Oxford Cambridge and RSA

# GCE

## Chemistry A

**H432/03:** Unified chemistry

Advanced GCE

# Mark Scheme for November 2020

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

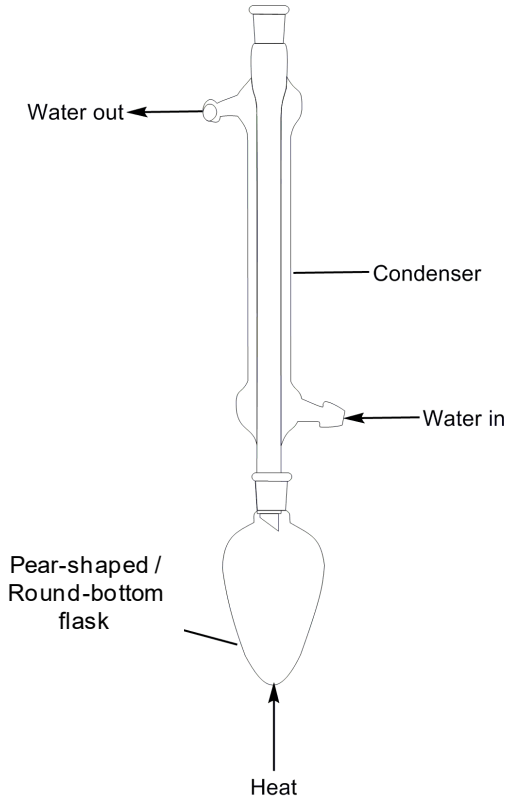
Mark schemes should be read in conjunction with the published question papers and the report on the examination.

**Annotations**

| Annotation | Meaning |
|---|---|
|  | Correct response |
|  | Incorrect response |
|  | Omission mark |
| BOD | Benefit of doubt given |
| CON | Contradiction |
| RE | Rounding error |
| SF | Error in number of significant figures |
| ECF | Error carried forward |
| L1 | Level 1 |
| L2 | Level 2 |
| L3 | Level 3 |
| NBOD | Benefit of doubt not given |
| SEEN | Noted but no credit given |
| I | Ignore |

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

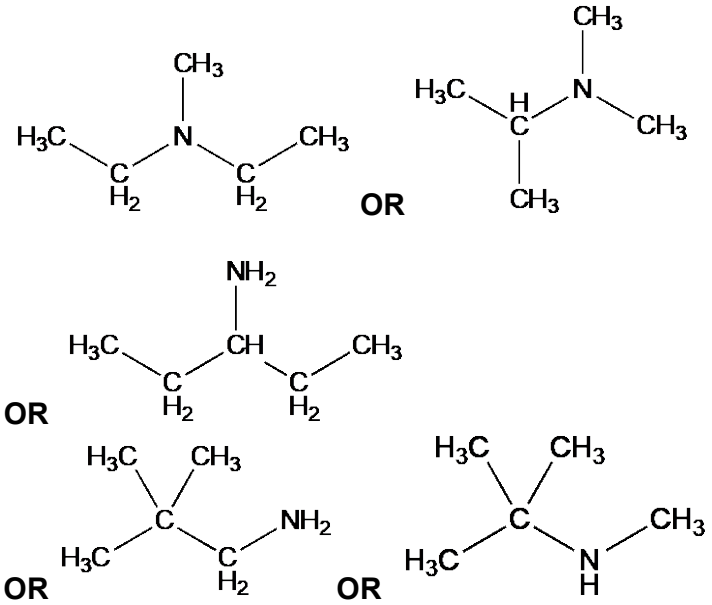
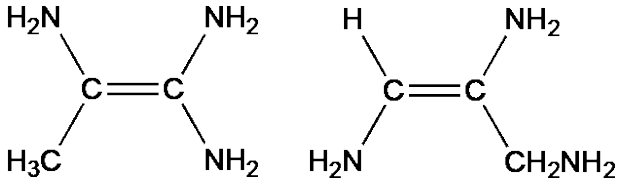
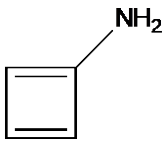
| Annotation | Meaning |
|---|---|
| **DO NOT ALLOW** | Answers which are not worthy of credit |
| **IGNORE** | Statements which are irrelevant |
| **ALLOW** | Answers that can be accepted |
| ( ) | Words which are not essential to gain credit |
| __ | Underlined words must be present in answer to score a mark |
| **ECF** | Error carried forward |
| **AW** | Alternative wording |
| **ORA** | Or reverse argument |

