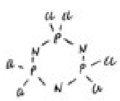
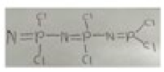
Mark scheme

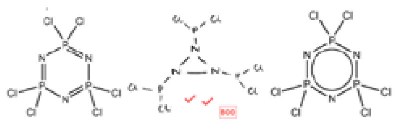
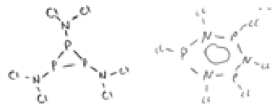
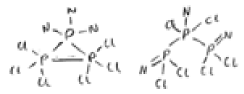
Question			Answer/Indicative content	Marks	Guidance
1			$C_5H_{12}O$+ **7½** $O_2 \rightarrow$ **5** CO_2 + **6** H_2O CO_2 **AND** H_2O products ✓ Complete equation balanced ✓	2	**ALLOW** multiples e.g. **2** $C_5H_{12}O$ + **15** $O_2 \rightarrow$ **10** CO_2 + **12** H_2O Watch for 15/2 **OR** 7.5 for 7½ **<u>Examiner's Comments</u>** Most candidates identified the correct products of this combustion as CO_2 and H_2O. The second mark was available for a balanced equation but many balanced O_2 with an 8 rather than with 7½. Candidates need to be very careful when writing equations for the combustion of alcohols as it is easy to miss the O atom within the alcohol formula.
			Total	**2**	
2	a	i	$4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$ ✓	1	**ALLOW** multiples **ALLOW** $2PH_3 + 4O_2 \rightarrow P_2O_5 + 3H_2O$ **IGNORE** state symbols, even if wrong **<u>Examiner's Comments</u>** Candidates found this question quite challenging, with only about one-third writing a correct equation. The question gave the reactants and products with only the formula of phosphorus(V) oxide having to be worked out. The actual reaction does produce P_4O_{10} but P_2O_5 was shown in almost all equations, and this was acceptable. Various incorrect formulae were seen

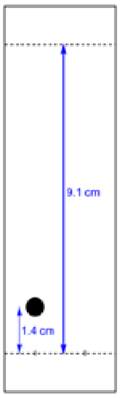
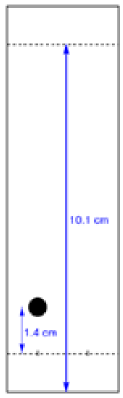
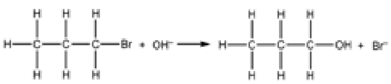
					for phosphorus(V) oxide including PO, PO_2, P_5O, HPO, etc. Unfortunately a significant number of candidates could not balance the equation, despite using correct formulae.
		ii	$6AgNO_3 + (1)PH_3 + 3H_2O \rightarrow 6Ag + (1)H_3PO_3 + 6HNO_3$ ✓ Ag is reduced from +1 to 0 ✓ P is oxidised from -3 to +3 ✓ **IGNORE** oxidation numbers written around equation *Treat as rough working* **IGNORE** reference to electrons *Question states oxidation numbers*	3	**ALLOW** equation with '1' omitted, i.e. $6AgNO_3 + PH_3 + 3H_2O \rightarrow 6Ag + H_3PO_3 + 6HNO_3$ ✓ **BUT DO NOT ALLOW** '0' **ALLOW** 1 mark for **BOTH** correct oxidation number changes with 'reduced' and 'oxidised' omitted **OR** 'oxidised and reduced the wrong way round + signs required for +1 and +3 For oxidation numbers, **ALLOW** 1+, 3- and 3+ **<u>Examiner's Comments</u>** This question generated a wide range of responses, testing many important chemical skills. Candidates often used oxidation numbers correctly to show that silver is reduced and phosphorus oxidised, with silver being the easier. Hydrogen was sometimes incorrectly chosen for oxidation. The oxidation number change of +1 to 0 for silver was usually correct although +9 and +11 were common errors for silver in $AgNO_3$, presumably by choosing the oxidation number of nitrogen as -3 or -5. Candidates usually recognised that phosphorus started with an oxidation number of -3 but the oxidation number of +5 was a common error in H_3PO_3. Balancing the equation was the most difficult part of this question with

					numbers being added almost at random. It is easier to balance equations for redox reactions by balancing the oxidation number changes first. **Assessment for learning** Ag^+ and NO_3^- are among the common ions that students should know (see also Question 4 (c) (i)). For a NO_3^- ion to have a charge of 1–, the oxidation number of nitrogen must be +5. By choosing –5, the charge on NO_3 would be –11 and silver would have an oxidation number of +11. This is completely unrealistic and should be rejected as it points to a serious error. The specification states the following: *2.1.5 (a) rules for assigning and calculating oxidation number for atoms in elements, compounds and ions.* This section will have been studied at the start of the two-year course and forms part of the backbone of chemical literacy. For success in chemistry, the ions should be learnt and the rules for assigning oxidation numbers need to be mastered.
	b	i	$3PCl_5 + 3NH_4Cl \rightarrow P_3N_3Cl_6 + 12HCl$ ✓	1	**ALLOW** multiples **IGNORE** state symbols, even if wrong <u>**Examiner's Comments**</u> This question again required candidates to construct an equation. Candidates were provided with the formula of all species reactants and products except for that of ammonium chloride. Candidates are expected to know

		ii			that the ammonium ion is NH_4^+ but many incorrect equations showed NH_3Cl. About half the candidates were able to construct a correctly balanced equation with the '12' balancing number for HCl being the hardest part. This links back to the 'assessment for learning' callout added to Question 4 (b) (ii) in this report. As with other questions requiring equations to be written, this question differentiated very well. Writing formulae and balancing equations are fundamentals for mastering chemistry and candidates are advised to practise these skills throughout the course. **Assessment for learning** The specification states the following. ***Formulae and equations*** ***2.1.2(a)*** *the writing of formulae of ionic compounds from ionic charges, including:* i. *prediction of ionic charge from the position of an element in the periodic table* ii. *recall of the names and formulae for the following ions:* NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} *and* Ag^+ This section will be studied at the start of the two-year course and form the backbone for chemical literacy. For success in chemistry, the common ions should be learnt.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE IF % by mass = 26.72, award 2 marks IF % by mass = 26.7, award 1 mark ---** M_r of $P_3N_3Cl_6$ = 348(.0) ✓	2	**ALLOW** 1 mark total for 26.7 *Question asks for 2 DP* **ALLOW** ECF from incorrect M_r

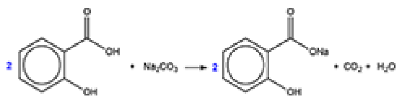
			% by mass of P = $\frac{31.0 \times 3}{348} \times 100 = 26.72$ ✓ **2 DP required**		**ALLOW** 1 mark for 8.91 (omission of ×3): $\frac{31.0}{348} \times 100 = 8.91$ **<u>Examiner's Comments</u>** In contrast to equation writing, candidates found this simple calculation far easier with the majority obtaining both marks for 26.72. Common incorrect percentages were 26.7 (wrong number of decimal places) and 8.91 (using 31 rather than 3 × 31 for the numerator).
		iii	(P-N) bond lengths are different ✓ **OR** enthalpy change of hydrogenation is more exothermic (than delocalised structure) **OR** reacts with bromine/electrophiles/by addition	1	**Throughout, ORA** for delocalised structure **IGNORE** C-C bond lengths are different **IGNORE** hydration **ALLOW** decolourises bromine (without a catalyst/halogen carrier) **IGNORE** more reactive without example **IGNORE** alternating single and double bonds **<u>Examiner's Comments</u>** About half the candidates suggested a range of creditworthy responses with 'different bond lengths' and 'decolorises bromine' being the most common.
		iv	Structure shown with molecular formula $P_3N_3Cl_6$ **1st mark** • Each P bonded to 2 Cl atoms • Each P bonded to N **AND** Cl • Each N has *at least* 2 bonds • Each Cl has 1 bond ✓ **2nd mark (dependent on 1st mark)**	2	1st mark *Meets criteria for 1st mark*   **ZERO** marks

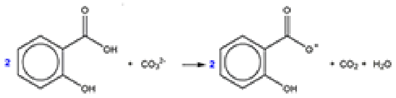
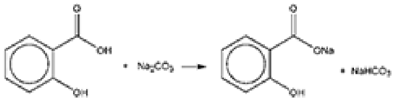
			• Each N has 3 bonds • Each P has 3 **OR** 5 bonds ✓ **IGNORE** charges Examples for 2 marks 		 *N bonded to Cl*  *N atom(s) with 1 bond only* **<u>Examiner's Comments</u>** This was another question where valuable information: *'all N and Cl atoms are bonded to P atoms'* had been provided. Many of the structures seen ignored this information with chlorine often been shown bonded to a nitrogen atom. Nitrogen atoms were often shown with 1 bond only and chlorine atoms in the ring structure with 2 or more bonds. Most structures contained 6 or 3-membered rings. This was a difficult question, requiring candidates to use the supplied information to come up with realistic structures that met chemical bonding rules. Only about a quarter of candidates could be given any mark. The Kekulé theme in Questions 4 (c) (i) - (iv) should have prompted candidates that a Kekulé structure was likely here. Several other structures were allowed providing that they met normal chemistry bonding rules
			Total	**10**	
3		i	$R_f \sim \frac{1.4}{9.1}$ in cm **OR** $\frac{14}{91}$ in mm = **0.15** ✓ *Working required* ***Check for ~ 9.1 as denominator***	1	**ALLOW** 0.12 - 0.18 (i.e. ±0.03) **DO NOT ALLOW** $\frac{1.4}{10.1}$ = 0.14

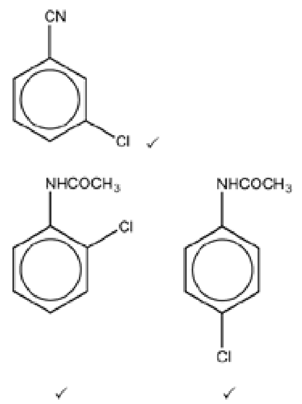
					***10.1** measured from bottom of plate to solvent front*  **<u>Examiner's Comments</u>** Candidates are well versed with calculating an R_f value, with nearly all candidates obtaining a value in the acceptable range of 0.12-0.18.
		ii	 Correct balanced equation **ALLOW** OH- above the arrow **DO NOT ALLOW** if a **CON** reagent is present, e.g. an acid For OH- and Br- **ALLOW** KOH and KBr **OR** NaOH and NaBr **BUT DO NOT ALLOW** K-OH *implies covalent bond*	1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW Missing H atoms** **DO NOT ALLOW** H_2O and HBr *Question asks for **alkaline** hydrolysis* **DO NOT ALLOW** C_3H_7, i.e. C_3H_7Br **OR** C_3H_7OH *Structure asked for in Question* **IGNORE** connectivity, e.g.  **BUT DO NOT ALLOW —HO** **<u>Examiner's Comments</u>** This question was answered well by candidates, with most showing correct structures for the organic reactant and its product, propan-1-ol, and skeletal formulae mostly used. The question asked for an equation

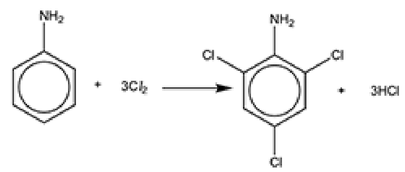
					for alkaline hydrolysis and candidates were expected to use an alkali. Acceptable answers would include NaOH/KOH and NaBr/KBr, or OH^- and Br^-. Equations including H_2O and HBr were not given a mark, a common error for alkaline hydrolysis.
		iii	**Difference** propan-1-ol/product/bottom spot is smaller **OR** 1-chloropropane/reactant/top spot bigger ✓ **Reasons** propan-1-ol/product/bottom spot is smaller C-Cl bond is stronger than C-Br **AND** 1-chloropropane reacts slower/is less reactive ✓ **Use of propan-1-ol** shows **formation** of propan-1-ol **OR** shows when reaction has **finished** **OR** monitors **course/progress** of reaction ✓	3	**FULL ANNOTATIONS MUST BE USED** **ALLOW ECF and ORA throughout** **---** **IGNORE** references to halogens as elements: *i.e.* chlorine is less reactive than bromine etc. **DO NOT ALLOW** chloride, bromide **DO NOT ALLOW** 1-chloropropane has larger bond enthalpy *C-Cl bond required* **IGNORE** 1-chloroproane has different R_f value **IGNORE** 'as a control' **OR** 'as a comparison' .... with no further explanation **<u>Examiner's Comments</u>** This novel question assessed whether candidates realised why chemists used TLC when carrying out organic reactions. A good response would identify the following key features after 20 minutes: • The C-C*l* bond energy is greater than C-Br and so the reaction would be slower. • The haloalkane spot would be larger and the propan-1-ol spot smaller. • The propan-1-ol is spotted on the chromatogram to monitor the progress of the reaction.

