Go to Sample Exam Questions

2013
VCE
Chemistry
VCAA Sample Examination
Suggested Answers

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  http://www.chem1.com/chemed/

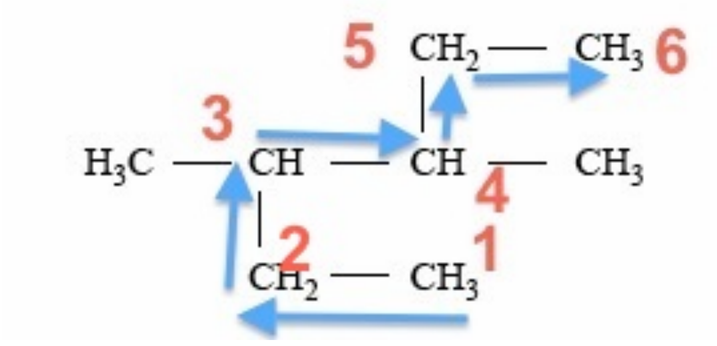
- While every care has been taken, no guarantee is given that these suggested answers are free from error. Please contact us if you believe you have found an error.

IMPORTANT NOTE:
At the time these detailed answers were produced, the sample examination provided by the VCAA and the answers provided for the multiple-choice questions had a number of errors. These were pointed out to the VCAA Chemistry Examiners and a corrected version of the Sample Examination has been promised for the VCAA website. This may or may not have occurred at the time you are using these answers.

Check this at http://www.vcaa.vic.edu.au/Pages/vce/studies/chemistry/chemindex.aspx

Question 1 Answer C

Identify the longest possible carbon chain. This is always the first thing you must do. Place your pen on the diagram and draw a line through as many carbon atoms as possible without lifting your pen off the paper. You can do this with 6 carbon atoms as shown below.



Therefore, the compound must be named after hexane. A CH_3 group is attached to carbon number 3. A CH_3 group is attached to carbon number 4. Hence, the systematic name is 3, 4-dimethylhexane.

Study Design Reference

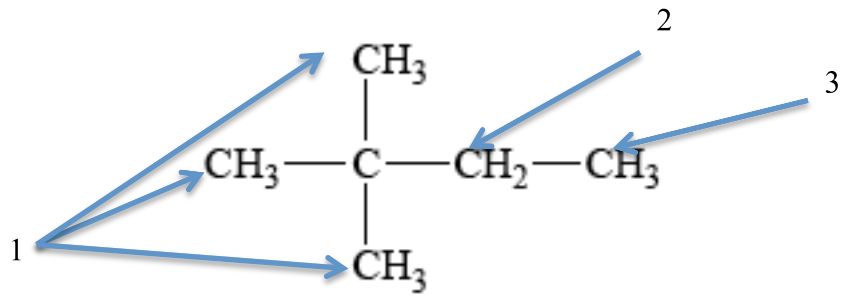
Structure including molecular, structural and semi-structural formulae, and International Union of Pure and Applied Chemistry (IUPAC) nomenclature of alkanes, alkenes, amines, haloalkanes, alkanols ($C_nH_{2n+1}OH$), alkanoic acids ($C_nH_{2n+1}COOH$) and esters up to C_{10}

Web Link

https://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/nomen1.htm

Question 2 Answer B

In 2,2-dimethylbutane, we can identify 3 carbon atoms with different environments which have hydrogen atoms bonded to them. They are shown by the arrows and the numbers in the diagram below.



Hence, when a single hydrogen atom in 2,2-dimethylbutane is replaced by one chlorine atom, there will be three different structural isomers for the compound $C_3H_{13}Cl$.

Study Design Reference

Structure including molecular, structural and semi-structural formulae, and International Union of Pure and Applied Chemistry (IUPAC) nomenclature of alkanes, alkenes, amines, haloalkanes, alkanols ($C_nH_{2n+1}OH$), alkanoic acids ($C_nH_{2n+1}COOH$) and esters up to C_{10}

Web Link

http://www.chemguide.co.uk/basicorg/isomerism/structural.html

Question 3 Answer B
This question asks you to identify the organic reaction that is **incorrect**.

A correctly shows the substitution reaction of 1-chlorobutane to produce butan-1-ol.

C correctly shows the condensation reaction between methanol and ethanoic acid to form the ester methyl ethanoate.

D correctly shows the addition reaction between propene and water to form propan-2-ol.

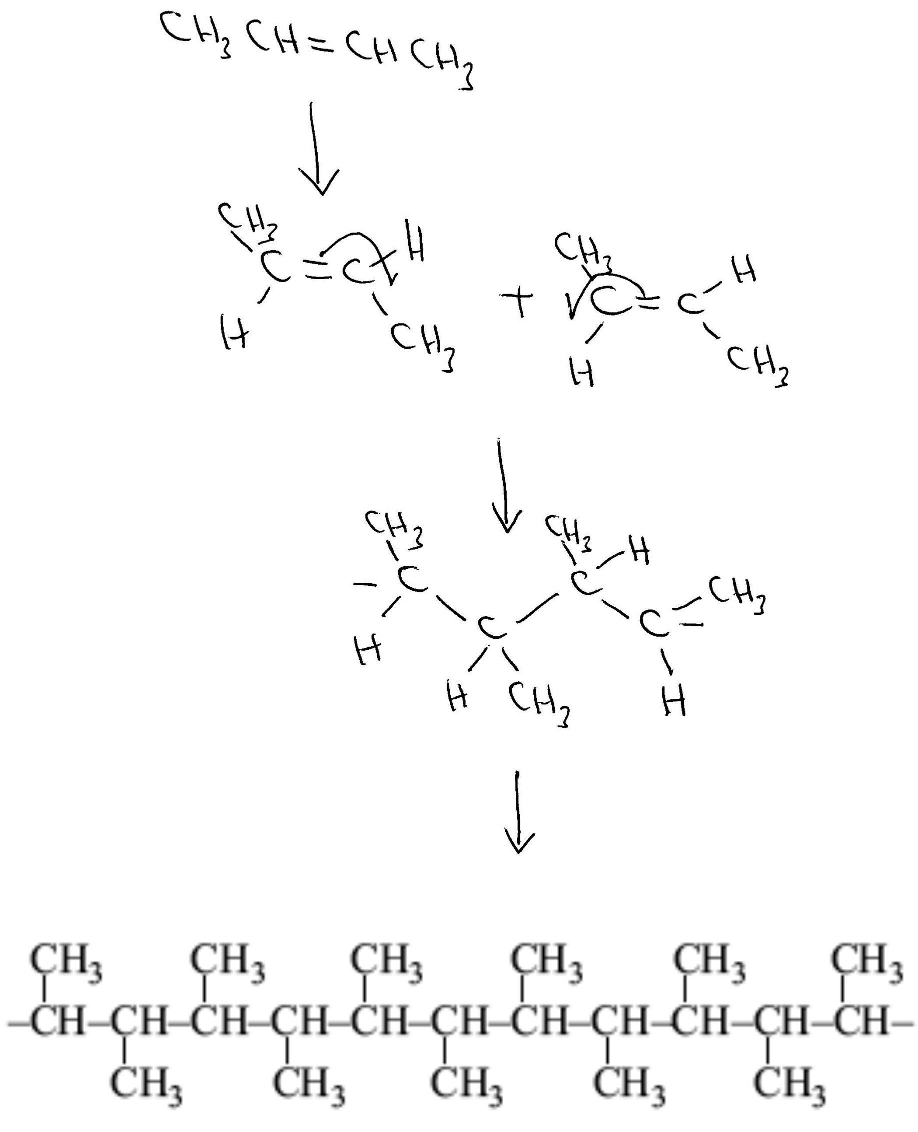
B incorrectly shows the addition reaction between but-2-ene and hydrogen chloride. In this reaction, the hydrogen chloride will add across the double bond to produce 2-chlorobutane **not** 1-chlorobutane as shown in the equation.

Study Design Reference
Common reactions of organic compounds including equations: addition reactions of alkenes (addition of hydrogen halides and water limited to symmetrical alkenes), substitution reactions of alkanes and primary haloalkanes, oxidation of primary alkanols, and esterification

Web Link
http://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/Questions/problems.htm

Question 4 Answer B

During addition polymerisation, the double bond in the monomer breaks down to produce a spare electron on each of the carbon atoms. These single electrons readily form carbon-carbon single bonds with other monomers. Hence, the structure of the polymer will maintain the arrangement of atoms in the original monomer. This is shown below.



Study Design Reference

Common reactions of organic compounds including equations: addition reactions of alkenes (addition of hydrogen halides and water limited to symmetrical alkenes), substitution reactions of alkanes and primary haloalkanes, oxidation of primary alkanols, and esterification

Web Link

http://www.chemguide.co.uk/organicprops/alkenes/polymerisation.html

Question 5 Answer A

Triglycerides and polysaccharides contain only carbon, hydrogen and oxygen. So not **C** or **D**. Proteins contain carbon, hydrogen oxygen and nitrogen but not phosphorus. So not **B**. DNA contains all five elements. DNA is the only possibility from this selection.

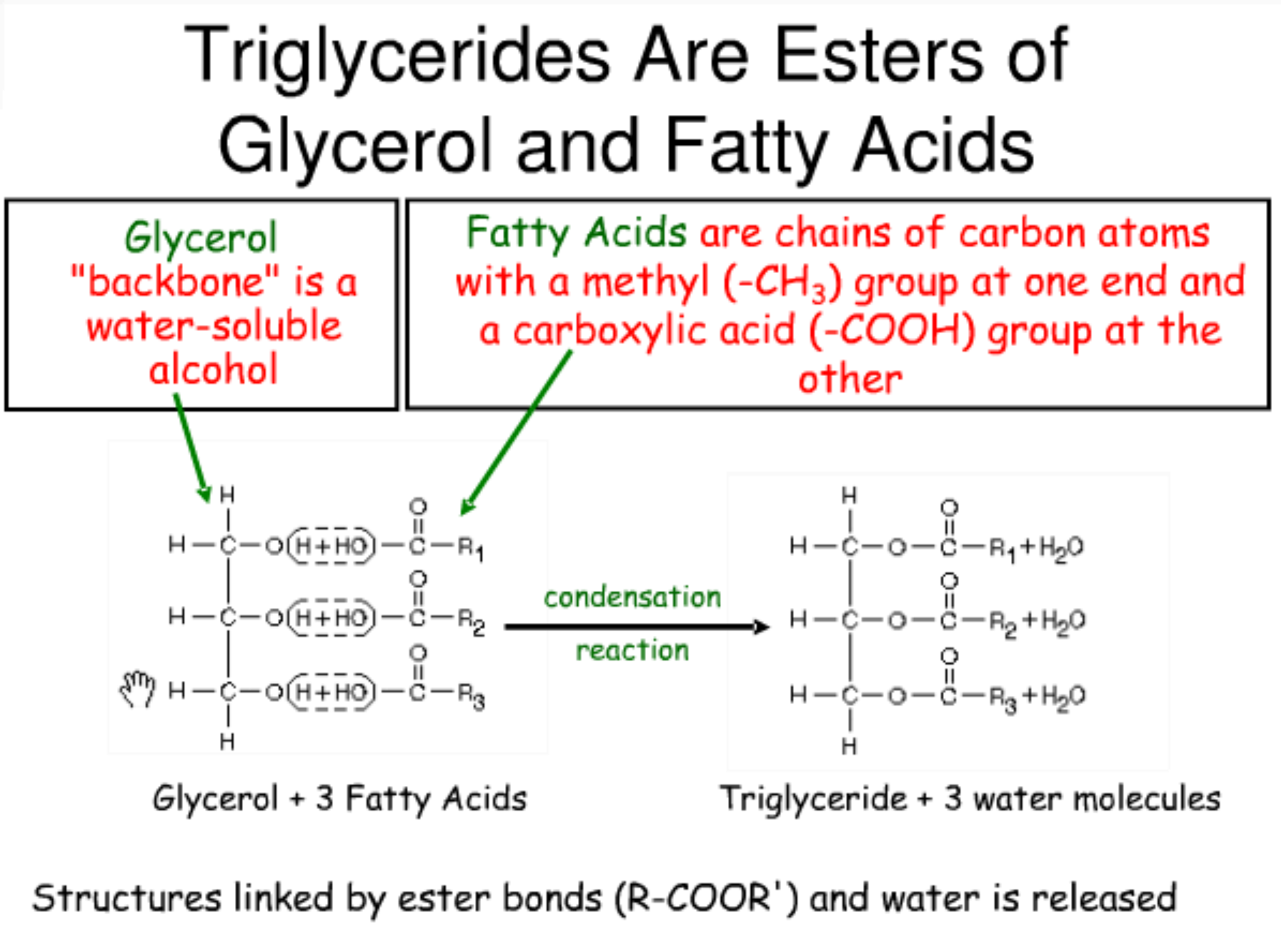
Study Design Reference

Condensation reactions that produce lipids (limited to triglycerides)
Condensation and polymerisation reactions that produce large biomolecules including carbohydrates, proteins and DNA

Web Link

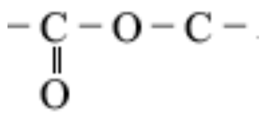
http://www.chemguide.co.uk/

Question 6 Answer A
Glycerol and three long-chain carboxylic acid molecules react in a condensation reaction in which three ester linkages are formed with the elimination of three water molecules as shown below.



http://bit.ly/12mE3j8

The ester linkage is

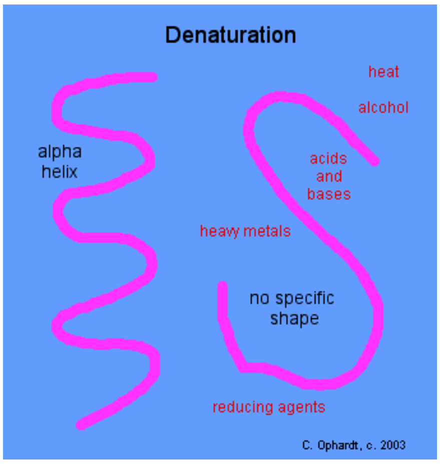


Study Design Reference
Condensation reactions that produce lipids (limited to triglycerides)

Web Link
http://www.chem1.com/chemed/

Question 7 Answer D

The three-dimensional structure of a protein can be destroyed by heat, alcohol, acids, bases, heavy metals and reducing agents.



Denaturation of proteins involves the disruption and possible destruction of both the secondary and tertiary structures. Since denaturation reactions are not strong enough to break the peptide bonds, the primary structure (sequence of amino acids) remains the same after a denaturation process. Denaturation disrupts the normal alpha-helix and beta sheets in a protein and uncoils it into a random shape.

Denaturation occurs because the bonding interactions responsible for the secondary structure (hydrogen bonds to amides) and tertiary structure are disrupted. In tertiary structure there are four types of bonding interactions between "side chains" including: hydrogen bonding, salt bridges, disulfide bonds, and non-polar hydrophobic interactions which may be disrupted. Therefore, a variety of reagents and conditions can cause denaturation. The most common observation in the denaturation process is the precipitation or coagulation of the protein.

Heat can be used to disrupt hydrogen bonds. This occurs because heat increases the kinetic energy and causes the molecules to vibrate so rapidly and violently that the bonds are disrupted.

Alcohol denatures proteins by disrupting the side chain intramolecular hydrogen bonding. New hydrogen bonds are formed instead between the new alcohol molecule and the protein side chains.

Salt bridges result from the neutralization of an acid and amine on side chains. The final interaction is ionic between the positive ammonium group and the negative acid group. Any combination of the various acidic or amine amino acid side chains will have this effect.
Acids and bases disrupt salt bridges held together by ionic charges. A type of double replacement reaction occurs where the positive and negative ions in the salt change partners with the positive and negative ions in the new acid or base added. This reaction occurs in the digestive system, when the acidic gastric juices cause the curdling (coagulating) of milk.

Study Design Reference

Primary, secondary and tertiary structures of proteins
The role of the tertiary structure of proteins in enzyme action
Denaturing of proteins: effect of changes in pH and temperature on bonding

Web Link

http://bit.ly/f0iJ6m

Question 8 Answer D
The number of double bonds in a fatty acid can be determined from the ratio between the number of carbon and hydrogen atoms. First of all, rewrite the formulas to show the COOH functional group. For a saturated fatty acid (only single carbon to carbon bonds), the formula for the acid will be $C_nH_{2n+1}COOH$.
Every double bond in the molecule will decrease the number of hydrogen atoms by 2.

