# Mark scheme – Amount of Substance

| Question | | | Answer/Indicative content | Marks | Guidance |
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| 1 | | i | **FIRST CHECK THE ANSWER ON ANSWER LINE**<br>**If answer = 5.8 award 3 marks**<br>--------------------------------------------------<br>$n(SrCl_2) = \frac{1.62}{158.6}$ = 0.0102……. (mol) ✓<br>$n(H_2O) = \frac{1.07}{18}$ = 0.0594……… (mol) ✓<br>**x** = $SrCl_2 : H_2O = \frac{0.0594.....}{0.0102......}$<br>= 5.8 ✓ | 3<br><br>(AO3.1x 2)<br><br>(AO3.2) | **Calculator**: 0.01021437579<br><br>**Calculator**: 0.05944444444<br><br>**ALLOW ECF** from $n(SrCl_2)$ and/or $n(H_2O)$<br><br>Answer must be to **TWO** significant figures<br><br>**ALLOW** 2 marks for 5.83 (answer must be to 2 SF)<br><br>**<u>Examiner's Comments</u>**<br><br>Most students managed to gain some marks on this question. The most common error was rounding to 6, something they have been taught to do for water of crystallisation. This caused them to lose a mark as the question asked for two significant figures. Many rounded too early so a variety of responses were seen. |
| | | ii | To make sure all the water had been removed ✓ | 1(AO3.4) | **IGNORE** just 'to weigh to constant mass'<br><br>**<u>Examiner's Comments</u>**<br><br>The majority of candidates answered this correctly, the main incorrect answer was "to achieve constant mass". |
| | | iii | Use balance that weighs to 3/more decimal places ✓<br><br>Use a larger mass (of hydrated strontium chloride) ✓ | 2(AO3.4× 2) | **ALLOW** more precise/more accurate/ more sensitive/higher resolution/smaller division/weigh to 0.001<br><br>**IGNORE** 'less error/smaller interval balance'<br><br>**IGNORE** any reference to lid on crucible (water can't escape)<br><br>**IGNORE** 'weigh straight after heating'<br><br>**IGNORE** idea of repeating the experiment/ taking an average/ getting concordant results /larger sample size, etc. |

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| | | | | | **Examiner's Comments**<br><br>Most candidates identified either using a larger mass or a more accurate balance, not many stated both. The most common incorrect answers involved heating for longer or taking less measurements. |
| | | | **Total** | **6** | |
| 2 | | | **FIRST CHECK THE ANSWER ON ANSWER LINE**<br>**If answer = 60 cm$^3$ award 3 marks**<br>-------------------------------------------------<br>$n(HCl) = \frac{50.0}{1000} \times 0.100$ = $5.00 \times 10^{-3}$ (mol) ✓<br><br>$n(H_2) = \frac{5.00 \times 10^{-3}}{2}$ = $2.50 \times 10^{-3}$ (mol) ✓<br><br>Volume = $2.5(0) \times 10^{-3} \times 24.0 \times 1000$<br>= 60(.0) cm$^3$ ✓ | 3(AO2.6×3) | **ALLOW** 120 cm$^3$ for 2 marks (no ÷ 2)<br>**ALLOW** 240 cm$^3$ for 2 marks (× 2 not ÷ 2)<br><br>**IGNORE** absence of trailing zeroes, e.g. for 0.100, **ALLOW** 0.1<br><br>**ALLOW ECF** from *n*(HCl)<br><br>**ALLOW ECF** from *n*(HCl) and/or *n*($H_2$)<br><br>**Examiner's Comments**<br><br>This was a well answered question, with the majority of candidates obtaining all 3 marks |
| | | | **Total** | **3** | |
| 3 | a | i | Oxidised<br>**AND**<br>(Mg) transfers/loses/donates **2** electrons ✓<br><br>**2** essential | **1** | **ALLOW** Mg loses 6 electrons: *3 Mg in equation*<br>**ALLOW** Mg → $Mg^{2+}$ + $2e^-$<br><br>**IGNORE** oxidation numbers (even if wrong)<br><br>**Examiner's Comments**<br><br>Despite the question clearly asking for a response in terms of the number of electrons transferred, most candidates answered in terms of oxidation number changes. Candidates are recommended to read the question and to answer in terms of its requirements. Underlining 'number of electrons' may have helped candidates to answer the question that had been set. |
| | | ii | **FIRST CHECK ANSWER ON THE ANSWER LINE**<br>**IF answer = 2.26 (3 SF) award 3 marks**<br>-------------------------------------------------<br>***n*($H_3PO_4$)** = $\frac{1.24 \times 50.0}{1000}$ = 0.062(0) (mol) ✓<br><br>***n*(Mg)** = $\frac{3}{2} \times 0.062(0)$ = 0.093(0) (mol) ✓<br><br>**mass of Mg** = 0.0930 × 24.3 = 2.26 (g) ✓ | **3** | At least **3SF** needed throughout **BUT**<br>**ALLOW** no trailing zeroes (e.g. 0.062 for 0.0620)<br><br>**ALLOW ECF** from *n*(H3PO4)<br><br>**ALLOW ECF** from *n*(Mg) |

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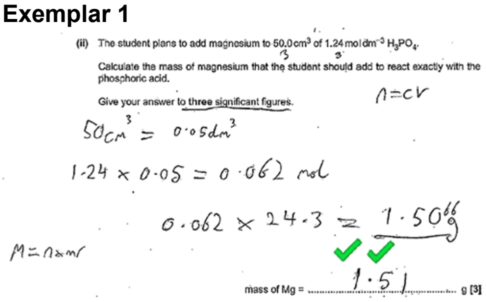
| | | | **3 SF required** | | ---------------------------------------------<br>**COMMON ERRORS for 2 marks**<br>**3:2 ratio omitted** → *n*(Mg) = 0.062(0) → 1.51 (g)<br>**Inverted 2:3 ratio** → *n*(Mg) = 0.0413 → 1.00 (g)<br><br>**<u>Examiner's Comments</u>**<br><br>Most candidates are competent at answering questions based on the mole. Almost all candidates were able to calculate the amount of H3PO4 as 0.062 mol. Candidates then needed to use the 2:3 mole stoichiometric ratio to show that 0.093 mol of Mg reacts, which has a mass of 2.26 g to the required 3 significant figures. The commonest errors were use of the inverse 3:2 ratio to obtain 1.00 g Mg, or to omit the ratio to obtain 1.51 g Mg, as shown in the exemplar. Candidates are advised to show clear working so that credit can be awarded for such responses by applying error carried forward.<br><br>**Exemplar 1**<br> |
| | | iii | **Separation of solid**<br><br>Filter to obtain solid/precipitate ✓<br>*Requires realisation that solid is filtered off.*<br>*Solid may be stated within in 'removal of water'*<br>**Removal of water**<br><br>Dry (solid)<br>**OR** Evaporate (water/solution/liquid) ✓ | **2** | **ALLOW**<br>**Removal of water**<br><br>Evaporate/ distil water/solution/liquid ✓<br>**IGNORE** 'distil' if product **OR** $H_2$ is distilled<br>**Collection of remaining solid** ✓<br><br>*Requires realisation that solid remains*<br>**IGNORE** 'Leave to crystallise' *(already solid)*<br><br>**<u>Examiner's Comments</u>**<br><br>Candidates often struggle with questions based on practical work. There were many random responses to this question, with relatively few candidates identifying that solid magnesium phosphate could be obtained by filtration, followed by drying. |
| | | iv | **Formula**<br><br>MgO **OR** $Mg(OH)_2$ **OR** $MgCO_3$ **OR** soluble Mg salt ✓<br><br>**Equation** | **2** | **In equation:**<br>**NO ECF** from incorrect formula<br>**ALLOW** multiples<br>**IGNORE** state symbols (even if incorrect) |

