M1.(a) $Mg + H_2O \rightarrow MgO + H_2$

ignore state symbols

1

White solid / powder / ash / smoke

ignore precipitate

ignore fumes

1

(Bright) white light / flame

allow glow

penalise effervescence under list principle

1

(b) $2Na + \frac{1}{2} O_2 \rightarrow Na_2O$ / $4Na + O_2 \rightarrow 2Na_2O$

Allow multiples, ignore state symbols

Allow $2Na + O_2 \rightarrow Na_2O_2$

1

white / yellow solid / ash / smoke

ignore precipitate

ignore fumes

1

orange / yellow flame

1

[6]

M2.(a) (i) 1500

1

(ii) Ionic lattice / giant ionic

Mention of vdW / covalent bonding / molecules / atoms / metal etc. CE = 0

1

Strong attraction between oppositely charged ions / Na^+ and O^{2-}
OR
lots of energy required to separate / overcome attraction between oppositely charged ions / Na^+ and O^{2-}

Do not allow incorrect formulae for ions.

1

(iii) 200 (K)

Allow range 10−273 (K)

CE = 0 if temperature >573 K, otherwise mark on

Allow correct answers in °C but units must be given.

1

SO_2 smaller (molecule) (than P_4O_{10}) (or converse)

also SO_2 has lower M_r / less surface area / less polarisable / fewer electrons

penalise SO_3 and P_2O_5 for M2 only

1

vdW forces between molecules are weaker / require less energy to separate molecules

ignore dipole−dipole

If covalent bonds broken lose M2 and M3 but can gain M1

1

(b) $SO_2 + H_2O \rightarrow H_2SO_3 / H^+ + HSO_3^- / 2H^+ + SO_3^{2-}$

can be equilibrium sign instead of arrow

1

1

Allow values between 1−3

mark independently

1

(c) Reacts with / neutralises bases / alkalis

Allow any given base or alkali including OH^-

1

$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$

Allow $CaO + SiO_2 \rightarrow CaSiO_3$ or equation with any suitable base

M2 can score M1 even if equation unbalanced or incorrect

1

[10]

M3.(a) MgO is ionic

If not ionic, CE = 0

1

Melt it

If solution mentioned, cannot score M2 or M3

1

(Molten oxide) conducts electricity

Allow acts as an electrolyte.

Cannot score M3 unless M2 is correct.

1

(b) Macromolecular

CE = 0 if ionic, metallic or molecular.

Allow giant molecule.

1

Covalent bonding

Giant covalent scores M1 and M2

1

Water cannot (supply enough energy to) break the covalent bonds / lattice

Hydration enthalpy < bond enthalpy.

1

(c) (Phosphorus pentoxide's melting point is) lower

If M1 is incorrect, can only score M2

1

Molecular with covalent bonding

M2 can be awarded if molecular mentioned in M3

1

Weak / easily broken / not much energy to break intermolecular forces
OR weak vdW / dipole-dipole forces of attraction between molecules

Intermolecular / IMF means same as between molecules.

1

(d) Reagent (water or acid)

Can be awarded in the equation.

1

Equation eg $MgO + 2HCl \rightarrow MgCl_2 + H_2O$

$MgO + H_2O \rightarrow Mg(OH)_2$

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 $6MgO + P_4O_{10} \rightarrow 2Mg_3(PO_4)_2$

1

(e) $P_4O_{10} + 12NaOH \rightarrow 4Na_3PO_4 + 6H_2O$

Allow P_2O_5 and acid salts.

Must be NaOH not just hydroxide ions.

1

[12]

M4.(a) The number of protons increases (across the period) / nuclear charge increases

1

Therefore, the attraction between the nucleus and electrons increases

Can only score M2 if M1 is correct

1

(b) S_8 molecules are bigger than P_4 molecules

Allow sulfur molecules have bigger surface area and sulfur molecules have bigger M_r

1

Therefore, van der Waals / dispersion / London forces between molecules are stronger in sulfur

1

(c) Sodium oxide contains O^{2-} ions

1

These O^{2-} ions react with water forming OH^- ions

$O^{2-} + H_2O \longrightarrow 2OH^-$ scores M1 and M2

1

(d) $P_4O_{10} + 12OH^- \longrightarrow 4PO_4^{3-} + 6H_2O$

1

[7]

