AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.2.4 PERIOD 3 ELEMENTS AND THEIR OXIDES

SCORE	PERCENTAGE
/220	%

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Q1.

(a) completely dissociates/ionises (to form H^+ ions)

1

(b) **M1** moles HCl = 1.035×10^{-3} and moles $Ba(OH)_2$ = 3.75×10^{-3}

If M1 incorrect, lose M1 and M6

1

M2 moles OH^- = 2 × ($3.75 \times 10^{-3} = 7.50 \times 10^{-3}$)

If M2 not x2, lose M2 and M6

1

M3 XS n OH^- = $7.50 \times 10^{-3} - 1.035 \times 10^{-3} = 6.465 \times 10^{-3}$ mol in 35.35 cm^3

If no subtraction for M3, lose M3 and M6

1

M4 [OH] = $6.465 \times 10^{-3} / 35.35 \times 10^{-3} = 0.182885$ mol dm^{-3}

= M3/35.35 × 10^{-3}

If M4 not /35.35 × 10^{-3}, lose M4 and M6

However, if divided by 35.35 only lose M4 and allow M6 (ecf = 10.09)

1

M5 $[H^+] = K_w/[OH^-] = 1.47 \times 10^{-14} / 0.182885 = 8.0378 \times 10–14$ mol dm^{-3}

= 1.47 × 10^{-14} / M4

If incorrect rearrangement or wrong equation, lose M5 and M6

If K_w = 1.00 × 10^{-14} used only lose M5 and allow M6 (ecf = 13.26)

1

M6 pH = 13.09 to 13.10

Must be 2dp

1

Alternative MS to get M2:

Starting amounts are 1.035×10^{-3} mol HCl and 3.75×10^{-3} mol $Ba(OH)_2$ M1

So the HCl will react with 5.175×10^{-4} mol of the $Ba(OH)_2$ leaving an excess of 3.2325×10^{-3} mol of $Ba(OH)_2$ (as alternative M2)

So n OH^- = $2 \times 3.2325 \times 10^{-3} = 6.465 \times 10^{-3}$ mol M3

Credit other methods eg limiting reagent method since HCl limiting reagent

(c) $[H^+] = [OH^-]$

1

(d) SO_2

1

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(e) $K_a = \frac{[CH_3COO^-][H^+]}{[CH_3COOH]}$

1

(f) **M1** moles HCl added = 0.01 mol and moles CH_3COOH = 0.035 mol

1

M2 moles CH_3COO^- = 0.025 – 0.01 (= 0.015)

M2 mol CH_3COO^- = 0.025 - M1(HCl)

1

M3 moles CH_3COOH = 0.035 + 0.01 (= 0.045)

M3 mol CH_3COOH = M1(CH_3COOH) + M1(HCl)

1

M4 $[H^+] = 1.76 \times 10^{-5} \times \frac{M3\ (/\ V)}{M2\ (/\ V)}$ (= 5.28×10^{-5})

M4 is conditional on an attempt at an addition/subtraction in M2 OR M3

1

M5 pH = 4.28

M5 must be 2dp

If used 0.07 mol for CH_3COOH can score M2, M3 and M4 (pH = 4.03)

1

[15]

Q2.

(a) $AlCl_3 + 6H_2O \rightarrow [Al(H_2O)_6]^{3+} + 3Cl^-$

Allow

$AlCl_3 + 6H_2O \rightarrow Al(H_2O)_5(OH)^{2+} + H^+ + 3Cl^-$

Or equation to form $Al(H_2O)_4(OH)_2^+$

1

(b) $[Al(H_2O)_6]^{3+} + H_2O \rightarrow [Al(H_2O)_5(OH)]^{2+} + H_3O^+$

allow equations to form $[Al(H_2O)_4(OH)_2]^+$

1

(c) white ppt/solid

M1 and M2 in either order

1

effervescence/bubbles/fizzing

1

$2[Al(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2[Al(H_2O)_3(OH)_3] + 3CO_2 + 3H_2O$

accept multiples

only allow spectator ions in a balanced equation

1

(d) White ppt/solid

1

$[Al(H_2O)_6]^{3+} + 3OH^- \rightarrow [Al(H_2O)_3(OH)_3] + 3H_2O$

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only allow spectator ions in a balanced equation

1

Colourless solution forms / ppt or solid dissolves

1

$[Al(H_2O)_3(OH)_3] + OH^- \rightarrow [Al(H_2O)2(OH)4]– + H_2O$

OR

$[Al(H_2O)_3(OH)_3] + OH^- \rightarrow [Al(OH)_4]^- + 3H_2O$

only allow 6 or 4 co-ordination

Allow $[Al(OH)_6]^{3-}$ in a balanced equation

1

[9]

Q3.

