CSSA

2023
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

MARKING GUIDELINES

Chemistry

Section I

20 marks
Questions 1-20 (1 mark each)

Question	Answer	Outcomes Assessed	Targeted Performance Band
1	A	CH11/12-5, CH12-15	2-3
2	D	CH11/12-2, CH12-13	2-3
3	B	CH12-14	2-3
4	C	CH11/12-2, CH12-13	3-4
5	C	CH12-13	3-4
6	B	CH12-14	3-4
7	C	CH12-12	3-4
8	B	CH12-15	3-4
9	D	CH12-14	3-4
10	D	CH12-14	3-4
11	B	CH11/12-5, CH12-12	4-5
12	A	CH11/12-5, CH12-13	4-5
13	D	CH11/12-6, CH12-13	4-5
14	A	CH12-14	4-5
15	A	CH11/12-5, CH12-15	4-5
16	A	CH12-14	4-5
17	C	CH11/12-6, CH12-13	5-6
18	C	CH11/12-6, CH12-13	5-6
19	B	CH11/12-5, CH12-12	5-6
20	D	CH11/12-6, CH12-15	5-6

Section II

80 marks
Question 21 (4 marks)
Outcomes Assessed: CH11/12-2, CH12-15
Targeted Performance Bands: 2-4

Criteria	Marks
• Describes chemical tests that clearly identify the THREE separate cations AND includes a correct relevant equation	4
• Describes chemical tests that clearly identify THREE separate cations OR • Describes chemical tests that clearly identify TWO separate cations AND includes a correct relevant equation	3
• Describes chemical tests that clearly identify TWO separate cations	2
• Any relevant information	1

Sample Answer:

1. Add dilute HCl to a sample of each (or any source of chloride ions like NaCl).
   A white precipitate will form indicating the presence of Ag^+.

   $Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s)$

2. To the remaining samples, add dilute NH_3 (or any source of dilute hydroxide ions, like NaOH).
   A pale green precipitate will form indicating the presence of Fe^{2+}.

   $Fe^{2+}(aq) + 2\ OH^-(aq) \rightleftharpoons Fe(OH)_2(s)$

3. To confirm the presence of Ca^{2+}, conduct a flame test.
   A red flame indicates the presence of Ca^{2+}.

Question 22 (4 marks)

Question 22 (a) (1 mark)

Outcomes Assessed: CH12-14

Targeted Performance Bands: 3-4

Criteria	Marks
• Provides correctly balanced symbol equation	1

Sample Answer:

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

Question 22 (b) (3 marks)

Outcomes Assessed: CH12-14, CH11/12-6

Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly calculates the mass of butane used	3
• Provides some correct calculations	2
• Provides some relevant understanding	1

Sample Answer:

$q = m \times c \times \Delta T$

$q = 500\ ml \times 4.18 \times 80$

$q = 167200\ J$

$q = 167.2\ kJ$

$\Delta Hc = q/n$

$n = q/\Delta Hc$

$n = 167.2/2.88 \times 10^3\ kJ/mol$

$n = 0.0581\ mol$

$m\ (butane) = n \times MM$

$m\ (butane) = 0.0581 \times 58.12\ g/mol$

$m = 3.37\ g$

Question 23 (5 marks)
Question 23 (a) (2 marks)
Outcomes Assessed: CH11/12-6, CH12-12
Targeted Performance Bands: 3-4

Criteria	Marks
• Writes a correct equilibrium expression and correctly substitutes the concentrations	2
• Writes a correct equilibrium expression OR correctly calculates the concentrations	1

Sample Answer:

	$NO_2(g)$	+	$ClNO(g)$	⇌	$ClNO_2(g)$	+	$NO(g)$
R	1		1		1		1
I	2.4		4.0		0		0
C	-0.15		-0.15		+0.15		+0.15
E	2.25		3.85		0.15		0.15
[ ] (V=5 L)	0.45		0.77		0.03		0.03

$K = [ClNO_2]x[NO]/([NO_2]x[ClNO]) = (0.03x0.03)/(0.45x0.77) = 2.6x10^{-3}$

Question 23 (b) (3 marks)
Outcomes Assessed: CH12-12
Targeted Performance Bands: 2-5

Criteria	Marks
• Explains how both kinetics AND equilibrium could be controlled to maximise yield	3
• Describes features of kinetics and/or equilibrium for controlling yield	2
• Identifies a relevant feature of kinetics or equilibrium	1

Sample Answer:

An increase in pressure causes more favourable collisions, but both sides have equal moles of gases, so there is no effect on the equilibrium position. So, a higher (safe) pressure would be preferred.