Original formula	Extended formula	Number of double bonds	Name from data book (Page 10)
$C_{18}H_{34}O_2$	$C_{17}H_{33}COOH$	1	Oleic acid
$C_{24}H_{48}O_2$	$C_{23}H_{47}COOH$	0 (saturated)	*not listed*
$C_{18}H_{32}O_2$	$C_{17}H_{31}COOH$	2	Linoleic acid
$C_{20}H_{32}O_2$	$C_{19}H_{31}COOH$	4	Arachidonic acid

Important: You should label all of the fatty acids on Page 10 of the Data book as either saturated or unsaturated and identify the number of double bonds in each of the unsaturated acids.

Study Design Reference
Structure including molecular, structural and semi-structural formulae, and International Union of Pure and Applied Chemistry (IUPAC) nomenclature of alkanes, alkenes, amines, haloalkanes, alkanols ($C_nH_{2n+1}OH$), alkanoic acids ($C_nH_{2n+1}COOH$) and esters up to C_{10}

Web Link
http://www.chem1.com/chemed/

Question 9 Answer B

The primary structure of a protein is the sequence of amino acids in the chain. The amino acids are held together by peptides links (–CONH-). These peptide links are shown by **bond C** in this diagram. The secondary structure of a protein is the spiral shape caused by hydrogen bonds between peptide links on nearby sections of the amino acid chain. These hydrogen bonds are shown by **bond A** in this diagram. The tertiary structure of a protein is the three-dimensional structure of the molecule. It is held in place by different kinds of bonding of which one is disulfide bonds. These disulfide bonds are shown by **bond B** in this diagram.

Study Design Reference

Primary, secondary and tertiary structures of proteins

Web Link

http://www.chem1.com/chemed/

Question 10 Answer A

Enzymes are proteins that act as biological catalysts. Like all catalysts, enzymes increase the rate of reactions. They increase the rate of the forward and reverse reactions identically. They increase the rate at which equilibrium is achieved but they do not change the position of equilibrium. They do not change the equilibrium constants for biochemical reactions.

Study Design Reference

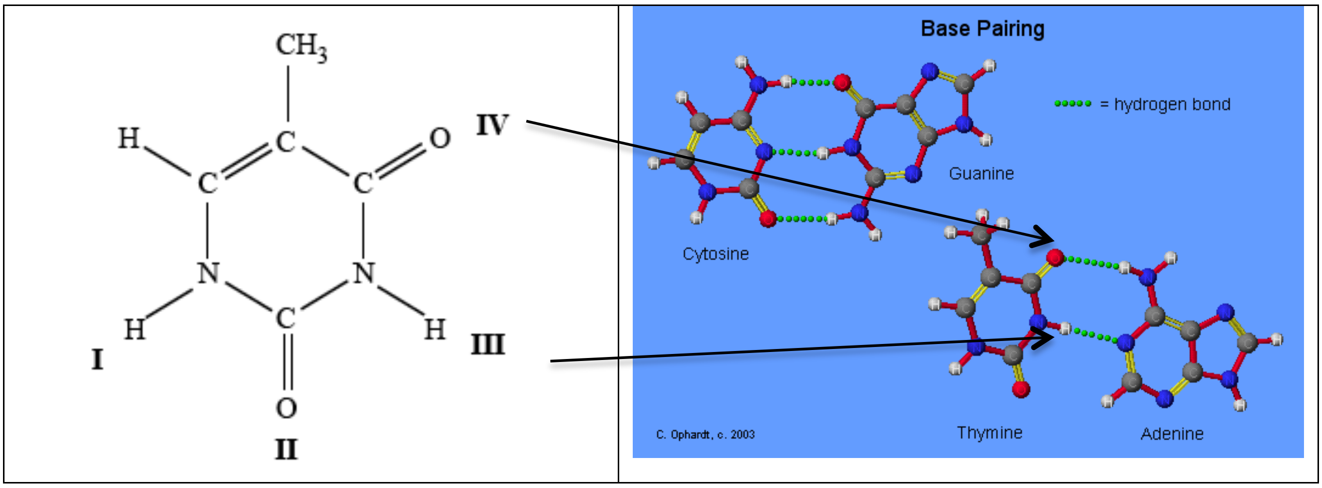
The role of the tertiary structure of proteins in enzyme action

Web Link

http://www.chem1.com/chemed/

Question 11 Answer C

The base pairing in DNA with hydrogen bonds is shown in the diagram below.



http://bit.ly/16xWOSj

These are positions **III** and **IV** in the diagram.

Study Design Reference

Primary and secondary structure of DNA.

Web Link

http://www.chem1.com/chemed/

Question 12 Answer A

Salicylic acid has two functional groups – the hydroxyl group –OH and the carboxyl group -COOH. In aspirin, the carboxyl group remains. The hydroxyl group has been converted into an ester linkage by reacting the salicylic acid with CH_3COOH. **D is correct.** The other product of the reaction is H_2O. Aspirin does contain both ester and carboxylic acid functional groups. **B is correct.** Because aspirin has an acidic functional group, it will react with the base $NaHCO_3$ to produce a salt, carbon dioxide and water. **C is correct.** The reaction between salicylic acid and methanol (CH_3OH) will form an ester linkage but the product formed is not aspirin. **A is not correct.**

Study Design Reference

Function of organic molecules in the design and synthesis of medicines including the production of aspirin from salicylic acid.

Web Link

http://www.chem1.com/chemed/

Question 13 Answer A

A mass spectrometer will sort isotopes of an element according to the mass to charge ratio of the atoms making up the sample. It will show the isotopic ratio of ^{235}U to ^{238}U in a sample of uranium. Gas-liquid chromatography is used to separate molecules (often organic) of different substances in a mixture. Atomic absorption spectroscopy is used to identify trace amounts of metal ions. Nuclear magnetic resonance spectroscopy is used to identify organic molecules.

Study Design Reference

Principles and applications of chromatographic techniques
Principles and applications of spectroscopic techniques

Web Link

http://www.chem1.com/chemed/

Question 14 Answer C

In this gas-liquid chromatography column, the lowest molecular mass molecule butane (C_4H_{10}) will pass through the column most quickly because it will have the least attraction for the stationary phase. The hexane (C_6H_{14}) will have the longest retention time in the column because it forms more temporary bonds with the material in the column and, therefore, spends more time adsorbed onto the column. Hence, the hexane is shown at the 8 minute mark on the graph.

The percentage of hexane =

$$\frac{\text{height of the hexane peak}}{\text{total height of peaks}} \times \frac{100}{1}$$

$$= \frac{2}{2+1+3} \times \frac{100}{1}$$

$$= \frac{2}{6} \times \frac{100}{1}$$

$$= 33\%$$

Study Design Reference

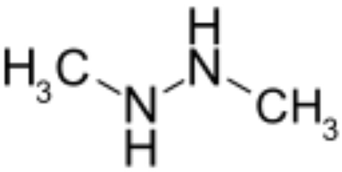
High performance liquid chromatography (HPLC) and gas chromatography (GC) including R_t and the use of a calibration graph to determine amount of analyte.

Web Link

http://www.chem1.com/chemed/

Question 15 Answer A

A molecular ion must have a charge on it. Therefore, B and D are not correct. The formula mass of CH_4N = 12 + 4 + 14 = 30. The largest reading on the mass spectrum (mass to charge ratio) is 60. A mass spectrum records whole molecules and parts of the molecule. The largest reading usually indicates the whole molecule with a single positive charge. This is $C_2H_8N_2^+$ which has a relative molecular mass of 60.



A possible structure of this compound is shown above. (1, 2 dimethyl hydrazine)

Study Design Reference

Mass spectroscopy including determination of molecular ion peak and relative molecular mass, and identification of simple fragments

Web Link

http://www.chem1.com/chemed/

Question 16 Answer B

The sum of the oxidation numbers must equal the charge on the ion. Therefore,

$$2P + (7 \times -2) = -4$$
$$\Rightarrow 2P - 14 = -4$$
$$\Rightarrow 2P = 10$$
$$\Rightarrow P = +5$$

Study Design Reference

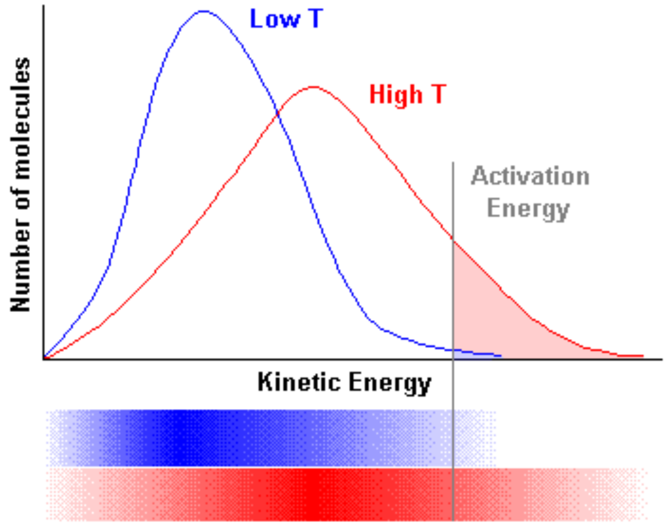
The writing of balanced chemical equations, including the use of oxidation numbers to write redox equations, and the application of chemical equations to volumetric and gravimetric analyses

Web Link

http://www.chem1.com/chemed/

Question 17 Answer D

For a chemical reaction to occur, particles must collide **with sufficient energy** to break existing chemical bonds so that new bonds can then be formed. The **sufficient energy** referred to is called the activation energy of the reaction. When the temperature increases, reactant particles will collide more frequently but many of these collisions will still be "soft" collisions in which the activation energy is not reached. It is the increase in the number of particles that have energy greater than the activation energy that provides the best explanation as to why the observed reaction rate is greater at higher temperature. Increasing the concentration also increases the rate of a reaction by increasing the number of collisions per second but increasing the concentration does not increase the energy of the collisions. The graph showing the increase in the number of particles with energy greater than the activation energy plotted against temperature increase is shown below.



http://bit.ly/11a69GW

Study Design Reference

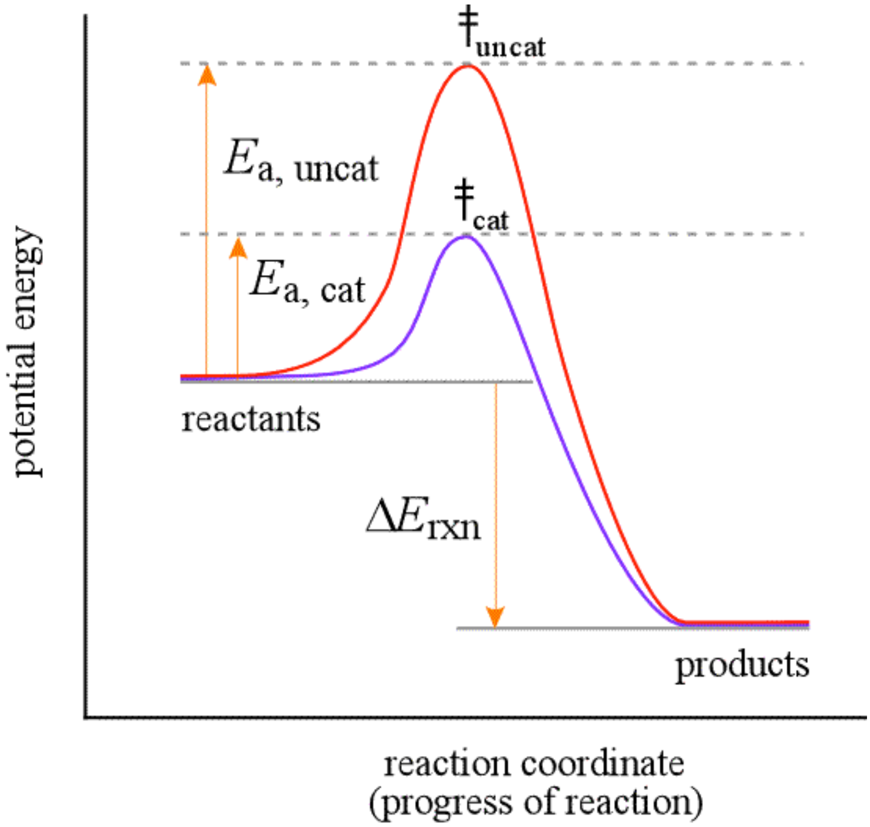
Collision theory and factors that affect the rate of a reaction including temperature, pressure, concentration and use of catalysts, excluding: a formal treatment of the Maxwell-Boltzmann distribution, reaction mechanisms and rate laws.

Web Link

http://www.chem1.com/chemed/

Question 18 Answer D

In an equilibrium mixture, the concentrations of the reactants and the products remain constant. When a catalyst is added to an equilibrium mixture, there is no change in the position of equilibrium. The rates of both the forward and reverse reactions would increase by the same amount. There is no change in ΔH or the temperature of the surroundings. This summarized in the diagram below.



http://bit.ly/16A8cgo

Study Design Reference

Energy profile diagrams and the use of ΔH notation including: activation energy; alternative reaction
pathways for catalysed reactions; and deduction of ΔH for an overall reaction given energy profiles or ΔH of two related reactions

Web Link

http://www.chem1.com/chemed/

Question 19 Answer B

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

$C(graphite) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -393 \text{ kJ mol}^{-1} \quad ...(2)$

Reverse equation (1) and change the sign of ΔH

$CO_2(g) \rightarrow C(diamond) + O_2(g) \quad \Delta H = +395 \text{ kJ mol}^{-1} \quad ...(3)$

Add equations (2) and (3) and add the ΔH values.

$C(graphite) + \cancel{O_2}(g) + \cancel{CO_2}(g) \rightarrow C(diamond) + \cancel{O_2}(g) + \cancel{CO_2}(g) \quad \Delta H = -393 + 395 = +2 \text{ kJ mol}^{-1}$

Study Design Reference
Deduction of ΔH for an overall reaction given energy profiles or ΔH of two related reactions.

Web Link
http://www.chem1.com/chemed/

Question 20 Answer D
The combustion of butane is shown by the equation:

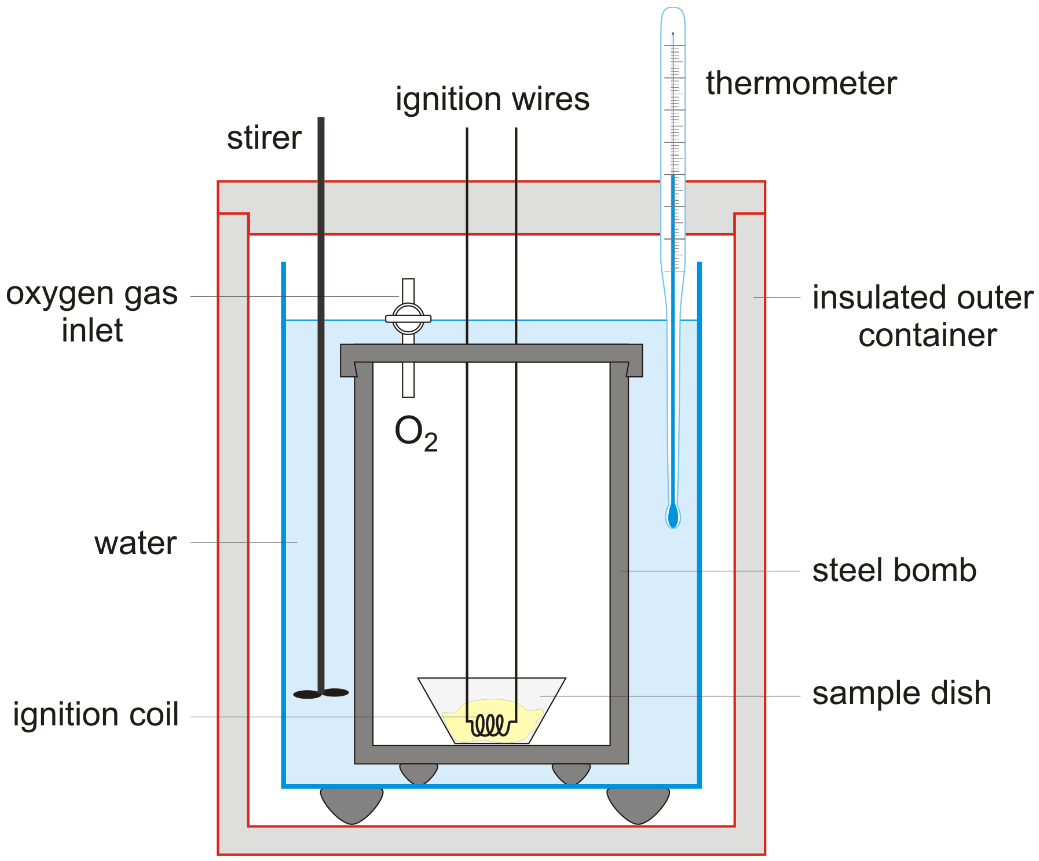
$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$$

The calibration factor (CF) of the bomb calorimeter is amount of energy required to raise the temperature of the calorimeter and its contents by one degree.