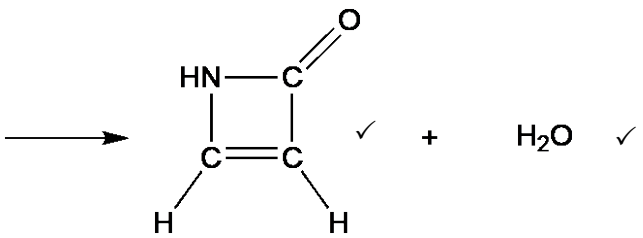
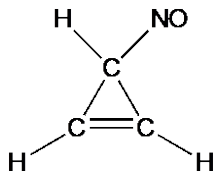
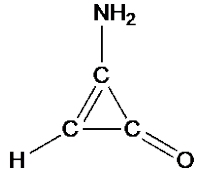
| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 1 | (a) | (i) |  <br>**Water flow AND condenser**<br>Water in at bottom and out at top **AND** condenser ✓<br><br>**Flask and technique**<br>Pear-shaped/round-bottom flask **AND** reflux ✓ | **2** | 1.2 × 2 | **DO NOT ALLOW** conical flask, volumetric flask, beaker in place of round bottom/pear shaped flask |

| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (ii) | **Diagram showing knowledge of filtration under reduced pressure**<br>Diagram showing Buchner flask<br>*must have **ONE** side arm*<br>**AND**<br>Buchner/Hirsh funnel on top of flask ✓<br>*Labels not required*<br><br>---<br>**Further details:**<br><br>• Funnel sealed or stoppered to flask<br><br>**AND**<br>• Apparatus capable of filtering under reduced pressure<br><br>**AND**<br>• Label for setup from side arm to indicate reduced pressure<br><br>**AND**<br>• Label for Buchner flask **OR** Buchner/Hirsh funnel ✓<br>*ALLOW slips in spelling of 'Buchner'* | **2** | 2.3<br><br>2.7 | Labels **NOT** required for diagram<br><br>**ALLOW** diagram of a conical flask with a filtering setup above<br>**AND**<br>Side arm either in conical flask **OR** between flask and filter paper of funnel<br><br>**IGNORE** absence of seals<br><br>---<br><br>**MUST** imply some type of seal between filter setup and flask. **ALLOW small** gaps<br><br>Examples of suitable labels (may have arrow from side arm or tube attached)<br>• to pump<br>• to vacuum<br>• air out<br>• suction<br>• reduced pressure<br>• etc.<br><br>For Buchner flask and Buchner funnel<br>**DO NOT ALLOW** just 'flask **OR** 'funnel'<br>*Flask and funnel used in normal filtration* |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | (b) | (i) | ***Comparison of branching and points of contact***<br>e.g. $CH_3CH_2CH_2NH_2$ has longer chain / straight chain / no branches<br>**AND**<br>e.g. $CH_3CH_2CH_2NH_2$ has more points of contact / more surface interaction (between molecules) ✓<br><br>***Relative strength of force***<br>e.g. $CH_3CH_2CH_2NH_2$ has stronger/more induced dipole(–dipole) interactions<br>**OR** London forces ✓<br><br>---<br>***Hydrogen bonds***<br>$CH_3CH_2CH_2NH_2$ **OR** $(CH_3)_2CHNH_2$ have hydrogen/H bonds<br>**OR**<br>$(CH_3)_3N$ has no hydrogen/H bonds ✓<br><br>***Relative strength of force***<br>Hydrogen bonds are stronger than London forces /permanent dipole interactions ✓<br><br>---<br>***Comparison of energy required to break force***<br>e.g. More energy to break/overcome London forces/intermolecular forces in $CH_3CH_2CH_2NH_2$<br>**OR**<br>More energy is needed to break H bonds (than London forces) ✓ | **5 → 4 max**<br><br>1.2<br><br>2.1<br><br>1.2<br><br>2.1 | **ANNOTATE WITH TICKS AND CROSSES, etc.**<br>---<br>**ALLOW ORA** throughout<br>**ALLOW** 'The straighter the chain, the more points of contact ….'<br><br>**IGNORE** comparison using 'primary', 'secondary' and 'tertiary'.<br>*Comparison of branching is required.*<br><br>For London forces,<br>• **ALLOW** induced dipole(–dipole) interactions<br>• **IGNORE** IDID **OR** van der Waals' forces/VDW<br><br>**DO NOT ALLOW** $CH_3CH_2CH_2NH_2$ has more electrons<br>*(number of electrons are the same)*<br><br>**DO NOT ALLOW** 'more energy to break covalent bonds<br><br>**ALLOW** little energy is required to break London forces (compared with H bonds) |

| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (b) (ii) | **FIRST CHECK MOLECULAR FORMULA and STRUCTURE**<br>**IF** molecular formula = $C_5H_{13}N$ **AND** correct structure<br>**AND** evidence of ideal gas equation → **6 marks**<br>Correct up to 87 **AND** $C_5H_{13}N$ → **5 marks**<br>Correct up to 87 → **4 marks**<br>---<br>***Rearranging ideal gas equation***<br>$n = \frac{pV}{RT}$ ✓<br>***Unit conversion AND substitution into*** $n = \frac{pV}{RT}$:<br>• $R = 8.314$ **OR** $8.31$<br>• $V = 72(.0) \times 10^{-6}$<br>• $T$ *in K:* $373$ K<br>*e.g.* $\frac{1.00 \times 10^5 \times 72.0 \times 10^{-6}}{8.314 \times 373}$ ✓<br>***Calculation of n***<br>$n = 2.32 \times 10^{-3}$ (mol) ✓<br>***Calculation of M***<br>$M = \frac{0.202}{2.32 \times 10^{-3}} = 87$ ✓<br>***Molecular formula***<br>$C_5H_{13}N$ ✓<br>**Molecular formula required** | 6 | 2.2×4<br>3.2 | **IF** $n = \frac{pV}{RT}$ is omitted, **ALLOW** when values are substituted into rearranged ideal gas equation.<br>Calculator: $n = 2.321740325 \times 10^{-3}$ from 8.314<br>*From 8.31,* $n = 2.322857889 \times 10^{-3}$<br>**ALLOW** elements in any order<br>**ALLOW** molecular formula = $C_3H_9N_3$<br>**ALLOW** other molecular formulae of an amine that has $M = 87$, e.g. $C_4H_9NO$ |

| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| | ***Structure of amine A from $C_5H_{13}N$*** ✓<br>  <br>**OR** **OR** **OR** **OR** | | 3.2 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>**ALLOW** structures below from molecular formula = $C_3H_9N_3$<br>  <br><br>**ALLOW ECF** but only if structure has calculated $M_r$ **AND** has 3 peaks in $^{13}C$ NMR spectrum. |
| | **Use of 24000** | 3 marks max possible for use of 72.0 $cm^3$ **OR** 0.720 $dm^3$ by **ECF**<br>**Calculation**<br>e.g. $n = \frac{72.0}{24000} = 3.00 \times 10^{-3}$ **No mark** (*calculation much simpler*)<br>$M = \frac{0.202}{3.00 \times 10^{-3}} = 67.3$ **OR** 67 ✓ **ECF**<br>**Molecular formula** = $C_4H_5N$ ✓ **ECF**<br>**Structure**  ✓ **ECF** | | | |

| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (c) |  ✓ + $H_2O$ ✓<br><br>**Organic product** and **water** marked **independently**.<br><br>*1st mark* correct organic product **OR** water<br>**IGNORE** balancing numbers<br><br>*2nd mark* **BOTH** products **AND** correctly balanced. | **2** | 3.2 | **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous<br><br>**ALLOW**<br>   <br><br>**NOTE**: For **ECF**, any structure must have correct number of bonds to C, H, O and N<br><br>**DO NOT ALLOW** structure of dimer<br>*Question states molecular formula = $C_3H_3NO$* |
| | **Total** | **16** | | |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 2* | | | *Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.*<br>**Level 3 (5-6 marks)**<br>Comprehensive explanation of the terms, ligand and coordination number and ligand substitution<br>**AND**<br>3D diagrams of suitable examples of 6 **AND** 4 coordinate complex ions with different shapes<br>**AND**<br>Ligand substitution illustrated with a balanced equation<br>*There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*<br>**Level 2 (3-4 marks)**<br>Explanation of the terms, ligand and coordination number and ligand substitution with some errors or omissions<br>**AND:**<br>Diagrams of suitable examples of 6 **AND** 4 coordinate complex ions with different shapes<br>**OR**<br>A 3D wedged diagram of a suitable example of 6 **OR** 4 coordination<br>**OR**<br>A diagram of a suitable example of 6 **OR** 4 coordination **AND** ligand substitution illustrated with an equation<br>**OR**<br>Ligand substitution illustrated with a balanced equation<br>*There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence* | **6** | 1.1×4<br>2.1×2 | **Indicative scientific points may include:**<br>**Terms**<br>• **Ligand:** Donates a lone pair to metal ion<br>Forms dative covalent (coordinate) bond with metal ion<br>• **Coordination number:** Number of coordinate bonds to metal ion. Could be implicit in annotated diagrams<br>**NOTE:** For monodentate ligands, 'number of ligands' is the same as the number of coordination number<br>• **Ligand substitution:** One **ligand** replacing another<br>**Suitable examples of complex ions with different shapes**<br>• ***Coordination no 6***<br>**Octahedral** e.g. $[Cu(H_2O)_6]^{2+}$, $[Fe(H_2O)_6]^{3+}$<br>• ***Coordination no 4***<br>**Tetrahedral** e.g. $CuCl_4^{2-}$, $CoCl_4^{2-}$<br>**OR Square planar** Pt complexes, e.g. $Pt(NH_3)_2Cl_2$<br>**Diagrams and equations**<br>• ***Diagrams of complex ions (may be 3D)***<br>• ***Equation for ligand substitution***<br>e.g. $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow CuCl_4^{2-} + 6H_2O$<br>$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$<br>***NOTE:** A clear and logically structured response would link shapes with some of: coordination number, names of shapes, connectivity, involvement of lone pairs, bond angles, etc. (not inclusive)*<br>**ALLOW** minor slips<br>**NOTE: Levels and the mark within a level is a 'best-fit', not perfection** |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | | **Level 1 (1-2 marks)**<br>Explanation of some terms: ligand, coordination number and ligand substitution with some errors or omissions.<br>**AND**<br>A suitable example of a complex ion **OR** Ligand substitution illustrated with an equation with some errors<br>*There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*<br>**0 marks**<br>No response or no response worthy of credit. | | | |
| | | | **Total** | **6** | | |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 3 | (a) | (i) | **FIRST, CHECK THE ANSWER ON ANSWER LINE**<br>**IF $\Delta_c H$ = –1860 OR –1850 (kJ mol$^{-1}$) with evidence of working, award 3 marks**<br>**IF $\Delta_c H$ = –1862, award 2 marks (not 3 SF)**<br>---<br>***Energy released in J OR kJ***<br>= 100 × 4.18 × 24.5 = ±10241 (J) **OR** ±10.241 (kJ) ✓<br>***3 SF minimum required***<br><br>***Calculates n($C_3H_8$)***<br>$= \frac{0.242}{44(.0)} = 0.0055(0)$ (mol) ✓<br><br>***Calculates $\Delta_c H$ with – sign AND 3 SF (appropriate)***<br>$\Delta_c H = \frac{10241}{0.0055 \times 1000} = -1862$ **No mark**<br><br>= –1860 **OR** –1.86 × 10$^3$ (kJ mol$^{-1}$) ✓<br>**– sign AND 3 SF required** | 3 | 2.4<br>2.4<br>2.8 | ***FULL ANNOTATIONS MUST BE USED***<br>---<br>**ALLOW ECF** throughout<br><br>**DO NOT ALLOW** $c$ = 4.2 → 10290<br>Next 2 marks available by ECF → –1870<br><br>**ALLOW** 10240/10200 J **OR** 10.24/10.2 kJ<br>**IGNORE** units<br><br>**ALLOW ECF** from initial 3 **SF** rounding to 10.2 kJ:<br>$\pm\frac{10200}{0.0055 \times 1000} \rightarrow \pm 1854.545455$ ✓ → 1850 ✓<br>---<br>**Common errors**<br>$\Delta H$ = **–54.6 OR –54.7** ***2 marks*** *by ECF from $mc\Delta T$*<br>*$m$ wrong as 0.242 and $\Delta T$ wrong as 297.5 K)*<br>*→ $mc\Delta T$ wrong as 300.9391 (J)*<br><br>$\Delta H$ = **–4.51** ***2 marks*** *by ECF from $mc\Delta T$*<br>*$m$ wrong as 0.242 and $\Delta T$ correct as 24.5)*<br>*→ $mc\Delta T$ wrong as 24.78322 (J)*<br><br>$\Delta H$ = **–22600** ***2 marks*** *by ECF from $mc\Delta T$*<br>*$m$ correct as 100 and $\Delta T$ wrong as 297.5)*<br>*→ $mc\Delta T$ wrong as 124355 (J)* |
| | (a) | (ii) | **Any two from:** **1 MARK ONLY** ✓<br>• Heat loss/released to surroundings<br>• Incomplete combustion/reaction with oxygen or air **OR** not everything burns<br>• Evaporation of water | 1 | 1.2 | **IGNORE** incomplete 'reaction'<br>*Needs link to combustion/burning/reaction with air/$O_2$*<br><br>**IGNORE** evaporation of $C_3H_8$ |