					The question differentiated very well between candidates, but many did not seem to know where to start with many candidates not scoring any marks. This suggested that candidates recognised chromatography as a technique but did not appreciate its relevance in organic chemistry. Some candidates referred to pigments, recalling their early chromatography experiments in finding the colours in ink.
			Total	**5**	
4		i	$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ ✓	1	***ALL*** *3 state symbols required* **<u>Examiner's Comments</u>** Candidates were required to write a straightforward ionic equation that they would have encountered many times during the A Level Chemistry course. It was surprising that only just over half the candidates produced an equation that could be given. Common errors included the following. • Omission of state symbols or incorrect state symbols, especially (aq) in Ag*Cl*(s). • Inclusion of nitrate ions or use of $AgNO_3$ instead of Ag^+. • An equation using Cl_2 and forming $AgCl_2$. Some candidates used the ideal gas equation to determine the moles of hydrogen, choosing suitable values for temperature and pressure. This approach was allowed, although the exercise would have wasted candidate time compared to the much simpler division by 24 for using RTP, which is stated in the question.
		ii	***n*($AgNO_3$) 1 mark** $= 2.50 \times 10^{-2} \times 60.0/1000 = 1.5(0) \times 10^{-3}$ (mol) ✓ **Essential mark**	3	**Check equation from 2b(i) at top of response** --

			Formula 2 marks **Ratio** 5.00×10^{-4} mol **A** contains $1.5(0) \times 10^{-3}$ mol Cl **OR** ratio A : Cl = $1.5(0) \times 10^{-3} \div 5.00 \times 10^{-4}$ = 1 : 3 ✓ **Formula** = $AlCl_3$ ✓ Automatically subsumes 1:3 ratio mark ✓ **ALLOW** Al_2Cl_6 **ALLOW** PCl_3		--------------------------- **ALLOW** 1:3 or 3:1 ratio seen anywhere, e.g. XCl_3 **ALLOW ECF** from formula of silver chloride in **2b(i)** e.g. From $AgCl_2$ *n*(Cl) = **2** × $1.5(0) \times 10^{-3}$ = $3.(00) \times 10^{-3}$ (mol) ratio = 1 : 6 Formula = SCl_6 **<u>Examiner's Comments</u>** Most candidates determined the moles of $AgNO_3$ and hence Ag^+ as 1.50×10^{-3} mol. This was given 1 mark, but candidates then needed to use this amount to predict the identity of compound **A**. Most candidates could not see the way forward and many received only 1 mark. Many candidates had worked out 'something' from the supplied data, without knowing where this initial step would take them. Candidates needed to spot that the ratio of the element : C*l* in compound **A** was 5×10^{-4} : 1.50×10^{-3} or 1 : 3. The correct formula of A*l*C*l*$_3$ then follows. MgC*l*$_2$ was a common error obtained by subtracting 5×10^{-4} from 1.50×10^{-3} to obtain a 1 : 2 ratio. This question would be a good exercise for improving the application skills of candidates.
			Total	**4**	
5		i	**Reaction with H_2SO_4** $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$ ✓ **Reaction with excess G** 	3	**ALLOW** multiples in both equations **IGNORE** state symbols **ALLOW** $Na_2CO_3 + 2H_2SO_4 \rightarrow 2NaHSO_4 + CO_2 + H_2O$ **ALLOW** ionic equation $CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$ **ALLOW** H_2CO_3 instead of $CO_2 + H_2O$ **ALLOW** $-COO^-$ (Na^+) for product structure mark **ALLOW** ionic equation

			Correct organic product structure ✓ Correct balanced equation ✓		 **ALLOW**  **ALLOW** H_2CO_3 instead of CO_2 + H_2O **ALLOW** correct Kekulé representation of benzene **<u>Examiner's Comments</u>** Another fairly challenging question, however most secured at least one mark for giving an equation for the reaction of sulfuric acid with sodium carbonate. Less confident candidates struggled to gain any marks as they were unable to give correct formula for sodium sulfate, giving $NaSO_4$ for example. Although many attempted the equation showing the reaction of compound **G** with sodium carbonate, only some correctly identified that only the carboxyl group would react, not the phenol. A small minority of students were able to balance the second equation gaining all 3 marks.
		ii	(NaOH) reacts with phenol / -OH (in compound G / H) **OR** (NaOH) would hydrolyse the ester / compound H	1	**IGNORE** comment about whether it improves or not **DO NOT ALLOW** (NaOH) reacts with alcohol **<u>Examiner's Comments</u>** The best responses correctly identified that using sodium hydroxide was not an improvement and explained this either bystating that it would react with the phenol group or hydrolyse the ester group in compound **H**. However, most candidates appeared not to consider a reaction with **H** in their answer. Many focused on the neutralisation of sulfuric acid in a similar way to sodium carbonate and gave responses such as:

					• stronger base • no effervescence so harder to see when completely reacted • no CO_2 produced so easier/safer/higher atom economy/less waste • requires double the moles compared to Na_2SO_4 to react
			Total	**4**	
6		i		3	**IGNORE** additional copies of the same structures **IGNORE** connectivity to CN and $NHCOCH_3$ in products. **IGNORE** HCl / H^+ **IGNORE** multisubstituted products **ALLOW** protonation of $NHCOCH_3$ group i.e. $NH_2^+COCH_3$ **ALLOW ECF** small slips on $NHCOCH_3$ e.g. extra O or missing 3 on CH_3 **<u>Examiner's Comments</u>** Most candidates were able to correctly recognise the correct direction for substitution, with over half gaining all 3 marks. Marks were most often lost for giving multiple substitution products despite being asked for the monosubstituted products. Many unnecessarily drew the same structures but with differentorientations i.e. substituting on carbon-3 of a ring is the same as substituting on carbon-5. ? **Misconception** Ensure students understand the term 'monosubstituted' and practise naming compounds to give the lowest possible numbering. This will

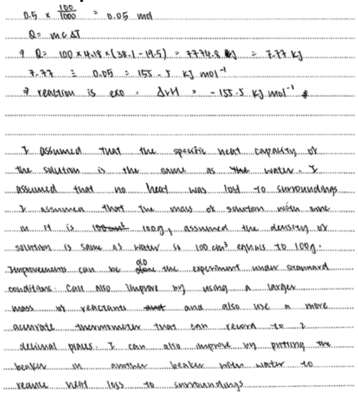
					also help them to recognise the equivalent structures.
		ii	 Correct organic product ✓ Correct balanced equation ✓	2	**ALLOW** any trichlorophenyl amine structure **ALLOW** $C_6H_2Cl_3NH_2$ **OR** $C_6H_4Cl_3N$ (allow elements in any order) for correct organic product **IGNORE** incorrect structural or molecular formula **IF** correct structure is drawn **ALLOW** ammonium salt of trichloro product $C_6H_2NH_3Cl_4$ **ALLOW** multiples for balanced equation **ALLOW** 1 mark for use of Br_2 with a correctly balanced equation **<u>Examiner's Comments</u>** The majority of candidates were able to give a suitable tri-substituted product, with many showing the structure although not asked for in the question. Many were also able to give a correct balancedequation too. Some were unsure how phenylamine would react showing the reaction with the aminegroup or only giving a monosubstituted product. Some didn't form HC*l* as another product, reacting phenyl amine with 1.5 Cl_2 instead. Others gave hydrogen as the product.
		iii	(In phenylamine) a (lone) pair of electrons on N is (partially) delocalised / donated into the π-system / ring ✓ Electron density increases/is higher (than benzene) ✓ **ORA** (phenylamine is) **more** susceptible to electrophilic attack **OR** (phenylamine) attracts/accepts electrophile/Cl_2 **more**	3	Must be clear that electrons come from N not just NH_2 **ALLOW** the electron pair (in the p-orbitals) on N atom becomes part of the π-system / ring **ALLOW** diagram to show movement of lone pair into ring from N **ALLOW** lone pair of electrons on N is (partially) drawn / attracted / pulled into π-system / ring **ALLOW** lone pair on N (i.e. no reference to electrons) **ALLOW** π-bond instead of π-system / ring

			OR (phenylamine) polarises electrophile/Cl_2 **more** ✓ **ORA**		**DO NOT ALLOW** (two) lone pair**s** are delocalised/donated into the π-system / ring **Responses must be comparative for 2nd and 3rd marking point.** **IGNORE** activating **IGNORE** charge density **IGNORE** electronegativity **IGNORE** phenylamines react more readily with electrophiles/Cl_2 (*given in question*) **ALLOW** Cl^+ for electrophile **IGNORE** Cl for electrophile **ALLOW** Benzene can't polarise electrophile/Cl_2 but phenylamine can (polarise electrophile/Cl_2) **<u>Examiner's Comments</u>** Similar questions have been seen previously and many candidates were able to give clear and concise responses. The first marking point was the most frequently lost as although many described $-NH_2$ aselectron donating, they were not able to fully explain its role. Some understood that a lone pair wasdonated into the π-ring but did not specify that the lone pair was on the nitrogen. Other marks were lostby not making comparison to benzene, e.g. high electron density, polarises Cl_2. Some repeated theinformation from the question regarding phenylamine being more reactive with electrophiles but notexplaining why. Lower attaining candidates often described the structure of the benzene ring or referredto phenylamine being more electronegative.
			Total	**8**	
7			**A**	1	**ALLOW** HC*l* **<u>Examiner's Comments</u>**

					The vast majority of candidates gave the correct option A, HC*l*. The most common incorrect response was B i.e. H_2O.
			Total	**1**	
8		i	iron(III) oxide ✓	1	**IGNORE** iron(3) oxide, iron(III) dioxide, etc i.e. **MUST** be systematic **ALLOW** no brackets **<u>Examiner's Comments</u>** This question required candidates to work out a systematic name from a formula. Transition elements can have different oxidation numbers in their compounds and the systematic name needs to contain a Roman numeral. Approximately half the candidates were able to write the correct name as iron(III) oxide. An array of incorrect names were seen, commonly iron(II) oxide, presumably from the number of iron atoms in Fe_2O_3. **Misconception** A systematic name may contain the oxidation number, not the number of atoms in the formula. So Fe_2O_3 is iron(III) oxide and **not** iron(II) oxide.
		ii	$Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$ ✓	1	**ALLOW** multiples e.g. **2** Fe_2O_3 + **6** CO → **4** Fe + **6** CO_2 **ALLOW** 1 Fe_2O_3 ….. but **NOT** 0 Fe_2O_3 ….. **<u>Examiner's Comments</u>** Most candidates were able to balance this straightforward equation.
			Total	**2**	
9			$2\ Ba + O_2 \rightarrow 2\ BaO$ ✓	3	**ALLOW** multiples **IGNORE** state symbols, even if

			$BaO + H_2O \rightarrow Ba(OH)_2$ ✓ Neutralisation **OR** acid-base ✓		incorrect **ALLOW** $Ba + H_2O \rightarrow BaO + H_2$ (reaction with steam) **ALLOW** other correct equations e.g. with less reactive metal oxide **<u>Examiner's Comments</u>** Some candidates coped well with this question which was based on the AS part of the specification and gained all three marks. Common errors were for unbalanced equations in reaction 1 or adding H_2 to the product of reaction 2. Reaction 3 was often, incorrectly, considered as: redox, halogenation, nucleophilic substitution or a precipitation reaction **Assessment for learning** **OCR support** We have produced a topic exploration pack to assist with learning about the reaction of group 2 elements and their compounds: [Teach Cambridge (ocr.org.uk)](https://teach.ocr.org.uk)
			Total	**3**	
10	a		**Level 3 (5-6 marks)** Calculates **CORRECT** enthalpy change **AND** states **multiple** assumptions **AND** improvements *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Calculates **CORRECT** enthalpy change **OR**	1	**Indicative Scientific Points** **<u>Energy change from $mc\Delta T$</u>** Energy in J **OR** kJ q = 100.0 × 4.18 × 18.6 = 7774.8(J) **OR** 7.7748 (kJ) **<u>ΔH in kJ mol^{-1}</u>** $n(Cu(NO_3)_2)$ = 0.05 (mol) $\Delta H = -q/n$ = 7.7748/0.05 = –155 kJ mol^{-1} (3 SF) **ALLOW** -156 kJ mol^{-1} (use of 7.775 kJ) **ALLOW** answer in J mol^{-1} if units are given

