2024
TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

CSSA

MARKING GUIDELINES

Chemistry

Section I

20 marks
Questions 1–20 (1 mark each)

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

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Section II

80 marks
Question 21 (3 marks)
Question 21 (a) (1 mark)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 2–3

Criteria	Marks
• Describes ONE difference between a condensation and addition polymer	1

Sample Answer:

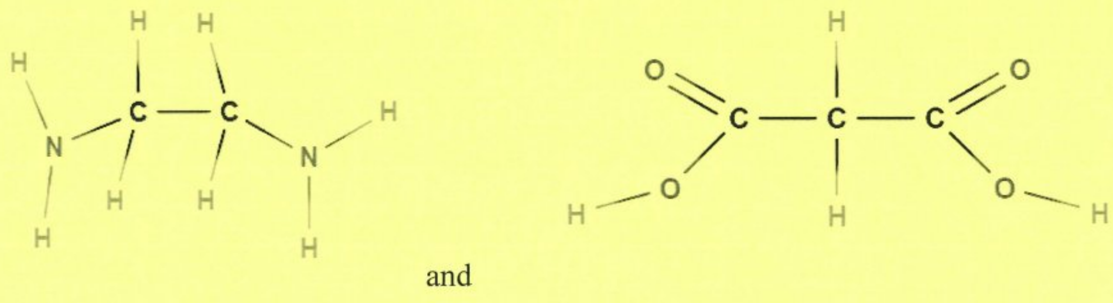
Answers may include, but not be limited to:

- Addition monomers usually have double bonds
- Simple addition polymers mainly start with one monomer
- Simple condensation polymers typically start with two different monomers
- Condensations reactions result in the polymer being more condensed than the combined monomers
- Condensation reactions usually produce a small molecule, like water, as a bi-product

Question 21 (b) (2 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 3–4

Criteria	Marks
• Correctly draws BOTH organic molecules	2
• Correctly draws ONE organic molecule	1

Sample Answer:



Question 22 (3 marks)
Outcomes Assessed: CH12-13
Targeted Performance Bands: 2–5

Criteria	Marks
• Explains the major difference between the theories using the reaction • Includes a balanced chemical equation, with states	3
• Outlines the major difference between the theories OR • Outlines an outline of a theory AND includes a balanced chemical equation	2
• Provides some relevant information	1

Sample Answer:

$HF(g) + NH_3(g) \rightleftharpoons NH_4F\ (s)$

The Arrhenius theory involves the production of hydrogen ions and hydroxide ions in solution. This reaction involves the gaseous and solid state, and there is no aqueous state for the formation of ions. However, the Bronsted-Lowry theory involves the donation and acceptance of protons, and does not require an aqueous state. Unlike the Arrhenius theory, this reaction would be considered an acid/base reaction under the Bronsted-Lowry theory.

Question 23 (5 marks)
Question 23 (a) (1 mark)
Outcomes Assessed: CH12-12
Targeted Performance Bands: 3–4

Criteria	Marks
• Correct balanced chemical equation with at least the solid state provided	1

Sample Answer:

$SrCl_2\,(aq) + Na_2SO_4\,(aq) \rightarrow SrSO_4\,(s) + 2\,NaCl\,(aq)$

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

Criteria	Marks
• Calculates the moles of both reactants to show they are equimolar • Correctly calculates the strontium ion concentration	3
• Correctly calculates the strontium ion concentration, without justification OR • Shows some steps towards calculating the strontium ion concentration, with some reasonable attempt at justification	2
• Provides some relevant information	1

Sample Answer:

$n(SrCl_2) = c \times V = 0.040 \text{ mol/L} \times 0.2000 \text{ L} = 8.0 \times 10^{-3} \text{ mol}$
$n(Na_2SO_4) = c \times V = 0.016 \text{ mol/L} \times 0.5000 \text{ L} = 8.0 \times 10^{-3} \text{ mol}$
Therefore, the combined solutions contain equal moles of reactants, so will have equal moles of strontium and sulfate ions in solution after precipitation.

