AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



MARK SCHEME

3.2.6 REACTIONS OF IONS IN AQUEOUS SOLUTION

SCORE	PERCENTAGE
/205	%

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Q1.

(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

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

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]

Q2.

(a) **A** Silver bromide / AgBr

1

B Iron(II) carbonate / $FeCO_3$

1

C Iron(II) sulphate / $FeSO_4$

1

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D Carbon dioxide / CO_2

1

Y Iron(II) bromide / $FeBr_2$

1

(b) $Ag^+ + Br^- \longrightarrow AgBr$

Allow equation if state symbols missing but penalise if state symbols are incorrect

1

(c) $2H^+ + CO_3^{2-} \longrightarrow H_2O + CO_2$

Allow $FeCO_3 + 2H^+ \longrightarrow Fe^{2+} + CO_2 + H_2O$

1

[7]

Q3.

(a) $[Fe(H_2O)_6]^{3+} + 4Cl^- \longrightarrow FeCl_4^- + 6H_2O$

1

(b) Cl^- is a bigger ligand

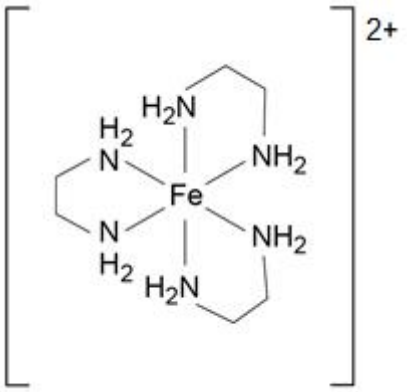
1

So only $4Cl^-$ can fit around the metal

Allow fewer Cl^- *can fit around the metal*

1

(c)



M1 for structure of complex

M2 for correct charge

1

1

(d) Change in entropy is positive

1

(e) $5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

1

(f) Amount of manganate (VII) = 6.50×10^{-4} mol

1

Amount of iron(II) = 3.25×10^{-3} mol

ie M1 × 5

1

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Mass of iron = 0.181 g = 181 mg

Allow M2 × 55.8

1

Percentage Fe = 181/1980 × 100 = 9.14(%) 3 sf

1

(g) Colourless to pale pink

1

[12]

Q4.

(a) An electron pair on the ligand

1

Is donated from the ligand to the central metal ion

1

(b) Blue precipitate

1

Dissolves to give a dark blue solution

1

$[Cu(H_2O)_6]^{2+} + 2NH_3 \longrightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$

1

$Cu(H_2O)_4(OH)_2 + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^- + 2H_2O$

1

(c) $[Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2NCH_2CH_2NH_2 \longrightarrow [Cu(H_2NCH_2CH_2NH_2)_2(H_2O)_2]^{2+} + 4NH_3$

1

(d) Cu–N bonds formed have similar enthalpy / energy to Cu–N bonds broken

1

And the same number of bonds broken and made

1

(e) 3 particles form 5 particles / disorder increases because more particles are formed / entropy change is positive

1

Therefore, the free-energy change is negative

M2 can only be awarded if M1 is correct

1

[11]

Q5.

D

[1]

Q6.

B

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[1]

Q7.

B

[1]

Q8.

(a) $Cr(OH)_3 + 3H_2O + 3H^+ \rightarrow [Cr(H_2O)_6]^{3+}$

Can start with $Cr(H_2O)_3(OH)_3$ for each equation

Ignore any unnecessary preliminary preparation of $Cr(OH)_3$

1

Green / grey−green solid

Mark colours independently from equations

Allow green ppt.

1

Forms green / purple / ruby / violet <u>solution</u>

ignore shades of colours

1

$Cr(OH)_3 + 2H_2O + OH^- \rightarrow [Cr(H_2O)_2(OH)_4]^-$

Allow with 5 or 6 OH^- provided complex has co−ordination number of 6

Penalise complex ions with incorrect charges overall or if shown on ligand.

