

|      |                                                                                                                                                                     |            |   |
|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|---|
| 2(b) | oxidising power decreases down the group.                                                                                                                           | <i>ora</i> | 1 |
|      | ability to accept electrons decreases (down the group)                                                                                                              | <i>ora</i> | 1 |
|      | because (outer shell experiences) more shielding<br>OR<br>increased distance from nucleus (to outer shell) (outweighs the increasing nuclear charge down the group) | <i>ora</i> | 1 |

May/June 2017 9701/23 · Q2 (b)

|         |                                                                                                                                                         |   |
|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 3(c)(i) | oxidation numbers / states of elements (Na-Si) increase from +1 to +4 / by 1 every time                                                                 | 1 |
|         | increasing number of valence electrons / $\text{NaCl}$ , $\text{MgCl}_2$ , $\text{AlCl}_3$ , $\text{SiCl}_4$ / number of chlorines matches group number | 1 |
|         | chlorine oxidation number / state $-1$ in all / stays the same                                                                                          | 1 |

May/June 2018 9701/21 · Q3 (c)(i)

|         |                                                                                                                     |   |
|---------|---------------------------------------------------------------------------------------------------------------------|---|
| 2(d)(i) | $\text{MnO}_4^- + 5\text{Fe}^{2+} + 8\text{H}^+ \rightarrow \text{Mn}^{2+} + 5\text{Fe}^{3+} + 4\text{H}_2\text{O}$ | 1 |
|---------|---------------------------------------------------------------------------------------------------------------------|---|

May/June 2018 9701/22 · Q2 (d)(i)

|           |                                                                                               |   |
|-----------|-----------------------------------------------------------------------------------------------|---|
| 3(e)(iii) | $3\text{Cl}_2 + 6\text{NaOH} \rightarrow 5\text{NaCl} + \text{NaClO}_3 + 3\text{H}_2\text{O}$ | 1 |
|           | 0 to $-1$ (+)5 AND chlorine has been oxidised and reduced.                                    | 1 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2018 9701/23 · Q3 (e)(iii)

|         |              |               |   |
|---------|--------------|---------------|---|
| 1(d)(i) | NO           | $\text{NO}_2$ | 1 |
|         | (+)2 / (+)II | (+)4 / (+)IV  |   |

March 2019 9701/22 · Q1 (d)(i)

|         |                                                                                                                                                                                   |   |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 1(b)(i) | Similarities (any two from the following list)<br>(both have) $+2$ ion / $(+2)$ same oxidation state / same stoichiometry of oxide / <del>carbonates</del> decompose (on heating) | 2 |
|         | Difference<br>(X) forms coloured compounds/oxides/ carbonates <b>OR</b> Group 2 elements form white compounds/oxides/carbonates                                                   | 1 |

May/June 2019 9701/21 · Q1 (b)(i)

|         |                              |               |              |               |
|---------|------------------------------|---------------|--------------|---------------|
| 3(b)(i) | Chlorine containing species  | $\text{Cl}_2$ | $\text{HCl}$ | $\text{HOCl}$ |
|         | Oxidation number of chlorine | 0             | -1           | (+)1          |

Award 2 marks for 3 correct oxidation numbers

Award 1 Mark for 2 correct oxidation numbers

May/June 2019 9701/22 · Q3 (b)(i)

|          |                                                                                                                                                                                                                                                                                |   |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2(c)(i)  | $2\text{H}_2\text{SO}_4 + 14\text{HI} \rightarrow 7\text{I}_2 + 8\text{H}_2\text{O} + \text{H}_2\text{S} + \text{S}$<br><b>M1</b> correct species<br><b>M2</b> correctly balanced equation                                                                                     | 2 |
| 2(c)(ii) | <i>explain with ref to ox no's why the reaction in (c)(i) is a redox reaction</i><br><b>M1</b> I (oxidation number increases) from –1 to 0 = oxidation / reducing agent<br><b>M2</b> S (oxidation number decreases) from (+) 6 to 0 <b>OR</b> –2 = reduction / oxidising agent | 2 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2019 9701/23 · Q2 (c)(i), (c)(ii)

|          |                                                                                                                                                                                                                                                                                          |   |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 4(b)(iv) | <b>M1</b> nitrogen dioxide increases the rate<br><b>OR</b><br>lowers the activation energy<br><b>M2</b> (NO <sub>2</sub> ) is regenerated by reaction of NO with O <sub>2</sub> (in the air)<br><b>OR</b><br>NO (formed) reacts with O <sub>2</sub> (in air) to (re)form NO <sub>2</sub> | 2 |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2019 9701/23 · Q4 (b)(iv)

|          |                                                                                                                                                    |   |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 1(a)(ii) | effervescence / fizzing / bubbling<br><b>OR</b><br><u>green</u> gas formed<br><b>OR</b><br>solid dissolves / disappears / soluble                  | 1 |
| 1(c)(i)  | <b>M1:</b> $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$<br><b>M2:</b> chlorine is oxidised and reduced | 2 |
| 1(c)(ii) | NaClO <sub>3</sub> / sodium chlorate(V)                                                                                                            | 1 |
| 1(d)     | <b>M1:</b> chloric(I) acid / hypochlorous acid / HClO<br><b>M2:</b> kills bacteria / micro-organisms / microbes                                    | 2 |

