Neap

Final Examination 2023

NSW Year 11 Chemistry

Solutions and Marking Guidelines

SECTION I

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 1 **B** An iron-56 atom contains 26 protons and 30 neutrons (26 + 30 = 56). As the atom is neutral, it contains 26 electrons.	Mod 1 Properties and Structure of Matter CH11–4 Bands 2–4
Question 2 **A** **A** is correct. The equation represents the decomposition of nitrogen dioxide (NO_2) into oxygen (O_2) and nitrogen (N_2). **B** is incorrect. A combustion reaction occurs between a fuel and oxygen gas to produce heat, carbon dioxide (CO_2) and water (H_2O). **C** is incorrect. A precipitation reaction occurs between ions in aqueous solution to produce a precipitate. **D** is incorrect. An acid/base reaction occurs between an acid and a base and involves the transfer of hydrogen ions, H^+.	Mod 3 Reactive Chemistry CH11–10 Bands 2–4
Question 3 **B** The overall charge of the ion is –2. The oxidation number of oxygen is –2. If the oxidation number of sulfur is *x*: $2x + (6 \times -2) = -2$ $2x = 10$ $x = +5$	Mod 3 Reactive Chemistry CH11–4, 11–10 Bands 2–4
Question 4 **D** **D** is correct. The diagram shows a separating funnel, which is used to separate liquids that are immiscible with each other and also have different densities. **A** and **C** are incorrect. Gravity and melting points are used for the separation of solids. **B** is incorrect. Liquids cannot be separated with a separating funnel based on different boiling points.	Mod 1 Properties and Structure of Matter CH11–2, 11–8 Bands 2–4
Question 5 **A** To convert the heat of combustion from kJ mol^{-1} to kJ g^{-1}, the value of the heat of combusion should be divided by the molar mass. Molar mass of propane (C_3H_8): $MM = (12.01 \times 3) + (1.008 \times 8)$ $= 44.094 \text{ g mol}^{-1}$ $\frac{2220 \text{ kJ mol}^{-1}}{44.094 \text{ g mol}^{-1}} = 50.35 \text{ kJ g}^{-1}$	Mod 4 Drivers of Reactions CH11–7 Bands 2–4

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 6 D Aluminium does not react with cold water. It only reacts with steam to produce aluminium oxide and hydrogen gas according to the following equation. $2Al(s) + 3H_2O(l) \rightarrow Al_2O_3(aq) + 3H_2(g)$	Mod 3 Reactive Chemistry CH11–3, 11–10 Bands 2–4
Question 7 B **B** is correct. In a flame test, potassium emits a lilac colour. **A**, **C** and **D** are incorrect. Sodium emits a yellow colour, copper emits a green colour and barium emits a yellow-green colour.	Mod 1 Properties and Structure of Matter CH11–4 Bands 2–4
Question 8 C $V = 500\text{ mL} = 0.500\text{ L}$ $c = 0.050\text{ mol L}^{-1}$ $m(AlCl_3) = ?$ $n = cV$ $= 0.500 \times 0.050$ $= 0.025\text{ mol}$ $MM(AlCl_3) = 133.33\text{ g mol}^{-1}$ $m = n \times MM$ $= 0.025 \times 133.33$ $= 3.33325$ $= 3.3\text{ g}$	Mod 2 Introduction to Quantitative Chemistry CH11–4, 11–6, 11–9 Bands 2–4
Question 9 C $T = 25°C = 298.15\text{ K}$ $P = 100\text{ kPa}$ The volume of 1 mol of ideal gas, V_m, is 24.79 L. $m(S) = 11.35\text{ g}$ $V(SO_2) = ?$ $n(S) = \frac{m}{MM}$ $= \frac{11.35}{32.07}$ $= 0.3539\text{ mol}$ Therefore, the amount of SO_2 produced is 0.3539 mol (1 : 1 ratio). $V = n \times V_m$ $= 0.3539 \times 24.79$ $= 8.774\text{ L}$	Mod 2 Introduction to Quantitative Chemistry CH11–4, 11–6, 11–9 Bands 4–6

