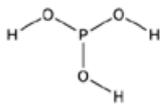
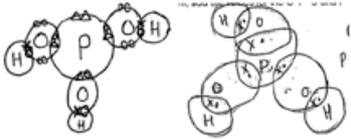


## Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	<p>In (Equilibrium) 1,</p> <p><math>\text{H}_2\text{PO}_4^-</math>/It acts as a base  <b>AND</b>  accepts/gains <math>\text{H}^+</math>/a proton  <b>OR</b> <math>\text{H}_2\text{PO}_4^-</math> forms <math>\text{H}_3\text{PO}_4</math> ✓</p> <p>In (Equilibrium) 2,</p> <p><math>\text{H}_2\text{PO}_4^-</math>/It acts as an acid,  <b>AND</b>  donates/loses <math>\text{H}^+</math>/a proton  <b>OR</b> <math>\text{H}_2\text{PO}_4^-</math> forms <math>\text{HPO}_4^{2-}</math>  ✓</p>	2	<p><b>ALLOW</b> description for 1 or 2 as long as unambiguous, e.g. Equation 1, etc</p> <p><b>IGNORE</b> missing charge on <math>\text{H}_2\text{PO}_4^-</math> throughout</p> <p><b>IGNORE</b> reference to <math>\text{H}_2\text{PO}_4^{2-}</math> acting as an acid/base <b>OR</b> Equilibrium 3  <i>Question is about <math>\text{H}_2\text{PO}_4^-</math></i></p> <p><b>ALLOW</b> 'dissociates into <math>\text{H}^+</math> and <math>\text{H}_2\text{PO}_4^{2-}</math>'  <b>IGNORE</b> 'partially'</p> <p><b><u>Examiner's Comments</u></b></p> <p>Candidates were expected to link proton-transfer behaviour in acids and bases to the provided equilibria. The question differentiated between candidates well.</p> <p>Some candidates just stated that an acid is a proton donor and a base a proton acceptor without referring to the provided equilibria. This was the answer to a much simpler question and could not be given marks.</p> <p>The best responses demonstrated excellent understanding within the context of the equilibria. Such candidates clearly explained how <math>\text{H}_2\text{PO}_4^-</math> behaves as an acid in the forward reaction of Equilibrium 2 and as a base in the reverse reaction of Equilibrium 1.</p>
		ii	<p>Diagram showing <b>all</b> bonds correctly  ✓</p> 	3	<p><b>IGNORE</b> geometry</p> <p><b>ALLOW</b> dot and cross diagram showing 2 shared electrons for each bond  ..... and <b>IGNORE</b> any lone pairs e.g.</p>

		<ul style="list-style-type: none"> <li>• 3 bonds only around each P</li> <li>• 2 bonds only around each O</li> <li>• Each O bonded to an H</li> </ul> <p><b>Bond angles</b></p> <p>O-P-O = 107° ✓</p> <p>P-O-H = 104.5° ✓</p>		 <p>Unambiguous bond angles may be shown on dot and cross diagram</p> <p><b>ALLOW</b> 106-108°</p> <p><b>ALLOW</b> 104-105°</p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates used the information in the question to draw a correct displayed formula of H<sub>3</sub>PO<sub>3</sub>. Another acceptable approach was to show a 'dot-and-cross' diagram.</p> <p>Candidates usually chose 104.5° for the P-O-H bond angles although a significant number suggested 180°. The O-P-O bond angle proved to be more difficult. Many suggested 120° by ignoring the lone pair of electrons on the P atom. The shape was analogous with NH<sub>3</sub> giving a bond angle of 107°.</p> <p>Overall, candidates answered this question well. Candidates are advised to assess the number of bonded pairs and lone pairs around each atom when suggesting bond angles. This would have reduced the number of incorrect bond angles such as 180° for P-O-H and 120° for O-P-O.</p>
	iii	<p>phosphoric(III) acid ✓</p> <p><i>Oxidation number <b>MUST</b> be in correct place</i></p>	1	<p><b>DO NOT ALLOW</b> phosphoric acid (III)</p> <p><b>DO NOT ALLOW</b> phosphorous acid</p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates wrote the correct systematic name of phosphorus(III) acid and the clue given in the question for the name of H<sub>3</sub>PO<sub>4</sub> should have helped.</p> <p>Common errors included</p>

					<p>phosphorus(IV) acid, the same as for <math>\text{H}_3\text{PO}_4</math>, and the (III) oxidation number being placed after 'acid' in the name. The commonest error though, was hydrogen phosphate.</p> <p>Candidates are advised to use any information provided in the question, which often contains clues. This certainly would have prevented hydrogen phosphate as a response.</p>
	b	i	$4\text{PH}_3 + 8\text{O}_2 \rightarrow \text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \checkmark$	1	<p><b>ALLOW</b> multiples</p> <p><b>ALLOW</b> <math>2\text{PH}_3 + 4\text{O}_2 \rightarrow \text{P}_2\text{O}_5 + 3\text{H}_2\text{O}</math></p> <p><b>IGNORE</b> state symbols, even if wrong</p> <p><b><u>Examiner's Comments</u></b></p> <p>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.</p> <p>The actual reaction does produce <math>\text{P}_4\text{O}_{10}</math> but <math>\text{P}_2\text{O}_5</math> was shown in almost all equations, and this was acceptable.</p> <p>Various incorrect formulae were seen for phosphorus(V) oxide including <math>\text{PO}</math>, <math>\text{PO}_2</math>, <math>\text{P}_5\text{O}</math>, <math>\text{HPO}</math>, etc. Unfortunately a significant number of candidates could not balance the equation, despite using correct formulae.</p>
		ii	$6\text{AgNO}_3 + (1)\text{PH}_3 + 3\text{H}_2\text{O} \rightarrow 6\text{Ag} + (1)\text{H}_3\text{PO}_3 + 6\text{HNO}_3 \checkmark$ <p>Ag is reduced from +1 to 0 <math>\checkmark</math></p> <p>P is oxidised from -3 to +3 <math>\checkmark</math></p> <p><b>IGNORE</b> oxidation numbers written around equation <i>Treat as rough working</i></p>	3	<p><b>ALLOW</b> equation with '1' omitted, i.e. <math>6\text{AgNO}_3 + \text{PH}_3 + 3\text{H}_2\text{O} \rightarrow 6\text{Ag} + \text{H}_3\text{PO}_3 + 6\text{HNO}_3 \checkmark</math></p> <p><b>BUT DO NOT ALLOW</b> '0'</p> <p><b>ALLOW</b> 1 mark for <b>BOTH</b> correct oxidation number changes with 'reduced' and 'oxidised' omitted</p> <p><b>OR</b> 'oxidised and reduced the wrong way round</p> <p>+ signs required for +1 and +3</p>

**IGNORE** reference to electrons  
*Question states oxidation numbers*

For oxidation numbers,  
**ALLOW** 1+, 3- and 3+

**Examiner's Comments**

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  $\text{AgNO}_3$ , 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  $\text{H}_3\text{PO}_3$ .

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**

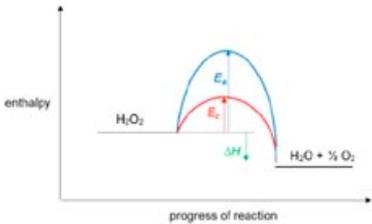
$\text{Ag}^+$  and  $\text{NO}_3^-$  are among the common ions that students should know (see also Question 4 (c) (i)).

