Period 3 Elements Answers

Q	Part	Sub Part	Marking Guidance	Mark	Comments
2	(a)		Macromolecular	1	Or giant molecule Or giant covalent (also gains M2) Do not allow giant atomic Ionic/metallic CE=0 for all 3 marks
			Covalent bonding (between atoms)	1	Do NOT allow if between molecules
			Many/strong bonds to be broken (or lots of energy required)	1	Lose both bonding marks if contradiction e.g. mention of intermolecular forces Note: 'covalent bonds between molecules' loses M2 but **not** M3
2	(b)		Al_2O_3 ionic	1	Allow ionic + covalent/ ionic with covalent character
2	(c)		$2Al + 3/2O_2 \rightarrow Al_2O_3$	1	Allow multiples Ignore state symbols
2	(d)		Insoluble/impermeable/non-porous	1	Or does not react/inert Do not allow thick layer Must imply property of Al_2O_3 not Al
2	(e)		$Na_2O + H_2O \rightarrow 2NaOH$	1	Or $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$
2	(f)	(i)	$Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$	1	Ionic equations with Al_2O_3 possible e.g. $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$ Do not allow formation of Al_2Cl_6

2	(f)	(ii)	$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$	1	Other equations with Al_2O_3 are possible e.g. $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$ $Al_2O_3 + 2OH^- + 7H_2O \rightarrow 2[Al(H_2O)_2(OH)_4]^-$
2	(g)		SiO_2 acidic/Lewis acid/electron pair acceptor $SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$	1 1	Allow SiO_2 **not** amphoteric Do NOT allow BL acid Other equations with SiO_2 are possible e.g. $SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$ $SiO_2 + 2OH^- + 2H_2O \rightarrow Si(OH)_6^{2-}$

Question	Part	Sub Part	Marking Guidance	Mark	Comments
8	(a)		Electronegativity increases	1	
			Proton number increases (increase in nuclear charge)	1	
			Same number of electron shells/levels	1	Or same radius or Shielding of outer electrons remains the same
			Attraction of <u>bond pair</u> to nucleus increases	1	Allow 'electrons in bond' instead of 'bond pair'
8	(b)		Big <u>difference</u> in electronegativity leads to ionic bonding, smaller covalent	1	Lose a mark if formula incorrect
			Sodium oxide ionic lattice	1	
			Strong forces of attraction <u>between ions</u>	1	
			P_4O_{10} covalent molecular	1	Must have covalent and molecular (or molecules)
			Weak (intermolecular) forces between molecules	1	Or weak vdW, or weak dipole-dipole between molecules
			melting point Na_2O greater than for P_4O_{10}	1	Or argument relating mpt to strength of forces

8	(c)		Moles NaOH = $0.0212 \times 0.5 = 0.0106$ Moles of H_3PO_4 = 1/3 moles of NaOH (= 0.00353) Moles of P in 25000 l = $0.00353 \times 10^6 = 3.53 \times 10^3$ Moles of $P_4O_{10} = 3.53 \times 10^3/4$ Mass of $P_4O_{10} = 3.53 \times 10^3/4 \times 284 = 0.251 \times 10^6$ g = 251 kg	1 1 1 1 1	M1 moles of NaOH correct M2 is for 1/3 M3 is for factor of 1,000,000 M4 is for factor of 1/4 (or 1/2 if P_2O_5) (Or if P_2O_5 $3.53 \times 10^3/2 \times 142$) M5 is for multiplying moles by M_r with correct units allow conseq on incorrect M4 (allow 250-252)

Question	Marking Guidance	Mark	Comments
4(a)(i)	white flame / white light	1	Mark flame independent of other observations
	solid / powder / smoke / ash / white fumes	1	penalise precipitate penalise wrong colour if more than one observation for M2 apply list principle. (If an observation is incorrect, the incorrect observation negates a correct one)
	$2Mg + O_2 \rightarrow 2MgO$	1	ignore state symbols allow multiples
	ionic	1	do not allow reference to covalent character
4(a)(ii)	blue flame	1	do not allow any other colour Mark flame independent of other observations
	fumes or misty or pungent/choking/smelly gas	1	do not allow incorrect smell (e.g. bad eggs) apply list principle as in (a) (i) do not allow just 'gas' or 'colourless gas'
	$S + O_2 \rightarrow SO_2$	1	ignore state symbols allow multiples and S_8
	covalent	1	penalise giant covalent