$K_{sp}(SrSO_4) = [Sr^{2+}] \times [SO_4^{2-}] = 3.44 \times 10^{-7}$
Let $[Sr^{2+}] = x$
$x^2 = 3.44 \times 10^{-7}$
$x = 5.9 \times 10^{-4}$ (2sf)

Therefore the concentration of strontium ions is 5.9×10^{-4} mol/L.

Question 23 (c) (2 marks)
Outcomes Assessed: CH12-12
Targeted Performance Bands: 2–4

Criteria	Marks
• Accounts for change in system of strontium ions moving in and out of solution stating dynamic equilibrium.	2
• Provides some relevant information	1

Sample Answer:

The system has reached a dynamic equilibrium where the strontium ions are moving in and out of solution, therefore radioactive strontium ions are detected in the solution, given enough time.

Question 24 (3 marks)
Outcomes Assessed: CH12-15
Targeted Performance Bands: 2–5

Criteria	Marks
• Describes ONE relevant chemical production for EACH chemical • Includes ONE equation (chemical or word)	3
• Describes ONE relevant chemical production for a chemical OR • Identifies ONE relevant chemical production for EACH chemical	2
• Identifies ONE relevant chemical industry	1

Sample Answer:

Sodium hydroxide:
Sodium hydroxide is used in the saponification reaction (making soap).

Sodium hydroxide + fat/oil → glycerol + soap

(Other chemical productions include (but are not limited to) using sodium hydroxide in producing textiles, food processing, paper manufacturing and aluminium ore processing)

Sulfuric acid:
Concentrated sulfuric acid is used as a dehydrating agent and catalyst in the production of esters.

$$\text{Alcohol} + \text{carboxylic acid} \xrightarrow{\text{Conc. } H_2SO_4} \text{ester} + \text{water}$$

(Other chemical productions include (but are not limited to) using concentrated sulfuric acid to convert an alcohol to an alkene or using dilute sulfuric acid to convert an alkene to an alcohol)

Question 25 (4 marks)
Question 25 (a) (3 marks)
Outcomes Assessed: CH11/12-2, CH12-12
Targeted Performance Bands: 2–4

Criteria	Marks
• Outlines a clear method for the investigation, with validity and safety included	3
• Outlines a method for the investigation. Some steps missing	2
• Some relevant steps provided	1

Sample Answer:

1. Prepare a hot water bath and cold water bath in two 250 mL beakers.

2. Transfer 15 mL of a 0.1 M cobalt chloride solution into three separate test tubes. Ensure safety glasses and gloves are worn.

3. Place one test tube into the hot water bath and another into the cold water bath. Leave the third test tube at room temperature. Record observation in table.

Question 25 (b) (1 mark)
Outcomes Assessed: CH12-12
Targeted Performance Bands: 4–5

Criteria	Marks
• Correctly justifies the reaction as endothermic, as written	1

Sample Answer:

The cobalt chloride solution is endothermic. According the Le Chatelier's Principle, when heat is applied to an endothermic system, the forward reaction is favoured, turning the solution blue and when heat is removed from the system, the system solution turns pink, favouring the reverse reaction.

$Co(H_2O)_6^{2+}(aq) + 4\ Cl^-(aq) + ENERGY \rightleftharpoons CoCl_4^{2-}(aq) + 6\ H_2O\ (l)$

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Question 26 (5 marks)
Question 26 (a) (1 mark)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 2–3

Criteria	Marks
• Provides correctly balanced chemical equation (states not required)	1

