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# Reactions of ions in aqueous solution 1

2002

XVIII

1583

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# CHEMISTRY

**AQA**

**AS & A LEVEL**

**Mark Schemes**

**Inorganic Chemistry**

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1

*Can start with  $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$  for each equation**Ignore any unnecessary preliminary preparation of  $\text{Cr}(\text{OH})_3$* 

1

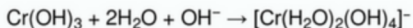
Green / grey-green solid

*Mark colours independently from equations**Allow green ppt.*

1

Forms green / purple / ruby / violet solution*ignore shades of colours*

1

*Allow with 5 or 6  $\text{OH}^-$  provided complex has co-ordination number of 6**Penalise complex ions with incorrect charges overall or if shown on ligand.*

1

Forms green solution*Note that for each equation final complex must be 6 co-ordinate*

1

*Allow two correct equations via intermediate hydroxide in both cases even if first equation uses  $\text{OH}^-$  instead of  $\text{NH}_3$* 

1

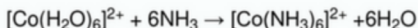
Blue (solution)

*Mark colours independently from equations*

1

Dark / deep / royal blue solution

1



1

pink / red (solution)

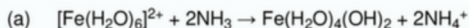
1

Brown / straw / yellow solution*ignore darkens in air / with time*

1

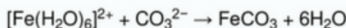
[11]

2



*Allow equation with  $\text{OH}^-$  provided equation showing formation of  $\text{OH}^-$  from  $\text{NH}_3$  given*

Green precipitate



Green precipitate

*effervescence incorrect so loses M4*

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

*Do not allow pale pink to purple*

Just after the end-point  $\text{MnO}_4^-$  is in excess / present



Moles  $\text{KMnO}_4 = 18.7 \times 0.0205 / 1000 = (3.8335 \times 10^{-4})$

*Process mark*

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

*Mark for M2  $\times 5$*

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

*Process mark for moles of iron in titration (M3)  $\times 10$*

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

*Answer for moles of iron (M4)  $\times 1000 / 50$*

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

[11]

3

- (a) An electron pair on the ligand

Is donated from the ligand to the central metal ion

- (b) Blue precipitate

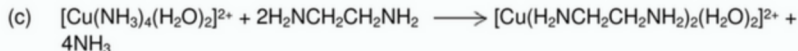
Dissolves to give a dark blue solution



1



1



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]

4 D

[1]

5 B

[1]

6 B

[1]

7 (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*

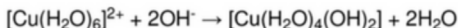
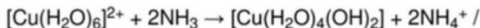
*Equations must start from  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  except in part (b)*

*Mark reagent, species and equation independently*

ammonia ( $\text{NH}_3$ ) (solution) / NaOH

1





*Do not allow OH<sup>-</sup> for reagent*

*Product 1, balanced equation 1*

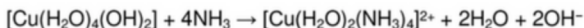
*Allow either equation for ammonia*

2

(b) **Reaction 2**

Ammonia (conc / xs)

1



*Product 1, balanced equation 1*

*Note that the equation must start from the hydroxide*

*[Cu(H<sub>2</sub>O)<sub>4</sub>(OH)<sub>2</sub>]*

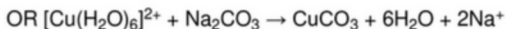
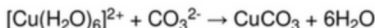
2

(c) **Reaction 3**

Na<sub>2</sub>CO<sub>3</sub> / any identified soluble carbonate / NaHCO<sub>3</sub>