4(b)	ionic O^{2-} / oxide ion reacts with water / accepts a proton forming OH^- ions/ NaOH / sodium hydroxide (can show in equation from Na_2O even if incorrect)	1 1 1	If covalent, can only score M3 M2 requires reference to O^{2-} / oxide ion allow $O^{2-} + H_2O \rightarrow 2OH^-$ or $O^{2-} + H^+ \rightarrow OH^-$ to score M2 & M3 also allow equations with spectator Na^+ ions on both sides.
4(c)	(heat until) molten conducts electricity / can be electrolysed / electrolyse and identify Al / O_2 at an electrode	1 1	or dissolve in <u>molten</u> cryolite do not allow solution in water M2 can only be gained if M1 scored
4(d)	insoluble (in water)	1	allow oxide impermeable to air / water or oxide is unreactive / inert
4(e)(i)	$Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$	1	allow $O^{2-} + 2H^+ \rightarrow H_2O$ and formation of aquated Al^{3+} species allow spectator Cl^- ions penalise HCl (not ionic!)
4(e)(ii)	$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$ or $Al_2O_3 + 6OH^- + 3H_2O \rightarrow 2Al(OH)_6^{3-}$	1	allow formation of $Al(H_2O)_2(OH)_4^-$ allow Na^+ spectator ions penalise NaOH (not ionic!)

Question	Marking Guidance	Mark	Comments
3(a)	Na_2O ionic	1	mention of molecules/intermolecular forces/delocalised electrons, CE = 0
	Strong forces between ions/strong ionic bonding	1	Allow lots of energy to break bonds provided M1 scored
	SiO_2 macromolecular	1	Allow giant molecular/giant covalent. If ions mentioned, CE = 0
	Strong <u>covalent bonds</u> (between atoms)	1	Allow lots of energy to break <u>covalent</u> bonds If breaking intermolecular forces are mentioned, CE = 0 for M4
3(b)	Higher	1	
	Li^+ (or Li ion) smaller than Na^+	1	Must imply Li^+ ion Allow Li^+ has higher charge/size ratio **not** charge/mass
	Attracts O^{2-} ion more strongly	1	Allow stronger ionic bonding Allow additional attraction due to polarisation in Li_2O M3 can only be scored if M2 gained
3(c)(i)	Molecular	1	Do not allow simple covalent BUT simple covalent molecule scores M1 and M2
	Covalent bonds (between P and O)	1	Ignore reference to van der Waals' or dipole-dipole

3(c)(ii)	Weak van der Waals' forces and/or dipole-dipole forces <u>between molecules</u>	1	Allow weak <u>inter-molecular</u> forces – can score "between" molecules in (c)(i) CE = 0 if ionic or macromolecular mentioned in (c)(i) Must state van der Waals' forces are weak ***OR*** low energy needed to break van der Waals' forces

3(d)	Allow –1 to +2	1	
	$P_4O_{10} + 6H_2O \rightarrow 12H^+ + 4PO_4^{3-}$ (or $4H_3PO_4$)	1	Allow balanced equations to form HPO_4^{2-} or $H_2PO_4^-$ ignore state symbols
	Allow 12 to 14	1	
	$Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$	1	Allow $2Na^+ + O^{2-}$ on LHS, 2NaOH on RHS, ignore s.s. Mark independently

3(e)	$6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$	1	
	Acid-base	1	Allow neutralisation, mark independently of M1 Do not allow Acid + Base $\rightarrow$ Salt + Water

Question	Marking Guidance	Mark	Comments
1(a)	To prevent it coming into contact/reacting with oxygen/air	1	Allow because it reacts with air/oxygen And because with air/oxygen it forms an oxide. (Oxide, if identified, must be correct :- P_4O_{10}, P_2O_5, P_4O_6, P_2O_6)
1(b)	One molecule contains 4P and 10O/the molecular formula is P_4O_{10}	1	Allow exists as P_4O_{10} Do not allow reference to combination of two P_2O_5 molecules Ignore any reference to stability
1(c)	P_4O_{10} is a bigger molecule (than SO_3)/greater M_r/more electrons/ greater surface area Van der Waals / vdW forces between molecules are stronger/require more energy to break	1 1	Penalise SO_2 for one mark (max 1) CE = 0 if mention of hydrogen bonding/ionic/ giant molecule/breaking of covalent bonds Do not allow just more vdW forces Ignore any reference to dipole-dipole forces
1(d)	$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ pH must be in the range -1 to +2	1 1	Allow correct ionic equations Ignore state symbols Allow -1 to +2 Mark independently

