

|         |                                                                                             |   |
|---------|---------------------------------------------------------------------------------------------|---|
| 3(b)(i) | general shape of the curve and peak are displaced to right of original and starts at origin | 1 |
|         | the peak is lower and curve crosses once only finishing <b>above</b> original               | 1 |

May/June 2017 9701/22 · Q3 (b)(i)

|          |                                                                                                                                                                                                                                                                                                                 |   |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 3(a)(i)  | (enthalpy / energy change) when one mole of a compound is formed                                                                                                                                                                                                                                                | 1 |
|          | from its elements in their standard states / standard conditions                                                                                                                                                                                                                                                | 1 |
| 3(a)(ii) | $(\Delta H_f = \sum \Delta H_f \text{ products} - \sum \Delta H_f \text{ reactants})$<br>$-196 = 2\Delta H_f \text{ SO}_3 - (2 \times -296.8)$<br>$2\Delta H_f \text{ SO}_3 = -196 + (2 \times -296.8) = -789.6$                                                                                                | 1 |
|          | $\Delta H_f \text{ SO}_3 = -394.8 \text{ (kJ mol}^{-1}\text{)}$                                                                                                                                                                                                                                                 | 1 |
| 3(b)(ii) | 2 marks for any two points: <ul style="list-style-type: none"> <li>• Benefit of using a catalyst in terms of increasing rate or economic benefit i.e. (less heat required)</li> <li>• Creates alternative pathway with lower <math>E_a</math></li> <li>• More molecules with <math>E &gt; E_a</math></li> </ul> | 2 |
| 3(c)(i)  | $\text{SO}_2 = 0.01 \text{ (mol)}$<br>AND<br>$\text{SO}_3 = 0.99 \text{ (mol)}$                                                                                                                                                                                                                                 | 1 |
| 3(c)(ii) | $n_{\text{TOT}} = 1.505$                                                                                                                                                                                                                                                                                        | 1 |
|          | $p\text{O}_2 = 1.50 \times 10^5 \times (0.505 / 1.505) = 5.03 \times 10^4 \text{ (Pa)}$                                                                                                                                                                                                                         | 1 |

May/June 2017 9701/23 · Q3 (a)(i), (a)(ii), (b)(ii), (c)(i), (c)(ii)

|           |                                                                                                                        |   |
|-----------|------------------------------------------------------------------------------------------------------------------------|---|
| 1(d)(iii) | <b>M1</b> $+82 (= E_{\text{O=O}} - 2E_{\text{N-O}}) = (+)496 - 2 \times E_{\text{N-O}}$                                | 2 |
|           | <b>M2</b> $E_{\text{N-O}} = \frac{1}{2} \times (496 - 82) = \frac{1}{2} \times 414 = 207 \text{ (kJ mol}^{-1}\text{)}$ |   |

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

March 2019 9701/22 · Q1 (d)(iii)

|           |                                                                 |   |
|-----------|-----------------------------------------------------------------|---|
| 2(c)(iii) | <b>M1</b> labelled reactants <b>AND</b> products lower on right | 2 |
|           | <b>M2</b> labelled enthalpy change with correct arrow           |   |

March 2019 9701/22 · Q2 (c)(iii)

|           |                                                                                                                                                                                  |   |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 1(c)(iii) | <b>M1</b> 3p                                                                                                                                                                     | 2 |
|           | <b>M2</b> It is less attracted to the nucleus (so takes less energy to lose)<br>OR<br>It is the highest energy orbital (which is occupied) / it is in the highest energy orbital |   |

May/June 2019 9701/23 · Q1 (c)(iii)

|          |                                                                                                                                                                            |   |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2(c)(ii) | <b>M1:</b> use of the correct expression in terms of specific bond energies.<br>( $514 - xE_{\text{Se-O}} = -346$ )                                                        | 2 |
|          | <b>M2:</b> use of correct stoichiometry AND correct processing of expression given in M1. Provided the values 514 and 346 are used.<br>( $514 - 2E_{\text{Se-O}} = -346$ ) |   |
|          | $= (+)430 \text{ (kJ mol}^{-1}\text{)}$                                                                                                                                    |   |