*Do not allow NaCO<sub>3</sub> or any insoluble carbonate but mark on*

1



OR with NaHCO<sub>3</sub>



*Product 1, balanced equation 1*

2

(d) **Reaction 4**

HCl (conc / xs) / NaCl

*Allow any identified soluble chloride*

1



*Product 1, balanced equation 1*

2



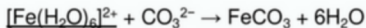
8

- (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



*Must start from  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$*

*Allow equations with  $\text{Na}_2\text{CO}_3$*

1

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

1

Effervescence / gas / bubbles

*Allow  $\text{CO}_2$  evolved but not just  $\text{CO}_2$*

1

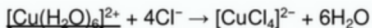


1

- (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

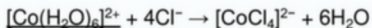


*Allow equations with  $\text{HCl}$*

1

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

1

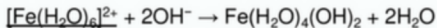


1

- (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



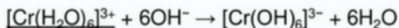
*Allow equations with  $\text{NaOH}$*

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



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

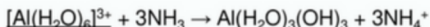
*Also allow two correct equations showing  $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$  as intermediate.*

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



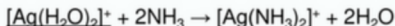
*Allow  $+ 3\text{OH}^- \rightarrow 3\text{H}_2\text{O}$  if*

*$\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$  also*

1

Ag: colourless (solution) remains a colourless solution / no visible change  
*Ignore brown ppt.*

1



*Allow 2 / 3 equations involving  $\text{Ag}_2\text{O}$  or  $\text{Ag}(\text{OH})_2$*

1

[17]

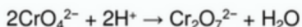
9

- (a) Yellow (solution)

1

Orange solution

1



*Allow equation with  $\text{H}_2\text{SO}_4$*

1

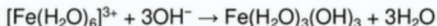
- (b) Yellow / purple (solution)

*Allow orange / brown (solution)*

1

Brown precipitate / solid

1



1



- (c) Blue (solution)

*Allow pale blue*

1

Dark / deep blue solution

*Ignore any reference to blue ppt*

1



*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<sub>2</sub>*

1



1

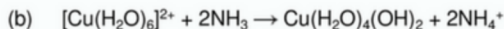
[13]

10

- (a) Electron pair donor

*Allow lone pair donor*

1



1

(Blue solution) gives a (pale) blue precipitate/solid

*M2 only awarded if M1 shows Bronsted–Lowry reaction*

1



*Allow formation in two equations via hydroxide*

1

(Blue solution) gives a dark/deep blue solution

*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)

1



Green precipitate of  $\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2$  /  $\text{Fe}(\text{OH})_2$  / 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*

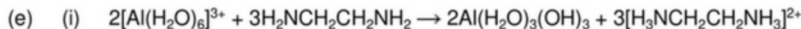
1

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

*Allow  $\text{Fe}(\text{OH})_2$  oxidised to  $\text{Fe}(\text{OH})_3$  by air /  $\text{O}_2$*

*Ignore equations even if incorrect*

1



*For correct Al species*

1

*For correct balanced equation*

*Allow equation with formation of  $3[\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_3] +$  from 1 mol*

*$[\text{Al}(\text{H}_2\text{O})_6]^{3+}$*

1

White precipitate

1



1

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

*Ignore charge*

*Accept N – N for ligand*

*Ignore incorrect H*

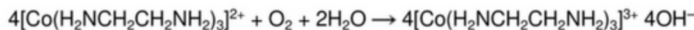
*If C shown, must be 2 per ligand*

1

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

*Can only score M3 if M2 correct*

1



*For Co(III) species*

1



For balanced equation (others are possible)

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

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]

11

- (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

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

Correct answer without working loses M1 and M2.

Allow  $7.58 \times 10^{-3}$

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.



12

- (a) Brown
- ppt/solid

1

Gas evolved/effervescence

1

*Must be stated, Allow CO<sub>2</sub> evolved. Do not allow CO<sub>2</sub> alone**Correct iron product (1) allow Fe(OH)<sub>3</sub> and in equation**Balanced equation (1)*

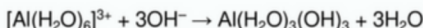
2

- (b) White
- ppt/solid

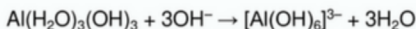
1

Colourless Solution*Only award M2 if M1 given or initial ppt mentioned*

1

*Allow  $[\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow \text{Al}(\text{OH})_3 + 6\text{H}_2\text{O}$* 