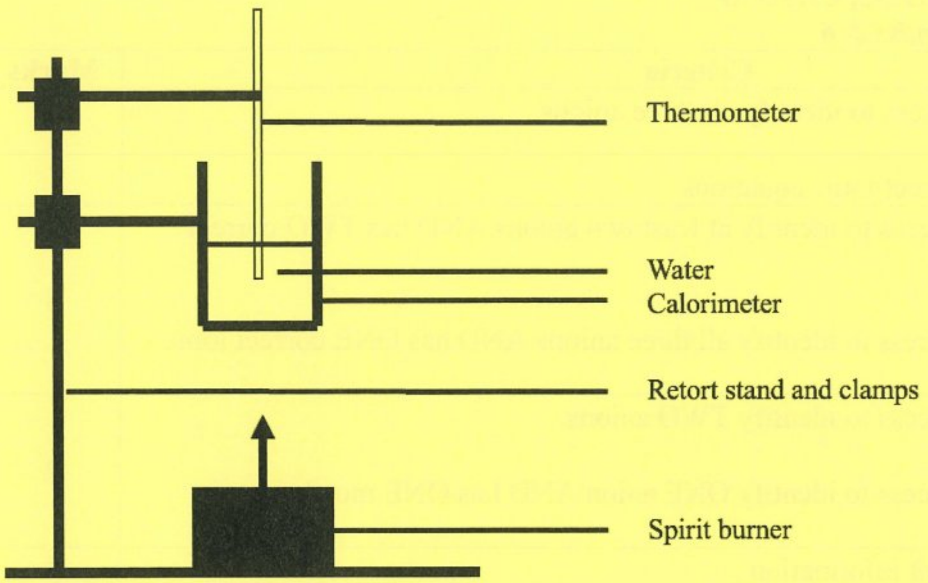
Sample Answer:

$C_4H_9OH (l) + 6 O_2 (g) \rightarrow 4 CO_2 (g) + 5 H_2O (g)$

Question 26 (b) (3 marks)
Outcomes Assessed: CH11/12-2, CH12-14
Targeted Performance Bands: 2–5

Criteria	Marks
• Outlines a logical method to collect data to determine the enthalpy of combustion of butanol AND • References quantities AND • Includes a correctly labelled diagram	3
• Outlines a logical method to collect data to determine the enthalpy of combustion of butanol AND/OR • References quantities AND/OR • Includes a correctly labelled diagram	2
• Provides some relevant information	1

Sample Answer:



1. Measure 100ml of water into a calorimeter.
2. Record starting temperature.
3. Weigh spirit burner containing butanol and record starting mass.
4. Light spirit burner.
5. Record highest temperature.
6. Weigh spirit burner and record final mass.
7. Repeat steps 1-6.

Question 26 (c) (1 mark)
Outcomes Assessed: CH11/12-5, CH12-14
Targeted Performance Bands: 3–4

Criteria	Marks
• Provides correct reason for difference in values	1

Sample Answer:

Heat loss to the surroundings.

Question 27 (4 marks)
Outcomes Assessed: CH11/12-2, CH12-15
Targeted Performance Bands: 2–6

Criteria	Marks
• Justifies a logical process to identify all three anions AND • Has at least TWO correct ionic equations	4
• Outlines a logical process to identify at least two anions AND has TWO correct ionic equations OR • Outlines a logical process to identify all three anions AND has ONE correct ionic equation	3
• Outlines a logical process to identify TWO anions OR • Outlines a logical process to identify ONE anion AND has ONE mostly correct ionic equation	2
• Provides some relevant information	1

Sample Answer:

STEP 1:
Add silver nitrate solution to a sample of each solution. The silver cations will react with both the solutions of chloride and carbonate to form white precipitates.
$Ag^{+}(aq) + Cl^{-}(aq) \rightarrow AgCl(s)$
$2\ Ag^{+}(aq) + CO_3^{2-}(aq) \rightarrow Ag_2CO_3(s)$

STEP 2:
To confirm between chloride and carbonate, add some dilute HNO_3 to each of the above samples. The silver carbonate will dissolve, the silver chloride will not dissolve.

STEP 3:
The sulfate sample will not form a precipitate with silver. To confirm this sample is sulfate, add barium nitrate solution to a fresh sample - a white precipitate will form and confirm the presence of sulfate.
$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

Question 28 (6 marks)
Question 28 (a) (2 marks)
Outcomes Assessed: CH11/12-6, CH12-12
Targeted Performance Bands: 2–4

Criteria	Marks
• Correctly demonstrates the calculation of the calcium ion concentration	2
• Provides some relevant information	1

Sample Answer:

Ksp = $[Ca^{2+}] \times [OH^-]^2 = 5.02 \times 10^{-6}$ (from the data sheet)
Let $[Ca^{2+}] = x$, so $[OH^-] = 2x$ (based on the solubility stoichiometry)