Oct/Nov 2019 9701/21 · Q2 (c)(ii)

|           |                                                                                                                                                                                                                                                                                                      |          |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(b)(ii)  | <b>M1</b> (enthalpy change when) 1 mol of a substance<br><b>M2</b> EITHER burns / combusts / reacts in excess air / oxygen<br>OR completely burns / combusts / reacts in air / oxygen                                                                                                                | <b>2</b> |
| 3(b)(iii) | <b>M1</b> $m = 200$ and $\Delta T = 37.5 - 18.5$<br><b>M2</b> $Q = mc \Delta T = 200 \times 4.18 \times (37.5 - 18.5) = 15\,884 \text{ (J)}$                                                                                                                                                         | <b>2</b> |
| 3(b)(iv)  | <b>M1</b> mol of thiophene used<br>$= 0.63 / 84.1$ OR $7.49(1\,082\,045) \times 10^{-3}$<br><b>M2</b> calculation $\div 1000$ AND negative sign<br>$\Delta H_c = \frac{-(iii)}{1000} \div n = \frac{-(iii)}{21000} \div (0.63 / 84.1)$<br>$= -2120 \text{ } (-2120.39) \text{ (kJ mol}^{-1}\text{)}$ | <b>2</b> |

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

Oct/Nov 2019 9701/21 · Q3 (b)(ii), (b)(iii), (b)(iv)

|           |                                                                                                                                                |          |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1(g)(ii)  | <b>M1</b> (enthalpy / energy change) when one mole of a compound / substance is formed<br><b>M2</b> from its elements in their standard states | <b>2</b> |
| 1(g)(iii) | $-(-602 + -188) + (\Delta H_f[\text{MgO}_2] + -286) = -96$<br>$\Delta H_f[\text{MgO}_2] = -600 \text{ (kJ mol}^{-1}\text{)}$                   | <b>2</b> |
| 1(g)(iv)  | $-(-600) - (+602) = -2 \text{ (kJ mol}^{-1}\text{)}$                                                                                           | <b>1</b> |

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

March 2020 9701/22 · Q1 (g)(ii), (g)(iii), (g)(iv)

|      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |          |
|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(a) | <b>M1</b> (enthalpy / energy change) when one mole of a compound/substance is formed<br><b>M2</b> from its elements in their standard states                                                                                                                                                                                                                                                                                                                                       | <b>2</b> |
| 3(b) | <b>M1</b> <i>use of correct stoichiometry in calculation</i><br>$3x\Delta H_f \text{ NO}_2 \quad 1x-\Delta H_f \text{ H}_2\text{O} \quad 2x\Delta H_f \text{ HNO}_3 \quad 1x\Delta H_f \text{ NO}$<br><b>M2</b> <i>correct signs associated with the appropriate <math>\Delta H_f</math> values/terms used for the calculation of <math>\Delta H_{\text{reaction}}</math></i><br><b>M3</b> $\Delta H_{\text{reaction}} = -(102 - 286) + (-346 + 91.1) = -70.9 \text{ kJ mol}^{-1}$ | <b>3</b> |
| 3(c) | <b>M1</b> nitrogen has a triple bond<br><b>M2</b> EITHER<br>high energy is needed to break the bond<br>OR<br>at normal temperatures there is not enough energy to break the bond / to overcome the activation energy                                                                                                                                                                                                                                                               | <b>2</b> |
| 3(d) | lightning                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>1</b> |