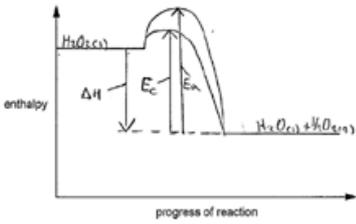
For a  $\text{NO}_3^-$  ion to have a charge of 1-, the oxidation number of nitrogen must be +5. By choosing -5, the charge on  $\text{NO}_3$  would be -11 and silver would have an oxidation number of +11.

This is completely unrealistic and should be rejected as it points to a serious error.

					<p>The specification states the following: <i>2.1.5 (a) rules for assigning and calculating oxidation number for atoms in elements, compounds and ions.</i></p> <p>This section will have been studied at the start of the two-year course and forms part of the backbone of chemical literacy.</p> <p>For success in chemistry, the ions should be learnt and the rules for assigning oxidation numbers need to be mastered.</p>
			<b>Total</b>	<b>10</b>	
2		i	iron(III) oxide ✓	1	<p><b>IGNORE</b> iron(3) oxide, iron(III) dioxide, etc i.e. <b>MUST</b> be systematic</p> <p><b>ALLOW</b> no brackets</p> <p><b><u>Examiner's Comments</u></b></p> <p>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<sub>2</sub>O<sub>3</sub>.</p> <p> <b>Misconception</b></p> <p>A systematic name may contain the oxidation number, not the number of atoms in the formula. So Fe<sub>2</sub>O<sub>3</sub> is iron(III) oxide and <b>not</b> iron(II) oxide.</p>
		ii	Fe <sub>2</sub> O <sub>3</sub> + 3 CO → 2 Fe + 3 CO <sub>2</sub> ✓	1	<p><b>ALLOW</b> multiples e.g. 2 Fe<sub>2</sub>O<sub>3</sub> + 6 CO → 4 Fe + 6 CO<sub>2</sub></p> <p><b>ALLOW</b> 1 Fe<sub>2</sub>O<sub>3</sub> ..... but <b>NOT</b> 0 Fe<sub>2</sub>O<sub>3</sub> .....</p>

					<p><b><u>Examiner's Comments</u></b></p> <p>Most candidates were able to balance this straightforward equation.</p>
			<b>Total</b>	<b>2</b>	
3			<b>A</b>	1	<p><b><u>Examiner's Comments</u></b></p> <p>About half of the candidates chose A correctly. Most candidates wrote oxidation numbers below the chlorine in the equations, which is good practice, with C proving to be the main distractor. Note also the point made in Question 6 about underlining the word 'not'.</p>
			<b>Total</b>	<b>1</b>	
4	a	i	<p><b>FIRST CHECK ANSWER ON ANSWER LINE</b>  <b>If answer = <math>-117 \text{ kJ mol}^{-1}</math>, award 4 marks.</b></p> <p>-----</p> <p><math display="block">\Delta H = -286 - (-188)</math> <math display="block">= -98 \text{ kJ mol}^{-1} \checkmark</math></p> <p><math display="block">\Delta S = 70 + \frac{1}{2}(205) - 110 = 62.5 \text{ (J K}^{-1} \text{ mol}^{-1})</math> or <math>0.0625 \text{ (kJ K}^{-1} \text{ mol}^{-1}) \checkmark</math></p> <p><math display="block">\Delta G = \Delta H - T\Delta S</math> <math display="block">= -98 - (298 \times 0.0625) \checkmark</math></p> <p><math display="block">\Delta G = -117 \text{ kJ mol}^{-1} \text{ (3SF)} \checkmark</math></p>	4	<p><b>ALLOW ECF</b> throughout</p> <p><b>ALLOW</b> <math>-98000 - (298 \times 62.5)</math></p> <p><b>Common Errors for <math>\Delta G</math></b>  <b>3 marks</b>  <math>-18700</math> (<math>\Delta S</math> not converted to kJ)  <math>-493</math> (<math>\Delta H = -286 + (-188) = -474</math>)  <math>-147</math> (<math>\Delta S = 165</math>: not halving 205)  <math>-99.6</math> (<math>T</math> not converted to K)  <math>-18.7</math> (<math>\Delta H</math> not converted J but <math>\Delta S</math> J <math>\text{K}^{-1} \text{ mol}^{-1}</math>)  <math>(+79.4</math> (<math>-188 - (-286) = +98</math>)</p> <p><b>2 marks</b>  <math>(+117</math> (incorrect signs for <math>\Delta H</math> and <math>\Delta S</math>)</p> <p><b>Final Answer MUST BE 3 SF</b></p> <p><b><u>Examiner's Comments</u></b></p> <p>Almost all candidates had a good attempt at this calculation, with many gaining full marks. Most were able to calculate the entropy change. Almost all could reproduce the equation for free energy. Of those who did not get the correct final answer, the most common error was not converting the entropy value into kJ and / or the temperature to K. There were a few</p>

				<p>candidates who did not manipulate the equation correctly. A few candidates incorrectly calculated <math>\Delta S</math>, obtaining the value of <math>165 \text{ J K}^{-1} \text{ mol}^{-1}</math> or <math>\Delta H</math>, obtaining <math>-474 \text{ kJ mol}^{-1}</math>. Candidates were given ECF in these cases.</p>
	ii	(Rate of reaction) slow OR Activation energy high ✓	1	<p><b>ALLOW</b> <math>\Delta G</math> takes no account of rate of reaction</p> <p><b>ALLOW</b> molecules do not have sufficient energy to equal or exceed the activation energy.</p> <p><b>IGNORE</b> molecules do not have sufficient energy to react.</p> <p><b>DO NOT ALLOW</b> there is not enough activation energy</p> <p><b>Examiner's Comments</b></p> <p>Lots of good answers from candidates were seen for this question. A few candidates attempted the explanation via a <math>\Delta G / \Delta S</math> argument and misinterpreted the comment within the question.</p>
b	i	 <p><math>\text{H}_2\text{O}_2</math> on LHS <b>AND</b> <math>\text{H}_2\text{O} + \frac{1}{2} \text{O}_2</math> on RHS <b>AND</b> <math>\Delta H</math> labelled with product line below reactant line <b>AND</b> Arrow downwards ✓ <math>E_a</math> correctly labelled ✓ <math>E_c</math> <u>correctly labelled</u> with <math>E_c &lt; E_a</math> ✓</p>	3	<p><b>Care enthalpy profile must match <math>\Delta H</math> sign in 16 a) i) – check calculation</b></p> <p><b>ALLOW</b> endothermic profile as <b>ECF</b> from <math>+\Delta H</math> calculated in 16 a) i) for all three marks</p> <p>State symbols not required</p> <p><b><math>\Delta H</math> DO NOT ALLOW <math>-\Delta H</math></b></p> <p><b>DO NOT ALLOW</b> double headed arrow on <math>\Delta H</math></p> <p><b>ALLOW</b> <math>\Delta H</math> arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line.</p> <p><b><math>E_a</math> and <math>E_c</math></b> <b>ALLOW</b> no arrowhead or arrowheads at both end of <math>E_a</math> or <math>E_c</math> lines <math>E_a</math> or <math>E_c</math> lines must reach maximum</p>