(a) $4Na + O_2 \rightarrow 2Na_2O$

Ignore state symbols

Allow multiples and fractions

Allow $2Na + O_2 \rightarrow Na_2O_2$

1

Yellow/orange flame/light AND white solid/powder/smoke/fumes/ash

Allow yellow solid

Do not allow ppt. Apply list principle

Ignore formulae in observations

1

(b) $4P + 5O_2 \rightarrow P_4O_{10}$ / $P_4 + 5O_2 \rightarrow P_4O_{10}$

Ignore state symbols

Do not allow equations with P_2O_5

Allow $4P + 3O_2 \rightarrow P_4O_6$ / $P_4 + 3O_2 \rightarrow P_4O_6$

1

white flame/light OR white fumes/smoke/solid/powder/ash

Do not allow ppt. Apply list principle

1

(c) Greater/increased charge/charge density on magnesium ion/Mg^{2+} (specific mention of ion(s) can be scored from M2)

Allow magnesium ion is smaller (than sodium ion);

Ignore atomic radius

If mention of molecules, intermolecular forces, metallic bonding then CE=0

1

Stronger attraction for anions/oxide ion / stronger attraction between oppositely charged ions/ stronger attraction between Mg^{2+} and O^{2-} / stronger ionic bonding

Ignore references to covalent character

Mark independently

1

(d) (SiO_2) giant covalent / macromolecular

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Do not allow M1 and M2 if it is clear that the candidate is referring to the structure of the elements rather than the oxides. M3 could score from correct comparison of giant covalent to simple molecular

Allow giant molecule

1

(P_4O_{10}) (simple) molecular

Not simple covalent

1

(Covalent) bonds (throughout structure) of SiO_2 much stronger than the forces between molecules/intermolecular forces in P_4O_{10}

Reference to 'between molecules' in M3 would also get M2

Allow van der Waals' forces between molecules

M3 dependent on correct M1 and M2

1

(e) **M1** Sample in suitable melting point apparatus (e.g. capillary in oil bath/Thiele tube / melting point apparatus)

Do not allow water bath

1

M2 Heat slowly/gradually/gently (to establish melting point range)

1

M3 Lower melting point / (broad) range of melting point indicates presence of impurities

OR melting point agrees with/close to data book value / melts sharply/over narrow range / melting point exactly 573K indicates purity

1

[12]

Q4.

A

[1]

Q5.

(a) $P_4 + 5\ O_2 \longrightarrow P_4O_{10}$

allow 4 P + 5 $O_2 \longrightarrow P_4O_{10}$

allow multiples

ignore state symbols

1

(b) React with water / add water / solution (of substances in question)

If no M1 then CE = 0/3

1

Add litmus paper / universal indicator / measure pH (with pH meter)

Allow other reagents in solution, e.g. sodium carbonate solution, that give a positive result

Allow other indicators with appropriate colour changes

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1

M3 is dependent on M2
Litmus: blue with sodium oxide (solution) **and** red with phosphorus oxide (solution)OR
If blue litmus added phosphorus oxide solution goes red OR
If red litmus added sodium (hydr)oxide goes blue

Universal Indicator: blue/ purple with sodium oxide (solution) **and** red with phosphorus oxide (solution)

pH meter or Universal Indicator: sodium (hydr)oxide (solution) has a higher pH (than phosphorus oxide (solution)) or vv

sodium (hydr)oxide pH (12 to 14) **and** phosphorus oxide (solution) pH (-1 to 2)

For pH meter or Universal Indicator: allow sodium (hydr)oxide (solution) has a higher pH and phosphorus oxide (solution) has lower pH.