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| Question | Answer                                                                                                                                                                                                                                                                                                                                                                                                                | Marks    |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(e)(i)  | <b>M1</b> <i>define homogeneous</i><br>(homogeneous catalyst is) in the same phase / state as the reactants<br><b>M2 and M3</b> <i>Define catalyst</i><br><i>All 3 points scores 2 marks. Any 2 points scores 1 mark</i><br>increase the rate<br><b>AND</b><br>lowers the activation energy<br><b>AND</b><br>without being chemically altered at the end of the reaction / are regenerated at the end of the reaction |          |
| 3(e)(ii) | <b>M1</b> $\text{NO}_2 + \text{SO}_2 \rightarrow \text{NO} + \text{SO}_3$<br><b>M2</b> $\text{NO} + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_2$                                                                                                                                                                                                                                                                   | <b>2</b> |

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

May/June 2020 9701/21 · Q3 (a), (b), (c), (d), (e)(i), (e)(ii)

|          |                                                                                                                                                                                                                                                                                                                                                                                                                                             |          |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(d)(i)  | <b>M1</b> (enthalpy change) when 1 mole of sucrose<br><b>M2</b> burns/combusts/reacts in excess air/oxygen<br><b>OR</b><br>completely burns/combusts/reacts in air/oxygen                                                                                                                                                                                                                                                                   | <b>2</b> |
| 3(d)(ii) | <b>M1</b> for finding amount of energy released per gram of sucrose using $\Delta H / Q = mc\Delta T$ OR $\Delta H = -mc\Delta T$<br>= $(-250 \times 4.18 \times (40.7 - 25)) = (-)16406.5$ J per gram OR $(-)16.4065$ kJ / g<br><b>M2</b> for finding amount (mol) sucrose in 1g = $1/342$ mol<br><b>M3</b> = $M1 / (M2 \times 1000)$<br>$\Delta H = -5610$ kJ mol <sup>-1</sup> (3 sig figs) OR $-5611$ kJ mol <sup>-1</sup> (4 sig figs) | <b>3</b> |

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

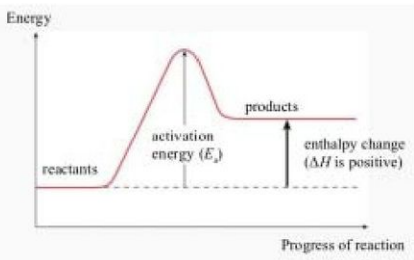
May/June 2020 9701/22 · Q3 (d)(i), (d)(ii)

|          |                                                                                                                                                                               |          |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(c)(i)  | <b>M1</b> (enthalpy change) when 1 mole of a substance<br><b>M2</b> burns/combusts/reacts in excess air/oxygen<br><b>OR</b><br>completely burns/combusts/reacts in air/oxygen | <b>2</b> |
| 3(c)(ii) | $C_{12}H_{22}O_{11} + 12 O_2 \rightarrow 12CO_2 + 11H_2O$                                                                                                                     | <b>1</b> |

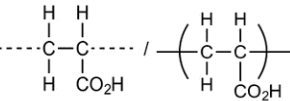
May/June 2020 9701/23 · Q3 (c)(i), (c)(ii)

|          |                                                                                                |          |
|----------|------------------------------------------------------------------------------------------------|----------|
| 2(c)(ii) | <b>M1:</b> $\Delta H_r = -1434 - (-635 + -297)$<br><b>M2:</b> = $-502$ (kJ mol <sup>-1</sup> ) | <b>2</b> |
|----------|------------------------------------------------------------------------------------------------|----------|

Oct/Nov 2020 9701/21 · Q2 (c)(ii)

|         |                                                                                                                                                                                                                               |          |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1(c)(i) |  <p><b>M1:</b> end higher than start AND 'hill' for <math>E_a</math><br/><b>M2:</b> <math>E_a</math> AND <math>\Delta H</math> labelled</p> | <b>2</b> |
|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|