Electrical energy = $V \times Q$
Temperature rise = ΔT_1

$$CF = \frac{V \times Q}{\Delta T_1}$$

A diagram of a bomb calorimeter is shown below.



http://bit.ly/13cOnHg

Study Design Reference
Application of calorimetry to measure energy changes in chemical reactions in solution calorimetry and bomb calorimetry, including calibration of a calorimeter and the effects of heat loss

Web Link
http://www.chem1.com/chemed/

Question 21 Answer A

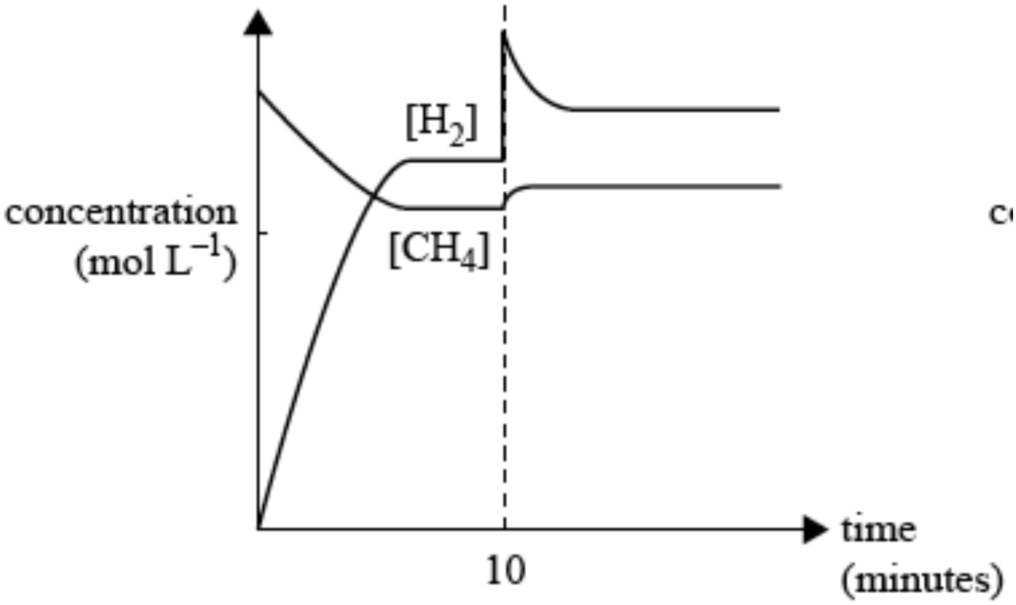
At high temperatures (700 – 1100 °C) and in the presence of a metal-based catalyst (nickel), steam reacts with methane to yield carbon monoxide and hydrogen. These two reactions are reversible in nature. $CH_4 + H_2O \rightleftharpoons CO + 3H_2$

http://bit.ly/11zNquW

The equation as written in the sample examination is not balanced.

The correctly balanced equation is $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +131$ kJ mol^{-1}

For every one mole of CH_4 used up, 3 mole of H_2 is produced. Graph D is incorrect because it shows some hydrogen gas present at the beginning. Graph B is incorrect because it shows methane and hydrogen being used up and produced in a ratio of 1 : 1 . The only graphs showing the proportion of 1 : 3 are graphs A and C. After the hydrogen is added at 10 minutes, **some** of the hydrogen reacts to produce methane. This also occurs in the ratio of 3 : 1 as shown in the balanced equation. Graph C is incorrect because it shows the methane decreasing. Graph A is correct.



Study Design Reference

Equilibrium: representation of reversible and non-reversible reactions: homogeneous equilibria and the equilibrium law (equilibrium expressions restricted to use of concentrations), Le Chatelier's Principle and factors which affect the position of equilibrium

Web Link

http://www.chem1.com/chemed/

Question 22 Answer B

The equilibrium equation is $C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$ ΔH = -46 kJ mol^{-1}

According to Le Chatelier's Principle "*When a chemical system at equilibrium experiences a change in concentration, temperature, volume, or partial pressure, the equilibrium shifts to counteract the imposed change and a new equilibrium is established*." In this equation, 2 mole of reactants produces 1 mole of products. Therefore, high pressure will cause the production of more ethanol at equilibrium. The forward reaction is exothermic, that is, it produces heat. Therefore, a low temperature will cause the production of more ethanol at equilibrium.

Study Design Reference

Equilibrium: representation of reversible and non-reversible reactions: homogeneous equilibria and the equilibrium law (equilibrium expressions restricted to use of concentrations), Le Chatelier's Principle and factors which affect the position of equilibrium

Web Link

http://www.chem1.com/chemed/

Question 23 Answer D

$Ba(OH)_2$ dissociates according to the equation $Ba(OH)_2(aq) \rightarrow Ba^{2+}(aq) + 2OH^-(aq)$

Since the concentration of $Ba(OH)_2 = 0.0050$ M, the concentration of $OH^- = 0.0050 \times 2 = 0.0100$ M

$$[H_3O^+] = \frac{10^{-14}}{[OH^-]} = \frac{10^{-14}}{0.0100} = \frac{10^{-14}}{10^{-2}} = 10^{-12}$$

$$\Rightarrow pH = 12$$

Study Design Reference

pH as a measure of strength of acids and bases.

Web Link

http://www.chem1.com/chemed/

Question 24 Answer C
You need to refer to the Data Book to do this question.

$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	+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

$Ag^+(aq)$ is a stronger oxidant than $Cu^{2+}(aq)$. Therefore, in this galvanic cell, $Ag^+(aq)$ will be reduced to Ag(s) and Cu(s) will be oxidised to $Cu^{2+}(aq)$. This is shown in equations A and C. Equation A is not balanced. Two silver ions and two silver atoms must be used to balance the charge.

Study Design Reference
Use of the electrochemical series in predicting the products of redox reactions and deducing overall equations from redox half equations.

Web Link
http://www.chem1.com/chemed/

Question 25 Answer A

You need to refer to the Data Book to do this question.

$Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$	+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

The predicted maximum voltage produced by this cell under standard conditions is the difference between the E^0 values of the two half-reactions. Predicted voltage = +0.80 - +0.34 = 0.46 V.

Study Design Reference

Use of the electrochemical series in predicting the products of redox reactions and deducing overall equations from redox half equations. Limitations of predictions made using the electrochemical series, including the determination of maximum cell voltage under standard conditions

Web Link

http://www.chem1.com/chemed/

Question 26 Answer D

The balanced chemical equations needed in this question are:

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

(2) $H_2O(l) \rightarrow H_2O(g)$ $\Delta H = +44 \text{ kJ mol}^{-1}$

When one mole of methane is oxidised, 900 kJ of energy is produced.

The conversion of one mole of liquid water to steam requires 44.0 kJ.

Therefore, the number of mole of liquid water that could be converted to steam by 900 kJ = $\frac{900}{44}$ mol.

Hence, the maximum mass of liquid water that could be converted = $\frac{900}{44} \times \frac{18}{1} = 368$ g

Study Design Reference

Calculations including amount of solids, liquids and gases; concentration; volume, pressure and temperature of gases

Web Link

http://www.chem1.com/chemed/

Question 27 Answer D

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

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

The corresponding equation for the half reaction at the cathode can be obtained by taking the overall equation and subtracting the anode half reaction as shown below.

Overall equation:	$\cancel{CH_4}(g) + 2O_2(g) \rightarrow \cancel{CO_2}(g) + 2H_2O(l)(g)$	(1)
Anode half reaction:	$\cancel{CH_4}(g) + 2H_2O(l) \rightarrow \cancel{CO_2}(g) + 8H^+(aq) + 8e^-$	(2)
Subtract (2) from (1):	$2O_2(g) + 8H^+(aq) + 8e^- \rightarrow 4H_2O(l)$	
In simplest form:	$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	

Study Design Reference

The chemical principles, half-equations and overall equations of fuel cells.

Web Link

http://www.chem1.com/chemed/

Question 28 Answer C

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

When one mole of methane is oxidised, 900 kJ of heat energy is produced. Therefore, the electrical energy is 900 kJ. From the equation, one mole of methane produces 8 mole of electrons. The charge on 8 mole of electrons = 8×96500 coulombs (You must use the Data Book Section 3 Physical Constants to obtain this value for the Faraday Constant).
The amount of electric charge, in coulomb, = 7.72×10^5. This is closest to 8×10^5.

Study Design Reference
Application of Faraday's laws in electrochemistry

Web Link
http://www.chem1.com/chemed/

Question 29 Answer C

The cell reaction for a car battery releasing energy is:

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

Therefore, the cell reaction when the battery is being recharged is:

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

When the battery is being recharged, the negative electrode is the cathode and this is where reduction is occurring. Hence, the reaction is the reduction of lead(II) sulfate to lead metal. Note that the electrons must be on the right hand side of the half equation.

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

Study Design Reference

The chemical principles, half-equations and overall equations of simple primary and secondary galvanic cells.

Web Link

http://www.chem1.com/chemed/

Question 30 Answer B
The half reactions for the metals being deposited on the cathode in this cell are shown below.

(1) $Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$
(2) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
(3) $Ag^{+}(aq) + e^- \rightarrow Ag(s)$

You must know that the nitrate ion has the formula NO_3^- so that you can use the correct charges on each of the ions.

The charge on the electrons passing through the solutions = 0.030 faraday.

1 faraday = 1 mole of electrons
0.030 faraday = 0.030 mole of electrons

From equation (1):

Number of mole of chromium metal deposited $\frac{1}{3} \times \text{number of mole of electrons} = \frac{1}{3} \times 0.030 = 0.010$

From equation (2):

Number of mole of copper metal deposited = $\frac{1}{2} \times \text{number of mole of electrons} = \frac{1}{2} \times 0.030 = 0.015$

From equation (3):

Number of mole of silver metal deposited = $\text{number of mole of electrons} = 0.030$

Study Design Reference
Application of Faraday's laws in electrochemistry.

Web Link
http://www.chem1.com/chemed/

End of Detailed Answers to 2013 VCAA VCE Chemistry Sample Examination
Multiple Choice Questions

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Section B

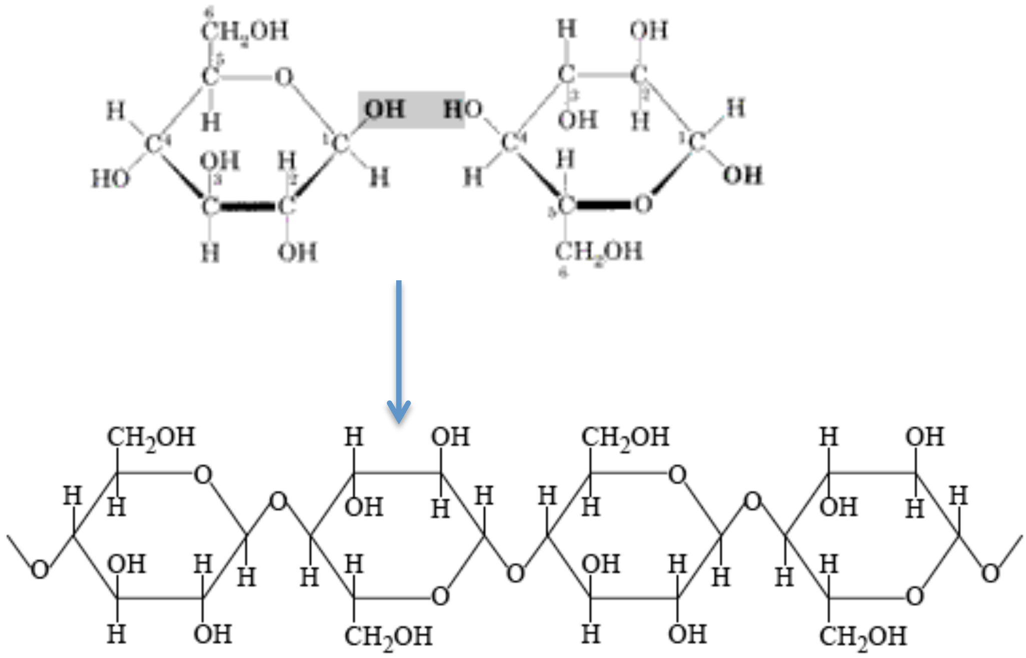
Question 1 (11 marks)

a. The reactions occurring here are:

(1) $(C_6H_{10}O_5)_n + nH_2O \rightarrow nC_6H_{12}O_6$

(2) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

Molecule A is cellulose. It is called a polysaccharide since it is a condensation polymer formed from the monomer glucose. *(1 mark)*



molecule A

b. The chemical formula for molecule B is $C_6H_{12}O_6$ *(1 mark)*

c. Ethanol produced in this way is renewable because the cellulose from which it is produced can be constantly provided by photosynthesis. *(1 mark)*
(1 mark)

The advantages of using bioethanol are (1) it is renewable, (2) it is available as a liquid, (3) it can be blended with petrol. *(1 mark)*

The disadvantages of using bioethanol are (1) it produces the greenhouse gas CO_2, (2) its production uses up land that might be needed for growing food, (3) it is not as good a fuel as oil based liquids. *(1 mark)*

Question 1 (continued)

d. From the Data Book, the molar enthalpy of ethanol is -1364 kJ mol^{-1} *(1 mark)*
The energy released in the bomb calorimeter
= calibration factor × temperature rise
= 12.5 × 13.75 kJ *(1 mark)*

$$n(C_2H_5OH) = \frac{12.5 \times 13.75}{1364}$$

$$m(C_2H_5OH) = \frac{12.5 \times 13.75}{1364} \times 46 = 5.80\,g$$ *(1 mark)*

e. If the ethanol is contaminated with water, the actual volume of ethanol will be less than 438 mL. (e.g. 400 mL of ethanol, 38 mL of water). Therefore, the temperature rise of 13.75°C is for a smaller volume of ethanol. The temperature rise would be greater than 13.75 °C for pure ethanol. Therefore, the number of mole of ethanol would be greater. Therefore, the mass of ethanol would be greater. *(1 mark)*

Hence, the real percentage yield of ethanol is greater than observed percentage yield. *(1 mark)*

Study Design Reference
Comparison of the renewability of energy sources including coal, petroleum, natural gas, nuclear fuels and biochemical fuels. Application of calorimetry to measure energy changes in chemical reactions in solution calorimetry and bomb calorimetry, including calibration of a calorimeter and the effects of heat loss. Make connections between concepts; process information; apply understandings to familiar and new contexts.