1

(c) For silicon dioxide - giant covalent (molecule)/ macromolecular

1

For sulfur trioxide - molecular / (simple) molecule

1

Do not allow simple covalent

(d) Covalent bonds (between atoms) in SiO_2

1

Van der Waals between molecules / intermolecular forces in SO_3

1

Covalent bonds are stronger than van der Waals forces

1

(Covalent bonds) take more energy to be overcome/broken or (Van der Waals) take less energy to be overcome/broken

1

If covalent bonds between molecules of SiO_2 lose M1 only
If hydrogen bonds in SO_3 lose M2 only
If metallic or ionic max score = 1 (either M1 or M2)
If IMF in SiO_2 then max 1 (M2 only)
Allow dipole-dipole forces between molecules
For M3 and M4 comparison is required/implied

(e) $SO_3 + 2KOH \longrightarrow K_2SO_4 + H_2O$
$SO_3 + KOH \longrightarrow KHSO_4$
$SO_3 + 2OH^- \longrightarrow SO_4^{2-} + H_2O$
$SO_3 + OH^- \longrightarrow HSO_4^-$

Allow multiples
Ignore state symbols

1

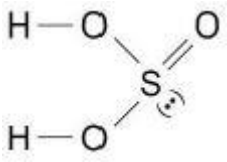
(f) $3\ MgO + 2\ H_3PO_4 \longrightarrow Mg_3(PO_4)_2 + 3\ H_2O$

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Allow multiples

Ignore state symbols

1

(g) 

Ignore lone pairs

1

[13]

Q6.

D

[1]

Q7.

(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]

Q8.

(a) (i) <u>Covalent</u>

Ignore simple / molecular

Do not allow macromolecular/giant covalent/dative/dipole-dipole/Hydrogen bonds

Ignore VdW

1

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(ii) P / phosphorus / P_4

1

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

*Mark independently of **(a)(ii)***

Accept multiples/fractions

Ignore state symbols

Allow ions on the RHS ($\longrightarrow 12H^+ + 4PO_4^{3-}$)

Allow correct equations from P_4O_6, P_2O_3 and P_2O_5

$P_4O_6 + 6H_2O \longrightarrow 4H_3PO_3$

$P_2O_3 + 3H_2O \longrightarrow 2H_3PO_3$

$P_2O_5 + 3H_2O \longrightarrow 2H_3PO_4$

1

(b) (i) Ionic

Ignore giant / lattice

1

(ii) Na / Sodium

1

(iii) $2Na + 2H_2O \longrightarrow 2Na^+ + 2OH^- + H_2$

Allow equation to form 2NaOH

Accept multiples/fractions

Ignore state symbols

1

(iv) $Na_2O + 2HCl \longrightarrow 2NaCl + H_2O$

Accept multiples/fractions

Ignore state symbols

Allow ions, but do not allow H+ only for the acid

1

(c) (i) Ionic

Allow ionic and covalent / ionic with covalent character

1

(ii) Al_2O_3

Ignore state symbols

1

(iii) Reacts with acids and bases

Allow reacts with acids and alkalis / acts as both an acid and a base / shows acidic and basic properties

1

(iv) $Al_2O_3 + 6HCl \longrightarrow 2Al^{3+} + 6Cl^- + 3H_2O$

$Al_2O_3 + 6H^+ \longrightarrow 2Al^{3+} + 3H_2O$

Allow equation to form $2AlCl_3$ (but not Al_2Cl_6)

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Allow equations with other acids

1

$Al_2O_3 + 2NaOH + 3H_2O \longrightarrow 2Na^+ + 2[Al(OH)_4]^-$

$Al_2O_3 + 2OH^- + 3H_2O \longrightarrow 2[Al(OH)_4]^-$

$Al_2O_3 + 2NaOH + 7H_2O \longrightarrow 2Na^+ + 2[Al(OH)_4\ (H_2O)_2]^-$

$Al_2O_3 + 2OH^- + 7H_2O \longrightarrow 2[Al(OH)_4\ (H_2O)_2]^-$

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

1

[12]

Q9.

(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]

Q10.

(a) (i) 1500

1

(ii) Ionic lattice / giant ionic

Mention of vdW / covalent bonding / molecules / atoms /

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metal etc. CE = 0

1

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-}

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 <u>between molecules</u> 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

$SiO_2 + 2NaOH$ □ $Na_2SiO_3 + H_2O$

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]

Q11.

(a) <u>White</u> powder / solid / ash / smoke

Ignore ppt / fumes

1

Bright / white light / flame

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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

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(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]

Q12.

(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

<u>Molecular</u> with <u>covalent</u> bonding

M2 can be awarded if molecular mentioned in M3

1

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

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]

Q13.

(a) Na_2O is an ionic <u>lattice</u> / 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 <u>van der Waals</u>' forces <u>between molecules</u> are stronger

Any mention of ions, CE= 0

1

(c) Ionic

Do not allow ionic with covalent character

1

Contains <u>O^{2-}</u> 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

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(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]

Q14.