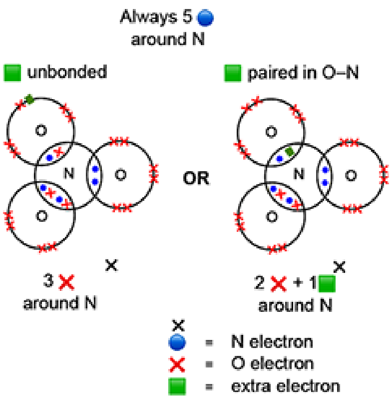
			Correctly calculates the moles **AND** attempts the calculation of q **AND** states **multiple** assumptions **OR** improvements. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Attempts any part of the calculation **AND** states **an** assumption **OR an** improvement. **OR** Correctly calculates the moles **AND** attempts calculation of q **OR** States **multiple** assumptions **OR** improvements *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant* **0 marks** *No response or no response worthy of credit.*		**ALLOW** a single slip/rounding errors **Assumptions and Improvements (NOT INCLUSIVE)** ***Assumptions*** • density of solution is 1 g cm^{-3}/same as water • *c* of solution is same as water • ignore the mass and *c* of zinc • no heat escapes the system/lost to surroundings • mass of solution remains constant • no water lost/evaporated • reaction goes to completion • reaction completed under standard conditions • measurements recorded are accurate ***Improvements*** • polystyrene cup /thermos flask • use a lid • more precise thermometer • more precise balance • measure mass of solution • use burette to measure volume • use a cooling curve • use standard conditions Aspects of the communication statement might typically have been met when calculations have been completed in a logical order, and for L3 or L2 (where level awarded for calculation only) the use of the correct sign with the final answer given to 3 or 4 significant figures. **Examiner's Comments** The calculation of enthalpy change was generally well-answered and the majority of candidates were able to recall the equation $q = mc\Delta T$. Many candidates forgot the minus sign or gave a positive sign for final enthalpy change. Errors in calculation were most

					commonly for using an incorrect mass, usually by finding the mass of copper(II) nitrate (from moles and M_r). Some also used the wrong value for the heat capacity, selecting the value for R from the data sheet instead. Many gave the final answer to an inappropriate six significant figures. Candidates often found it challenging to give appropriate assumptions and improvements, limiting the level achieved to Level 2. However, many candidates did correctly give the assumptions that the specific heat capacity and density of the solution was the same as water. This is usually stated for the candidates with these types of questions. The most common improvements suggested were use of a polystyrene cup, adding a lid or using a thermometer with a higher resolution. Quite a few candidates suggested using a larger volume of solution which would indeed reduce the % uncertainty in the volume measurement. However, it would lead to a smaller temperature change, increasing the % uncertainty in the temperature measurement. Some confused the question with a calculation of enthalpy change of combustion and gave improvements accordingly, e.g. ‘use a copper or bomb calorimeter’, ‘draft shields’, ‘heat for longer’, ‘position of flame and supplies of oxygen’. Exemplar 2  $0.5 \times \frac{100}{1000} = 0.05$ mol $Q = mc\Delta T$ $Q = 100 \times 4.18 \times (38.1 - 19.5) = 7774.8$ J $= 7.77$ kJ $7.77 \div 0.05 = 155.5$ kJ mol^{-1} reaction is exo, $\Delta_r H = -155.5$ kJ mol^{-1} I assumed that the specific heat capacity of the solution is the same as the water. I assumed that no heat was lost to surroundings. I assumed that the mass of solution with zinc in it is ~~100cm³~~ 100g, assumed the density of solution is same as water so 100 cm³ equals to 100g. Improvements can be do the experiment under standard conditions. Can also improve by using a larger mass of reactants ~~and~~ and also use a more accurate thermometer that can record to 2 decimal places. I can also improve by putting the beaker in another beaker with water to reduce heat loss to surroundings

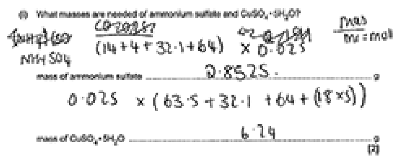
					This response achieved Level 3 - 6 marks. There is a correct calculation for ΔH, the final value has a correct negative sign and is given to 4 significant figures. Lots of valid assumptions and improvements are given.
	b		Half the energy/q **OR** volume/mass of solution **AND** half the moles ✓ Temperature change would be same✓	2	**ALLOW** response that links the same proportionality/ratio of energy/volume/mass of solution to number of moles **ALLOW** same amount of energy (released) per mole **ALLOW both marks** if seen by a calculation i.e. q = 50.0 x 4.18 x 18.6 = 3887.4(J) **OR** 3.8874(kJ) $n(Cu(NO_3)_2)$= 0.025 (mol) ΔH = (–) q/n = 3.8874/0.025 = (–)155 kJ mol^{-1}✓ Use of same temperature✓ May need to check answer in 3b to compare **IGNORE** Sign **<u>Examiner's Comments</u>** There was a lot of misunderstanding associated with this question, with many candidates failing to score any marks. Many said that nothing would change as the concentration was still the same or because the same bonds were being broken and formed. Under a quarter of students scored 1 mark, usually for making the link between the drop in volume to a change in the q and n values. A few did state that the temperature didn't change. Only a small proportion scored both marks, usually by showing by calculation that the temperature change was the same, moles was half and energy was half. Some did believe that the temperature changed, either that it decreased as less reacted or increased as there was less volume

					to heat. A wide variety of alternative responses were given including: 'Enthalpy change the same regardless of mass used' 'Number of moles doesn't impact energy required as it is the same bonds breaking' 'Energy to break and form bonds will still be the same with any volume' 'Amount of energy required to make the new bond would be the same' 'Only concentration has an effect on bond enthalpy values not volume' 'Decrease in volume increases concentration' '$Cu(NO_3)_2$ would still run out first so enthalpy change is the same' 'Zn is in excess so it doesn't matter how much volume we use because Zn and $Cu(NO_3)_2$ still 1:1 ratio.' 'Mole ratio is still the same' or 'same molar ratio' wasn't enough.
			Total	**8**	
11	a		**H–O–N** 104.5° ✓ 2 bonded pairs/regions **AND** 2 lone pairs (around O) **AND** lone pairs repel more ✓ *Independent of bond angle* **O–N–O**	4 (AO 1.2) (AO 2.1) (AO 1.2) (AO 2.1)	**Throughout,** • **IGNORE** names of shapes (even if wrong) • **IGNORE** 'electrons repel' • **DO NOT ALLOW** 'atoms repel' --- **ALLOW** 104–105º **ALLOW** lp for lone pair (of electrons) bp for bonding pair (of electrons) 'bond' for 'bonded pair'

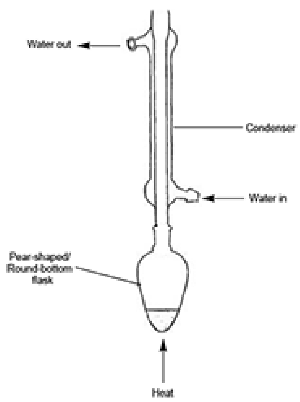
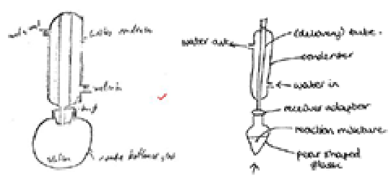
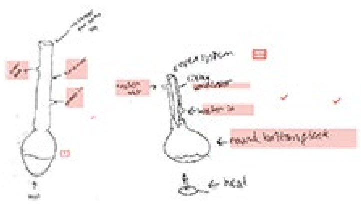
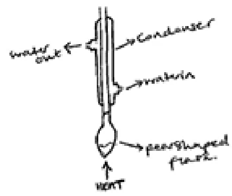
			120° ✓ 3 bonded regions/pairs (around N) ✓ *Independent of bond angle*		**IGNORE** electron density **ALLOW** 115–125º **ALLOW** 3 bonded areas / environments 3 regions / areas of electron density 3 bonded groups **ALLOW** 2 bonded pairs and 1 double bond **OR** 2 bonded pairs and 1 bonded region **<u>Examiner's Comments</u>** This question required candidates to apply their knowledge and understanding of bond angles and electron pair repulsion in a novel context. The best candidates rose to this challenge, securing all four marks for correct bond angles and explanations in terms of the numbers of bonded and lone pairs. The 104.5° and 120° were commonly seen and high scoring candidates provided excellent reasoning. The best explanation for 120° was in terms of three bonding regions and no lone pairs. Lower scoring responses often reasoned that bond angles are determined by lone pairs repelling the atoms, with the role of bonding pairs often being ignored.
	b	i	$Al_2O_3 + 6HNO_3 \rightarrow 2Al(NO_3)_3 + 3H_2O$ Any **THREE** species correct ✓ Correct balanced equation ✓ **DO NOT ALLOW** more than 4 species in equation	2 (AO 2.5) (AO 2.6)	**ALLOW** multiples **IGNORE** state symbols (even if wrong) **ALLOW ionic equation** $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$ Mark using same criteria

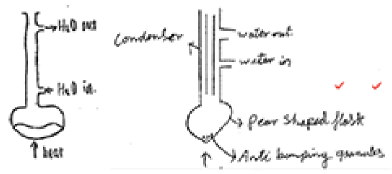
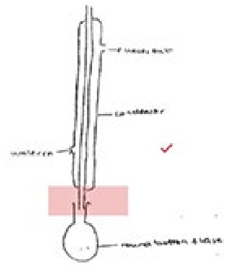
					<u>Examiner's Comments</u> Candidates were required to write a balanced equation for an acid–base reaction. As with Question 4 (b) (ii), candidates needed to write formulae from what should have been common ions, but the formulae for aluminium oxide and aluminium nitrate were often incorrect. In the equation, the reactants and products were sometimes unbalanced, or incorrectly balanced. A common error was H_2 instead of H_2O as the second product. The question was an excellent discriminator.
		ii	 **1st mark:** 8 Electrons around N as above 1 single covalent bond, 1 dative covalent bond 1 double bond **2nd mark:** 8 electrons around each O **AND** 6 O electrons around each O Only award 2nd mark if 1st mark awarded **NO ECFOR**	2 (AO 2.1) (AO 2.5)	**NOT REQUIRED** • Charge ('–') • Brackets • Circles • N and O symbols **IGNORE** inner shells **ALLOW rotated diagram** In **N=O bond, ALLOW** sequence **× × • •** **ALLOW** non-bonding electrons unpaired **ALLOW** dot and cross labels swapped: i.e. • for O electrons and × for N electrons **<u>Examiner's Comments</u>** Candidates were expected to use the displayed formula of nitric acid to identify that the central N atom had one double bond, one covalent bond and one dative covalent bond. This information then gave the strategy for the dot and cross diagram.

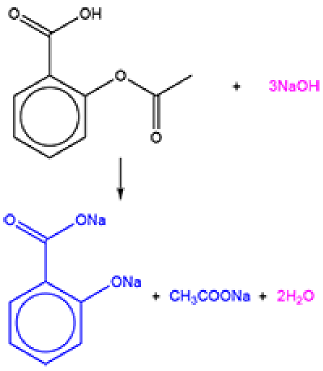
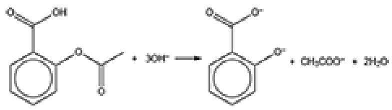
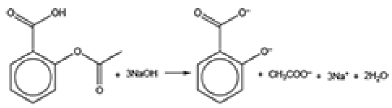
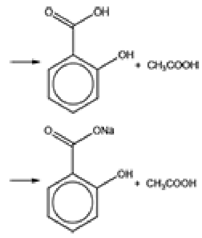
					Although virtually all candidates attempted the dot and cross diagram, only about a quarter of candidates could be credited with a meaningful response. The key was to use nitrogen's 5 outer shell electrons and to combine these with 3 oxygen electrons or 2 oxygen electrons and the extra electron. Then the remaining oxygen electrons could be added, taking care that there were 6 around out O atom. Finally the extra electron would need to be placed in an octet gap. Many candidates showed just 4 nitrogen electrons and this approach resulted in no marks. Other common errors included 3 double bonds around the N atom, and a lone pair on the N atom. This dot and cross diagram discriminated between higher scoring candidates extremely well.
			Total	**8**	
12	a		Any correct formula for $\mathbf{X}_2\mathbf{Y}(\mathbf{Z}O_4)_2 \cdot 6H_2O$ ✓ with suitable elements for **X**, **Y** and **Z** using information in stem: • **X** can be K, Rb, Cs, Fr **ONLY** • **Y** can be Mg or a transition element in period 4: Ti → Ni • Z must be Cr **Example: $K_2Mg(CrO_4)_2 \cdot 6H_2O$**	1 (AO 3.2)	Suitable transition elements: Ti, V, Cr, Mn, Fe, Co, Ni • *Cu in in the Tutton's salt in Q4* • *Sc and Zn and not classified as transition elements* **<u>Examiner's Comments</u>** Question 4 assesses candidates' ability to apply their chemical knowledge and understanding from different parts of the specification in a novel context. Information is supplied throughout the question, and clues are sometimes presented to candidates. In part (a), candidates are introduced to Tutton's salts and are given an example of a Tutton's salt that forms the context of the whole question. A

					candidate needs to apply the information in the bullet points to predict the formula of a different Tutton's salt. This question discriminated extremely well across different abilities and highlighted that some candidates struggled to use supplied information. This was repeated in other parts of Question 4. Just over half the candidates gave a correct formula from the information. Some candidates did not choose one of the acceptable ions shown in the first and second bullet points, and many chose S rather than Cr, despite S being in the supplied Tutton's salt; a significant number omitted the $\bullet 6H_2O$.
	b	i	Mass $(NH_4)_2SO_4$ = 3.3025 g ✓ Mass $CuSO_4\bullet 5H_2O$ = 6.24 g ✓	2 (AO 1.2 ×2)	**ALLOW** 3.3, 3.30. 3.303 **ALLOW** 6.2 __**Examiner's Comments**__ This question required candidates to calculate the masses of two reactants that could be used to prepare a sample of the Tutton's salt. Candidates were supplied with the formula of hydrated copper(II) sulfate but not the formula of ammonium sulfate, so candidates needed to work out its formula from ions that candidates are expected to be able to recall from the specification. Just over half the candidates obtained both correct masses but many obtained just one correct mass, usually that of $CuSO_4\bullet 6H_2O$. Exemplar 3 

