CAMBRIDGE INTERNATIONAL AS & A LEVEL CHEMISTRY · 9701

CHEMISTRY



MARK SCHEME

12 NITROGEN AND SULFUR

SCORE	PERCENTAGE
/	%

STEMUP

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Paper 1 Multiple Choice Answers: Nitrogen and Sulfur

Question	Paper	Q. No.	Answer
691	9701_m21_qp_12	18	C
692	9701_s21_qp_11	13	B
693	9701_s21_qp_11	18	C
694	9701_s21_qp_12	18	B
695	9701_s21_qp_13	14	C
696	9701_w21_qp_11	19	B
697	9701_w21_qp_12	11	D
698	9701_w21_qp_12	18	A
699	9701_w21_qp_12	19	D
700	9701_w21_qp_13	2	C
701	9701_m20_qp_12	15	B
702	9701_m20_qp_12	19	C
703	9701_s20_qp_12	15	B
704	9701_s20_qp_13	5	D
705	9701_s20_qp_13	12	B
706	9701_s20_qp_13	16	A
707	9701_w20_qp_11	17	D
708	9701_w20_qp_12	15	D
709	9701_m19_qp_12	19	D
710	9701_s19_qp_11	19	B
711	9701_s19_qp_12	18	A
712	9701_s19_qp_12	19	D
713	9701_s19_qp_13	18	B
714	9701_s19_qp_13	19	D
715	9701_w19_qp_11	18	A
716	9701_w19_qp_11	19	D
717	9701_w19_qp_12	18	C
718	9701_w19_qp_12	19	B
719	9701_s18_qp_11	17	A
720	9701_s18_qp_12	19	D
721	9701_s18_qp_13	19	B
722	9701_w18_qp_11	19	D
723	9701_w18_qp_12	18	C
724	9701_m17_qp_12	19	D
725	9701_s17_qp_11	16	C
726	9701_s17_qp_12	18	D
727	9701_s17_qp_13	18	B
728	9701_s17_qp_13	19	C
729	9701_w17_qp_11	16	D
730	9701_w17_qp_12	18	B
731	9701_m16_qp_12	17	A
732	9701_s16_qp_11	18	C
733	9701_s16_qp_11	19	C
734	9701_s16_qp_12	15	C
735	9701_s16_qp_13	19	B
736	9701_w16_qp_11	17	B

Paper 1 Multiple Choice Answers: Nitrogen and Sulfur (continued)

Question	Paper	Q. No.	Answer
737	9701_w16_qp_12	19	D
738	9701_s15_qp_11	18	A
739	9701_s15_qp_12	17	D
740	9701_s15_qp_12	18	C

72. 9701_s19_ms_22 Q: 3

(a)(i)	$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq/g)$ (state symbols required)	**1**
(a)(ii)	hydrolysis	**1**
(a)(iii)	$NaCl$ – ionic	**1**
	$SiCl_4$ – covalent	**1**
(a)(iv)	**M1** statement correctly comparing the **difference** in electronegativity between Si and Cl AND Na and Cl OR Na is less electronegative that Si *ORA*	**1**
	M2 $NaCl$ transfer of electrons	**1**
	M3 $SiCl_4$ shared (pair of) electrons	**1**
(b)(i)	<table><tr><td>Chlorine containing species</td><td>Cl_2</td><td>HCl</td><td>$HOCl$</td></tr><tr><td>Oxidation number of chlorine</td><td>0</td><td>–1</td><td>(+)1</td></tr></table> Award 2 marks for 3 correct oxidation numbers Award 1 Mark for 2 correct oxidation numbers	**2**
(b)(ii)	disproportionation	**1**
(b)(iii)	kills micro-organisms	**1**
(c)	$2NaOH + HCl + HClO \rightarrow NaCl + NaClO + 2H_2O$ **M1** Identifies the product $NaClO$ **M2** Correctly balances the equation OR The overall equation may be seen as: $NaOH + HCl \rightarrow NaCl + H_2O$ **AND** $NaOH + HClO \rightarrow NaClO + H_2O$	**2**