				<p>(or near to maximum) on curve</p> <p><b>ALLOW</b> overlapping lines <b>OR</b> lines on side reaching maximum</p> <p>For <math>E_a</math>, <b>ALLOW</b> <math>A_E</math> <b>OR</b> <math>A_E</math> <b>OR</b> <math>E_{act}</math> <b>OR</b> suitable alternatives</p> <p><b>ALLOW ECF</b> marks for <math>E_a</math> and <math>E_c</math> for correctly labelled endothermic diagram from a <math>-\Delta H</math> value (from 16 a i))</p> <p><b><u>Examiner's Comments</u></b></p> <p>This question proved more difficult for candidates with lots of inaccuracies. The profile was dependent on the calculation for <math>\Delta H</math> in Question 16 (a) (i). The arrowhead for <math>\Delta H</math> needs to be pointing from the reactants to the products. The activation energies, again, need to start at the reactant line and go to the maximum level of the curve. Those that needed to draw an endothermic profile were far more likely to make an error with the <math>E_a</math> and <math>E_c</math> arrows, often starting from the product line or even from the base line of the graph. A significant number of candidates did not add arrows and instead labelled the curves <math>E_a</math> and <math>E_c</math>. Some candidates drew a Boltzmann distribution curve scoring 0 marks.</p> <p>Exemplar 1</p>  <p>The candidate has the correct exothermic profile but has the incorrect starting point for the activation energy going from the product line.</p>
	ii	( $MnO_2$ ) is in different phase/state (to the reactant / $H_2O_2$ )	<b>OR</b>	<p>1</p> <p><b>ASSUME</b> 'it' is <math>MnO_2</math></p> <p><b>ALLOW</b> 'species in the reaction'</p>

			catalyst is a <u>solid</u> <b>AND</b> reactant is <u>liquid</u> ✓		<b>IGNORE</b> references to products  <b><u>Examiner's Comments</u></b>  This was a well answered question. A few candidates, incorrectly, suggested that it was heterogeneous due to the reactants and products being in different states, and did not mention the catalyst.
		iii	Mn is +2 <b>AND</b> +3  <b>OR</b>  Mn is +1 <b>AND</b> +6 ✓	1	+ required  <b>ALLOW</b> 2+ and 3+  <b>DO NOT ALLOW</b> Mn <sup>2+</sup> Mn <sup>3+</sup>  <b>DO NOT ALLOW</b> + 4 (this is the oxidation state in MnO <sub>2</sub> )  <b><u>Examiner's Comments</u></b>  This question proved more challenging for candidates. Candidates stating +4 was the most common error; this is the oxidation state in MnO <sub>2</sub> . Some candidates stated fractions, negative values and gave the state symbol instead i.e. solid and liquid.
			<b>Total</b>	<b>10</b>	
5			<b>D</b>	1	<b><u>Examiner's Comments</u></b>  The correct answer was D. This proved a more challenging question. Successful candidates often presented oxidation numbers above the equations to identify the element that was simultaneously oxidised and reduced. Most candidates recognised that A and B could be ruled out, with C being the most common error.
			<b>Total</b>	<b>1</b>	
6		i	Ca loses <b>2</b> electrons <b>AND</b> Oxidised✓  H gains 1 electron (per atom) <b>AND</b> Reduced✓	2	<b>ALLOW</b> H gains an electron <b>OR</b> gains electrons <b>OR</b> gains 2 electrons  <b>ALLOW</b> 1 mark for Ca is oxidised

				<p><b>AND</b> H is reduced</p> <p><b>ALLOW</b> 1 mark for Ca loses electron(s) <b>AND</b> H gains electron(s)</p> <p><b>IGNORE</b> oxidation numbers even if incorrect</p> <p><b><u>Examiner's Comments</u></b></p> <p>Explaining redox reactions is a common question in exam papers, however here candidates needed to do it 'in terms of electron transfer'. Subsequently, many lost a mark as they identified oxidation and reduction in terms of oxidation numbers only. However, many gave responses both in terms of oxidation numbers and electrons.</p> <p>It was necessary to be specific here and say Ca had lost 2 electrons, so a few lost the mark by only referring to 'Ca losing electrons'. Some lost marks for only describing oxidation of Ca and not reduction of H.</p> <p>There was some evidence that candidates were not sure of Cl's role in the reaction (i.e. as a spectator ion) with some stating it was reduced and/or accepted electrons from Ca but then gave them to H.</p>
	ii	<p><math>n(\text{HCl}) = 0.012 \text{ (mol)} \checkmark</math></p> <p><math>n(\text{Ca})</math> required to react with HCl = 0.006 (mol)</p> <p><b>OR</b></p> <p>0.0100 mol Ca would need 0.02 mol HCl to completely react <math>\checkmark</math></p> <p>Ca reacts with water <math>\checkmark</math></p>	3	<p>Second mark must show recognition of the 2:1 ratio e.g. <b>ALLOW</b> ratio is 1:2 but here only 1:1.2 so Ca is in excess</p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates correctly calculated the amount of HCl as 0.012 mol. However, many struggled with demonstrating that Ca is in excess. Responses often highlighted misconceptions here in terms of candidates' understanding about excess and limiting reagents. For example, 'Ca has a lower concentration than HCl so becomes</p>

				<p>the limiting reagent' and 'Not all the HCl had reacted'</p> <p>Many compared moles of HCl calculated (i.e. 0.012) directly to moles of Ca (i.e. 0.01) saying that HCl was in excess, despite being told otherwise in the question. Some had the 2:1 ratio of HCl to Ca the wrong way around. Some attempted to calculate mass of Ca and HCl to use for comparison.</p> <p>Only a small proportion of candidates were able to access the third mark and correctly suggest that Ca was also reacting with water. Some other suggestions that were seen included:</p> <ul style="list-style-type: none"><li>• 'Ca reacted with oxygen or was impure'. In both cases this would mean that we would expect solid to remain</li><li>• 'Higher concentration of HCl added', or 'HCl is a strong acid', or 'acid acts as a catalyst'.</li><li>• 'H<sub>2</sub> evolved' or 'Ca reacts with hydrogen formed'.</li><li>• 'Human error', 'didn't weigh Ca correctly', 'measured volume of HCl incorrectly'.</li></ul> <p> <b>Misconception</b></p> <p>Candidates often struggle to understand the concepts around limiting reagents and those in excess. Using a simple baking analogy can help to relate this to everyday life.</p> <p>For example:</p> <p>To make 10 pancakes you need 100 g flour, 2 eggs and 300 ml milk</p> <p>How many pancakes can I make if I have only 50 g flour, 2 eggs and 300 ml milk?</p> <p>Which is the limiting ingredient and which are in excess?</p>
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					The number of pancakes we can make is the theoretical yield.
			<b>Total</b>	<b>5</b>	
7	i	Rubidium chlorate(VII) ✓		1 (AO 1.1)	<p><b>ALLOW</b> Rubidium(I) chlorate(VII) Rubidium chloroate(VII)</p> <p><b>IGNORE</b> Rubidium (VII)chlorate Rubidium chlorate(IIV) Rubidium chlorate (7) Rubidium perchlorate</p> <p><b>Examiner's Comments</b></p> <p>Candidates had difficulty in naming a compound using Roman numerals for an element which can have different oxidation numbers. For the name of <math>\text{RbClO}_4</math>, many omitted the number entirely, showing just rubidium chlorate. Many inventive names such as rubidium chlorotetraoxide were seen. Some candidates wrote the correct VII before chlorate and many different Roman oxidation numbers were seen. Roman numerals' use in naming compounds is part of chemical nomenclature, included in the specification.</p>
	ii	<p><b>FIRST CHECK THE ANSWER ON ANSWER LINE</b> If answer = 54.0 OR 54.1 OR 54.2 (kJ mol<sup>-1</sup>) award 3 marks</p> <hr/> <p><b>Energy change from mcΔT</b></p> <p>Energy in J <b>OR</b> kJ = 102 × 4.18 × 1.5 <b>OR</b> 639.54 (J) <b>OR</b> 0.63954 (kJ) ✓</p> <hr/> <p><b>Amount in mol of RbClO<sub>3</sub></b></p> <p><math>n(\text{RbClO}_3) = \frac{2.00}{169}</math> <b>OR</b> 0.0118..... (mol) ✓</p> <hr/> <p><b>Δ<sub>sol</sub>H(RbClO<sub>3</sub>)</b></p>		3 (AO 2.8 ×3)	<p><b>ALLOW ECF throughout</b></p> <p><b>IGNORE</b> sign <b>IGNORE RE and SF in 1st 2 marks</b></p> <p>0.01183431953 unrounded <b>ALLOW</b> 54 (from 54.0) <b>CARE 54.00 is a rounding error</b></p> <hr/> <p><b>COMMON ERRORS</b></p> <p><b>52.98 OR 53.14</b>                      <b>2 marks</b></p> <p>100 instead of 102:</p> <p>Energy = 100 × 4.18 × 1.5 = 627 J</p>