An increase in temperature will add kinetic energy to the systems increase the number of collisions, however, the endothermic reaction is favoured as temp increases, so a decrease will favour the products. So, a moderate temperature is preferred.

A catalyst creates an alternate reaction pathway with lower energy which will make the reaction reach equilibrium faster, countering a lower than ideal temperature for kinetics.

Question 24 (5 marks)

Question 24 (a) (1 mark)

Outcomes Assessed: CH12-14

Targeted Performance Bands: 3-4

Criteria	Marks
• Correctly orders molecules from lowest to highest boiling point	1

Sample Answer:

Lowest - butane -propanal - ethanamide - **highest**

Question 24 (b) (4 marks)

Outcomes Assessed: CH12-14

Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly identifies the different types of intermolecular bonding AND • Correctly links strength of bond to the boiling point	4
• Correctly identifies some of the different types of intermolecular bonding OR • Correctly links strength of bond to the boiling point	2-3
• Any relevant information	1

Sample Answer:

- Butane has the lowest boiling point as the only forces present are weak dispersion forces. Less energy is needed to break these bonds between molecules thus a lower boiling point.
- Propanal also has dispersion forces but additionally contains polar bonds (C=O) and can therefore form dipole-dipole forces with other molecules. These attractions are stronger and therefore require more energy to overcome, hence a higher boiling point.
- Ethanamide has the highest boiling point as it is able to form strong hydrogen bonds with other molecules (NH--OC), as well as dispersion and dipole-dipole forces. These require more energy to break and therefore result in a high boiling point.

Question 25 (6 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 2-6

Criteria	Marks
• Shows a comprehensive understanding of the environmental, social and economic impacts of fossil fuels and biofuels • Outlines positive and negative aspects of both fuels • Makes an informed judgement • Includes a relevant chemical equation	6
• Shows a detailed understanding of the environmental, social and economic impacts of fossil fuels and biofuels • Outlines positive and negative aspects of both fuels AND • Makes an informed judgement OR • Includes a relevant chemical equation	4-5
• Describes positive features of either fuel OR • Describes negative features of either fuel OR • Describes some environmental, social and economic impacts of fossil fuels and biofuels	2-3
• Provides any relevant information	1

Sample Answer:

Fossil Fuels

- Used for fuels – such as natural gas for cooking, crude oil for petrol, diesel and aviation fuel, and coal for electrical power stations. Our society derives most its domestic and industrial energy needs from these fossil fuels.
- Used as a starting material for other organics, such as ethanol and polymers. Our society and economics have a huge reliance on fossil fuels for a breadth of consumer products. Fossil fuels remain the dominant supplier of starting ingredients for these compounds.
- High energy content compared to other sources so more cost efficient compared to other fuel sources.
- Limited reserves resulting in high prices, leading to negative effects on members of society, such as inequity between social classes based on income.
- Combustion of fossil fuels releases carbon dioxide which contributes heavily to global warming and the effects of climate change. Governments are beginning to acknowledge the massive impact this could have on the environment and society for generations to come.
- Extraction process is harmful to the environment - mining/oil spills etc.