Oct/Nov 2019 9701/21 · Q1 (a)(i), (a)(ii), (c)(i), (c)(ii), (d)

|         |                                                                            |   |
|---------|----------------------------------------------------------------------------|---|
| 4(b)(i) | acidified potassium dichromate[ <b>(VI)</b> ] <b>AND</b> heat under reflux | 1 |
|---------|----------------------------------------------------------------------------|---|

Oct/Nov 2019 9701/21 · Q4 (b)(i)

|           |                                                                                                                                                                                                                                                                          |   |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 3(a)(iii) | <ul style="list-style-type: none"> <li>• P goes from 0 to (+)5 / (+)V</li> <li>• P is oxidised</li> <li>• N goes from (+)5 / (+)V to (+)4 / (+)IV</li> <li>• N is reduced</li> </ul> Award one mark for two correct bullet points, award two marks for all four correct. | 2 |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2019 9701/22 · Q3 (a)(iii)

|          |                                                                                                                    |   |
|----------|--------------------------------------------------------------------------------------------------------------------|---|
| 4(b)(iv) | $\text{C}_5\text{H}_{12}\text{O}_2 + 3[\text{O}] \rightarrow \text{C}_5\text{H}_8\text{O}_3 + 2\text{H}_2\text{O}$ | 1 |
|----------|--------------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2019 9701/22 · Q4 (b)(iv)

|         |    |   |
|---------|----|---|
| 1(g)(i) | –1 | 1 |
|---------|----|---|

March 2020 9701/22 · Q1 (g)(i)

|           |                                                                                                                                                                            |   |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2(a)(i)   | 2CuSO <sub>4</sub> (aq) + 4KI(aq) → 2CuI(s) + (1)I <sub>2</sub> (aq) + 2K <sub>2</sub> SO <sub>4</sub> (aq)<br><b>M1</b> correct balancing <b>M2</b> correct state symbols | 2 |
| 2(a)(ii)  | Oxidation state of copper in CuSO <sub>4</sub> (+)2<br>AND<br>Oxidation state of copper in CuI (+)1                                                                        | 1 |
| 2(a)(iii) | <b>M1</b> redox                                                                                                                                                            | 1 |
|           | <b>M2</b> iodide ions – lost electron(s) AND copper ions – gained electron(s)                                                                                              | 1 |

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| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Marks |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 2(b)     | <div> <div>Mass of 0.0982mol CuSO<sub>4</sub> in 17.43g CuSO<sub>4</sub>·yH<sub>2</sub>O</div> <div> <b>M1</b> calculate <i>M<sub>r</sub></i> CuSO<sub>4</sub> using <i>A<sub>r</sub></i> from data booklet<br/>63.5 + 32.1 + 64.0 = 159.6<br/><b>M2</b> use <i>M<sub>r</sub></i> to calculate mass of CuSO<sub>4</sub><br/>(0.0982 × M1) = 15.67272g </div> </div> <div> <div>number of water in 17.43g of CuSO<sub>4</sub>·yH<sub>2</sub>O</div> <div> <b>M3</b> calculate the mass amount of water in sample AND use this value to calculate the amount of water present<br/>(17.43–15.67)/18 = 0.097778 mol </div> </div> <div> <div>value of y</div> <div> <b>M4</b> use the ratio of M2: 0.0982 to find y<br/>(mol H<sub>2</sub>O + mol CuSO<sub>4</sub>) = 1 </div> </div> | 4     |

| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2020 9701/21 · Q2 (a)(i), (a)(ii), (a)(iii), (b)

|          |                                                                                                                                                                                                                                                                                                                                                                                                                                   |   |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2(c)(i)  | $3\text{NO}_2 + \text{H}_2\text{O} \rightarrow 2\text{HNO}_3 + \text{NO}$<br><div> <div>(+)4</div> <div>(+)5</div> <div>(+)2</div> </div> 3 correct oxidation numbers – 2 marks<br>2 correct oxidation numbers – 1 mark                                                                                                                                                                                                           | 2 |
| 2(c)(ii) | relates the term disproportionation to the reaction described<br><b>M1</b> nitrogen /N (in nitrogen dioxide) is both gaining electrons and losing electrons during the reaction<br><b>M2</b> refer to relevant transfer of electrons when NO <sub>2</sub> reacts to form HNO <sub>3</sub> and NO<br>NO <sub>2</sub> to HNO <sub>3</sub> involves loss of electron(s)<br>AND<br>NO <sub>2</sub> to NO involves gain of electron(s) |   |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2020 9701/22 · Q2 (c)(i), (c)(ii)

