

1.1		an answer of 67.8 (%) scores 3 marks an answer of 67.8160919 (%) or correctly rounded answer to 2, 4 or more sig figs scores 2 marks an incorrect answer for one step does not prevent allocation of marks for subsequent steps		AO2 4.3.3.2
	(total M_r of reactants =) 87		1	
	(percentage atom economy)	allow (percentage atom economy)	1	
	$= \frac{59}{87} \times 100$	$= \frac{59}{\text{incorrectly calculated } M_r} \times 100$		
	= 67.8 (%)	allow an answer from an incorrect calculation to 3 sig figs	1	

2.1	chlorine reacts with water or chlorine dissolves (in the solution)		1	AO3 4.3.5 4.4.3.4
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Question	Answers	Extra information	Mark	AO / Spec. Ref.
2.2	(volume=) $\frac{6.6}{1000}$ (dm³) or 0.0066 (dm³) (moles=) $\frac{0.0066}{24}$ = 2.75×10^{-4} (mol)	an answer of 2.75×10^{-4} (mol) or 2.8×10^{-4} (mol) scores 3 marks an answer of 0.000275 / 0.00028 / 2.75×10^{-1} / 2.8×10^{-1} (mol) / scores 2 marks an incorrect answer for one step does not prevent allocation of marks for subsequent steps allow 6.5 (cm³) for 6.6 (cm³) allow use of incorrect volume from step 1 allow 2.8×10^{-4} (mol) allow answer from incorrect calculation given in standard form alternative approach for marking points 1 and 2 24 dm³ = 24 000 cm³ (1) (moles =) $\frac{6.6}{24\ 000}$ (1)	1 1 1	AO2 4.3.5

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3.1	(actual mass =) $\frac{92.3}{100} \times 13.5$ or (actual mass =) 0.923×13.5 = 12.5 (kg)	an answer 12.5 (kg) scores 2 marks allow 12 / 12.46 / 12.461 / 12.4605 (kg)	1 1	AO2 4.3.3.1

				Spec. Ref.
4.1	(titre): chooses titrations 3, 4, 5 average titre = 22.13 (cm³) (calculation): (moles NaOH = $\frac{22.13}{1000} \times 0.105 = 0.002324$) (moles H₂SO₄ = $\frac{1}{2} \times 0.002324 = 0.001162$) (concentration = $\frac{0.001162}{25} \times 1000$) = 0.0465 (mol/dm³)	an incorrect answer for one step does not prevent allocation of marks for subsequent steps allow average titre = 22.13(3...) (cm³) allow a correctly calculated average from an incorrect choice of titrations allow use of incorrect average titre from step 2 allow use of incorrect number of moles from step 3 allow use of incorrect moles from step 4 alternative approach for step 3, step 4 and step 5 $\frac{2}{1} = \frac{22.13 \times 0.105}{25.0 \times \text{conc. H}_2\text{SO}_4} \quad (1)$ (concentration H₂SO₄ =) $\frac{22.13 \times 0.105}{25.0 \times 2}$ = 0.0465 (mol/dm³) (1) an answer of 0.046473 or 0.04648 correctly rounded to at least 2 sig figs scores marking points 3, 4 and 5 an answer of 0.092946 or 0.09296 or 0.185892 or 0.18592 correctly rounded to at least 2 sig figs scores marking points 3 and 5	1 1 1 1 1	AO2 4.3.4 4.4.2.5

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4.2	pipette measures a fixed volume (accurately)		1	AO1 4.4.2.5
	(but) burette measures variable volume	allow can measure drop by drop	1	

