

2(b)(i)	Any 2 points covered correctly scores 2 marks Any 1 point covered correctly scores 1 mark - nitrogen (and oxygen) from the air / atmosphere (react): - high temperature (of internal combustion engine) / (engine) produces enough OR a lot of heat (energy) : (so) breaks (strong) bond(s) in nitrogen (and oxygen) :	2
2(b)(ii)	reduction / decomposition of NO _x using a catalyst / catalytic convertor	1
	2NO ₂ + 4CO → 4CO ₂ + N ₂ OR 2NO + 2CO → 2CO ₂ + N ₂	1
2(b)(iv)	2NO ₂ + H ₂ O → HNO ₂ + HNO ₃ OR 4NO ₂ + 2H ₂ O + O ₂ → 4HNO ₃	1
2(c)	fertiliser / nitrates dissolve in (river water) OR fertiliser / nitrates are washed / leached out / flows into (river water)	1

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Question	Answer	Marks
	algal bloom / promote algal growth / explosion of plant growth AND EITHER sunlight is blocked out (preventing photosynthesis) / plants can no longer carry out photosynthesis (and die) OR bacteria break down or decay dead organisms / plants / algae	1
	drop in oxygen (concentration)	1
	Total:	13

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Question	Answer	Marks
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May/June 2017 9701/22 · Q2 (b)(i), (b)(ii), (b)(iv), (c)

3(b)(i)	Mark to right of original E_a	1
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Question	Answer	Marks
3(b)(iii)	(rate) increases AND correct explanation in terms of 'more collisions'	1
	more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1
	(yield) increases and shifts equilibrium to the right / in the forward direction / towards SO_3 / towards the product / in exothermic direction	1
	to oppose the change or oppose the increase in pressure / fewer molecules on RHS so eqm moves to right (to oppose change)	1

May/June 2017 9701/23 · Q3 (b)(i), (b)(iii)

1(b)	$-196 + 6\text{S}=\text{O} = (4 \times 534) + 496$	1
	$\text{S}=\text{O} = 2828 / 6 = 471(.3)$	1
1(c)	1 = B	1
	2 = A	1
	3 = D	1

May/June 2018 9701/21 · Q1 (b), (c)

3(d)(i)	any 2 from:	2
	lowers pH / increases acidity of rivers / lakes / oceans / seas / soil	
	kills/harms fish OR harms / kills coral / plants / crops / trees	
	leaches (toxic) aluminium (ions / salts) from soil (into rivers / lakes)	
	leaches away soil nutrients	
3(d)(ii)	damages / weathers / erodes buildings / statues	1
	$\text{NO}_2 + \text{SO}_2 \rightarrow \text{NO} + \text{SO}_3$	
	$\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$	

May/June 2018 9701/22 · Q3 (c)(i), (c)(ii), (d)(i), (d)(ii)

1(c)(i)	molecules / particles / reacting species are closer together	1
	so frequency of collisions increases	1
	few(er) moles on right	1
	so (equilibrium) reaction shifts right / towards products / (as pressure increases to oppose the change)	1

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Question	Answer	Marks
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May/June 2018 9701/23 · Q1 (c)(i)

1(c)(ii)	M1 CaO displaces NH_3 (from its salt / NH_4^+)	2
	M2 CaO is a stronger base / more basic (than NH_3)	

March 2019 9701/22 · Q1 (c)(ii)

4(a)	M1 sulfur impurities OR sulfur in fossil fuels M2 converted into SO ₂ by combustion / burning sulfur OR heat sulfur with oxygen (from the air)	2
4(b)(i)	M1 1 mol SO ₂ → 1 mol H ₂ SO ₄ 64.1 g / tonne → 98.1 g / tonne M2 SO ₂ → 98.1 / 64.1 × 1590 = 2433.369735 tonnes	2
4(b)(ii)	high (enough) temperature / (a lot of) heat (energy) is produced AND to break (strong) triple bond in N ₂ / break N≡N AND nitrogen (and oxygen) from the air / atmosphere react Award two marks for three correct points Award one mark for two correct points	2
4(b)(iii)	lightning	1

May/June 2019 9701/23 · Q4 (a), (b)(i), (b)(ii), (b)(iii)

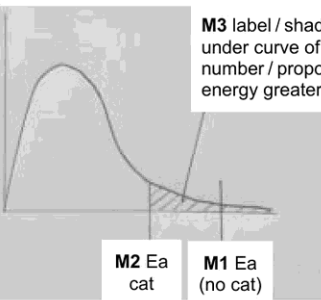
3(a)(iii)	C ₄ H ₈ + 4O ₂ → 4CO + 4H ₂ O	1
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Oct/Nov 2019 9701/21 · Q3 (a)(iii)