					This exemplar shows a typical response with the incorrect formula of ammonium sulfate clear shown by the candidate, resulting in the incorrect mass of 2.8525 g. This incorrect formula and mass were seen in many responses and, from the initial crossings out, this candidate is clearly confused about how to tackle this simple mole calculation. The incorrect answer of 2.85 g was seen on almost as many scripts as the correct answer of 3.30 g. The moral is that candidates need to learn the formula and charges of the common ions encountered in chemistry. The comments here apply also to Question 6 (b) (i), where formulae need to be written using ions listed in the specification.
		ii	• Prevents water of crystallisation from being removed • Anhydrous salt would form • Prevents dehydration ✓	1 (AO 3.4)	**IGNORE** all the water would be removed *water is the solvent* **IGNORE** prevents decomposition **IGNORE** increases the size of crystals **<u>Examiner's Comments</u>** The majority of candidates did not answer this question correctly. Candidates were expected to refer back to the formula of the Tutton's salt, spot that there was water of crystallisation present, and that this would be lost if all the solvent was boiled off. Many responded vaguely in terms of decomposition or formation of larger crystals but a mark was only awarded if there was a definite link to the water contained within the crystals. **Assessment for learning** In the specification, Section 2.1.2a states the following:

					(a) the writing of formulae of ionic compounds from ionic charges, including: i. prediction of ionic charge from the position of an element in the periodic table ii. recall of the names and formulae for the following ions: NO_3^-, CO_3^{2-}, SO_4^{2-}, OH^-, NH_4^+, Zn^{2+} and Ag^{+u}. This section will be studied at the start of the 2 year course. Candidates need to be confident with using these common formulae. For success in chemistry, these ions must be learnt.
			Total	**4**	
13		i	 **Reaction apparatus (Labels NOT required)** flask **AND** upright condenser **AND** open system at top ✓ *(Could be labelled)* **Labels AND direction of water flow** Pear-shaped/round-bottom flask **AND** condenser **AND** water in at bottom and out at top ✓ Heat **NOT** required **DO NOT ALLOW** flask, conical flask,	2 (AO 3.3 ×2)	For open system, **DO NOT ALLOW**  **For open system, ALLOW** label. e.g. 'open at top'  **ALLOW** line across flask 

			volumetric flask **DO NOT ALLOW** thermometer **DO NOT ALLOW** condensing tube as label		 **ALLOW small** gap between flask and condenser **BOD**, e.g.  **If in doubt, ask Team Leader** **<u>Examiner's Comments</u>** Most candidates drew a diagram that looked like a vertical condenser above a flask. The quality of the diagrams was not very good. Candidates then needed to label their diagram. Errors included a bung or thermometer inserted at the top of the condenser and water flowing the wrong way in the condenser. For labelling, candidates were expected to use scientific terminology. Responses such as 'condensation tube' and vague terms such as 'flask' were not credited. These labels were often omitted. A significant number drew a set up for distillation instead of reflux.
		ii		3 (AO 2.6 ×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** annotations of provided structure of aspirin at top left **ALLOW** equation with 3OH– **OR**

			 Organic products ✓ ✓ ***2 marks*** 3NaOH AND $2H_2O$ ✓ ***1 mark*** NOTE: ALLOW O^-Na^+ for ONa throughout **SCROLL DOWN FOR PRODUCTS**		3NaOH giving anions for organic products, i.e.  **OR**  **ALLOW** 1 of the 2 organic products mark for BOTH structures as COOH and OH (or mixture) e.g  **<u>Examiner's Comments</u>** This question was the hardest part of Question 5 and about half the candidates were not given any marks. Some drew the sodium carboxylate salt of aspirin structure, leaving the ester link intact. A large number of candidates realised that the ester would be hydrolysed. Sometimes the sodium salts were often not shown and, even they were shown, the phenol group was often shown intact. The hardest mark was the formation of $2H_2O$ and a large number of candidates showed the more intuitive but incorrect '$3H_2O$' instead.
			Total	**5**	
14	a	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **if answer = 6.77 award 2 marks** --	2 (AO 1.1 × 1)	**DO NOT ALLOW** use of A^- or X^- **<u>Examiner's Comments</u>**

			K_w = [H⁺][OH⁻] **OR** K_w = $[H^+]^2$ **OR** [H⁺] = $\sqrt{K_w}$ ✓ ([H⁺] = $\sqrt{(2.92 \times 10^{-14})}$) pH = –log($1.71 \times 10^{-7}$) = 6.77 ✓	(AO 2.2 × 1)	Most candidates were given the first mark from a correct or rearranged equation. Many candidates then answered this question correctly and were given both marks. Those who didn't, either used 1.00×10^{-7} as [OH⁻] when calculating [H⁺]=K_w/[OH⁻] or calculated pH as -log(2.92×10^{-14}).
		ii	(In pure water), [H⁺] (always) equals [OH⁻]	1 (AO 3.2 × 1)	**ALLOW** moles/number of H^+ is (always) equal to moles/number of OH^-. **DO NOT ALLOW** ratio [H⁺] : [OH⁻] doesn't change **<u>Examiner's Comments</u>** This question proved difficult with only a few candidates able to state that in neutral water, [H⁺] = [OH⁻]. Many candidates said that as the pH is close to 7, water is therefore neutral.
	b		• **Equation** $Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ ✓ **CHECK THE ANSWER ON ANSWER LINE** **if answer = 11.51 award 4 calculation marks** --- • **n($Sr(OH)_2$)** = $\frac{0.145}{121.6}$ = 1.1924… x 10^{-3} ✓ • **[OH⁻]** = 2 x (1.1924 x 10^{-3} ÷ 0.25) = 9.539… x 10^{-3} ✓ • **[H+]** = K_w ÷ [OH⁻] = $\frac{0.145}{121.6}$ = 3.061… x 10^{-12} ✓ • **pH** = –log(3.061… x 10^{-12}) = 11.51 ✓	5 (AO 2.6) (AO 2.4 × 3) (AO 1.2 × 1)	**IGNORE** state symbols (even if wrong) **ALLOW** multiples **ALLOW** Sr^{2+} + $2OH^-$ for $Sr(OH)_2$ **ALLOW** 3 SF up to the calculated value. Ignore RE after 3SF. **ALLOW** ECF throughout but final answer must be pH>7 **Final answer must be from calculated values.** **Common errors for 3 calculation marks** 11.98 *(Use of K_w = 1 × 10^{-14})* 11.21 *(no × 2)* 10.91 *(÷ by 2)* **Common error for 2 calculation**

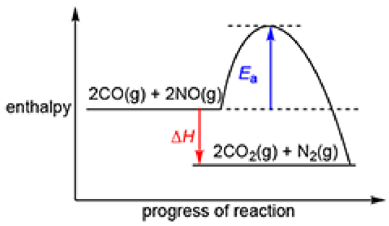
			2 DP required		**marks** pH = 11.67 *(no × 2 and wrong K_w)* --- **Alternative method for:-** **pH = pKw – pOH** ○ ***n*(Sr(OH)$_2$)** = $\frac{0.145}{121.6}$ = 1.1924… x 10^{-3} ○ **[OH$^-$]** = 2 x (1.1924 x 10^{-3} ÷ 0.25) = 9.539… x 10^{-3} ○ ***pH*** *= pKw - pOH* *= (-log 2.92 x 10^{-14}) - (-log 9.539..x 10^{-3})* • ***pH*** *= 13.53(46) - 2.02(05)* **= 11.51** **Examiner's Comments** Most candidates wrote the correct equation. Common errors were using Sr^{2+} as reactant, not balancing the H_2O and not having the H_2 as second product. Most candidates calculated the moles of $Sr(OH)_2$ correctly but fewer recognised that [OH^-] = twice the [$Sr(OH)_2$]. As a result, most candidates scored 3 calculation marks. A few candidates chose the incorrect K_w value.
	c	i	$SrCO_3 + 2HNO_3 \rightarrow Sr(NO_3)_2 + H_2O + CO_2$ ✓	1 (AO 2.6)	**IGNORE** state symbols **DO NOT ALLOW** H_2CO_3 for $H_2O + CO_2$ (question states that a gas was produced)

					ALLOW multiples **<u>Examiner's Comments</u>** This was often answered correctly but some candidates gave the incorrect formulae for $Sr(NO_3)_2$ and either no other product or H_2 gas.
		ii	M_r of $SrCO_3$ is different to M_r $CaCO_3$ / moles $SrCO_3$ are different to moles $CaCO_3$ ✓ M_r of $SrCO_3$ > M_r $CaCO_3$ / moles $SrCO_3$ < moles $CaCO_3$ **AND** **More** moles/volume gas (from $CaCO_3$)✓	2 (AO 3.1 × 1) (AO 3.2 × 1)	**ALLOW** ORA **ALLOW** $n(SrCO_3)$ = (1.00 ÷ 147.6) = 6.78 × 10^{-3} (mol) **AND** $n(CaCO_3)$ = (1.00 ÷ 100.1) = 9.99 × 10^{-3} (mol) For the 2nd mark, we are assessing the idea of the greater moles of carbonate produces more gas. Subsumes first mark **ALLOW** $n(SrCO_3)$ = (1.00 ÷ 147.6) = 6.78 × 10^{-3} (mol) **AND** $n(CaCO_3)$ = (1.00 ÷ 100.1) = 9.99 × 10^{-3} (mol) **AND** Calculated values (CO_2) 163 cm^3 **AND** 240 cm^3 **<u>Examiner's Comments</u>** Only a few candidates used the mass value given in the question to link the number of moles of the group 2 metal carbonate and the number of moles, and hence volume, of gas produced. **Misconception** Many candidates answered this question in terms of the relative reactivity, or solubility of Ca and Sr and then continuing by explaining their respective ionisation energies.

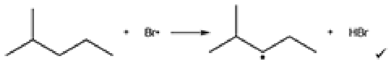
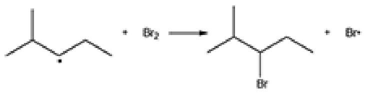
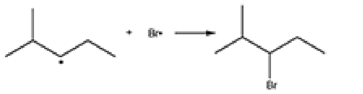
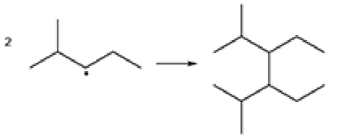
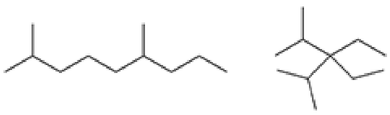
			Total	**11**	
15			**3**V^{3+} + $Cr_2O_7{}^{2-}$ + **2**H^+ → **3** $VO_2{}^+$ + **2**Cr^{3+} + H_2O **ALL** reactant and product species correct ✓ Correct balancing (of correct equation) **AND** cancelling of species ✓	2 (AO 2.5) (AO 2.6)	**IGNORE** Balancing and electrons for first mark **DO NOT ALLOW** electrons in final answer __**Examiner's Comments**__ Very few candidates were able to produce the balanced overall equation; a few had the correct reactants and products but not balanced. Candidates are advised to look for the information contained within the question. The formulas were given, and it was stated that the solution was acidified, leaving only water to be identified. Some candidates approached this through two half equations whereas others used oxidation numbers to balance their equations.
			Total	**2**	
16		**C**		1 (AO 2.6)	__**Examiner's Comments**__ Most candidates answered this question correctly with C.
			Total	**1**	
17			**Correct structural isomers of C_3H_8O** *1 mark* $CH_3CH_2CH_2OH$ **AND** $CH_3CHOHCH_3$ ✓ **Reaction conditions** *1 mark* Distillation for aldehyde **AND** reflux for carboxylic acid **OR** ketone ✓		**ANNOTATE WITH TICKS AND CROSSES** **Throughout,** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IF functional group is NOT given,** **ALLOW** propanal / RCHO **ALLOW** propanoic acid / RCOOH