Therefore, $x \times (2x)^2 = 5.02 \times 10^{-6}$

$4x^3 = 5.02 \times 10^{-6} \rightarrow x^3 = 1.255 \times 10^{-6} \rightarrow x = 0.0107865$

$[Ca^{2+}] = 0.0108$ mol/L (3sf)

Question 28 (b) (4 marks)
Outcomes Assessed: CH11/12-6, CH12-13
Targeted Performance Bands: 3–6

Criteria	Marks
• Provides all steps to correctly calculate change in pH	4
• Provides most steps to correctly calculate change in pH	3
• Provides some steps to correctly calculate change in pH	2
• Provides some relevant information	1

Sample Answer:

Initial pH:

$[OH^-] = 2x = 2 \times 0.0108 = 0.0216$ mol/L

$pOH = -\log_{10}[OH^-] = -\log_{10}(0.0216) = 1.666$

$pH = 14 - pOH = 14 - 1.666 = 12.334$

Final pH:

$n(OH^-) = c \times V = 0.0216 \text{ M} \times 0.1000 \text{ L} = 2.16 \times 10^{-3}$ mol

$n(H^+) = c \times V = 0.123 \text{ M} \times 0.0500 \text{ L} = 6.15 \times 10^{-3}$ mol

Remaining $n(H^+) = 6.15 \times 10^{-3} - 2.16 \times 10^{-3} = 3.99 \times 10^{-3}$

$[H+] = n/V = 3.99 \times 10^{-3} / 0.150 = 0.0266$ mol/L

$pH = -\log_{10}[H^+] = -\log_{10}(0.0266) = 1.575$

Change in pH = 12.334 – 1.575 = 10.759

Question 29 (4 marks)
Outcomes Assessed: CH12-13
Targeted Performance Bands: 2–5

Criteria	Marks
• Clearly explains how the buffer resists changes in pH, with reference to at least ONE relevant chemical equation	4
• Describes a buffer in a natural system, with reference to ONE relevant chemical equation	3
• Outlines a buffer in a natural system	2
• Provides some relevant information	1

Sample Answer:

Students can use any valid buffering system in nature.

One of the blood buffering systems is carbonic acid (H_2CO_3) and its conjugate base, the bicarbonate ion (HCO_3^-). The equilibrium between carbonic acid and bicarbonate helps regulate the pH of blood. When excess hydronium ions (H_3O^+) are present, they can react with bicarbonate ions to form carbonic acid, preventing a drastic decrease in pH. If there is an excess of hydroxide ions (OH^-), the carbonic acid donates a proton to form bicarbonate ions, preventing a significant increase in pH. The movement/shift in the reactions is important to maintain pH for biological processes.

$HCO_3^-(aq) + H_3O^+(aq) \rightleftharpoons H_2CO_3(aq) + H_2O(aq)$

$H_2CO_3(aq) + OH^-(aq) \rightleftharpoons HCO_3^-(aq) + H_2O(aq)$

Question 30 (5 marks)
Question 30 (a) (1 mark)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 3–4

Criteria	Marks
• Correctly identifies a relevant condition	1

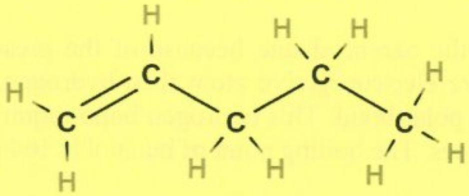
Sample Answer:

Answers may include:
- Al_2O_3 catalyst
- High temperatures
- Concentrated acid catalyst

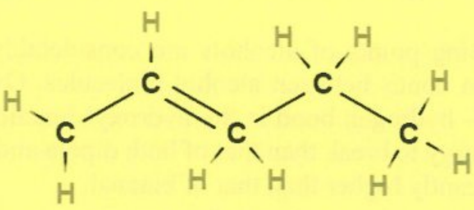
Question 30 (b) (4 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 3–5

