**Mark Scheme**

| Question | | | Answer | Marks | | Guidance |
|---|---|---|---|---|---|---|
| 1 | (a) | | $Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$ ✓ | 1 | | **ALLOW multiples**<br>**IGNORE** state symbols (even if wrong) |
| | (b) | | *Increasing size:*<br>Atomic radius increases<br>**OR**<br>more shells<br>**OR**<br>more (electron) shielding ✓<br><br>*Attraction*<br>Nuclear **attraction** decreases<br>**OR**<br>(outer) electron(s) experience less **attraction** ✓<br><br>*Ionisation energy*<br>Ionisation **energy** decreases<br>**OR**<br>less **energy** needed to remove electron(s) ✓ | 3 | | **FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED**<br><br>**IGNORE** more orbitals **OR** more sub-shells<br>*Alternative must refer to shells*<br><br>**ALLOW** Energy levels for shells<br><br>**ALLOW more** electron repulsion between shells<br>**IGNORE** just 'shielding' (*more/greater needed)*<br>**IGNORE** 'nuclear shielding'<br><br>**IGNORE** 'pull' for attraction<br>**IGNORE** 'electrons less tightly held'<br>**IGNORE** 'nuclear charge' for 'nuclear attraction'<br><br>**IGNORE** 'easier to remove electron'<br>***Energy** is required*<br><br>**ALLOW** less energy to oxidise |

**Mark Scheme**

| Question | | | Answer | Marks | | Guidance |
|---|---|---|---|---|---|---|
| | (c) | (i) | *Disproportionation*:<br>oxidation and reduction of the same **element** ✓<br><br>*Redox*:<br>C*l* is oxidised from +5 (in KC*l*$O_3$) to +7 (in KC*l*$O_4$) ✓<br><br>C*l* is reduced from +5 (in KC*l*$O_3$) to –1 (in KC*l*) ✓ | **3** | | **ALLOW** 'chlorine' **OR** 'C*l*' for same element<br>**IGNORE** 'species' for 'element'<br><br>**ALLOW** after number, e.g. 5+<br>**IGNORE** ionic charges, e.g. $Cl^{5+}$<br><br>**IGNORE** '5' (signs required)<br><br>**IGNORE** any reference to electron loss/gain (even if wrong)<br><br>**ALLOW** one redox mark if oxidation numbers are correct but reduction/oxidation is incorrectly assigned |
| | | (ii) | potassium chlorate(VII) ✓ | **1** | | Brackets required |
| | (d) | (i) | *Equation*<br>$Ba(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$ ✓<br><br>*Entropy change **and** explanation*<br>entropy decreases **OR** entropy change negative<br>**AND**<br>($BaSO_4$) solid/ppt has less disorder/ more order/ fewer ways of arranging energy/ less freedom/ less random particles/dispersal of energy ✓ | **2** | | **ALLOW** multiples<br><br>M2 is dependent on $BaSO_4(s)$ (even if formula is incorrect – eg $Ba(SO_4)_2(s)$) seen as a product in the attempted equation as long as reactants are not solid.<br>$BaSO_4$ solid/ppt may be assumed from $BaSO_4(s)$ seen in the attempted equation. |

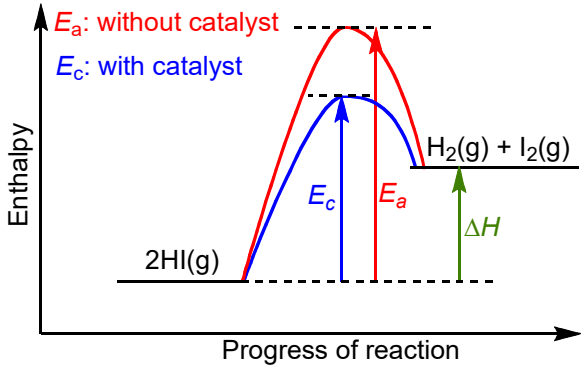
**Mark Scheme**

| Question | | | Answer | Marks | | Guidance |
|---|---|---|---|---|---|---|
| | | (ii) | *Equation*<br>½ $I_2$(s) → I(g) ✓<br>*state symbols required*<br><br>*Entropy change **and** explanation*<br>entropy increases **OR** entropy change positive<br>**AND**<br>gas has more disorder/ less order/ more ways of arranging energy/ more freedom/ more random particles / more dispersal of energy ✓ | **2** | | **DO NOT ALLOW** $I_2$(s) → 2I(g)<br><br>**DEPENDENT** on ½ $I_2$(s) → I(g) **OR** $I_2$(s) → 2I(g) |
| | | | **Total** | **12** | | |