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

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 $MgO + H_3PO_4 \rightarrow MgHPO_4 + H_2O$

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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]

Q15.

(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 between molecules stronger

Allow stronger IMF

1

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

Allow 2NaOH

1

14

Allow 12–14

1

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

Allow ions

1

0

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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]

Q16.

(a) (i) white flame / white light

Mark flame independent of other observations

1

solid / powder / smoke / ash / white fumes

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

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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]

Q17.

(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

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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 <u>between molecules</u>

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

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.

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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]

Q18.

(a) Macromolecular

Or giant molecule
Or giant 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 ionic

Allow ionic + covalent/ionic 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

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(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]

Q19.

(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

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(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]

Q20.

(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]

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Q21.

(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]

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Q1.

(a) 86.2% of students gave the correct definition.

(b) Most students calculated the amounts, in moles, of the reactants but often did not multiply the amount of barium hydroxide by two to give the amount of hydroxide ions. Some students did not convert the amount in moles to concentration and some did not quote their pH to two decimal places. This part of the question discriminated very well, with just over 20% of students scoring full marks.

(c) 81.8% of students gave the correct reason here.

(d) 78.5% correctly identified sulphur dioxide.

(e) 91% of students could give the correct expression for K_a.

(f) Most students could calculate the amount, in moles, of hydrochloric acid and of ethanoic acid, but many were unsure of how to use these numbers. Many students failed to recognise the need to increase the amount of acid and decrease the amount of salt due to the shift in the equilibrium when H^+ ions are added. Many added and subtracted the wrong way round or managed one process but not the other. Students could generally rearrange the K_a expression correctly; just over 40% of students scored full marks for this part of the question.

Q2.

(a) Just over half of the students (50.2%) could give the correct equation; common errors included giving chlorine as a product, incorrect balancing and sometimes an incorrect formula for aluminium chloride.

(b) Only a small proportion of students (22.6%) could give a correct equation here; many did not include protonation of water, as implied in the question. A surprisingly high proportion of students (10.8%) failed even to attempt this question.

(c) Here, students were more able to state observations than to write the equations. Some students stated that carbon dioxide was evolved, but this is not an observation – it is a deduction from the effervescence seen. Just over 25% of students scored all the marks in this part of the question.

(d) Students were better able to state observations than write equations but only 35% of students scored all of the marks available. Again, just over 10% of students failed to attempt this part.

Q3.

(a) This was expected to be a straightforward question on a familiar equation and set of observations. However, many students were unable to balance the equation, with $2Na + O_2 \rightarrow Na_2O$ seen frequently. Incorrect observations included numerous mentions of a ‘red’ flame and of the formation of a ‘precipitate’. Only 23.6% of students scored both marks.

(b) The need for only a single observation probably resulted in the higher marks here than in part (a) (39.4% fully correct). The formula of the oxide was usually correct, but incorrect reference to a ‘precipitate’ was again seen frequently.

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(c) This was another example where reading the question was key; many students incorrectly gave a comparison of sodium and magnesium (rather than their oxides), while others wasted time and space discussing the trend across the whole period. Any references to metallic bonding, or any suggestion of the presence of 'molecules', made it impossible to award credit in this question. 38.7% of students were able, however, to score both marks.

(d) The confusion in students' minds between 'molecular' and 'giant' structures was evident in many of the answers to this question. Contradictions were frequently seen, such as "silicon dioxide has a macromolecular structure with strong covalent bonds between the molecules". An ideal answer would be structured with clear statements that silicon dioxide is giant covalent (or macromolecular) and phosphorous oxide is (simple) molecular, followed by the statement that the covalent bonds between the atoms in silicon dioxide are much stronger then the intermolecular forces in phosphorous oxide. Use of the word 'bonds' should be avoided when referring to intermolecular forces (apart from the specific case of hydrogen bonds, not relevant in the answer to this question).

(e) This was answered quite well, although some answers were spoiled by reference to a water bath and many students failed to mention the need to heat slowly (near the melting point). More surprising at this level were those students who confused melting and boiling or who suggested dissolving the solid in water before starting to heat it.

Q4.

In a question where just under half of students arrived at the correct answer, D was the commonest incorrect response. This was presumably because sulfur forms an acidic oxide that reacts with alkali – but sulfur oxides are molecular, not ionic.

Q5.

(a) Students generally scored the mark for the equation (78.8% correct), though some students used P_2 or gave P_2O_5 as the product and lost the mark.

(b) Many students failed to realise that water was all that was required; those students who used water mostly went on to give a correct method for testing the solution.