1(e)(i)	$3MgO + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 3H_2O$ OR $MgO + 2H_3PO_4 \rightarrow Mg(H_2PO_4)_2 + H_2O$ OR $MgO + H_3PO_4 \rightarrow MgHPO_4 + H_2O$	1	Allow $MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$ Allow magnesium phosphates shown as ions and ionic equations Ignore state symbols
1(e)(ii)	MgO is sparingly soluble/insoluble/weakly alkaline	1	Excess/unreacted MgO can be filtered off/separated
1(e)(iii)	An excess of NaOH would make the lake alkaline/toxic/kill wildlife	1	Allow pH increases

Question	Marking Guidance	Mark	Comments
3(a)(i)	<u>Ionic lattice / solid / giant ionic</u> Strong (electrostatic) forces/attraction between ions	1 1	CE = 0/2 if molecules / IMFs / atoms / metallic Allow strong ionic bonds for M2 only Allow lot of energy to break ionic bonds
3(a)(ii)	Molecular/molecules Weak dipole-dipole and/or van der Waals forces <u>between molecules</u>	1 1	 QoL Type of force must be mentioned
3(b)	P_4O_{10} bigger molecule/has larger surface area than SO_2 van der Waals forces <u>between molecules</u> stronger	1 1	Allow M_r of P_4O_{10} greater than for SO_2 If P_4O_{10} macromolecule/ionic, CE = 0/2 Allow stronger IMF
3(c)	$Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ 14 $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ 0	1 1 1 1	Allow 2NaOH Allow 12-14 Allow ions Allow -1 to +2
3(d)	$6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$	1	Allow ionic Allow correct formula of product with atoms in any order

Question	Marking Guidance	Mark	Comments
4(a)	MgO is ionic	1	If not ionic, CE = 0
	Melt it	1	If solution mentioned, cannot score M2 or M3
	(Molten oxide) conducts electricity	1	Allow acts as an electrolyte. Cannot score M3 unless M2 is correct.
4(b)	Macromolecular	1	CE = 0 if ionic, metallic or molecular. Allow giant molecule.
	Covalent bonding	1	Giant covalent scores M1 and M2
	Water cannot (supply enough energy to) break the covalent bonds / lattice	1	Hydration enthalpy < bond enthalpy.
4(c)	(Phosphorus pentoxide's melting point is) lower	1	If M1 is incorrect, can only score M2
	Molecular with covalent bonding	1	M2 can be awarded if molecular mentioned in M3
	Weak / easily broken / not much energy to break intermolecular forces ***OR*** weak vdW / dipole-dipole forces of attraction between molecules	1	Intermolecular / IMF means same as between molecules.

4(d)	Reagent (water or acid) Equation eg $MgO + 2HCl \rightarrow MgCl_2 + H_2O$	1 1	Can be awarded in the equation. $MgO + H_2O \rightarrow Mg(OH)_2$ Equations can be ionic but must show all of the reagent eg $H^+ + Cl^-$ Simplified ionic equation without full reagent can score M2 only. Allow $6MgO + P_4O_{10} \rightarrow 2Mg_3(PO_4)_2$
4(e)	$P_4O_{10} + 12NaOH \rightarrow 4Na_3PO_4 + 6H_2O$	1	Allow P_2O_5 and acid salts. Must be NaOH not just hydroxide ions.

Question	Marking Guidance	Mark	Comments
4(a)	Na_2O is an ionic <u>lattice</u> / giant ionic / ionic crystal	1	CE= 0 if molecules, atoms, metallic mentioned Mention of electronegativity max 1 out of 2
	With strong forces of attraction between ions	1	Allow strong ionic bonds/lots of energy to separate ions
4(b)	SO_3 is a larger molecule than SO_2	1	Allow greater M_r / surface area
	So <u>van der Waals'</u> forces <u>between molecules</u> are stronger	1	Any mention of ions, CE= 0
4(c)	Ionic	1	Do not allow ionic with covalent character
	Contains <u>O^{2-}</u> ions / oxide ions	1	Equations of the form $O^{2-} + H^+ \rightarrow OH^-$ / $O^{2-} + 2H^+ \rightarrow H_2O$ / $O^{2-} + H_2O \rightarrow 2OH^-$ score M2 and M3
	These / O^{2-} ions (accept protons to) form OH^- / hydroxide / water (must score M2 to gain M3)	1	
4(d)(i)	$SO_2 + H_2O \rightarrow H^+ + HSO_3^-$	1	Allow $2H^+ + SO_3^{2-}$ but no ions, no mark Only score (d)(ii) if (d)(i) correct
4(d)(ii)	Reaction is an equilibrium / reversible reaction displaced mainly to the left / partially ionised / dissociated	1	Allow reaction does not go to completion
4(e)	SiO_2 reacts with bases / NaOH / CaO / $CaCO_3$	1	Ignore incorrect formulae for silicate