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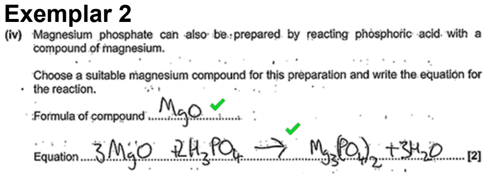
| | | | $3MgO + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3H_2O$<br>**OR**<br>$3Mg(OH)_2 + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 6H_2O$<br>**OR**<br>$3MgCO_3 + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3CO_2 + 3H_2O$ | | **Soluble Mg salts** include<br>$MgCl_2$, $MgSO_4$, $Mg(NO_3)_2$, $MgBr_2$, $MgI_2$<br>If unsure, check with TL<br>e.g. $3MgCl_2 + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 6HCl$<br><br>**<u>Examiner's Comments</u>**<br><br>Candidates were expected to identify a suitable reagent for this reaction, with most choosing magnesium oxide, hydroxide or carbonate. Credit was also given for using a soluble magnesium salt such as its sulfate, chloride or nitrate. The correct equation often followed, but errors sometimes appeared in the form of incorrect formulae, such as MgOH for magnesium hydroxide. The exemplar shows a good clear response, using MgO as the reagent.<br><br>**Exemplar 2**<br> |
| | b | i | **FIRST CHECK ANSWER ON THE ANSWER LINE**<br>**IF answer = 315 (cm3) award 4 marks**<br>-------------------------------------------------------<br>**Amount of $PH_3$**<br>$n(PH_3) = \frac{3.20 \times 10^{-2}}{4}$ **OR** $8(.00) \times 10^{-3}$ (mol) ✓<br><br>**Unit conversions**<br><br>$p$ conversion → Pa = $100 \times 10^3$ (Pa)<br>**AND**<br>$T$ conversion → K = 473 (K) ✓<br><br>**Evidence of use of rearranged gas equation**<br><br>**OR** $V = \frac{nRT}{p}$<br><br>**OR** $V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 473}{100 \times 10^3}$<br><br>**OR** $V = 3.15 \times 10^{-4}$ ✓<br>*Calculator:* = $3.1460176 \times 10^{-4}$<br><br>**$V$ conversion of $m^3 \rightarrow cm^3$ ✓**<br>$V = 3.15 \times 10^{-4} \times 10^6 = 315\ cm^3$ ✓<br><br>*Calculator from unrounded $cm^3$*: $314.60176\ cm^3$<br><br>***Requires 3 OR MORE SF, correctly rounded*** | **4** | **If there is an alternative answer, check to see if there is any ECF credit possible**<br><br>**ALLOW ECF** throughout<br>-----------------------------------------------<br><br>**Common Errors (3 marks)**<br><br>***Use of n(H3PO4) = $3.20 \times 10^{-2}$*** *(Very common)*<br>$V = \frac{3.2(0) \times 10^{-2} \times 8.314 \times 473}{100 \times 10^3} \times 10^6$<br><br>= $1258.40704\ cm^3$ (1260 to 3 SF)<br><br>***No temperature conversion from °C to K***<br>$V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 200}{100 \times 10^3} \times 10^6$<br><br>= $133\ cm^3$<br><br>***No p conversion from kPa to Pa***<br>$V = \frac{8(.00) \times 10^{-3} \times 8.314 \times 473}{100} \times 10^6$<br><br>= $315000\ cm^3$<br><br>***No volume conversion from $m^3$ to $cm^3$***<br><br>$V = 3.15 \times 10^{-4}$ |

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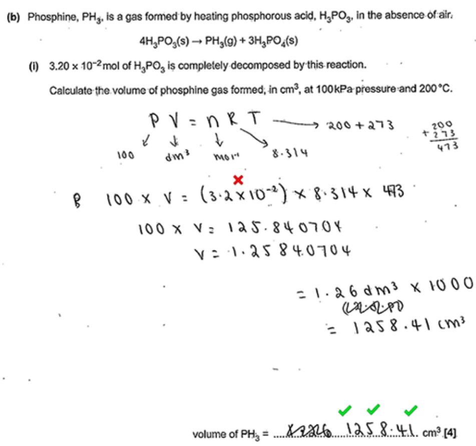
| | | | ***ALLOW use of R = 8.31 → 314.4504 → 314 to 3SF*** | | **IGNORE** use of 24/24000 for molar volume e.g.<br>3.2(0) × $10^{-3}$ × 24000 = 768 scores zero<br>8(.00) × $10^{-3}$ × 24000 = 292 scores 1st mark only<br><br>**<u>Examiner's Comments</u>**<br><br>Almost all candidates realised that the calculation required the ideal gas equation. Most candidates correctly rearranged the equation and used the data from the question to obtain a value for the volume of phosphine. The most common errors were with conversion of units into Pa and m3. It is recommended that candidates learn how to carry out these conversions. In their calculations, many candidates used the amount of phosphoric acid, 3.20 × $10^{-3}$ mol, rather than 8.00 × $10^{-3}$ mol of phosphine, obtaining a volume of 1258 cm3. Error carried forward ensured that 3 of the available 4 marks could be credited, provided that the working was clear. The exemplar shows such a response.<br><br>Answer = 315 $cm^3$<br><br>**Exemplar 3**<br> |
| | | ii | $4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$ ✓ | **1** | **ALLOW** multiples<br><br>**<u>Examiner's Comments</u>**<br><br>Most candidates were able to write a correctly balanced equation for this reaction. |
| | | | **Total** | **13** | |
| 4 | | | **FIRST CHECK THE ANSWER ON THE ANSWER LINE**<br>**IF** answer = 76.5 (%) award 3 marks<br><br>$n(NH_3)$ = (1 × $10^6$) / 17 = 5.88 × $10^4$ (58824) (mol) | 3 | **If there is an alternative answer, check to see if there is any ECF credit possible using working below**<br><br>**allow** up to full calculator display |

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| | | | **AND**<br><br>*Theoretical yield:*<br>*n*($NH_2CONH_2$) = 5.88 × $10^4$ / 2 = 2.94 × $10^4$ (29412) (mol) (1)<br><br>*Actual yield:*<br>*n*($NH_2CONH_2$) = 1.35 × $10^6$ / 60 = 2.25 × $10^4$ (22500) (mol) (1)<br><br>% yield = (2.94 × $10^4$ / 2.25 × $10^4$) × 100% = 76.5(%) (1) | | For 2nd and 3rd marks, **allow** calculation in mass.<br><br>*Theoretical mass yield:*<br>*m*($NH_2CONH_2$) = 60 × 5.88 × $10^4$ / 2 = 1.764 tonne<br><br>% yield = (1.35 / 1.764) × 100 = 76.5%<br><br>**allow** 76% (2 sig figs) up to calculator answer correctly rounded from previous values<br>**allow ecf** from calculated actual and theoretical yields |
| | | | **Total** | **3** | |
| 5 | | i | $P_4 + 6Br_2 \rightarrow 4PBr_3$ | 1 | **ignore** state symbols |
| | | ii | **FIRST CHECK THE ANSWER ON THE ANSWER LINE**<br>**If answer = 3.01 × $10^{21}$ award 3 marks**<br><br>$M_r$($PBr_3$) = 270.7 (g $mol^{-1}$) (1)<br><br>*n*($PBr_3$) = 1.3535 / 270.7 = 5.000 × $10^{-3}$ mol (1)<br><br>number of molecules = 5.000 × $10^{-3}$ × 6.02 × $10^{23}$ = 3.01 × $10^{21}$ molecules (1) | 3 | If there is an alternative answer, check to see if there is any **ecf** credit possible using working below.<br><br>**allow** in working shown as 28.1 + 35.5 × 4<br><br>**allow ecf** from incorrect molar mass of $PBr_3$<br>**allow** 0.005(00) (mol) for two marks<br><br>**allow ecf** for incorrect amount of $PBr_3$<br>**allow** calculator value or rounding to 3 significant figures or more **but ignore** 'trailing' zeroes, e.g. 0.200 allowed as 0.2<br><br>**do not allow** any marks for:<br>1.3535 × 6.02 × $10^{23}$ = 8.15 × $10^{23}$ |
| | | iii | Pyramidal (1)<br><br>(because there are) 3 bonded pairs and 1 lone pair (around the central phosphorus atom) (1)<br><br>and electron pairs repel each other as far apart as possible so will take on a tetrahedral arrangement (giving a pyramidal shape overall) (1) | 3 | |
| | | | **Total** | **7** | |
| 6 | | | **FIRST check the molar mass on answer line MUST be derived from *pV* = *nRT*,**<br>**Award 4 marks for calculation for:** | **5** | **FULL ANNOTATIONS MUST BE USED**<br>--------------------------------------------------------- |

- **answer = 70**
- **OR answer that rounds to 69.9 OR 70.0**

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*Rearranging ideal gas equation to make n subject*

$n = \frac{pV}{RT}$ ✓

*Substituting all values including conversion to Pa and m*$^3$

$n = \frac{(101 \times 10^{3}) \times (82.5 \times 10^{-6})}{8.314 \times 373}$ ✓

$n = 2.68693073 \times 10^{-3}$ (unrounded) $\rightarrow 2.69 \times 10^{-3}$ (mol) (rounded to 3 SF) ✓

*Calculation of molar mass, M*

$M = \frac{m}{n} = \frac{0.1881}{2.68693073 \times 10^{-3}}$ = 70(.0) (g mol$^{-1}$)

$\rightarrow \frac{0.1881}{2.69 \times 10^{-3}}$ = 69.9 (g mol$^{-1}$)

*Molecular formula of* **D**

$C_5H_{10}$ ✓

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**IF** candidate has failed to derive suitable value of *n*, **ALLOW** value of *M* from 0.1881 **AND** 24000 with alkene closest to calculated value for last 2 marks

**See Guidance column.**

**If there is an alternative answer, check to see if there is any ECF credit possible using working below**

1st mark may be implicit by direct substitution of correct values below into rearranged equation.