March 2021 9701/22 · Q1 (c)(i)

|           |                                                                                                                                                                                                                    |          |
|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(a)(i)   | <b>M1:</b> $\Delta H_f + (-2036) = 4 \times -384$<br><b>M2:</b> $\Delta H_f = (+)500$                                                                                                                              | <b>2</b> |
| 3(a)(ii)  | strong triple bond / high activation energy                                                                                                                                                                        | <b>1</b> |
| 3(b)(i)   | <b>M1:</b> proton / $H^+$ donor<br><b>M2:</b> partially dissociates / does not fully dissociate (in solution)                                                                                                      | <b>2</b> |
| 3(b)(ii)  | <b>M1:</b> overlap of two p orbitals side-on / above and below the plane<br><b>M2:</b><br> <p>pi (<math>\pi</math>) orbital</p> | <b>2</b> |
| 3(d)(i)   | addition polymerisation                                                                                                                                                                                            | <b>1</b> |
| 3(d)(ii)  |                                                                                                                                 | <b>1</b> |
| 3(d)(iii) | propan-1-amine / 1-aminopropane                                                                                                                                                                                    | <b>1</b> |
| 3(d)(iv)  | alcoholic / ethanolic solution<br>AND high pressure / heat in a sealed container                                                                                                                                   | <b>1</b> |

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

March 2021 9701/22 · Q3 (a)(i), (a)(ii), (b)(i), (b)(ii), (d)(i), (d)(ii), (d)(iii), (d)(iv)

|          |                                                                                                                                                                                                                                                               |          |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1(b)(i)  | <b>M1</b> (enthalpy/energy change when) 1 mole of a compound<br><b>M2</b> burns/combusts/reacts in <b>excess</b> oxygen/O <sub>2</sub><br><b>OR</b><br><b>completely</b> burns/ <b>completely</b> combusts/ <b>completely</b> reacts in oxygen/O <sub>2</sub> | <b>2</b> |
| 1(b)(ii) | <b>M1</b> $(-394 + 2(-297) - (+89.7))$<br><b>M2</b> = $-1080$ (kJ mol <sup>-1</sup> )                                                                                                                                                                         | <b>2</b> |

Oct/Nov 2021 9701/21 · Q1 (b)(i), (b)(ii)

|      |                                                                                                             |          |
|------|-------------------------------------------------------------------------------------------------------------|----------|
| 1(b) | (enthalpy / energy change) when one mole of a compound is formed from its elements in their standard states | <b>2</b> |
|------|-------------------------------------------------------------------------------------------------------------|----------|

Oct/Nov 2021 9701/22 · Q1 (b)

|           |                                 |          |
|-----------|---------------------------------|----------|
| 2(c)(iii) | $-1640$ (kJ mol <sup>-1</sup> ) | <b>1</b> |
|-----------|---------------------------------|----------|

March 2022 9701/22 · Q2 (c)(iii)

|           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |          |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1(b)(iii) | <b>M1</b> (enthalpy change / energy change) when one mole of a compound / substance is formed from its elements in their standard states                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>2</b> |
| 1(b)(iv)  | <b>M1</b> correct method to find amount Mg <sub>3</sub> N <sub>2</sub> formed in reaction<br>$3.645 \div 24.3$ mol Mg produces $0.15 \div 3$ mol of Mg <sub>3</sub> N <sub>2</sub> <b>OR</b> $0.05$ mol of Mg <sub>3</sub> N <sub>2</sub><br><b>M2</b> use <b>M1</b> in correct expression to find energy released by 1 mol Mg <sub>3</sub> N <sub>2</sub><br>$23.05 \div \mathbf{M1}$ <b>OR</b> $23.05 \div \text{mol Mg}_3\text{N}_2$<br><b>OR</b> $23\,050 \div \mathbf{M1}$ <b>OR</b> $23\,050 \div \text{Mg}_3\text{N}_2$<br><b>M3</b> calculate value from <b>M2</b> expression correctly<br>$\Delta H = -(\mathbf{M2}) = -461(.0)$ kJ mol <sup>-1</sup> <b>OR</b> $-461\,000$ J mol <sup>-1</sup> | <b>3</b> |