1

Forms green <u>solution</u>

Note that for each equation final complex must be 6 co−ordinate

1

(b) $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$

Allow two correct equations via intermediate hydroxide in both cases even if first equation uses OH^- instead of NH_3

1

Blue (solution)

Mark colours independently from equations

1

Dark / deep / royal blue <u>solution</u>

1

$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$

1

pink / red (solution)

1

Brown / straw / yellow <u>solution</u>

ignore darkens in air / with time

1

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[11]

Q9.

(a) $4Fe(s) + 6H_2O(g) + 3O_2(g) \rightarrow 4Fe(OH)_3(s)$

Accept fractions, multiples and equations showing formation of hydrated hydroxide.

1

Correct states as above

Lose this mark if any state is missing or incorrect.

1

(b) Aluminium (metal) forms an oxide coat (on exposure to air)

1

This coat prevents / inhibits further reaction (by water or oxygen)

Ignore references to a 'less reactive coating' unless further qualified.

1

[4]

Q10.

(a) $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow Fe(H_2O)_4(OH)_2 + 2NH_4^+$

Allow equation with OH^- provided equation showing formation of OH^- from NH_3 given

1

Green precipitate

1

$[Fe(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow FeCO_3 + 6H_2O$

1

Green precipitate

effervescence incorrect so loses M4

1

(b) (i) Colourless / (pale) green changes to pink / purple (solution)

Do not allow pale pink to purple

1

Just after the end−point MnO_4^- is in excess / present

1

(ii) $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$

1

Moles $KMnO_4 = 18.7 \times 0.0205 / 1000 = (3.8335 \times 10^{-4})$

Process mark

1

Moles $Fe^{2+} = 5 \times 3.8335 \times 10^{-4} = 1.91675 \times 10^{-3}$

Mark for M2 × 5

1

Moles Fe^{2+} in 250 $cm^3 = 10 \times 1.91675 \times 10^{-3} = 0.0191675$ moles in 50

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cm^3

Process mark for moles of iron in titration (M3) × 10

1

Original conc Fe^{2+} = 0.0191675 × 1000 / 50 = 0.383 $\underline{\text{mol dm}^{-3}}$

Answer for moles of iron (M4) × 1000 / 50

Answer must be to at least 2 sig. figs. (0.38)

1

[11]

Q11.

(a) **Reaction 1**

General principles in marking this question

Square brackets are not essential

Penalise charges on individual ligands rather than on the whole complex

Reagent and species can be extracted from the equation

Ignore conditions such as dilute, concentrated, excess

Reagent must be a compound NOT just an ion

Equations must start from $[Cu(H_2O)_6]^{2+}$ except in part (b)

Mark reagent, species and equation independently

ammonia (NH_3) (solution) / NaOH

1

$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(H_2O)_4(OH)_2] + 2NH_4^+$ /

$[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow [Cu(H_2O)_4(OH)_2] + 2H_2O$

Do not allow ~~OH^-~~ for reagent

Product 1, balanced equation 1

Allow either equation for ammonia

2

(b) **Reaction 2**

Ammonia (conc / xs)

1

$[Cu(H_2O)_4(OH)_2] + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2H_2O + 2OH^-$

Product 1, balanced equation 1

Note that the equation must start from the hydroxide $[Cu(H_2O)_4(OH)_2]$

2

(c) **Reaction 3**

Na_2CO_3 / any identified soluble carbonate / $NaHCO_3$

Do not allow $NaCO_3$ or any insoluble carbonate but mark on

1

$[Cu(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CuCO_3 + 6H_2O$

OR $[Cu(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow CuCO_3 + 6H_2O + 2Na^+$

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OR $2[Cu(H_2O)_6]^{2+} + 2CO_3^{2-} \rightarrow Cu(OH)_2.CuCO_3 + 11H_2O + CO_2$

OR with $NaHCO_3$

$[Cu(H_2O)_6]^{2+} + HCO_3^- \rightarrow CuCO_3 + 6H_2O + H^+$

Product 1, balanced equation 1

2

(d) **Reaction 4**

HCl (conc / xs) / NaCl

Allow any identified soluble chloride

1

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

Product 1, balanced equation 1

2

[12]

Q12.