As an example, the complete combustion of butane produces carbon dioxide, a greenhouse gas:

C_4H_{10} (g) + 13/2 O_2 (g) → 4 CO_2 (g) + 5 H_2O (l)

Biofuels

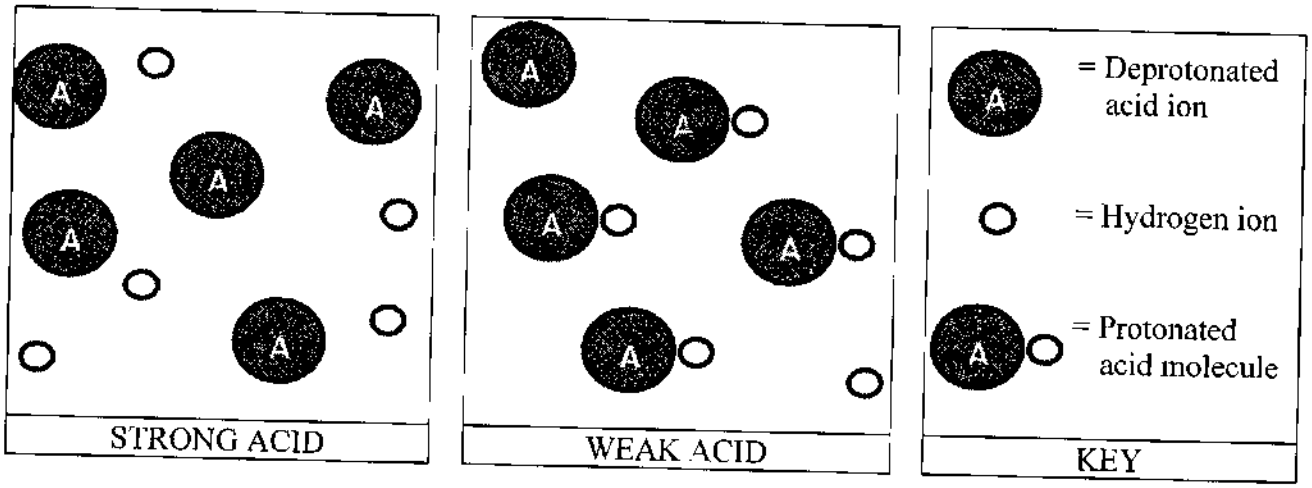
- Widespread, but limited, use as a petrol extender. The cost of producing usable quantities of biofuels has been relatively high and not competitive with fossil fuel production, thereby requiring significant government investment (potentially at the expense of alternative projects for society).
- Renewable resource but land space is needed to grow crops, therefore land needs to be cleared and possibly at the expense of food crops for a growing population.
- Can be made from waste products and therefore reduces waste, which is beneficial to the economy, the environment and society in general.
- Carbon dioxide production is partially offset by growing crops. While not completely carbon-neutral (due to energy requirements for harvesting and processing), it does minimise the impact on the atmosphere as a cyclic process.
- Lower energy content than petrol, more needs to be combusted to release the same amount. This leads to higher fuel costs for families and/or greater investment by governments.

Judgement: Considering the non-renewable nature of fossil fuels, coupled with the harsh environmental impacts, biofuels offer a sustainable alternative with reduced environmental impacts. More investment is needed to promote the use of biofuels in society.

Question 26 (6 marks)
Question 26 (a) (3 marks)
Outcomes Assessed: CH12-13
Targeted Performance Bands: 2-4

Criteria	Marks
• Draws a clear diagram or clearly describes a model, which demonstrates a clear difference between the ionisation of strong and weak acids, including labelling	3
• Draws a diagram or describes a model, which demonstrates some difference between the ionisation of strong and weak acids	2
• Provides some relevant information	1

Sample Answer:



An alternative answer could show dance partners in a dance hall– strong acids have decoupled dancers (like the start of a primary school dance!), while weak acids are like a dance floor with most couples together.