$$= \frac{0.63954}{0.0118\dots} = (+) \mathbf{54.0} \checkmark$$

From unrounded values,  $\Delta H = 54.04113$

Examples of mixed acceptable intermediate rounding, e.g.

$$\frac{0.640}{0.0118} \Delta H = 54.237 \rightarrow 54.2$$

$$\frac{0.63954}{0.01183} \Delta H = 54.06 \rightarrow 54.1$$

From unrounded  $n$ ,

$$\Delta H = \frac{0.627}{0.0118\dots} = \mathbf{52.98} \text{ kJ mol}^{-1}$$

**OR 53.0 (3SF) OR 53**

From rounded 0.0118,

$$\Delta H = \frac{0.627}{0.0118} = 53.14 \text{ OR } 53.1$$

**0.02078 OR 0.0208**      **1 mark**

102 and 2 swapped:  
Energy =  $2 \times 4.18 \times 1.5 = 12.54 \text{ J}$

$$n = \frac{102}{169} = 0.60355\dots$$

$$\text{ECF } \Delta H = \frac{0.01254}{0.60355\dots} = \mathbf{0.0208} \text{ kJ mol}^{-1}$$

**1.06**      **2 marks**

102 for  $n$  instead of 2.00:

$$n = \frac{102}{169} = 0.60355\dots$$

$$\Delta H = \frac{0.63954}{0.60355\dots} = \mathbf{1.06} \text{ kJ mol}^{-1}$$

**OR**

2 for energy instead of 102

Energy =  $2 \times 4.18 \times 1.5 = 12.54 \text{ J}$

$$\Delta H = \frac{0.01254}{0.0118\dots} = \mathbf{1.06} \text{ kJ mol}^{-1}$$

**107.4 – 107.7**      **2 marks**

8.314 for  $c$  instead of 4.18:

Energy =  $102 \times 8.314 \times 1.5 = 1272 \text{ J}$

Energy =  $102 \times 8.31 \times 1.5 = 1271.4 \text{ J}$

$\Delta H = \mathbf{107.4 – 107.7} \text{ kJ mol}^{-1}$

*depends on intermediate rounding*  
**CHECK**

-----  
Apply **ECF** for any other comparable responses. If in doubt contact TL

**Examiner's Comments**

This question was a good discriminator, producing marks across the whole 3 mark range. More successful candidates correctly calculated the energy change, moles of  $\text{RbC/O}_3$  and enthalpy change of solution. However, there were pitfalls for many including the following:

- calculating the energy change using the mass of water rather than the mass of the solution. This was despite the supplied information that the specific heat capacity of the solution is the same as for water. Candidates should understand that  $m$  in  $mc\Delta T$  is the mass of the substance that produces  $\Delta T$
- calculating an incorrect value for the molar mass of  $\text{RbC/O}_3$ . Instead of 169, this was often seen as 120.5 (using the atomic number of 37 for Rb, rather than the mass number of 85.5) and 185 (for  $\text{RbC/O}_4$ )
- using values of  $m$  at the wrong stages in the calculation. e.g. 2 g with the energy change and 102 g or 100 g with the moles calculation
- calculating the correct numerical value for the enthalpy change of solution, but then placing a '-' sign in front of the value, despite  $\Delta T$  being for a decrease in temperature.

Finally, as with all multi-step calculations, candidates are advised to use calculator values throughout. Any intermediate rounding introduces rounding errors in the final value. The

					final value can be rounded either to the significant figures demanded by the question or to the lowest number of significant figures used in the provided data.
			<b>Total</b>	<b>4</b>	
8			<b>C</b>	1 (AO 2.6)	<b><u>Examiner's Comments</u></b> Most candidates answered this question correctly with C.
			<b>Total</b>	<b>1</b>	
9			<b>D</b>	1 (AO 1.2)	<b><u>Examiner's Comments</u></b> The correct answer was D. Most candidates recognised that the complex represented cisplatin. Cisplatin has a bond angle of 90 degrees due to being square planar and shows cis/trans isomerism, but some candidates thought it showed optical isomerism too. Most could tell the oxidation number of platinum is not +4.
			<b>Total</b>	<b>1</b>	
10		i	$\text{CuO} + 2\text{HCl} \rightarrow \text{CuCl}_2 + \text{H}_2\text{O} \checkmark$	1 (AO2.6)	<b>ALLOW</b> multiples <b>IGNORE</b> state symbols <b>IGNORE</b> charges, even if wrong  <b><u>Examiner's Comments</u></b> 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 <sub>2</sub> and CuCl. Overall, most candidates produced a correct equation.
		ii	$(\text{NH}_4)_2\text{CO}_3 + 2\text{HNO}_3 \rightarrow 2\text{NH}_4\text{NO}_3 + \text{CO}_2 + \text{H}_2\text{O}$ Any 4 formulae correct ✓ All 5 formulae correct and balanced ✓	2 (AO2.6 ×2)	<b>ALLOW</b> multiples <b>IGNORE</b> state symbols <b>IGNORE</b> charges, even if wrong  <b>ALLOW</b> H <sub>2</sub> CO <sub>3</sub> for CO <sub>2</sub> + H <sub>2</sub> O <i>Counts as 2 formulae for marking criteria</i>