Web Link
http://www.chem1.com/chemed/

Question 2 (8 marks)

a. The balanced half-equation for the cathode reaction is $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

(1 mark)

b. From the balanced half-equation:

$n(Cu) = 2 \times n(e^-)$ $(1\ mark)$

$= 2 \times \dfrac{Q}{F}$

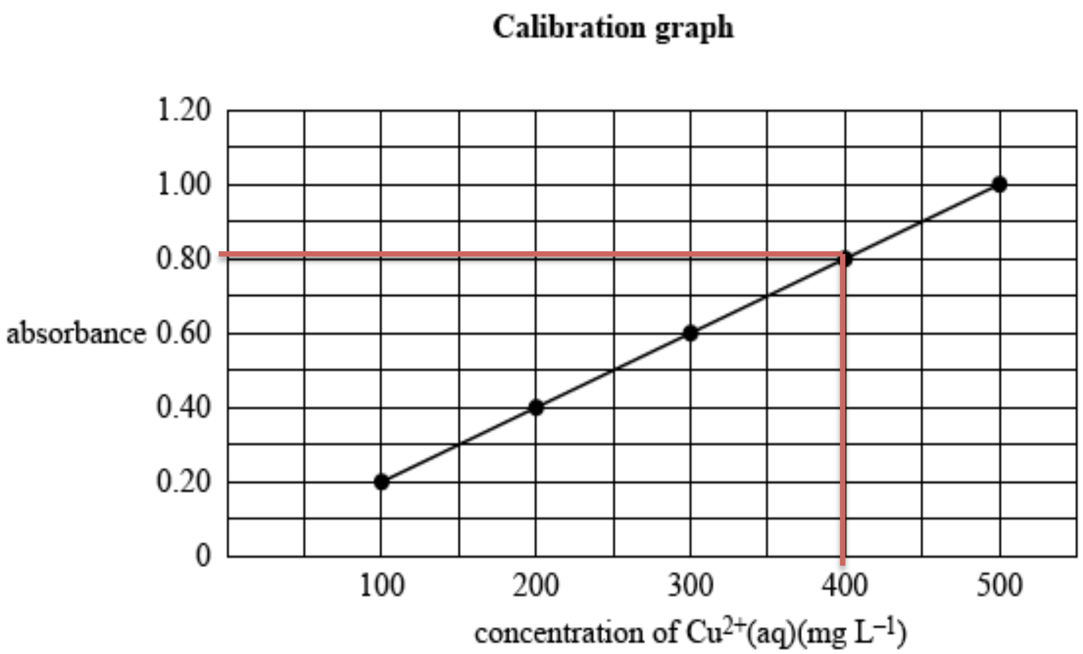
$= 2 \times \dfrac{I \times t}{F}$ $(1\ mark)$

$= 2 \times \dfrac{0.900 \times 315 \times 60}{96500}$ $(1\ mark)$

$m(Cu) = 2 \times \dfrac{0.900 \times 315 \times 60 \times 63.5}{96500}$

$= 22.4 g$ $(1\ mark)$

c. **i.** From the graph, an absorbance of 0.80 corresponds to a concentration of $Cu^{2+}(aq)$ of 400 mgL^{-1} as shown below. *(1 mark)*



Question 2 (continued))

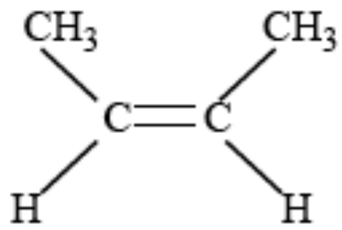
c. **ii.** Use this concentration to calculate the mass of copper in the 100.0 mL volumetric flask. This is the same as the mass of copper in the 25.0 mL solution since this process is simply a dilution with water.

$$m(Cu)\text{in 100 mL volumetric flask and 25 mL}$$
$$= \frac{400 \times 0.1}{1000}$$
$$= 0.04 g \qquad (1\,\text{mark})$$
$$m(Cu)\text{in 500 mL}$$
$$= 0.04 \times \frac{500}{25}$$
$$= 0.8 g$$
$$\%\text{ purit}$$
$$= \frac{0.8}{0.855} \times 100$$
$$= 93.6\% \qquad (1\,\text{mark})$$

Study Design Reference
Visible and ultraviolet spectroscopy (visible-UV) including electron transitions and use of calibration graph to determine amount of analyte. Application of Faraday's laws in electrochemistry

Web Link
http://www.chem1.com/chemed/

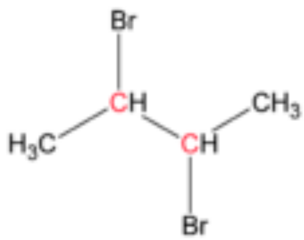
Question 3 (8 marks)



a. The systematic name for compound A shown above is but-2-ene. You must get the longest possible carbon chain. This is 4 carbons. Then you must specify the position of the double bond.

(1 mark)

b. **i.** The structure of 2,3-dibromobutane is shown below.



In this molecule, there are only 2 different carbon environments.

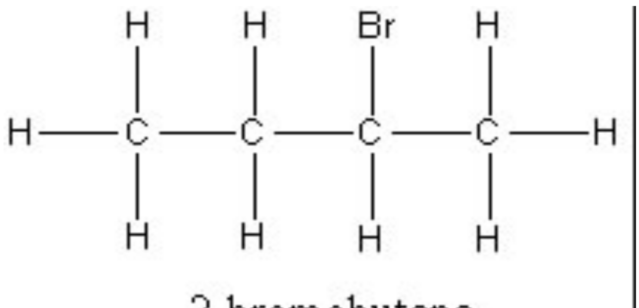
(1 mark)

The ^{13}C NMR spectrum of compound C shows 4 different carbon environments.

(1 mark)

Therefore, compound C cannot be 2,3-dibromobutane

ii. The structure of 2-bromobutane is shown below.



2-bromobutane
C_4H_9Br

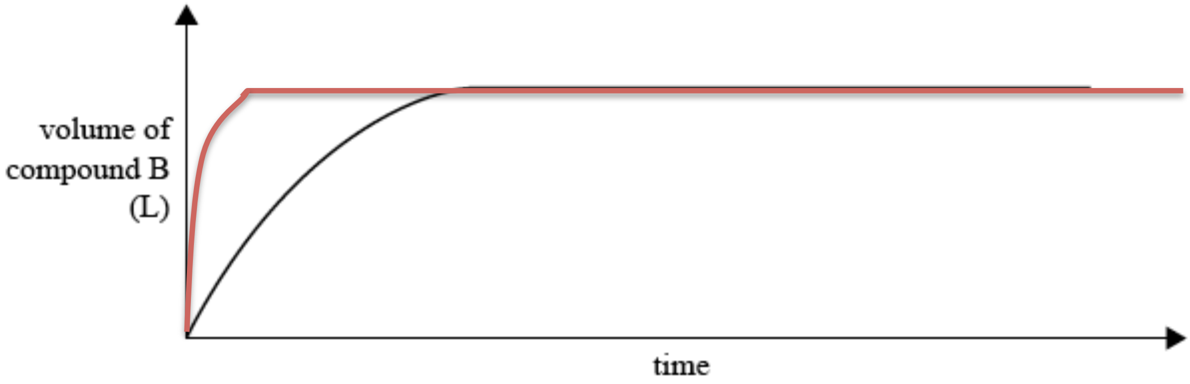
(1 mark)

iii. In order to produce 2-bromobutane from but-2-ene, a hydrogen atom and a bromine atom must add across the double bond. Reagent D is hydrogen bromide (HBr)

(1 mark)

Question 3 (continued)

c. **i.** A catalyst changes the rate at which equilibrium is achieved but does not alter the position of equilibrium. Hence, in this reaction $C_4H_8(g) + H_2(g) \rightleftharpoons C_4H_{10}(g)$, with a catalyst, the graph will be steeper at the beginning and will reach the same constant value as shown below.



(1 mark)

ii. A catalyst changes the rate of a reaction by providing a substrate on its surface to bring the reactants closer together.

(1 mark)

This lowers the activation energy and increases the number of effective collisions per unit time.

(1 mark)

Study Design Reference

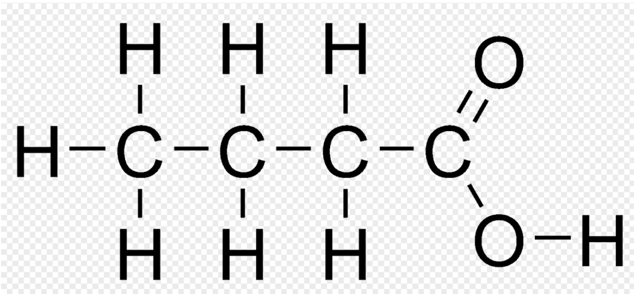
Carbon-13 nuclear magnetic resonance spectroscopy (NMR) including spin, the application of carbon-13 to determine number of equivalent carbon environments. Common reactions of organic compounds including equations: addition reactions of alkenes (addition of hydrogen halides and water limited to symmetrical alkenes). Factors which affect the position of equilibrium.

Web Link

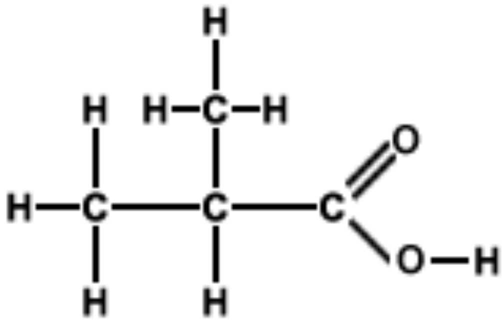
http://www.chem1.com/chemed/

Question 4 (18 marks)

a. HA is a weak monoprotic acid with the molecular formula $C_4H_8O_2$.
There are 2 possible structures for this compound. These are shown below.



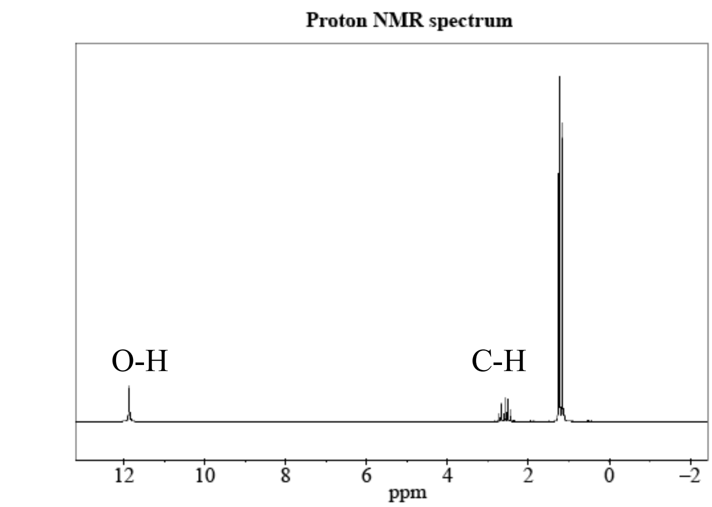
butanoic acid



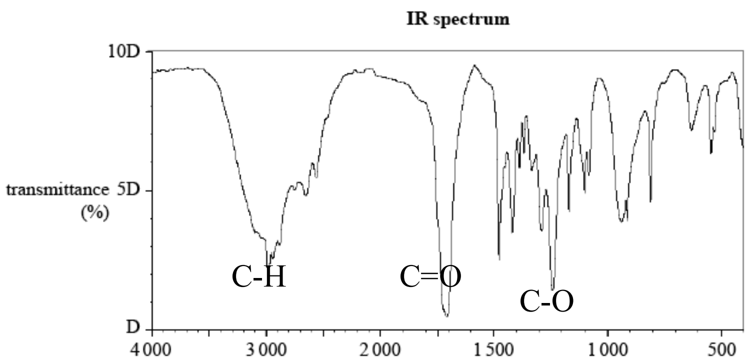
methylpropanoic acid

In the proton NMR spectrum for HA there are 3 main peaks which indicates 3 unique hydrogen environments. See diagram below.

(1 mark)



The IR spectrum clearly shows the C-H , C=O and C-O bonds in the molecule. See below.



Question 4 (continued)

b. At 2.6 ppm, the signal is split into 7 peaks. Therefore, the number of C-H bonds on the neighbouring carbon atoms = 7 – 1 = 6.

(1 mark)

c. From the Data Book, the group of atoms responsible for the absorptions at

i. 3000 cm^{-1} is C-H

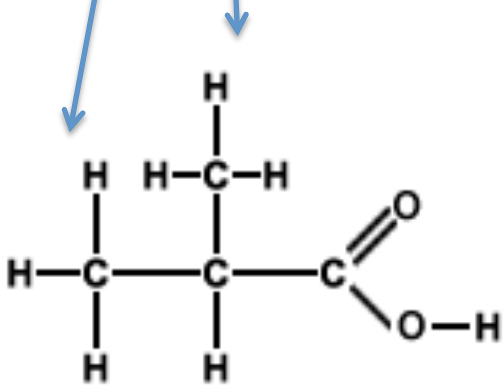
(1 mark)

ii. 1700 cm^{-1} is C=O

(1 mark)

d. The structure of HA must be

(1 mark)
(1 mark)



e. ^{13}C must be used because ^{12}C has a spin quantum number of zero and, therefore, is not magnetically active like ^{13}C.

(1 mark)

A ^{13}C NMR spectrum would provide the following information about the structure of HA:

(1) 3 peaks indicating 3 different carbon environments

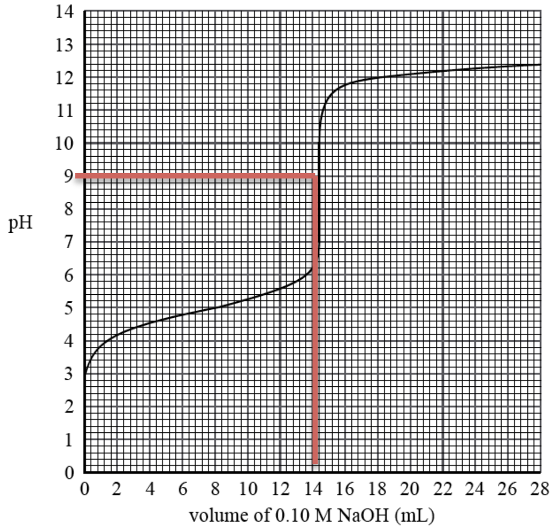
(1 mark)
(1 mark)

(2) Since butanoic acid has 4 different carbon environments, the ^{13}C NMR spectrum would provide sufficient information to choose between the two possible structures for HA as long as the molecular formula is known and the compound has been identified as a monoprotic acid.

(1 mark)

Question 4 (continued)

f. In a titration between a weak acid and a strong base, the pH is greater than 7 at the equivalence point as shown in the graph below.



i. The volume of NaOH used to neutralize the solution of HA is 14 mL.

(1 mark)

ii. The balanced equation is: $HA(aq) + NaOH(aq) \rightarrow NaA(aq) + H_2O(l)$

From the balanced equation, $n(HA) = n(NaOH)$

$$c(HA)$$

$$= \frac{n(NaOH)}{V(HA)} \qquad \text{(1 mark)}$$

$$= \frac{0.100 \times 0.014}{0.010} \qquad \text{(1 mark)}$$

$$= 0.140M \qquad \text{(1 mark)}$$

iii. From the graph, the pH of HA before it was reacted with the NaOH = 3.

(1 mark)

Therefore, the concentration of hydronium ions (H_3O^+) = 10^{-3} M

(1 mark)

Question 4 (continued)

iv. The equation showing HA acting as a weak, monoprotic acid is:

$HA + H_2O \rightleftharpoons H_3O^+ + A^-$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]} = \frac{[H_3O^+]^2}{[HA]}$$ (1 mark)

since the concentrations of the products are equal.

$$K_a = \frac{(10^{-3})^2}{0.140} = 7.14 \times 10^{-6}$$ (1 mark)

Study Design Reference

Proton and carbon-13 nuclear magnetic resonance spectroscopy (NMR) including spin, the application of carbon-13 to determine number of equivalent carbon environments; and application of proton NMR to determine structure: chemical shift, areas under peak and peak splitting patterns (excluding coupling constants), and application of n+1 rule to simple compounds. Titration curves: simple titrations

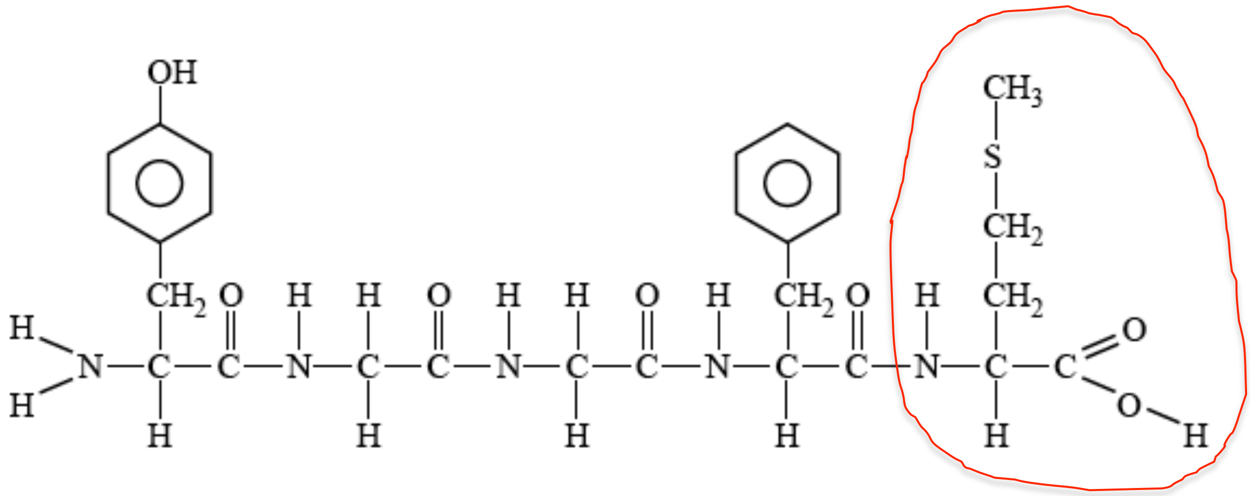
Web Link

http://www.chem1.com/chemed/

Question 5

a. The methionine residue is circled below. "Residue" means "left over". Note that the residue has fewer atoms than the actual amino acid. This is because atoms are lost when the peptide link is formed. Get the formula for methionine amino acid from the Data Book.