M5.(a) White powder / solid / ash / smoke

Ignore ppt / fumes

1

Bright / white light / flame

Allow glows white / glows bright

1

$Mg + H_2O \rightarrow MgO + H_2$

Ignore state symbols

Ignore reference to effervescence or gas produced

1

(b) Mg^{2+} / magnesium ion has higher charge than Na^+

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

1

Attracts <u>delocalised / free / sea of</u> electrons more strongly / metal–metal bonding stronger / metallic bonding stronger

Wrong type of bonding (vdW, imf), mention of molecules CE = 0

1

(c) **Structure:** Macromolecular / giant molecule / giant covalent

Mark independently

1

Bonding: Covalent / giant covalent

1

Physical Properties:

Any **two** from: Hard/
Brittle / not malleable
Insoluble
Non conductor

Ignore correct chemical properties

Ignore strong, high boiling point, rigid

2

(d) **Formula:** P_4O_{10}

Mention of ionic or metallic, can score M1 only

1

Structure: Molecular

If macromolecular, can score M1 & M3 only

1

Bonding: Covalent / shared electron pair

1

van der Waals' / dipole–dipole forces <u>between molecules</u>

Allow vdW, imf and dipole–dipole imf but do not allow imf alone

1

(e) $SO_2 + H_2O \rightarrow H^+ + HSO_3^-$

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

1

(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

Ignore state symbols

Allow multiples

1

[15]

M1.(a) Na_2O is an ionic lattice / giant ionic / ionic crystal

CE= 0 if molecules, atoms, metallic mentioned

Mention of electronegativity max 1 out of 2

1

With strong forces of attraction between ions

Allow strong ionic bonds / lots of energy to separate ions

1

(b) SO_3 is a larger molecule than SO_2

Allow greater M_r / surface area

1

So van der Waals' forces between molecules are stronger

Any mention of ions, CE= 0

1

(c) Ionic

Do not allow ionic with covalent character

1

Contains O^{2-} ions / oxide ions

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

1

These / O^{2-} ions (accept protons to) form OH^- / hydroxide / water (must score M2 to gain M3)

1

(d) (i) $SO_2 + H_2O \rightarrow H^+ + HSO_3^-$

Allow $2H^+ + SO_3^{2-}$ but no ions, no mark

Only score (d)(ii) if (d)(i) correct

1

(ii) Reaction is an equilibrium / reversible reaction displaced mainly to the left / partially ionised / dissociated

Allow reaction does not go to completion

1

(e) SiO_2 reacts with bases / NaOH / CaO / $CaCO_3$

Ignore incorrect formulae for silicate

1

[10]

M2.(a) (i) Ionic lattice / solid / giant ionic

CE = 0/2 if molecules / IMFs / atoms / metallic

1

Strong (electrostatic) forces/attraction between ions

Allow strong ionic bonds for M2 only

Allow lot of energy to break ionic bonds

1

(ii) Molecular/molecules

1

Weak dipole-dipole and/or van der Waals forces between molecules

QoL

Type of force must be mentioned

1

(b) P_4O_{10} bigger molecule/has larger surface area than SO_2

Allow M_r of P_4O_{10} greater than for SO_2

If P_4O_{10} macromolecule/ionic, CE = 0/2

1

van der Waals forces <u>between molecules</u> stronger

Allow stronger IMF

1

(c) $Na_2O + H_2O \longrightarrow 2Na^+ + 2OH^-$

Allow 2NaOH

1

14

Allow 12–14

1

$P_4O_{10} + 6H_2O \longrightarrow 4H_3PO_4$

Allow ions

1

0

Allow –1 to +2

1

(d) $6Na_2O + P_4O_{10} \longrightarrow 4Na_3PO_4$

Allow ionic

Allow correct formula of product with atoms in any order

1

[11]

M3. (a) <u>Macro</u>molecular

Or <u>giant</u> molecule

Or <u>giant</u> covalent (also gains M2)

Do not allow giant atomic

Ionic/metallic CE=0 for all 3 marks

1

Covalent bonding (between atoms)

Do NOT allow if between molecules

1

Many/strong bonds to be broken (or lots of energy required)

Lose both bonding marks if contradiction e.g. mention of intermolecular forces
*Note: 'covalent bonds between molecules' loses M2 but **not** M3*

1

(b) Al_2O_3 <u>ionic</u>

Allow <u>ionic</u> + covalent/<u>ionic</u> with covalent character

1

(c) $2Al + 3/2O_2 \rightarrow Al_2O_3$

Allow multiples
Ignore state symbols

1

(d) Insoluble/impermeable/non-porous

Or does not react/inert
Do not allow thick layer
Must imply property of Al_2O_3 not Al