					<p><b><u>Examiner's Comments</u></b></p> <p>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 <math>\text{NH}_3</math> often shown instead of <math>\text{NH}_4</math>. 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.</p>
			<b>Total</b>	<b>3</b>	
11			<b>B</b>	1 (AO 1.2)	<p><b><u>Examiner's Comments</u></b></p> <p>Most candidates corrected selected option B. Many candidates wrote their oxidation numbers by each response with most identifying the oxidation number of S in <math>\text{S}_8</math> as being 0. The main distractors were A and C. Annotations showed that many assignments of oxidation number had the wrong sign. For example, assigning S as <math>-2</math> for S (<math>\text{SF}_2</math>) would result in C being chosen. This suggests that some candidates have an insufficient understanding of the rules for assigning oxidation numbers.</p>
			<b>Total</b>	<b>1</b>	
12			<p><b>Disproportionation</b></p> <p>Oxidation <b>AND</b> reduction of same element/chlorine</p> <p><b>OR</b></p> <p>Chlorine/<math>\text{Cl}/\text{Cl}_2</math> has been <b>oxidised</b> <b>AND</b> chlorine/<math>\text{Cl}/\text{Cl}_2</math> has been <b>reduced</b></p> <p>✓</p> <p><b>Oxidation</b></p> <p>from <b>0</b> in <math>\text{Cl}_2</math> to <b>+1</b> in <math>\text{Ca}(\text{OCl})_2</math> <b>OR</b> <math>\text{ClO}^-</math> ✓</p>	3 (AO 1.1) (AO 2.2) (AO 2.2)	<p><b>IGNORE</b> numbers around equation for oxidation numbers</p> <p><b>IGNORE</b> 'species' or 'reactant' for element</p> <p><b>ALLOW</b> 1+ for +1 <b>AND</b> 1- for -1</p> <p><b>NOTE</b> for chlorine/<math>\text{Cl}_2</math> <b>from 0</b> only needs to be seen once, does not need to be stated twice</p> <p><b>ALLOW</b> 1 mark for 3 oxidation numbers correct but no mention of words <b>oxidation/reduction</b>: e.g.</p>

			<p><b>Reduction</b></p> <p>from <b>0</b> in <b>Cl<sub>2</sub></b> to <b>-1</b> in <b>CaCl<sub>2</sub></b> OR <b>Cl<sup>-</sup></b> ✓</p>	<p>0 in Cl<sub>2</sub> <b>AND</b> -1 in CaCl<sub>2</sub> <b>AND</b> +1 in Ca(OCl)<sub>2</sub></p> <p><b>ALLOW</b> 1 mark for species missing</p> <p>oxidised from 0 to +1 <b>AND</b> reduced (from 0) to -1</p> <p><b><u>Examiner's Comments</u></b></p> <p>Most were able to explain the term disproportionation. Some missed the mark by not stating an element or chlorine. A very common error was giving final oxidation numbers of Cl as +2 and/or -2, rather than per atom. The link between oxidation number and species was not always clearly indicated or changes not specified as oxidation/reduction (or given as the wrong way round). It is vital to set out answers clearly showing oxidation numbers, species and stating if oxidised or reduced. It is not enough to write on the equation given in the question as it often challenging to read these numbers, or they contradict the main answer. Some attempted to show that Ca has been disproportionated.</p>
			<b>Total</b>	<b>3</b>
13	i	Titanium (IV) oxide ✓		<p><b>DO NOT ALLOW</b> titanium dioxide</p> <p><b><u>Examiner's Comments</u></b></p> <p>Very few candidates gave the correct answer for this question. The most common errors included: titanium oxide, titanium(IV) <b>d</b>ioxide, titanium oxide(IV), titanium(II) oxide. A few also attempted to give names like those for organic compounds: 1,1-titanium dioxide or the reverse 1,1-dioxytitanium.</p> <p><b>How Science Works</b></p> <p>It is important in Chemistry to have clear communication by use of systematic and unambiguous nomenclature. This includes the use of Roman numerals to indicate the</p>

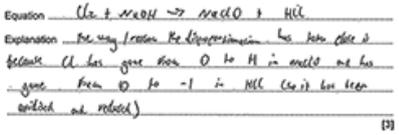
					<p>magnitude of the oxidation number when an element, such as Ti, may have different oxidation numbers in different compounds. See specification statement 2.1.5(c) and HSW8.</p>
		ii	<p><b>FIRST CHECK ANSWER ON ANSWER LINE</b>  <b>If answer = 2.67 kg award 4 marks</b></p> <hr style="border-top: 1px dashed blue;"/> <p><math>n(\text{Ti}) = \frac{1000}{47.9}</math> <b>OR</b> 20.8768... (mol) ✓</p> <p><math>n(\text{Na})</math> for 72% yield = <math>20.88 \times 4</math> <b>OR</b> 83.5073... (mol) ✓</p> <p><math>n(\text{Na})</math> for 100% yield = <math>83.51 \times \frac{100}{72}</math> <b>OR</b> 115.98237... (mol) ✓</p> <p>mass Na = <math>115.98 \times 23.0</math> = 2667.659... (g)  = 2.67 (kg) ✓  <b>3 SF AND kg required</b></p>	<p>4 (AO2.2 × 4)</p>	<p><b>ALLOW ECF</b> throughout  <b>TAKE CARE: values shown may be truncated calculator values.</b></p> <p>Steps can be calculated in any order which will change the intermediate answers. Marks are for the processing of the data.</p> <p><b>ALLOW 3SF</b> up to calculated value throughout</p> <p><b>IGNORE</b> rounding errors past <b>3SF</b></p> <p><b>Common Errors for 3 marks:</b>  1.92 (missing yield )  1.38 (yield wrong way round)  0.673 (use of Mr 189.9 for <math>\text{TiCl}_4</math> instead 47.9 for Ti)</p> <p><b><u>Examiner's Comments</u></b></p> <p>Candidates found this calculation quite challenging, with less than a quarter achieving full marks. The most common errors are highlighted on the mark scheme. Many that struggled were often given credit for the x4 ratio mark but only if it was possible to see this in the working. Many gave multiple, often contradictory attempts at the calculation. It was not always clear how the final answer had been obtained. Clear working enables us to follow the logic and give ECF where appropriate.</p> <p>Many divided 1000 g by the molar mass for <math>\text{TiCl}_4</math> and then found 72% of this. It was important here to read the question carefully to ensure complete understanding.</p> <p>Exemplar 1</p>

					 <p>This candidate achieved 3 out of the 4 possible marks. The steps in their calculation are logical and it is easy to follow their working and therefore spot the error in their calculation. They have divided by 4 rather than multiplying. It also shows the calculation can be performed in a different order to that on the mark scheme. All intermediate values are used in calculations as calculator values without rounding to ensure an accurate answer.</p>
	iii		<p>Add water <b>AND</b> filter ✓</p> <p>Ti does not dissolve <b>OR</b> NaCl does dissolve ✓</p>	<p>2 (AO 3.3 × 2)</p>	<p><b>ALLOW</b> dissolve in water</p> <p><b>ALLOW</b> Ti is insoluble <b>OR</b> NaCl is soluble/aqueous</p> <p><b>ALLOW</b> Ti is the residue <b>OR</b> NaCl is the filtrate</p> <p><b>Examiner's Comments</b></p> <p>Most candidates did not gain any credit here. However, the range of responses seen highlighted some misconceptions in their understanding of how different mixtures can be separated. Many assumed that sodium chloride was in solution/aqueous, not recognising that water was not present in this reaction. Responses such as "sodium chloride will evaporate" or "remove the water" were seen. Some gave a description of the purification method for an organic liquid - the use of a separating funnel and/or distillation were common. Some suggested the use of a magnet to remove Ti despite it being a non-magnetic metal.</p> <p> <b>Misconception</b></p>