**ONLY award this mark if *n* has been derived from correct rearranged ideal gas equation ALLOW 3 SF up to calculator value, correctly rounded**

**NOTE: ALLOW** 69.9 → 70.0 **AND** 70 (**2 SF**)
*Calculator from unrounded: 70.00552634*

**ALLOW** any unambiguous structure
**ALLOW ECF** provided that formula given is an alkene and matches *M* calculated from 0.1881 **AND** $pV = nRT$

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$\boldsymbol{M} = \frac{0.1881}{82.5/24000}$ **OR** $\frac{0.1881}{3.4375 \times 10^{-3}}$

= 54.72 **OR** 54.7 **OR** 55 ✓

**ALLOW** 54.68 from use of $3.44 \times 10^{-3}$

From **54.72, ONLY ALLOW** = $C_4H_8$ ✓

**Examiner's Comments**

Most candidates realised the need to use the ideal gas equation. The equation was usually rearranged correctly, with substituted values for *p*, *V*, *R* and *T* being added. Pressure and volume were not always converted correctly into Pa and m$^3$, creating problems for subsequent parts. Many candidates attempted to convert from cm$^3$ to m$^3$ by multiplying by $10^{-3}$ rather than $10^{-6}$.

Candidates usually obtained a value for *n*, although those who had struggled with unit conversion obtained values that differed by powers of 10. Finally, candidates needed to derive the molar mass using their value of *n* and the mass of the alkene. Some candidates over-rounded their value of *n*, introducing an error in calculating the molar mass. Surprisingly, an appreciable number of candidates wrote their value of *n* on the answer line rather than the molar mass indicated by the answer prompt. This

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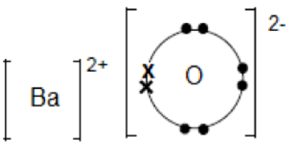
| | | | | | suggested that some candidates do not understand the term molar mass.<br><br>Candidates who had obtained a molar mass of 70.0 usually determined that the alkene had the formula $C_5H_{10}$.<br>Answer: 70.0 g $mol^{-1}$ |
| | | | **Total** | **5** | |
| 7 | a | i | <u>Electrostatic</u> <u>attraction</u> between positive and negative ions ✓ | **1** | **ALLOW** oppositely charged ions<br>**ALLOW** cations and anions<br>**ALLOW** '+' for positive and '−' for negative<br>**IGNORE** references to metal and non-metal<br>**IGNORE** references to transfer of electrons<br><br>**Examiner's Comments**<br><br>The specification describes ionic bonding as an electrostatic attraction and a small proportion of answers were missing this key phrase. |
| | | ii | <br>Ba shown with either 0 or 8 electrons<br>**AND**<br>O shown with 8 electrons with 6 dots and 2 crosses (or vice versa) ✓<br><br>Correct charges on both ions ✓ | **2** | **For first mark,**<br>if eight electrons are shown around Ba, the 'extra' electrons around O must match the symbol chosen for the electrons for Ba.<br><br>**IGNORE** inner shells<br><br>Circles **not** required<br>Brackets **not** required<br><br>**Examiner's Comments**<br><br>Covalent bonding diagrams were not common and this question was well answered by the vast majority of candidates. |
| | | iii | **FIRST CHECK THE ANSWER ON THE ANSWER LINE**<br>**IF** answer = $5.89 \times 10^{21}$ award 2 marks for calculation<br><br>*Moles of barium oxide*<br>n(BaO) =1.50/153.3 **OR** $9.78 \times 10^{-3}$ ✓<br><br>*Number of barium ions*<br>$(9.78 \times 10^{-3} \times 6.02 \times 10^{23}) = 5.89 \times 10^{21}$ ✓<br>3 **SF AND** standard form required | **2** | **ALLOW** 0.00978 up to calculator value 0.009784735<br><br>**ALLOW ECF** from incorrect moles of BaO<br>**Common incorrect answers are shown below**<br>**IF** 137.3 is used for the molar mass **ALLOW 1 mark** total for $6.58 \times 10^{21}$ (0.010924981 mol) **OR** $6.56 \times 10^{21}$ (0.0109 mol) |

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| | | | | | **IF** 153 is used for the molar mass **ALLOW 1 mark** total for $5.90 \times 10^{21}$<br><br>**Examiner's Comments**<br><br>Use of the relative mass of barium to calculate moles of barium oxide was a common error but these candidates were usually able to pick up one mark for correctly multiplying their moles by the Avogadro constant. Some candidates correctly calculated moles but then divided by two thus losing the final mark. |
| | b | i | Barium chloride does not conduct electricity when solid<br>**AND**<br>because it has ions which are fixed (in position / in lattice) ✓<br><br>Barium chloride conducts when in aqueous solution<br>**AND**<br>because it has mobile ions ✓ | **2** | **IGNORE** use of 'free' instead of 'mobile'<br>**ALLOW** ions are not free to move<br>**ALLOW ions** are held (in position / in lattice)<br>**ALLOW ions** are not mobile<br>**IGNORE** charge carriers<br>**DO NOT ALLOW** electrons moving<br>**ALLOW** one mark for comparison that does not identify (s) and (aq).<br><br>**Examiner's Comments**<br><br>Many precise answers gained full marks by describing the fixed position of ions in a lattice and the mobility of ions in aqueous solution. Delocalised or free electrons were occasionally mentioned. Vague answers often used the terms 'free' instead of mobile, 'charge carrier' instead of ion and 'carry a charge' instead of conduct electricity. |
| | | ii | Test for sulfate / $SO_4^{2-}$ ✓<br><br><u>White</u> precipitate forms (when barium chloride solution is mixed with a solution containing sulfate ions) ✓ | **2** | **IGNORE** hydrochloric acid<br><br>**ALLOW** white solid<br>**IGNORE** cloudy<br>**DO NOT ALLOW** test result linked to incorrect anion<br><br>**Examiner's Comments**<br><br>There was some confusion with the displacement reactions of halogens, the test for halide ions and the use of silver nitrate but the majority of students could recall the use of aqueous barium chloride to test for sulfate ions. Occasionally candidates described the use of dilute hydrochloric acid to remove carbonate ions from solution before their creditworthy description of the sulfate test. |
| | | iii | **FIRST CHECK THE ANSWER ON THE ANSWER LINE**<br>**IF** answer = 2 award 2 marks<br><br>$M(BaCl_2)$ = ((137.3 + (35.5 × 2))<br>= <u>208.3</u> (g mol$^{-1}$) ✓ | **2** | **ALLOW** 208 (g mol$^{-1}$) |

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| | | | 244.3 - 208.3 = 36<br>**AND**<br>36/18 = 2 ✓ | | **ALLOW ECF** for incorrectly calculated molar mass provided the final answer is rounded to nearest whole number<br><br>**Examiner's Comments**<br><br>Very well answered, the majority of candidates scored full marks for this simple calculation. |
| | | | **Total** | **11** | |
| 8 | | | **IF answer = 259 (litres), award 4 marks**<br><br>…………………………………………………………<br><br>($n(CO_2)$ decrease = $5.6 \times 10^5/44.0$) = 12727.27273 (mol) ✓<br><br>($n(C_8H_{16})$ decrease = 12727 ÷ 8) = 1590.909091 (mol) ✓<br><br>(mass of $C_8H_{18}$ decrease) = 1591 × 114 = 181363.6364 (g) ✓<br><br>($C_8H_{18}$ decrease) = 181363.6364 ÷ 700 g = 259 (litres) ✓ | 4 | **ANNOTATE ANSWER WITH TICKS AND CROSSES**<br><br>**ALLOW 3 SF** up to calculator value correctly rounded throughout.<br><br>**NOTE:** Be generous for values. Depending on any intermediate rounding, you may see a range of values for each stage. For guidance, the expected answers give unrounded values throughout.<br><br>**ALLOW ECF** throughout for approaches that use moles $CO_2$ / $C_8H_{18}$<br><br>**IGNORE** rounding of 259 to 260 and credit 259 from working<br><br>**ALLOW** the following alternate method<br>…………………………………………………………<br>annual reduction($n$ $C_8H_{18}$ in a litre = 700 ÷ 114) = 6.140350877 (mol) ✓<br><br>($n(CO_2)$ produced per litre = 6.14 × 8) = 49.12280702 (mol) ✓<br><br>(mass $CO_2$ produced per litre = 49.12 × 44) = 2161.403509 (g) ✓<br><br>(annual reduction = $5.6 \times 10^5/2161$) = 259.0909091 (litres) ✓<br>…………………………………………………………<br><br>**Examiner's Comments**<br><br>In general candidates coped well with this unstructured calculation. The majority chose to convert the mass of $CO_2$ into moles and use the balanced equation to determine the mass of octane, before obtaining the reduction in petrol consumption. However, alternative approaches were also seen and awarded full credit where due. Error carried forward marks were awarded, and most candidates |