|          |                                                   |                                                             |          |
|----------|---------------------------------------------------|-------------------------------------------------------------|----------|
| 1(c)(ii) | reagent and conditions                            | Formula of gallium containing product                       | <b>2</b> |
|          | <b>M1</b> gallium oxide+ hot HCl(aq)              | <b>M1</b> GaCl <sub>3</sub>                                 |          |
|          | <b>M2</b> gallium oxide+hot concentrated NaOH(aq) | <b>M2</b> NaGa(OH) <sub>4</sub><br>OR<br>NaGaO <sub>2</sub> |          |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2020 9701/23 · Q1 (c)(ii)

|          |               |          |
|----------|---------------|----------|
| 2(d)(ii) | 0   (+)4   -1 | <b>1</b> |
|----------|---------------|----------|

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

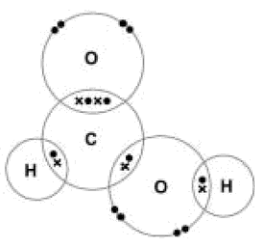
Oct/Nov 2020 9701/21 · Q2 (d)(ii)

|      |                                                                                                                                       |          |
|------|---------------------------------------------------------------------------------------------------------------------------------------|----------|
| 2(b) | <b>M1:</b> increases (from Na to S / across period)                                                                                   | <b>2</b> |
|      | <b>M2:</b> increasing (number of) <b>valence</b> electrons <b>OR</b> (number of) electrons in <b>outer</b> (electron) shell increases |          |

Oct/Nov 2020 9701/22 · Q2 (b)

|          |                                                                                                            |          |
|----------|------------------------------------------------------------------------------------------------------------|----------|
| 2(c)(i)  | <b>M1:</b> (thermal stability) decreases (down group)<br><b>M2:</b> (H—X) bond energy / strength decreases | <b>2</b> |
| 2(c)(ii) | (+)6, (+)4, -2                                                                                             | <b>1</b> |
| 2(d)(i)  | when a species is both oxidised and reduced                                                                | <b>1</b> |

March 2021 9701/22 · Q2 (c)(i), (c)(ii), (d)(i)

|           |                                                                                                                                                                                                                                        |   |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 4(a)      | Br / bromine as the oxidation number of Br decreases / goes from 0 → -1<br>OR<br>bromine as it causes oxidation number of C (in methanoic acid) to increase / go from (+)2 → (+)4                                                      | 1 |
| 4(b)      | (solution) turns (from brown / orange / red to) colourless / decolorises<br>OR brown / orange / red fades                                                                                                                              | 1 |
| 4(c)(i)   | rate = total change in concentration of Br <sub>2</sub> divided by time taken<br><i>calculation dependent on graph</i><br>$(100 \times 10^{-5} - 12 \times 10^{-5}) / 600$<br><b>M1</b> average rate of reaction $1.47 \times 10^{-6}$ | 1 |
|           | <b>M2</b> units mol dm <sup>-3</sup> s <sup>-1</sup>                                                                                                                                                                                   | 1 |
| 4(c)(ii)  | graph shown on same axes has steeper initial gradient<br>AND reaches the same final [Br <sub>2</sub> ]                                                                                                                                 | 1 |
| 4(c)(iii) | <b>M1</b> (at increased temp the average kinetic) energy of particles / species / molecules increases.                                                                                                                                 | 1 |
|           | <b>M2</b> (many) more/greater proportion of particles with energy > E <sub>a</sub>                                                                                                                                                     | 1 |
| 4(d)      |                                                                                                                                                       | 1 |
|           | <b>M1</b> correct bonding electrons                                                                                                                                                                                                    |   |
|           | <b>M2</b> correct number of non-bonding electrons around each oxygen                                                                                                                                                                   | 1 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2021 9701/21 · Q4 (a), (b), (c)(i), (c)(ii), (c)(iii), (d)

|      |                                                                                                                           |   |
|------|---------------------------------------------------------------------------------------------------------------------------|---|
| 1(f) | <b>M1</b> products contain C <sup>+</sup> AND C <sub>2</sub>                                                              | 1 |
|      | <b>M2</b> correct balanced equation $\text{C/O}^- + 2\text{HCl} \rightarrow \text{C}^+ + \text{H}_2\text{O} + \text{C}_2$ | 1 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2021 9701/23 · Q1 (f)

|           |                                                                               |   |
|-----------|-------------------------------------------------------------------------------|---|
| 1(c)(iii) | <b>M1</b> S (increases) oxidation number -2 → 0 so oxidation / or is oxidised | 2 |
|           | <b>M2</b> O (decreases) O.N. 0 → -2 so reduction / is reduced                 |   |