(1 mark)



b. In the diagram, the solvent front is at 29 cm when the methionine is at 17.5 cm. Let x = the distance of the methionine spot when the solvent was at 20 cm. Therefore,

$$R_f = \frac{x}{20} = \frac{17.5}{29} \qquad \text{(1 mark)}$$

$$\Rightarrow x = \frac{17.5 \times 20}{29}$$

$$\Rightarrow x = 12.1 \text{ cm} \qquad \text{(1 mark)}$$

c. The different amino acids form bonds of different strengths with the stationary phase and the solvent.

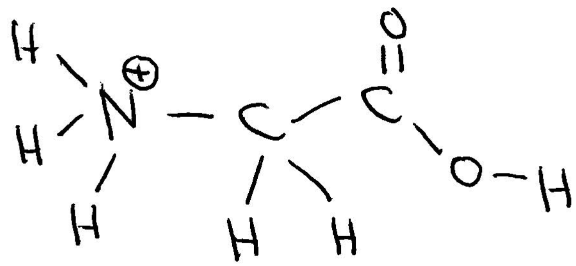
(1 mark)

Hence, separation occurs as bonds form and break while the amino acids are carried along the strip.

(1 mark)

Question 5 (continued)

d. From the Data Book, find the formula for glycine. It is $H_2N - CH_2 - COOH$. When the pH is low, the concentration of hydrogen ions (H^+) is high. The formula for glycine in this low pH environment is $^+H_3N - CH_2 - COOH$. The structural formula is shown below.



(1 mark)

Study Design Reference
Thin layer chromatography (TLC), including calculation of R_f
Primary, secondary and tertiary structures of proteins.

Web Link
http://www.chem1.com/chemed/

Question 6

a. The balanced equation is $2CH_3OH(g) \rightleftharpoons CH_3OCH_3(g) + H_2O(g)$
The expression for the equilibrium constant, K_1, at 350 °C is shown below.

$$K_1 = \frac{[CH_3OCH_3]_e[H_2O]_e}{[CH_3OH]_e^2} = 5.74$$

(1 mark)

b. The new balanced equation is the reverse of the equation in **a.**
$CH_3OCH_3(g) + H_2O(g) \rightleftharpoons 2CH_3OH(g)$

$$K_2 = \frac{[CH_3OH]_e^2}{[CH_3OCH_3]_e[H_2O]_e} = \frac{1}{5.74} = 0.174$$

(1 mark)

c. It is very important to distinguish between initial states and equilibrium states in equilibrium calculations. Use the subscript *i* for initial states and the subscript *e* for equilibrium states.

i. The equilibrium concentration of methanol, $[CH_3OH]_e$

$$= \frac{\text{number of mole at equilibrium}}{\text{volume}}$$

$$= \frac{0.340}{20.0}$$

$$= 0.017 \text{mol L}^{-1}$$

(1 mark)

ii. From the balanced equation, the concentration of dimethyl ether formed equals the concentration of water formed. Hence,

$$\frac{[CH_3OCH_3]_e^2}{0.017} = 5.74 \qquad \text{(1 mark)}$$

$$\Rightarrow [CH_3OCH_3]_e^2 = 5.74 \times 0.017$$

$$\Rightarrow [CH_3OCH_3]_e = \sqrt{5.74 \times 0.017}$$

$$\Rightarrow n(CH_3OCH_3)_e = \sqrt{5.74 \times 0.017} \times 20.0$$

$$\Rightarrow n(CH_3OCH_3)_e = 6.25 \text{ mol} \qquad \text{(1 mark)}$$

Question 6 (continued)

c. **iii.** The **initial** number of mole of methanol
= number of mole of methanol at equilibrium + number of mole of methanol reacting

$$n(CH_3OH)_i = n(CH_3OH)_e + n(CH_3OH)_{reacting}$$

(1 mark)

From the balanced equation, 2 mol of methanol produces 1 mol of dimethyl ether. Therefore,

$$n(CH_3OH)_e = n(CH_3OH)_e + 2 \times n(CH_3OCH_3)_e$$

$$n(CH_3OH)_e = 0.340 + 2 \times 5.74 = 11.82 \text{ mol}$$

(1 mark)

Study Design Reference
Equilibrium: representation of reversible and non-reversible reactions: homogeneous equilibria and the equilibrium law (equilibrium expressions restricted to use of concentrations).

Web Link
http://www.chem1.com/chemed/

Question 7

a. In the Data Book, hydrogen peroxide is listed both as an oxidant and as a reductant. A reductant donates electrons, so you must use the equation

$$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq) \qquad E^0 = +0.68\ V$$

(1 mark)

$H_2O_2(aq)$ will react with any oxidant with a more positive E^0 value than +0.68. You can choose any oxidant from $F_2(g)$ down to $Fe^{3+}(aq)$. For example,

$$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$$

$$H_2O_2(aq) \rightleftharpoons O_2(g) + 2H^+(aq) + 2e^-$$

Balanced overall equation is $H_2O_2(aq) + Br_2(l) \rightleftharpoons 2Br^-(aq) + O_2(g) + 2H^+(aq)$

(1 mark)

b. Since $Cu^{2+}(aq)$ acting as an oxidant has a more positive E^0 value than $H_2(g)$ acting as a reductant, the prediction is for a chemical reaction to occur. However, the electrochemical series predicts only the **position of equilibrium** for a chemical reaction but not the **rate** at which the reaction occurs. Apparently, this reaction is very slow.

(1 mark)

Study Design Reference

Use of the electrochemical series in predicting the products of redox reactions and deducing overall equations from redox half equations.

Web Link

http://www.chem1.com/chemed/

Question 8

a. A primary galvanic cell such as the lithium button cell cannot be recharged. A secondary galvanic cell such as a lithium ion cell can be recharged.

(1 mark)

b. In the Data Book, the electrochemical series shows that Li(s) is the strongest reductant with an E^0 value of -3.02 V. Hence, when Li(s) is used in a galvanic cell with a strong oxidant, the cell potential will be large. Cell potential = E^0(oxidant) – E^0(reductant)

(1 mark)

c. The balanced equation for the reaction is: $2Li(s) + 2H_2O(l) \rightarrow H_2(g) + 2LiOH(aq)$

From the balanced equation, $n(H_2)$ produced = $\frac{1}{2} \times n(Li)$ reacting.

(1 mark)

Since excess water is used, all of the Li will react.

$$V(H_2) = \frac{nRT}{P} \quad \text{(1 mark)}$$

$$V(H_2) = \frac{1}{2} \times \frac{1.00}{6.9} \times \frac{8.31 \times 293}{\frac{950}{760} \times 101.3} = 1.39 \text{ L} \quad \text{(1 mark)}$$

Question 8 (continued)

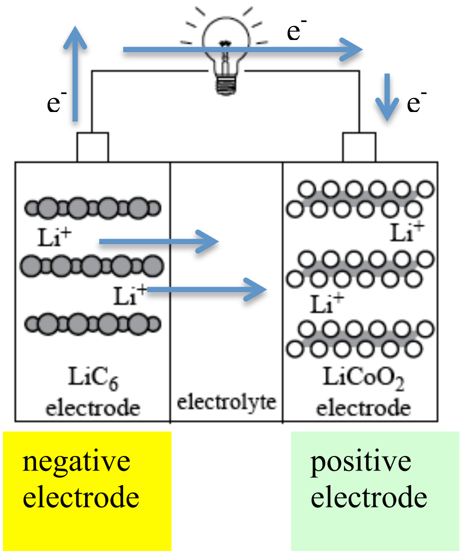
d. The electrode equations as the lithium ion cell is discharged are the **reverse** of the equations for when the cell is being recharged. The discharge equations are:

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

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

Therefore, the electrons and Li^+ ions are moving as shown in the diagram below. The LiC_6 electrode is producing electrons and so this is the negative electrode. The $LiCoO_2$ electrode is accepting electrons and so this is the positive electrode.

(1 mark)



Study Design Reference
The chemical principles, half-equations and overall equations of simple primary and secondary galvanic cells. Calculations including amount of solids, liquids and gases; concentration; volume, pressure and temperature of gases.

Web Link
http://www.chem1.com/chemed/

Question 9

a. You must calculate the initial and final masses of carbon dioxide and then subtract.

$$CO_2\text{(initial)} = \frac{0.42}{100} \times 5.15 \times 10^{18} = 2.163 \times 10^{16}\,\text{kg} \quad (1)$$

$$CO_2\text{(final)} = \frac{0.58}{100} \times 5.15 \times 10^{18} = 2.987 \times 10^{16}\,\text{kg} \quad (2)$$

$$\Rightarrow CO_2\text{(added)}$$

$$= (2) - (1)$$

$$= 0.824 \times 10^{16}$$

$$= 8.24 \times 10^{15}\,\text{kg}$$

(1 mark)

b. The balanced equation for the burning of coal (assumed to be pure carbon) is
$C(s) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -394\ \text{kJ mol}^{-1}$

First, calculate the number of mole of carbon and then calculate the energy released.
Don't forget to use only half the mass of carbon!

$$n(CO_2) = \frac{\frac{8.24}{2} \times 10^{15}}{44} \qquad \text{(1 mark)}$$

$$\Rightarrow \text{Energy produced}$$

$$= \frac{\frac{8.24}{2} \times 10^{15}}{44} \times 394$$

$$= 36.89 \times 10^{15}$$

$$= 3.7 \times 10^{16}\ \text{kJ} \qquad \text{(1 mark)}$$

c. The first equilibrium is $CO_2(g) \rightleftharpoons CO_2(aq)$
According to Le Chatelier's Principle, increasing the concentration of atmospheric carbon dioxide will shift the first equilibrium to the right, thereby increasing the concentration of dissolved carbon dioxide at the ocean surface.

(1 mark)

The second equilibrium is $CO_2(aq) + H{+}O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$
Increasing the concentration of dissolved carbon dioxide will then shift the second equilibrium to the right, thereby increasing the concentration of hydrogen ions in sea water.

(1 mark)

Increasing the hydrogen ion concentration lowers the pH of seawater because $pH = -\log_{10}[H^+]$

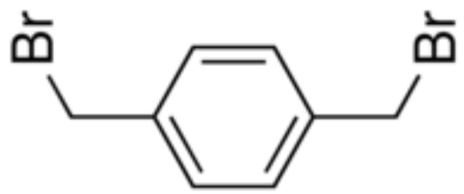
(1 mark)

Study Design Reference
Calculations including amount of solids, liquids and gases; concentration; volume, pressure and temperature of gases. Le Chatelier's Principle and factors which affect the position of equilibrium.

Web Link
http://www.chem1.com/chemed/

Question 10

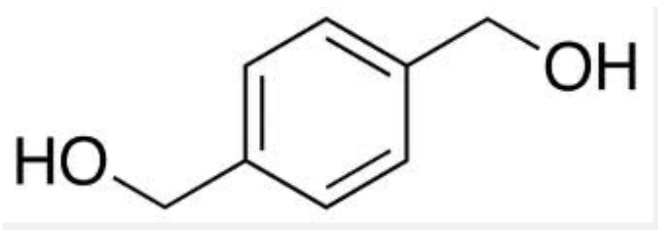
Note: in two of the structures drawn on this page (in the original sample exam posted on the VCAA website), the carbon atoms are **incorrectly** shown connected to the sides of the benzene ring instead of the vertices. The structure of the original compound should be drawn as shown below. The carbon atoms occur where lines join. The hydrogen atoms have been omitted.



a. Reagent A is sodium hydroxide – NaOH. This is a substitution reaction in which the bromide functional group has been replaced by the hydroxyl functional group. The other product in the reaction is sodium bromide (NaBr). Note that, in organic chemistry, the by-products of chemical reactions are frequently omitted.

(1 mark)

b. The structure of compound 1 is shown below. The carbon atoms occur where lines join. The hydrogen atoms have been omitted everywhere except on the functional group.



(1 mark)

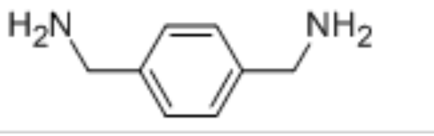
c. Dichromate ions in an acidic environment are commonly used in organic chemistry to carry out oxidation reactions. The balanced half-equation for the reduction of dichromate ions ($Cr_2O_7^{2-}$) to chromium(III) ions (Cr^{3+}) is shown below.

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

(1 mark)

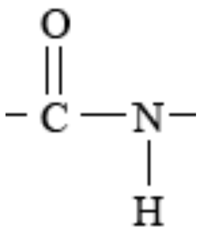
Question 10 (continued)

d. The dichromate ions have oxidised the hydroxyl functional group (OH) to the carboxyl functional group (COOH). The reaction of this dicarboxylic acid with compound 2 produces a condensation polymer with links containing the atoms NHCO. Compound 2 must contain the amine functional group (NH_2) as shown below. The carbon atoms occur where lines join. The hydrogen atoms have been omitted everywhere except on the functional group.



(1 mark)

e. The functional group shown below is known as amide or peptide.



(1 mark)

Study Design Reference
Organic reaction pathways including appropriate equations and reagents:

Web Link
http://www.chem1.com/chemed/

Question 11

Lots of reading here but you need to find the important stuff. All of the phosphorus has been precipitated as $MgNH_4PO_4.6H_2O$. Notice that there is one atom of phosphorus in this formula. When the P_2O_5 in the fertiliser is converted to $MgNH_4PO_4.6H_2O$, two molecules of precipitate are formed from one molecule of P_2O_5. You could write a balanced equation for the reaction with all of the other information given in the question, but this is unnecessary. You just need the ratio between the P_2O_5 and the $MgNH_4PO_4.6H_2O$.

Here is the simple calculation for what looks like a very difficult problem!
When in doubt, start with a calculation of the number of mole of something!

$m(MgNH_4PO_4.6H_2O) = 4.141$ g

$$n(MgNH_4PO_4.6H_2O) = \frac{4.141}{245.3}$$

(1 mark)

One mole of P_2O_5 produces two mole of $MgNH_4PO_4.6H_2O$

$$n(P_2O_5) = \frac{1}{2} \times n(MgNH_4PO_4.6H_2O) = \frac{4.141}{2 \times 245.3}$$

(1 mark)

$$m(P_2O_5) \text{ in the 3.256 g sample of fertiliser} = \frac{4.141}{2 \times 245.3} \times \frac{142.0}{1}$$

(1 mark)

$$m(P_2O_5) \text{ in the 1 kg (1000 g) of fertiliser} = \frac{4.141}{2 \times 245.3} \times \frac{142.0}{1} \times \frac{1000}{3.256} = 368.1 \text{ g}$$

(1 mark)

Study Design Reference
Gravimetric analysis. Calculations including amount of solids.

Web Link
http://www.chem1.com/chemed/

Question 12

a. Make up a number (say 10) solutions of X of different, known concentrations.