			Functional group of organic product *2 marks* $CH_3CH_2CH_2OH$ → aldehyde **OR** → carboxylic acid ✓ $CH_3CHOHCH_3$ → ketone ✓ **One correct equation** *1 mark* $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ **OR** $CH_3CHOHCH_3 + [O] \rightarrow CH_3COCH_3 + H_2O$ **OR** $CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓		**ALLOW**propanone / ..... RCOR **IGNORE** small slips in formulae (assessed in equation) __**Examiner's Comments**__ There were some excellent responses to this question which discriminated extremely well. Unfortunately, there were a significant number of incorrect responses and some less successful candidates had clearly struggled to recall and apply this important material. The identification of the isomers was usually correct, as was the identification of the oxidation products from the primary and secondary alcohols, and the conditions required to produce the organic products. The equation proved to be the hardest requirement with the H_2O by-product often being omitted or H_2 shown instead. A general point applies to organic structures. Some candidates did not show the structures of the isomers and attempted this question using the molecular formula of C_3H_8O supplied in the question for both alcohol isomers and no structural formulae. It was then impossible to know which isomer was being reacted and this could cost the candidate a significant number of marks. It is essential in organic chemistry to use unambiguous formulae which can be any combination of skeletal, structural or displayed. Unless a question specifies that a molecular formula is required, candidates should assume that an unambiguous formula is required.
			Total	**5**	
18		i	$CuO + 2HCl \rightarrow CuCl_2 + H_2O$ ✓	1 (AO2.6)	**ALLOW** multiples **IGNORE** state symbols **IGNORE** charges, even if wrong

					Examiner's Comments This question required candidates to recognise the reaction as being 'acid–base' and to interpret a formula from a name containing a Roman numeral. Candidates identifying the formula of copper(II) oxide as CuO were normally able to complete the equation. A reasonably large number identified the copper compounds as CuO_2 and CuCl. Overall, most candidates produced a correct equation.
		ii	$(NH_4)_2CO_3 + 2HNO_3 \rightarrow 2NH_4NO_3 + CO_2 + H_2O$ Any 4 formulae correct ✓ All 5 formulae correct and balanced ✓	2 (AO2.6 ×2)	**ALLOW** multiples **IGNORE** state symbols **IGNORE** charges, even if wrong **ALLOW** H_2CO_3 for $CO_2 + H_2O$ *Counts as 2 formulae for marking criteria* **Examiner's Comments** This item was much more demanding than the equation in 22(b)(i) and was often answered incorrectly. Most were unable to work out the formula of the two ammonium compounds, with NH_3 often shown instead of NH_4. A mark was available for 4 of the 5 formulae being correct but comparatively few were able to construct the correct balanced equation. Candidates are expected to know the formula and charge of ammonium and carbonate ions and the common acids (sulfuric, hydrochloric and nitric) and these are clearly listed in the specification.
			Total	**3**	
19		i	$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$ Correct species ✓ Balanced ✓	2 (AO2.6 ×2)	**ALLOW** multiples **IGNORE** state symbols For heptane formula, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW 1 mark** for balanced combustion equation for a different

					alkane (**ECF**) e.g. $C_6H_{14} + 9½O_2 \rightarrow 6CO_2 + 7H_2O$ **Examiner's Comments** Most candidates were able to construct a balanced equation for the combustion of heptane. Most were aware that CO_2 and H_2O would be the products although some generated CO, C_6H_{12} or unusual compounds such as $C_7H_{14}O$. The hardest part was the formula of heptane itself with use of hexane instead being a common error; candidates who made this error were given 1 mark, provided that their equation was balanced.
		ii	 **Reactants, products and Δ*H*** **2CO + 2NO** on LHS **AND** **$2CO_2$ + N_2** on RHS **AND** Δ*H* labelled with products **below** reactants **AND** **Arrow downwards** ✓ ***E_a* (independent of ΔH)** curve with arrow from reactants to top of curve **AND** E_a labelled ✓ **IF** endothermic diagram shown,	2 (AO2.1) (AO1.2)	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** state symbols Δ*H* **DO NOT ALLOW** –Δ*H* **DO NOT ALLOW** double headed arrow on Δ*H* **ALLOW** Δ*H* arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line. **ALLOW** –746 for Δ*H* ***E_a*** **ALLOW** AE **OR** A_E **ALLOW 2** arrowheads at **each** end of E_a line **OR** no arrowhead **BUT DO NOT ALLOW** arrowhead down E_a line must reach maximum (or near to maximum) on curve **Examiner's Comments**

			ALLOW ECF for E_a using MS criteria		Most candidates obtained 1 or 2 of the available marks, the commonest errors being use of a doubleheaded arrow for Δ*H* or a –Δ*H* label. Some candidates showed endothermic profiles and these could create issues with positioning of the Δ*H* and E_a arrows. Generally, positioning of Δ*H* and E_a arrows was imprecise and candidates are advised to start and finish the positions of their arrows accurately. The mark scheme did allow for some leeway but positioning of arrows could generally be improved.
		iii	Catalyst lowers activation energy **OR** Catalyst increases rate without itself changing ✓ Reaction proceeds via a different route/pathway **OR** More molecules/particles exceed activation energy ✓	2 (AO1.2 ×2)	**ALLOW** 2nd labelled curve on profile diagram in **23(a)(ii)** with lower activation energy/E_c with catalyst **ALLOW** E_c needs less energy to start reaction **ALLOW** E_c curve is lower than E_a curve **IGNORE** 'shorter route' for alternative route **IGNORE** more successful collisions **<u>Examiner's Comments</u>** Almost all candidates knew that a catalyst lowered activation energy and most were aware that an alternative pathway was made possible by a catalyst.
			Total	**6**	
20			**C**	1 (AO 2.1)	**<u>Examiner's Comments</u>** Most candidate chose the correct response of C. From the annotations on the scripts, most candidates identified the largest jump between the 3rd and 4th ionisation energies. Option D proved to be the main distractor. Having identified the correct large jump, a significant number of candidates chose the

					group at the end of the jump (Group 4) rather than the group at the start of the jump (Group 3). This suggests a misconception.
			Total	**1**	
21		i	**Initiation** $Br_2 \rightarrow 2Br•$ **AND** ultraviolet / UV ✓ **Propagation**  ✓  ✓ **Termination** $2Br• \rightarrow Br_2$ ✓  ✓  ✓	6 (AO1.1) (AO2.5) (AO2.5) (AO2.5) (AO3.1)	**DOT REQUIRED** throughout **IGNORE** temperature and pressure **ALLOW ECF** for use of Cl• (from Cl2) in subsequent propagation and termination steps **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** 1 mark for propagation for 2 'correct' equations but with dot omitted or in wrong position **DO NOT ALLOW ECF** from incorrect radical intermediate for termination steps __**Examiner's Comments**__ Many candidates tackled this question confidently, especially when using skeletal formula following the format of the structure given in the question. Over half the candidates scored 5 or 6 marks. Only the highest attaining candidates were able to provide all three correct termination steps. Many lost a mark for the combination of the two alkyl radicals, typically either by simply joining the ends of the chains or by missing the connecting C-C bond.  Those that attempted to use structural formula often lost marks due to missing Hs. Other common errors included the incorrect

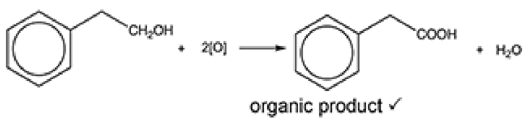
					positioning of the radical dot, most typically on the terminal carbon, addition of Br in the first propagation step or use of molecular formula. Lower attaining candidates were often able to score a mark for the initiation step and the termination step involving two Br radicals. However, for some this was not a well-known mechanism, with attempts to break up the chain or form hydrogen radicals or charged species. Errors were also seen with correct balancing of equations such as truncated C chains or extra Br atoms added.
		ii	C_6Br_{14} ✓ Correct balanced equation $C_6H_{14} + 14\ Br_2 \rightarrow C_6Br_{14} + 14\ HBr$ ✓	2 (AO2.6 ×2)	**ALLOW** 1 mark for correct balanced equation using any combination of skeletal **OR** structural **OR** displayed formula **<u>Examiner's Comments</u>** Most responses gained at least 1 mark for this question giving the correct molecular formula of C_6Br_{14}. However many hadn't assimilated that when a hydrogen atom is substituted in an alkane it requires one mole of a halogen and produces one mole of the hydrogen halide. So many gave this incorrect equation instead: $C_6H_{14} + 7Br_2 \rightarrow C_6Br_{14} + 7H_2$. Some lost marks for C_5H_{14} or for use of structural formulae.
		iii	$n(\mathbf{B}) = \frac{72.0}{40000}$ **OR** $\frac{0.072}{40}$ **OR** $1.8(0) \times 10^{-3}$ (mol) ✓ $M(\mathbf{B}) = \frac{0.8649}{1.8(0) \times 10^{-3}} = 480.5$ ✓ Molecular formula = $C_6H_9Br_5$ ✓	3 (AO2.2 ×2) (AO3.2)	**ALLOW 2SF** up to calculator value **ALLOW ECF** from incorrect *n*(**B**) **ALLOW ECF** from incorrect *M*(**B**) from *n*(**B**) --- **COMMON ERROR** $n(\mathbf{B}) = \frac{72.0}{24000} = 3 \times 10^{-3}$ (mol) ✗ $M(\mathbf{B}) = \frac{0.8649}{3 \times 10^{-3}} = 288.3$ ……………✓

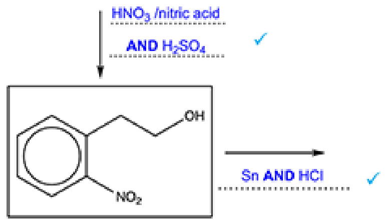
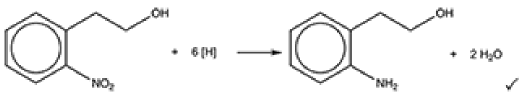
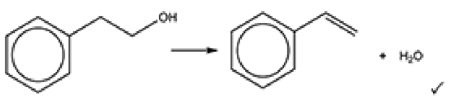
					Molecular formula = $C_6H_{12}Br_2$ **OR** $C_6H_{11}Br_3$ ✓ **ALLOW ECF** for viable molecular formula with C_6 but must be derived from a calculated value for *M*(**B**) **Examiner's Comments** Overall, this question was well answered with over half of candidates gaining all 3 marks. The use of a different molar volume confused some candidates. Some attempted to use PV=nRT or different combinations of the figures given with varying degrees of success. Lower attaining candidates typically struggled with unit conversions and were unable to make use of the units to help them work out the methodology to use.
			Total	**11**	
22			$C_6H_{11}OH$ ✓ Correct balanced equation $C_6H_{11}OH + 8½ O_2 \rightarrow 6 CO_2 + 6 H_2O$ ✓	2 (AO2.6 ×2)	For $C_6H_{11}OH$, **ALLOW** $C_6H_{12}O$ **OR** any combination of skeletal **OR** structural **OR** displayed formula **ALLOW** multiples **IGNORE** state symbols **ALLOW** multiple OH groups in structure for both marks e.g. $C_6H_{12}O_2$ ✓ $C_6H_{12}O_2 + 8 O_2 \rightarrow 6 CO_2 + 6 H_2O$ ✓ **Examiner's Comments** Approximately half the candidates gained both marks here but just over a third gained no credit. A very common error was $C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$ missing the need for an alcohol group. Another common error was balancing with $9O_2$ i.e. not deducting O from alcohol from their count of O atoms. Some struggled to determine the correct number of Hs when a single C=C bond is introduced so gave $C_6H_{12}OH$ or $C_6H_{13}OH$ instead. Lower attaining candidates did not understand what

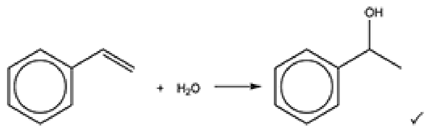
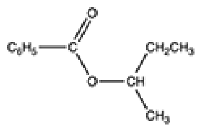
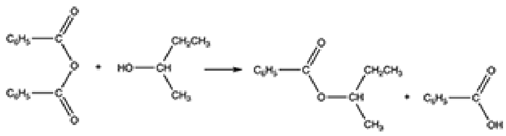
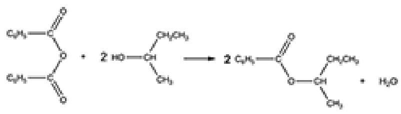
					happens during complete combustion. For example, they used [O] instead of molecular oxygen or didn't have CO_2 and water as the products. Some used structural formula which made it easier to get the correct formula of the reactant but often made it trickier to balance the equation.
			Total	**2**	
23			**B**	1 (AO2.2)	**<u>Examiner's Comments</u>** This was a demanding question. Candidates needed to calculate the moles of oxygen and then determine the ratio of alkane to oxygen to find the correct response. The majority of successful candidates clearly showed their working to help them to arrive at the correct answer. The most common incorrect answer was C.
			Total	**1**	
24	a	i	**Equation** $Ca + 2H_2O \rightarrow Ca(OH)_2 + H_2$ All formulae and balancing correct ✓ **Observation** Effervescence/fizzing/bubbles **OR** Ca/solid disappears/dissolves **OR** Forms a white ppt/solid ✓	2 (AO 2.6) (AO 1.2)	**ALLOW** correct multiples including fractions **IGNORE** state symbols, even if wrong **IGNORE** temperature change, pH change or gas formed i.e. must be an observable change. **IGNORE** turns cloudy **DO NOT ALLOW** Colour change **<u>Examiner's Comments</u>** Most candidates scored the mark for the correct observation. A few said what would happen rather than what they would see, e.g. gas is formed, pH would increase, mass lost or even reference to the 'squeaky pop' test. Many struggled to give the correct balanced equation with either CaO being given as a product or incorrect balancing. Many did not have a gas

