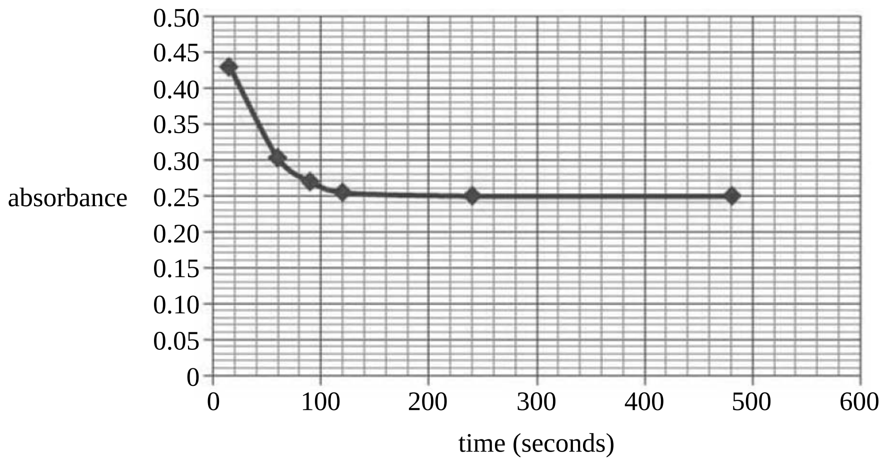
The concentration of X can be determined using UV-visible spectroscopy. X absorbs strongly at 290 nm. Y shows no absorption at this wavelength.

In a particular experimental arrangement at 25 °C, the relationship between absorbance at 290 nm and concentration of X is given by

$$\text{absorbance} = 4.15 \times [X]$$

a. Describe how this relationship between absorbance and concentration can be experimentally determined. 3 marks

In the experiment, 0.110 mol of X is dissolved rapidly in 1.00 L of water at 25 °C. The absorbance of the solution changes as some of the X is converted to Y. The graph below shows the change in absorbance over time (measured in seconds).



b. **i.** Calculate the concentration of X, in M, when the reaction reached equilibrium. 1 mark

ii. Calculate the absorbance at the instant that X was dissolved in the water, before any reaction occurred. 1 mark

iii. Calculate the percentage of the original 0.110 mol of X that has been converted into Y at equilibrium. 2 marks

Question 13 (6 marks)

A student was asked to design an experiment to determine the effect of acid concentration on the rate of the reaction between hydrochloric acid and calcium carbonate.

The student proposed the following experimental design.

The aim of the investigation is to determine the effect of concentration of acid on the rate of the reaction between calcium carbonate and hydrochloric acid.

The equation for the reaction is

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

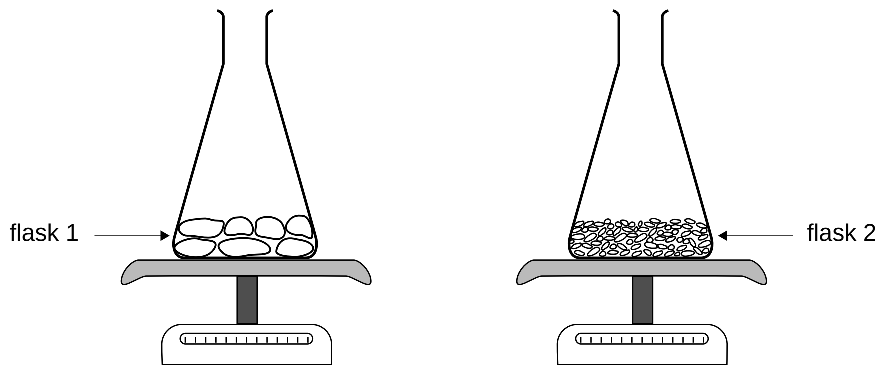
The experiment will be conducted using two flasks.

Flask 1 will contain 5.0 g $CaCO_3$ lumps to which 100 mL of 0.1 M HCl at 15 °C will be added.

Flask 2 will contain 10.0g $CaCO_3$ powder to which 200 mL 2.0M HCl at 30 °C will be added.

The rate of the reaction will be determined by measuring the decrease in mass of each flask at 10-second intervals.

The experimental procedure is summarised in the following diagrams.



Critically evaluate the student's proposal.

- Will the experimental design enable a valid conclusion to be made about the effect of concentration on rate? Provide reasons for your answer.
- What changes, if any, should be made to improve the experimental design? Justify your suggestions.

END OF QUESTION AND ANSWER BOOK

Answers to multiple-choice questions

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