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| | | | | | scored three or four marks. Weaker candidates often divided the mass of $CO_2$ by 700 and failed to achieve a meaningful answer. Candidates should be encouraged to start multistep calculations by considering amounts in moles, rather than just experimenting with the data provided in the question.<br><br>Answer: 259 litres |
| | | | **Total** | **4** | |
| 9 | | i | Elimination **OR** dehydration ✓ | 1 | **Examiner's Comments**<br><br>Many candidates correctly named the type of reaction. There were a significant number of incorrect responses, the most common of which included hydrolysis, dehydrogenation and condensation. |
| | | ii | **IF answer = 14.0 OR 14.1 g award 3 marks**<br>………………………………………………………….<br><br>**actual**<br>$n(C_5H_8)$ produced = $\frac{5.00}{68.0}$ = 0.0735 (mol) ✓<br><br>**theoretical**<br><br>$n(C_5H_9OH) = n(C_5H_8)$ = 0.0735 × $\frac{100}{45.0}$ = 0.163 (mol) ✓<br><br>Mass of $C_5H_9OH$ = 0.163 × 86.0 = 14.0 (g) **OR** 14 g<br>**OR** 14.1 g ✓ (*use of unrounded values in calculator throughout*) | 3 | **ANNOTATE ANSWER WITH TICKS AND CROSSES**<br><br>**ALLOW ECF** at each stage<br><br>**ALLOW 3 SF** up to calculator value correctly rounded for intermediate values<br><br>**ALLOW** expected mass $C_5H_8$ = 5.00 × $\frac{100}{45.0}$ = 11.111 (g)<br><br>**ALLOW** Mass $C_5H_9OH$ reacted = 0.0735 × 86.0 = 6.321 (g)<br><br>**ALLOW** Mass of $C_5H_9OH$ used = 6.321 × $\frac{100}{45.0}$ = 14.0 **OR** 14<br><br>**ALLOW 2 SF** up to calculator value correctly rounded for mass of $C_5H_9OH$<br><br>**Note:**<br>2.84 **OR** 2.85 g would get 2 marks<br>*(use of 45.0/100 instead of 100/45.0)*<br>13.76 **OR** 13.8 would get 2 marks<br>*(use of 0.16 for moles $C_5H_9OH$)*<br><br>**Examiner's Comments**<br><br>Candidates coped well with this calculation based on percentage yield. Most were able to calculate the moles of cyclopentene produced and the strongest |

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| | | | | | scaled this correctly to give the moles of cyclopentanol required. A common mistake was to scale by a factor of 45/100, rather than 100/45. However, error carried forward marks were awarded and the majority of candidates scored two or three marks.<br><br>Answer: 14.1 g |
| | | | **Total** | **4** | |
| 10 | | i | $\frac{2 \times 0.005}{0.58} \times 100 = 1.72\%$ ✓ | 1 | **ALLOW** 2% **OR** 1.7% up to calculator value of 1.724137931<br><br>**Examiner's Comments**<br><br>This part was poorly answered. Candidates rarely seemed to understand the relationship between the precision of the balance and the uncertainly in taking two readings – hence 0.86%, half of 1.72%, was a common error.<br><br>Answer = 1.72% |
| | | ii | Use balance weighing to 3/more decimal places<br><br>**OR**<br><br>Use a larger mass/amount □ ✓ | 1 | **ALLOW** more precise/more accurate/ more sensitive/higher resolution/smaller division<br><br>**IGNORE** 'less error/smaller interval balance'<br><br>**IGNORE** any reference to lid on crucible (*water can't escape*)<br><br>**IGNORE** 'weigh straight after heating'<br><br>**IGNORE** idea of repeating the experiment/ taking an average/ getting concordant results /larger sample size, etc.<br><br>**Examiner's Comments**<br><br>Correct answers suggested using a larger mass of the salt or a more accurate balance with more decimal places. Many responses instead discussed repeating the experiment and taking an average, or using a lid. |
| | | iii | Heat to constant mass ✓ | 1 | **ALLOW** response that implies heating to constant mass,<br>e.g. Heat again until the mass does not change<br><br>**IGNORE** 'heat for longer'<br>*Needs link to constant mass*<br><br>**Examiner's Comments**<br><br>This was a good question to distinguish practical ability. Many candidates suggested simply 'heating |

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| | | | | | for longer' or 'until no further colour change' but didn't link this to the idea of heating to constant mass. |
| | | | **Total** | **3** | |
| 1<br>1 | | i | **FIRST CHECK ANSWER ON THE ANSWER LINE**<br>**If answer = 63.62 award 2 marks**<br>___<br>$\frac{(63 \times 69.17) + (65 \times 30.83)}{100}$<br><br>**OR** 63.6166 **OR** 63.617 ✓<br><br>= 63.62 (to 2 DP) ✓<br><br>***IGNORE** any units with $A_r$* | 2 | **ALLOW ECF** for a correct calculation to 2 DP if:<br>• %s have been used with wrong isotopes i.e. $\frac{(63 \times 30.83) + (65 \times 69.17)}{100} \rightarrow$ **64.38**<br>**OR**<br>• decimal places for **ONE** % have been transposed,<br><br>i.e. 69.71 → **63.96**; 30.38 → **63.32**<br><br>**<u>Examiner's Comments</u>**<br><br>This part was mostly correct. Low-scoring candidates sometimes produced errors in averaging or rounding. Most final answers were given to the required two decimal places.<br><br>Answer = 63.62 |
| | | ii | **FIRST CHECK ANSWER ON THE ANSWER LINE**<br>**If answer = 3.97 × $10^{22}$ (from 63.62) award 2 marks**<br>**If answer = 3.98 × $10^{22}$ (from 63.5) award 2 marks**<br>___<br>**Using 63.62:** *correct $A_r$ of Cu from 21(b)(i)*<br>See bottom of answer zone<br><br>$n(\text{Cu}) = \frac{5.00 \times 0.840}{63.62} = \frac{4.2}{63.62}$ = 0.066(0) (mol) ✓<br><br>Cu atoms = 0.0660 × 6.02 × $10^{23}$ = **3.97 × 23 $10^{22}$** ✓<br>*Must be calculated in standard form **AND** to 3 SF*<br><br>**OR**___<br><br>**Using 63.5:** *$A_r$ of Cu from periodic table*<br><br>$n(\text{Cu}) = \frac{5.00 \times 0.840}{63.5} = \frac{4.2}{63.5}$ = 0.0661 (mol) ✓ | 2 | If there is an alternative answer, check to see if there is any **ECF** credit possible<br><br>**SEE** answer from **21b(i)** at bottom of answer zone<br><br>**ALLOW** correct answer from 3 SF up to calculator value of 0.06601697579<br><br>**ALLOW** incorrect $n$(Cu) × 6.02 × $10^{23}$ correctly calculated to 3 SF **AND** in standard form *For **ECF**, $A_r$ **must** have been used for n(Cu)*<br>___<br><br>**ALLOW** correct answer from 3 SF up to calculator |

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| | | | Cu atoms = 0.0661 × 6.02 × $10^{23}$ = **3.98 × $10^{22}$** ✓<br>*Must be calculated in standard form **AND** to 3 SF* | | value of 0.06614173228<br><br>**ALLOW** incorrect *n*(Cu) × 6.02 × $10^{23}$ correctly calculated to 3 SF **AND** in standard form *For **ECF**, $A_r$ **must** have been used for n(Cu)*<br><br>**Common errors**<br>**Using 63.62:**<br>3.984 × $10^{22}$ — 1 mark (SF)<br>4.73 × $10^{22}$ — 1 mark (ECF: omitting 0.840)<br><br>**Using 63.5:**<br>3.982 × $10^{22}$ — 1 mark (SF)<br>4.74 × $10^{22}$ — 1 mark (ECF: omitting 0.840)<br><br>**<u>Examiner's Comments</u>**<br><br>This part was generally well answered with most candidates processing the data correctly. Candidates sometimes failed to consider 84% or rounded incorrectly in places.<br><br>Answer = 3.97 × $10^{22}$ atoms |
| | | | **Total** | **4** | |
| 12 | | | ***Initial ratios***<br>Cr, $\frac{19.51}{52.0}$ ; Cl, $\frac{39.96}{35.5}$ ; H, $\frac{4.51}{1.0}$ ; O, $\frac{36.02}{16.0}$<br><br>**OR**<br>Cr, 0.375; Cl,1.126; H,4.51; O, 2.25 ✓<br><br>***Whole number ratios***<br>Cr, 1; Cl, 3; H, 12; O, 6 ✓<br><br>***Formula with water of crystallisation***<br>$CrCl_3•6H_2O$ ✓ | 3 | **NOTE**: If only the correct answer of $CrCl_3•6H_2O$ is seen with no working, award 1 mark only<br><br>**IF** there is no whole number ratio,<br>**ALLOW** empirical formula: $CrCl_3H_{12}O_6$<br><br>**ALLOW ECF** from incorrect whole number ratio, provided **ONLY Cl incorrect AND** $6H_2O$, e.g. $CrCl_2•6H_2O$<br><br>**<u>Examiner's Comments</u>**<br><br>Many candidates were able to calculate the empirical formula of the hydrated salt. While the majority went on to shown the formula as $CrCl_3•6H_2O$ to score all three marks, a significant minority failed to convert 12 H and 6 O into $6H_2O$. |
| | | | **Total** | **3** | |
| 13 | | | First check the answer line. If answer = 0.120 award 4 marks. | 4 | **ALLOW ECF** |