Criteria	Marks
• Correctly draws TWO organic products of the reaction AND • Correctly names TWO organic products of the reaction	4
• Correctly draws at least ONE organic product of the reaction AND/OR • Correctly names at least ONE organic product of the reaction	2–3
• Substantially draws a product of the reaction OR • Correctly names a product of the reaction	1

Sample Answer:



Pent-1-ene



Pent-2-ene

(NB: no marks for water)

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Question 31 (6 marks)
Outcomes Assessed: CH11/12-6, CH12-14
Targeted Performance Bands: 2–6

Criteria	Marks
• Demonstrates an extensive knowledge of the relationship between bonding and boiling point • Makes specific reference to the data in the table • Correctly explains each type of bonding • Links the type of bonding to HOW each affects the boiling point of a molecule • Provides information to explain the higher boiling point of carboxylic acids	6
• Demonstrates a thorough knowledge of the relationship between bonding and boiling point • Makes specific reference to the data in the table • Explains each type of bonding • Some links to the type of bonding to HOW each affects the boiling point of a molecule • Attempts to explain the higher boiling point of carboxylic acids	4–5
• Demonstrates a sound knowledge of the relationship between bonding and boiling point • References to the data in the table • Attempts to explain each type of bonding • Some links to the type of bonding and the boiling point of a molecule	2–3
• Demonstrates some understanding of how bonding affects boiling point	1

Sample Answer:

Alkane molecules are non-polar, the only intermolecular forces of attraction between them are weak dispersion forces. As the length of the carbon chain increases, the overall forces of attraction between molecules also increase. The strength of dispersion forces between molecules increases because of the increased strength of temporary dipoles within the molecules, due to the increased number of valence electrons.

Aldehydes also have weak dispersion forces between molecules but their boiling points are much higher - butane's boiling point is -1 degree whilst butanal has a boiling point of 75 degrees. This is because aldehydes are a polar molecule due to the double bonded oxygen they contain, allowing them to form permanent dipoles that are stronger and require more energy to separate.

The boiling points of alcohols are considerably higher than the parent alkane because of the presence of hydrogen bonds between alcohol molecules. Oxygen is a more electronegative atom than hydrogen, so the oxygen – hydrogen bond in the hydroxyl functional group is a polar bond. This hydrogen bond requires even more energy to break than that of both dipole and dispersion forces. The boiling point of butanol is 164 degrees - significantly higher than that of butanal.

Carboxylic acid boiling points are much higher than alcohols of similar sizes. This is because carboxylic acids also form hydrogen bonds, but each molecule has the ability to form two hydrogen bonds and often exist as stable dimers - where the H from the OH bond is strongly attracted to the =O of a second carboxylic acid.

As the carbon chain length increases, the difference in boiling point is significantly higher in alkanes than aldehydes than alcohols and acids, implying that as the length of the carbon chain increases, the influence of dipole-dipole and hydrogen bonding becomes less important relative to the dispersion forces.

Question 32 (5 marks)
Outcomes Assessed: CH12-12, CH12-13
Targeted Performance Bands: 2–6

Criteria	Marks
• Correctly writes an equilibrium word equation for esterification • Correctly writes an equilibrium chemical equation for the ionisation of acetic acid • Explains how an alkaline pH affects the acetic acid equilibrium and the ester equilibrium • Links the high pH to lack of fragrance • Explains how lowering the pH of the soil affects the acetic acid equilibrium and the ester equilibrium • Links the lowering of the pH to an increase in fragrance	5
• Correctly writes a word equation for esterification AND/OR the ionisation of acetic acid • Explains how an alkaline pH affects the acetic acid equilibrium AND/OR the ester equilibrium • Links the pH to the level of fragrance • Explains how lowering the pH of the soil affects the acetic acid equilibrium AND/OR the ester equilibrium	3–4
• Explains how pH affects the acetic acid equilibrium OR the ester equilibrium AND • Provides a mostly correct word OR chemical equation	2
• Some relevant information provided	1

Sample Answer:

The fragrance of the rose is due to an ester, 2-phenylethyl acetate. The ester is in equilibrium:

Acetic acid + phenylethanol ⇌ 2-phenylethyl acetate + water

If the pH is 8.5, the soil is alkaline in nature. Excess hydroxide ions can react with hydronium ions produced by the acetic acid, which is a weak acid.