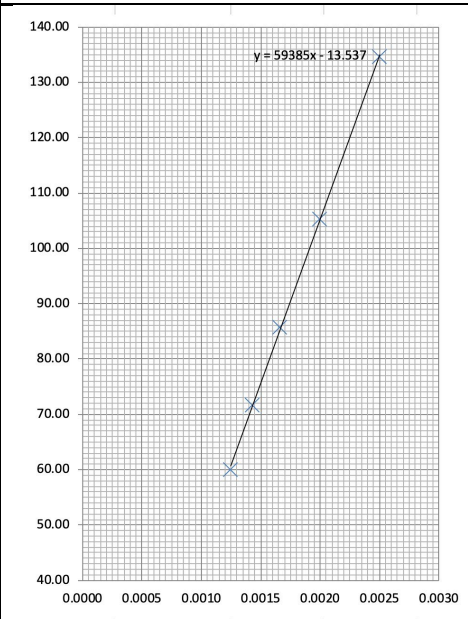
| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (b)* | *Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.*<br><br>**Level 3 (5-6 marks)**<br>Calculates $\Delta_r H$ for **reaction 3.1** correctly with correct sign **AND**<br>Calculates a value for $\Delta_c H^{\ominus}$ of propane using $\Delta_r H$ **AND** $\pm 4 \times \Delta_{vap} H$<br><br>*There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.*<br><br>**Level 2 (3-4 marks)**<br>Calculates $\Delta_r H$ for **reaction 3.1** correctly with correct sign **OR**<br>Calculates bonds broken **OR** bonds made correctly to obtain a value of $\Delta_r H$ for **reaction 3.1** **AND** attempts to link $\Delta_r H$ with $\Delta_{vap} H$ **OR** calculates $4 \times \Delta_{vap} H$<br><br>*There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.*<br><br>**Level 1 (1-2 marks)**<br>Uses bond enthalpies for bonds broken and bonds made but may contain errors or omissions **AND** obtains a value for $\Delta_r H$. **OR**<br>Calculates bonds broken **OR** bonds made correctly.<br><br>*There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*<br><br>**0 marks** No response or no response worthy of credit. | **6** | 2.4×2<br>3.1×2<br>3.2×2 | **Indicative scientific points may include:**<br><br>**Bond enthalpy calculation of $\Delta_r H$**<br>**Bonds broken**<br>$= (2 \times 347) + (8 \times 413) + (5 \times 498)$<br>$= (694) + (3304) + (2490)$<br>$= \pm$ **6488** kJ mol$^{-1}$<br>**Bonds made**<br>$= (6 \times 805) + (8 \times 464)$<br>$= (4830) + (3712) =$ **± 8542** kJ mol$^{-1}$<br>$\Delta_r H =$ **6488** – **8542** = **–2054** kJ mol$^{-1}$<br><br>**NOTE:** 3 C–C → 6835 for bond broken: $\Delta H = -1707$<br>2 C–C omitted from bonds broken gives: $\Delta H = -2748$<br>---<br>**Determination of $\Delta_c H(C_3H_8)$**<br>$\Delta_c H^{\ominus}$ of propane using $\Delta_r H$ **AND** $\pm 4 \times \Delta_{vap} H$<br>**Correct**<br>$\Delta_c H(C_3H_8) = \Delta_r H - 4 \times \Delta_{vap} H$<br>$= -2054 - (4 \times 40.65)$<br>$= -2054 - 162.6$<br>$=$ **–2216.6** / **–2217** kJ mol$^{-1}$<br>**Incorrect**<br>$\Delta_c H(C_3H_8) = -2054 + (4 \times 40.65)$<br>$= -2054 + 162.6$<br>$=$ **–1891.4** / **–1891** kJ mol$^{-1}$<br><br>***NOTE**: A clear and logically structured response would include a **correct** energy cycle for $\Delta_c H(C_3H_8)$ using $\Delta_r H$ **AND** $4 \times \Delta_{vap} H$ in energy cycle or expression:*<br><br>**ALLOW** trailing zeroes **OR** minor slips |
| | **Total** | **10** | | |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 4 | (a) | (i) | **Overall equation AND state symbols:**<br>**M**(s) + 2HCl(aq) → **M**$Cl_2$(aq) + $H_2$(g) ✓<br><br>**STATE SYMBOLS required in overall equation ONLY**<br><br>**Half equations:**<br>Oxidation **M** → **M**$^{2+}$ + 2$e^-$ ✓<br><br>Reduction 2$H^+$ + 2$e^-$ → $H_2$<br>**OR** $H^+$ + $e^-$ → ½$H_2$ ✓ | **3** | 2.6×3 | **All 3 marks are independent.**<br><br>**IGNORE** charges/oxidation numbers shown around overall *equation.* *Treat as rough working*<br><br>**ALLOW** overall equation shown with some or all ions that are present<br>e.g. (**with state symbols**)<br>M + 2$H^+$ → $M^{2+}$ + $H_2$<br>M + 2HCl → $M^{2+}$ + 2$Cl^-$ + $H_2$<br>M + 2$H^+$ + 2$Cl^-$ → $M^{2+}$ + 2$Cl^-$ + $H_2$<br>In half equations,<br>**IGNORE** state symbols even is wrong BUT half equations MUST only have species that change.<br><br>For charges on half equations,<br>**ALLOW** $M^{+2}$ for $M^{2+}$ **OR** $H^{+1}$ for $H^+$<br>**ALLOW** **M** – 2$e^-$ → **M**$^{2+}$<br><br>If **BOTH** half equations are correct but shown with oxidation and reduction the wrong way around, award 1 mark from the 2 marks for half equations |
| | (a) | (ii) | Bubbles/effervescence/fizzing stops ✓<br><br>**M**/metal/solid has disappeared/dissolved ✓ | **2** | 3.3×2 | Responses must imply that all fizzing has stopped and that all the solid has dissolved<br>**i.e.** 'metal disappears' is not quite enough.<br>'All the metal disappears' is enough<br><br>**IGNORE** constant mass<br>**IGNORE** no increase in temperature |
| | (a) | (iii) | $H^+$ + $OH^-$ → $H_2O$ ✓ | **1** | 2.5 | **ALLOW** multiples<br>e.g. 2$H^+$ + 2$OH^-$ → 2$H_2O$<br><br>**IGNORE** state symbols, even if wrong |