(1 mark)

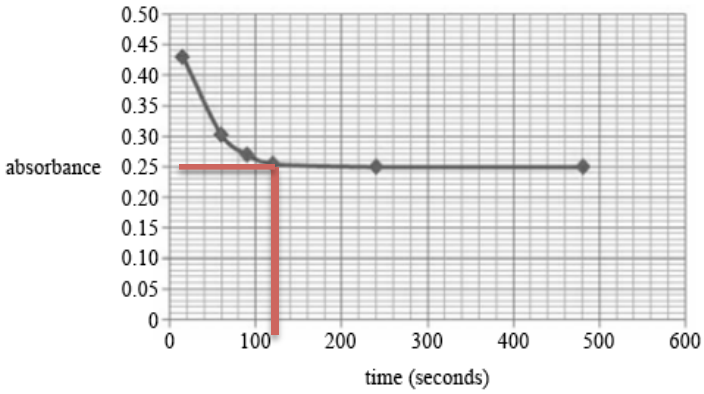
Measure the absorbance of each of these solutions using electromagnetic radiation of wavelength 290 nm.

(1 mark)

Plot a graph of absorbance (*Y* axis) against concentration (*X* axis).
The straight line graph of best fit for these data will have a gradient of 4.15

(1 mark)

b. When the absorbance becomes constant after about 120 seconds, equilibrium has been established and the concentration of X does not change.



i. At equilibrium, the absorbance = 0.25
Therefore, from the given relationship, $0.25 = 4.15 \times [X]_e$

Hence, $[X]_e = \dfrac{0.25}{4.15} = 0.06(02)\ M$

(1 mark)

ii. $[X]_{initial} = \dfrac{0.110}{1.00} = 0.110\ M$

Hence, absorbance at the instant that X was dissolved in the water
$= 4.15 \times [X]_{initial}$
$= 4.15 \times 0.110 = 0.457$

(1 mark)

Question 12 (continued)

b. **iii.** n(X) that has been converted into Y at equilibrium = n(X) reacting

n(X) reacting = n(X) initially present - n(X) at equilibrium
= 0.110 – 0.0602
= 0.0498
= 0.05 mol

(1 mark)

$$\% \text{ conversion} = \frac{0.0498}{0.110} \times 100$$
$$= 45.3\%$$

(1 mark)

Study Design Reference
Visible and ultraviolet spectroscopy (visible-UV)

Web Link
http://www.chem1.com/chemed/

Question 13

A critical evaluation of the student's proposal.

(1) The equation as given in the experimental design is **not balanced** and so any calculations based on this equation will be wrong.

The correct balanced equation is $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

(2) The variables in the experiment have not been controlled.
  a. the mass of the calcium carbonate is different in each flask.
  b. the surface area of the calcium carbonate in each flask is different.
  c. the volume of hydrochloric acid used in each flask is different.
  d. the temperature in each flask is different.

(3) No valid conclusion can be reached about the effect of concentration of acid on the rate of reaction between calcium carbonate and hydrochloric acid.

(4) In order to achieve the aim of the experiment, the student must use the same mass of calcium carbonate in each flask, must have particles with the same surface area, must use the same volume of acid and must keep the temperature constant.

(5) The basic rule of experimental design is to test for only one variable at one time.

Study Design Reference (Key Skills)
Conduct investigations that include collecting, processing, recording and analysing qualitative and quantitative data; draw conclusions consistent with the question under investigation and the information collected; evaluate procedures and reliability of data. Construct questions (and hypotheses); plan and/or design, and conduct investigations; identify and address possible sources of uncertainty.

Web Link
http://www.chem1.com/chemed/

End of Detailed Answers to 2013 VCAA VCE Chemistry Sample Examination Short Answer Questions

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Go to Sample Exam Answers

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

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

Letter

Figures									
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.

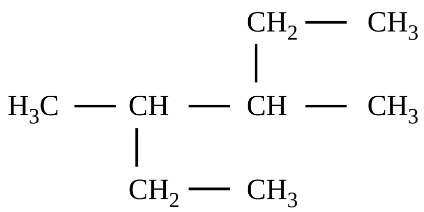
A correct answer scores 1, an incorrect answer scores 0.

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?

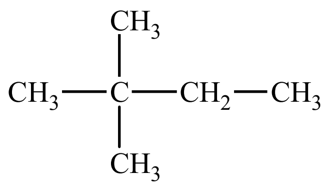


A. 2-ethyl-3-methylpentane
B. 3-methyl-4-ethylpentane
C. 3,4-dimethylhexane
D. 2,3-diethylbutane

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.



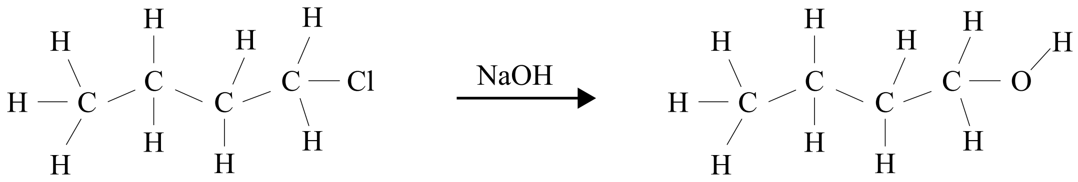
The number of different carbon compounds that could be formed in this monosubstitution reaction is

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

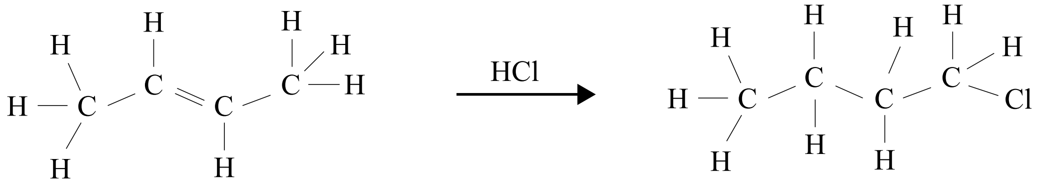
Question 3

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

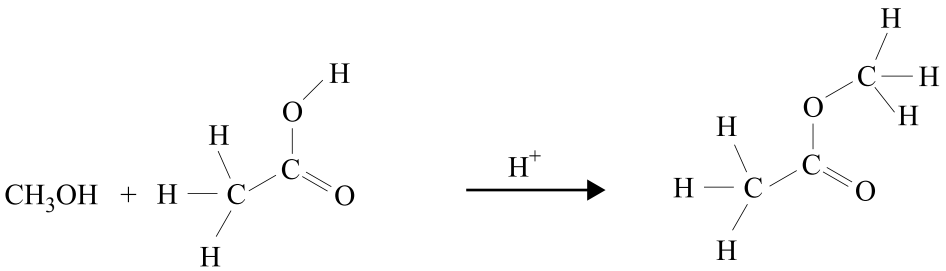
A.



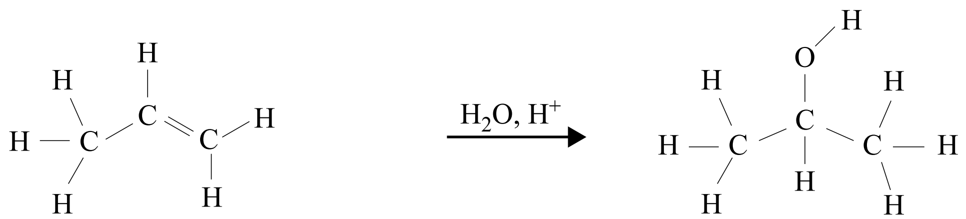
B.



C.



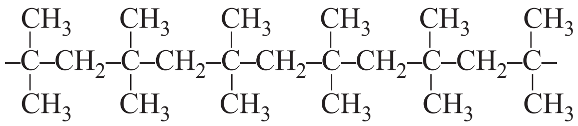
D.

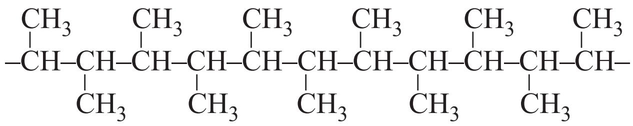


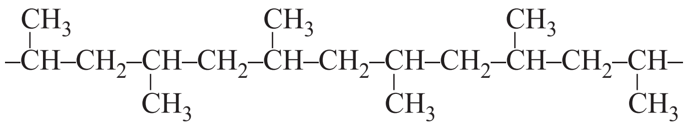
Question 4

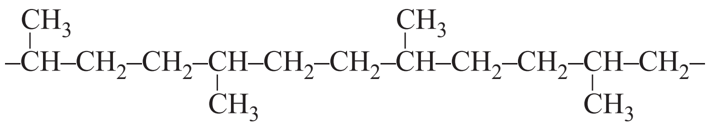
Consider the addition polymerisation of $CH_3CH = CHCH_3$.

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 $-\underset{\underset{O}{\|}}{C}-O-C-$ group.

B. hydrolysis reaction and the product contains a $-\underset{\underset{O}{\|}}{C}-O-C-$ 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. $C_{18}H_{34}O_2$

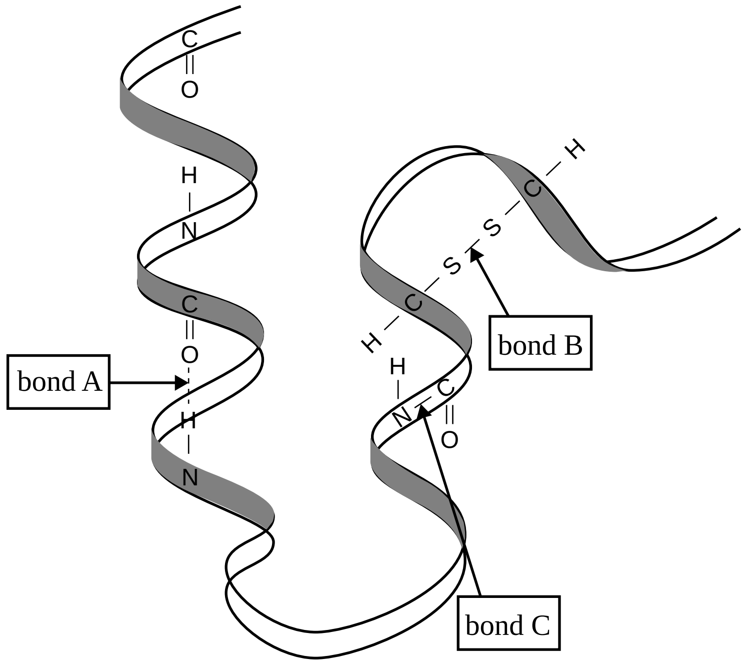
B. $C_{24}H_{48}O_2$

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.

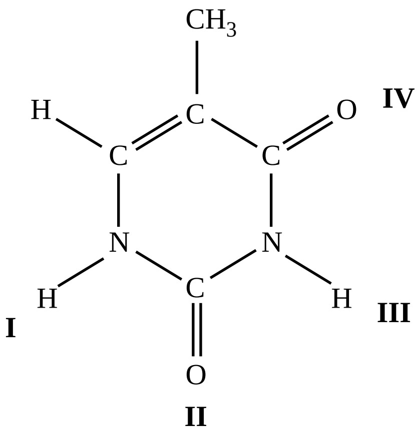
I Enzymes are proteins.
II Enzymes increase the rate of biochemical reactions.
III Enzymes increase the equilibrium constant of biochemical reactions.

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

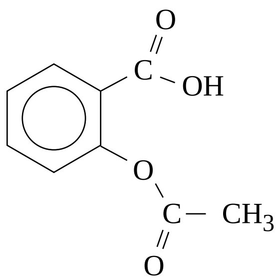
C. III and IV only

D. II, III and IV only

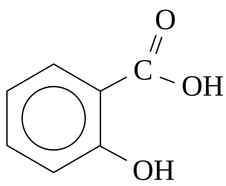
Question 12

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

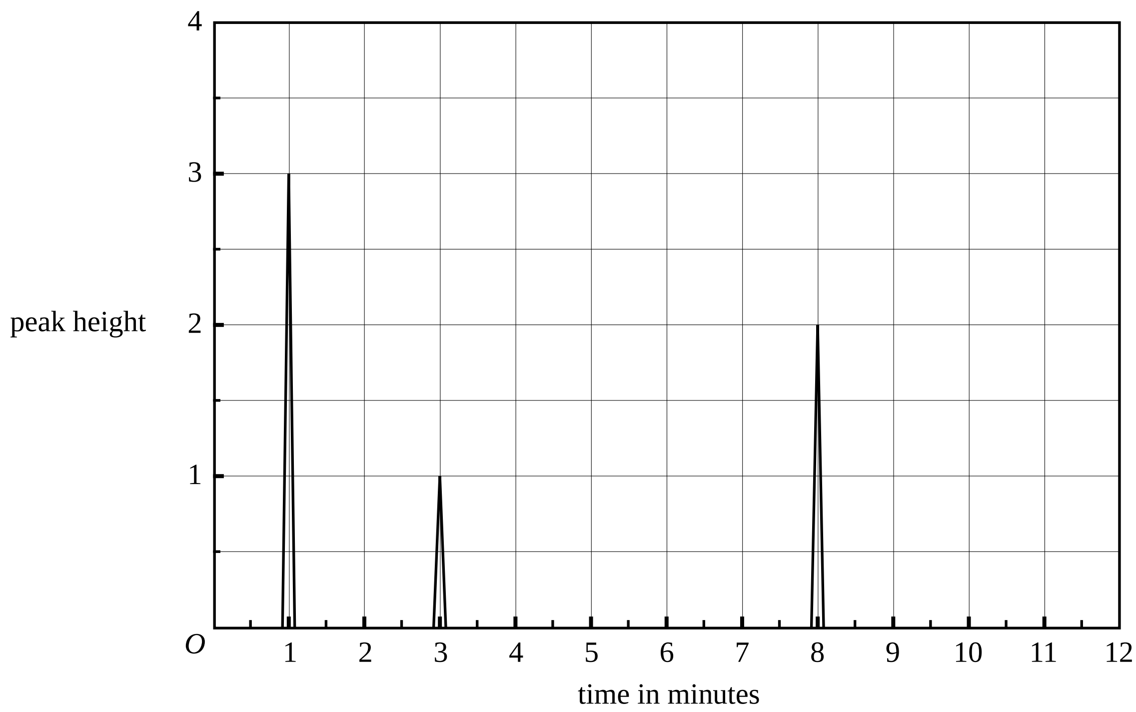
B. gas-liquid chromatography

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

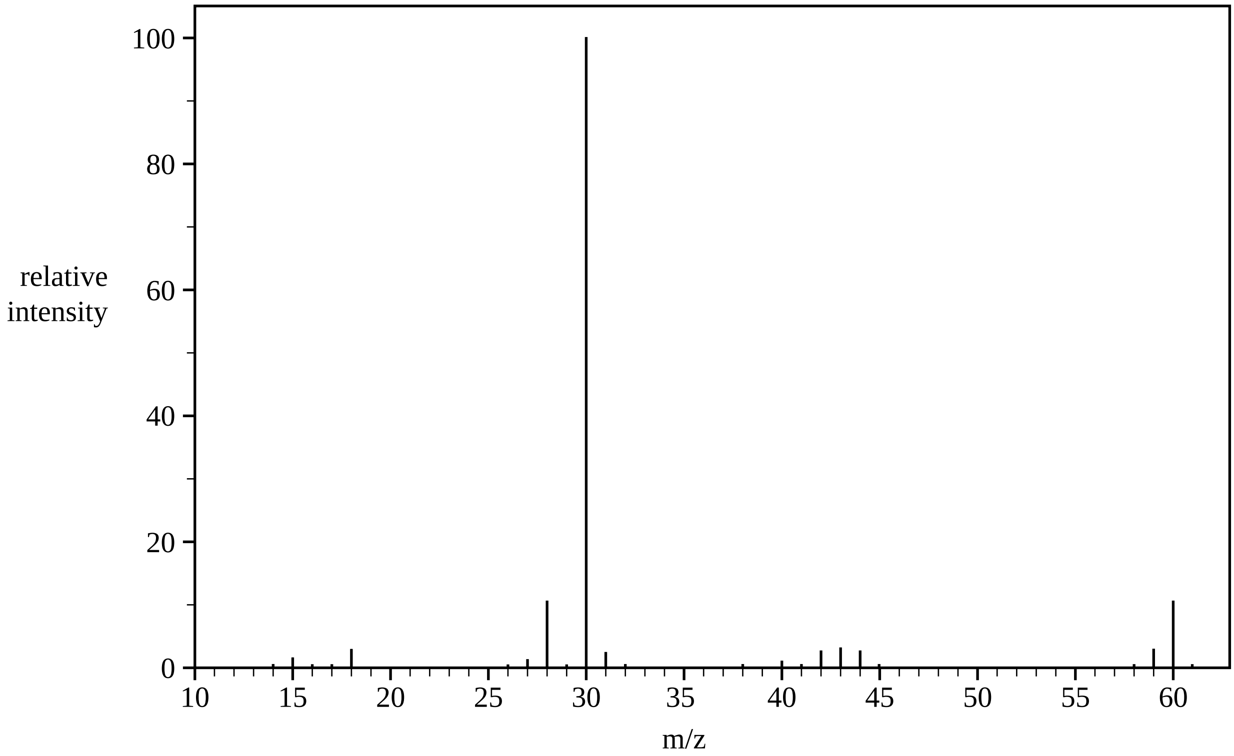
B. 30

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.