$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + CH_3COO^-\ (aq)$
Acetic acid + water ⇌ hydronium ion + acetate ion

The removal of hydronium ions results in a shift to the right-hand side of the ionisation of acetic acid, causing a decrease in acetic acid concentration.The removal of acetic acid causes a shift to the left-hand side of the ester equilibrium, decreasing the amount of the ester. Hence there will be a decrease in the amount of fragrance detected.

To rectify this issue, the farmer should apply a soil treatment to lower the pH so that it is less than 7. By increasing the acidity, it will cause a shift to the left-hand side of the acetic acid ionisation equilibrium, producing more acetic acid. The increase in acetic acid will cause a shift to the right-hand side of the ester equilibrium, producing more ester and greater fragrance.

Question 33 (4 marks)
Outcomes Assessed: CH11/12-6, CH12-12
Targeted Performance Bands: 2–6

Criteria	Marks
• Correct calculations provided with units • Identifies spontaneity of reaction	4
• Performs MOST steps in the calculation • Identifies spontaneity of reaction	3
• Provides SOME steps in calculation	2
• Provides some relevant information	1

Sample Answer:

Enthalpy of reaction –

$\Delta H = \Sigma\ \Delta H$ (products) – $\Sigma\ \Delta H$ (reactants)

$\Delta H = (-1273 + 0) - ((6 \times -393) + (6 \times -285)) = + 2795$ kJ mol^{-1}

Entropy of reaction –

$\Delta S = \Sigma\Delta S$ (products) – $\Sigma\Delta S$ (reactants)

$\Delta S = (212 + 6 \times 205) - (6 \times 214 + 6 \times 70) = - 262$ JK^{-1} mol^{-1} = - 0.262 k JK^{-1} mol^{-1}

Gibbs free energy –

$\Delta G = \Delta H - T\Delta S$

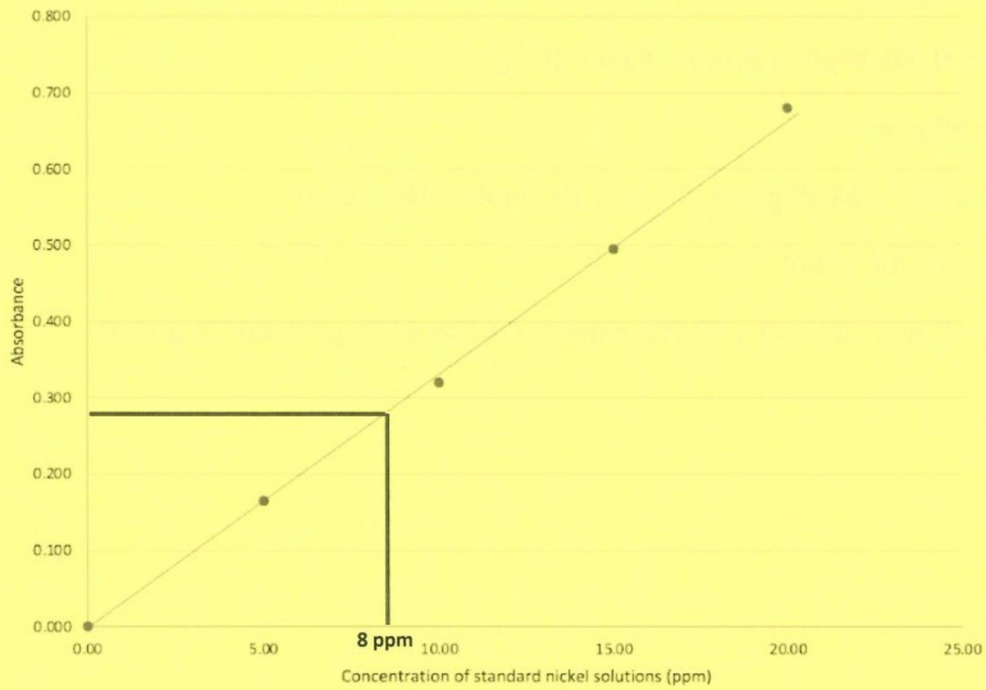
$\Delta G = 2795 - (320 \times -0.262) = +2878$ kJ mol^{-1}

Therefore, the reaction is not spontaneous at 320K.