(c) Most students answered this well, but "simple covalent" was a common incorrect, incomplete answer for sulfur dioxide.

(d) Most students understood that covalent bonds were broken for silicon dioxide and that intermolecular forces were overcome for sulfur trioxide. Some students lost marks because they thought intermolecular forces were also overcome in silicon dioxide. There were only a few examples where students got the type of bonding completely wrong.

(e) Many students struggled with the equation here and gave the products as potassium oxide and sulfuric acid.

(f) Many students found the formula of magnesium phosphate challenging and hence could not write a correct balanced equation. Often, students failed to pick up on the information that magnesium oxide was in excess and gave magnesium hydrogenphosphate as the product.

(g) Many students found this question quite challenging; sulfuric(VI) acid was often thought to be the product. Very few students gave a correct fully displayed formula.

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Q8.

This question was generally high scoring especially by the more able students. The types of bonding were generally well known. Common errors included sulfur in part (a), magnesium in part (b) and silicon in part (c) and therefore the equations could not gain credit. The correct equation between aluminium oxide and sodium hydroxide (or other alkalis) was not common in part (c) whilst the equation between aluminium oxide and an acid was better known.

Q9.

The quality of answers to inorganic questions of this type continues to be lower than hoped. The problem lies partly with a lack of knowledge and partly with imprecise language. In part (a) many equations were incorrect, showing formation of magnesium hydroxide rather than magnesium oxide. Students should know that precipitates and effervescence are only observed in reactions that take place in solution. In this question, magnesium oxide is formed as a solid, the hydrogen gas produced is invisible. In part (b) the equation was usually correct but the flame colour was not well known.

Q10.

In their answers to questions such as part (a)(ii) students should be encouraged to read the question carefully before answering. In this case the question asked students to explain the melting point in terms of structure **and** bonding. Parts (a)(iii) and (b) were answered well by most students. In part (c) a correct equation proved to be a challenge and it was surprising to note how often students attempted to balance an acid-base equation by producing hydrogen gas.

Q11.

Few students scored all three marks for part (a) and even the highest-scoring students often gave only one correct observation. Weaker students often suggested incorrectly that it would be possible to see a gas being evolved and also wrote an incorrect equation showing formation of magnesium hydroxide rather than the oxide. In part (b), metallic bonding was not explained well by most students, often being confused with ionic bonding or intermolecular forces. In part (c), very few students scored more than three marks, often being unable to give a correct second physical property of silicon dioxide. Incorrect answers usually involved misreading the question and giving ‘high melting point’ or suggesting a chemical property. The formula, structure and bonding for phosphorus(V) oxide were usually correct in part (d) but only the highest-scoring students gave correct equations in parts (e) and (f). In part (e), a very common error was to write an equation with sulfur trioxide rather than sulfur dioxide.

Q12.

This question was answered well and students of all abilities were able to score reasonable marks. In part (a), the most common error was to suggest that the conductivity of a solution could be tested. Apart from the problem that magnesium oxide is only sparingly soluble, A-level students should know that many covalent substances form ions in water so that testing the conductivity of a solution is not a good method for the identification of an ionic solid. In parts (b) and (c) only the higher-scoring students scored all marks. The marks for structure and bonding were usually gained but in part (b) a suggestion as to why water does not break down the structure was not given and in part (c) students often did not state clearly that the forces of attraction between molecules are weak.

Q13.

Answers to part (a) were usually correct. In part (b), weak students often confused intramolecular and intermolecular forces. In order to score both marks in a question like this, an answer must state that the stronger van der Waals' forces are between molecules. This was not often seen. In part (c), most students knew that basic oxides are usually ionic but only 18% of students could go on to explain fully how and why an oxide ion would act as a proton acceptor. Despite the statement in part (d)(i) that 'ions are formed', many students wrote an equation showing formation of the molecule H_2SO_3. Such answers lost the mark for this part of the question and made it very difficult for a mark to be scored in part (d)(ii). Answers to part (e) were usually correct.

Q14.