Oct/Nov 2021 9701/21 · Q1 (c)(iii)

|         |        |   |
|---------|--------|---|
| 3(b)(i) | (+)5/V | 1 |
|---------|--------|---|

Oct/Nov 2021 9701/21 · Q3 (b)(i)

|           |                                                                                                               |   |
|-----------|---------------------------------------------------------------------------------------------------------------|---|
| 4(a)(i)   | potassium/sodium dichromate [(VI)] / $K_2Cr_2O_7$ / $Na_2Cr_2O_7$<br>acidified <b>AND</b> (heat) under reflux | 2 |
| 4(a)(ii)  | $C_2H_5OH + 2[O] \rightarrow CH_3CO_2H + H_2O$                                                                | 1 |
| 4(a)(iii) | substitution                                                                                                  | 1 |
| 4(c)(i)   | $NaO-C(=O)-CH_2OH \quad \text{OR} \quad Na^+ \quad ^-O-C(=O)-CH_2OH$                                          | 1 |
| 4(c)(ii)  | Not a strong (enough) reducing agent                                                                          | 1 |

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| Question  | Answer                                                                              | Marks |
|-----------|-------------------------------------------------------------------------------------|-------|
| 4(c)(iii) | Construct an equation<br>$(CH_2OH)_2 + SOCl_2 \rightarrow (CH_2Cl)_2 + SO_2 + H_2O$ | 1     |
| 4(d)      | Forms hydrogen bonds <b>with water</b>                                              | 1     |

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Oct/Nov 2021 9701/21 · Q4 (a)(i), (a)(ii), (a)(iii), (c)(i), (c)(ii), (c)(iii), (d)

|          |                                                                                                                                                                                                                                                                                |   |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 1(d)(ii) | <b>M1</b> I / iodine (increases) oxidation number $-1 \rightarrow 0$ so oxidation / is oxidised<br><b>OR</b><br>HI / is oxidised as I (increases) oxidation number $-1 \rightarrow 0$<br><b>M2</b> O (decreases) oxidation number $0 \rightarrow -2$ so reduction / is reduced | 2 |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2021 9701/22 · Q1 (d)(ii)

|          |                                                                                                                                                  |   |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2(a)(iv) | <div style="border: 1px solid black; display: inline-block; padding: 2px;">             (+)1   (+)2   (+)3   (+)4   (+)5   (+)6           </div> | 1 |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2021 9701/22 · Q2 (a)(iv)

|          |                |   |
|----------|----------------|---|
| 3(e)(ii) | Iodine / $I_2$ | 1 |
|----------|----------------|---|

Oct/Nov 2021 9701/22 · Q3 (e)(ii)

|      |                                        |          |
|------|----------------------------------------|----------|
| 4(d) | Forms hydrogen bonds <b>with water</b> | <b>1</b> |
|------|----------------------------------------|----------|

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Oct/Nov 2021 9701/23 · Q4 (d)

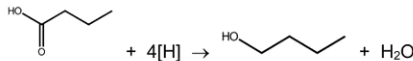
|           |                                                                                                                                                            |          |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 2(a)(i)   | species that donates electrons                                                                                                                             | <b>1</b> |
| 2(b)(i)   | reacts with both acids and bases / shows both acidic and basic behaviour                                                                                   | <b>1</b> |
| 2(b)(ii)  | $\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl}(\text{OH})_4$                                                         | <b>1</b> |
| 2(c)(i)   | (structure =) simple/molecular, because it has a low melting/boiling point [1]<br>(bonding =) covalent, because it is hydrolysed [1]                       | <b>2</b> |
| 2(c)(ii)  | (+ )3 / III                                                                                                                                                | <b>1</b> |
| 2(d)(ii)  | peroxyac(et)ynitrate / PAN                                                                                                                                 | <b>1</b> |
| 2(d)(iii) | position of equilibrium moves / farther to right (at 20 km) [1]<br>(forward) reaction is exothermic <b>AND</b> temperature colder at 20 km (cf. 50 km) [1] | <b>2</b> |

| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

March 2022 9701/22 · Q2 (a)(i), (b)(i), (b)(ii), (c)(i), (c)(ii), (d)(ii), (d)(iii)

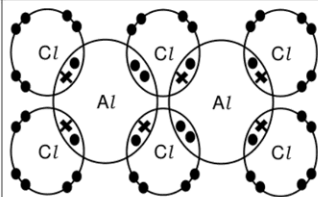
|         |                  |                                      |                                     |          |
|---------|------------------|--------------------------------------|-------------------------------------|----------|
| 1(b)(i) | species          | magnesium in $\text{Mg}_3\text{N}_2$ | nitrogen in $\text{Mg}_3\text{N}_2$ | <b>1</b> |
|         | oxidation number | 2(+) / (+)II                         | 3- / -III                           |          |