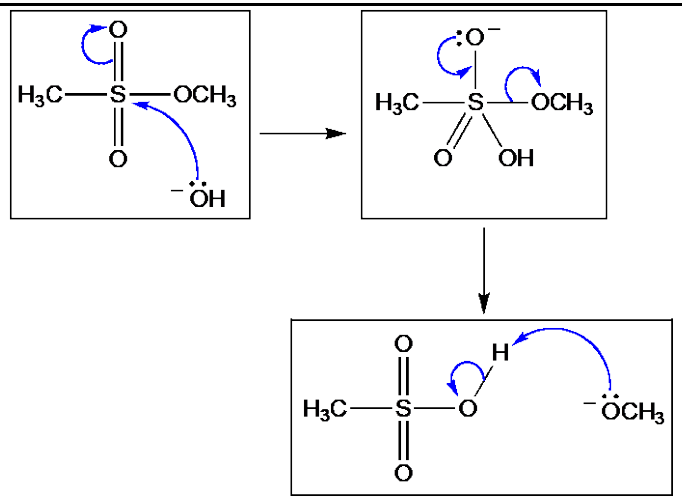
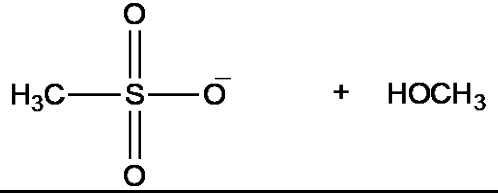
| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | (a) | (iv) | **Mean titre** **1 mark**<br>$= \frac{(27.30 + 27.20)}{2} = 27.25\ (cm^3)$ ✓<br>**Analysis of results** **5 marks**<br>$n(NaOH) = 27.25 \times \frac{0.320}{1000} = 8.72 \times 10^{-3}$ (mol) ✓<br>$n(HCl)$ in 25.0 $cm^3$ = $n(NaOH)$<br>$n(HCl)$ in 250 $cm^3$<br>$= 8.72 \times 10^{-3} \times 10 = 8.72 \times 10^{-2}$ (mol) ✓<br>$n(HCl)$ that reacted with **M**<br>$= 0.210 - 8.72 \times 10^{-2} = 0.1228$ (mol) ✓<br>$n$(**M**) that reacted $= \frac{0.1228}{2} = 0.0614$ (mol) ✓<br>$A_r$ of **M** $= \frac{6.90}{0.0614} = 112.4$ **AND M** = cadmium/Cd ✓ | **6** | 2.8×5<br><br>3.2 | ***FULL ANNOTATIONS MUST BE USED***<br>**Common error:**<br>Incorrect mean from all 3 titres = 27.35 $cm^3$<br>**Use ECF throughout**<br>Intermediate values for working to **at least 3 SF.**<br>**TAKE CARE:** Value written down may be truncated calculator value.<br>Depending on rounding, either can be credited.<br>**ALLOW** 0.123 (mol) i.e. 3SF<br>**ALLOW** 0.0615 (mol) **IF** 0.1228 rounded to 0.123<br>**ALLOW** 112.2 from 0.0615 **AND** Cd<br>**ALLOW** $A_r$ to nearest whole number<br>**ALLOW ECF** for metal closest to calculated $A_r$<br>**DO NOT ALLOW** Ga **OR** Sc (Form 3+ ions only) |
| | | | **COMMON ERRORS:**<br>Mean of 27.35 (use of all 3 titres)<br>→ $8.752 \times 10^{-3}$ → $8.752 \times 10^{-2}$ → 0.12248<br>→ 0.06124 → 112.7 **AND** Cd: *5 marks*<br>No ÷2 to *obtain n(M)*<br>→ 56.2 **AND** Fe (from 27.25) *5 marks*<br>→ 56.3 **AND** Fe (from 27.35) *4 marks*<br>*No subtraction from 0.210*<br>→ $8.72 \times 10^{-2}/2 \rightarrow 4.36 \times 10^{-2} \rightarrow \frac{6.90}{4.36 \times 10^{-2}}$<br>→ 158.2 to 158.3 **AND** Tb *5 marks* | | | No ×10 to *obtain n(HCl) in 250 $cm^3$* *5 marks*<br>$0.210 - 8.72 \times$ **$10^{-3}$** = 0.20128 **OR** 0.201<br>$n(M)$ = 0.20128/2 = 0.10064<br>$A_r$ = 6.90/0.10064 = 68.56 → Zn<br>*No ×10 and no ÷ 2* *4 marks*<br>$0.210 - 8.72 \times$ **$10^{-3}$** = 0.20128<br>$A_r$ = 6.9/0.20128 = 34.28 → Ca<br>*Omitting initial titration calculation* *Zero marks*<br>0.210/2 = 0.105 → 6.9/0.105 = 65.71 → Zn |