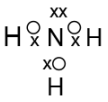
73. 9701_s20_ms_21 Q: 3

(a)	**M1** (enthalpy / energy change) when one mole of a compound/substance is formed **M2** from its elements in their standard states	**2**
(b)	**M1** *use of correct stoichiometry in calculation* $3x\Delta H_f NO_2$ $1x\text{-}\Delta H_f H_2O$ $2x\Delta H_f HNO_3$ $1x\Delta H_f NO$ **M2** *correct signs associated with the appropriate* ΔH_f values/terms *used for the calculation of* $\Delta H_{reaction}$ **M3** $\Delta H_{reaction} = -(102 - 286) + (-346 + 91.1) = -70.9\ kJ\ mol^{-1}$	**3**
(c)	**M1** nitrogen has a triple bond **M2 EITHER** high energy is needed to break the bond **OR** at normal temperatures there is not enough energy to break the bond / to overcome the activation energy	**2**
(d)	lightning	**1**
(e)(i)	**M1** *define homogeneous* (homogeneous catalyst is) in the same phase / state as the reactants **M2 and M3** *Define catalyst* *All 3 points scores 2 marks. Any 2 points scores 1 mark* increase the rate **AND** lowers the activation energy **AND** without being chemically altered at the end of the reaction / are regenerated at the end of the reaction	
(e)(ii)	**M1** $NO_2 + SO_2 \rightarrow NO + SO_3$ **M2** $NO + ½\ O_2 \rightarrow NO_2$	**2**

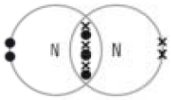
74. 9701_s20_ms_21 Q: 4

(a)	Accepts a proton / H^+ (ion)	1
(b)	*Two reasons why product mixture is added to soil – allow in any order* **M1** Acts as a fertiliser / adds nutrients (for plants) **M2** Neutralise acid soils / increases the pH of acid soil	2
(c)	<table><tr><td></td><td>name of shape</td><td>bond angle / °</td></tr><tr><td>CO_2</td><td>Linear</td><td>180</td></tr><tr><td>NH_3</td><td>Pyramid(al)</td><td>107</td></tr><tr><td>H_2O</td><td>non-linear / V / bent</td><td>104.5</td></tr></table>All 6 correct – 3 marks 4 or 5 correct – 2 marks 2 or 3 correct – 1 mark	3

75. 9701_s20_ms_22 Q: 2

(a)	$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$	1
(b)		1
(c)(i)	$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$ (+)4 (+)5 (+)2 3 correct oxidation numbers – 2 marks 2 correct oxidation numbers – 1 mark	2
(c)(ii)	*relates the term disproportionation to the reaction described* **M1** nitrogen /N (in nitrogen dioxide) is both gaining electrons and losing electrons during the reaction **M2** *refer to relevant transfer of electrons when NO_2 reacts to form HNO_3 and NO* NO_2 to HNO_3 involves loss of electron(s) **AND** NO_2 to NO involves gain of electron(s)	
(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
(e)	**M1** *number of mol in sample of NH_4NO_3* 40t NH_4NO_3 = 500 000 mol ammonium nitrate **M2** *ratio of mol NO_2: NH_4NO_3* 3/2 mol NO_2 :1 mol NH_4NO_3 **M3** *volume of no mol NO_2 at rtp using 1 mol = 24dm^3* 18 000 000 dm^3 of NO_2	3
(f)	fertiliser	1

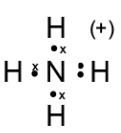
76. 9701_w18_ms_21 Q: 2

(a)(i)	1 mark for each bullet, max 2 • triple bond • non-polar / no dipole • needs a lot of energy to break / strong	**2**
(a)(ii)	 6 e^- between atoms **AND** two electrons on each N atom	**1**
(b)(i)	(lightning) provides the (high) activation energy	**1**
(b)(ii)	**M1** $NO + ½ O_2 \rightarrow NO_2$ **M2** $2NO_2 + H_2O + ½ O_2 \rightarrow 2HNO_3$	**2**
(c)	**M1** fertiliser / nitrates dissolve in (river / ground water) **OR** fertiliser / nitrates are washed / leached out / flows into (river/groundwater) **M2** algal bloom / promote algal growth / explosion of plant growth **AND** sunlight is blocked out (preventing photosynthesis) / plants can no longer carry out photosynthesis (and die) **AND** bacteria break down or decay **dead** organisms / plants / algae **M3** drop in oxygen (concentration)	**3**
(d)(i)	to increase / raise pH	**1**
(d)(ii)	**M1** ammonia / NH_3 **M2** displaces NH_3	**2**
(d)(iii)	**M1** effervescence / fizzing / bubbling **M2** solid disappears	**2**
(d)(iv)	$2Ca(NO_3)_2 \rightarrow 2CaO + 4NO_2 + O_2$	**1**