					<p>Understanding how to separate mixtures is covered in both KS3 and KS4 but it is important that these concepts can be applied during further study. Asking this type of problem solving question would make a good starter activity.</p> <p>Some useful activities for separating mixtures can be found in the <a href="#">GCSE Chemistry B (Twenty First Century Science) Chemical analysis transition guide</a></p>
			<b>Total</b>	<b>7</b>	
14			<p><math>C_2H_5COOH + KOH \rightarrow C_2H_5COOK + H_2O</math> ✓</p> <p><math>2HCOOH + Mg \rightarrow (HCOO)_2Mg + H_2</math> ✓</p> <p><math>H_2O</math> <b>AND</b> <math>CO_2</math> ✓</p> <div style="text-align: center;"> <math display="block">  \begin{array}{c}  H \\    \\  H_2N - C - COONa \\    \\  CH_2 \\    \\  COONa \quad \checkmark  \end{array}  </math> </div> <p>Correct formula of salt:</p>	<p>4 (AO2.6×4)</p>	<p><b>ALLOW</b> any combination of skeletal <b>OR</b> structural <b>OR</b> displayed formula as long as unambiguous</p> <p><b>IGNORE</b> state symbols and use of equilibrium sign</p> <p><b>ALLOW</b> <math>KC_2H_5COO</math></p> <p><b>DO NOT ALLOW</b> a missing charge (e.g. <math>C_2H_5COO^-K</math>) the 1st time seen but <b>IGNORE</b> for next equations.</p> <p>For salts, <b>ALLOW</b> <math>C_2H_5COO^-K^+</math> <b>OR</b> <math>C_2H_5COO^- + K^+</math></p> <p><b>DO NOT ALLOW</b> <math>-COO-K</math> (covalent bond) the 1st time seen but <b>IGNORE</b> for next equations.</p> <p><b>FOR</b> <math>CO_2 + H_2O</math> <b>ALLOW</b> <math>H_2CO_3</math></p> <p><b><u>Examiner's Comments</u></b></p> <p>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</p>

					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.												
			<b>Total</b>	<b>4</b>													
15			<table border="1"> <thead> <tr> <th>Name of oxyanion</th> <th>Ionic charge</th> <th>Formula of oxyanion</th> </tr> </thead> <tbody> <tr> <td>Bromate(III) ✓</td> <td>1-</td> <td>BrO<sub>2</sub><sup>-</sup></td> </tr> <tr> <td>Sulfate(VI)</td> <td>2-</td> <td>SO<sub>4</sub><sup>2-</sup></td> </tr> <tr> <td>Phosphate(V)</td> <td>3-</td> <td>PO<sub>4</sub><sup>3-</sup> ✓</td> </tr> </tbody> </table>	Name of oxyanion	Ionic charge	Formula of oxyanion	Bromate(III) ✓	1-	BrO <sub>2</sub> <sup>-</sup>	Sulfate(VI)	2-	SO <sub>4</sub> <sup>2-</sup>	Phosphate(V)	3-	PO <sub>4</sub> <sup>3-</sup> ✓	2 (AO3.1 ×2)	<p><b>ALLOW</b> PO<sub>4</sub><sup>-3</sup></p> <p><b><u>Examiner's Comments</u></b></p> <p>Although this question included important clues within the table, these were usually ignored by candidates and this item did not score as well as expected. The bromate(III) was poorly identified, with many candidates missing the oxidation state of the bromine. Many candidates wrote bromide, bromate without (III), bromide (III), bromate (VI) and other oxidation numbers. The phosphate ion was more familiar with many candidates identifying its formula as PO<sub>4</sub><sup>3-</sup>. A common error was the inclusion of the wrong number of oxygen atoms in the ion, such as PO<sub>5</sub> with various charges.</p>
Name of oxyanion	Ionic charge	Formula of oxyanion															
Bromate(III) ✓	1-	BrO <sub>2</sub> <sup>-</sup>															
Sulfate(VI)	2-	SO <sub>4</sub> <sup>2-</sup>															
Phosphate(V)	3-	PO <sub>4</sub> <sup>3-</sup> ✓															
			<b>Total</b>	<b>2</b>													
16		i	<p>Oxidation and reduction of the same <b>element</b>✓</p> <p>'Atom' is insufficient for element</p>	1 (AO1.1 ×1)	<p><b>ALLOW</b> 'chlorine' <b>OR</b> 'Cl' for same element <b>IGNORE</b> 'species' for 'element'</p> <p><b><u>Examiner's Comments</u></b></p> <p>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</p>												

					incorrect chemistry and had clearly not learnt this specification content.
		ii	<p><b>Equation</b>  <math>\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaClO} + \text{NaCl} + \text{H}_2\text{O}</math>  ✓</p> <p><b>Redox:</b>  Cl is oxidised from 0 (in Cl<sub>2</sub>) to +1 in NaClO ✓  Cl is reduced from 0 (in Cl<sub>2</sub>) to -1 in NaCl/HCl ✓  <b>IGNORE</b> oxidation numbers shown in equation  <i>(treat as rough working)</i>  <b>BUT</b>  If <b>no</b> oxidation numbers in explanation, <i>look at equation for oxidation numbers</i></p>	3 (AO2.6×1) (AO2.1×2)	<p><b>DO NOT ALLOW</b>  <math>\text{Cl}_2 + \text{NaOH} \rightarrow \text{NaClO} + \text{HCl}</math>  <b>ALLOW ECF</b> from HCl in equation  <b>ALLOW</b> 1 out of 2 redox marks if NaClO AND NaCl omitted, i.e.  Cl is oxidised from 0 to +1  <b>AND</b>  Cl is reduced from 0 to -1  <b>ALLOW</b> 1 out of 2 redox marks if oxidation number changes are <b>BOTH</b> correct ...<b>BUT</b> reduction/oxidation is incorrectly assigned, i.e.  Cl is reduced from 0 (in Cl<sub>2</sub>) to +1 in NaClO  Cl is oxidised from 0 (in Cl<sub>2</sub>) to -1 in NaCl/HCl  <b>General: ALLOW number before sign in ox no, i.e.</b> 1+ for +1 1- for -1  <b>IGNORE</b> ionic charges, e.g. Cl<sup>1+</sup>  <b>IGNORE</b> '1' (signs required)  <b>IGNORE</b> references to electron loss/gain (even if wrong)</p> <p><b><u>Examiner's Comments</u></b></p> <p>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.</p>

