1. (a) +1 or Cu+ **(1)**

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$ or Ar $3d^{10}$ **(1)**

3d sub-shell is fully filled **(1)** 3

(b) $Cu\ C1_4^{2-}$ **(1)**

Tetrahedral **(1)** 2

(c) Oxidising agent **(1)** 1

(d) $2e^- + 2H^+ + H_2O_2 \rightarrow 2H_2O$ **(1)** 1

(e) $CuC1_4^{2-} + 6H_2O \rightarrow [Cu\ (H_2O)_6]^{2+} + 4C1^-$ **(1)**

Ligand, or electron pair donor **(1)**

or Lewis base 2

[9]

2. (a) electron pair acceptor **(1)** <u>or</u> lone

proton donor **(1)** 2

(b) (i) $AlCl_3 + 6H_2O \rightarrow [Al\ (H_2O)_6]^{3+} + 3Cl^-$ **(1)**

(ii) $[Al\ (H_2O)_6]^{3+} + H_2O$ (<u>or</u> any base) **(1)**
$\rightarrow [Al(OH)\ (H_2O)_5]^{2+}$ **(1)** + H_3O^+ **(1)** (<u>or</u> protonated base)

(iii) $AlCl_3 + Cl^- \rightarrow [AlCl4]^-$ **(1)**

<u>or</u> $[Al(H_2O)_6]^{3+} + 4Cl^- \rightarrow [AlCl4]^- + 6H_2O$ **(1)** 3

(c) (i) effervescence **(1)**

brown ppt **(1)**

$Fe(OH)_3\ (H_2O)_3$ or $Fe(OH)_3$ **(1)**

(ii) green **(1)** solution **(1)**

(ignore mention of ppt)

$[Cr(OH)_6]^{3-}$ **(1)**

<u>or</u> $[Cr(OH)_4(H_2O)_2]^-$ 6

[11]

3. (i) replacement of one ligand by another **(1)**

(ii) $[Ti\ (H_2O)_4Cl_2]^+ + 2\ H_2O \rightarrow [Ti\ (H_2O)6]^{3+} + 2Cl^-$ **(1)**

(iii) change of ligand **(1)** 3

[3]

4. $[Co(H_2O)_6]^{2+}$ **(1)**

AgCl **(1)**

$[Ag(NH_3)_2]^+$ **(1)**

$[CoCl_4]^{2-}$ **(1)**

$[Co(OH)_2(H_2O)_4]$ <u>or</u> $Co(OH)_2$ **(1)**

$[Co(NH_3)_6]^{2+}$ **(1)**

$[Co(NH_3)_6]^{3+}$

$CoCl_2$ <u>or</u> $CoCl_2.xH_2O$ **(1)**

[8]

5. (a) A shared <u>electron</u> pair or a <u>covalent</u> bond **(1)**
Both electrons from one atom **(1)**
OR when a Lewis base reacts with a Lewis acid
Mark points separately **2**

(b) *Brønsted-Lowry acid*: A proton or H^+ donor **(1)**
Not H_3O^+

Lewis acid: A lone or electron pair acceptor **(1)** 2

(c) Two atoms or two points of attachment **(1)**
Each donating a lone electron pair **(1)**
OR forms 2 (1) co-ordinate bonds (1)
OR donates two (1) pairs of electrons (1)

2

(d) *Change in co-ordination number*: 6 to 4 **(1)**

Reason for change: chloride ligands are larger than water ligands **(1)**
OR greater repulsion between chloride ligands
DO NOT allow chlorine or Cl

2

(e) Same number **(1)**, and same type of bonds **(1)**, broken and made 2

(f) $ClNH_3CH_2CH_2NH_3Cl$ **(1)**
OR $(NH_3CH_2CH_2NH_3)^{2+}$ $2Cl^-$
Allow $C_2H_{10}N_2Cl_2$ and $NH_3ClCH_2CH_2NH_3Cl$

1

[11]

6. (a) octahedral **(1)** 1

(b) $[Fe(H_2O)_6]^{3+} + H_2O \rightarrow [Fe(OH)(H_2O)_5]^{2+} + H_3O^+$ **(1)**

(<u>or</u> any base) (protonated base) 1

(c) $[Fe(OH)(H_2O)_5]^{2+}$ <u>or</u> $[Fe(OH)_2(H_2O)_4]^+$ **(1)** 1

	(d)	$HNO_3 \equiv H_3O^+$ addition <u>or</u> increases concentration of acid **(1)** reverses equilibrium <u>or</u> forms $[Fe(H_2O)_6]^{3+}$ **(1)**	2
	(e)	change of ligand **(1)** change of shape <u>or</u> coord^n number **(1)**	2
	(f)	*Identity* H_2 **(1)** $Fe(OH)_3(H_2O)_3$ **or** $Fe(OH)_3$ **(1)** $3Mg + 2[Fe(H_2O)_6]^{3+} \rightarrow 3Mg^{2+} + 3H_2 + 2[Fe(OH)_3(H_2O)_3]$ **(1)** or 2 separate eqns each correct but not necessarily combined or $Mg + [Fe(OH)(H_2O)_5]^{2+} \rightarrow Mg^{2+} + H_2 + [Fe(OH)_3(H_2O)_3]$	3