77. 9701_s17_ms_22 Q: 2

(a)	strong triple bond	**1**
	non-polar / no dipole	**1**
(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**
(b)(ii)	reduction / decomposition of NO_x using a catalyst / catalytic convertor	**1**
	$2NO_2 + 4CO \rightarrow 4CO_2 + N_2$ OR $2NO + 2CO \rightarrow 2CO_2 + N_2$	**1**
(b)(iii)	(acts as a homogeneous) catalyst OR oxidising agent	**1**
	$SO_2 + NO_2 \rightarrow SO_3 + NO$	**1**
	$NO + ½O_2 \rightarrow NO_2$ OR $SO_3 + H_2O \rightarrow H_2SO_4$	**1**
(b)(iv)	$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$ OR $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$	**1**
(c)	fertiliser / nitrates dissolve in (river water) OR fertiliser / nitrates are washed / leached out / flows into (river water)	**1**
	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**

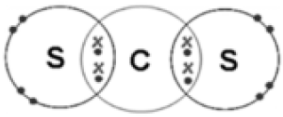
78. 9701_s16_ms_23 Q: 2

(a)	$NH_3 + HNO_3 \rightarrow NH_4NO_3$	[1]
(b) (i)	line from origin AND below left-hand end of original with peak to right of and lower than original crosses original once AND above right-hand end of original AND above energy axis	[1] [1]
(ii)	(curves show) more molecules with $E > E_a$ (at higher T) so greater frequency of successful (owtte) collisions / more successful (owtte) collisions per unit time	[1] [1]
(iii)	catalysed E_a shown to left of original on horizontal axis so more molecules with $E > E_a$ (in presence of catalyst)	[1] [1]
(iv)	production of ammonia is exothermic / (forward) reaction exothermic position of eqm would move to left / reverse / reduce yield (at higher T)	[1] [1]
(c)	$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$ N changes from –3 to +2 (so oxidation) O changes from 0 to –2 (so reduction)	[1] [1] [1]
(d) (i)	 (+)	[1+1]
(ii)	shape = tetrahedral angle = 109°–109.5°	[1] [1]
(e)	eutrophication / algal bloom / stimulates growth of algae (bacteria) use up oxygen when decomposing the plants / algae block light for plants so less oxygen produced aquatic life / fish die (due to lack of oxygen)	[1] [1] [1] [1]

79. 9701_w15_ms_21 Q: 2

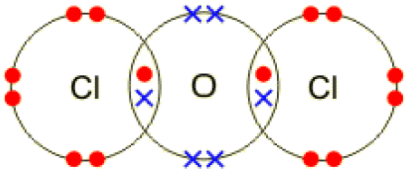
(a) (i)	The enthalpy change when one mole of a compound is formed from its element(s)	[1] [1]
(ii)	$S(s) + 1½O_2(g) \rightarrow SO_3(l)$	[1]
(b) (i)	$944 + (3 \times 436) = 2252$ $6 \times 390 = 2340$ $2252 - 2340 = -88\ (kJ\,mol^{-1})$	[1] [1] [1]
(ii)	Fe catalyst 200 atm 400–500 (°)C	[1] [1] [1]
(iii)	High T increases rate AND Low T improves yield owtte Chosen temp is a compromise High P favours / increases (both rate and) yield owtte pressure chosen limited by cost (of compression and 'thick walls')	[1] [1] [1] [1]
(c) (i)	$2NH_3 + H_3PO_4 \rightarrow (NH_4)_2HPO_4$	[1]
(ii)	NH_3 identified as base AND H_3PO_4 identified as acid base accepts protons AND acid donates protons	[1] [1]
(d) (i)	nitrates / fertilisers wash into rivers eutrophication / algal bloom / promote algal growth bacteria use up oxygen in decay process	[1] [1] [1]
(ii)	(oxides of nitrogen / NO_x / NOs) cause acid rain $2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$ OR $4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$ OR $SO_2 + NO_2 \rightarrow SO_3 + NO$ AND $SO_3 + H_2O \rightarrow H_2SO_4$	[1] [1]

80. 9701_w21_ms_21 Q: 1

Question	Answer	Marks
(a)(i)	easily vaporised / easily evaporates / turns to gas easily	1
(a)(ii)	 **M1** bonding pairs **M2** Correct number of remaining outer electrons	2
(a)(iii)	180°	1
(a)(iv)	**M1** CS_2 has more electrons **M2** So stronger induced dipole (forces) (between molecules)	2
(b)(i)	**M1** (enthalpy/energy change when) 1 mole of a compound **M2** *burns/combusts/reacts in* ***excess*** *oxygen/O_2* **OR** ***completely*** *burns/* ***completely*** *combusts/****completely*** *reacts in oxygen/O_2*	2
(b)(ii)	**M1** (–394 +**2** (–297) – (+89.7) **M2** = –1080 (kJ mol^{-1})	2
(c)(i)	*weak [acid]* partially dissociates/partially ionises (into H^+ ions/protons)	1
(c)(ii)	HS^-	1