(a) Iron(II): green (solution) gives a green precipitate

Apply list principle throughout if extra colours and / or extra observations given. Ignore state symbols in equations.

Not blue-green ppt.

1

$\underline{[Fe(H_2O)_6]^{2+}} + CO_3^{2-} \rightarrow FeCO_3 + 6H_2O$

Must start from $[Fe(H_2O)_6]^{2+}$

Allow equations with Na_2CO_3

1

Iron(III): yellow / purple / brown / lilac / violet (solution) gives a brown / rusty precipitate

1

Effervescence / gas / bubbles

Allow CO_2 evolved but not just CO_2

1

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

1

(b) Copper(II): blue (solution) gives a green / yellow solution ***OR*** blue solution (turns) to green / yellow / olive green

Apply list principle throughout if extra colours and / or extra observations given. Ignore state symbols in equations.

1

$\underline{[Cu(H_2O)_6]^{2+}} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

Allow equations with HCl

1

Cobalt(II): pink (solution) gives a blue solution ***OR*** pink solution turns blue

1

$\underline{[Co(H_2O)_6]^{2+}} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$

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1

(c) Iron(II): green (solution) gives a green precipitate

Apply list principle throughout if extra colours and / or extra observations given. Ignore state symbols in equations.

1

$\underline{[Fe(H_2O)_6]^{2+}} + 2OH^- \rightarrow Fe(H_2O)_4(OH)_2 + 2H_2O$

Allow equations with NaOH

1

Chromium(III): green / ruby / purple / violet / red-violet (solution) gives a green solution ***OR*** green / ruby / purple / violet / red-violet solution turns green

Ignore green ppt.

1

$\underline{[Cr(H_2O)_6]^{3+}} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$

Allow also with 4 or 5 OH balanced with 2 or 1 waters.

Also allow two correct equations showing $Cr(H_2O)_3(OH)_3$ as intermediate.

1

(d) Al: colourless (solution) gives a white ppt

Apply list principle throughout if extra colours and / or extra observations given. Ignore state symbols in equations.

1

$\underline{[Al(H_2O)_6]^{3+}} + 3NH_3 \rightarrow Al(H_2O)_3(OH)_3 + 3NH_4^+$

Allow $+ 3OH^- \rightarrow 3H_2O$ if

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ also

1

Ag: colourless (solution) remains a colourless solution / no visible change

Ignore brown ppt.

1

$\underline{[Ag(H_2O)_2]^+} + 2NH_3 \rightarrow [Ag(NH_3)_2]^+ + 2H_2O$

Allow 2 / 3 equations involving Ag_2O or $Ag(OH)_2$

1

[17]

Q13.

(a) Yellow (solution)

1

Orange <u>solution</u>

1

$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$

Allow equation with H_2SO_4

1

(b) Yellow / purple (solution)

Allow orange / brown (solution)

1

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Brown precipitate / solid

1

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

1

(c) Blue (solution)

Allow pale blue

1

Dark / deep blue <u>solution</u>

Ignore any reference to blue ppt

1

$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$

Can be in two equations

1

(d) Colourless (solution)

1

White precipitate / solid

Do not allow grey

1

Bubbles / effervescence / gas evolved / given off

Do not allow just CO_2

1

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

1

[13]

Q14.