**Mark Scheme**

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 2 | (a) | | **ASSUME** trend is down the group<br>(unless stated otherwise)<br><br>**Forces**<br>London forces increase<br>**OR** induced dipole(–dipole) interactions increase ✓<br><br>**Reason**<br>(Number of) electrons increases ✓<br><br>**Link to energy and particles**<br>More energy to break intermolecular forces<br>**OR**<br>to break London forces<br>**OR**<br>to break induced dipole(–dipole) interactions ✓ | 3 | **FULL ANNOTATIONS MUST BE USED**<br>**---------- ALLOW** reverse argument throughout<br><br>**IGNORE** van der Waals'/vdW forces<br>**DO NOT ALLOW** hydrogen bonds **OR** permanent dipole(-dipole) interactions for first and third marking points<br><br>**ALLOW** more (electron) shells<br><br>**DO NOT ALLOW** covalent bonds break |

**Mark Scheme**

| Question | Answer | Marks | Guidance |
|---|---|---|---|
| (b) |  <br>2HI(g) on LHS **AND** $H_2(g) + I_2(g)$ on RHS ✓<br><br>$\Delta H$ labelled with product above reactant **AND** arrow upwards ✓<br><br>$E_a$ **AND** $E_c$ correctly labelled with $E_c$ below $E_a$ ✓ | 3 | **FULL ANNOTATIONS MUST BE USED**<br>**Mark each point independently**<br><br>**IGNORE** state symbols.<br><br>$\Delta H$: **DO NOT ALLOW** $-\Delta H$.<br>**ALLOW** $\Delta H$ arrow even with a gap at the top and bottom, i.e. does not quite reach reactant or product line<br><br>$E_a$: **ALLOW** no arrowhead or arrowheads at both ends of $E_a$ line<br>$E_a$ line must reach (near or not too far beyond) maximums regardless of position<br><br>**ALLOW** AE or EA for $E_a$<br><br>Exothermic diagram can access the first and third marks |

**Mark Scheme**

| Question | Answer | Marks | Guidance |
|---|---|---|---|
| (c) | **FIRST CHECK THE ANSWER ON THE ANSWER LINE**<br>**IF *M* = 183 AND Formula = $Cl_2O_7$ award 4 marks**<br>**IF *M* = 183 award 3 marks**<br>---<br>**Use of data and unit conversions**<br>• (R = 8.314)<br>• T in K: 373K<br>• V in $m^3$: $76.0 \times 10^{-6}$<br>• (p in Pa: $1.00 \times 10^5$) ✓<br><br>**Calculation of n**<br>$n = \frac{(1.00 \times 10^5) \times (76.0 \times 10^{-6})}{8.314 \times 373}$<br><br>$n = 2.45 \times 10^{-3}$ (mol) ✓<br><br>**Molar mass**<br>$M = \frac{m}{n} = \frac{0.4485}{2.45 \times 10^{-3}} = 183$ (g $mol^{-1}$) ✓<br><br>**Molecular formula**<br><br>$Cl_2O_7$ ✓ | **4** | **If there is an alternative answer, check to see if there is any ECF credit possible using working below**<br><br>Correct value of n subsumes first mark<br><br>**ALLOW ECF** from incorrectly **calculated** *n*<br><br>**ALLOW ECF** from incorrect M if formula of $Cl_xO_y$ is the **closest** to the with **calculated** value of *M*<br><br>**IGNORE** use of 24 000 $cm^3$ for calculation of n<br>**BUT** then Mark molar mass and Molecular formula by **ECF** for two marks maximum.<br>$n = \frac{76.0}{24000} = 3.17 \times 10^{-3}$ (mol)<br>$M = \frac{0.4485}{3.17 \times 10^{-3}}$ = 141.6/141.5 (g $mol^{-1}$) ✓<br>Molecular formula = $Cl_3O_2$ ✓ |

**Mark Scheme**

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | **(d)** | **(i)** | Titres correct and **ALL** recorded to **2 decimal places**<br><br>Titre: 24.00 23.40 23.75 23.85 ✓<br><br>mean titre = 23.80 ($cm^3$) ✓ | **2** | <br><br><br><br>**ALLOW** 23.8 $cm^3$ |
| | **(d)** | **(ii)** | Percentage uncertainty = $\frac{0.05 \times 2}{23.40} \times 100 = 0.43$ (%) ✓ | **1** | **ALLOW ECF** from incorrect subtraction in **(i)** or incorrect mean<br>**ALLOW** 0.42% from titre values 2, 3 or 4 or mean titre or trial titre.<br>**2 DP required** |
| | **(d)** | **(iii)** | Add starch (near the end point) ✓<br><br>Blue to colourless ✓ | **2** | <br><br>**ALLOW** blue/black **OR** black **OR** purple for colour of mixture<br>**ALLOW** blue colour disappears (to colourless)<br>**IGNORE** 'clear'<br>**IGNORE** 'colorimetry' |