Question	Answer	Marks
(c)(iii)	**M1** S (increases**)** oxidation number –2 → 0 so oxidation / or is oxidised **M2** O (decreases) O.N. 0 → –2 so reduction / is reduced	2
(d)(i)	**M1** moles of As_2S_3 = 0.198 / 246.1 / 8.05×10^{-4} **M2** moles SO_2 (using moles of As_2S_3 as limiting factor) = $2.41(36) \times 10^{-3}$ moles ($6 / 2 \times 8.05 \times 10^{-4}$) Volume SO_2 = $2.41(36) \times 10^{-3} \times 24$ = 0.0579 dm^3 **M3** Moles O_2 used in reaction = $8.05 \times 10^{-4} \times 9 / 2 = 3.62 \times 10^{-3}$ Volume O_2 used in reaction = $3.62 \times 10^{-3} \times 24$ = 0.0869 dm^3 **M4** Final total volume gas = (0.1 – 0.0869) + 0.0579 = [0.0131 + 0.0579] = <u>0.071</u>(0) dm^3 **M4 ONLY award 4th mark if the final answer rounds to <u>0.071</u>** 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
(d)(ii)	acid rain	
(d)(iii)	**M1** $SO_2(g) + 2NaOH(aq) \rightarrow Na_2SO_3(aq) + H_2O(l)$ **AND** correct species and balancing **M2** State symbols	2

81. 9701_w20_ms_21 Q: 2

(a)(i)	$P_4 + 5O_2 \rightarrow P_4O_{10}$	**1**
(a)(ii)	any **two** from: • reacts vigorously • solid disappears / colourless solution forms • hydrolysis • exothermic • acid(ic) (solution) • steamy / misty fumes	**2**
(a)(iii)	Simple and covalent OR molecular and covalent	**1**
(b)(i)	**M1:** proton / H^+ donor	**2**
	M2: partially dissociates (in solution)	
(b)(ii)	$SO_2 + H_2O \rightarrow H_2SO_3$	**1**
(b)(iii)	(homogeneous) catalyst	**1**
(c)(i)	**thermal** decomposition	**1**
(c)(ii)	**M1:** $\Delta H_r = -1434 - (-635 + -297)$	**2**
	M2: = –502 (kJ mol^{-1})	
(d)(i)		**1**
(d)(ii)	0 | (+)4 | –1	**1**
(d)(iii)	***(at 1000 K and 100 kPa)*** **M1:** (yield) **decreases**	**4**
	M2: reaction is exothermic **AND** equilibrium moves **left**	
	(at 500 K and 500 kPa) **M3:** (yield) **increases**	
	M4: fewer moles (<u>of gas</u>) on right-hand side **AND** equilibrium moves right	
(e)(i)	**M1:** ionic	**2**
	M2: ions only able / free to move / free to conduct (when liquid / molten)	
(e)(ii)	**M1:** covalent	**2**
	M2: hydrolysed (by water)	

82. 9701_s19_ms_23 Q: 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**
(b)(i)	**M1** 1 mol SO_2 → 1 mol H_2SO_4 64.1 g / tonne → 98.1 g / tonne **M2** SO_2 → 98.1 / 64.1 □ 1590 = 2433.369735 tonnes	**2**
(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**
(b)(iii)	lightning	**1**
(b)(iv)	**M1** nitrogen dioxide increases the rate **OR** lowers the activation energy **M2** (NO_2) is regenerated by reaction of NO with O_2 (in the air) **OR** NO (formed) reacts with O_2 (in air) to (re)form NO_2	**2**

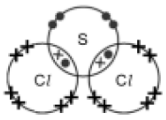
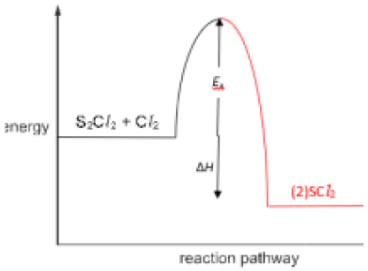
83. 9701_w19_ms_22 Q: 1