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

May/June 2022 9701/22 · Q1 (b)(iii), (b)(iv)

|          |                                                                                                                                                                                                                                                                                                                |          |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(d)(ii) | Correct use of enthalpy values / correct direction / use of arrows (with or without an energy cycle)<br><b>M1</b> $((-58.2) + (-40.6))$ <b>OR</b> $(-98.8)$<br><b>M2</b> $((-58.2 + 4(-40.6) = 8\Delta H_f))$<br>Correct calculation and correct stoichiometry<br>$\Delta H_f = -27.6$ (kJ mol <sup>-1</sup> ) | <b>2</b> |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|

Oct/Nov 2022 9701/23 · Q3 (d)(ii)

|          |                                                                                                                                                                                                                                                                                                                                                                                                                             |          |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 2(a)     | <b>M1</b> (enthalpy change) when 1 mole of water is formed<br><b>M2</b> from an (aqueous) acid and an alkali / (aqueous) base                                                                                                                                                                                                                                                                                               | <b>2</b> |
| 2(b)(i)  | $0.05$ mol                                                                                                                                                                                                                                                                                                                                                                                                                  | <b>1</b> |
| 2(b)(ii) | <b>M1</b> correct volume and correct temperature change<br><b>M2</b> calculation to calculate Q based on M1 volume and temp and $Q = mc\Delta T$<br>$Q = mc\Delta T = 175 \times 4.18 \times (27.8 - 20) = (-)5705.7$<br><b>M3</b> energy change when 0.1 mol H <sub>2</sub> O is made with appropriate unit and sign<br>$\Delta H = \mathbf{M2} / 0.1 = -57.1$ kJ mol <sup>-1</sup> <b>OR</b> $-57100$ J mol <sup>-1</sup> | <b>3</b> |
| 2(c)(ii) | precipitation (of BaSO <sub>4</sub> ) (also) involves an energy change                                                                                                                                                                                                                                                                                                                                                      | <b>1</b> |

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

May/June 2023 9701/21 · Q2 (a), (b)(i), (b)(ii), (c)(ii)

|          |                                                                                                                                                                                                                                                                                                                                                                                                          |          |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 3(a)     | <b>M1</b> (energy change) when 1 mole of water is formed<br><b>M2</b> from an (aqueous) acid and an alkali / aqueous base                                                                                                                                                                                                                                                                                | <b>2</b> |
| 3(b)(i)  | 0.05 mol (H <sub>2</sub> SO <sub>4</sub> (aq))                                                                                                                                                                                                                                                                                                                                                           | <b>1</b> |
| 3(b)(ii) | <b>M1</b> correct value for Q (using 0.1 mol H <sub>2</sub> O / <b>OR</b> 2 × (b)(i)) (and Q in Joules)<br><b>M2</b> calculate $\Delta T$ (using their Q <b>AND</b> 110)<br>$Q/mc = \Delta T = (Q) \div (4.18 \times 110) = 12.42$ (°C)<br><b>M3</b> use $\Delta T$ and initial temperature to find temperature of final solution<br>$21.4 + M2 = 33.8$ (°C)<br>[M3 $\Delta T + 21.4 = T_{\text{max}}$ ] | <b>3</b> |
| 3(c)(i)  | CH <sub>3</sub> COOH + NaOH → CH <sub>3</sub> COONa + H <sub>2</sub> O                                                                                                                                                                                                                                                                                                                                   | <b>1</b> |
| 3(c)(ii) | (additional) energy is involved / required to fully ionise / dissociate (weak / ethanoic acid)<br><b>OR</b><br>(additional) energy is involved / required to donate/ release H <sup>+</sup> ions                                                                                                                                                                                                         | <b>1</b> |

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

May/June 2023 9701/23 · Q3 (a), (b)(i), (b)(ii), (c)(i), (c)(ii)

|         |                                                                    |          |
|---------|--------------------------------------------------------------------|----------|
| 3(c)(i) | 0 for both $\Delta H_f^\circ$ of N <sub>2</sub> and H <sub>2</sub> | <b>1</b> |
|         | −46 for $\Delta H_f^\circ$ of NH <sub>3</sub>                      | <b>1</b> |