(a) Electron <u>pair</u> donor

Allow lone <u>pair</u> donor

1

(b) $[Cu(H_2O)_6]^{2+} + 2NH_3 \longrightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$

1

(Blue solution) gives a (pale) <u>blue precipitate/solid</u>

M2 only awarded if M1 shows Bronsted–Lowry reaction

1

(c) $[Cu(H_2O)_6]^{2+} + 4NH_3 \longrightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$

Allow formation in two equations via hydroxide

1

(Blue solution) gives a <u>dark/deep blue solution</u>

If (b) and (c) are the wrong way around allow one mark only for each correct equation with a correct observation (max 2/4)

M2 only awarded if M1 shows Lewis base reaction

1

(d) (Start with) green (solution)

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1

Green precipitate of $Fe(H_2O)_4(OH)_2$ / $Fe(OH)_2$ / iron(II) hydroxide

Do not allow observation if compound incorrect or not given

1

Slowly changes to brown solid

Allow red-brown ppt

Allow turns brown or if precipitate implied

Can only score M3 if M2 scored

1

(Iron(II) hydroxide) oxidised by air (to iron(III) hydroxide)

Allow $Fe(OH)_2$ oxidised to $Fe(OH)_3$ by air / O_2

Ignore equations even if incorrect

1

(e) (i) $2[Al(H_2O)_6]^{3+} + 3H_2NCH_2CH_2NH_2 \longrightarrow 2Al(H_2O)_3(OH)_3 + 3[H_3NCH_2CH_2NH_3]^{2+}$

For correct Al species

1

For correct balanced equation

Allow equation with formation of $3[H_2NCH_2CH_2NH_3]$ + from 1 mol $[Al(H_2O)_6]^{3+}$

1

White precipitate

1

(ii) $[Co(H_2O)_6]^{2+} + 3H_2NCH_2CH_2NH_2 \longrightarrow [Co(H_2NCH_2CH_2NH_2)_3]^{2+} + 6H_2O$

1

Complex with 3 en showing 6 correct bonds from N to Co

Ignore charge

Accept N – N for ligand

Ignore incorrect H

If C shown, must be 2 per ligand

1

Co–ordinate bonds (arrows) shown from N to Co

Can only score M3 if M2 correct

1

$4[Co(H_2NCH_2CH_2NH_2)_3]^{2+} + O_2 + 2H_2O \longrightarrow 4[Co(H_2NCH_2CH_2NH_2)_3]^{3+} 4OH^-$

For Co(III) species

1

For balanced equation (others are possible)

Allow + O_2 + $4H^+ \longrightarrow 2H_2O$

If en used can score M4 and M5 only

If Cu not Co, can only score M2 and M3

Allow $N_2C_2H_8$ in equations

1

[17]

Q15.

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(a) Idea that over time / after storage meter does not give accurate readings

Do not accept 'to get an accurate reading' without further qualification.

Allow 'temperature variations affect reading'.

1

(b)

$$\frac{[[Fe(H_2O)_5OH]^{2+}(aq)]\,[H^+(aq)]}{[[Fe(H_2O)_6]^{3+}(aq)]}$$

Allow without (aq) symbols.

Need at least one set of square brackets around complex ions

1

(c) $pH = -\log [H^+]$

1

$[H^+] = 0.0240$

Do not penalise precision of $[H^+]$

Correct answer scores M1 and M2.

1

$K_a = (0.0240)^2 / 0.1 = 5.75 \times 10^{-3}$ or 5.76×10^{-3}

Correct answer without working loses M1 and M2.

Allow 7.58×10^{-3}

1

Answer, even if incorrect, given to 3 sig figs

1

(d) Oxygen (in the air) / O_2

Ignore 'air' or 'the atmosphere' or 'chemicals in soil'.

List principle.

1

(e) 4.0 – 6.9

Do not penalise precision.

[7]

Q16.