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| | | | M1 Mol of $H_2SO_4 = 3.00 \times 10^{-2} \times \frac{35.0}{1000} = 1.05 \times 10^{-3}$ mol ✓<br>M2 Mol of $Al_2(SO_4)_3 = \frac{1.05 \times 10^{-3}}{3} = 3.5(0) \times 10^{-4}$ mol ✓<br><br>M3 = 342.3 ✓<br><br>M4 Mass $Al_2(SO_4)_3 = 3.5(0) \times 10^{-4} \times 342.3$<br>**and**<br>= 0.120 g ✓<br>**Answer must be 3 sf** | | **ALLOW** 0.00105 mol<br><br>**ALLOW** 0.00035(0) mol<br><br>**ALLOW 342**<br><br>**DO NOT ALLOW 0.12**<br><br>**Examiner's Comments**<br><br>This open style calculation would have usually proved difficult for the typical AS candidate but this year a significant majority of candidates were able to secure all four marks. |
| | | | **Total** | **4** | |
| 14 | | | First check the answer line.<br>If answer = 1200 $cm^3$ award 3 marks.<br><br>Mol of $Mg(NO_3)_2$ = = $2(.00) \times 10^{-2}$ **OR** 0.02(00) mol✓<br><br>Mol of gas = $2(.00) \times 10^{-2} \times 5/2 = 5(.00) \times 10^{-2}$ **OR** 0.05(00) mol ✓<br><br>Vol of Gas = 0.05 x 24 000 = 1200 $cm^3$ ✓ | 3 | If answer = 960 $cm^3$ award 2 marks.<br>If answer = 240 $cm^3$ award 2 marks.<br><br>**ALLOW** ECF for answers to at least two significant figures up to calculator value, correctly rounded<br><br>**ALLOW** separate numbers of mol of each gas for M2 (0.04(00) mol $NO_2$ **and** 0.0100 mol $O_2$)<br><br>**ALLOW** a second mark if only volume of $O_2$ (240 $cm^3$) **OR** only volume of $NO_2$ (960 $cm^3$) is calculated<br><br>**Examiner's Comments**<br><br>This seemingly difficult calculation was answered successfully by all but a relatively small handful of candidates. |
| | | | **Total** | **3** | |
| 15 | a | | First check the answer line.<br>If answer = $1.7(0) \times 10^{-3}$ award 2 marks.<br>……………………………………………………..<br>M1 (Dividing by $6.02 \times 10^{23}$)<br>Number of $N_2$ molecules = $\frac{5.117 \times 10^{20}}{6.02 \times 10^{23}} = 8.5. \times 10^{-4}$<br><br>**OR** $0.85 \times 10^{-3}$ **OR** $0.085 \times 10^{-2}$ **OR** $0.0085 \times 10^{-1}$ **OR** 0.00085 ✓<br><br>M2 (Correct conversion of molecules to atoms + **standard form**)<br>M1 x 2 **and** in standard form ✓<br>From 0.0085, answer = 2 x 0.00085 = 0.00170<br>**= 1.7(0) x 10–3** | 2 | **ALLOW** one mark for<br>$0.17 \times 10^{-2}$ **OR** $0.017 \times 10^{-1}$ **OR** 0.0017 (not standard form)<br>**ALLOW** one mark for<br>$4.25 \times 10^{-4}$ (dividing by 2 in M2 + standard form)<br>**ALLOW** one mark for<br>$6.16 \times 10^{44}$ (multiplying by $6.02 \times 10^{23}$ in M1 + standard form<br><br>**Examiner's Comments**<br><br>This proved to be one of the more difficult questions on the paper. A significant number of candidates |

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| | | | *Alternative method*<br>M1 (Correct conversion of molecules to atoms)<br>= 5.117 x $10^{20}$ x 2 = 1.02(34) x $10^{21}$<br><br>**OR** 10.2(34) x $10^{20}$ **OR** 102.(34) x $10^{19}$ etc<br><br>M2 (Correct use of 6.02 x $10^{23}$ + **standard form**)<br>$\frac{1.02(34) \times 10^{21}}{6.02 \times 10^{23}}$ = **1.7(0) x 10$^{-3}$** | | were able to secure one mark by dividing by Avogadro's constant but failed to convert the number of molecules calculated into number of atoms present. |
| | b | i | (Actual) number of atoms of **each element** present in a molecule ✓ | 1 | **ALLOW** 'compound' for 'molecule'<br>**IGNORE** 'simplest whole' before 'number'<br>**ALLOW** 'actual ratio'<br>**IGNORE** 'ratio' alone<br>**DO NOT ALLOW** 'simplest ratio'<br><br>**Examiner's Comments**<br><br>Many candidates were successful in describing the term 'molecular formula' but weaker candidates gave answers which confused terms such as atoms and molecules. By far the most common erroneous response was 'The number of atoms in a molecule'. |
| | | ii | $HNO_2$ ✓ | 1 | **ALLOW** $O_2HN$ etc<br><br>**Examiner's Comments**<br><br>Weaker candidates convinced themselves that the acid formed when water is added to nitrogen dioxide was $HNO_3$. Better candidates were able to work out the product would have the formula $H_2N_2O_4$ but failed to convert this to its simplest form. |
| | | | **Total** | **4** | |
| 16 | a | i | carbon dioxide lost/evolved/given off/or produced as a gas ✓ | 1 | **DO NOT ALLOW** water or steam or $CO_2$ evaporates<br><br>**Examiner's Comments**<br><br>Candidates who failed to state that the gas being lost was $CO_2$ could not access the mark for this question. Vague answers relating to water being produced, products being gases, products being lost or a gas evolved were often given by Candidates. |
| | | ii | **FIRST CHECK ANSWER ON THE ANSWER LINE**<br>**IF answer = 1.85 OR 1.845 g award 3 marks**<br>**…………………………………………………………**<br>n($HNO_3$)<br>$= 1.25 \times \frac{20.0}{1000} = 0.0250$ mol ✓<br><br>n($SrCO_3$)<br>$= \frac{0.0250}{2} = 0.0125$ mol ✓ | 3 | **If there is an alternative answer, check to see if there is any ECF credit possible** |

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| | | | $m(SrCO_3)$<br>= 0.0125 × 147.6 = 1.845 g **OR** 1.85 g ✓ | | **ALLOW ECF** from incorrect $n(HNO_3)$<br><br>molar mass of $SrCO_3$ = 147.6 (g $mol^{-1}$)<br>**ALLOW ECF** from incorrect $n(SrCO_3)$<br><br>**Examiner's Comments**<br><br>The vast majority of candidates were able to complete this calculation arriving at the correct answer to score all three available marks. The most common error was in calculating the amount, in moles, of the $SrCO_3$ from the stoichiometry given in the equation. This resulted in an answer which was twice that expected however two marks could still be obtained by applying error carried forward.<br><br>Answer = 1.845 g or 1.85 g |
| | b | i | rate of reaction decreases<br>**AND**<br>concentration decreases / reactants are used up ✓ | 1 | **ALLOW** reaction slows down<br><br>**ALLOW** concentration of reactants decreases. |
| | | i | less frequent collisions ✓ | 1 | **ALLOW** fewer collisions per unit time<br>**OR** collisions less often<br>**OR** decreased rate of collision<br><br>**IGNORE** less successful collisions / less collisions less chance of collisions<br><br>**Examiner's Comments**<br><br>Very few candidates were able to explain the change in the rate of the reaction during the first 200 seconds of the experiment. This relatively straightforward question required a statement that the rate decreases as the concentration of the reactants decreases due to there being less frequent collisions. Although a large number of candidates were able to state that the rate decreases few were able to explain why. This was possibly due to candidates having to apply their understanding in an unfamiliar context rather than from a lack of knowledge |
| | | ii | Attempted tangent on graph drawn to line at approximately $t$ = 200 s ✓ | 1 | |
| | | ii | Gradient ($y/x$)<br>e.g. $\frac{0.20}{290} = 6.9 \times 10^{-4}$ ✓ | 1 | **ALLOW** 1 SF up to calculator value, in range $5 \times 10^{-4}$ to $8 \times 10^{-4}$<br><br>**IGNORE** units<br>**IGNORE** sign<br><br>**Examiner's Comments** |