4.3	(moles =) $\frac{30}{1000} \times 0.105$ or 0.00315 (mol) or (mass per dm³ =) 0.105×40 or 4.2 (g) (mass = $\frac{30}{1000} \times 0.105 \times 40$) = 0.126 (g)	an answer of 0.126 (g) scores 2 marks an answer of 126(g) scores 1 mark an incorrect answer for one step does not prevent allocation of marks for subsequent steps	1 1	AO2 4.3.2.5 4.3.4 4.4.2.5
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5.1	Level 3: The design/plan would lead to the production of a valid outcome. All key steps are identified and logically sequenced.	5–6	AO3 AO1
	Level 2: The design/plan would not necessarily lead to a valid outcome. Most steps are identified, but the plan is not fully logically sequenced.	3–4	AO1 x 2
	Level 1: The design/plan would not lead to a valid outcome. Some relevant steps are identified, but links are not made clear.	1–2	AO1 x 2
	No relevant content	0	
	Indicative content allow converse using acid added to alkali Key steps • measure the volume of acid • add indicator to the acid • add sodium hydroxide solution • until the colour changes • record volume of sodium hydroxide solution added • repeat procedure with the other acid Use of results • compare the two volumes of sodium hydroxide solution to find which sample P or Q is more concentrated Other points • pipette to measure volume of acid • use a few drops of indicator • swirl • use a white tile • rough titration to find approximate end point • add dropwise near the endpoint • read volume from bottom of meniscus • repeat and take a mean		4.4.2.5

6.1	$\left(\frac{150\,000}{71} = \right) 2113 \text{ (mol of Cl}_2\text{)}$ or $\text{(volume of 1 g of Cl}_2\text{ = } \frac{24}{71} = \text{) } 0.34 \text{ (dm}^3\text{)}$ $\left(\frac{150\,000}{71} \times 24\right) = 50700 \text{ (dm}^3\text{)}$	an answer of 50700 (dm³) scores 2 marks an answer of 50.7 (dm³) scores 1 mark	1	AO2 4.3.5
		allow 50704.22535 (dm³) correctly rounded to at least 2 significant figures allow correct calculation using their calculated number of moles and/or calculated volume of 1 g	1	

7.1		an answer of 0.62 (mol/dm ³) for concentration in mol/dm ³ scores 4 marks		AO2/2 4.3.1.2 4.3.2.5 4.3.4 4.4.2.5
		an answer of 0.31 (mol/dm ³) for concentration in mol/dm ³ scores 3 marks		
	(moles H ₂ SO ₄ = 0.500 × $\frac{15.5}{1000}$) = 0.00775		1	
	(moles KOH = 2 x moles H ₂ SO ₄ = 2 x 0.00775) = 0.0155	allow correct calculation using incorrectly calculated value of moles of H ₂ SO ₄	1	
	(conc KOH = moles KOH × $\frac{1000}{25.0}$) = 0.0155 × $\frac{1000}{25.0}$	allow correct calculation using incorrectly calculated value of moles of KOH	1	
	= 0.62 (mol/dm ³)	allow correct answer using incorrectly calculated value of moles of KOH	1	
	(M _r KOH ⇒) 56		1	
	(conc = M _r × conc in mol/dm ³ = 56 × 0.62) = 34.7 (g/dm ³)	allow 35 or 34.72 (g/dm ³)	1	
		allow correct answer using incorrectly calculated value of concentration in mol/dm ³ and/or incorrect M _r		
	alternative approach for step 1 to step 4			
	$\frac{2}{1} = \frac{25 \times \text{conc KOH}}{15.5 \times 0.500}$ (2)			
	(conc KOH) = $\frac{2 \times 15.5 \times 0.500}{25.0}$ (1)			
	= 0.62 (mol/dm ³) (1)	allow 1 mark if mole ratio is incorrect		

8.1	ratio of O ₂ : CO ₂ = 5 : 3		1	4.7.1.3
	(oxygen needed = $\frac{3.60 \times 5}{3}$) = 6.0 (dm ³)	allow correct calculation using an incorrectly determined mole ratio	1	
	(oxygen unreacted = 7.25 – 6.0) = 1.25 (dm ³)	allow correct subtraction of an incorrectly calculated volume of oxygen	1	
	(oxygen unreacted = 1.25 × 1000) = 1250 (cm ³)	allow correct conversion to cm ³ anywhere in response	1	
		alternative approach for MP1 and MP2 moles CO ₂ = 0.15 and moles O ₂ = 0.25 (1) (0.25 × 24 =) 6.0 (dm ³ oxygen needed) (1)		

9.1	$\frac{6}{34} \times 100$ = 17.6 (%)	an answer of 17.6470588 (%) correctly rounded to at least 2 significant figures scores 2 marks allow 17.6470588 (%) correctly rounded to at least 2 significant figures	1 1	AO2 4.3.3.2
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10.1	(total $M_r = 170 + 150) = 320$	allow $(235 + 85) = 320$	1	AO2 4.3.3.2
	(% atom economy =) $\frac{235}{320} \times 100$	allow correct use of incorrectly calculated total M_r	1	
	= 73.4375 (%)		1	
	= 73.4 (%)	allow an answer correctly calculated to 3 significant figures from an incorrect percentage calculation which uses the values in the question	1	