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

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

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

$$C(graphite) \rightarrow C(diamond)$$

is

A. -2 kJ mol^{-1}

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

C. -788 kJ mol^{-1}

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

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

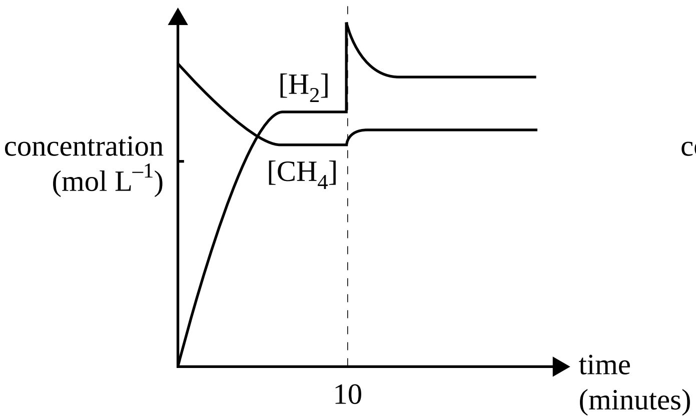
Water gas, a mixture of carbon monoxide and hydrogen, can be produced on an industrial scale by the following reaction.

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

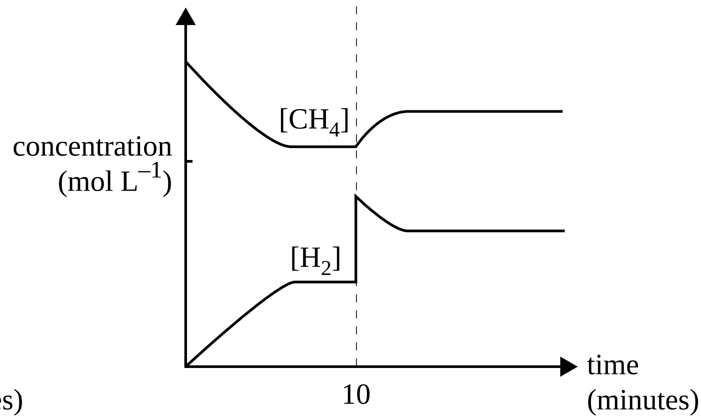
Equal amounts of $CH_4(g)$ and $H_2O(g)$ are added to a reaction vessel and allowed to react. After 10 minutes, equilibrium has been reached. At that time, some H_2 is added to the mixture and equilibrium is re-established.

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

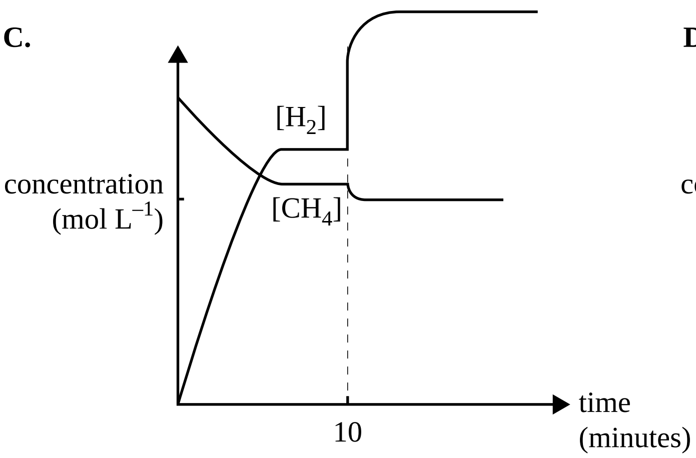
A.



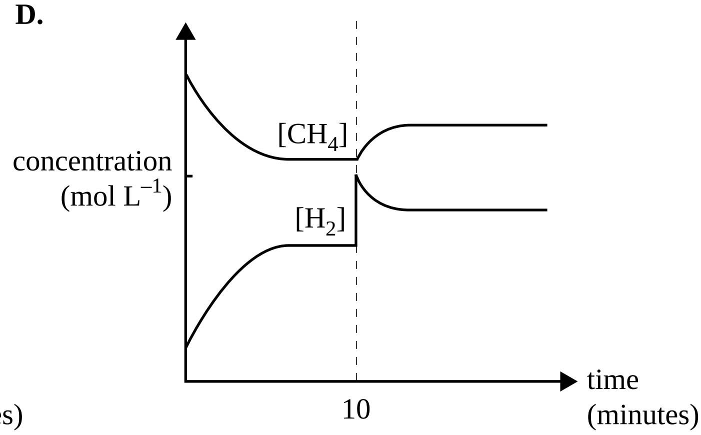
B.



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

SECTION A – continued

Question 23

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

A. 2.0

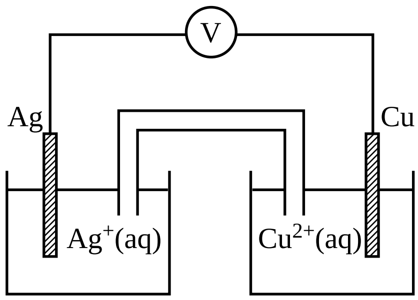
B. 2.3

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

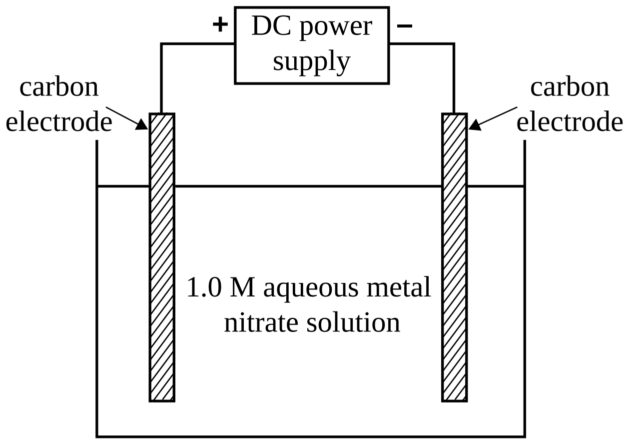
B. $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightarrow PbSO_4(s) + 2H_2O(l)$

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.

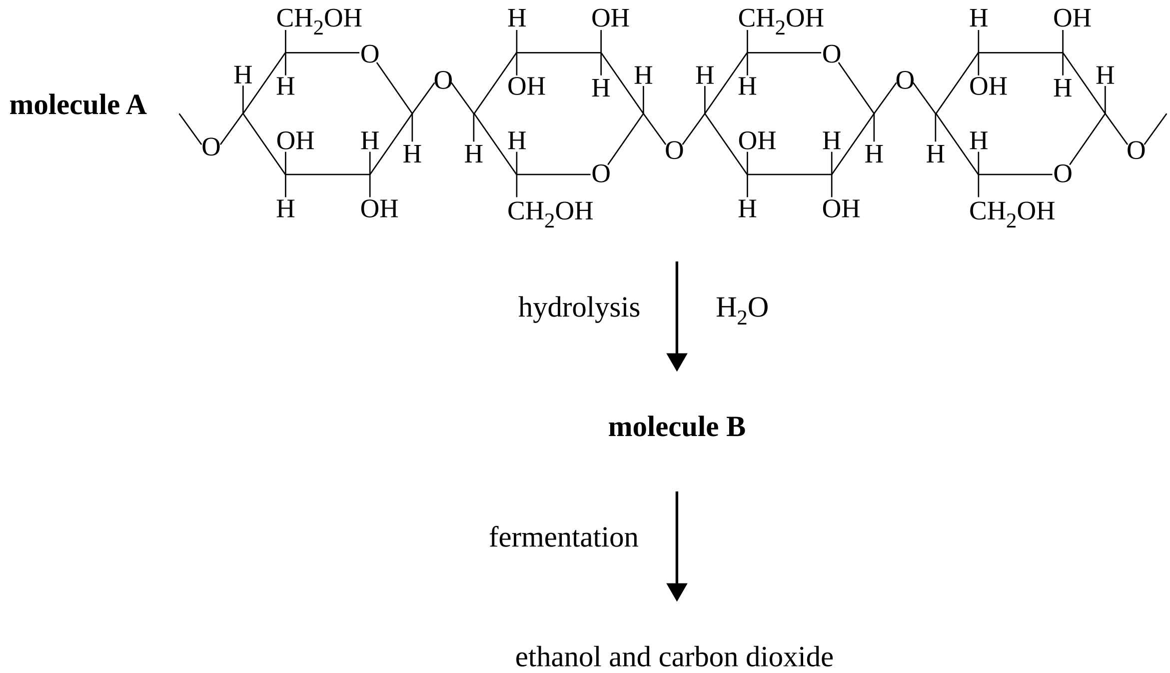
To obtain full marks for your responses you should

- 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.



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

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

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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 $^{\circ}C^{-1}$.

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

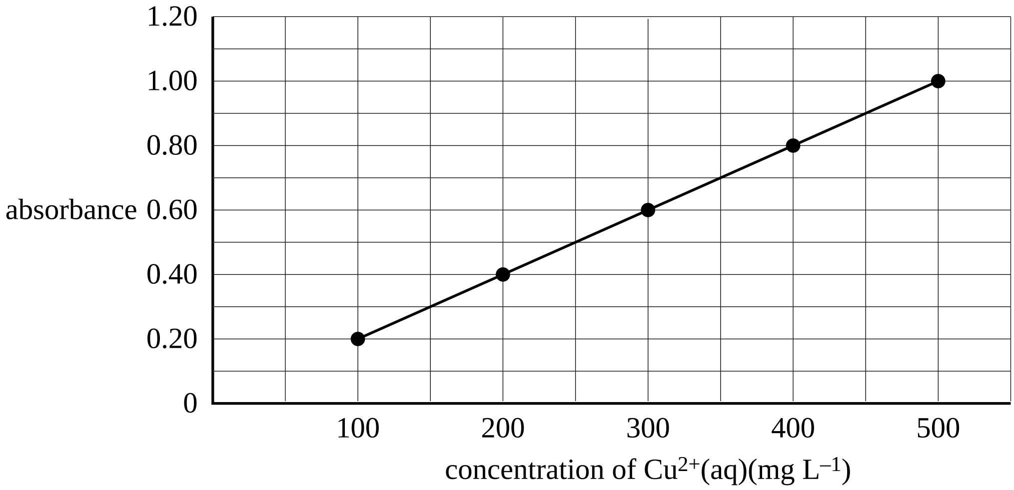
An experiment was carried out to determine the purity of the copper anode that had been used in the electroplating cell. A 0.855g sample of copper plate is removed from the medal and dissolved in nitric acid, producing a solution of copper(II) ions, $Cu^{2+}(aq)$.

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

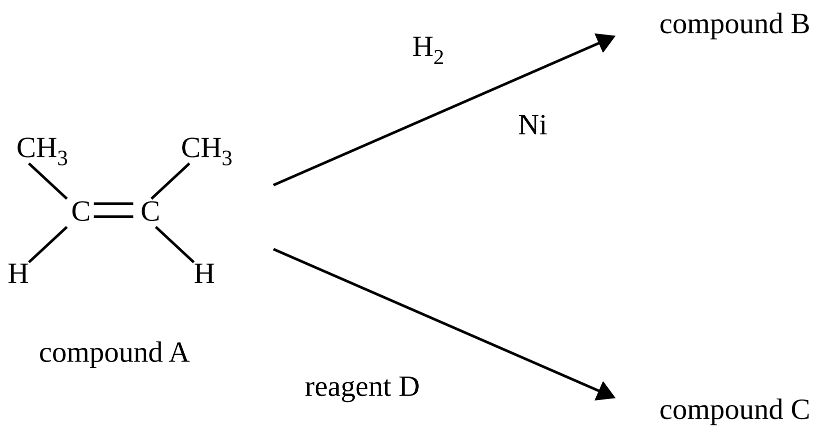


c. **i.** What is the concentration, in mg L^{-1}, of $Cu^{2+}(aq)$ ions in the diluted solution in the volumetric flask? 1 mark

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

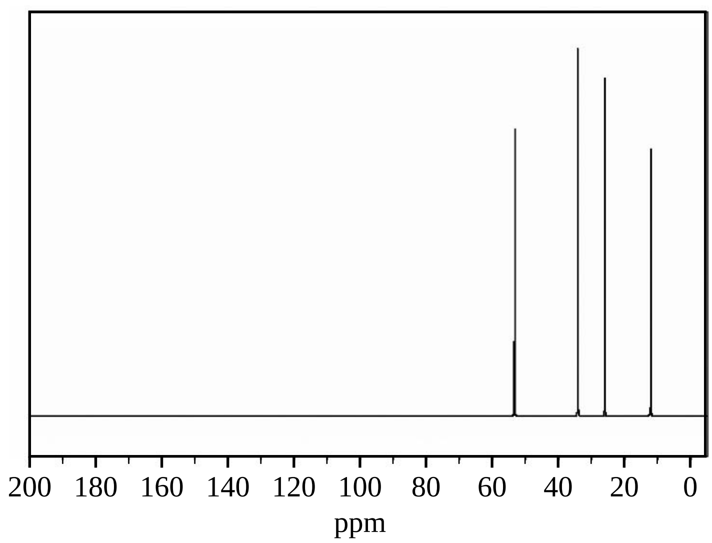
Question 3 (8 marks)

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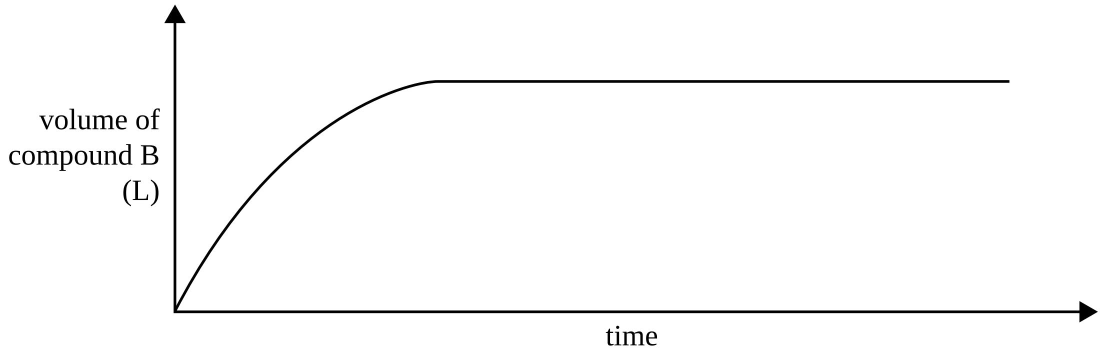
The graph below shows the volume of compound B formed over time **without** the nickel catalyst present.