May/June 2022 9701/22 · Q1 (b)(i)

|           |                                                                                                                                                                                                                                |          |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 5(c)(iii) | $\text{HOOC}(\text{CH}_2)_2\text{CH}_3 + 4[\text{H}] \rightarrow \text{HO}(\text{CH}_2)_3\text{CH}_3 + \text{H}_2\text{O}$<br><b>OR</b><br> | <b>1</b> |
| 5(c)(iv)  | $\text{LiAlH}_4$ <b>OR</b> lithium tetrahydridoaluminate (in ether)                                                                                                                                                            | <b>1</b> |

| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2022 9701/22 · Q5 (c)(iii), (c)(iv)

|                                                                                        |                                                                                                                                                                                                                                                                                                             |                   |                   |                   |                  |   |        |   |   |   |
|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------------------|-------------------|------------------|---|--------|---|---|---|
| 2(a)                                                                                   | <table border="1"> <tr> <td>NaCl</td> <td>AlCl<sub>3</sub></td> <td>SiCl<sub>4</sub></td> <td>PCl<sub>5</sub></td> </tr> <tr> <td>I</td> <td>I OR C</td> <td>C</td> <td>C</td> </tr> </table>                                                                                                               | NaCl              | AlCl <sub>3</sub> | SiCl <sub>4</sub> | PCl <sub>5</sub> | I | I OR C | C | C | 1 |
|                                                                                        | NaCl                                                                                                                                                                                                                                                                                                        | AlCl <sub>3</sub> | SiCl <sub>4</sub> | PCl <sub>5</sub>  |                  |   |        |   |   |   |
|                                                                                        | I                                                                                                                                                                                                                                                                                                           | I OR C            | C                 | C                 |                  |   |        |   |   |   |
|                                                                                        | <table border="1"> <tr> <td>G</td> <td>G</td> <td>S</td> <td>S</td> </tr> </table>                                                                                                                                                                                                                          | G                 | G                 | S                 | S                | 1 |        |   |   |   |
| G                                                                                      | G                                                                                                                                                                                                                                                                                                           | S                 | S                 |                   |                  |   |        |   |   |   |
| <table border="1"> <tr> <td>+1</td> <td>+3</td> <td>+4</td> <td>+5</td> </tr> </table> | +1                                                                                                                                                                                                                                                                                                          | +3                | +4                | +5                | 1                |   |        |   |   |   |
| +1                                                                                     | +3                                                                                                                                                                                                                                                                                                          | +4                | +5                |                   |                  |   |        |   |   |   |
| <table border="1"> <tr> <td>+3</td> <td>+2</td> </tr> </table>                         | +3                                                                                                                                                                                                                                                                                                          | +2                | 1                 |                   |                  |   |        |   |   |   |
| +3                                                                                     | +2                                                                                                                                                                                                                                                                                                          |                   |                   |                   |                  |   |        |   |   |   |
| 2(b)                                                                                   | <b>M1</b> $\text{NaCl(s)} \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$                                                                                                                                                                                                                      | 1                 |                   |                   |                  |   |        |   |   |   |
|                                                                                        | $\text{PCl}_5(\text{s}) + 4\text{H}_2\text{O(l)} \rightarrow \text{H}_3\text{PO}_4(\text{aq}) + 5\text{HCl(aq)}$<br><b>M2</b> balanced equation                                                                                                                                                             | 1                 |                   |                   |                  |   |        |   |   |   |
|                                                                                        | <b>M3</b> all state symbols for PCl <sub>5</sub> equation                                                                                                                                                                                                                                                   | 1                 |                   |                   |                  |   |        |   |   |   |
| 2(c)(i)                                                                                |                                                                                                                                                                                                                            | 1                 |                   |                   |                  |   |        |   |   |   |
|                                                                                        | <p>'dot-and-cross' diagram to show</p> <p><b>M1</b> correct number and connectivity of Cl and Al atoms</p> <p><b>M2</b> 2 correct dative bonds (••) between Cl and Al of AlCl<sub>3</sub> neighbour <b>AND</b> correct number of non-bonding electrons around each atom of Al<sub>2</sub>Cl<sub>6</sub></p> | 1                 |                   |                   |                  |   |        |   |   |   |