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 10 **B** **B** is not a true statement and is therefore the required response. Catalysts do not change the overall enthalpy change, ΔH, of a reaction; they only lower the activation energy, E_a. **A**, **C** and **D** are true statements and are therefore not the required response.	Mod 4 Drivers of Reactions CH11–11 Bands 2–4
Question 11 **C** $m(CaCO_3) = 21.34$ g $MM(CaCO_3) = 100.09$ g mol^{-1} $n(\text{CaCo}_3) = \frac{m}{MM}$ $= \frac{21.34}{100.09}$ $= 0.2132$ mol 1 mol of $CaCO_3$ requires 178.3 kJ of energy. 0.2132 mol of $CaCO_3$ requires x kJ of energy. $x = 0.2132 \times 178.3$ $= 38.02$ kJ	Mod 4 Drivers of Reactions CH11–6 Bands 4–6
Question 12 **D** **D** is correct. Increasing the concentration of the nitric acid will increase the rate of reaction as there will be more reactant particles present, which will result in more successful collisions. **A** and **B** are incorrect. Changes in pressure and in the volume of the solution will not change the reaction rate. **C** is incorrect. Larger particle size will result in a slower reaction rate.	Mod 3 Reactive Chemistry CH11–6, 11–7 Bands 2–4

Answer and explanation	Syllabus content, outcomes and targeted performance bands
Question 13 **D** **D** is correct. 49.5% C: $\frac{49.5}{12.01} = 4.12$ 5.2% H: $\frac{5.2}{1.008} = 5.2$ 28.7% N: $\frac{28.7}{14.01} = 2.05$ 16.6% O: $\frac{16.6}{16.00} = 1.04$ Therefore, the empirical formula is $C_4H_5N_2O$ ($MM = 97.1$ g mol^{-1}). As the molar mass of caffeine is 194.19 g mol^{-1}, the molecular formula is $C_8H_{10}N_4O_2$. **A** and **B** are incorrect. These options do not show the correct ratio of elements. **C** is incorrect. This option is the empirical formula.	Mod 2 Introduction to Quantitative Chemistry CH11–4, 11–6, 11–9 Bands 4–6
Question 14 **A** **A** is correct. The diagram shows hydrogen bonding between molecules of ethanol. An ethanol molecule is polar, and the hydrogen atom attached to the oxygen atom can undergo hydrogen bonding with an oxygen atom in another ethanol molecule. **B** is incorrect. Dispersion forces are present between non-polar molecules. **C** is incorrect. Intramolecular forces hold the atoms in a molecule together; they do not hold molecules together. **D** is incorrect. Ion–dipole forces are present between an ion and a molecule that has a dipole.	Mod 1 Properties and Structure of Matter CH11–8 Bands 2–4
Question 15 **C** **C** is correct. In this reaction, 3 mol of gas converts to 1 mol of liquid. There is more order in the liquid state; therefore, entropy decreases. **A** is incorrect. In this reaction, 1 mol of solid converts to 2 mol of gas. There is less order in the gas state; therefore, entropy increases. **B** is incorrect. In this reaction, a solid is dissolving. Entropy increases in dissolutions. **D** is incorrect. In this reaction, 3 mol of gas converts to 4 mol of gas. There is less order as more gas is produced; therefore, entropy increases.	Mod 4 Drivers of Reactions CH11–11 Bands 2–4