				<p>Exemplar 2</p>  <p>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</p>
			<b>Total</b>	<b>4</b>
17	i	<p>Ca fizzes faster  <b>AND</b>            Ca dissolves/disappears more quickly            ✓</p>	<p>1            (AO2.3)</p>	<p><b>CARE</b> Both needed for <b>1 mark</b>.</p> <p><b>ORA ALLOW AW</b></p> <p><b>IGNORE</b> finishes first  <b>IGNORE</b> more bubbles (need idea of rate)  <b>IGNORE</b> exothermic</p> <p><b>Examiner's Comments</b></p> <p>Very few candidates made two valid statements where both clearly indicated an idea of relative rate – in almost all cases one of the descriptions would be about quantity of gas rather than rate of gas production. Some candidates identified a precipitate being formed, colour change, or gave a general answer of the reaction happening quicker.</p>
	ii	<p>Oxidation <math>\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-</math> ✓            Reduction <math>2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2</math>  <b>OR</b> <math>\text{H}^+ + \text{e}^- \rightarrow \frac{1}{2}\text{H}_2</math> ✓</p>	<p>2            (AO2.6×2)</p>	<p>In half equations,  <b>ALLOW</b> the use of e for e<sup>-</sup></p> <p><b>ALLOW</b> <math>\text{Mg} - 2\text{e}^- \rightarrow \text{Mg}^{2+}</math></p> <p><b>IGNORE</b> state symbols even is wrong</p>

				<p>BUT half equations <b>MUST</b> only have species that change.</p> <p>For charges on half equations,</p> <p><b>ALLOW</b> Mg<sup>+2</sup> for Mg<sup>2+</sup></p> <p><b>OR</b> H<sup>+1</sup> for H<sup>+</sup></p> <p>If <b>BOTH</b> half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations</p> <p><b><u>Examiner's Comments</u></b></p> <p>Some candidates coped well with this question which was based on the AS part of the specification and gained both marks. More candidates gained 1 mark through writing one half equation, usually the oxidation of magnesium. Common errors were for chlorine to featuring in the reduction half equation and the lack of electrons in their answers. Very few candidates mixed up the oxidation and reduction equations.</p>
			<b>Total</b>	<b>3</b>
18	i	$\text{Sr} + 2\text{H}_2\text{O} \rightarrow \text{Sr}(\text{OH})_2 + \text{H}_2$ <p>All formulae and balancing correct ✓</p>	<p><b>IGNORE STATE SYMBOLS</b></p> <p><b>ALLOW</b> multiples</p> <p><b>IGNORE</b> state symbols (even if wrong)</p> <p><b><u>Examiner's Comments</u></b></p> <p>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<sub>2</sub>O, SrOH as the formula of the hydroxide and no hydrogen formed (often giving H<sub>2</sub>O instead)).</p>	<p>1 (AO2.6)</p>

					 <p><b>Assessment for learning</b></p> <p>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.</p>
		ii	<p><b>Oxidation</b> Sr from <b>0</b> to <b>+2</b> ✓</p> <p><b>Reduction</b> H from <b>+1</b> to <b>0</b> ✓</p>	<p>2 (AO 2.1 × 2)</p>	<p><b>ALLOW</b> 2+ for +2 and 1+ for +1 '+' is required in +2 and +1 oxidation numbers</p> <p><b>ALLOW</b> H<sub>2</sub> for hydrogen</p> <p><b>ALLOW</b> 1 mark for elements <b>AND</b> all oxidation numbers correct but oxidation and reduction wrong way round <b>OR</b> not given.</p> <p><b>IGNORE</b> numbers around equation in (i) (<i>treat as rough working</i>)</p> <p><b>Examiner's Comments</b></p> <p>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.</p>
		iii	<p><i>Atomic radius</i> Ca has smaller atomic radius <b>OR</b> fewer shells ✓</p>	<p>3 (AO 1.2) (AO 1.2) (AO 1.2)</p>	<p><b>FULL ANNOTATIONS MUST BE USED</b></p> <p>-----</p> <p>-----</p> <p><b>ORA in terms of Sr</b></p>

			<p><i>Effect of nuclear charge/shielding</i> Ca has <b>less/decreased</b> shielding ✓</p> <p><i>Nuclear attraction</i> Ca has greater nuclear attraction (for electrons) <b>OR</b> Ca has a higher ionisation energy <b>OR</b> more energy is required to lose the outer electrons✓</p>		<p><b>Comparison</b> needed for each mark.</p> <p><b>ALLOW</b> 'fewer energy levels' <b>ALLOW</b> 'electrons closer to nucleus'</p> <p><b>IGNORE</b> fewer orbitals <b>OR</b> fewer sub-shells <b>OR</b> different shell</p> <p><b>ALLOW more</b> electron repulsion from inner shells</p> <p><b>IGNORE</b> nuclear charge/effective nuclear charge <b>ALLOW</b> 'less nuclear pull' <b>OR</b> 'electrons held less tightly'</p> <p><b><u>Examiner's Comments</u></b></p> <p>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.</p>
			<b>Total</b>	<b>6</b>	
19	i		<p><b>Structure and bonding</b> NH<sub>3</sub> is (simple) molecular/simple covalent/</p>	2 (2× AO1.1)	<p>For intermolecular bonds/forces <b>ALLOW</b> hydrogen bonds <b>OR</b> London Forces/induced dipole</p>

		<p>/has intermolecular forces  <b>AND</b>  <math>\text{NH}_4\text{NO}_3</math> is ionic ✓</p> <p><b>Comparison of strength</b>          Ionic bonds are stronger than intermolecular bonds / forces between molecules <b>OR</b>          Ionic bonds need more energy to break than intermolecular bonds ✓</p>	<p>forces/permanent dipole forces  <b>OR</b> van der Waals' forces</p> <p><b>ALLOW</b> <math>\text{NH}_4\text{NO}_3</math> has molecular ions  <math>\text{NH}_4^+</math> and <math>\text{NO}_3^-</math> are molecular ions</p> <p><b>ORA</b></p> <p><b>ALLOW:</b>          Intermolecular bonds are weak  <b>AND</b> ionic bonds are strong ✓</p> <p><b><u>Examiner's Comments</u></b></p> <p>Candidates found the explanation difficult, and the responses showed some misconceptions. For example, many suggested that <math>\text{NH}_3</math> and <math>\text{NH}_4\text{NO}_3</math> both have hydrogen bonds. Those identifying that <math>\text{NH}_4\text{NO}_3</math> has ionic bonding usually compared the greater strength of ionic bonding over intermolecular forces in <math>\text{NH}_3</math>. Unfortunately, many candidates described the ionic bonds as acting between molecules.</p> <p>This question proved to be one of the most difficult on the paper.</p> <p> <b>Misconception</b></p> <p>A good understanding of structure and bonding continues to be difficult for candidates, demonstrated by many incorrect explanations for the different boiling points. This is a key misconception.</p> <p>Understanding could be improved by first considering the following.</p> <ul style="list-style-type: none"> <li>• What is the type of bonding?</li> <li>• What are particles in the structure?</li> </ul> <p>Candidates need to be very careful when describing the two types of structure containing covalent bonds:</p>
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				<ul style="list-style-type: none"> <li>Simple molecular with strong covalent bonds within the molecules and weaker intermolecular bonds between the molecules in the structure</li> </ul> <p>Giant covalent with strong covalent bonds between the atoms in the structure.</p> <p>Exemplar 1</p> <p><i>NH<sub>3</sub> and NH<sub>4</sub>NO<sub>3</sub> both have hydrogen bonding, however NH<sub>4</sub>NO<sub>3</sub> has many more H bonds due to size of compound. This means more energy is required to break bonds.</i></p> <p>Exemplar 1 is typical of many, suggesting that NH<sub>4</sub>NO<sub>3</sub> has hydrogen bonding, which is either stronger than in NH<sub>3</sub>, or that NH<sub>4</sub>NO<sub>3</sub> has more hydrogen bonds. This response was given 0 marks.</p>
		ii	<p>(NH<sub>4</sub><sup>+</sup>) nitrogen has oxidation number of -3  <b>AND</b>  (NO<sub>3</sub><sup>-</sup>) nitrogen has oxidation number of +5 ✓</p> <p><i>i.e. nitrogens are -3 <b>AND</b> +5 gets the mark</i>  <b>BOTH signs essential</b></p>	<p>1 (AO1.2)</p> <p>Statement that one student is correct is <b>NOT</b> required.  <i>Implicit in answer</i>  <b>ALLOW 3- AND 5+</b></p> <p><b><u>Examiner's Comments</u></b></p> <p>Considering the large number of candidates describing NH<sub>4</sub>NO<sub>3</sub> as molecular in Question 1 (a) (i), most candidates identified here that NH<sub>4</sub>NO<sub>3</sub> contains NH<sub>4</sub><sup>+</sup> and NO<sub>3</sub><sup>-</sup> ions. Most then went on to show that the nitrogen atoms in the ions have different oxidation numbers: -3 and +5 respectively.</p> <p>Candidates were only given marks if <b>both</b> signs had been included and this was usually the case. -4 and +6 were common incorrect responses, presumably by ignoring the charges on the ions. Comparatively few candidates grouped the nitrogen atoms together and suggested that they had the same oxidation number.</p>
			<b>Total</b>	<b>3</b>