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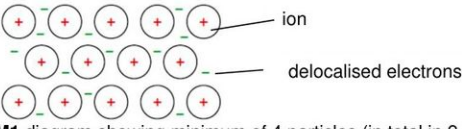
| Question | Answer                                                                                                                                                                                                                                                                                                    | Marks |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 2(c)(ii) | reaction is exothermic so equilibrium shifts to the LHS<br>OR<br>equilibrium shifts to LHS because forward reaction is exothermic<br>OR<br>equilibrium shifts to LHS because backward reaction is endothermic<br>OR<br>endothermic reaction is favoured so more reactants / are AlCl <sub>3</sub> is made | 1     |
| 2(e)(i)  | <b>M1</b> orange colour (of solution) remains / no visible reaction                                                                                                                                                                                                                                       | 1     |
|          | <b>M2</b><br>bromine/Br <sub>2</sub> cannot oxidise chloride/Cl <sup>-</sup><br>OR<br>bromine/Br <sub>2</sub> is not a strong enough oxidising agent (to oxidise chloride/Cl <sup>-</sup> )                                                                                                               | 1     |

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| Question | Answer                                                                                                                                                                                                                                                                                                                       | Marks |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|
| 2(e)(ii) | <b>M1</b> sum of instantaneous dipole – dipole attractions and permanent dipole attractions in SCl <sub>2</sub> is greater than those in SBr <sub>2</sub><br>OR<br>permanent dipole-permanent dipole (forces) in SCl <sub>2</sub> are stronger<br>OR<br>intermolecular forces are stronger in SCl <sub>2</sub><br><b>ora</b> | 1     |
|          | <b>M2</b> SCl <sub>2</sub> (molecule / bond) is more polar than SBr <sub>2</sub><br>OR<br>Cl is more electronegative than Br so SCl <sub>2</sub> has stronger (permanent) dipoles <b>ora</b>                                                                                                                                 | 1     |

Oct/Nov 2022 9701/22 · Q2 (a), (b), (c)(i), (c)(ii), (e)(i), (e)(ii), (f)(i), (f)(ii) (continued ·)

|          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2(f)(i)  |  <p><b>M1</b> diagram showing minimum of 4 particles (in total in 2 rows)</p> <ul style="list-style-type: none"> <li>circles containing <math>\text{Bi}^{n+}</math> do not have to be labelled</li> <li>must be labelled as 'ion' OR empty circles / circles with Bi must be labelled + ion / positive ion / cation / <math>\text{Bi}^{n+}</math></li> </ul> <p>AND</p> <ul style="list-style-type: none"> <li>with the circles surrounded by electrons shown as <math>e^-</math> / – OR little circles labelled electrons</li> </ul> <p><b>M2</b> label / legend showing <u>delocalised</u> electrons</p> | 1 |
| 2(f)(ii) | <p><b>M1</b> (structure =) simple/molecular, because it has a low melting/boiling point <i>owtte</i></p> <p><b>M2</b> (bonding =) covalent, because it is hydrolysed</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

Oct/Nov 2022 9701/22 · Q2 (a), (b), (c)(i), (c)(ii), (e)(i), (e)(ii), (f)(i), (f)(ii) (cont.)

|         |                                                                                                                                                                              |   |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 1(f)(i) | $\text{TeF}_x + x\text{H}_2\text{O} \rightarrow \text{Te}(\text{OH})_x + x\text{HF}$ OR $\text{TeF}_6 + 6\text{H}_2\text{O} \rightarrow \text{Te}(\text{OH})_6 + 6\text{HF}$ | 1 |
|---------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|

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| Question | Answer     | Marks |
|----------|------------|-------|
| 1f(ii)   | hydrolysis | 1     |

| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2023 9701/21 · Q1 (f)(i)

|          |                                                                                                                             |   |
|----------|-----------------------------------------------------------------------------------------------------------------------------|---|
| 3(c)(ii) | oxidation number / state of <u>chlorine</u> / <u>Cl</u> increases / goes (from 0) to +5 AND decreases / goes (from 0) to –1 | 1 |
|----------|-----------------------------------------------------------------------------------------------------------------------------|---|

May/June 2023 9701/21 · Q3 (c)(ii)

|           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |   |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2(a)(ii)  | number of outer/valence electrons                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 1 |
| 2(b)(i)   | $\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 1 |
| 2(b)(ii)  | 1–4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1 |
| 2(c)(i)   | $\text{PCl}_5 + 4\text{H}_2\text{O} \rightarrow 5\text{HCl} + \text{H}_3\text{PO}_4$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 |
| 2(c)(ii)  | 1–4                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 1 |
| 2(d)(ii)  | $3\text{Cl}_2 + 6\text{NaOH} \rightarrow 5\text{NaCl} + \text{NaClO}_3 + 3\text{H}_2\text{O}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1 |
| 2(e)(i)   | $\text{ClO}^-$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 1 |
| 2(e)(ii)  | $\text{NaClO} + \text{H}_2\text{O}_2 \rightarrow \text{O}_2 + \text{NaCl} + \text{H}_2\text{O}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 1 |
| 2(e)(iii) | <p><b>M1</b> (show how to calculate) mol <math>\text{O}_2</math> gas<br/> <math>42 \text{ cm}^3 \text{ gas} = 42 / 24000 \text{ mol oxygen gas} (= 1.75 \times 10^{-3} \text{ mol})</math><br/> <b>M2</b> (process to find) amount <math>\text{NaClO}</math> in <math>10 \text{ cm}^3</math> sample = <math>100 \text{ cm}^3</math> (diluted) bleach<br/> <math>\text{M1} \times 4 (= 4 \times 1.75 \times 10^{-3} \text{ mol in } 10 \text{ cm}^3 = 0.007)</math><br/> <b>M3</b> correct calculation using M2 to find concentration<br/> <math>= (\text{M2} / 10) \times 1000 \times 74.5 = 52.2 \text{ (g / dm}^3\text{)}</math></p> | 3 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2023 9701/22 · Q2 (a)(ii), (b)(i), (b)(ii), (c)(i), (c)(ii), (d)(ii), (e)(i), (e)(ii), (e)(iii)