**Mark Scheme**

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | (d) | (iv) | **FIRST CHECK THE ANSWER ON THE ANSWER LINE**<br>**IF B = $RbIO_3$ AND relative formula mass = 260.5 award 5 marks**<br>**IF relative formula mass = 260.5 award 4 marks**<br>---<br>**$n(S_2O_3^{2-})$ in titration**<br>$= \frac{0.150 \times 23.80}{1000} = 3.57 \times 10^{-3}$ (mol) ✓<br><br>**$n(IO_3^-)$ in titration**<br>$= \frac{3.57 \times 10^{-3}}{6} = 5.95 \times 10^{-4}$ (mol) ✓<br><br>**$n(IO_3^-)$ in original 250 $cm^3$**<br>$= 10 \times 5.95 \times 10^{-4} = 5.95 \times 10^{-3}$ (mol) ✓<br><br>**Relative formula mass of B**<br>$= \frac{1.55}{5.95 \times 10^{-3}} = 260.5$ (g $mol^{-1}$) ✓<br><br>**Formula of B (must be derived from relative formula mass)**<br>Iodate of Group 1 metal that most closely matches calculated molar mass of **B**<br><br>Formula from 260.5 = $RbIO_3$ ✓ | **5** | **ALLOW ECF** from incorrect mean titre in **(a)(i)**<br><br>**ECF** from $n(S_2O_3^{2-})$ in titration<br>**ALLOW** a two-step calculation<br>$n(I_2) = n(S_2O_3^{2-}) \div 2$ and $n(IO_3^-) = n(I_2) \div 3$<br><br>**ECF** from $n(IO_3^-)$ in titration<br><br>**ECF** from $n(IO_3^-)$ in original 250 $cm^3$<br>**IF** scaling × 10 is omitted,<br>**ALLOW ECF** from $n(IO_3^-)$ in titration<br><br>**ALLOW ECF** from incorrect RFM of **B** provided metal is from Group 1<br>**ALLOW** $RbIO_3^-$<br>**DO NOT ALLOW** $RbIO_3$ without relative formula mass value.<br>**DO NOT ALLOW** 260.4 (without working) and $RbIO_3$<br>**IF B** = $RbIO_3$ AND relative formula mass = 261 award 5 marks |
| | | | **Total** | **20** | |

**Mark Schemes**

| Question | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|
| **3** | **C** | **1** | AO1.2 | |
| **4** | **B** | **1** | AO2.6 | |

**Mark Scheme**

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| 5 | (a) | | **Interpretation of Results**<br>Orange contains bromine **AND** no reaction<br>**AND** violet contains iodine ✓ | 5 | 2.3× 1 | Results can be interpreted anywhere in answer.<br><br>**ALLOW** multiples, e.g. ½$Br_2$ + $I^-$ → $Br^-$ + ½$I_2$ |
| | | | **Ionic equation**<br>$Br_2 + 2I^- \rightarrow 2Br^- + I_2$ ✓ | | 2.6×1 | **IGNORE** other halogen/halide equations<br><br>**IGNORE** state symbols |
| | | | **Reactivity (down the group)**<br>Reactivity decreases<br>**AND**<br>oxidising power decreases<br>**OR** gains electrons less easily<br>**OR** forms negative ion/1– ion less easily<br>**OR** less energy released when electron **gained** ✓<br>OR more negative electron affinity | | 1.1×3 | **ALLOW** ORA<br><br>**DO NOT ALLOW** idea of losing electrons/ionisation energy<br><br>**IGNORE** chlorine is the most electronegative<br><br>**IGNORE** explanations in terms of displacement |
| | | | **Size/shells/shielding (down the group)**<br>Greater atomic radius<br>**OR** more shells<br>**OR** more shielding ✓ | | | |
| | | | **Attraction (down the group)**<br>Less **nuclear** attraction down the group ✓ | | | |

**Mark Scheme**

| Question | | | Answer | Marks | AO element | Guidance |
|---|---|---|---|---|---|---|
| | | | | | | |
| | **(b)** | | *Benefit **AND** risk required for **ONE** mark*<br><br>**Benefit:** kills bacteria ✓<br>**AND**<br>**Risk:** toxic/poisonous<br>**OR** forms chlorinated hydrocarbons<br>**OR** forms carcinogens/toxic compounds ✓ | **1** | 1.1 | **ALLOW** kills micro-organisms<br>**OR** kills pathogens **OR** kills viruses **OR** sterilises/disinfects water<br><br>**IGNORE** antiseptic, reduces risk of disease, cleans water<br><br>**IGNORE** 'harmful'/'dangerous'<br><br>**IGNORE** chlorine is carcinogenic/ dangerous for health/causes breathing problems |
| | **(c)** | | $n(\mathbf{A}) = \frac{0.209}{29} = 0.00721$ (mol) ✓<br><br>$M_r = \frac{1.26}{0.00721} = 174.8$ ✓<br><br>Molecular formula = $BrF_5$ ✓<br><br>Formula is dependent on $M_r$ | **3** | 2.2×2<br><br>3.2 | **ALLOW ECF**<br><br>**ALLOW 2SF** 0.0072 up to calculator value 0.0072068965517<br><br>**ALLOW** 175 up to calculator value 174.8325359<br><br>**ALLOW** $F_5Br$<br><br>**ALLOW ECF** that matches calculated $M_r$ |
| | | | **Total** | **9** | | |