[10]

7.	(a)		$3d^7$	1
	(b)		$[Co(H_2O)_6]^{2+}$	1
			Pink	1
	(c)	(i)	$[Co(NH_3)_6]^{2+}$	1
			Pale brown or straw	1
		(ii)	$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$	1
	(d)		$[Co(NH_3)_6]^{3+}$	1
			An oxidising agent	1

[8]

8.	(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;	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) $Is^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$; 1

(ii) role of Cu: a reducing agent; 1

[17]

9. (a) **A** $Cr(H_2O)_3(OH)_3$ (or $Co(OH)_3$ 1

B CO_2 1

$2[Cr(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2[Cr(H_2O)_3(OH)_3] + 3CO_2 + 3H_2O$ 1

(or gives $2Cr(OH)_3 + 3CO_2 + 9H_2O$)

(b) (i) NaOH

(or KOH) 1

(ii) +6

(or 6 or +VI or VI) 1

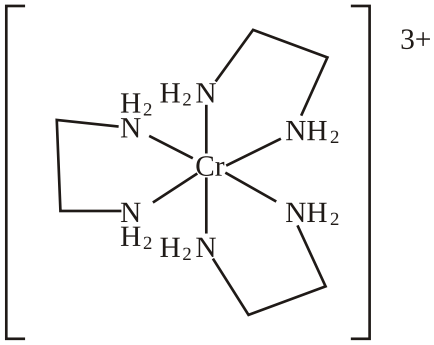
(iii) H_2O_2

(orNa_2O_2 or BaO_2) 1

$[Cr(OH)_6]^{3-} + 2OH^- \rightarrow CrO_4^{2-} + 4H_2O + 3e^-$ 1

(or $[Cr(OH)_6]^{3-} \rightarrow CrO_4^{2-} + 2H_2O + 2H^+ + 3e^-$)

(c) (i)



At least one $H_2NCH_2CH_2NH_2$ with correct structure and bonding to Cr via N 1

6 co–ordination with 3 en drawn correctly 1

Correct 3+ charge 1

(Mark independently but must not have 6 monodentate ligands)

(ii) Same (or similar) type of bonds broken and made 1

Same number of bonds broken and made (or same co–ordination number) 1

(iii) Entropy change (or ΔS) is positive (or increase in disorder) 1

Because there are more product particles than reactant particles 1

(d) $[Cr(H_2O)_6]^{2+}$ 1

Reducing agent 1

(mark independently)

(e) (i) Ethanal (or CH_3CHO) (not CH_3COH) 1

(ii) Ethanoic acid (or correct formula) 1

[18]

10. 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

Max 4

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

[4]

11. (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 1
or H_2O or NH_3 or $C_2O_4^{2-}$ by Cl^-

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 1
or H_2O orNH_3 by $C_2O_4^{2-}$ and NH_3 or Cl^- by $EDTA^{4-}$

(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]

12. (i) *Cobalt-containing species*: $[Co(H_2O)_6]^{2+}$ **(1)**

*Precipitate **M***: $Co(H_2O)_4(OH)_2$ or $Co(OH)_2$ **(1)**

(ii) $[Co(NH_3)_6]^{2+}$ **(1)**

(iii) *Type of reaction*: Co^{2+} oxidised to Co^{3+} **(1)**

Reactant responsible: Oxygen **(1)**

5

[5]

13. (a) (i) Cu $3d^{10}\ 4s^1$ / $4s^1\ 3d^{10}$) **(1)**
) mark independently
$Cu^{2+}\ 3d^9$) **(1)** 2

(b) (i) coordinate / dative / dative covalent **(1)** 1

(ii) octahedral **(1)**

tetrahedral / square planar **(1)** 2

(iii) any blue not blue-green or green **(1)**

to yellow / green **(1)** 2

(c) (i) any blue precipitate

royal / darker / deep blue solution not just blue **(1)**

if solution said to form before precipitate then 0 marks 2

(ii) $[Cu(NH_3)_4(H_2O)_2]^{2+}$ only **(1)** 1

[10]

14. (a) (i) dissolves in acids and alkalis (bases) **(1)**
<u>or</u> reacts with
<u>or</u> behaves as

(ii) (Al species correct **(1)**/balance **(1)**)