(a) oxidation state of N in $Cu(NO_3)_2$: +5;

1

oxidation state of N in NO_2: +4;

1

oxidation product: oxygen;

1

(b) copper-containing species: $[Cu(H_2O)_6]^{2+}$;

1

shape: octahedral;

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1

(c) (i) precipitate B: $Cu(H_2O)_4(OH)_2$ or $Cu(OH)_2$ or name;

1

equation: $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$

OR

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

and

$[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(H_2O)_4(OH)_2 + 2H_2O$;

1

(ii) NH_3 accepts a proton;

1

(d) (i) identity: $[Cu(NH_3)_4(H_2O)_2]^{2+}$;

1

colour: deep blue;

1

equation:

$Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$;

1

(ii) NH_3 is an electron pair donor;

1

(e) identity: $[CuCl_4]^{2-}$;

1

colour: yellow-green;

1

shape: tetrahedral;

1

(f) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$;

1

(ii) role of Cu: a reducing agent;

1

[17]

Q17.

(a) Brown <u>ppt/solid</u>

1

Gas evolved/effervescence

1

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

Must be stated, Allow CO_2 evolved. Do not allow CO_2 alone

Correct iron product (1) allow $Fe(OH)_3$ and in equation

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Balanced equation (1)

2

(b) White ppt/solid

1

Colourless Solution

Only award M2 if M1 given or initial ppt mentioned

1

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

Allow $[Al(H_2O)_6]^{3+} + 3OH^- \rightarrow Al(OH)_3 + 6H_2O$

1

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

Allow formation of $[Al(H_2O)_{6-x}(OH)_x]^{(x-3)-}$ where x = 4,5,6

Allow product without water ligands

Allow formation of correct product from $[Al(H_2O)_6]^{3+}$

1

(c) Blue ppt/solid

1

(Dissolves to give a) deep blue solution

Only award M2 if M1 given or initial ppt mentioned

1

$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$

Allow $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2 + 2NH_4^+ + 4H_2O$

Allow two equations: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

then $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 4H_2O$ etc

1

$Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2OH^- + 2H_2O$

Allow $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$

1

(d) Green/yellow solution

1

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

1

[14]

Q18.

(a) Iron

1

Heterogeneous; catalyst in a different phase from that of the reactants

1

Poison; a sulphur compound (allow sulphur)

1

Poison strongly adsorbed onto active sites/ blocked

1

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Poison not desorbed or reactants not adsorbed or catalyst surface area reduced

1

(b) Pale green solution 1

Green precipitate formed

1

Insoluble in excess ammonia

1

Equation:

e.g. $[Fe(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Fe(H_2O)_4(OH)_2] + 2NH_4^+$ Species

1

Balance

1

NB Allow equations with H_2O and OH^- if reaction of H_2O with NH_3 also given

Max 4

[9]

Q19.

(a) (i) An atom, ion or molecule which can donate a lone electron pair

1

(ii) A central metal ion/species surrounded by co-ordinately bonded ligands or ion in which co-ordination number exceeds oxidation state

1

(iii) The number of co-ordinate bonds formed to a central metal ion or number of electron pairs donated or donor atoms

1

(b) (i) *Allow the reverse of each substitution*

$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$

Complex ions

1

Balanced

1

Allow partial substitution

(ii) $[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow CoCl_4^{2-} + 6H_2O$

Complex ions

1

Balanced

or H_2O or NH_3 or $C_2O_4^{2-}$ by Cl^-

1

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eg. (iii) $[Co(H_2O)_6]^{2+} + 3C_2O_4^{2-} \rightarrow [Co(C_2O_4)_3]^{4-} + 6H_2O$

Complex ions

1

Balanced

1

Allow all substitution except
(i) NH_3 by H_2O
(ii) more than $2Cl^-$ substituted for NH_3 or H_2O

eg. (iv) $[Co(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [Co(EDTA)]^{2-} + 6H_2O$

Complex ions

1

Balanced

or H_2O or NH_3 by $C_2O_4^{2-}$ and NH_3 or Cl^- by $EDTA^{4-}$

1

(c) (i) $[Fe(H_2O)_6]^{2+}$

1

(ii) $Fe(OH)_2$ or $Fe(OH)_2(H_2O)_x$ where x = 0 to 4

1

(iii) Fe^{2+} is oxidised to Fe^{3+} or $Fe(OH)_3$

1

By oxygen in the air

1

[15]

Q20.