Question 26 (b) (3 marks)
Outcomes Assessed: CH11/12-6, CH12-13
Targeted Performance Bands: 3-6

Criteria	Marks
• Explains all THREE colours correctly for the salt solutions, with appropriate equations	3
• Describes at least TWO colours correctly for the salt solutions, with ONE appropriate equation	2
• Identifies ONE correct colour OR writes a correct equation	1

Sample Answer:

- NH_4Cl is the product of the neutralisation of a strong acid (HCl) and a weak base (NH_3), so it will be an acidic salt. Hence the colour would red/orange. NH_4^+ is the conjugate acid of a weak base, so will predominantly form ammonia and the hydronium ion, which will cause the solution to be acidic.
- $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
- NaCl is the product of the neutralisation of a strong acid (HCl) and a strong base (NaOH), so it will be a neutral salt solution, and so it would be green.
- $NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$
- NaF is the product of the neutralisation of a weak acid (HF) and a strong base (NaOH), so it will be a basic salt solution. Hence the colour would be dark green/purple. The F^- is the conjugate of a weak acid and therefore will react with water to form OH^-, which will cause the solution to be basic:
- $F^-(aq) + H_2O(l) \rightleftharpoons HF(aq) + OH^-(aq)$

Question 27 (3 marks)
Outcomes Assessed: CH12-13
Targeted Performance Bands: 3-5

Criteria	Marks
• Provides a clear definition of a buffer AND • Provides TWO correct chemical equations	3
• Provides a clear definition of a buffer AND ONE correct chemical equation OR • Provides TWO correct chemical equations	2
• Provides some relevant information	1

Sample Answer:

- The pH of a buffer resists small additions of acids or bases. $H_2PO_4^-$ is amphiprotic, so can gain or lose protons to form conjugate acids and bases.
- If a small amount of acid is added, the $H_2PO_4^-$ ion can react with the additional acid to form phosphoric acid, thus partially removing some of the additional hydronium ions and minimising the pH change:
- $H_2PO_4^-(aq) + H_3O^+(aq) \rightleftharpoons H_3PO_4(aq) + H_2O(l)$
- If a small amount of base is added, the $H_2PO_4^-$ ion can react with the additional hydroxide ions to form HPO_4^{2-} ions, thus partially removing some of the hydroxide ions and minimising the pH change:
- $H_2PO_4^-(aq) + OH^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + H_2O(l)$
- Hence, the addition of small amounts of acid or base result in only very small changes in blood pH.

Question 28 (4 marks)

Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-15

Targeted Performance Bands: 3-6

Criteria	Marks
• Accounts for THREE relevant factors • Makes specific reference to the flow chart	4
• Accounts for TWO relevant factors with some reference to the flow chart OR • Accounts for THREE relevant factors without specific reference to the flow chart	3
• Accounts for ONE relevant factor OR • Outlines TWO relevant factors	2
• Any relevant information	1

Sample Answer:

Students could choose three factors from any of the factors below (anything reasonable based on the process):

- Access to raw materials needs to be considered. The plant would be located near the ocean so that brine would be easily accessible.
- Also, it would be preferable that the plant would be located near a limestone quarry with a road/rail network to get the limestone.
- Markets need to be accessed for sodium carbonate. This means that the product can be sold to suppliers ensuring the process is economically viable. So, the plant would need to be located near a port and/or road and rail networks, to meet supply needs.
- While ammonia is recovered during the process, so it can then be reused, it will still be needed, so access to ports will be necessary (or access to a Haber plant?).
- The plant will need energy/electricity to run, so will need to be located to have reliable access to energy (renewable energy would be good – solar, wind and/or tidal).
- Pollution needs to be considered. Ammonia is a smelly, poisonous gas, and if it escaped it could cause respiratory problems for people. So, you want the plant away from residential areas if possible (but not so far that it is hard for workers to commute to the plant).

Question 29 (4 marks)
Outcomes Assessed: CH11/12-2, CH12-15
Targeted Performance Bands: 3-6

Criteria	Marks
• Evaluates at least FOUR steps, including explaining at least THREE errors	4
• Evaluates at least THREE steps, including describing at least TWO errors	3
• Evaluates at least TWO steps, including identifying at least ONE error	2
• Provides some relevant information	1

Sample Answer:

Step 1: Good step. The reason for the dilution to make the concentration required for neutralisation less, for a more workable volume.