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | (b) | (i) | $n(CO_2) = \frac{2.75}{44} = 0.0625$ (mol) ✓ | 1 | 2.8 | |
| | (b) | (ii) | $n(\mathbf{X}_2CO_3) = 0.0625$ (mol)<br>**OR**<br>0.0625 used in molar mass expression below ✓<br><br>Molar mass of $\mathbf{X}_2CO_3$ $= \frac{14.57}{0.0625} = 233.12$ (g mol$^{-1}$) ✓<br><br>Metal **X** = Rubidium/Rb ✓ | 3 | 1.2<br><br>2.8<br><br>3.2 | **ALLOW ECF** from **4b(i)**<br><br>**ALLOW** to nearest whole number<br><br>**DO NOT ALLOW** strontium/Sr<br>*wrong carbonate formula*<br>---<br>**ALLOW ECF** for **X** from calculated molar mass **ONLY IF X** is a Group 1 metal **OR** Ag<br><br>**Working:**<br>Mass of **X** in $\mathbf{X}_2CO_3$ = 233.14 – 60<br>= 173.12 **OR** 173<br>$A_r$ of **X** $= \frac{173.12}{2}$ **OR** 86.56 **OR** 85.6 **OR** 87 |
| | (c) | (i) | Reweigh to constant mass ✓ | 1 | 3.4 | **ALLOW** response implying leaving for longer and monitoring by reweighing to constant mass,<br>e.g. Leave flask until the mass does not change<br><br>**IGNORE** 'leave for longer' **OR** wait till fizzing stops<br>*Needs link to constant mass*<br><br>**ALLOW** Collect gas until gas volume is constant |
| | (c) | (ii) | Mass ($CO_2$) **OR** $n(CO_2)$ loss would be smaller<br>**OR**<br>Mass $X_2CO_3$ **OR** $n(X_2CO_3)$ reacted (seems to be) less ✓<br><br>Molar mass would be greater ✓ | 2 | 3.1<br><br>3.2 | |
| | | | **Total** | **19** | | |

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>5</td><td>(a)</td><td></td><td>
<table>
<tr><td>$T$ /K</td><td>500</td><td>600</td><td>700</td><td>800</td><td></td></tr>
<tr><td>$K_p$</td><td>$5.86 \times 10^{45}$</td><td>$1.83 \times 10^{37}$</td><td>$1.46 \times 10^{31}$</td><td>$1.14 \times 10^{26}$</td><td></td></tr>
<tr><td>$\frac{1}{T}$ /K$^{-1}$</td><td>$2.00 \times 10^{-3}$</td><td>$1.67 \times 10^{-3}$</td><td>$1.43 \times 10^{-3}$</td><td>$1.25 \times 10^{-3}$</td><td>✓</td></tr>
<tr><td>ln $K_p$</td><td>105</td><td>86</td><td>72</td><td>60</td><td>✓</td></tr>
</table>
Calculator values<br>
1/$T$ /$10^{-3}$ 2.00 1.66 recurring 1.428571429 1.25<br>
ln $K_p$ 105.3844788 85.79996441 71.75857432 59.99824068</td><td>2</td><td>1.2×2</td><td>Mark by row<br><br>ALLOW 2 SF or more for 1/$T$ but ignore trailing zeroes<br><br>ALLOW whole numbers <s>(±1)</s> for ln $K_p$<br><br>ALLOW 1 small slip in each row.<br>e.g. 1.66 for 1.67; 71.7 for 71.8<br>Check with calculator values below table<br><br>BUT DO NOT ALLOW whole number errors, e.g. 85 for 86 ☒</td></tr>
<tr><td></td><td>(b)</td><td></td><td>Equilibrium (position) shifts to the left<br>AND<br>(forward) reaction is exothermic ✓</td><td>1</td><td>2.2</td><td>ALLOW ‘favours reverse reaction’<br>Implies shift to left<br><br>ALLOW ‘shifts in endothermic direction’ BUT only if (forward) reaction stated as exothermic</td></tr>
</table>

| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| (c) | **Plotting of graph**<br>**All** points correctly plotted<br>**AND** best-fit straight line ✓ | **4** | 3.1 |  <br>**ALLOW** 4 points on graph<br>Tolerance 1 small square |
| | **Gradient**<br>Correct gradient of best-fit straight line within the range ±57000 → ±63000 ✓ | | 3.1 | |
| | **$\Delta H$ calculation (subsumes mark for gradient)**<br>$\Delta H$ = (–) gradient × 8.31(4) **OR** calculated value ✓<br>*e.g. from ±60000,* $\Delta H$ *= (+)498840* (J) **OR** ±498.840 (kJ) | | 3.2 | |
| | ***$\Delta H$ in kJ mol$^{-1}$***<br>$\Delta H$ correct in kJ mol$^{-1}$<br>**AND 3SF**<br>**AND** – sign ✓<br>*e.g. from ±498840,* $\Delta H$ *= –499 (kJ mol$^{-1}$)* | | 3.2 | **ALLOW** $\Delta H$ in range: –480 → –530 *(kJ mol$^{-1}$)*<br>**This mark subsumes gradient mark** |
| (d) | Extrapolate line to ($y$) intercept **OR** Measure/Use ($y$) intercept ✓<br>Intercept = $\frac{\Delta S}{R}$ **OR** $\Delta S = R \times$ ($y$) intercept ✓<br>*This statement automatically subsumes 1st mark*<br>**NOTE**: If 'x' intercept, **DO NOT ALLOW** 1st mark but 2nd mark available for × $R$ as **BOD** | **2** | 3.1×2 | **ALLOW** substitute values of ln $K_p$, 1/$T$ and gradient into **Equation 5.1** ✓<br>From provided values and gradient = 60000:<br>$\frac{\Delta S}{R}$ = ln $K_p$ – gradient × 1/$T$<br>**OR** $135 - 60000 \times 2.50 \times 10^{-3} = -15$ ✓ |
| | **Total** | **9** | | |

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>AO element</th><th>Guidance</th></tr>
<tr><td>6</td><td>(a)</td><td></td><td>
<table>
<tr><td>Bond angle</td><td>Name of shape</td></tr>
<tr><td>120(°)</td><td>Trigonal planar</td></tr>
<tr><td>104–105(°)</td><td>Non-linear</td></tr>
</table>
Mark by row OR by column to give higher mark<br><br>
i.e. 2 bond angles correct ✓<br>
2 shapes correct ✓<br>
OR<br>
i.e. bond angle AND shape correct in 1st row ✓<br>
bond angle AND shape correct in 2nd row ✓
</td><td>2</td><td>1.2×2</td><td>For non-linear,<br>ALLOW bent, v-shaped, angular<br>IGNORE planar, ‘not straight’</td></tr>
<tr><td></td><td>(b)</td><td></td><td>
$CH_3SO_2OH + H_2O \rightleftharpoons CH_3SO_2O^- + H_3O^+$ ✓<br><br>
A1 B2 B1 A2 ✓<br><br>
For an equilibrium shown using $CH_3COOH$ instead of $H_2O$, mark acid–base pairs by ECF, i.e.<br>
$CH_3SO_2OH + CH_3COOH \rightleftharpoons CH_3SO_2O^- + CH_3COOH_2^+$ ☒<br>
A1 B2 B1 A2 ECF ✓<br><br>
$CH_3SO_2OH$ dissociates more (than $CH_3COOH$)<br>
OR $CH_3SO_2OH$ is a stronger acid ✓<br><br>
ORA in terms of $CH_3COOH$ being a weaker acid<br><br>
Student is correct<br>
AND<br>
(sulfonic acid has) lower p$K_a$/higher $K_a$ OR greater $[H^+]$<br>
ORA ✓
</td><td>4</td><td>2.1×2<br><br>3.1<br><br>3.2</td><td>ALLOW → for ⇌<br><br>ALLOW acid–base pairs labelled other way round.<br>i.e. $CH_3SO_2OH + H_2O \rightleftharpoons CH_3SO_2O^- + H_3O^+$<br>A2 B1 B2 A1<br>ALLOW <s>small slip</s><br><br>If ONE charge is missing from equilibrium.<br>ALLOW ECF for acid–base pairs mark<br><br>IGNORE ‘more acidic’<br>Response needs strength/dissociation<br><br>ALLOW maths explanation for final 2 marks, e.g.<br>$K_a(CH_3COOH) = 10^{-(4.76)} = 1.74 \times 10^{-5}$<br>$[H^+] = \sqrt{(1.74 \times 10^{-5}) \times 1} = 4.17 \times 10^{-3}$<br>$pH = -\log 4.17 \times 10^{-3} = 2.38$ ✓<br><br>$K_a(CH_3SO_2OH) = 10^{-(-1.90)} = 79.4$<br>$[H^+] = \sqrt{(79.4) \times 1} = 8.91$<br>$pH = -\log 8.91 = -0.95$ ✓<br>BOTH pH calcs subsumes ‘Student is correct’</td></tr>
</table>

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | (c) | |  <br>6 curly arrows correct ✓✓✓✓<br>5 curly arrows correct ✓✓✓<br>4 curly arrows correct ✓✓<br>3 curly arrows correct ✓ | 4 | 3.1×4 | **IGNORE** any added charges **OR** dipoles.<br>*Marks solely for curly arrows*<br><br>**IGNORE** any curly arrows on bottom structures (not in boxes):<br>  |
| | | | **Total** | **10** | | |

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