Most students answered part (a) correctly by stating that phosphorus would be kept out of contact with air/oxygen or that phosphorus reacts with oxygen. In part (b), it was expected that students would understand that P_4O_{10} represents a single molecule with 4 atoms of phosphorus and ten of oxygen but this answer was seldom seen. A very common wrong answer was to suggest that the representation P_4O_{10} is used because it is more stable than P_2O_5. Answers to part (c) were often good but common mistakes were to refer to SO_2 rather than SO_3 and to state that P_4O_{10} is macromolecular. A common omission was a failure to explain that van der Waalsű forces are between molecules. Part (d) was answered well by most students. Part (e)(i) was answered correctly by good students but weaker students sometimes could not give a correct formula for a magnesium phosphate and sometimes used phosphorus(V) oxide instead of phosphoric(V) acid. In parts (e)(ii) and (iii), some students did not appreciate that the question referred to an excess of the reagent and confined their answers to the neutralisation reaction only. Many students did not appreciate or mention that magnesium oxide is sparingly soluble.

Q15.

Parts (a)(i) and (a)(ii) were answered correctly by most students. Part (b) proved to be more demanding and only the best students appreciated that the van der Waals' forces between molecules in P_4O_{10} are stronger than in SO_2. Too many students thought incorrectly that P_4O_{10} was macromolecular or ionic. Part (c) was answered well and more than 80% of students scored at least three marks. As expected, part (d) was a little more demanding and only about 50% of students gained the mark.

Q16.

Period 3 chemistry always provides a challenge for candidates and this question was no exception to that rule. Part (a)(i) was well answered with almost 80% of candidates scoring at least 3 marks out of the four available. The observation that indicated the formation of magnesium oxide, a white solid, was most often omitted. Part (a)(ii) proved to be more difficult and although the blue flame observed when sulfur burns was quite well known, a positive observation for sulfur dioxide, such as a gas with a pungent odour, was not. In part (b) many candidates knew that sodium oxide is ionic and that it forms sodium hydroxide in water but they did not mention oxide ions and go on to explain why an oxide ion would form hydroxide ions in water. Answers to part (c) were very disappointing. Only about 18% of candidates suggested testing the conductivity of molten aluminium oxide. Most candidates suggested dissolving the oxide in water, even though, in part (d) they went on to state that aluminium oxide is insoluble in water. Answers to parts (e)(i) and (e)(ii) were only very occasionally correct. Many candidates appeared to be unfamiliar with the concept of an ionic equation and they often attempted to use HCl or NaOH. Perhaps, in future candidates could be encouraged to recognise that equations between aluminium oxide and H^+ or OH^- ions are easier to write than equations with HCl or NaOH.

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Q17.

Part (a) was answered quite well, especially for Na_2O. For SiO_2 candidates too often spoiled their answers by referring to molecules and intermolecular forces or in some cases to ions. Quite often, such references appear to be careless use of contradictory terms rather than a completely false understanding of the structure and bonding. Answers to part (b) were very disappointing and the average score for this question was only one out of three. In the Specification, candidates are expected to understand that the melting point and lattice enthalpy of an ionic crystal depend on the size of the ions and on their charges. Answers to part (c)(i) were generally good but in part (c)(ii), candidates often failed to mention 'between molecules'. Part (d) produced the expected range of answers and a pleasing 60% of candidates scored full marks. As expected part (e) was much harder and only a very few candidates were able to write a correct equation.

Q18.

This question proved to be a little easier than question 1. Most candidates gave correct explanations in part (a) but weak candidates did not make a clear distinction between molecules and a macromolecule. Parts (b) and (c) were answered well but part (d) proved to be more testing and a significant number of candidates gave no answer. Most candidates answered part (e) correctly. As expected part (f)(i) was more challenging and in part (f)(ii), only the very best candidates could write a correct, balanced equation. It was pleasing to find that part (g) was usually correct.

Q19.

The first part of this question tested synoptic understanding of periodicity. The question discriminated well with good candidates gaining full marks. Weaker candidates often confused electronegativity with ionisation energy. Part (b) also produced a wide spread of marks. Many candidates did not include in their explanations, reasons for the strong forces between ions in sodium oxide and why the forces between molecules in phosphorus(V) oxide are relatively weak. Common errors amongst weak candidates were to mistake sodium oxide for an oxide of sulfur or to refer to the existence of molecules in sodium oxide. Part (c) demanded an appreciation that three moles of sodium hydroxide react with one mole of phosphoric acid and that one mole of phosphorus(V) oxide gives four moles of phosphoric acid. This, together with the dilution factor of one million, resulted in a wide but even spread of marks for the question with only 15% of candidates gaining all six marks.

Q21.

The acidity of Period 3 oxides was well known but a surprisingly large number of candidates were unable to write equations for their reactions as required in part (b). The structure and bonding in P_4O_{10} and SiO_2 were well known and most candidates were able to make the link to the volatility of the compound.

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