20	i	<p><b>FIRST CHECK ANSWER ON THE ANSWER LINE</b>  <b>If answer = <math>2.19 \times 10^{-3}</math> award 3 marks</b></p> <p>-----</p> <p>-----</p> <p><math>n(\text{Cl}_2) = 420/24 = 17.5 \text{ (mol)} \checkmark</math>  <math>n(\text{Ca}(\text{ClO})_2) = \frac{17.5}{2} = 8.75 \text{ (mol)} \checkmark</math></p> <p>Concentration <math>\text{Ca}(\text{ClO})_2 = \frac{8.75}{4 \times 1000}</math></p> <p><b>= <math>2.19 \times 10^{-3} \text{ (mol dm}^{-3}\text{)} \checkmark</math></b>  <b>3SF AND standard form</b></p>	<p>3 (3 ×AO2.2)</p>	<p>Use of ideal gas equation for all 3 marks provided 'sensible' <math>p</math> and <math>T</math> used: e.g.  from 101 kPa and 298 K  <math>\rightarrow n = 17.122 \rightarrow 2.14 \times 10^{-3}</math>  from 100 kPa and 298 K  <math>\rightarrow n = 16.952 \rightarrow 2.12 \times 10^{-3}</math>  Examples of 'sensible'  <math>p = 100 \text{ kPa, } 101 \text{ kPa, } 101,325 \text{ Pa}</math>  <math>T = 273 - 298 \text{ K}</math>  <b>ALLOW ECF</b></p> <p>-----</p> <p><b>Common errors</b>  <math>4.38 \times 10^{-3} \text{ (no } \div 2) \rightarrow 2 \text{ marks}</math>  <math>2.19 \times 10^n \rightarrow 2 \text{ marks}</math>  <math>4.38 \times 10^n \rightarrow 1 \text{ mark}</math>  <math>2.2 \times 10^{-3} \rightarrow 2 \text{ marks}</math>  <i>not appropriate SF</i></p> <p><b><u>Examiner's Comments</u></b></p> <p>Most candidates calculated the amounts of <math>\text{Cl}_2</math> and <math>\text{Ca}(\text{ClO})_2</math> correctly as 17.5 mol and 8.75 mol respectively. Only the least successful did not use the equation's stoichiometry to halve 17.5 to 8.75. For the final step in the calculation, candidates needed to convert <math>4.00 \text{ m}^3</math> into <math>4000 \text{ dm}^3</math> and to then determine the concentration to an appropriate number of significant figures and standard form. As all the data had been provided to 3 significant figures, the final answer was also required to 3 significant figures, as <math>2.09 \times 10^{-3} \text{ mol dm}^{-3}</math>. Answers such as <math>2.2 \times 10^{-3}</math>, <math>2.1875 \times 10^{-3}</math> and <math>2.19 \times 10^{-6}</math> and 0.00219 illustrate errors in these areas.</p>
	ii	<p><b>Equation</b>  <math>3 \text{ Ca}(\text{ClO})_2 \rightarrow 2 \text{ CaCl}_2 + \text{Ca}(\text{ClO}_3)_2</math>  <math>\checkmark</math></p> <p><b>Reduction</b>  <math>\text{Cl}</math> reduced from +1 to -1 <math>\checkmark</math></p> <p><b>Oxidation</b></p>	<p>3 (AO2.6) (2 ×AO1.2)</p>	<p><b>ALLOW</b> multiples  <b>ALLOW</b> <math>3 \text{ ClO}^- \rightarrow 2 \text{ Cl}^- + \text{ClO}_3^-</math></p> <p><b>ALLOW</b> 1 out of 2 redox marks if oxidation number changes are <b>BOTH</b> correct  ...<b>BUT</b> reduction/oxidation is</p>

		<p>Cl oxidised from +1 to +5 ✓</p> <p>+1 starting oxidation number seen once</p> <p>Cl required for both explanation marks</p> <p><b>IGNORE</b> oxidation numbers shown below/above equation (<i>treat as rough working</i>)</p> <p><b>BUT</b></p> <p>If <b>no</b> oxidation numbers in explanation, <i>look at equation for oxidation numbers</i></p>	<p>incorrectly assigned, i.e.</p> <p>Cl is oxidised from +1 to -1</p> <p>Cl is reduced from +1 to +5</p> <p><b>ALLOW</b> 1 out of 2 redox marks if oxidation changes correct but red and ox not stated</p> <p>Cl <b>changes</b> from +1 to -1</p> <p>Cl <b>changes</b> from +1 to +5</p> <p>-----</p> <p>-----</p> <p><b>General:</b></p> <p><b>ALLOW</b> number before sign in ox no, e.g. 1- for -1</p> <p><b>IGNORE</b> ionic charges, e.g. <math>\text{Cl}^{5+}</math></p> <p><b>IGNORE</b> '1' (signs required)</p> <p><b>IGNORE</b> references to electron loss/gain (even if wrong)</p> <p><b><u>Examiner's Comments</u></b></p> <p>Candidates were required to write a balanced equation from provided reactants and products and to use oxidation numbers to illustrate disproportionation.</p> <p>In the equation, the reactants and products were sometimes unbalanced, or incorrectly balanced. A common error was to balance the equation after first adding <math>\text{O}_2</math> as an extra reactant.</p> <p>Illustrating disproportionation proved to be easier with the oxidation number changes from the initial +1 being required.</p> <p>Otherwise, more successful responses sometimes missed out on marks if they omitted detail. For example, the oxidation number changes were stated but the candidate omitted to state which change was oxidation and which was reduction. The best responses identified <math>\text{Ca}(\text{ClO}_3)_2</math> as the oxidation product and <math>\text{CaCl}_2</math> as the reduction product.</p>
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					One unexpected error on many scripts was for calcium to be identified as the element undergoing disproportionation, with oxidation number changes from +6 to +14 and +2. It was difficult to see why this happened, with Ca forming +2 compounds, but the error was common.
			<b>Total</b>	<b>6</b>	