|          |                                                                                                                          |   |
|----------|--------------------------------------------------------------------------------------------------------------------------|---|
| 1(d)(ii) | Cu <sup>2+</sup> OR CuSO <sub>4</sub> <b>AND</b> copper (species / ion) has gained / taken electron(s) from iodide (ion) | 1 |
|----------|--------------------------------------------------------------------------------------------------------------------------|---|

May/June 2023 9701/23 · Q1 (d)(ii)

|          |                                                                                          |   |
|----------|------------------------------------------------------------------------------------------|---|
| 1(b)(i)  | $2\text{Bi} + 3\text{H}_2\text{O} \rightarrow \text{Bi}_2\text{O}_3 + 3\text{H}_2$       | 1 |
| 1(c)(i)  | $\text{Bi}_2\text{O}_3$ (+)3 / III <b>AND</b> $\text{NaBiO}_3$ (+)5 / V                  | 1 |
| 1(c)(ii) | $\text{Bi}_2\text{O}_3$                                                                  | 1 |
| 1(d)(i)  | a substance that removes electrons from another / causes electron loss / gains electrons | 1 |
| 1(d)(iv) | $\text{CH}_3\text{CHO} + 2[\text{H}] \rightarrow \text{CH}_3\text{CH}_2\text{OH}$        | 1 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

March 2024 9701/22 · Q1 (b)(i), (c)(i), (c)(ii), (d)(i), (d)(iv)

|         |                    |   |
|---------|--------------------|---|
| 2(b)(i) | disproportionation | 1 |
|---------|--------------------|---|

March 2024 9701/22 · Q2 (b)(i)

|         |           |                                             |
|---------|-----------|---------------------------------------------|
| 2(c)(i) |           | oxidation number in $\text{Mg}_3\text{N}_2$ |
|         | magnesium | (+)II / 2(+)                                |
|         | nitrogen  | –III/ 3 –                                   |

Both correct for one mark

May/June 2024 9701/21 · Q2 (c)(i)

|          |                                     |   |
|----------|-------------------------------------|---|
| 1(b)(ii) | number of outer / valence electrons | 1 |
| 1(d)(i)  | (+)IV                               | 1 |

May/June 2024 9701/23 · Q1 (b)(ii), (d)(i)

|          |                                                                                                              |   |
|----------|--------------------------------------------------------------------------------------------------------------|---|
| 2(c)(ii) | a reaction where a species / same species is both oxidised and reduced simultaneously / in the same reaction | 1 |
|----------|--------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2024 9701/21 · Q2 (c)(ii)

|         |                                                                                                 |   |
|---------|-------------------------------------------------------------------------------------------------|---|
| 4(c)(i) | $\text{CH}_3\text{COCH}_3 + 2[\text{H}] \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ | 1 |
|---------|-------------------------------------------------------------------------------------------------|---|

Oct/Nov 2024 9701/21 · Q4 (c)(i)

|           |                                                                                                   |   |
|-----------|---------------------------------------------------------------------------------------------------|---|
| 2(a)(iii) | it increases                                                                                      | 1 |
|           | as number of valence electrons (which can be used in bonding / lost / shared / donated) increases | 1 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

Oct/Nov 2024 9701/22 · Q2 (a)(iii)

|         |          |   |
|---------|----------|---|
| 3(b)(i) | (+)5 / V | 1 |
|---------|----------|---|