Step 2: A standard solution is accepted way to determine the concentration of an acid, as you know the exact concentration of the sodium carbonate, because it has been made by the company. **BUT** should have specified the distilled water as the ions in the normal tap water may cause other reaction and also impact concentration, as there is no control over the ions present in the water, there may be carbonate ions present in the water, which will impact concentration; **AND** there is no mention of the glassware needed for this step (presumably a volumetric flask).

Step 3: The student describes a typical titration, which is the next reasonable step **BUT** does not explicitly include a burette in the method **AND** they have not chosen an appropriate indicator for this type of titration (weak base/strong acid).

Step 4: Because the student is determining unknown acetic acid, it is reasonable to prepare a primary standard for an acid, then to standardise a base (NaOH). NaOH cannot be used as a primary standard for a number of reasons, such as being hygroscopic. **HOWEVER**, some might expect the titration to take place in a conical flask.

Step 5: Due to the addition of a base the pH will rise and phenolphthalein changes to pink around pH10 and is a reasonable indicator. This step is repeated to find an average which increases the reliability of the experiment.

Step 6. A calculation is needed **BUT** this step doesn't mention that the final value needed to be multiplied by 10, due to the 1 in 10 dilution of the original vinegar solution. **ALSO**, this calculation will give you a concentration in mol/L and needs to be converted to compare with the original units of 5% (v/v).

Students may suggest using a different primary standard, such as oxalic acid or potassium hydrogen phthalate, to standardise the sodium hydroxide, thereby skipping a couple of steps (and potential errors). This is a valid and beneficial alternative to the given procedure and so, holistically, depending on the depth of the explanation, could be worth higher than one mark.

Question 30 (5 marks)

Outcomes Assessed: CH11/12-5, CH12-12

Targeted Performance Bands: 3-6

Criteria	Marks
• Correctly calculates the pH, with working	5
• Calculates the pH, with ONE error	4
• Correctly shows some steps in the calculation	2-3
• Identifies a correct step	1

Sample Answer:

$Ksp = [Mg^{2+}][OH^-]^2$

Let [OH-] = S

$5.61 \times 10^{-12} = 0.0073 \times S^2$

$S^2 = \frac{5.61 \times 10^{-12}}{0.0073}$

$S = \sqrt{7.68493 \times 10^{-10}}$

$S = 2.7717 \times 10^{-5}$

$pOH = -\log[2.7717 \times 10^{-5}] = 4.55716$

$pH = 14 - 4.55716$

$pH = 9.44$

Solution will start to precipitate at pH 9.44

Question 31 (4 marks)
Question 31 (a) (1 mark)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 3-4

Criteria	Marks
• Correctly explains why the molecules are position isomers	1

Sample Answer:

Isomer A and B have the same molecular formula and the same functional group. The functional group is located on a different carbon atom.

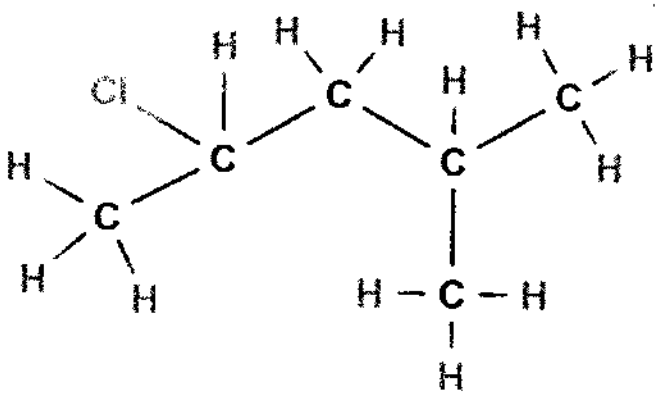
Question 31 (b) (3 marks)

Outcomes Assessed: CH12-14, CH11/12-6
Targeted Performance Bands: 3-6

Criteria	Marks
• Identify the second reactant • Draw the second product • Name the second product • Identify the major product	3
• Any TWO of the above	2
• Identifies a second reactant OR product	1

Sample Answer:

The alkene needs to be reacted with **HCl**. From this reaction, Isomer B will be produced. The other product, and **major product** will be **2-chloro-4-methylpentane** (due to Markovnikov's Rule – but explanation is not required):



Question 32 (7 marks)

Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-13

Targeted Performance Bands: 2-6

Criteria	Marks
• Fully correct answer with ○ writes equation, with states for HCl + NaOH ○ calculates moles NaOH ○ shows ratio of HCl:NaOH ○ moles of $SiCl_4$ ○ mass of $SiCl_4$ ○ % purity of $SiCl_4$ ○ Correct significant figures	7
• Answer has major steps with some errors	4-6
• Answer contains ONE or TWO valid steps	2-3
• Contains some relevant information	1

Sample Answer:

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

n(NaOH) = 0.15 x 0.0193 = 0.002895 mol NaOH

From the equation, n(NaOH):n(HCl) = 1:1, therefore 0.002895 mol HCl

25 mL aliquot taken from 250 mL, therefore (x10) 0.02895 mol HCl

$SiCl_4(s) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$

From the equation, $n(SiCl_4) = \frac{1}{4} \times n(HCl)$

$n(SiCl_4) = 0.02895/4 = 0.0072375$ mol

m = n x MM

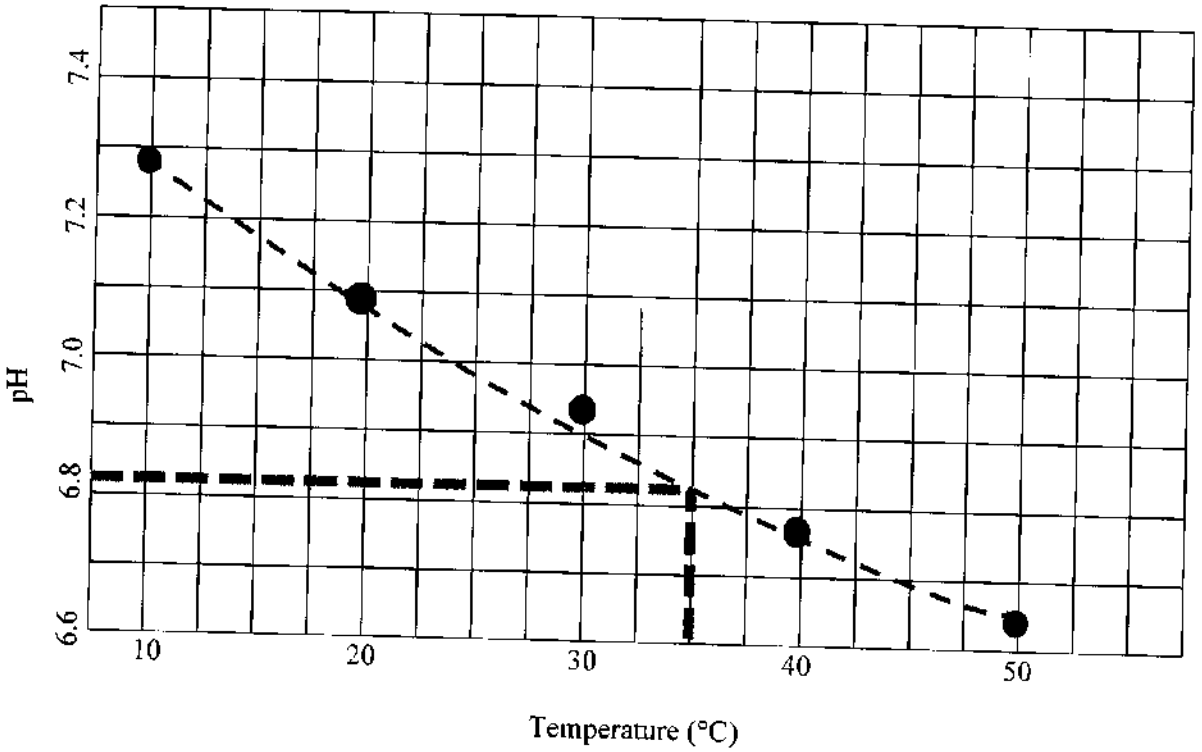
0.0072375 x 169.89 = 1.2296 g $SiCl_4$ in sample