2(d)	M1 state the effect of NO gas on contact with moist air NO reacts with water OR NO reacts with oxygen and water. M2 consequence of M1 in terms of atmospheric pollution causing acid rain OR photochemical smog / ground level ozone OR destroy ozone layer	2
2(e)	M1 number of mol in sample of NH ₄ NO ₃ 40t NH ₄ NO ₃ = 500 000 mol ammonium nitrate M2 ratio of mol NO ₂ : NH ₄ NO ₃ 3/2 mol NO ₂ : 1 mol NH ₄ NO ₃ M3 volume of no mol NO ₂ at rtp using 1 mol = 24dm ³ 18 000 000 dm ³ of NO ₂	3
2(f)	fertiliser	1

Question	Answer	Marks
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May/June 2020 9701/22 · Q2 (d), (e), (f)

3(a)(ii)	 M3 label / shading indicating greater area under curve of Ea(cat) AND state greater number / proportion of sucrose molecules have energy greater than Ea(cat) (so faster rate)	3
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Question	Answer	Marks
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May/June 2020 9701/23 · Q3 (a)(ii)

2(b)(iii)	(homogeneous) catalyst	1
2(c)(i)	thermal decomposition	1

Oct/Nov 2020 9701/21 · Q2 (b)(iii), (c)(i)

1(b)(i)	CaC ₂ O ₄ (s) → CaO(s) + CO ₂ (g) + CO(g) M1 correct formulae	1
	M2 balancing equation AND state symbols.	1

May/June 2021 9701/21 · Q1 (b)(i)

2(a)(i)	M1 both make triple (covalent) bond / 3 shared pairs of electrons	1
	M2 one bond in CO is coordinate / dative covalent / formed by donating a pair of electrons from O (to C)	1

May/June 2021 9701/21 · Q2 (a)(i)

5(e)(i)	carbon dioxide / CO ₂	1
5(e)(ii)	CO / hydrocarbons AND toxic / poisonous / harmful to health / (catalyses formation of) photochemical smog	1

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Question	Answer	Marks
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May/June 2021 9701/21 · Q5 (e)(i), (e)(ii)

1(d)(i)	M1 moles of As₂S₃ = 0.198 / 246.1 / 8.05 × 10⁻⁴ M2 moles SO₂ (using moles of As₂S₃ as limiting factor) = 2.41(36) × 10⁻³ moles (6 / 2 × 8.05 × 10⁻⁴) Volume SO₂ = 2.41(36) × 10⁻³ × 24 = 0.0579 dm³ M3 Moles O₂ used in reaction = 8.05 × 10⁻⁴ × 9 / 2 = 3.62 × 10⁻³ Volume O₂ used in reaction = 3.62 × 10⁻³ × 24 = 0.0869 dm³ M4 Final total volume gas = (0.1 – 0.0869) + 0.0579 = [0.0131 + 0.0579] = <u>0.071(0)</u> dm³ M4 ONLY award 4th mark if the final answer rounds to 0.071 Answer to minimum of 2 sig figs MAX 3 for using ecf from M1 to M2 to M3 and M4 Award all 4 marks if final answer rounds to 0.071	4
1(d)(ii)	acid rain	
1(d)(iii)	M1 SO₂(g) + 2NaOH(aq) → Na₂SO₃(aq) + H₂O(l) AND correct species and balancing M2 State symbols	2

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Question	Answer	Marks
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Oct/Nov 2021 9701/21 · Q1 (d)(i), (d)(ii), (d)(iii)

2(d)(i)	NO + ½O ₂ → NO ₂	1
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March 2022 9701/22 · Q2 (d)(i)

3(b)(ii)	M1: All three correct for two marks: row 1 • acid–base row 2 • acid–base • redox M2: explanation H₂SO₄ is strong enough to oxidise / is an oxidising agent with NaBr / HBr / bromide	3
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Question	Answer	Marks
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March 2022 9701/22 · Q3 (b)(ii)