(a) (i) Deductions:

Ionic **(1)**
Ions not free to move in the solid state **(1)**
Ions free to move when molten or in aqueous solution **(1)**
Identity of **P**: Na_2O or sodium oxide **(1)**

N.B. If a formula given this must be correct

Equation: $Na_2O + H_2O \rightarrow 2\ NaOH$ **(1)**

5

(ii) Deductions:

Covalent
Intermolecular forces are weak or van der Waals forces,
or dipole-dipole

N.B. Any answer including a reference to hydrogen bonding is incorrect

Identity of **Q**: SO_2 or sulphur dioxide **(1)**

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Equation: $SO_2 + H_2O \rightarrow H_2SO_3$ **(1)**

NB Allow max one for SO_3

4

(b) (i) Amphoteric **(1)**

(ii) Equation with NaOH

$Al(OH)_3 + NaOH \rightarrow NaAl(OH)_4$

OR $Al(OH)_3(H_2O)_3 + OH^- \rightarrow [Al(OH)_4(H_2O)_2]^- + H_2O$
OR $Al(OH)_3 + OH^- \rightarrow [Al(OH)_4]^-$

R identified as $Al(OH)_3$ or $Al(OH)_3(H_2O)_3$ **(1)**
A balanced equation **(1)**

N.B. Allow equation with six co-ordinate Aluminium and up to six OH^- ligands
N.B. Allow equation mark if $M(OH)_3$ given in a balanced equation

Equation with H_2SO_4

$2Al(OH)_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 6H_2O$

OR $Al(OH)_3(H_2O)_3 + H^+ \rightarrow [Al(OH)_2(H_2O)_4]^+ + H_2O$

NB Allow equations with six co-ordinate Aluminium and up to six H_2O ligands NB Allow equation mark if $M(OH)_3$ given in a balanced equation

Correct Al species as product **(1)**
A balanced equation **(1)**

(iii) Large lattice energy
or strong covalent bonds
or ΔH_{soln} is very positive
or ΔG is positive
or sum of hydration energies less than covalent bond energies **(1)**

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[15]

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Q1.

(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.

Q8.

In part (a) the observations were usually described accurately. Attempts at the equations were less successful. Again, students should be encouraged to read the question carefully before starting to answer it. Many students attempted to start from an aqueous solution of chromium(III) ions instead of the solid hydroxide. Students were asked to write ionic equations because it was thought hat this would make the equations simpler and easier to write. A significant number of students ignored this instruction and were penalised. In part (b) of this question students were asked to write equations for ligand substitution reactions. It was not possible to answer this question correctly unless it was realised that the initial complex ion, in aqueous solution, was a hexaaqua ion with six water ligands. When describing an observation it is important to give the phase to which the colour applies so that the product of reacting an excess of aqueous ammonia with copper(II) sulphate solution is a ‘deep blue solution’, not just ‘deep blue’.

Q9.

Better students had little problem with this question but there was some poor marking of part **(a)** with equation errors and missing state symbols often overlooked. Marking was sometimes overgenerous in **(b)** where a clearer statement was needed for the second mark.

Q10.

Most students gave correct observations in part (a) but their attempts at equations were less successful and often unbalanced. Very few correct answers to part (b)(i) were seen. The most usual response was to suggest, without any explanation, that the colour change was from purple to colourless. Part (b)(ii) produced a whole range of responses. Good students were able to score all 5 marks in impressive style but others lost marks. The most common mistake was an incorrect equation and the use of an incorrect molar ratio for moles of iron(II) to manganate(VII). Many students were also unable to calculate the concentration of iron(II) ions in the original solution from the number of moles of iron(II) ions in the 250 cm^3 flask. A factor of 1000/50 was required but factors such as 1000/250 or 250/25 were common mistakes.

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Q11.