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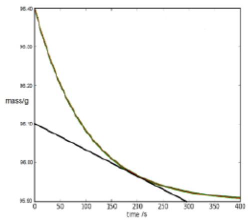
| | | |  | | This was the first time AS level candidates have been required to calculate a rate of reaction from a graph and many found this quite testing. Although many knew that a tangent was required only the most able candidates were able to arrive at a value for the gradient that was within the expected range. Candidates sometimes took as their values the point at which their tangent cut the axes rather than calculating the change in mass or change in time.<br><br>Acceptable range $5 \times 10^{-4}$ to $8 \times 10^{-4}$ |
| | c | | Flask **OR** beaker<br>**AND**<br>balance<br>**AND**<br>stopwatch **OR** stop clock **OR** other timing device ✓ | 1 | **DO NOT ALLOW** round-bottomed flask.<br><br>**IGNORE** weighing scales |
| | | | Records **mass** at time intervals ✓ | 1 | **ALLOW** 'weigh at time intervals' |
| | | | Time interval quoted between 10-50s ✓ | 1 | **Examiner's Comments**<br><br>This was the second question that required candidates to describe an experiment that they could have carried out as part of their course. Even if this experiment had not been completed in class, candidates should be able to recognise that mass needs to be measured over a period of time. As the reaction was between an acid and a carbonate a suitable named reaction vessel such as a beaker or flask was required. A balance was needed for mass measurement and a timing device to monitor time. A simple statement that mass should be recorded at a given time interval scored two marks with one mark being allocated to suitable apparatus. At this level it is expected that candidates will be familiar with the correct names for the apparatus required to carry out an investigation. |
| | | | **Total** | **11** | |
| 17 | | | **FIRST CHECK ANSWER ON THE ANSWER L**<br>**IF answer = $4.46 \times 10^6$ (Pa) award 4 marks** | | **If there is an alternative answer, check to see if there is any ECF credit possible** |
| | | | **Amount of $N_2O$**<br><br>$n(N_2O) = \frac{187}{44}$ **OR** 4.25 (mol) ✓ | 1 | **ALLOW ECF** from incorrect amount of $N_2O$<br>e.g. use of incorrect $M_r$ for $N_2O$ could still score 3 marks |
| | | | **Unit conversion**<br><br>Volume conversion to $m^3 = 2.32 \times 10^{-3}$ ($m^3$) ✓ | 1 | |
| | | | **Ideal gas equation / temperature conversion**<br><br>$p = \frac{nRT}{V}$ **OR** $p = \frac{4.25 \times 8.314 \times 293}{2.32 \times 10^{-3}}$ | 1 | ………………………………………………………<br>**Common Errors** (3 marks)<br>*No temperature conversion* |

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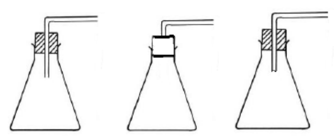
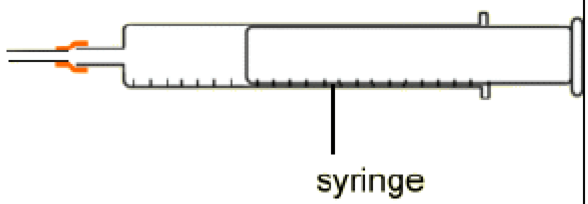
| | | | **AND**<br>Use of $T$ = 293 K ✓<br><br>**Final answer**<br><br>$p = 4.46 \times 10^6$ (Pa) ✓<br><br>*Must be calculated in standard form **AND** to 3 SF* | 1 | $p = \frac{4.25 \times 8.314 \times 20}{2.32 \times 10^{-3}} = 3.05 \times 10^5$<br>*Incorrect volume conversion*<br><br>$p = \frac{4.25 \times 8.314 \times 293}{2.32 \times 10^{-6}} = 4.46 \times 10^9$<br><br>*No volume conversion*<br>$p = \frac{4.25 \times 8.314 \times 293}{2.32} = 4.46 \times 10^3$<br><br>*No standard form* = 4460000<br><br>**Examiner's Comments**<br><br>This was a new addition to the OCR specification as part of the curriculum changes. The vast majority of candidates made a good attempt at this calculation which required both the rearrangement of a formula and the conversion of units of temperature and volume. The conversions and calculation did not prove that difficult for many candidates however answers were often not given to three significant figures or quoted in standard form resulting in the loss of one mark. Candidates clearly need to develop their mathematical skills in order to access the 20% of marks available for quantitative work.<br><br>Answer = 4.46 × $10_{6}$(Pa) |
| | | | **Total** | **4** | |
| 18 | a | i | Diagram of **labelled** reaction vessel for reaction ✓ | 1 | **ALLOW** (conical) flask, test-tube or boiling tube.<br><br>**DO NOT ALLOW** volumetric flask, beaker, measuring cylinder<br><br>**DO NOT ALLOW** delivery tube below reacting solution<br><br>**ALLOW** any of these diagrams.<br><br><br>**ALLOW** a single line for the tube<br>**IGNORE** Sealed end of delivery tube |
| | | i | **Labelled** (gas) syringe **OR** diagram of gas collection over water in a **labelled** measuring cylinder / inverted burette.<br>**AND**<br>closed system with a tube connecting reaction vessel to gas collection apparatus ✓ | 1 | <br> |

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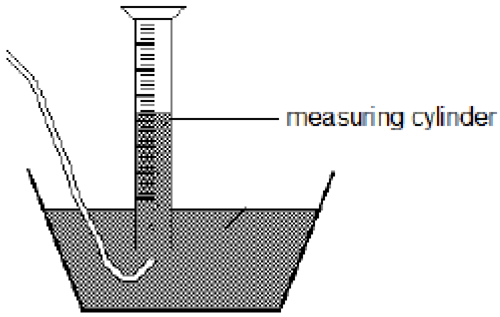
| | | | | | <br>**DO NOT ALLOW** measuring tube<br><br>**Examiner's Comments**<br><br>Clearly candidates were not expecting to be asked about how to set up the apparatus to measure the volume of a gas produced in an experiment. The specification states that candidates can be assessed on the techniques and procedures required during experiments requiring the measurement of mass, volumes of solutions and gas volumes. Many diagrams were unlabelled or suggested apparatus that was totally unsuitable for the set task. Some provided unsealed systems which would lead to gas being lost which would be inappropriate. |
| | | ii | **FIRST CHECK CALCULATED VALUE FOR MOLAR / ATOMIC MASS OF CALCIUM**<br>**IF answer = 40.1 OR 40.08 is seen anywhere award first two marks** | | **DO NOT ALLOW** *pV* = *nRT* for the calculation of the amount in moles for marking point 1. |
| | | ii | *n*($H_2$) OR *n*(Group 2 metal)<br>$= \frac{97.0}{24\,000} = 4.04 \times 10^{-3}$ (mol) ✓ | 1 | **ALLOW** 3 SF up to calculator value correctly rounded (0.004041666) |
| | | ii | molar mass / atomic mass of Group 2 metal<br>$= \frac{0.162}{0.00404} = 40.1$ (g mol$^{-1}$) ✓ | 1 | **ALLOW** 3 SF up to calculator value correctly rounded (40.08247423)<br><br>**ALLOW ECF** from incorrectly calculated amount in moles |
| | | ii | Group 2 metal:<br>calcium / Ca ✓ | 1 | **DO NOT ALLOW** Calcium if no working<br><br>**ALLOW ECF** as element in Group 2 closest to the value calculated<br><br>**Examiner's Comments**<br><br>On the whole candidates were able to carry out this calculation to a satisfactory conclusion obtaining the relative atomic mass of the unknown metal and then suggesting that this was calcium. With an increased emphasis on the mathematical requirements within the specification, it is important that candidates are aware of suitable rounding within answers. A rounding error in the first part of this calculation frequently resulted in the atomic mass being calculated as 40.5 which did not gain credit. Although the mark for locating the metal as calcium |

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| | | | | | was still awarded as an error carried forward.<br><br>Answer = 40.1 |
| | b | | Less (volume / products)<br>**AND**<br>Smaller amount / fewer moles / fewer atoms of the **metal**<br>**OR** element reacting ✓ | 1 | **IGNORE** higher relative atomic mass / molar mass<br><br>**ALLOW** a calculation **showing** that moles and volume are less<br><br>*n*($H_2$) = 0.162/87.6 = 0.0018493156<br>Volume = 0.0018493156 × 24000 = 44(.4) $cm^3$<br><br>**Examiner's Comments**<br><br>This question was not well answered. Most candidates did not specify that there would be fewer moles of the metal. Many candidates were unable to grasp the concept that the amount of substance was linked to mass and relative atomic mass and that a larger atomic mass would lead to a smaller number of moles of the metal and hence a decrease in the volume of hydrogen produced. |
| | | | **Total** | **6** | |
| 19 | a | | Method 1: 100% **OR** (only) one product **OR** no waste product **OR** addition (reaction) ✓<br><br>Method 2: < 100%<br>**AND**<br>two products<br>**OR** (also) produces NaBr<br>**OR** (There is a) waste product<br>**OR** substitution (reaction) ✓ | 2 | **ALLOW** co-product or by-product for waste product<br><br>For '< 100%' **ALLOW** not 100% **OR** method 2 has a low(er) atom economy (compared to method 1)<br><br>**IGNORE** produces $Br^-$ / $Na^+$<br>**DO NOT ALLOW** incorrect waste products e.g. $Br_2$, HBr, Br, Na<br><br>**ALLOW** correctly calculated value of 42 or 41.8 up to calculator value of 41.83154324 correctly rounded for second mark<br><br>**DO NOT ALLOW** incorrect values for the atom economy of method 2.<br><br>**ALLOW ONLY** 1 mark for a statement that both methods have 100% atom economy.<br><br>**Examiner's Comments**<br><br>The majority of candidates recognised that the preparation of butan-2-ol from but-2-ene was an addition reaction with an atom economy of 100%. Over half the candidates appreciated the preparation of butan-2-ol from 2-bromobutane resulted in the formation of a by-product and stated that the atom economy would be less than 100%, with the strongest candidates providing a correctly calculated |