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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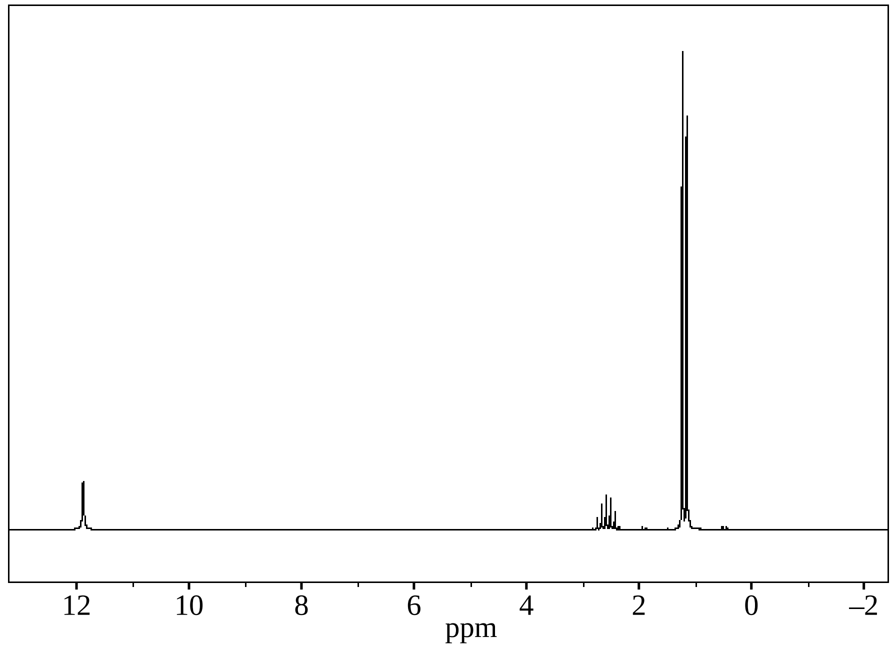
Question 4 (18 marks)

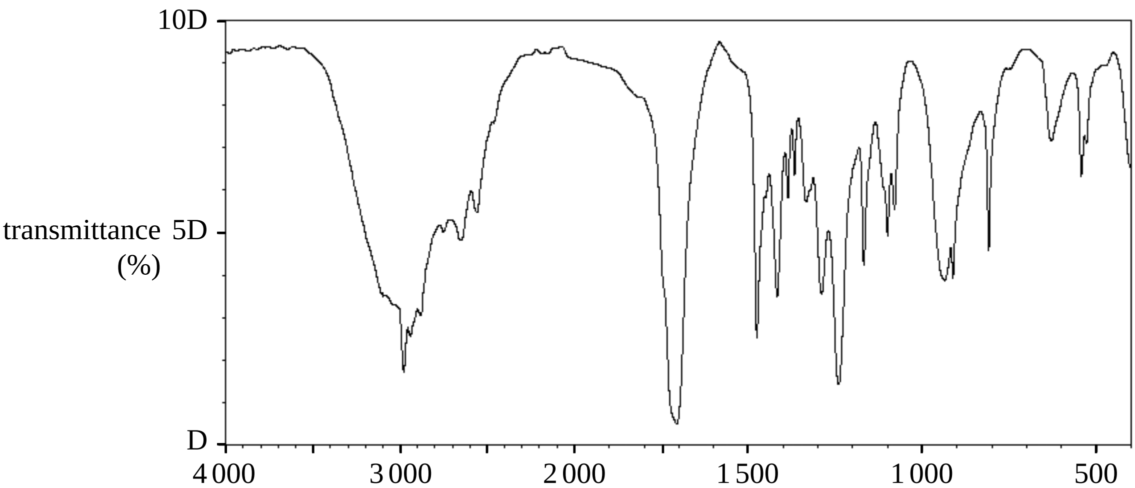
A student is to determine the identity and concentration of a solution of a weak, monoprotic acid, HA, with molecular formula $C_4H_8O_2$.

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

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

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

i. 3000 cm^{-1} ______________________________

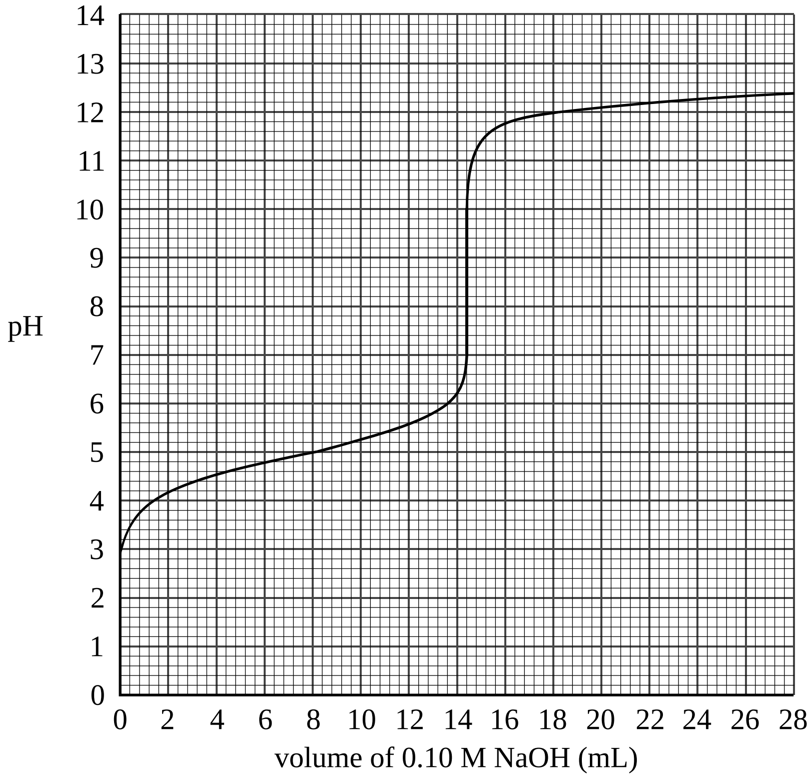
ii. 1700 cm^{-1} ______________________________

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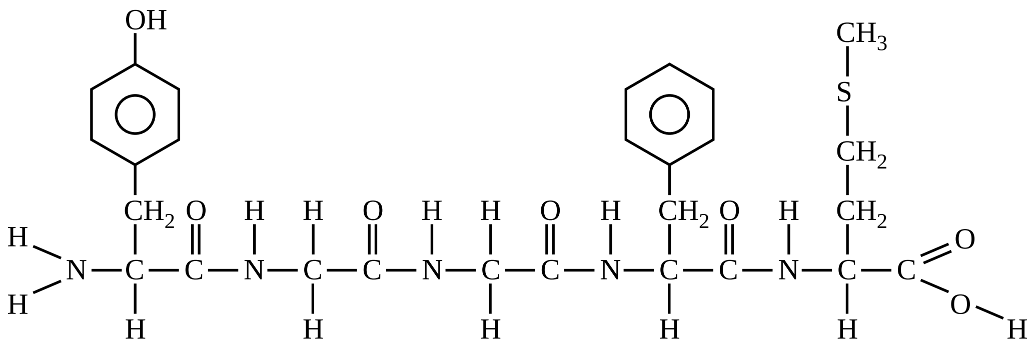
iii. the concentration of hydronium ions, H_3O^+, in the solution of HA before it was reacted with NaOH 2 marks

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

Question 5 (6 marks)

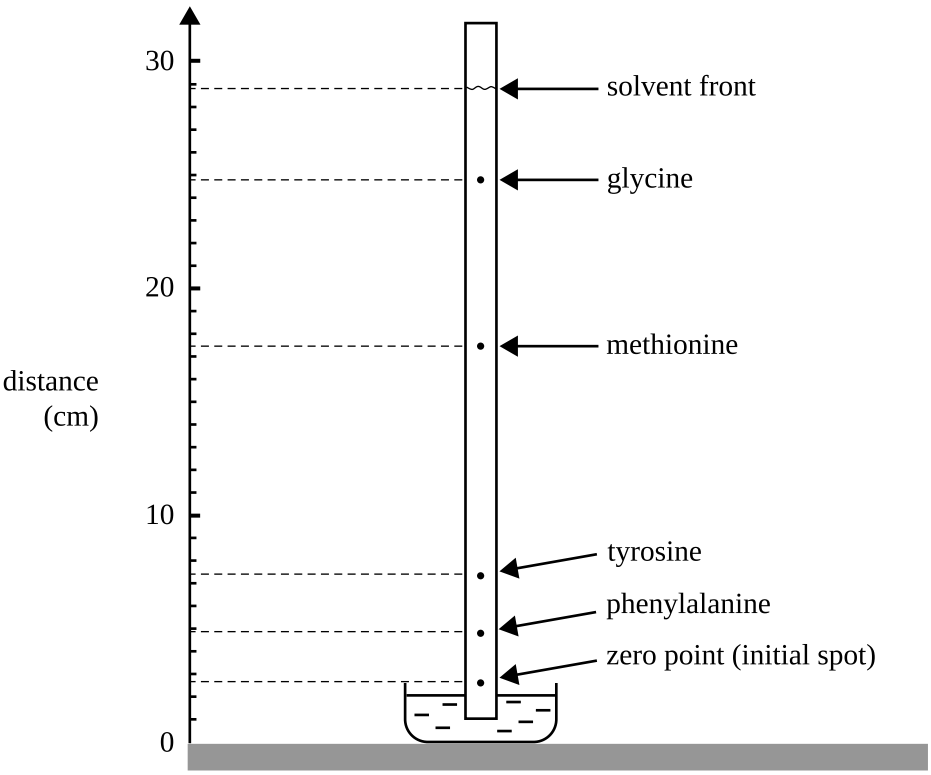
Chromatography is often used for the analysis of the mixture of amino acids that is formed when proteins are broken down. The small protein methionine enkephalin has some painkilling activity. The amino acids that make up this protein include methionine, phenylalanine, tyrosine and glycine.

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

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

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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

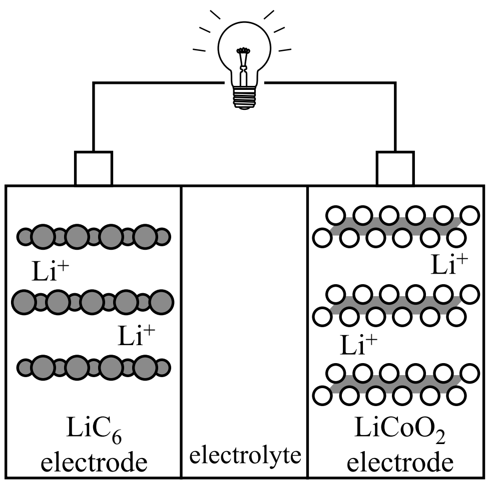
In lithium ion cells, lithium ions move between the electrodes as the cell is discharged and recharged. The negative electrode consists of lithiated graphite, LiC_6, and the positive electrode consists of lithium cobalt oxide, $LiCoO_2$.

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



SECTION B – continued

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

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

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

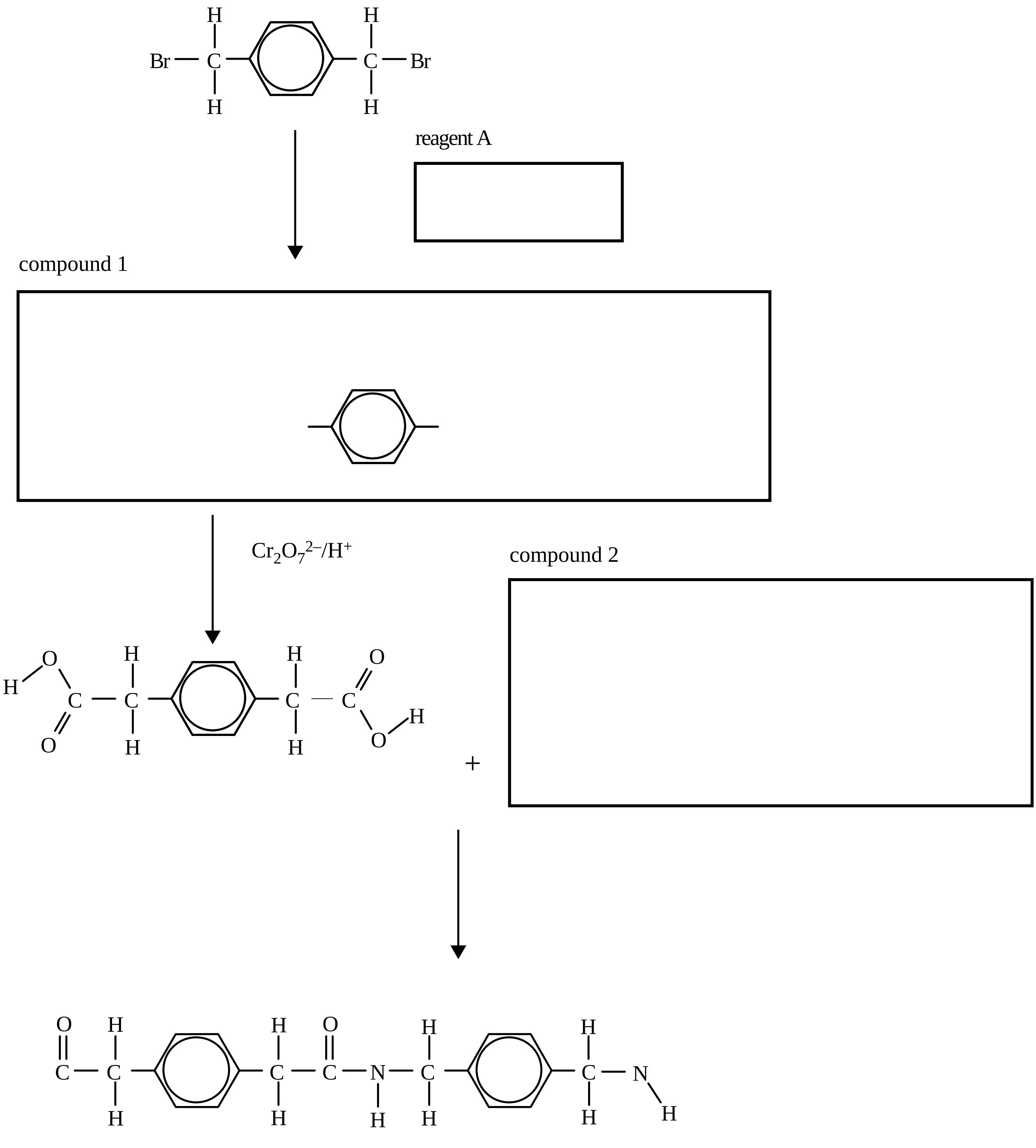
c. Earth's oceans contain significant amounts of dissolved carbon dioxide. The dissolving process can be described by the following chemical equilibria.

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

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

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

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

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

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}.)

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

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

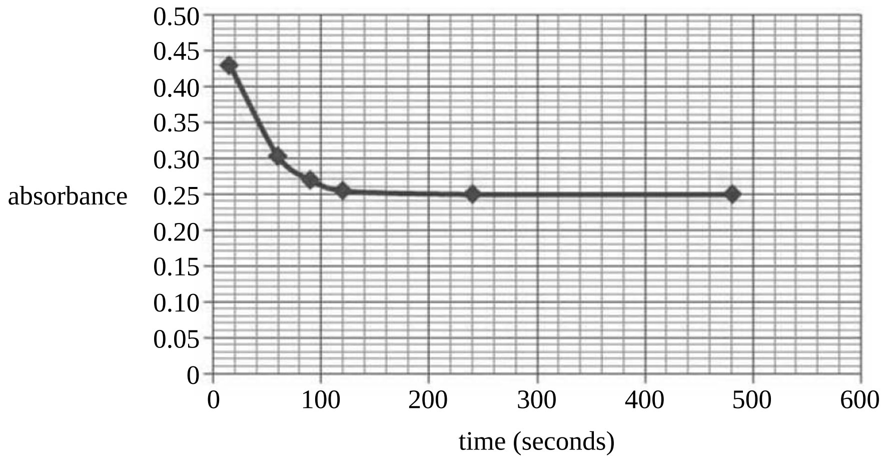
The concentration of X can be determined using UV-visible spectroscopy. X absorbs strongly at 290 nm. Y shows no absorption at this wavelength.

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

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

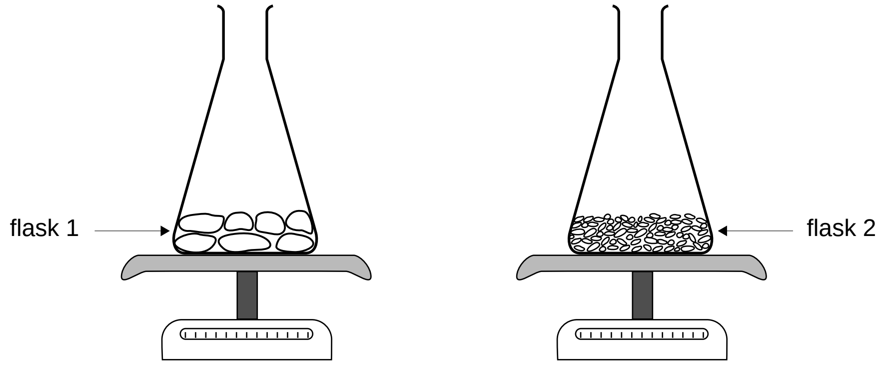
The experiment will be conducted using two flasks.

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