This question was answered well and students of all abilities were able to score a reasonable number of marks. The most common errors were to give wrong overall charges for some of the complex ions and a failure to give a complete name or formula for the reagent. In part (b), some students lost the equation mark because an aqueous copper ion rather than the hydroxide precipitate was used as the starting material. Part (c) was answered least well. Some students did not recognise that the green-blue precipitate was copper carbonate and many who did were unable to give a correct formula for sodium carbonate.

Q12.

Answers to this type of question demand careful attention to the colour and state of the transition metal ions or compounds before and after reaction and careful attention to balancing of equations with numbers of atoms and charges on ions. Some students continue to lose marks because they give charges on ligands within the formula for a complex ion. The only charge required on a complex ion is the overall charge that, ideally, should appear outside square brackets, although a lack of brackets was not penalised. In part (a), the most common error was to omit the observation that a gas is evolved when sodium carbonate is added to a solution containing iron(III) ions. Part (b) was answered well although some students just gave the colour of the products and did not state that solutions rather than precipitates are formed. In part (c), the most usual errors were unbalanced equations. Part (d) proved to be the hardest part of this question. Many students gave an unbalanced equation for the reaction between ammonia and aluminium ions and most students stated incorrectly that the solution of $[Ag(H_2O)_2]^+$ ions appeared to be a silver colour.

Q13.

This question depended on accurate recall of the reactions of metal ions in solution. It discriminated well. Good students were able to score full marks. Weaker students found the equations difficult and did not always recall correct colours. In questions of this nature, it has been reported previously but it is worthwhile repeating that an observation of a colour is only complete if the colour is tied to the species that is coloured. For instance, in part (b), a brown precipitate is formed but in part (c) the product is a deep blue solution.

Q14.

Parts (a) and (b) were usually correct. Part (c) proved to be more difficult than part (b). Weaker students gave an ammine complex with six rather than four ammonia molecules and the charge of the ammine complex was often incorrect. Part (d) was very discriminating. Only the best students identified the initial green precipitate as a form of iron(II) hydroxide and went on to explain that this would be oxidised to a brown solid by oxygen in the air. Part (e)(i) was set as a ‘stretch and challenge’ question and it proved to be so. It was disappointing to find that only a very few students could draw a parallel with the reaction in part (b) and hence predict that aluminium hydroxide would be formed. Part (e)(ii) was very discriminating; most students could gain some credit but only the very best students were able to gain four or more marks out of the five available. Only about 2% of students were able to write a correct equation for the oxidation of the cobalt(II) complex.

Q15.

Part (a) proved to be the most demanding question in the paper. The great majority of candidates appreciated that calibration improves accuracy but did not explain why it is necessary in the first place. At A2 candidates should be wary of providing an answer such as ’to get a more accurate result’ without an appropriate qualification.

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The expression in part (b) was widely known and many candidates were able to complete the calculation in part (c) in full.

In part (c) the great majority of candidates remembered to record the equilibrium constant to three significant figures.

Part (d) and part (e) defeated many candidates. The likelihood of oxidation by oxygen in the air seemed to be elusive while most candidates thought the iron(II) aqua ion to be a strong acid and estimated the pH accordingly.

Q16.

Most candidates deduced correctly the oxidation state of nitrogen in NO_2 but rather less correctly determined the oxidation state of nitrogen in $Cu(NO_3)_2$- Many failed to identify the oxidation product as oxygen with CuO being the most common incorrect answer. Part (b) was generally well answered but identifying the precipitate B as copper(II) hydroxide, in (c)(i), proved more difficult. Many candidates failed to give an equation, or a pair of equations, showing the role of ammonia in the formation of this precipitate and lost a mark. Most stated correctly that ammonia is a proton acceptor in answer to (c)(ii) but many failed to correctly identify the copper-containing species in solution **C** as $[Cu(NH_3)_4(H_2O)_2]2^+$ with $[Cu(NH_3)_6]2+$ being the most common incorrect answer. The colour of this complex was generally well known but only the better candidates were able to write a correct equation for its formation. The role of ammonia as a Lewis base was generally well known but the formula and colour of the copper-containing species, $[CuC_4l]^{2-}$, present in solution **D**, were less well known. Part (f) proved to be particularly testing and only the better candidates gave a correct electronic arrangement for a Cu^+ ion and correctly identified copper metal as the reducing agent in the formation of $[CuCl_4]^{3-}$.