1

(e) $Na_2O + H_2O \rightarrow 2NaOH$

Or $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$

1

(f) (i) $Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O$

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

1

(ii) $Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$

Other equations with Al_2O_3 are possible e.g.
$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2[Al(OH)_4]^-$
$Al_2O_3 + 2OH^- + 7H_2O \rightarrow 2[Al(H_2O)_2(OH)_4]^-$

1

(g) SiO_2 acidic/Lewis acid/electron pair acceptor

1

$SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$

*Allow SiO_2 **not** amphoteric*
Do NOT allow BL acid
Other equations with SiO_2 are possible e.g.
$SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$
$SiO_2 + 2OH^- + 2H_2O \rightarrow Si(OH)_6^{2-}$

1

[11]

M4.(a) To prevent it coming into contact/reacting with oxygen/air

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}

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

Penalise SO_2 for one mark (max 1)
CE = 0 if mention of hydrogen bonding/ionic/ giant molecule/breaking of covalent bonds

1

Van der Waals / vdW forces between molecules are stronger/require more energy to break

Do not allow just more vdW forces
Ignore any reference to dipole-dipole forces

1

(d) $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

Allow correct ionic equations

Ignore state symbols

1

pH must be in the range –1 to +2

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 $MgO + H_3PO_4 \rightarrow MgHPO_4 + H_2O$

Allow $MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$

Allow magnesium phosphates shown as ions and ionic equations

Ignore state symbols

1

(ii) MgO is sparingly soluble/insoluble/weakly alkaline

Excess/unreacted MgO can be filtered off/separated

1

(iii) An excess of NaOH would make the lake alkaline/toxic/kill wildlife

Allow pH increases

1

[9]

M5. (a) (i) white flame / white light

Mark flame independent of other observations

1

solid / powder / smoke / ash / <u>white fumes</u>

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)

1

$2Mg + O_2 \rightarrow 2MgO$

ignore state symbols

allow multiples

1

ionic

do not allow reference to covalent character

1

(ii) blue flame

do not allow any other colour

Mark flame independent of other observations

1

fumes or misty or pungent/choking/smelly gas

do not allow incorrect smell (e.g. bad eggs)

apply list principle as in (a) (i)

do not allow just 'gas' or 'colourless gas'

$S + O_2 \rightarrow SO_2$

ignore state symbols

allow multiples and S_8

1

covalent

penalise giant covalent

1

(b) ionic

If covalent, can only score M3

1

O^{2-} / oxide ion reacts with water / accepts a proton

M2 requires reference to O^{2-} / oxide ion

1

forming OH^- ions/ NaOH / sodium hydroxide
(can show in equation from Na_2O even if incorrect)

allow

1

$O^{2-} + H_2O \rightarrow 2OH^-$ or

$O^{2-} + H^+ \rightarrow OH^-$ to score M2 & M3

also allow equations with spectator Na+ ions on both sides.

1

(c) (heat until) molten

or dissolve in <u>molten</u> cryolite

do not allow solution in water

1

conducts electricity / can be electrolysed / electrolyse and identify Al / O_2 at an electrode

M2 can only be gained if M1 scored

1

(d) insoluble (in water)

allow oxide impermeable to air / water

or oxide is unreactive / inert

1

(e) (i) $Al_2O_3 + 6H^+ 2Al^{3+} + 3H_2O$

allow $O^{2-} + 2H^+ \rightarrow H_2O$

and formation of aquated Al^{3+} species

allow spectator Cl^- ions

penalise HCl (not ionic!)

1

(ii) $Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$

or $Al_2O_3 + 6OH^- + 3H_2O \rightarrow 2Al(OH)_6^{3-}$

allow formation of $Al(H_2O)_2(OH)_4^-$

allow Na^+ spectator ions

penalise NaOH (not ionic!)

1

[16]

M1. (a) Na_2O ionic

mention of molecules/intermolecular forces/delocalised electrons, CE = 0

1

Strong forces between ions/strong ionic bonding

Allow lots of energy to break bonds provided M1 scored

1

SiO_2 macromolecular

Allow giant molecular/giant covalent.