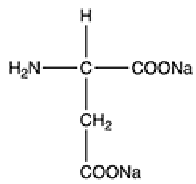
					produced but then had bubbling as an observation. **OCR support** OCR has some resources to help support the understanding of balancing symbol equations such as this delivery guide for Atoms and equations.
		ii	More vigorous effervescence/fizzing/bubbling **OR** Ba/solid disappears/dissolves faster **OR** White ppt formed less rapidly ✓	1 (AO1.2)	**ORA** if clearly references Ca **ALLOW** AW such as stronger/ rapid/ quicker/ more quickly/ more violent **ALLOW** less or no ppt (as barium hydroxide is more soluble) **Note**: Must reference observation not just reaction e.g. more vigorous reaction. **IGNORE** finishes first **IGNORE** more bubbles (need idea of rate) **IGNORE** exothermic **Examiner's Comments** Responses not about observations were very common, e.g. more vigorous reaction, Ba is more reactive. Some described Ba as being less reactive. Many responses did not include the idea of rate (for example, 'more bubbles') or were not comparative (for example, 'vigorous bubbling').
	b	i	$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$ Balanced equation ✓ State symbols ✓	2 (AO 2.5 x 2)	**ALLOW** ionic equation $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ **M2 dependent on M1** **IGNORE** NaCl balanced on both sides **Examiner's Comments** Less than half the candidates gained

					credit for this challenging question. There was lots of information to process. Many struggled to give the correct formula for the products, e.g. $NaNO_3$, Ba_2SO_4, or had issues with balancing. Some tried to involve the NaCl in the reaction, either recognising that it didn't react (acceptable on the mark scheme) or forming barium chloride or even Cl_2. Lots of candidates lost the mark for state symbols as they left $Ba(NO_3)_2$ as (s), not recognising that in step 1 the mixture was dissolved in water so should now be (aq).
		ii	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 26.6 % award 4 marks** --- *n*($BaSO_4$) $= \frac{3.28}{233.4}$ **OR** 0.014053… (mol) ✓ mass $Ba(NO_3)_2$ = 0.014053… × 261.3 **OR** 3.672.......(g) ✓ mass Na*Cl* = 5.00 – 3.672.. **OR** 1.3279… (g) ✓ % Na*Cl* $= \frac{1.3279 \times 100}{5.00}$ = 26.6(%) **3 SF** ✓	4 (AO 3.1 ×3) (AO 3.2)	**ALLOW ECF** from incorrect equation in 2(b)(i) and throughout **ALLOW 3SF** up to calculated value throughout **IGNORE** rounding errors past **3SF** *Calculator:* 0.01405312768 *Calculator:* 3.672082262 *Calculator:* 1.327917738 **ALLOW ECF** for use of calculated mass NaCl e.g. 0.014053…x 58.5 = 0.8221…. to give final % 16.4 to 3SF -- **Alternative approach for last 2 marks** % $Ba(NO_3)_2$ $= \frac{3.672 \times 100}{5.00}$ = 73.44 … ✓ % Na*Cl* = 100 – 73.44 = 26.6 % ✓ **<u>Examiner's Comments</u>** This was a tricky calculation, made more challenging if candidates hadn't been able to successfully complete (i). Many were able to calculate the moles of $BaSO_4$ but often rounded their answer to only 2 significant figures at this stage i.e. 0.014. Many assumed a direct ratio between $BaSO_4$ and NaCl so mass was found by multiplying moles by 58.5 (molar mass for NaCl) - if this was done

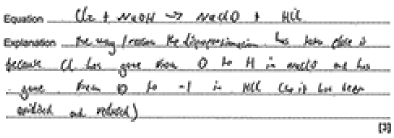
					then credit was given for ECF for the final marking point. OCR support The M1 section of the Mathematical Skills handbook contains useful information on handling data, including M1.1 use of significant figures.
		iii	Silver chloride/AgC*l* would be produced (as a precipitate) ✓ (Mass of NaC*l*) can be calculated from the mass/moles of AgC*l* ✓	2 (AO 3.4 × 2)	**ALLOW** Chloride reacts to give (white) ppt **IGNORE** incorrect formula of silver chloride **ALLOW** equation showing formation of AgCl(s) **ALLOW** Weigh AgC*l* and use to calculate %/mass/moles **Examiner's Comments** Another tricky question with less than half gaining credit. Many were able to recognise the addition of silver nitrate as the test for halide ions but did not realise that it could be used quantitatively. Many didn't read the question carefully and assumed Na_2SO_4 was still present, giving a mixture of two precipitates. Some, despite recognising the formation of AgCl, could not then see how to calculate the mass of NaCl i.e. "you won't have formation of $BaSO_4$". Some suggested that barium nitrate would also form a precipitate, perhaps confused by the (s) state symbol in the question.
			Total	**11**	
25	a		 Correct balanced equation ✓	2 (AO2.5) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_6H_5 for phenyl group **Examiner's Comments**

					Most candidates were able to score at least 1 mark for this question. Common errors included candidates producing two water molecules or failing to balance [O]. A significant proportion of candidates did not score any marks, frequently due to the organic product having too many carbon atoms in it.
	b	i		2 (AO1.2×2)	**IGNORE** references to concentration **IGNORE** ‘dilute’ for HCl/ **IGNORE** H_2 **IGNORE** NaOH if seen as a reagent to convert nitro group into amine e.g ‘Sn/(concentrated) HCl then NaOH’ scores the mark
		ii		1 (AO2.6)	<u>**Examiner’s Comments**</u> Candidates were familiar with the reagents required in these two reactions. The most able candidates were able to identify the use of 6[H] as the reducing agent and the production of 2 water molecules. Incorrect responses commonly included the use of HCl and $NaBH_4$ as a reactant.
	c		**Stage 1** *Reagents*: H_2SO_4 ✓  **Stage 2**	4 (AO3.1) (AO2.6) (AO3.1) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ **OR** HCl **OR** H_3PO_4 **DO NOT ALLOW** other named acids **IGNORE** concentration/pressure **IGNORE** water/steam For steam, **ALLOW** H_2O with temperature ≥100°C **ALLOW** use of H_3PO_4/H_2SO_4 as catalyst

			Reagents: Steam/H_2O(g) **AND** acid/H^+ (catalyst) ✓ 		**DO NOT ALLOW** HCl **IGNORE** pressure **Examiner's Comments** This question proved challenging with only the most able being given full marks. The reagents and conditions were not well known and candidates did not include water in their equations to make sure they were balanced.
	d		Structure of ester product ✓  Correct balanced equation ✓ 	2 (AO3.1) (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  **Examiner's Comments** Most candidates did not secure a mark in this question. Many candidates used butan-1-ol in their equations or used benzoic acid rather than benzoic anhydride as the reactant. The most able candidates suggested that the benzoic acid product would then further react with butan-2-ol to produce a second ester molecule and water. This was an acceptable alternative response.
			Total	**11**	
26			$C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O$ ✓	4 (AO2.6×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

			$2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2$ ✓ H_2O **AND** CO_2 ✓  ✓ Correct formula of salt:		**IGNORE** state symbols and use of equilibrium sign **ALLOW** KC_2H_5COO **DO NOT ALLOW** a missing charge (e.g. $C_2H_5COO^-K$) the 1st time seen but **IGNORE** for next equations. For salts, **ALLOW** $C_2H_5COO^-K^+$ **OR** $C_2H_5COO^- + K^+$ **DO NOT ALLOW** –COO–K (covalent bond) the 1st time seen but **IGNORE** for next equations. **FOR** $CO_2 + H_2O$ **ALLOW** H_2CO_3 **<u>Examiner's Comments</u>** This question proved challenging for candidates. The first equation was often answered correctly, although some candidates used sodium hydroxide rather than potassium hydroxide in their response. The second equation was frequently incorrect. Candidates frequently missed a hydrogen from the structure for methanolic acid or did not recognise that hydrogen was a product. Many candidates did not account for magnesium having a 2+ charge when working out the product. For the third equation, the majority of candidates identified that carbon dioxide and water would be produced but were unable to give the correct formula of the salt as they did not interpret the information given regarding the R group.
			Total	**4**	
27	a	i	Oxidation and reduction of the same **element**✓ 'Atom' is insufficient for element	1 (AO1.1 ×1)	**ALLOW** 'chlorine' **OR** '*Cl*' for same element **IGNORE** 'species' for 'element' **<u>Examiner's Comments</u>**

					Candidates answered this question well and most were given the mark. Where candidates didn't receive credit, it was mainly because they used the term 'same atom' instead of 'same element'. Some less successful responses responded with completely incorrect chemistry and had clearly not learnt this specification content.
		ii	**Equation** $Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$ ✓ **Redox:** C*l* is oxidised from 0 (in Cl_2) to +1 in NaC*l*O ✓ C*l* is reduced from 0 (in Cl_2) to -1 in NaC*l*/HC*l* ✓ **IGNORE** oxidation numbers shown in equation *(treat as rough working)* **BUT** If **no** oxidation numbers in explanation, *look at equation for oxidation numbers*	3 (AO2.6×1) (AO2.1×2)	**DO NOT ALLOW** $Cl_2 + NaOH \rightarrow NaClO + HCl$ **ALLOW ECF** from HCl in equation **ALLOW** 1 out of 2 redox marks if NaClO AND NaCl omitted, i.e. C*l* is oxidised from 0 to +1 **AND** C*l* is reduced from 0 to -1 **ALLOW** 1 out of 2 redox marks if oxidation number changes are **BOTH** correct ...BUT reduction/oxidation is incorrectly assigned, i.e. C*l* is reduced from 0 (in Cl_2) to +1 in NaC*l*O C*l* is oxidised from 0 (in Cl_2) to -1 in NaC*l*/HC*l* **General: ALLOW number before sign in ox no, i.e.** 1+ for +1 1- for -1 **IGNORE** ionic charges, e.g. Cl^{1+} **IGNORE** '1' (signs required) **IGNORE** references to electron loss/gain (even if wrong) **<u>Examiner's Comments</u>** Candidates found the equation hard, despite this reaction being specification content and the inclusion in the earlier part of the stem of 'NaClO' as one product. The correct response required candidates to realise that NaCl would be a product and to balance the resulting equation. Some did not add the balancing '2' before NaOH, and many selected HCl as the second product, a compound that would react further with NaOH to produce NaCl. The explanation worked the same whether NaCl or HCl had been identified as the second product. There were some excellent

					responses, providing the correct oxidation number changes, linking these to the species involved and identifying the changes as either oxidation or reduction. Two explanation marks were available with marks not being given for omission of one of the three features described above. Exemplar 2  Equation $Cl_2 + NaOH \rightarrow NaClO + HCl$ Explanation the way I reckon the disproportionation has taken place is because Cl has gone from 0 to +1 in NaClO and has gone from 0 to -1 in HCl (so it has been oxidised and reduced) [3] This exemplar has been included to emphasise the points made above. It was only possible to award this response 1/3 marks. The equation shows the common error of the second chlorine-containing product being HCl and not NaCl: 0 marks The candidate has identified the oxidation number changes and has linked these to the correct species. The last statement in brackets is correct but the candidate has not communicated which oxidation number change is oxidation and which is reduction: 1/2 marks
	b		**Identification of halide** Add (aqueous) silver nitrate **OR** $AgNO_3$ **OR** Ag^+/silver ions ✓ **Observations - mark independently** Chloride/Cl^- gives white precipitate Bromide/Br^- gives cream precipitate Iodide/I^- gives yellow precipitate ✓ **Precipitate/solid seen at least once** **Equation for at least one halide** e.g. $Ag^+ + Cl^- \rightarrow AgCl$ **ALLOW** $Ag^+ + X^- \rightarrow AgX$ ✓ ***IGNORE*** *state symbols (ppt already assessed)* **Identification of B and C** **B**: NaBr **OR** sodium bromide ✓ **C**: $CaCl_2$ **OR** calcium chloride ✓	5 (AO3.3×3 AO3.2×2)	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** addition of HNO_3 but HCl **CONs** $AgNO_3$ **IGNORE** references to solubility in NH_3 (dil or conc), even if incorrect **ALLOW** chlorine for chloride, etc **ALLOW** equation with Br^- **OR** I^- e.g. $Ag^+ + Br^- \rightarrow AgBr$ **ALLOW** full/partial equations, e.g. $AgNO_3 + Cl^- \rightarrow AgCl + NO_3^-$ **ALLOW** explanation for identification: i.e. **B (Group 1):** Subtract molar/atomic mass of halide/Br from number in range 100–115/molar mass of B ✓ **C (Group 2):** Subtract **2** × molar/atomic mass of halide/Cl from number in range 100–115/molar mass of **C** ✓