March 2024 9701/22 · Q3 (c)(i)

| 4(a)                           | <b>M1</b> (enthalpy change / energy change) when one mole of a compound / substance is formed<br><b>M2</b> from its elements in their standard states                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>2</b>           |                       |                    |                                |                                                                                                |        |    |                                                                            |        |                 |                                                                         |        |          |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-----------------------|--------------------|--------------------------------|------------------------------------------------------------------------------------------------|--------|----|----------------------------------------------------------------------------|--------|-----------------|-------------------------------------------------------------------------|--------|----------|
| 4(b)(i)                        | <table border="1"> <thead> <tr> <th></th><th>equation for reaction</th><th><math>\Delta H_f^\circ</math></th></tr> </thead> <tbody> <tr> <td>Fe<sub>2</sub>O<sub>3</sub></td><td><math>2\text{Fe (s)} + \frac{3}{2}\text{O}_2\text{(g)} \rightarrow \text{Fe}_2\text{O}_3\text{(s)}</math></td><td>−824.2</td></tr> <tr> <td>CO</td><td><math>\text{C (s)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CO (g)}</math></td><td>−110.5</td></tr> <tr> <td>CO<sub>2</sub></td><td><math>\text{C (s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}</math></td><td>−393.5</td></tr> </tbody> </table> |                    | equation for reaction | $\Delta H_f^\circ$ | Fe <sub>2</sub> O <sub>3</sub> | $2\text{Fe (s)} + \frac{3}{2}\text{O}_2\text{(g)} \rightarrow \text{Fe}_2\text{O}_3\text{(s)}$ | −824.2 | CO | $\text{C (s)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CO (g)}$ | −110.5 | CO <sub>2</sub> | $\text{C (s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$ | −393.5 | <b>2</b> |
|                                | equation for reaction                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | $\Delta H_f^\circ$ |                       |                    |                                |                                                                                                |        |    |                                                                            |        |                 |                                                                         |        |          |
| Fe <sub>2</sub> O <sub>3</sub> | $2\text{Fe (s)} + \frac{3}{2}\text{O}_2\text{(g)} \rightarrow \text{Fe}_2\text{O}_3\text{(s)}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | −824.2             |                       |                    |                                |                                                                                                |        |    |                                                                            |        |                 |                                                                         |        |          |
| CO                             | $\text{C (s)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CO (g)}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | −110.5             |                       |                    |                                |                                                                                                |        |    |                                                                            |        |                 |                                                                         |        |          |
| CO <sub>2</sub>                | $\text{C (s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | −393.5             |                       |                    |                                |                                                                                                |        |    |                                                                            |        |                 |                                                                         |        |          |
| 4(b)(ii)                       | $\Delta H_{\text{reaction}} = -\Delta H_{\text{Fe}_2\text{O}_3} - (3 \times -\Delta H_{\text{CO}}) + (3 \times -\Delta H_{\text{CO}_2})$<br>$= -(-824.2) - (3 \times -110.5) + (3 \times -393.5)$<br>$= -24.8 \text{ kJ mol}^{-1}$<br><ul style="list-style-type: none"> <li>evidence of use of correct expression and / or any rearrangement of only these bond energy values</li> <li>use correct stoichiometry for these bond energy values only</li> <li>calculate their expression correctly provided the expression uses only addition / subtraction and all 3 values</li> </ul>                               | <b>2</b>           |                       |                    |                                |                                                                                                |        |    |                                                                            |        |                 |                                                                         |        |          |