5(b)(i)	M1 • high temperature • high pressure • N ₂ M2 N ₂ + O ₂ → 2NO OR N ₂ + 2O ₂ → 2NO ₂ OR N ₂ + xO ₂ → 2NO _x Any two correct for M1	2
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Question	Answer	Marks
5(b)(ii)	M1 NO ₂ is the catalyst (for SO ₂ → SO ₃) OR catalytic oxidation (of SO ₂) by NO ₂ M2 NO ₂ + SO ₂ → NO + SO ₃ AND 2NO + O ₂ → 2NO ₂ M3 SO ₃ reacts with rain OR moisture/water (in atmosphere) to form sulfuric acid / H ₂ SO ₄ OR SO ₃ + H ₂ O → H ₂ SO ₄	3
5(b)(iii)	photochemical smog / PAN	1

May/June 2023 9701/21 · Q5 (b)(i), (b)(ii), (b)(iii)

3(b)(i)	e.g. N ₂ + 1½O ₂ → NO + NO ₂	1
3(c)(iii)	rate is lowered	1
	lower frequency of successful collisions / number of successful collisions per unit time	1

March 2024 9701/22 · Q3 (b)(i), (c)(iii)

4(c)

Chemical test	observation with 2-bromooctane	observation with octan-2-ol	observation with $\text{CH}_3(\text{CH}_2)_5\text{CHCH}_2$
Br_2 in the dark	×		orange / brown to colourless
PCl_5		steamy fumes	×
$\text{AgNO}_3(\text{aq})$	cream precipitate OR off white precipitate	×	

6 correct answers = 3 marks
4 or 5 correct answers = 2 marks
2 or 3 correct answers = 1 mark
0 or 1 correct answer = 0 marks

3

May/June 2024 9701/22 · Q4 (c)

2(d)(i)	M1 catalyst M2 2 equations to show the catalytic activity of NO ₂ in formation of SO ₃ from SO ₂ • SO ₂ + NO ₂ → NO + SO ₃ • 2NO + O ₂ → 2NO ₂ M3 describe production of H ₂ SO ₄ from SO ₃ and water (can be shown in an equation). SO ₃ then reacts with (rain)water / moisture / water vapour to make sulfuric acid / H ₂ SO ₄ OR SO ₃ + H ₂ O → H ₂ SO ₄	3
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May/June 2024 9701/23 · Q2 (d)(i)

3(a)(i)	(natural =)lightning	1															
	(man-made =)internal combustion engines	1															
3(a)(ii)	$2\text{NO}_2 + \text{H}_2\text{O} \rightarrow \text{HNO}_2 + \text{HNO}_3$ OR $4\text{NO}_2 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{HNO}_3$	1															
3(a)(iii)	It / NO_2 reacts with (unburned) hydrocarbons / VOCs ALLOW reaction of unburned hydrocarbons / VOCs in presence of NO_2	1															
3(a)(iv)	$2\text{HNO}_3 + \text{CaO} \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{H}_2\text{O}$	1															
3(a)(v)	brown fumes given off	1															
3(b)(ii)	aluminium / Al	1															
3(b)(iii)	(NH_3 is an) H^+ acceptor	1															
3(b)(iv)	tetrahedral	1															
3(d)	<table border="1"> <thead> <tr> <th>element</th><th>nitrogen</th><th>phosphorus</th></tr> </thead> <tbody> <tr> <td>state and appearance</td><td>colourless gas</td><td>white solid</td></tr> <tr> <td>electrical conductivity</td><td>• poor</td><td>poor</td></tr> <tr> <td>type of bonding</td><td>• covalent</td><td>• covalent</td></tr> <tr> <td>type of structure</td><td>simple</td><td>• simple</td></tr> </tbody> </table>	element	nitrogen	phosphorus	state and appearance	colourless gas	white solid	electrical conductivity	• poor	poor	type of bonding	• covalent	• covalent	type of structure	simple	• simple	2
element	nitrogen	phosphorus															
state and appearance	colourless gas	white solid															
electrical conductivity	• poor	poor															
type of bonding	• covalent	• covalent															
type of structure	simple	• simple															
3(e)	simple molecular (lattice structure)	1															
3(f)(i)	M1 one sigma / σ bond AND head-on (overlap of) p / sp (orbitals)	1															
	M2 two pi / π bond(s) AND side-on (overlap of / involving) p (orbitals)	1															
3(f)(ii)	$\text{P}=\text{P}$ is much weaker so P_2 is more reactive (than N_2)	1															

Question	Answer	Marks
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Oct/Nov 2024 9701/22 · Q3 (a)(i), (a)(ii), (a)(iii), (a)(iv), (a)(v), (b)(ii), (b)(iii), (b)(iv), (d), (e), (f)(i), (f)(ii)