Oct/Nov 2024 9701/22 · Q3 (b)(i)

|          |                                                                                                              |   |
|----------|--------------------------------------------------------------------------------------------------------------|---|
| 2(c)(ii) | a reaction where a species / same species is both oxidised and reduced simultaneously / in the same reaction | 1 |
|----------|--------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2024 9701/23 · Q2 (c)(ii)

|           |                                                                                                                                    |   |
|-----------|------------------------------------------------------------------------------------------------------------------------------------|---|
| 1(a)(i)   | <ul style="list-style-type: none"> <li>• (+)3 / III      • -1 / I</li> <li>• (+)5 / V      • -1 / I</li> </ul>                     | 2 |
| 1(a)(ii)  | high pressure<br>low temperature                                                                                                   | 2 |
| 1(a)(iv)  | (structure ⇒) simple / molecular because low melting point / weak intermolecular forces<br>(bonding ⇒) covalent because hydrolysed | 2 |
| 1(b)(i)   | green colour (of gas) disappears                                                                                                   | 1 |
| 1(b)(iii) | $P_4 + 5O_2 \rightarrow P_4O_{10}$                                                                                                 | 1 |
| 1(b)(iv)  | phosphoric(V) acid                                                                                                                 | 1 |
| 1(b)(v)   | HO—CH <sub>2</sub> —CH <sub>2</sub> —OH                                                                                            | 1 |
| 1(c)(i)   | contains a(/ one or more) C=C / double / multiple bonds                                                                            | 1 |
| 1(c)(ii)  | ethanol (solvent) <b>AND</b> heat                                                                                                  | 1 |
| 1(d)(ii)  | <b>D</b> is $Cl-C \equiv C-H$                                                                                                      | 1 |

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| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

March 2025 9701/22 · Q1 (a)(i), (a)(ii), (a)(iv), (b)(i), (b)(iii), (b)(iv), (b)(v), (c)(i), (c)(ii), (d)(ii)

|      |                                                                                                                                                                                                                              |   |
|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 1(c) | <b>M1</b> $NaCl + 1$ <b>AND</b> $PCl_5 + 5$<br><b>M2</b> Na has only 1 valence (shell) electrons <b>AND</b> P has 5                                                                                                          | 2 |
| 1(d) | <i>All three for two marks:</i> <ul style="list-style-type: none"> <li>• false</li> <li>• comparison or statement of oxidation number</li> <li>• correct link to melting point from their comparison or statement</li> </ul> | 2 |

| Question | Answer | Marks |
|----------|--------|-------|
|----------|--------|-------|

May/June 2025 9701/21 · Q1 (c), (d)

|         |           |   |
|---------|-----------|---|
| 5(e)(i) | $LiAlH_4$ | 1 |
|---------|-----------|---|

May/June 2025 9701/21 · Q5 (e)(i)

|         |        |   |
|---------|--------|---|
| 2(c)(i) | $SO_3$ | 1 |
|---------|--------|---|

May/June 2025 9701/23 · Q2 (c)(i)

|          |                                                                                                      |   |
|----------|------------------------------------------------------------------------------------------------------|---|
| 2(b)(ii) | oxidation number of S in $SCl_2 = (+)2 / (+)II$<br>oxidation number of S in $H_2SO_3 = (+)4 / (+)IV$ | 2 |
|----------|------------------------------------------------------------------------------------------------------|---|

May/June 2025 9701/24 · Q2 (b)(ii)

|          |      |   |
|----------|------|---|
| 1(c)(ii) | (+)4 | 1 |
|----------|------|---|

Oct/Nov 2025 9701/21 · Q1 (c)(ii)

|         |    |       |      |      |      |      |      |   |
|---------|----|-------|------|------|------|------|------|---|
| 2(b)(i) | M1 | (+)1  | (+)2 | (+)3 | (+)4 | (+)5 | (+)6 | 2 |
|         | M2 | 12-14 | 8-10 | —    | —    | 0-4  | 0-4  |   |

Oct/Nov 2025 9701/21 · Q2 (b)(i)

|          |                                            |   |
|----------|--------------------------------------------|---|
| 1(c)(i)  | Mn / $MnO_2$ <b>AND</b> it gains electrons | 1 |
| 1(c)(ii) | (+)4                                       | 1 |

Oct/Nov 2025 9701/22 · Q1 (c)(i), (c)(ii)

|      |           |    |     |     |     |     |          |
|------|-----------|----|-----|-----|-----|-----|----------|
| 2(c) | <b>M1</b> | +1 | +2  | +3  | +4  | +5  | <b>4</b> |
|      | <b>M2</b> | 7  | 6.5 | 0–4 | 0–4 | 0–4 |          |
|      | <b>M3</b> | I  | I   | I   | C   | C   |          |
|      | <b>M4</b> | G  | G   | G   | S   | S   |          |

Oct/Nov 2025 9701/22 · Q2 (c)

|          |                                                                                                                               |          |
|----------|-------------------------------------------------------------------------------------------------------------------------------|----------|
| 4(c)(ii) | $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + 2[\text{O}] \rightarrow \text{CH}_3\text{CH}_2\text{COOH} + \text{H}_2\text{O}$ | <b>1</b> |
|----------|-------------------------------------------------------------------------------------------------------------------------------|----------|

Oct/Nov 2025 9701/22 · Q4 (c)(ii)