% purity = 1.2296/1.49 x 100 = 82.522% = 83% pure $SiCl_4$ in sample (2sf)

Question 33 (4 marks)
Question 33 (a) (1 mark)
Outcomes Assessed: CH11/12-4
Targeted Performance Bands: 2-3

Criteria	Marks
• Correctly plots all points and includes a reasonable line of best fit (straight or slightly curved)	1

Sample Answer:



Question 33 (b) (3 marks)
Outcomes Assessed: CH11/12-5, CH12-12
Targeted Performance Bands: 3-6

Criteria	Marks
• Uses graph to approximate pH • Determines [H+] using pH = log[H+] • Determines [OH-] using [H+] • Correctly calculates Kw	3
• Correctly completes at least TWO steps in the calculation	2
• Identifies any relevant information	1

Sample Answer:

From the graph, pH = 6.82± 0.02 (depends on their graph).
$[H+] = 10^{-pH} = 10^{-6.82}$

$H_2O\ (l) \rightleftharpoons H^+ + OH^-$
So $[OH-] = [H+] = 10^{-6.82}$

$Kw = [H+]x[OH-] = 10^{-6.82} \times 10^{-6.82} = 10^{-13.64} = 2.3 \times 10^{-14}$

Question 34 (6 marks)

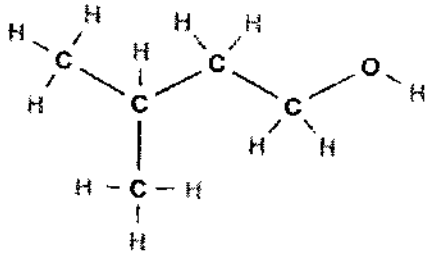
Question 34 (a) (5 marks)

Outcomes Assessed: CH11/12-6, CH12-14, CH12-15

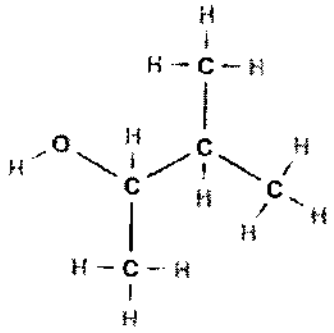
Targeted Performance Bands: 2-6

Criteria	Marks
• Correctly draws AND names all FOUR organic molecules	5
• Correctly draws AND names some of the four molecules	3-4
• Correctly draws OR names some of the four molecules	2
• Correctly draws OR names ONE of the four molecules	1

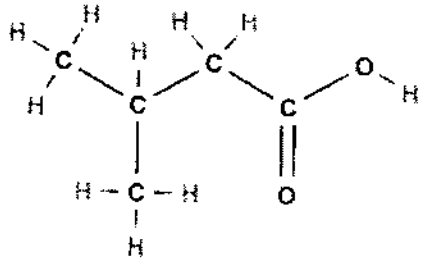
Sample Answer:



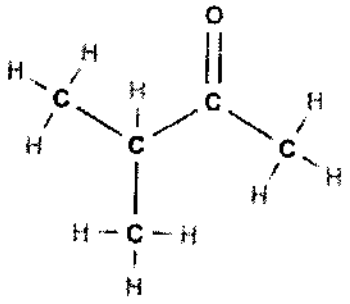
A - 3-methylbutan-1-ol



B- 3-methylbutan-2-ol



C - 3-methylbutanoic acid



D- 3-methylbutan-2-one

Question 34 (b) (1 mark)
Outcomes Assessed: CH11/12-2, CH12-14
Targeted Performance Bands: 3-4

Criteria	Marks
• Correctly provides ONE reason for using a reflux apparatus	1

Sample Answer:

The condenser on the reflux apparatus allows for volatile products and reactants to remain in liquid form to react. Reflux allows the reaction to occur under high heat, which speeds up the reaction.