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| | | | | | value of 41.8%. Some candidates incorrectly identified the by-product as either Na or Br, so did not receive the second mark. A small proportion of candidates did not interpret the reaction scheme sufficiently and simply stated that both methods would have an atom economy of 100%. |
| | b | | **FIRST, CHECK THE ANSWER ON ANSWER LINE**<br>**IF mass = 8.21 (g) award 3 marks**<br><br>**Actual**<br><br>$n(C_4H_9OH)$ produced = $\frac{3.552}{74}$ = 0.048 (mol) ✓<br><br>**theoretical**<br><br>$n(C_4H_9OH) = n(C_4H_9Br)$ = 0.048 × $\frac{100}{80}$ = 0.06 (mol) ✓<br><br>Mass of $C_4H_9Br$ = 0.06 + 136.9 = 8.21 (g) ✓<br>***3 SF required*** | 3 | **ALLOW ECF** at each stage<br><br>**ALLOW** expected mass $C_4H_9OH$ = 3.552 × $\frac{100}{80}$ = 4.44 (g)<br><br>**ALLOW** Mass $C_4H_9Br$ reacted = 0.048 × 136.9 = 6.5712 (g)<br><br>**ALLOW** Mass of $C_4H_9Br$ used = 6.5712 × $\frac{100}{80}$ = 8.21 (g)<br><br>**DO NOT ALLOW** 8.22 (*from use of 137 as $M_r$ of $C_4H_9Br$*)<br><br>**Examiner's Comments**<br><br>In general candidates coped well with this more demanding calculation based on percentage yield. Most were able to calculate the moles of butan-2-ol and the strongest scaled this correctly to give the moles of 2-bromobutane required. A common mistake was to scale by a factor of 0.8, rather than 1.25, however error carried forward marks were awarded and the majority of candidates scored two or three marks.<br><br>Answer: 8.21 g |
| | | | **Total** | **5** | |
| 20 | a | | **Check the answer line.**<br>**If answer = 1080 $cm^3$ award 2 marks**<br><br>Amount of Eu = 9.12 / 152.0 = 0.06(00) mol ✓<br><br>Amount of $O_2$ = 0.0600 × 3 / 4 = 0.045(0) mol<br>**and**<br>Volume of $O_2$ = 0.0450 × 24000 = 1080 $cm^3$ ✓ | 2 | **If there is an alternative answer, check to see if there is any ECF credit possible using working below.**<br>**ALLOW** calculator value or rounding to 2 significant figures or more but **IGNORE** 'trailing zeroes'<br>eg 0.200 is allowed as 0.2.<br><br>**ALLOW** incorrectly calculated *amount* of Eu × 3 / 4 and × 24000 correctly calculated for 2nd mark<br>Eg 2605.7 would come from (9.12 / 63) × 3 / 4 × 24000<br>(note: a mass of Eu × 3 / 4 and × 24000 would not score M2) |

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| | | | | | **Examiner's Comments**<br><br>This potentially difficult calculation was well addressed by candidates and many scored both marks available. |
| | b | i | The simplest **whole** number ratio of **atoms** (of each element) present in a compound ✓ | 1 | **ALLOW** smallest **OR** lowest for simplest<br>**ALLOW** molecule for compound<br><br>**Examiner's Comments**<br><br>This was a definition that appears directly in the specification but has not featured recently in F321 and as such presented a significant number of candidates with a challenge. Where this mark was not secured the common errors were to either omit the 'whole number' part of the definition or to omit the idea that the empirical formula is actually a ratio of atoms.<br><br>For future calculations such as this, centres need to be aware the common errors to be avoided in are the use of the atomic number in determining the number of moles of Eu and an incorrect application of a difficult 4:3 stoichiometric ratio. |
| | | ii | **Check the answer line**.<br>**If answer = $O_{12}S_3Tm_2$ award 2 marks**<br><br>O = 30.7 / 16.0 S 15.4 / 32.1 Tm = 53.9 / 168.9<br>**OR**<br>1.9(2) mol 0.480 mol 0.319 mol ✓<br><br>$O_{12}S_3Tm_2$ ✓ | 2 | **ALLOW** 0.479 **OR** 0.48 for mol of S<br>**ALLOW** 0.32 for mol of Tm<br><br>**DO NOT ALLOW** $Tm_2(SO_4)_3$ as empirical formula<br>**IGNORE** $Tm_2(SO_4)_3$ if seen in working.<br><br>**Examiner's Comments**<br><br>This question perhaps demonstrated the extent to which candidates rely upon rote application of a 'mathematical' method without fully understanding what they are actually attempting to do.<br><br>Nearly all candidates were able to convert a ratio by mass to a ratio by moles of atoms, by dividing the mass ratios by the relevant relative atomic masses. These candidates were further able to obtain a unit value for one atom by the mathematical operation of dividing all values by the smallest number.<br><br>This gave a formula of $TmS_{1.5}O_6$ and many candidates were convinced that increasing the value of S atoms from 1.5 to 2 (the nearest whole number) would meet the requirements that an empirical formula has to have whole number values of atoms. Only the stronger candidates were able to realise that the initial ratio calculated needed to be doubled to obtain integer values which kept the same ratio of atoms. |

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| | | | **Total** | **5** | |
| 2<br>1 | | | FIRST CHECK THE ANSWER ON THE ANSWER LINE<br>IF answer = $SrCl_2 \cdot 2H_2O$ award 3 marks<br><br>M1 Correctly calculates<br>Mol of $SrCl_2$•$6H_2O$ = (5.332 / 266.6) = 0.02 mol ✓<br><br>M2 Correctly calculates<br>Mol of water given off **[**(5.332 − 3.892) / 18**]** = 0.08 mol ✓<br><br>M3 Correctly calculates<br>0.08 / 0.02 = 4 mol of water lost from one mol of SrC*l*2•6$H_2O$ Therefore<br>Answer = $SrCl_2 \cdot 2H_2O$ ✓ | 3 | **Allow alternative methods**<br><br>**eg**<br>M1 Correctly calculates<br>mol of $SrCl_2 \cdot 6H_2O$ as 5.332 / 266.6 = 0.02(00) mol<br>**DO NOT ALLOW** M1 if a second mass is divided by 266.6<br><br>M2 Correctly calculates<br>molar mass of partially hydrated product as 3.892 / 0.02(00) = 194.6<br><br>M3 Correctly calculates<br>mass of $H_2O$ present as 194.6 − 158.6 = 36.0<br>**AND**<br>product is $SrCl_2$•$2H_2O$<br><br>**ALLOW** ECF for the third mark for showing 158.6 taken from an incorrect stated molar mass leading to an ECF formula<br>**OR**<br>**ALLOW** 266.6 − 194.6 = 72.0 to find amount of water lost<br><br>**Examiner's Comments**<br><br>Many of the more able candidates were able to give the correct formula here and did so with very clear working, which revealed that they understood the path that lay behind their calculations. Less able candidates converted the mass of the hydrate and the mass of water lost into the respective mol of substance (0.02 and 0.08). This is perhaps not surprising as these steps are common to the more familiar problem of working out the number of waters of crystallisation in a hydrated salt that is then fully dehydrated by the action of heat. However the degree of difficulty caused many to become unclear as to what to do with these numbers and hence $SrCl_2$•G4$H_2O$ was a common incorrect answer. |
| | | | **Total** | **3** | |
| 2<br>2 | | | FIRST CHECK THE ANSWER ON THE ANSWER LINE<br>IF answer = $CH_4N_2O$ award 2 marks<br>C H N O<br>20.00/12.0 6.67/1.0 46.67/14.0 26.66/16.0<br>**OR**<br>1.67 6.67 3.33 1.67 ratio of mo | 2 | **ALLOW** 1.66 for C **OR** 1.66 for O<br><br>**IGNORE** Significant figures beyond the 3rd significant figure.<br>(eg **ALLOW** 3.3335 for N **OR** 1.666 for C)<br><br>**ALLOW** ECF from incorrectly calculated ratio of mol,<br>**DO NOT ALLOW** ECF from using an atomic number **OR** any original sums inverted (eg 12.00 / 20.00) |