10.2	any one from: • for sustainable development • for economic reasons • to produce a high(er) percentage of useful product	allow to reduce waste	1	AO1 4.3.3.2
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11.1	(58 MJ =) 58 000 kJ or (290 kJ =) 0.290 MJ (moles = $\frac{58000}{290}$ or $\frac{58}{0.290}$ =) 200 (volume =) 200 × 24 = 4800 (dm³) alternative approach: (58 MJ =) 58 000 kJ (1) (energy released per dm³ = $\frac{290}{24}$ =) 12.08333 (kJ/dm³) (1) (volume =) $\frac{58000}{12.08333}$ (1) = 4800 (dm³) (1)	allow (58 MJ =) 58 000 000 J and (290 kJ =) 290 000 J allow correct use of an incorrectly converted or unconverted value of energy allow correct use of an incorrectly calculated number of moles of hydrogen allow correct use of an incorrectly converted or unconverted value of energy allow correct use of an incorrectly calculated energy released per dm³	1 1 1 1	AO2 4.3.2.1 4.3.5 4.5.2.2
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12.1	$(M_r \text{ citric acid} =) 192$ $(\text{moles} = \frac{250}{1000} \times 0.0500)$ $= 0.0125$ $(\text{mass} = 0.0125 \times 192 =) 2.4 \text{ (g)}$ alternative approach: $(M_r \text{ citric acid} =) 192 \text{ (1)}$ $(\text{concentration} = 0.0500 \times 192)$ $= 9.6 \text{ (g/dm}^3\text{) (1)}$ $(\text{mass} = \frac{250}{1000} \times 9.6 =) 2.4 \text{ (g) (1)}$	 allow correct use of an incorrectly calculated M_r allow correct use of an incorrectly calculated number of moles allow correct use of an incorrectly calculated M_r allow correct use of an incorrectly calculated concentration in g/dm^3	1 1 1	AO2 4.3.2.5 4.3.4
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12.2	add the citric acid (to the flask) until there is a (permanent) colour change	ignore colours of indicator	1	AO1 4.4.2.5 RPA 2
	measure / record the volume (of citric acid) added	allow take the final (and initial) burette reading	1	
	any one from: • swirl • use a white tile • add the citric acid dropwise (near the end-point) • repeat and calculate a mean	allow add the citric acid slowly (near the end-point)	1	

12.3	any two from: • can add (the citric acid) in small increments • can measure variable volumes • more accurate than a measuring cylinder	allow can add (the citric acid) drop by drop allow can add (the citric acid) slowly allow has a scale	2	AO1 4.4.2.5 RPA 2
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12.4	(moles citric acid = $\frac{13.3}{1000} \times 0.0500$) = 0.000665 (moles NaOH = 3×0.000665) = 0.001995 (conc = $\frac{1000}{25} \times 0.001995$) = 0.0798 (mol/dm³) alternative approach: $\frac{25.0 \times \text{conc NaOH}}{13.3 \times 0.0500} = \frac{3}{1} \quad (1)$ (conc NaOH =) $3 \times \frac{13.3 \times 0.0500}{25.0}$ (1) = 0.0798 (mol/dm³) (1)	allow correct use of an incorrectly calculated number of moles of citric acid allow 0.08 or 0.080 (mol/dm³) allow correct use of an incorrectly calculated number of moles of NaOH allow $\frac{13.3 \times 0.0500}{25.0 \times \text{conc NaOH}} = \frac{1}{3}$ allow 0.08 or 0.080 (mol/dm³)	1 1 1	AO2 4.3.4 4.4.2.5 RPA 2
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Question	Answers	Extra information	Mark	AO / Spec. Ref.
13.1	(total M_r of reactants) = 163		1	AO2 4.3.1.2 4.3.3.2
	(% atom economy =) $\frac{119}{163} (\times 100)$	allow correct use of an incorrectly calculated value of total M_r	1	
	= 73 (%)	allow 73.00613 (%) correctly rounded to at least 2 significant figures	1	