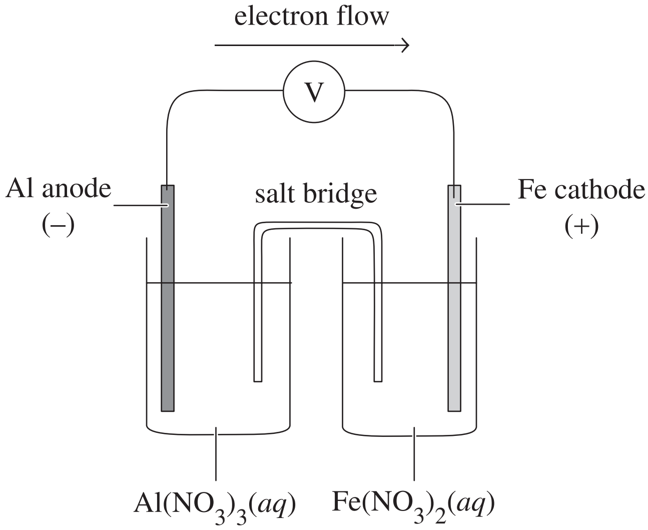
SECTION II

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 16	
$m(\text{HCl}) = 267$ g $n(\text{HCl}) = \frac{m}{MM}$ $= \frac{267}{36.458}$ $= 7.3235$ mol $n(\text{Cl}_2) = n(\text{HCl}) \times \frac{1}{2}$ $= 7.3235 \times \frac{1}{2}$ $= 3.6617$ mol $m(\text{Cl}_2) = n \times MM$ $= 3.6617 \times 70.9$ $= 260$ g	Mod 2 Introduction to Quantitative Chemistry CH11–6, 11–9 Bands 4–6 • Calculates the number of moles of HCl. AND • Calculates the number of moles of Cl_2. AND • Calculates the mass of Cl_2 . . . . 3 --- • Calculates the number of moles of HCl. AND • Calculates the number of moles of Cl_2. . . . . 2 --- • Provides some relevant working . . . 1
Question 17	
(a) $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$	Mod 3 Reactive Chemistry CH11–9 Bands 2–4 • Provides the correct balanced chemical equation 1
(b) 103 – 45 = 58 kJ	Mod 4 Drivers of Reactions CH11–4 Bands 2–4 • Calculates the value of the activation energy 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(c) The energy profile diagram shows that the reactants have greater energy (45 kJ mol^{-1}) than the products (10 kJ mol^{-1}). This means that the ΔH of the reaction is 10 – 45 = –35 kJ. Therefore, the reaction is exothermic.	Mod 4 Drivers of Reactions CH11–4, 11–10 Bands 2–4 • Identifies the energy of the reactants and products. AND • Calculates ΔH. AND • States that the reaction is exothermic 3
	• Identifies the energy of the reactants and products. AND • Calculates ΔH. OR • States that the reaction is exothermic 2
	• Provides some relevant information or working 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 18	
The reactivity of a metal refers to how readily it loses electrons. It increases down a group because the number of electron shells increases down a group, meaning electrons are not as strongly attracted to the nucleus. It decreases across a period as the increased core charge means electrons are less readily lost. The reactivity of a non-metal refers to how readily it gains electrons. It decreases down a group as there are more electron shells, meaning electrons are gained less readily. It increases across a period due to the increased core charge making it easier to gain electrons. Electronegativity is the measure of how strongly an atom attracts a pair of electrons to form a bond. It decreases down a group. This is because, moving down a group, valence electrons become further away from the nucleus and so are not as strongly attracted to the nucleus. Electronegativity increases across a period. Moving across a period, the number of occupied electron shells is constant; however, as core charge increases across a period, valence electrons become more attracted to the nucleus. The atomic radius is a measure of the size of an atom. It increases down a group because the number of electron shells increases down a group. It decreases across a period because the number of occupied shells is constant across a period. First ionisation energy is the amount of energy required to remove the outermost valence electron from an atom. It decreases down a group because the energy required to remove the electron decreases with increasing atom size, due to weaker attraction between valence electrons and the nucleus. First ionisation energy increases across a period. This is because core charge increases across a period, causing valance electrons to become more attracted to the nucleus, which means more energy is required to remove the outermost electron.	Mod 1 Properties and Structure of Matter Mod 3 Reactive Chemistry CH11–7, 11–8, 11–10 Bands 4–6 • Defines and describes the trends of metal and non-metal reactivity down a group and across a period. AND • Defines and describes the trends of electronegativity down a group and across a period. AND • Defines and describes the trends of atomic radii down a group and across a period. AND • Defines and describes the trends of first ionisation energy down a group and across a period .... 8 • ALL of the above points with some errors .... 7 • Any THREE of the above points . . . 6 • Any THREE of the above points with some errors .... 5 • Any TWO of the above points. . . . . 4 • Any TWO of the above points with some errors .... 3 • Any ONE of the above points ..... 2 • Provides some relevant information 1