Question	Marking Guidance	Mark	Comments
3(a)	<u>White</u> powder / solid / ash / smoke	1	Ignore ppt / fumes
	Bright / white light / flame	1	Allow glows white / glows bright
	$Mg + H_2O \rightarrow MgO + H_2$	1	Ignore state symbols Ignore reference to effervescence or gas produced
3(b)	Mg^{2+} / magnesium ion has higher charge than Na^+	1	Allow Mg^{2+} ions smaller / greater charge density than Na^+ ions Allow Mg atoms smaller than Na (atoms) Allow magnesium has more delocalised electrons Must be a comparison Ignore reference to nuclear charge
	Attracts <u>delocalised / free / sea of</u> electrons more strongly / metal–metal bonding stronger / metallic bonding stronger	1	Wrong type of bonding (vdW, imf), mention of molecules CE = 0

3(c)	**Structure**: Macromolecular / giant molecule / giant covalent	1	Mark independently
	Bonding: Covalent / giant covalent	1	
	Physical Properties:		
	Any **two** from: Hard Brittle / not malleable Insoluble Non conductor	2	Ignore correct chemical properties Ignore strong, high boiling point, rigid

3(d)	**Formula**: P_4O_{10}	1	Mention of ionic or metallic, can score M1 only
	Structure: Molecular	1	If macromolecular, can score M1 & M3 only
	Bonding: Covalent / shared electron pair	1	
	van der Waals' / dipole–dipole forces <u>between molecules</u>	1	Allow vdW, imf and dipole–dipole imf but do not allow imf alone

3(e)	$SO_2 + H_2O \rightarrow H^+ + HSO_3^-$	1	Products must be ions Allow $SO_2 + H_2O \rightarrow 2H^+ + SO_3^{2-}$ Allow two equations showing intermediate formation of H_2SO_3 that ends up as ions Ignore state symbols Allow multiples

3(f)	$P_4O_{10} + 6MgO \rightarrow 2Mg_3(PO_4)_2$ OR $P_4O_{10} + 6MgO \rightarrow 6Mg^{2+} + 4PO_4^{3-}$ OR $P_2O_5 + 3MgO \rightarrow Mg_3(PO_4)_2$ etc	1	Ignore state symbols Allow multiples

Question	Marking Guidance	Mark	Comments
4(a)	$Mg + H_2O \rightarrow MgO + H_2$	1	ignore state symbols
	White solid/powder/ash/smoke	1	ignore precipitate ignore fumes
	(Bright) white light/flame	1	allow glow penalise effervescence under list principle
4(b)	$2Na + \frac{1}{2}O_2 \rightarrow Na_2O$ / $4Na + O_2 \rightarrow 2Na_2O$	1	Allow multiples, ignore state symbols Allow $2Na + O_2 \rightarrow Na_2O_2$
	white / yellow solid/ash/smoke	1	ignore precipitate ignore fumes
	orange / yellow flame	1	

Question	Marking Guidance	Mark	Comments
5(a)(i)	1500	1	
5(a)(ii)	Ionic lattice / giant ionic	1	Mention of vdW / covalent bonding / molecules / atoms / metal etc CE=0
	Strong <u>attraction</u> between <u>oppositely charged ions</u> / Na^+ and O^{2-} OR lots of energy required to separate/ overcome attraction between oppositely charged ions / Na^+ and O^{2-}	1	Do not allow incorrect formulae for ions.
5(a)(iii)	200 (K)	1	Allow range 10–273 (K) CE = 0 if temperature >573 K, otherwise mark on Allow correct answers in ^oC but units must be given.
	SO_2 smaller (molecule) (than P_4O_{10}) (or converse)	1	also SO_2 has lower M_r / less surface area/less polarisable / fewer electrons penalise SO_3 and P_2O_5 for M2 only
	vdW forces <u>between molecules</u> are weaker / require less energy to separate molecules	1	ignore dipole-dipole If covalent bonds broken lose M2 and M3 but can gain M1