14.1	(moles Fe = $\frac{14}{56}$ =) 0.25 (mol)		1	AO2
	(moles Cl ₂ = $\frac{3}{2}$ × 0.25 =) 0.375 (mol)	allow correct use of an incorrectly calculated number of moles of Fe	1	4.3.2.1 4.3.2.2 4.3.5
	(volume Cl ₂ = 24 × 0.375) = 9.0 (dm ³)	allow correct use of an incorrectly calculated number of moles of Cl ₂	1	

Question	Answers	Extra information	Mark	AO / Spec. Ref.
15.1	any two from: • swirl (the solution) • white tile (under the flask) • add (ethanedioic) acid dropwise (near the endpoint) • repeat and calculate mean		2	AO3 4.4.2.5 RPA2

15.2	(concentration = $90 \times 0.0480 =$ 4.32 (g/dm³) (mass = $4.32 \times \frac{250}{1000}$) = 1.08 (g) alternative approach: (moles = $0.0480 \times \frac{250}{1000} =$ 0.012 (mol) (1) (mass = 0.012×90) = 1.08 (g) (1)	allow correct use of an incorrectly calculated value of concentration in g/dm³ allow correct use of an incorrectly calculated value of number of moles	1 1	AO2 4.3.2.1 4.3.2.5 4.3.4
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15.3	(moles $\text{H}_2\text{C}_2\text{O}_4 = \frac{15.0}{1000} \times 0.0480$) $= 0.00072 \text{ (mol)}$ (moles $\text{NaOH} =$ moles $\text{H}_2\text{C}_2\text{O}_4 \times 2 =$) 0.00144 (mol) (concentration = $\frac{0.00144}{25.0} \times 1000$) $= 0.0576 \text{ (mol/dm}^3\text{)}$ alternative approach: $\frac{\text{volume} \times \text{conc (acid)}}{\text{volume} \times \text{conc (NaOH)}} = \frac{1}{2} \text{ (1)}$ (conc $\text{NaOH} =$) $2 \times \frac{15.0 \times 0.0480}{25.0} \text{ (1)}$ $= 0.0576 \text{ (mol/dm}^3\text{)} \text{ (1)}$	allow correct use of an incorrectly calculated value of number of moles of $\text{H}_2\text{C}_2\text{O}_4$ allow $0.058 \text{ (mol/dm}^3\text{)}$ allow correct use of an incorrectly calculated value of number of moles of NaOH allow inverse allow correct use of incorrect mole ratio	1 1 1	AO2 4.3.4 4.4.2.5 RPA2
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16.1	(volume of oxygen for 30 cm³ Si₂H₆ = 3.5 × 30) = 105 (cm³) (volume of excess oxygen = 150 – 105) = 45 (cm³) (volume of water (vapour) = 3 × 30) = 90 (cm³) (volume of gases = 45 + 90) = 135 (cm³) allowed alternative approach: (moles Si₂H₆ = $\frac{0.03}{24}$ =) 0.00125 (1) (moles water vapour formed = 3 × 0.00125 =) 0.00375 and (moles oxygen used = 3.5 × 0.00125 =) 0.004375 (1) (moles excess oxygen = $\frac{0.15}{24}$ - 0.004375 =) 0.001875 (1) (volume of gases = 24 × (0.00375 + 0.001875) = 0.135 dm³ =) 135 (cm³) (1)	allow correct use of an incorrectly calculated volume of oxygen for 30 cm³ Si₂H₆ allow correct use of incorrectly calculated volumes of excess oxygen and / or water vapour allow correct use of an incorrectly calculated number of moles of Si₂H₆ allow correct use of an incorrectly calculated number of moles of oxygen used allow correct use of an incorrectly calculated number of moles of excess oxygen and / or moles of water vapour formed	1 1 1 1	AO2 4.3.2.4 4.3.5
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17.1	the mean of titration numbers 2 to 5 values is calculated (because) 23.90 (cm³) is an anomalous result	allow identification of titration by titration number or volume allow (because) 23.90 (cm³) is not concordant allow (because) 23.90 (cm³) is too high a value allow (because) the first titration is a rough value allow for 2 marks an answer of (because) the mean is taken of the values within 0.10 (cm³) allow for 2 marks an answer of (because) the mean is taken of the concordant values	1 1	AO3 4.4.2.5 RPA2
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17.2	(moles $\text{Ba(OH)}_2 = \frac{23.50}{1000} \times 0.100 = 0.00235$ (moles $\text{HCl} = 0.00235 \times 2 = 0.00470$ (concentration =) $0.00470 \times \frac{1000}{25.0}$ $= 0.188 \text{ (mol/dm}^3\text{)}$ alternative approach: $\left(\text{ratio } \frac{\text{moles HCl}}{\text{moles Ba(OH)}_2} = \right)$ $\frac{2}{1} = \frac{25.0 \times \text{concentration}}{23.50 \times 0.100} \quad (2)$ (concentration =) $\frac{2 \times 23.50 \times 0.100}{25.00} \quad (1)$ $= 0.188 \text{ (mol/dm}^3\text{)} \quad (1)$	allow correct use of an incorrectly calculated number of moles of Ba(OH)_2 allow correct use of an incorrectly calculated number of moles of HCl allow inverted expression allow 1 mark for the expression with an incorrect mole ratio allow correct use of the expression with an incorrect mole ratio	1 1 1 1	AO2 4.3.4 4.4.2.5 RPA2
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Question	Answers	Extra information	Mark	AO / Spec. Ref.
18.1	there is only one product		1	AO2 4.3.3.2 4.10.4.1