					ALLOW displacement by addition of halogen ✓ 2 correct colours in water or organic solvent ✓ Equation, e.g. $Cl_2 + 2Br^- \rightarrow Br_2 + 2Cl^-$ ✓ **Examiner's Comments** Candidates generally answered the first part of this question well. Most candidates were able to identify silver nitrate (or a halogen displacement method), to describe the expected observations, supported with mainly correct ionic equations. Candidates found it much harder to identify B and C as NaBr and $CaCl_2$. They could do this in various ways by matching possible formula with the provided molar mass ranges. The mark scheme did allow marks to be given when candidates described the identification process, although this was often very muddled, so, only the most able few candidates fully identified the unknown B and C.
			Total	**9**	
28			**B**	1(AO2.1)	**Examiner's Comments** Although two steps were required to solve this problem, most candidates answered this question correctly. Candidate annotations showed that many identified element X as being in Group 2 and even as magnesium. The correct formula of XCl_2 (B) then usually followed.
			Total	**1**	
29			**D**	1(AO2.6)	**Examiner's Comments** Candidates found this question very difficult. B was the main distractor, obtained by multiplying the number of moles (4) by the Avogadro constant. Only the highest-attaining candidates realised that the question asked for the number of **ions** and multiplied the answer to B by 3 to obtain option D. The lesson here is to consider

					carefully any bold text in the question (**ions**).
			Total	**1**	
30	a	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 2.53(g) award 5 marks** **--** **[H⁺]** = $10^{-13.12}$ **OR** 7.58..... × 10^{-14} (mol dm^{-3}) ✓ $[OH^-] = \frac{1 \times 10^{-14}}{7.58\ldots\ldots \times 10^{-14}}$ **OR** 0.1318 .... (mol dm^{-3}) ✓ $n(OH^-)$ in 250 cm^3 = $\frac{0.1318\ldots}{4}$ **OR** 0.0329...... (mol) ✓ $n(Ba(OH)_2)$ or $n(BaO)$ = $\frac{0.0329\ldots}{2}$ **OR** 0.0164….. (mol) ✓ **Mass of BaO** = 0.0164..... × 153.3 = 2.53 (g) **3SF** ✓	5 (AO2.4×5)	**ALLOW ECF and 3SF throughout.** **ALLOW** calculation process in any order. **IGNORE** rounding errors past **3SF** **--** Calculator: 7.58577575 × 10^{-14} Calculator: 0.1318256739 **ALLOW** alternative approach using pOH for first 2 marks. $p[OH^-]$ = 14 − 13.12 = 0.88 $[OH^-] = 10^{-0.88}$ = 0.1318….. Calculator: 0.03295641846 0.033(0) comes from $[OH^-]$ = 0.132 Calculator: 0.01647820923 Calculator: 2.526109475 **Common errors 4 marks** 5.05g Not dividing by 2 2.82g Use of M_r for $Ba(OH)_2$ 5.06g rounds to 0.132 in M2 then not dividing by 2 **3 marks** 5.65g not dividing by 2 and using Mr for $Ba(OH)_2$ **<u>Examiner's Comments</u>** Although few candidates got the correct final answer, however almost all achieved some marks from this calculation through error carried forward, with marks spread across the available range. Almost all candidates were able to find the concentrations of hydrogen and

					hence hydroxide ions. A few candidates successfully used p[OH^-] method. Most were able to calculate the moles of hydroxide ions in $250cm^3$. Many then did not realise the need to half this number to find the moles of barium, and/or used the Mr for barium hydroxide instead of barium oxide.
		ii	Ba^{2+}(aq) +$2H^+$(aq) + SO_4^{2-}(aq) +$2OH^-$(aq) → $BaSO_4$(s) +$2H_2O$(l)✓	1 (AO3.2)	**ALLOW** multiples **ALLOW** H^+(aq)+ OH^-(aq) → H2O(l) **OR** Ba^{2+}(aq) + SO_4^{2-}(aq) → $BaSO_4$(s) __**Examiner's Comments**__ This question was answered well, with many candidates giving one of the equations in the 'ALLOW' part of the mark scheme. Those candidates who did not gain this mark gave full equations or missed out state symbols.
	b	i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 731(g) award 3 marks** **--** ***n*(Z)** $n(Ca_5NH_4(NO_3)_{11}{\cdot}10H_2O) = \frac{1500}{1080.5}$ **OR** 1.388246… ✓ **Mass of limestone** *n*($CaCO_3$) = 1.388246.... × 5 **OR** 6.94123& **AND** mass $CaCO_3$ = 6.94123.... × 100.1 **OR** 694.8 g ✓ mass limestone = $\frac{694.8 \times 100}{95.0}$ =	3 (AO2.6×3)	**ALLOW ECF throughout** **ALLOW** calculation process in any order. **IGNORE** rounding errors past **3SF** **DO NOT ALLOW** 100 for M_r of $CaCO_3$ **Common errors** **2 marks** 146g no x 5 for moles of $CaCO_3$ 660g use of 95.0/100 29.3g divide by 5 rather than x5 __**Examiner's Comments**__ This proved a difficult question for most candidates. Most were able to

			731 g (**3SF**) ✓		correctly calculate the moles of fertiliser by converting kg to g. The next step was to deduce that 5 moles of calcium carbonate would be required for each mole of Z and multiply by 5, rather than the common error of dividing by 5. Few candidates were able to multiply by 100/95, to account for the impurities in limestone, with many multiplying by 95/100.
		ii	$Mg_3Ca(CO_3)_4$ (s) + 8HC*l*(aq) → $3MgCl_2$(aq) + $CaCl_2$(aq)+ $4H_2O$(l) + $4CO_2$(g) Correct formulae ✓ Balanced **AND** state symbols ✓	2 (AO2.6×2)	**ALLOW** multiples **M2** dependent on **M1** **IGNORE** incorrect state symbol for $Mg_3Ca(CO_3)_4$ <u>**Examiner's Comments**</u> This was another very challenging question using an unfamiliar mineral. Most candidates identified a formula of salts containing both magnesium and calcium, or carbonates of the separate elements. Only the most successful candidates were able to give the correct formula. Common errors, for those who solved the formulae, were the use of "4"HCl in balancing and the absence of state symbols.
			Total	**11**	
31	a	i	$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$ ✓	1(AO2.6)	**IGNORE** state symbols, even if wrong **ALLOW** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2(H_2O)_4 + 2H_2O$ **OR** $[Fe(H_2O)_6]^{2+} + 2OH^- \rightarrow Fe(OH)_2 + 6H_2O$ <u>**Examiner's Comments**</u>

					Most students scored this mark, although several gave no response.
		ii	**Explanation of the brown precipitate** The brown ppt is $Fe(OH)_3$ **OR** $Fe(OH)_2$ loses electrons/ $Fe(OH)_2$ oxidised ✓ **Comparison of *E* values** (*E* of) Fe/Redox system 1 is more negative/less positive (than *E* of O_2/redox system 2) **OR** (*E* of) O_2/Redox system 2 is more positive/less negative (than *E* of Fe/redox system 1) ✓ **Equilibrium shift** More negative/less positive **OR** Fe system **OR** Redox system 1 shifts left **OR** More Positive/less negative **OR** O_2 system **OR** Redox system 2 shifts right ✓ **Equation** $4Fe(OH)_2(s) + O_2(g) + 2H_2O(l) \rightarrow 4Fe(OH)_3(s)$ ✓	4(AO3.1×4)	**ORA** **ALLOW** Fe^{2+} is oxidised to Fe^{3+} **ALLOW** Fe **ALLOW** E_{cell} is (+) 0.96V **IGNORE** 'lower/higher' **For equilibrium shift** **ALLOW** E_{cell} is +ve therefore the reaction is feasible. **OR** Direction of half equation correctly written. **ALLOW** multiples **ALLOW** equilibrium **IGNORE** state symbols, even if wrong **DO NOT ALLOW** uncancelled species **<u>Examiner's Comments</u>** Although a spread of marks across the full available range was seen, a good proportion of candidates gained 3 or 4 marks. Most candidates were able to produce a balanced equation, but candidates should take care cancelling out any species present on both side of the equation, e.g. the hydroxide ions. A common error within the formula of iron (III) hydroxide was to place the number of hydroxide ions within the brackets, e.g. $Fe(OH_3)$. Candidates are advised to read the instructions contained within the equation and to use or comment on all the data presented. When commenting on electrode potentials, candidates should avoid the use of higher/lower

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>as these phrases are meaningless due to the negative signs involved.</td></tr>
<tr><td></td><td>b</td><td></td><td>
Level 3 (5–6 marks)
Reaches a comprehensive conclusion to determine the correct formulae of almost all of B, C, D, E, F and G.
AND
most correct equations and identifies some changes in oxidation number
AND
Calculation of M_r of the gas

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)
Reaches a conclusion to determine the correct formulae of at least half of B, C, D, E, F and G.
AND EITHER
some correct equations
OR
Any one correct equation and a relevant change in oxidation number
OR
any one correct equation and a correct calculation of the M_r

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)
Reaches a simple conclusion to determine the correct formulae of some of B, C, D, E, F and G
OR
The correct formulae for 1 of B, C, D, E, F and G with correct equation or calculation.

There is an attempt at a logical structure with a line of reasoning.
The information is in the most part relevant.
</td><td>6(AO3.1×3
AO3.2×3)</td><td>
Indicative scientific points may include

<table>
<tr><td></td><td>Formula</td></tr>
<tr><td>B</td><td>$CuCl_4^{2-}$
OR
$[CuCl_4]^{2-}$</td></tr>
<tr><td>C</td><td>$[Cu(H_2O)_6]^{2+}$
OR
$CuSO_4$</td></tr>
<tr><td>D</td><td>SO_2</td></tr>
<tr><td>E</td><td>$Cu(NO_3)_2$
OR
$[Cu(H_2O)_6]^{2+}$</td></tr>
<tr><td>F</td><td>CuI</td></tr>
<tr><td>G</td><td>I_2</td></tr>
</table>

Experiment 1

Equation

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$
$[Cu(H_2O)_6]^{2+} + 4HCl \rightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$

Experiment 2

Evidence
$n(D) = \frac{45}{24000} = 1.875 \times 10^{-3}$
Molar mass (D) $= \frac{0.12}{1.875 \times 10^{-3}} = 64$
Equation
$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2 + 2H_2O$

Oxidation numbers
Cu 0 → Cu +2; S +6 → S +4

Experiment 3

Equation

$CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$

$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$
</td></tr>
</table>

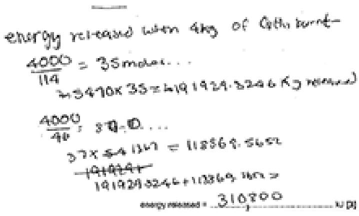
			0 marks *No response or no response worthy of credit.*		**OR** $2Cu(NO_3)_2 + 4KI \rightarrow 2CuI + I_2 + 4KNO_3$ **Oxidation numbers** Cu +2 → Cu +1; I −1 to 0 **<u>Examiner's Comments</u>** Answers were distributed across all 3 levels of achievement. Most of the candidates managed to identify at least some of the substances. Of the equations, the reaction of copper (II) oxide with nitric acid was most regularly seen correct, although many students could also represent the ligand replacement in Experiment 1. Many candidates were able to calculate Mr for gas D but some of those suggesting SO_2 as a possible formula preferred to have an equation in experiment 2 producing hydrogen. A few candidates used the M_r to suggest that the gas was $2O_2$ and as such candidates found the equation between copper and sulphuric acid challenging. A good number of candidates identified F and G, recognising what they had learned from their work on redox titrations, and some were able to reproduce the equation. Incorrect formula of copper (I) iodide (CuI_2) was a common error. Many candidates made no attempt at identifying changes in oxidation states. Candidates are advised to address all parts of the question in order to access the higher levels and to allow sufficient time to attempt the LoR questions.
			Total	**11**	
32			**C**	1(AO1.2)	**<u>Examiner's Comments</u>** This question was quite well answered with many candidates identifying the correct response as C. Candidates had to link the volume of gas with the moles of each gas and

					then match to the stoichiometry of the equation. Some candidates calculated the moles of gas and then appeared to choose an answer at random.
			Total	**1**	
33			**B**	1(AO1.2)	**Examiner's Comments** This was generally well answered. The key to candidates quickly arriving at the correct answer of B was to focus on identifying the number of CN^- ions and calculating the total of 18 negatively charge ions. More successful candidates could clearly see that the combination of iron ions must add up to the total of 18 positively charged ions. Some candidates lost time here by working out formulae and trying to write out the structure of Prussian blue.
			Total	**1**	
34	a	i	Any value in range: 8–14 ✓	1 (AO1.1)	**Examiner's Comments** Most candidates gained this mark. The most common incorrect response was pH 7 with a few giving a pH value of less than 7.
		ii	White precipitate/white solid ✓ $BaSO_4$ ✓	2 (AO 3.1) (AO 3.2)	**Examiner's Comments** Most candidates were able to give the formula of the barium compound as $BaSO_4$. However, they did not recognise that this would cause a white ppt to be seen, presumably as not in the context of qualitative ions testing. Many candidates said they would see bubbling/fizzing. Some gave a colour change as they were possibly considering what would be seen if an indicator is present. Others mentioned a precipitate but with no colour given. Some candidates gave the incorrect formula, such as Ba_2SO_4 or