<table>
<tr><th>Sample answer</th><th>Syllabus content, outcomes, targeted performance bands and marking guide</th></tr>
<tr><td>Question 19</td><td></td></tr>
<tr><td>(a)
<table><tr><td>Species that is oxidised and oxidation half-equation</td><td>Species that is reduced and reduction half-equation</td></tr><tr><td>aluminium, Al
$Al(s) \rightarrow Al^{3+}(aq) + 3e^-$</td><td>iron(II) ion, Fe^{2+}
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$</td></tr></table></td><td>Mod 3 Reactive Chemistry
CH11–10 Bands 2–4
• Identifies the species that is oxidised.
AND
• Provides the correct oxidation half-equation.
AND
• Identifies the species that is reduced.
AND
• Provides the correct reduction half-equation . . . . 4<hr>• Any THREE of the above points . . . 3<hr>• Any TWO of the above points. . . . . 2<hr>• Any ONE of the above points . . . . . 1</td></tr>
</table>

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b)  $2Al(s) + 3Fe^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Fe(s)$	Mod 3 Reactive Chemistry CH11–10 Bands 4–6 • Draws a clear diagram. AND • Labels ALL of: – anode (with charge and Al) – cathode (with charge and Fe) – electron flow from anode to cathode – electrolytes – salt bridge. AND • Provides the correct balanced chemical equation 5
	• Draws a clear diagram. AND • Labels at least FOUR of the above points. AND • Provides the correct balanced chemical equation 4
	• Draws a clear diagram. AND • Labels at least THREE of the above points. AND • Provides the correct balanced chemical equation 3
	• Draws a clear diagram. AND • Labels at least TWO of the above points. AND • Provides the correct balanced chemical equation 2
	• Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(c) cathode: Fe, E° = –0.44 V anode: Al, E° = –1.68 V $E°_{cell} = E°_{cathode} - E°_{anode}$ $= -0.44 - (-1.68)$ $= 1.24$ V	Mod 3 Reactive Chemistry CH11–4 Bands 3–6 • Calculates the cell potential 1
Question 20	
(a) $PV = nRT$ $P = 100$ kPa $V(N_2) = 65$ L $R = 8.314$ J mol^{-1} K^{-1} $n(N_2) = ?$ $T = 25°C = 298.15$ K $n(N_2) = \frac{PV}{RT}$ $= \frac{100 \times 65}{8.314 \times 298.15}$ $= 2.6222$ mol $n(NaN_3) = n(N_2) \times \frac{6}{9}$ $= 2.6222 \times \frac{6}{9}$ $= 1.7481$ mol $m(NaN_3) = n \times MM$ $= 1.7841 \times 65.03$ $= 114$ g	Mod 2 Introduction to Quantitative Chemistry CH11–6, 11–9 Bands 4–6 • Converts temperature to kelvin. AND • Calculates the number of moles of N_2 using the Ideal Gas Law formula. AND • Calculates the number of moles of NaN_3 using stoichiometry. AND • Calculates the mass of NaN_3 . . . . . . 4 • ALL of the above points with some errors . . . . 3 • Converts temperature to kelvin. AND • Calculates the number of moles of N_2 using the Ideal Gas Law formula . . . . 2 • Provides some relevant working . . . 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide

Sample answer

(b)

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$V_1 = 65$ L

$T_1 = 25°C = 298.15$ K

$T_2 = 35°C = 308.15$ K

$V_2 = ?$

$$V_2 = \frac{V_1 \times T_2}{T_1}$$

$$= \frac{65 \times 308.15}{298.15}$$

$$= 67 \text{ L}$$

Syllabus content, outcomes, targeted performance bands and marking guide

Mod 2 Introduction to Quantitative Chemistry
CH11–6, 11–9 Bands 2–4

- Converts temperatures to kelvin.

AND

- Calculates the volume of N_2 using the Charles' Law formula . . . 2

- Provides some relevant working . . . 1

Question 21

Sample answer

Substance name	*Substance formula*	*Bonding present in substance*
gold	**Ag**	**metallic**
dinitrogen pentoxide	N_2O_5	**covalent molecular**
nitrogen gas	$\mathbf{N_2}$	**covalent molecular**
ammonium sulfate	$(NH_4)_2SO_4$	**ionic**
aluminium carbonate	$\mathbf{Al_2(CO_3)_3}$	**ionic**
sulfur trioxide	SO_3	**covalent molecular**
silicon dioxide	$\mathbf{SiO_2}$	**covalent network**

Syllabus content, outcomes, targeted performance bands and marking guide

Mod 1 Properties and Structure of Matter
CH11–7, 11–8 Bands 4–6

- Provides SEVEN correct rows 7

- Provides SIX correct rows 6

- Provides FIVE correct rows 5

- Provides FOUR correct rows 4

- Provides THREE correct rows 3

- Provides TWO correct rows 2

- Provides ONE correct row.