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| | | | to give $CH_4N_2O$ ✓ | | **ALLOW** any order of atoms<br><br>**Examiner's Comments**<br><br>Calculating empirical formulae is a skill which most candidates are familiar with and consequently the vast majority of candidates were awarded both marks. |
| | | | **Total** | **2** | |
| 23 | a | | FIRST CHECK THE ANSWER ON THE ANSWER LINE<br>IF answer = 2.88 $dm^3$ award 2 marks<br><br>Mol of $H_2$ = 0.12 ✓<br>Volume of $H_2$ = 0.12 × 24.0 = 2.88 $dm^3$ ✓ | 2 | ALLOW ECF from incorrectly calculated moles of $H_2$<br>0.08 × 24 = 1.92 gets 1 mark<br><br>**Examiner's Comments**<br><br>Weaker candidates forgot to consider the stoichiometric ratio between Al and $H_2$ but were still able to gain credit for the correct use of the molar gas volume, leading to an answer of 1.92 $cm^3$, rather than the expected 2.88 $cm^3$. |
| | b | | FIRST CHECK THE ANSWER ON THE ANSWER LINE<br>IF answer = 10.7 g award 2 marks<br><br>Correctly calculates molar mass of $AlCl_3$ = 133.5 g ✓<br><br>Mass of $AlCl_3$ formed = 0.0800 × 133.5 = 10.7 (g) ✓ | 2 | If there is an alternative answer, check to see if there is any ECF credit possible using working below<br><br>**ALLOW** ECF for incorrect molar mass of $AlCl_3$ multiplied by 0.0800 and correctly rounded to 3 significant figures<br><br>**Examiner's Comments**<br><br>This was a slightly easier calculation and as a result many candidates scored both marks, with only a few forgetting to give the answer to three significant figures required. |
| | c | | FIRST CHECK THE ANSWER ON THE ANSWER LINE<br>IF answer = 200(.0) $cm^3$ award 2 marks<br><br>Correctly calculates moles of $HCl$ needed = 0.0800 × 3 = 0.24(0) mol ✓<br><br>Volume of $HCl$ = 0.24(0) × 1000 / 1.2 = 200 $cm^3$ ✓ | 2 | If there is an alternative answer, check to see if there is any ECF credit possible using working below<br><br>**ALLOW** ECF for incorrect mol of $HCl$ × 1000 / 1.20<br>**ALLOW** 66.7 (66.67 or 66.667 etc) for 1 mark<br>**DO NOT ALLOW** 66.6 (66.66 or 66.666 etc)<br><br>**Examiner's Comments**<br><br>Nearly all candidates were able to convert the amount of hydrochloric acid into a volume and so |

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| | | | | | the common error in this calculation occurred when the stoichiometric ratio between aluminium and the acid was not taken into account. |
| | | | **Total** | **6** | |
| 24 | | i | $\left(\frac{136.9}{291.1} \times 100\right) = 47\%$ ✓ | 1 | **ALLOW** 47 up to calculator value correctly rounded. 47.0 or 47.03 or 47.029 will be correct common answers<br><br>**IGNORE** any working shown.<br><br>**Examiner's Comments**<br><br>This was a very well answered question and most candidates were able to calculate to the atom economy for the reaction. |
| | | ii | NaBr **OR** LiBr ✓ | 1 | **ALLOW** correct name or formula<br>**DO NOT ALLOW** HBr (it is an acid)<br><br>**Examiner's Comments**<br><br>This novel question required candidates to suggest a way of increasing the atom economy by using an alternative reactant. The most able correctly identified that either sodium or lithium bromide would be an appropriate replacement for potassium bromide. The most common response was HBr which was not credited as the question specified a chemical other than an acid should be suggested. |
| | | iii | **Look at answer if 88.8% AWARD 3 marks if 88.75% AWARD 2 marks (not 3 sig. fig.)**<br><br>Moles of butan-1-ol = 0.08(00) ✓<br><br>Moles of 1-bromobutane = 0.071(0) ✓<br><br>% yield = 88.8% ✓ | 3 | Answer **MUST** be to 3 significant figures.<br><br>**ALLOW** ECF but do not allow a yield >100%<br><br>**ALLOW** Mass of 1-bromobutane expected = 10.952 g<br><br>**Examiner's Comments**<br><br>This was a very well answered question and the majority of responses were clearly laid out. Consequently most of the candidates scored two or three marks. Some candidates gave their final answer to more than three significant figures, despite the prompt in the question. Other candidates decided to over-round the actual yield of 1-bromobutane to one significant figure which led to a yield of 87.5%. |
| | | | **Total** | **5** | |
| 25 | | i | *Amount of each element mark*<br>H: $\frac{0.025}{1.0}$ O: $\frac{0.300}{16.0}$ N: $\frac{0.175}{14.0}$ | 2 | |

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| | | | = 0.025   0.01875   0.0125 (1)<br><br>*Simplest whole number ratio empirical formula*<br>$\frac{0.025}{0.0125} = 2$   $\frac{0.01875}{0.0125} = 1.5$   $\frac{0.0125}{0.0125} = 1$<br><br>**AND** $H_4O_3N_2$ (1) | | **allow** 2 marks for correct answer without working |
| | | ii | acid: $HNO_3$ **AND** base: $NH_3$ (1) | 1 | **allow** atoms within $HNO_3$ and $NH_3$ in any order |
| | | | **Total** | **3** | |
| 26 | a | i | CO is toxic | 1 | **allow** responses linked to effect of CO in blood |
| | | ii | *Calculation:*<br>$n$(butane) = 600/58.0 = 10.34 (mol)<br>**AND** $n(O_2)$ required = 6.5 × 10.34 = 67.2 (mol) (1)<br><br>$n(O_2)$ consumed = 1.50 × $10^3$ / 24.0 = 62.5 (mol)<br>**OR**<br>volume $O_2$ required for complete combustion = 67.2 × 24.0/1000 = 1.61 $m^3$ (1)<br><br>*Conclusion:*<br>incomplete combustion / stove not safe to use<br>**AND**<br>62.5 < 67.2 **OR** 1.61 > 1.50 (1) | 3 | using 1 : 6.5 ratio<br><br>**allow** number rounding to 67 |
| | b | | *Rearranging ideal gas equation to make n subject*<br><br>$n = pV / RT$ (1)<br><br>*Substituting all values taking into account conversion of units*<br><br>$n = \frac{(101\times10^3)\times(2.00\times10^{-3})}{8.314\times297}$ (1)<br>$n$ = 0.0818 … (mol) (1)<br><br>number of C atoms in alkane = 0.0818/0.0117 = 7<br><br>alkane = $C_7H_{16}$ (1) | 4 | **allow** 3SF up to calculator value of 0.08180595142, correctly rounded<br><br>**allow ecf** from incorrect $n$ |
| | | | **Total** | **8** | |
| 27 | | i | $Sr(s) + 2H_2O(l) \rightarrow Sr(OH)_2(aq) + H_2(g)$<br><br>**Note: all** state symbols required | 1 | **allow** multiples |
| | | ii | $n(Sr) = n(Sr^{2+})$ = 0.200 / 87.6 = 2.28 × $10^{-3}$ (1)<br><br>$[Sr^{2+}]$ = 2.28 × $10^{-3}$ × 1000 / 250 = 9.13 × $10^{-3}$ (mol $dm^{-3}$) (1) | 2 | **allow ecf** |

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| | | iii | Greater volume with Ca<br><br>**AND** larger amount / more moles of Ca **OR** $A_r$ Ca is smaller (1)<br><br>$n$(Ca) = 0.200/40.1 = 0.005(0) (mol) (1)<br><br>volume $H_2$ with Sr = 55 $cm^3$ **AND** volume with Ca = 120 $cm^3$ **OR** 65 $cm^3$ more $H_2$ with Ca (1) | 3 | **ora**<br><br>**allow** values up to calculator values<br><br>**allow** volumes ± 1 $cm^3$ |
| | | | **Total** | **6** | |
| 28 | a | | $n$(Eu) = 0.0019 / 152.0 = 1.25 × $10^{-5}$ (1)<br>Atoms of Eu = 1.25 × $10^{-5}$ × 6.02 × $10^{23}$ = 7.5 × $10^{18}$ (1) | 2 | **allow** 0.0000125<br>Must be standard form **AND** two significant figures<br>**allow ecf** from incorrect amount<br>**allow** 2 marks for correct answer without working |
| | b | | $n(H_2)$ = 144 / 24000 = 6(.00) × $10^{-3}$ (mol) (1)<br><br>$n$(Eu) = 0.608 / 152.0 = 4(.00) × $10^{-3}$ (mol)<br>**AND**<br>ratio $n$(Eu) : $n(H_2)$ = 2 : 3 (1)<br><br>$2Eu + 3H_2SO_4 \rightarrow Eu_2(SO_4)_3 + 3H_2$ (1) | 3 | Look for evidence of 2 : 3 anywhere.<br>*Could be within an attempted equation.*<br>**ignore** state symbols |
| | | | **Total** | **5** | |
| 29 | | i | *Determining limiting factor*<br><br>$n$(Zn) 0.27/65.4 = 0.0041 mol<br><br>**AND**<br><br>$n(CaCO_3)$ = 0.38/100.1 = 0.0038 mol<br>so Zn is in excess (1)<br><br>*Determining volume of CO*<br>ratio 1:1, so $n$(CO) = 0.0038 (mol)<br><br>vol. CO = 0.0038 x 24.0 = 0.091 $dm^3$ = **91** ($cm^3$) (1) | 2 | evidence of 0.27/65.4 is required (or using the mass ratio to predict 0.116g of CO from 0.27g Zn)<br><br>or use of the mass ratio to predict 0.106g CO from 0.38g $CaCO_3$, and dividing by 28.0 to get 0.0038 mol CO<br><br>**allow** 2 sig figs up to calculator answer<br>**allow** second and third marks for correct final answer with no working<br>**allow** 2 marks for 99 $cm^3$ from excess Zn mass |
| | | ii | heat until syringe stops moving / no further gas produced (1)<br><br>wait until the gas has cooled (to room temperature) before measuring the volume *owtte* (1) | 2 | **allow** heat for longer than two minutes<br><br>**allow** heat a greater mass |
| | | | **Total** | **4** | |