Question	Answers	Extra information	Mark	AO / Spec. Ref.
19.1	the mass of acid dissolved is doubled and the volume of the solution is halved		1	AO2 4.3.2.5

[illegible]

Question	Answers	Extra information	Mark	AO / Spec. Ref.
20.1	(percentage atom economy =) $\frac{A_rX}{A_rX + 54} \times 100 = 77.3$		1	AO2 4.3.3.2
	100 $A_rX = 77.3 (A_rX + 54)$	allow $A_rX = 0.773 (A_rX + 54)$	1	
	22.7 $A_rX = 4174.2$	allow 0.227 $A_rX = 41.742$	1	
	$A_rX = 184$	allow 183.8854626 correctly rounded to at least three significant figures	1	
	alternative approach 1: $(3M_r \text{ H}_2\text{O} = (3 \times 16) + (6 \times 1) =)$ 54 and (percentage = $100 - 77.3 =$) 22.7% (1)			
	(total M_r of reactants =) $\frac{100}{22.7} \times 54 \text{ (1)}$	allow correct use of an incorrectly determined value for $3M_r \text{ H}_2\text{O}$ and/or percentage of unwanted products		
	= 238 (1)			
	($A_rX = 238 - 54$) or $\left(A_rX = 238 \times \frac{77.3}{100} \right)$ = 184 (1)	allow correct use of an incorrectly determined value of total M_r of reactants and/or value for $3M_r \text{ H}_2\text{O}$ allow 183.8854626 correctly rounded to at least three significant figures		

	alternative approach 2: $(3M_r \text{ H}_2\text{O} = (3 \times 16) + (6 \times 1) =)$ 54 and (percentage = $100 - 77.3 =$) 22.7% (1) $\left(\frac{1}{22.7} \times 54 =\right) 2.3788546$ (1) 2.3788546×77.3 (1) = 184 (1)	allow correct use of an incorrectly determined value for $3M_r \text{ H}_2\text{O}$ and/or percentage of unwanted products allow correct use of an incorrectly determined value for 1% of the total M_r of reactants allow 183.8854626 correctly rounded to at least three significant figures		
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Question	Answers	Extra information	Mark	AO / Spec. Ref.
21.1	$(M_r \text{ TiO}_2 =) 80$		1	AO2 4.3.1.2
	(conversion 100 kg $\Rightarrow$) 100 000 (g)		1	4.3.2.1 4.3.2.2 4.3.5
	$\left(\text{moles TiO}_2 = \frac{100\,000}{80} = \right)$ 1250	allow correct use of an incorrectly determined M_r allow correct use of an incorrect / no conversion of mass	1	
	(moles $\text{Cl}_2 = 1250 \times 2 =$) 2500	allow correct use of an incorrectly determined number of moles of TiO_2	1	
	(volume $\text{Cl}_2 =$) 2500 $\times$ 24 = 60 000 (dm^3)	allow correct use of an incorrectly determined number of moles of Cl_2	1 1	