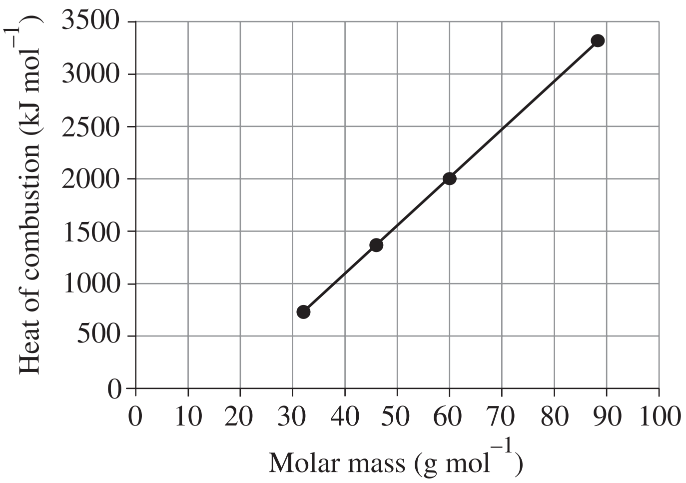
OR

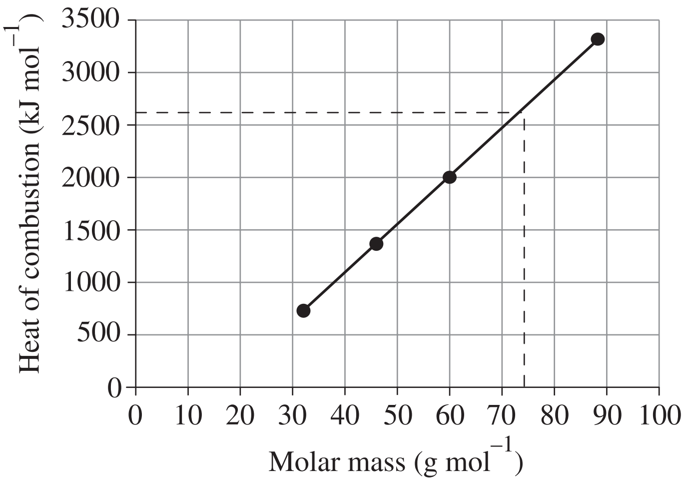
- Provides some relevant information 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 22	
Aluminium (Al), barium (Ba), sodium (Na) and nickel (Ni) would react with dilute sulfuric acid (H_2SO_4) to produce hydrogen gas (H_2). No reaction would occur for silver (Ag) and copper (Cu). This is because metals that appear higher up than H_2 in the metal activity series produce H_2 when reacting with dilute acid due to their greater reactivity. The reactions would occur according to the following equations. $Ba(s) + H_2SO_4(aq) \rightarrow BaSO_4(aq) + H_2(g)$ $2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$ $2Na(s) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2(g)$ $Ni(s) + H_2SO_4(aq) \rightarrow NiSO_4(aq) + H_2(g)$ *Note: The reaction between Na and H_2SO_4 is explosive and should not be attempted by students or teachers.*	Mod 3 Reactive Chemistry CH11–10 Bands3–4 • Identifies the FOUR metals that would have reacted and produced H_2. AND • Identifies the TWO metals that would not have reacted and produced H_2. AND • Explains why the metals would or would not have reacted. AND • Provides the correct balanced equation for each reaction . . . . 4 • ALL of the above with some errors . . . . 3 • Identifies at least TWO metals that would have reacted and produced H_2. AND • Identifies at least ONE metal that would not have reacted and produced H_2. AND • Explains why the metals would or would not have reacted OR provides the correct balanced equation for each reaction . . . . 2 • Provides some relevant information 1