If ions mentioned, CE = 0

1

Strong <u>covalent bonds</u> (between atoms)

Allow lots of energy to break <u>covalent</u> bonds

If breaking intermolecular forces are mentioned, CE = 0 for M4

1

(b) Higher

1

Li^+ (or Li ion) smaller than Na^+

Must imply Li^+ ion

*Allow Li^+ has higher charge/size ratio **not** charge/mass*

1

Attracts O^{2-} ion more strongly

Allow stronger ionic bonding

Allow additional attraction due to polarisation in Li_2O

M3 can only be scored if M2 gained

1

(c) (i) Molecular

Do not allow simple covalent BUT simple covalent molecule scores M1 and M2

1

Covalent bonds (between P and O)

Ignore reference to van der Waals' or dipole-dipole

1

(ii) Weak van der Waals' forces and/or dipole-dipole forces between molecules

Allow weak inter-molecular 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

1

(d) Allow –1 to +2

1

$P_4O_{10} + 6H_2O \rightarrow 12H^+ + 4PO_4^{3-}$ (or $4H_3PO_4$)

Allow balanced equations to form HPO_4^{2-} or $H_2PO_4^-$

ignore state symbols

1

Allow 12 to 14

1

$Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$

Allow $2Na^+ + O^{2-}$ on LHS, 2NaOH on RHS, ignore s.s.

Mark independently

1

(e) $6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$

1

Acid-base

Allow neutralisation, mark independently of M1

Do not allow Acid + Base → Salt + Water

1

[16]

M2. (a) Electronegativity increases

1

Proton number increases (increase in nuclear charge)

1

Same number of electron shells/levels

Or same radius or Shielding of outer electrons remains the

same

1

Attraction of <u>bond pair</u> to nucleus increases

Allow 'electrons in bond' instead of 'bond pair'

1

(b) Big <u>difference</u> in electronegativity leads to ionic bonding, smaller covalent

Lose a mark if formula incorrect

1

Sodium oxide ionic lattice

1

Strong forces of attraction <u>between ions</u>

1

P_4O_{10} covalent molecular

Must have covalent and molecular (or molecules)

1

Weak (intermolecular) forces between molecules

Or weak vdW, or weak dipole–dipole between molecules

1

melting point Na_2O greater than for P_4O_{10}

Or argument relating mpt to strength of forces

1

(c) Moles NaOH = 0.0212 × 0.5 = 0.0106

M1 moles of NaOH correct

1

Moles of H_3PO_4 = 1/3 moles of NaOH (= 0.00353)

M2 is for 1/3

1

Moles of P in 25000 l = $0.00353 \times 10^6 = 3.53 \times 10^3$

M3 is for factor of 1,000,000

1

Moles of $P_4O_{10} = 3.53 \times 10^3/4$

M4 is for factor of 1/4 (or 1/2 if P_2O_5)

1

Mass of $P_4O_{10} = 3.53 \times 10^3/4 \times 284 = 0.251 \times 10^6$ g

= 251 kg

(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)

1

[15]

M3. (a) (i) *can form a solution with pH less than 3*: P_4O_{10} or SO_3 **(1)**

(ii) *can form a solution with with a pH greater than 12*: Na_2O **(1)**

penalise any wrong answer to zero

2

(b) (i) $MgO + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2O$ or an ionic equation **(1)**
i.e. $MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$
not $O^{2-} + 2H^+ \rightarrow H_2O$

(ii) $2NaOH + SiO_2 \rightarrow Na_2SiO_3 + H_2O$ or ionic equation **(1)**
i.e. $SiO_2 + 2OH^- \rightarrow SiO_3^{2-} + H_2O$

(iii) $3Na_2O + 2H_3PO_4 \rightarrow 2Na_3PO_4 + 3H_2O$ etc or ionic equation **(1)**
i.e. $Na_2O + 2H^+ \rightarrow 2Na^+ + H_2O$

3

(c) P_4O_{10} is a molecular (structure) or simple covalent **(1)**
Weak intermolecular forces or van der Waals forces (between molecules) **(1)**
SiO_2 is a macromolecule / giant covalent / giant molecule **(1)**
Not giant lattice

(Strong) covalent bonds (between atoms) must be broken **(1)**

4

[9]

M4. (a) (i) Oxide 1 B

1

Oxide 2 E

1

Explanation Low melting point or weak van der Waals' forces between molecules

1

(ii) Chemical test Add water or flame test

1

Test pH or flame colour

1

Observation pH = 13/14 or colour yellow

1

(b) (i) Equation $CaCO_3 \rightarrow CaO + CO$

1

(ii) Product $CaSO_3$

1

(iii) Disposal of large quantities of $CaSO_3$ (allow $CaSO_4$)

1

Produces CO_2 or uses up $CaCO_3$

1

[10]