1

*Allow formation of  $[\text{Al}(\text{H}_2\text{O})_{6-x}(\text{OH})_x]^{(x-3)-}$  where  $x = 4, 5, 6$* *Allow product without water ligands**Allow formation of correct product from  $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$* 

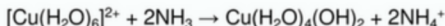
1

- (c) Blue
- ppt/solid

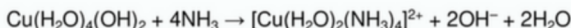
1

(Dissolves to give a) deep blue solution*Only award M2 if M1 given or initial ppt mentioned*

1

*Allow  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu}(\text{OH})_2 + 2\text{NH}_4^+ + 4\text{H}_2\text{O}$* *Allow two equations:  $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$* *then  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_2 + 4\text{H}_2\text{O}$  etc*

1

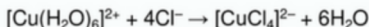
*Allow  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 4\text{H}_2\text{O}$* 

1



- (d) Green/yellow
- solution

1



1

[14]

13

- (a) oxidation state of N in
- $\text{Cu}(\text{NO}_3)_2$
- : +5;

1

oxidation state of N in  $\text{NO}_2$ : +4;

1

oxidation product: oxygen;

1

- (b) copper-containing species:
- $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$
- ;

1

shape: octahedral;

1

- (c) (i) precipitate B:
- $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$
- or
- $\text{Cu}(\text{OH})_2$
- or name;

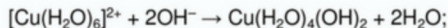
1



OR



and



1

- (ii)
- $\text{NH}_3$
- accepts a proton;

1

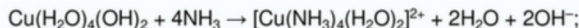
- (d) (i) identity:
- $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$
- ;

1

colour: deep blue;

1

equation:



1





- (ii)  $\text{NH}_3$  is an electron pair donor; 1
- (e) identity:  $[\text{CuCl}_4]^{2-}$ ; 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]

14

- (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
- 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.  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow [\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{NH}_4^+$  Species 1
- Balance 1
- NB Allow equations with  $\text{H}_2\text{O}$  and  $\text{OH}^-$  if reaction of  $\text{H}_2\text{O}$  with  $\text{NH}_3$  also given*

Max 4

[9]

15

- (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:  $\text{Na}_2\text{O}$  or sodium oxide (1)

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

Equation:  $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2 \text{NaOH}$  (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:  $\text{SO}_2$  or sulphur dioxide (1)

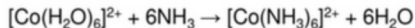
Equation:  $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$  (1)

*NB Allow max one for  $\text{SO}_3$*

4



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



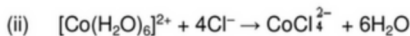
Complex ions

1

Balanced

1

*Allow partial substitution*



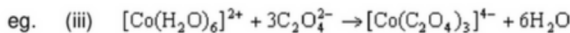
Complex ions

1

Balanced

*or  $\text{H}_2\text{O}$  or  $\text{NH}_3$  or  $\text{C}_2\text{O}_4^{2-}$  by  $\text{Cl}^-$*

1



Complex ions

1

Balanced

1

*Allow all substitution except*

*(i)  $\text{NH}_3$  by  $\text{H}_2\text{O}$*

*(ii) more than  $2\text{Cl}^-$  substituted for  $\text{NH}_3$  or  $\text{H}_2\text{O}$*



Complex ions

1

Balanced

*or  $\text{H}_2\text{O}$  or  $\text{NH}_3$  by  $\text{C}_2\text{O}_4^{2-}$  and  $\text{NH}_3$  or  $\text{Cl}^-$  by  $\text{EDTA}^{4-}$*

1



- (c) (i)  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  1
- (ii)  $\text{Fe}(\text{OH})_2$  or  $\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_x$  where  $x = 0$  to 4 1
- (iii)  $\text{Fe}^{2+}$  is oxidised to  $\text{Fe}^{3+}$  or  $\text{Fe}(\text{OH})_3$  1
- By oxygen in the air 1

[15]