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

May/June 2024 9701/21 · Q4 (a), (b)(i), (b)(ii)

|          |                                                                                                                                                                                                                                                                                                                                                                                                           |   |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 3(a)     | $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$<br><b>M1</b> correct equation only<br><b>M2</b> correct state symbols based on this equation                                                                                                                                                                                                            | 2 |
| 3(b)     | $\Delta H = -(-1264) - (2 \times -46) + (2 \times -134) + (3 \times -286) = (+)230 \text{ kJ mol}^{-1}$<br><b>M1</b> correct expression in terms of all 4 enthalpy changes of formation <b>AND</b> correct stoichiometry (as described in given equation)<br><b>M2</b> correct calculation based on figures given                                                                                         | 2 |
| 3(c)(i)  | giant (molecular and) covalent                                                                                                                                                                                                                                                                                                                                                                            | 1 |
| 3(c)(ii) | <b>M1</b> give correct expression or calculate mol B compared to mol C<br>$78.26 / 10.8 (= 7.246 / 7.25 \text{ mol B})$ <b>AND</b> $21.74 / 12 (= 1.81(2) \text{ mol C})$<br><b>M2</b> Find B : C ratio <b>AND</b> use this to state empirical formula<br>$7.246 \text{ to } 7.25 / 1.817 \text{ to } 1.82 = 3.99 \text{ to } 3.98 \text{ mol B : 1 mol C}$<br>(so) $\text{B}_4\text{C}$ OR $\text{CB}_4$ | 2 |

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

May/June 2024 9701/23 · Q3 (a), (b), (c)(i), (c)(ii)

|      |                                        |   |
|------|----------------------------------------|---|
| 4(b) | $= -37.8 \text{ (kJ mol}^{-1}\text{)}$ | 1 |
|------|----------------------------------------|---|

Oct/Nov 2024 9701/22 · Q4 (b)

|          |                                                                                                                                                                |   |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 3(d)(ii) | <b>M1</b> (reaction 1): $-3115 - 286 + 3292 = -109 \text{ (kJ mol}^{-1}\text{)}$<br><b>M2</b> $\Delta H_2 = -53 - (-109) = (+)56 \text{ (kJ mol}^{-1}\text{)}$ | 2 |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2025 9701/21 · Q3 (d)(ii)

|           |                                                                                                                                                                                                                                                                                                                                                                            |   |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 2(e)(iii) | <b>M1</b> (mixture / solution becomes more) yellow<br><b>M2</b> (forward) reaction is exothermic (equilibrium shifts left)<br><b>OR</b> equilibrium / reaction shifts (left) to absorb (additional) heat / energy<br><b>M3</b> (mixture / solution becomes more) red<br><b>M4</b> fewer moles of gas on right-hand side<br><b>OR</b> (gas on left and) no gas on the right | 4 |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2025 9701/22 · Q2 (e)(iii)

|          |                                                                            |   |
|----------|----------------------------------------------------------------------------|---|
| 3(e)(ii) | <b>M1</b> $+215 + (-156) - (+48) =$<br><b>M2</b> $+11 \text{ kJ mol}^{-1}$ | 2 |
|----------|----------------------------------------------------------------------------|---|

Oct/Nov 2025 9701/22 · Q3 (e)(ii)

|          |                                                                                                                                                                |   |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| 3(d)(ii) | <b>M1</b> (reaction 1): $-3115 - 286 + 3292 = -109 \text{ (kJ mol}^{-1}\text{)}$<br><b>M2</b> $\Delta H_2 = -53 - (-109) = (+)56 \text{ (kJ mol}^{-1}\text{)}$ | 2 |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|---|

Oct/Nov 2025 9701/23 · Q3 (d)(ii)

|           |                                                                                                                                                                       |          |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| 1(b)(iii) | <b>M1</b> (enthalpy change / energy change) when one mole of a compound / substance is formed<br><b>M2</b> from its (constituent) elements in their standard state(s) | <b>2</b> |
| 1(b)(iv)  | <b>M1</b> $(6 \times -92) - (2 \times -46) =$<br><b>M2</b> $-460 \text{ (kJ mol}^{-1}\text{)}$                                                                        | <b>2</b> |

Oct/Nov 2025 9701/24 · Q1 (b)(iii), (b)(iv)