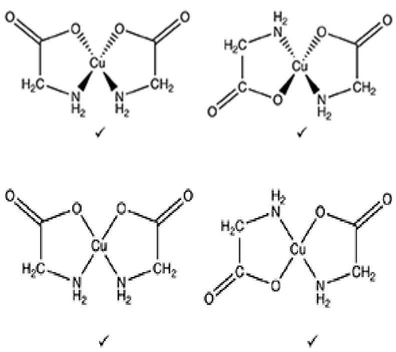
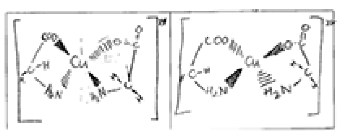
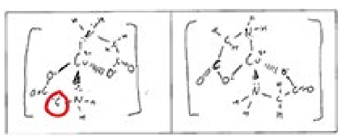
					$Ba(SO_4)_2$, again showing the importance of practising writing formulae. In addition, some candidates wrote out the whole equation for the reaction. **OCR support** We have produced a topic support pack to assist with learning about the reaction of group 2 elements and their compounds: http:/www.ocr.org.uk/Images/364103-chemistry-of-group2.docx
	b	i	$Sr + 2H_2O \rightarrow Sr(OH)_2 + H_2$ All formulae and balancing correct ✓	1 (AO2.6)	**IGNORE STATE SYMBOLS** **ALLOW** multiples **IGNORE** state symbols (even if wrong) **<u>Examiner's Comments</u>** Around half of all candidates did not score this mark. The most common error was giving SrO as the product rather than the hydroxide. Other errors included incorrect balancing (missing 2 on H_2O, SrOH as the formula of the hydroxide and no hydrogen formed (often giving H_2O instead)). **Assessment for learning** Regular practice writing formulae and balancing chemical equations will help to consolidate these concepts, avoiding basic errors such as giving formula of group 2 hydroxide as SrOH.
		ii	**Oxidation** Sr from **0** to **+2** ✓	2 (AO 2.1 × 2)	**ALLOW** 2+ for +2 and 1+ for +1 '+' is required in +2 and +1 oxidation numbers

			Reduction H from **+1** to **0** ✓		**ALLOW** H_2 for hydrogen **ALLOW** 1 mark for elements **AND** all oxidation numbers correct but oxidation and reduction wrong way round **OR** not given. **IGNORE** numbers around equation in **(i)** *(treat as rough working)* **<u>Examiner's Comments</u>** Most candidates managed to score at least 1 mark for this question. The most common reason for losing a mark, despite demonstrating a good understanding of redox, was stating that H changed from +2 to 0 (need to give oxidation number per atom). Other errors seen included only giving change for Sr, descriptions in terms of electrons rather than oxidation numbers, Sr change from 0 to +1 (linked to SrOH), oxygen being reduced rather than H and mixing up oxidation/reduction or not specifying.
		iii	*Atomic radius* Ca has smaller atomic radius **OR** fewer shells ✓ *Effect of nuclear charge/shielding* Ca has **less/decreased** shielding ✓ *Nuclear attraction* Ca has greater nuclear attraction (for electrons) **OR** Ca has a higher ionisation energy **OR** more energy is required to lose the outer electrons✓	3 (AO 1.2) (AO 1.2) (AO 1.2)	**FULL ANNOTATIONS MUST BE USED** --- **ORA in terms of Sr** **Comparison** needed for each mark. **ALLOW** 'fewer energy levels' **ALLOW** 'electrons closer to nucleus' **IGNORE** fewer orbitals **OR** fewer sub-shells **OR** different shell **ALLOW more** electron repulsion from inner shells

					IGNORE nuclear charge/effective nuclear charge **ALLOW** 'less nuclear pull' **OR** 'electrons held less tightly' **Examiner's Comments** Most candidates gained some marks here although a significant proportion were unable to score all 3 marks covering atomic radius, shielding, nuclear attraction/IE. The mark most often missed was for shielding. Some candidates did not answer the question asked and gave the trend down the group so could not be given marks unless they made it clear Sr is below Ca in the group. Care must be taken to answer question asked not similar questions they have seen before. The best responses were those with direct comparative statements, e.g. "Ca has a smaller atomic radius than Sr". It is worth noting that harder/easier to lose electrons didn't gain marks, but was seen fairly frequently, as response needs to be in terms of energy required or linked to nuclear attraction.
			Total	**9**	
35		i	$C_8H_{18} + C_2H_5OH + 15½\ O_2 \rightarrow 10\ CO_2 + 12\ H_2O$ ✓	1 (AO2.6)	**ALLOW** multiples e.g. $2\ C_8H_{18} + 2\ C_2H_5OH + 31\ O_2 \rightarrow 20\ CO_2 + 24\ H_2O$ **ALLOW** $C_{10}H_{24}O$ for $C_8H_{18} + C_2H_5OH$ *Combining ethanol and octane!* **Examiner's Comments** Most candidates attempted to write an equation for the combustion of the 1:1 molar mixture of octane and ethanol. The formulae of C_8H_{18} and C_2H_5OH were usually seen although some candidates combined these as a 'mixture formula' of $C_{10}H_{24}O$ (which was accepted). The balancing of the equation using

					$15½O_2$ was the hardest part of the equation and many different balancing numbers for O2 were seen ($10CO_2$ and $12H_2O$ where usually correct). Less successful responses often attempted a combustion equation using octane OR ethanol, but not both. This is not an easy equation to construct, and the context was novel. Overall candidates made a good attempt at this question.
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 341850 to 2 SF or more award 3 marks** --- $M(C_8H_{18})$ = 114 **AND** $M(C_2H_5OH)$ = 46 **OR** 1 mol C_8H_{18} + 1 mol C_2H_5OH has mass of 160 g ✓ 50 mol C_8H_{18} **OR** 50 mol C_2H_5OH **OR** 50 mol (C_8H_{18} + C_2H_5OH) **OR** 8.00 kg fuel contains 50 mol C_8H_{18} + 50 mol C_2H_5OH ✓ Energy = (50 × 5470) + (50 × 1367) **OR** 50 × (5470 + 1367) **OR** 50 × 6837 **OR** 273500 + 68350 **=341850(kJ)✓**	3 (3 ×AO2.2)	**IGNORE** sign throughout **ALLOW** approach based on mass for 2nd mark $m(C_8H_{18})$ = (114/160) × 8000 = 5700 g **AND** $m(C_2H_5OH)$ = (46/160) × 8000 = 2300 g Energy = 5700/114 × 5470 + 2300/46 × 1367 = 341850 (kJ) **ALLOW 2 SF or more** correctly rounded -- **Common errors** **310800 → 2 marks** *Use of equal masses (4 kg) of C_8H_{18} & C_2H_5OH (rather than equal moles)* **Example**  **Examiner's Comments** This question took the novel context introduced in 5b a stage further by considering the energy released during the combustion of this fuel. Most candidates were able to obtain some credit, and many obtained the correct energy of 341,850 kJ. The commonest error was for candidates to assume that the 8 kg mixture would contain 4 kg of octane and 4 kg of ethanol, rather than an equal

					moles of each. Such an approach could still be partly given marks by ECF, provided that the method was sound and clear.
			Total	**4**	
36		i	***Bond angles*** H_2NCH_2COONa, bond angle = 107° **AND** $HOOCCH_2NH_3Cl$, bond angle = 109.5° ✓ ***Number of electron pairs*** ***Mark independently of angles*** In NaOH/107°, (NH_2 has) **3** bonded pairs **/ 3** bonds **AND** **1** lone pair ✓ In HCl/109.5°, (NH_3^+ has) **4** bonded pairs / **4** bonds ✓	3 (3 ×AO1.2)	**ALLOW** 107 ± 0.5 **ALLOW** 109 **OR** 110° **ALLOW** NH_2 has **4** pairs, one of which is a lone pair **For bonded pairs/bonds** **ALLOW bonded** groups, atoms, elements, regions ***Bonded*** *essential* **IGNORE** electron region **OR** electron density **IGNORE** NH_3 has no lone pairs **IGNORE** lone pairs repel more (than bonded pairs) **IGNORE** shapes, even if wrong **ALLOW** bp for bonded pair and lp for lone pair **Examiner's Comments** This question required candidates to apply their knowledge and understanding of bond angles and electron pair repulsion of NH_3 and NH_4^+ to amino acid salts. The best candidates rose to this challenge and secured all 3 marks for correct bond angles and explanations in terms of the numbers of bonded and lone pairs around the N atoms. Overall, candidates found this question quite difficult. Many different bond angles were predicted, with 120° being the commonest incorrect H-N-H bond angle in H_2NCH_2COONa. The explanation for 120° was in terms of three bonding pairs and no lone pairs. 104.5° was

					also seen, presumably relating H_2N to H_2O. The 109.5° bond angle was correct more often, as was its explanation in terms of 4 bonding pairs. Many successful responses showed working on diagrams in which bonded and lone pairs had been included. This strategy will have helped candidates in their conclusions.
		ii	**Equation:** **2** $H_2NCH_2COOH + Cu(CH_3COO)_2 \rightarrow Cu(H_2NCH_2COO)_2 +$ **2** CH_3COOH ✓ **Structures**  Ligands **must** shown as bidentate rings **IGNORE** connectivity for NH_2 **BUT** connectivity **must** be to O of COO	3 (AO2.6) (2 ×AO2.5)	**ALLOW** molecular formulae or mixture, e.g. $2C_2H_5NO_2 + CuC_4H_6O_4 \rightarrow CuC_4H_8N_2O_4 + 2C_2H_4O_2$ **IGNORE** charges **i.e. IGNORE** wrong or missing charges in ionic compounds if formula is correct/ e.g. **ALLOW** $Cu(CH_3COO^-)_2$, $Cu^+(CH_3COO^-)_2$ **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** charges **ALLOW** arc to represent $-CH_2-$ between: C of C=O and NH_2  **ALLOW** 1 mark for 2 'correct' structures shown as tetrahedral e.g.  **IGNORE** missing Hs on C, e.g.  **<u>Examiner's Comments</u>** Candidates were asked to predict an unfamiliar equation from provided

					information and to draw structures of square planar complexes containing an amino acid. Candidates found the structures easier than the equation, with many drawing 3D structures with 2 out-wedges and 2 in-wedges and attaching the NH_2 and COO groups correctly. It was also common to see a 'criss-cross' orientation, looking down on the complex, which is easier to draw. Many candidates connected the NH_2 and COO groups next to, and across from, each another in the isomers. A common error was for candidates to rotate their first structure, to produce a second drawing of the first structure. Less successful responses often tried to attach NH_2 and COO groups but with no CH_2 between the groups to produce a cyclic attachment. A minority of candidates ignored 'square planar' and drew tetrahedral structures instead. The equation proved to be very difficult, the commonest error being omission of the '2' balancing numbers for H_2NCH_2COOH and CH_3COOH. The formulae for ethanol or propanoic acid were also often seen for ethanoic acid. Candidates are advised to check all formulae and then to check balancing, the golden rules for successfully constructing all equations.
			Total	**6**	
37			$5\ H_2S + 2\ MnO_4^- + 6\ H^+ \rightarrow 2\ Mn^{2+} + 5\ S + 8\ H_2O$ **OR** $40\ H_2S + 16\ MnO_4^- + 48\ H^+ \rightarrow 16\ Mn^{2+} + 5\ S_8 + 64\ H_2O$ Any **FIVE** correct species ✓ Correct balanced equation ✓	2 (AO3.2)	**ALLOW** multiples e.g. $2\frac{1}{2}\ H_2S + MnO_4^- + 3\ H^+ \rightarrow Mn^{2+} + 2\frac{1}{2}\ S + 4\ H_2O$ $20\ H_2S + 8\ MnO_4^- + 24\ H^+ \rightarrow 8\ Mn^{2+} + 2\frac{1}{2}\ S_8 + 32\ H_2O$ **IGNORE** extra species containing: Mn, H, S and O **ONLY** **BUT ALLOW** $KMnO_4$ on LHS, forming K^+ on RHS **IGNORE** electrons

					IGNORE state symbols **<u>Examiner's Comments</u>** Candidates needed to interpret the information provided and to use this as the basis for their redox equation. The clue of a yellow product proved to be very difficult to interpret as being sulphur. The equation then required H^+ to be added as a reactant ('acidified' in the information) and H_2O as the other product. Balancing required use of oxidation numbers. Candidates found this equation very difficult and relatively few correct equations were seen. The mark scheme did allow 1 mark for any correct five species but the correct equation proved to be challenging in demand.
			Total	**2**	