Question 34 (6 marks)
Question 34 (a) (3 marks)
Outcomes Assessed: CH11/12-5, CH12-14
Targeted Performance Bands: 2–4

Criteria	Marks
• Correctly plotted graph • Correct absorbance determined, with working on the graph	3
• Correctly plotted graph OR • Graph plotted with ONE error AND absorbance determined from the graph	2
• Some points correctly plotted on the graph	1

Sample Answer:



Absorbance of 8.00 ppm solution = 0.28 ± 0.01

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Question 34 (b) (3 marks)
Outcomes Assessed: CH12-14
Targeted Performance Bands: 3–5

Criteria	Marks
• Correctly calculates mass of precipitate formed, with correct sig figs	3
• Provides some calculation steps	2
• Provides any relevant information	1

Sample Answer:

Nickel concentration = 8.00 ppm

Converting, ppm converted to g/L, nickel concentration = 8.00 mg/L = 0.00800 g/L

molar mass of Ni^{2+} = 58.69 g/mol

mass of Ni^{2+} in 100 mL = 0.00800 g/L x 0.100 = 8.00 x 10^{-4} g

molar mass of Ni^{2+} = 58.69 g/mol

n(Ni^{2+}) = m/MM = 8.00 x 10^{-3} g/58.69 g/mol = 1.36 x 10^{-5} mol = n($Ni(OH)_2$)

molar mass of $Ni(OH)_2$ = 92.706 g/mol

m($Ni(OH)_2$) = n x MM = 1.36 x 10^{-5} mol x 92.706 g/mol = 0.012608016 g = 0.00126 g (3sf)

Question 35 (8 marks)
Outcomes Assessed: CH11/12-6, CH12-13
Targeted Performance Bands: 2–6

Criteria	Marks
• Correctly calculates the moles of HCl • Correctly calculates the volume and concentration of NaOH from HCl • Correctly calculates the volume of NaOH with linolenic acid • Correctly calculates the number of moles of NaOH and linolenic acid • Correctly calculates the mass of linolenic acid in 20 g of berries • Correctly calculates the percentage intake of 20 berries	8
• Performs MOST steps, with one or two errors	5–7
• Performs SOME steps	2–4
• Provides some relevant information	1

Sample Answer:

<u>Standardisation</u>

c(HCl) = 0.01978 mol/L
V(HCl) = 25.00 mL = 0.02500 L
n(HCl) = c x V = 4.945 x 10^{-4} mol

n(NaOH) = n(HCl) (equimolar stoichiometry)
V(NaOH) = (32.95+32.90+32.90)/3 mL = 32.917 mL (all three titrations are concordant)

c(NaOH) = n(NaOH)/V(NaOH) = 4. 945 x 10^{-4} mol/0.032917 L **= 0.01502 mol/L (4sf)**

<u>Blueberry investigation</u>

c(NaOH) = 0.01502 mol/L
The first titration is an outlier, so ignore it.
V(NaOH) = (3.20+3.10+3.10)/3 = 3.13333333 mL
n(NaOH) = c x V = 0.01502 x 0.00313333333 = 4.7062666667 x 10^{-5} mol

n(linolenic acid) = n(NaOH) as the acid is monoprotic
MM(linolenic acid) = 278.7 g/mol

m(linolenic acid) = n x MM = 4.7062666667 x 10^{-5} x 278.7 = 0.013116 g

This is the mass in a 5.00 mL aliquot, so
m(linolenic acid in 20 g of berries) = 5 x 0.013116 = 0.06558 g

Percentage of requirement = (0.06558/1.7) x 100% = 3.87647% = 3.9% (2sf)
Therefore % of daily intake = 3.9%

Question 36 (8 marks)
Outcomes Assessed: CH11/12-6, CH12-15
Targeted Performance Bands: 2–6