Q17.

The general standard of answers to this question was very disappointing. It was clear to examiners that a large majority of students could not recall what should be observed and what happens in the various reactions given. In part (a), only 8% of candidates scored full marks. Examiners hoped that candidates would understand that the action of carbonate ions on a metal ion with a 3+ charge always leads to a hydroxide precipitate and evolution of carbon dioxide gas, but most candidates were unable to give a full answer. In part (b) most candidates suggested either the formation of a hydroxide precipitate or a complex $[Al(OH)_6]^{3-}$ (or $[Al(OH)_4]^-$) ion but only the best candidates knew that one would be formed first followed by the other. The same sort of responses were common in part (c) with only the best candidates explaining correctly that a blue hydroxide precipitate would be followed by a deep blue solution containing $[Cu(H_2O)_2(NH_3)_4]^{2+}$ ions. Answers to part (d) were more often correct.

Q18.

In answer to part (a), most candidates identified iron as the heterogeneous catalyst in the Haber process and explained the term *heterogeneous* correctly. Although poisoning of the iron catalyst by sulphur is clearly stated in the Specification, many other elements and compounds were stated incorrectly to poison this catalyst. The method by which the poison works was well known and well explained. Only the best candidates gave a correct equation for the reaction of an aqueous iron(II) salt with an excess of aqueous ammonia as required in part (b). Candidates who gave equations involving the reaction of either water or hydroxide ions were allowed to score full marks provided that they also gave an equation showing the equilibrium reaction of ammonia with water. Correct observations were given by most of the good candidates but others either failed to state any observations or gave incorrect answers.

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Q19.

Although part (a) was generally well done, a significant number of candidates lost marks as their definitions were imprecise. This was most notable in section (iii) where candidates who stated that *the co-ordination number was the number of ligands co-ordinately bonded to the central metal ion* lost a mark as this statement is only correct if the ligands are unidentate. The ligand substitution reactions in part (b) were generally well done. Candidates should be reminded that although it is necessary to use the charges on ligands when deducing the overall charge on the complex ion, these charges should not be included in the formula of the complex. The answer to (b)(iii) was not, as a significant number thought, an acid-base reaction. Most candidates understood the chemistry required in part (c) but some lost a mark as they failed to state that the oxidation of iron(II) to iron(III) was caused by oxygen in the air.

Q20.

This was a question on the oxides of Period 3 elements. In part (a) candidates were required to identify two oxides, P and Q. Candidates who used the given information to correctly identify the bonding present in the two oxides were awarded marks even when the oxides were then identified incorrectly. Although many candidates identified P correctly as sodium oxide and gave a correct equation for its reaction with water others lost marks when they attempted to explain the electrical conductivity in terms of electron movement. Oxide Q was identified correctly as SO_2 by many candidates. Those who identified it as SO_3 were penalised by the loss of one mark. Almost every candidate stated correctly that hydroxide R was amphoteric. Most also identified it as aluminium hydroxide. Although any correct equations for the reactions of this hydroxide with sodium hydroxide, or hydroxide ions, and sulphuric acid, or hydrogen ions, were accepted, candidates often gave unbalanced equations with incorrect species. Nevertheless there were many excellent answers which scored full marks. Most candidates were unable to suggest a reason why R, aluminium hydroxide, is insoluble in water. It was hoped that candidates would realise that a great deal of energy is needed to break down the bonding in the hydroxide and that hydration would not supply sufficient energy for this change to occur. In the event any sensible suggestion such as the hydroxide had strong covalent bonds was accepted for the one mark.

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