Sample answer	**Syllabus content, outcomes, targeted performance bands and marking guide**
Question 23	
(a) $\Delta G° = \Delta H° - T\Delta S°$ $\Delta H°_{reaction} = \Sigma\Delta H_f°(\text{products}) - \Sigma\Delta H_f°(\text{reactants})$ $= \Sigma\Delta H_f°\left[CO_2(g) + 2\left(NH_3(g)\right)\right] -$ $\Sigma\Delta H_f°\left[\left(CO\left(NH_2\right)_2(aq)\right) + H_2O(l)\right]$ $= [-393.5 + 2\times(\ 46.19)] - [-319.2 + (-285.9)]$ $= 119.22\text{ kJ mol}^{-1}$ $T = 25°C = 298.15\text{ K}$ $\Delta S°_{reaction} = \Sigma\Delta S°(\text{products}) - \Sigma\Delta S°(\text{reactants})$ $= \Sigma\Delta S°\left[CO_2(g) + 2\left(NH_3(g)\right)\right] -$ $\Sigma\Delta S°\left[\left(CO\left(NH_2\right)_2(aq)\right) + H_2O(l)\right]$ $= (213.6 + 2\times 192.5) - (173.8 + 69.96)$ $= 354.84\text{ J mol}^{-1}\text{ K}^{-1}$ $= 0.35484\text{ kJ mol}^{-1}\text{ K}^{-1}$ $\Delta G° = 119.22 - 298.15\times 0.35484$ $= 13.42\text{ kJ}$	Mod 4 Drivers of Reactions CH11–6, CH–11 Bands 4–6 • Converts temperature to kelvin and entropy to kilojoules per mole. AND • Calculates $\Delta H°$. AND • Calculates $\Delta S°$. AND • Calculates $\Delta G°$. . . . . 4 • ALL of the above with some errors . . . . 3 • Calculates any ONE of the above values . . . . 2 • Provides some relevant working . . . 1
(b) $\Delta G° = \Delta H° - T\Delta S°$ For the reaction to be spontaneous, $\Delta G° < 0$. $0 = \Delta H° - T\Delta S°$ $T = \frac{\Delta H°}{\Delta S°}$ $= \frac{119.22}{0.35484}$ $= 335.9824\text{ K}$ $= 62.83\text{ °C}$ *Note: Consequential on working to* ***Question 23(a)***.	Mod 4 Drivers of Reactions CH11–4, 11–11 Bands 4–6 • Identifies that $\Delta G°$ needs to be 0 ($\Delta G° < 0$) for a reaction to be spontaneous. AND • Calculates the temperature at which the reaction will be spontaneous. . . . . 2 • Provides some relevant information or working 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 24	
(a) $MM(Na_3AlF_6) = (22.99 \times 3) + 26.98 + (19.00 \times 6)$ $= 210.0 \text{ g mol}^{-1}$	Mod 2 Introduction to Quantitative Chemistry CH11–6 Bands 2–4 • Calculates the molar mass of Na_3AlF_6 1
(b) $\%Na = \frac{3 \times 22.99}{209.95} \times 100$ $= 32.85\%$ $\%Al = \frac{26.98}{209.95} \times 100$ $= 12.85\%$ $\%F = \frac{6 \times 19.00}{209.95} \times 100$ $= 54.30\%$ *Note: Consequential on answer to* ***Question 24(a)****.*	Mod 2 Introduction to Quantitative Chemistry CH11–6 Bands 4–6 • Calculates the percentage composition of all THREE elements in Na_3AlF_6 . . . . . . 3 • Calculates the percentage composition of TWO elements in Na_3AlF_6 . . . . . . 2 • Calculates the percentage composition of ONE element in Na_3AlF_6 1
(c) $m(Na_3AlF_6) = 50 \text{ kg} = 50\ 000 \text{ g}$ $m(Al) = \frac{50\ 000 \times 12.85}{100}$ $= 6425 \text{ g}$ $= 6.4 \text{ kg}$ *Note: Consequential on answer to* ***Question 24(b)****.*	Mod 2 Introduction to Quantitative Chemistry CH11–6 Bands 2–4 • Calculates the mass of Al in kilograms . . . . . . 2 • Calculates the mass of Al in grams 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
Question 25	
(a) The molar masses of the alcohols are: • methanol, CH_3OH = 32.042 g mol^{-1} • ethanol, C_2H_5OH = 46.068 g mol^{-1} • propan-1-ol, C_3H_7OH = 60.094 g mol^{-1} • pentan-1-ol, $C_5H_{11}OH$ = 88.146 g mol^{-1} *Relationship between molar mass and heat of combustion*  	Mod 2 Introduction to Quantitative Chemistry CH11–6 Bands 2–4 • Calculates the molar mass of each alcohol. AND • Plots the correct data points. AND • Draws a line of best fit. AND • Includes a title, axis labels and appropriate scales . . . . 3 • Calculates the molar mass of each alcohol. AND • Plots the correct data points. AND • Draws a line of best fit. . . . . 2 • Provides some relevant data 1

Sample answer	Syllabus content, outcomes, targeted performance bands and marking guide
(b) The molar mass of butan-1-ol, C_4H_9OH is 74.12 g mol^{-1}. Based on the line of best fit, the heat of combustion, $\Delta_c H$, of butan-1-ol is 2670 kJ mol^{-1}. *Relationship between molar mass and heat of combustion*  Reading from the graph, the $\Delta_c H$ of butan-1-ol is 2670 kJ mol^{-1}. *Note: Accept responses in the range 2625–2685 kJ mol^{-1}. Consequential on answer to* ***Question 25(a)***.	Mod 4 Drivers of Reactions CH11–6, 11–8 Bands 4–6 • Estimates the $\Delta_c H$ of butan-1-ol using the graph 1
(c) $\Delta_c H = 2670 \text{ kJ mol}^{-1}$ In kilojoules per gram: $\Delta_c H = \frac{2670}{74.12}$ $= 36.02 \text{ kJ g}^{-1}$ *Note: Consequential on answer to* ***Question 25(b)***.	Mod 4 Drivers of Reactions CH11–6, 11–8 Bands 4–6 • Calculates the $\Delta_c H$ of butan-1-ol in kilojoules per gram 1