(a)(i)		**1**
(a)(ii)	$Si(g) \rightarrow Si^{+}(g) + e^{-}$	**1**
(a)(iii)	**M1:** similar shielding AND increase in proton number / atomic number / nuclear charge **M2:** increased nuclear attraction	**2**
(a)(iv)	**M1:** 3 **OR** 13 **M2:** large(r) *increase* between third and fourth ionisation energies **OR** large(r) *increase* after third electron removed	**2**
(b)(i)	**M1:** $\frac{[92.2 \times 28] + [^{29}Si \times 29] + [^{30}Si \times 30]}{100} = 28.09$ **M2:** (x =) 6.6 **OR** 28.09 = 28.078 + x (where x = abundance of Si-29*)* **M3:** *7.8 – M2 calculated correctly to one decimal place (or more)* (=) 1.2%	**3**
(b)(ii)	**M1** giant (molecule) **M2** strong covalent bonds (between atoms / particles) **M3** no mobile charged particles / carriers	**3**
(c)(i)	$C_2H_5SH + 4\frac{1}{2}O_2 \rightarrow 2CO_2 + 3H_2O + SO_2$	**1**
(c)(ii)	**M1:** (causes) acid rain OR reacts/dissolves with (rain)water (vapour) to form (sulfuric / sulfurous) acid **M2:** one point from the following list. • lowers pH / increases acidity of rivers / lakes / oceans / water supplies / seas / soil / ground water • kills/harms / damages fish • kills / harms / damages plants / damages coral / aquatic life / plants / crops / trees or deforestation • leaches (toxic) aluminium (ions / salts) from soil (into rivers / lakes) • leaches away soil nutrients / soil unfit for agriculture • damages / weathers / erodes / destroys buildings / statues	**2**
(d)(i)	**M1:** no effect / none **M2:** equal mol(es) (*of gas*) on both sides (of equilibrium / equation) owtte	**2**
(d)(ii)	**M1:** (forward reaction is) endothermic **M2:** Any temperature higher than 300 K	**2**

84. 9701_w18_ms_21 Q: 1

(a)(i)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ (4s^0)$	**1**
(a)(ii)	–1	**1**
(b)	**M1** attraction/hold **M2 positive** ions / cations **AND** delocalised electrons (may be seen in a labelled diagram)	**2**
(c)(i)	**M1** <u>acid rain</u> **M2** • destroys / damages / weathers / erodes / buildings / statues • kills/harms fish / coral / plants / crops / trees / deforestation • leaches salts / ions (aluminium) from soil (into rivers / lakes) • leaches away soil nutrients • breathing difficulties • lowers pH / increases acidity of soil / rivers / oceans / seas	**2**
(c)(ii)	balanced equation with $11O_2$ and $8SO_2$ **M1**: O_2 and SO_2 **M2**: 11 and 8	**2**
(c)(iii)	**M1** *is for process of calculating number of moles of* Fe_2O_3 33.18 ÷ 159.6 (= 0.2079 mol) **M2** *for correct use of stoichiometry and 120.0 with candidate's* ***M1*** **M2** (0.2079) × 4 / 2 × 120.0 = 49.89 (g)	**2**
(c)(iv)	(0.37/(0.37+49.89)) = 0.74	**1**

85. 9701_w18_ms_22 Q: 2

<table>
<tr><td>(a)</td><td>
<table>
<tr><td>Na</td><td>Mg</td><td>Al</td><td>Si</td><td>P</td></tr>
<tr><td>metallic</td><td>metallic</td><td>metallic</td><td>covalent</td><td>covalent</td></tr>
<tr><td>Na_2O</td><td>MgO</td><td>Al_2O_3</td><td>SiO_2</td><td>P_4O_{10}</td></tr>
<tr><td>NaCl</td><td>$MgCl_2$</td><td>$AlCl_3$</td><td>$SiCl_4$</td><td>PCl_5</td></tr>
</table>
[1] for each correct row</td><td>3</td></tr>
<tr><td>(b)(i)</td><td>
</td><td>1</td></tr>
<tr><td>(b)(ii)</td><td>

M1 profile for exothermic reaction [1]
M2 identification of ΔH and E_a [1]</td><td>2</td></tr>
<tr><td>(c)(i)</td><td>graph rises to maximum for Si, then falls</td><td>1</td></tr>
<tr><td>(c)(ii)</td><td>Max. 3 from:
• increasing strength of metallic bond; Na < Mg < Al
OR
stronger attraction between delocalised electrons and (positive) ion so melting point of Na < Mg < Al