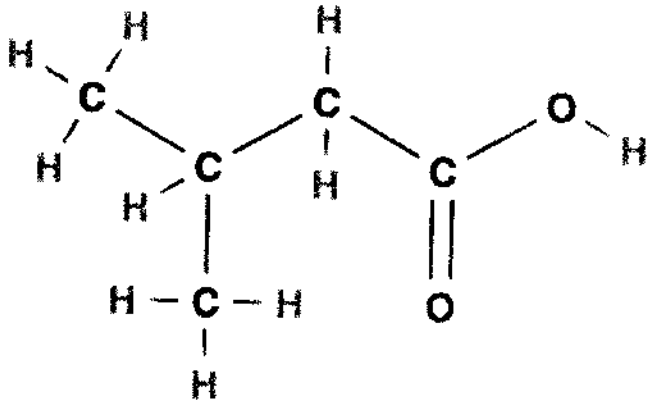
Question 35 (7 marks)

Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-14, CH12-15

Targeted Performance Bands: 2-6

Criteria	Marks
• Draws correct structure of 3-methylbutanoic acid • Justifies the correct structure showing an extensive understanding of the interpretation of spectroscopic data • References the relevant spectroscopic data	7
• Draws correct structure for 3-methylbutanoic acid • Justifies the structure showing a thorough understanding of the interpretation of spectroscopic data • References spectroscopic data	6
• Shows a sound understanding of the interpretation of spectroscopic data • Uses relevant information presented in the question to justify the structure of the compound • Provides a structural formula consistent with the analysis	4-5
• Demonstrates some understanding of the interpretation of spectroscopic data	2-3
• Provides any relevant information	1

Sample Answer:



Infra-red

O-H (broad) peak at 2500-3000cm^{-1} consistent with carboxylic acid

C=O peak at 1680-1750cm^{-1} consistent with carboxylic acid

^{13}C–NMR

4 peaks = 4 carbon environments, however 5 carbons in molecular formula, suggesting symmetrical carbon environments for two carbons.

Peak at 180ppm is consistent with acids.

^{1}H–NMR

4 peaks = 4 hydrogen environments

A singlet (OH) – peak area and splitting are consistent with an isolated hydrogen atom on an oxygen.

A doublet (CH_2) – peak area is consistent with a CH_2 group, with splitting consistent with having a neighbouring carbon with one hydrogen atom.

A nonet (CH) – peak area is consistent with a CH group, with splitting consistent with having neighbouring carbons with 8 hydrogen atoms in total ($2xCH_3 + CH_2$)

A doublet ($2xCH_3$) – peak area is consistent with two CH_3 groups attached to the same carbon, which has a single hydrogen atom, which is consistent with the splitting.

Question 36 (6 marks)
Question 36 (a) (2 marks)
Outcomes Assessed: CH11/12-5, CH12-12
Targeted Performance Bands: 3-5

Criteria	Marks
• Correctly calculates the concentration	2
• Provides some relevant information	1

Sample Answer:

$Ksp = [Ba^{2+}][NO_3]^2 = 4.6x10^{-3}$

Let $[Ba^{2+}] = x$; therefore $[NO_3^-] = 2x$

$[x][2x]^2 = 4x^3 = 4.6x10^{-3}$

$x = 0.1048$ mol/L

Question 36 (b) (4 marks)
Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-12
Targeted Performance Bands: 2-6

Criteria	Marks
• Determines the correct age range for people affected by the barium	4
• Completes most of the main steps	3
• Completes ONE relevant calculation	2
• Provides some relevant information	1

Sample Answer:

Mass of $Ba(NO_3)_2$ in the paint = (10 x 10) x (0.01/100) = 0.01 g

$m(Ba^{2+}) = 0.01 \times (137.3/261.32) = 0.00525$ g = 5.25 mg

Divide by the minimum value (0.125 mg/L) to determine the critical body volume:

Critical volume to impact heart is 5.25/0.125 = 42 L

People with a body mass less than 42 litres would suffer some effects of barium poisoning, that is, an average person under about 71 years of age.

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