5(b)	$SO_2 + H_2O \rightarrow H_2SO_3 / H^+ + HSO_3^- / 2H^+ + SO_3^{2-}$	1	can be equilibrium sign instead of arrow
	1	1	Allow values between 1–3 mark independently
5(c)	Reacts with / neutralises bases / alkalis	1	Allow any given base or alkali including OH^-
	$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$	1	Allow $CaO + SiO_2 \rightarrow CaSiO_3$ or equation with any suitable base M2 can score M1 even if equation unbalanced or incorrect

Question	Marking guidance	Mark	Comments
1ai	Covalent	1	Ignore simple / molecular Do not allow macromolecular/giant covalent/dative/dipole-dipole/Hydrogen bonds Ignore VdW
1aii	P / phosphorus / P_4	1	
1aiii	$P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$	1	Mark independently of 1aii Accept multiples/fractions Ignore state symbols Allow ions on the RHS ($\rightarrow 12H^+ + 4PO_4^{3-}$) Allow correct equations from P_4O_6, P_2O_3 and P_2O_5 $P_4O_6 + 6H_2O \rightarrow 4H_3PO_3$ $P_2O_3 + 3H_2O \rightarrow 2H_3PO_3$ $P_2O_5 + 3H_2O \rightarrow 2H_3PO_4$
1bi	Ionic	1	Ignore giant / lattice
1bii	Na / Sodium	1	
1biii	$2Na + 2H_2O \rightarrow 2Na^+ + 2OH^- + H_2$	1	Allow equation to form 2NaOH Accept multiples/fractions Ignore state symbols

1biv	$Na_2O + 2HCl \rightarrow 2NaCl + H_2O$	1	Accept multiples/fractions Ignore state symbols Allow ions, but do not allow H^+ only for the acid.
1ci	Ionic	1	Allow ionic and covalent / ionic with covalent character
1cii	Al_2O_3	1	Ignore state symbols
1ciii	reacts with acids and bases	1	Allow reacts with acids and alkalis / acts as both an acid and a base / shows acidic and basic properties
1civ	$Al_2O_3 + 6HCl \rightarrow 2Al^{3+} + 6Cl^- + 3H_2O$ $Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$ $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2Na^+ + 2[Al(OH)_4]^-$ $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$ $Al_2O_3 + 2NaOH + 7H_2O \rightarrow 2Na^+ + 2[Al(OH)_4(H_2O)_2]^-$ $Al_2O_3 + 2OH^- + 7H_2O \rightarrow 2[Al(OH)_4(H_2O)_2]^-$	1 1	Allow equation to form $2AlCl_3$ (but not Al_2Cl_6) Allow equations with other acids Allow equations to form $2Na[Al(OH)_4]$ or $2Na[Al(OH)_4(H_2O)_2]$ Allow equations with other alkalis Allow correct equations which form $[Al(OH)_6]^{3-}$ Allow equations to form $[Al(OH)_x(H_2O)_{6-x}]^{3-x}$ etc. Ignore state symbols

Question	Marking guidance	Mark	Comments
3a	$MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq)$	1	State symbols essential Do not allow this equation with H_2O on the LHS Ignore + aq on the LHS Allow H_2O written over the arrow / allow equation written as an equilibrium, Allow correct equations to form $[Mg(H_2O)_6]^{2+}$ ions.
3b	$\Delta H_{soln}\ MgCl_2 = LE + (\Delta H_{hyd}Mg^{2+}) + 2(\Delta H_{hyd}Cl^-)$ $\Delta H_{soln}\ MgCl_2 = 2493 - 1920 + (2 \times -364)$ $= -155\ (kJ\ mol^{-1})$	1 1	M1 for expression in words or with correct numbers Ignore units, but penalise incorrect units
3c	M1: Solubility decreases (as temp increases) M2: the enthalpy of solution is exothermic / reaction is exothermic / backwards reaction is endothermic M3: (According to Le Chatelier) the equilibrium moves to absorb heat/reduce temperature/oppose the increase in temperature (in the endothermic direction)	1 1 1	If M1 is incorrect then CE=0/3 If answer to 3b is a +ve value, allow: M1: Solubility increases (as temp increases) M2: Enthalpy of solution is endothermic etc. M3: (According to Le Chatelier) the equilibrium moves to absorb heat/reduce the temperature/oppose the increase in temperature (in the endothermic direction)