• Si is giant covalent AND it has the highest melting point due to breaking / presence of strong (covalent) bonds
OR
Si requires the most energy because the covalent bonds in Si are stronger than metallic bonds (in Na / Mg / Al)

• P and S have weak(er) intermolecular forces / induced dipoles / van der Waals forces (than covalent / metallic bonds) so have low(er) melting points

• $S_{(8)}$ has stronger / more intermolecular forces / van der Waals forces / induced dipoles than $P_{(4)}$ so melting point of $S_{(8)}$ is higher</td><td>3</td></tr>
<tr><td>(d)</td><td>$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$</td><td>1</td></tr>
<tr><td>(e)</td><td>M1 acid rain [1]

M2 any of the following [1]
• lowers pH / increases acidity of rivers / lakes / oceans / water supplies / seas / soil / ground water
• kills / harms / damages fish / coral / aquatic life / plants / crops / trees or deforestation
• leaches (toxic) aluminium (ions / salts) from soil (into rivers/lakes)
• leaches away soil nutrients / soil unfit for agriculture
• damages / weathers / erodes / destroys buildings / statues
• causes breathing difficulties</td><td>2</td></tr>
<tr><td>(f)</td><td>M1 process of ‘first ionisation energy’ involves the loss/removal of an electron [1]

M2 Mg and Al AND S and P (in either order) [1]

M3 For Al <u>3p</u> (orbital / sub-level / sub-shell) is higher in energy / further from the nucleus / more shielded (than Mg) [1] ora

M4 For S the pair of electrons in the (3)p-orbital repel [1] ora</td><td>4</td></tr>
</table>

86. 9701_S15_ms_22 Q: 2

(a) (i)	$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$ reagents and formulae balancing	 [1] [1]
(ii)	S (is oxidised) –2 to (+)4 O (is reduced) 0 to –2	[1] [1]
(b) (i)	T = 400 – 600 °C (chosen as a compromise because) High T increases rate ora High T decreases yield / moves eqm left / makes less SO_3 as forward reaction exothermic ora	[1] [1] [1]
(ii)	High pressure increases rate as collision frequency increases ora High pressure moves eqm right / favours forward reaction as more moles on left ora Uneconomic to use high pressures / high yield at low pressure	[1] [1] [1]
(c) (i)	Reaction (too) exothermic / acid spray produced	[1]
(ii)	$SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$	[1] [1]
(d)	Preservative owtte antimicrobial / antioxidant / reducing agent	[1] [1]
(e) (i)	$12.35 \times 0.01 / 1000 = 1.235 \times 10^{-4}$	[1]
(ii)	$1.235 \times 10^{-4} \times 1000 / 50 = 2.47 \times 10^{-3}$	[1]
(iii)	$2.47 \times 10^{-3} \times 64.1 = 0.158327$ g = 158 (3 sf only)	[1]

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87. 9701_w15_ms_22 Q: 3

(a) (i)	Na_2O or Na_2O_2; MgO; P_4O_{10} or P_4O_6 ; SO_2	[1] [1]
(ii)	Na: Yellow / orange / gold flame / white solid / powder / smoke $4Na + O_2 \rightarrow 2Na_2O$ or $2Na + O_2 \rightarrow Na_2O_2$ S: Blue flame / (yellow) solid melts / turns red / amber / white fumes $S + O_2 \rightarrow SO_2$	[1] [1] [1] [1]
(b) (i)	acidic P and S amphoteric Al and basic Na and Mg	[1] [1]
(ii)	acidic: covalent (bonding) basic: ionic (bonding)	[1] [1]
(iii)	$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$ **OR** $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$ $Al_2O_3 + 2NaOH + 7H_2O \rightarrow 2NaAl(OH)_4(H_2O)_2$ **OR** $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$ **OR** $Al_2O_3 + 2NaOH \rightarrow 2NaAlO_2 + H_2O$ **OR** $Al_2O_3 + 2OH^- + 7H_2O \rightarrow 2[Al(OH)_4(H_2O)_2]^-$ **OR** $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$ **OR** $Al_2O_3 + 2OH^- \rightarrow 2AlO_2^- + H_2O$	[1] [1]
(c)	sulfur forms SO_2 / SO_2 + / mixes $H_2O \rightarrow H_2SO_3$ or in words OR SO_2 + / mixes H_2O (→acid) / or in words OR SO_2 + / mixes $H_2O + (1/2O_2) \rightarrow H_2SO_4$ / or in words	[1] [1]