Criteria	Marks
• Correctly identifies FOUR spectra • Justifies the correct structures, showing an extensive understanding of the interpretation of spectroscopic data	8
• Correctly identifies FOUR spectra • Justifies the correct structures, showing a thorough understanding of the interpretation of spectroscopic data	6–7
• Correctly identifies TWO or THREE spectra • Justifies the correct structures, showing a sound understanding of the interpretation of spectroscopic data	4–5
• Demonstrates some understanding of the interpretation of spectroscopic data	2–3
• Provides some relevant information	1

Sample Answer:

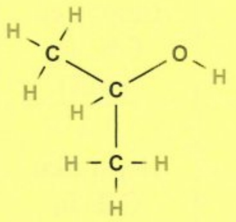
Spectrum	Compound
A	Ethyl methanoate
B	1-propanol
C	2-propanol
D	propanoic acid

Starting with **Spectrum D** (IR spectrum):

Big broad peak around 3000 cm^{-1}, indicating Spectrum D is most likely an acid (very broad peak for -OH around 2500 – 3000 cm^{-1}), so **propanoic acid**. This is further confirmed by a C=O peak in the 1680-1750 cm^{-1} range and a C-O peak in the 1000-1300 cm^{-1} range.

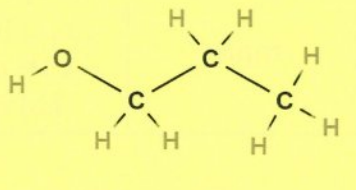
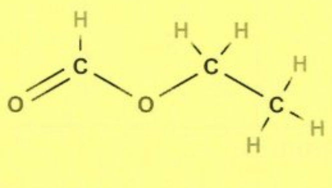
Looking next at **Spectrum C** (C-NMR):

There are only two peaks (25 ppm and 65 ppm), meaning only two carbon environments. Given that each molecule has three carbons, this means that two carbons must be in an identical environment. 2-propanol has the structure:



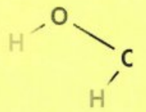
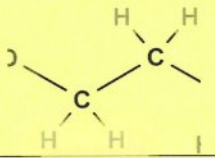
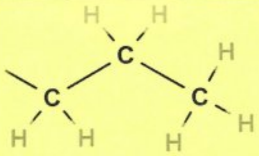
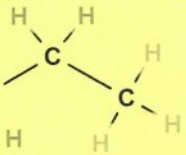
The two $-CH_3$ groups should be a single peak in the range of 5 – 40 ppm, which 25 ppm is, and one carbon is attached to the -OH group and the peak should be in the 50 -90 ppm range, which 65 ppm is. Thus, we expect that Spectrum C is **2-propanol**.

The remaining two compounds are:

	
1-propanol	Ethyl methanoate

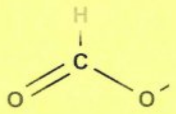
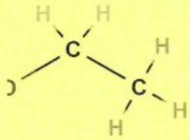
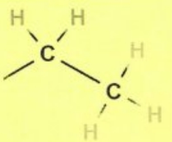
The two remaining spectra are H-NMR spectra.

If one spectrum belonged to 1-propanol, we would expect 4 hydrogen environments:

Environment	Part of molecule (hydrogens highlighted)	Number of hydrogens	Number of hydrogen neighbours	Number of splits in spectra	Expected order from 0 ppm
1		1	0 (oxygen screening)	singlet	3/4 (least like CH_3 in TMS)
2		2	2	triplet	3/4 (least like CH_3 in TMS)
3		2	6	sextet	2
4		3	2	triplet	1 (most like CH_3 in TMS)

1-propanol corresponds to Spectrum B.

If one spectrum belonged to ethyl methanoate, we would expect 3 hydrogen environments:

Environment	Part of molecule (hydrogens highlighted)	Number of hydrogens	Number of hydrogen neighbours	Number of splits in spectra	Expected order from 0 ppm
1		1	0 (oxygen screening)	singlet	3 (least like CH_3 in TMS)
2		2	3	quartet	2
3		3	2	triplet	1 (most like CH_3 in TMS)

Ethyl methanoate corresponds to Spectrum A.

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