Equation 1 $[Al(OH)_3(H_2O)_3]$ (or $Al(OH)_3$) + 3 H_3O (<u>or</u> H^+) $\rightarrow$
$[Al(H_2O)_6]^{3+} + 3H_2O$ **[2]**

Equation 2 $[Al(OH)_3(H_2O)_3] + OH^- \rightarrow [Al(OH)_4(H_2O)_2]^- + H_2O$ **[2]**
<u>or</u> $[Al(OH)_4]^-$
<u>or</u> $[Al(OH)_6]^{3-}$ 5

(b)

Cl^-/Br^- reagent stated **(1)** filter off AgX **(1)** dissolve in NH_3 or $Na_2S_2O_3$ or KCN **(1)**	XS **(1)** NH_3 **(1)** filter off $Al(OH)_3$ or precipitates **(1)**	XS NaOH **(1)** filter off Ag_2O **(1)** dissolve in NH_3 or $Na_2S_2O_3$ or KCN or HNO_3 **(1)**

$[Ag(NH_3)_2]^+$, $[Ag(S_2O_3)_2]^{3-}$, $[Ag(CN)_2]^-$, $[Ag(H_2O)_2]^+$ **(1)**

linear **(1)** 5

[10]

15. (i) *Yellow-green species* $[CuCl4]^{2-}$ **(1)**

Shape tetrahedral **(1)**

Oxidation state of copper +2 **(1)**

(ii) $[CuCl_4]^{2-} + 6H_2O \rightleftharpoons [Cu(H_2O)_6]^{2+} + 4Cl^-$ **(1)**

(iii) Cu^+ has <u>full</u> d-shell ($[Ar]d^{10}$) **(1)** 5

[5]

16. (a) Fe **(1)**
$[Fe(H_2O)_6]^{2+}$ **(1)**
$[Fe(OH)_2(H_2O)_4]$ **(1)**
$[Fe(OH)_3(H_2O)_3]$ **(1)** 4

(b) Cu **(1)**
$[Cu(H_2O)_6]^{2+}$ **(1)**
$[CuCl_4]^{2-}$ **(1)**
$[Cu(OH)_2(H_2O)_4]$ **(1)**
$[Cu(NH_3)_4(H_2O)_2]^{2+}$ **(1)** 5

[9]

17. (a) (i) $[Cr(H_2O)_6]^{3+} + H_2O \rightarrow [Cr(H_2O)_5(OH)]^{2+} + H_3O^+$ **(1)**
OR $[Cr(H_2O)_6]^{3+} \rightarrow [Cr(H_2O)_5(OH)]^{2+} + H^+$
DO NOT allow reactions with bases other than water
Allow loss of up to 2 H^+

(ii) Cr^{3+} is smaller than Cr^{2+} **(1)**
OR Cr^{3+} has a greater charge density or charge to size ratio

Cr^{3+} is more polarising **(1)**
OR draws electron density from oxygen

So more O—H bonds break (weakened) **(1)**
Max 2 from three

3

(b) (i) $Cr(H_2O)_3(OH)_3$ **or** $Cr(OH)_3$ **or** $Cr(OH)_3$ x H_2O, where x =, 1, 2 or 3 **(1)**
OR name chromium (III) hydroxide

(ii) Base or electron pair donor or proton acceptor **(1)**
NOT alkali, ignore nucleophile but penalise 'ligand'

(iii) *Gas evolved*: CO_2 or name **(1)**
Equation:
$3CO_3^{2-} + 2[Cr(H_2O)_6]^{3+} \rightarrow 2[Cr(H_2O)_3(OH)_3] + 3CO_2 + 3H_2O$ **(1)**
N.B if separate equations for CO_3^{2-} and Cr^{3+} (aq) given an overall equation must be deduced

4

[9]

18. (a) (i) $GaCl_3 + 6H_2O \rightarrow [Ga(H_2O)_6]^{3+} + 3Cl^-$ **(1)**

(ii) 2 – 5 **(1)**
Ga 3^+ ion <u>or</u> high change density **(1)**
hydrolysis <u>or</u> polarises H_2O or O–H bond **(1)**

<u>or</u> correct eqn showing H_3O^+ formation **(2)** 4

(b) (i) effervescence **(1)**
ppt **(1)**

penalise if coloured

$[Ga(H_2O)_6]^{3+} + 3H_2O \rightarrow [Ga(OH)_3(H_2O)_3] + 3H_3O^+$ **(1)**

$2H_3O^+ + CO_3^{2-} \rightarrow CO_2 + 3H_2O$ **(1)**

<u>or</u> $2[Ga(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2[Ga(OH)_3(H_2O)_3] + 3CO_2 + 3H_2O$ (2)

(ii) ppt **(1)**

not if coloured

dissolves in excess **(1)**

$[Ga(H_2O)_6]^{3+} + 3OH^- \rightarrow [Ga(OH)_3(H_2O)_3] + 3H_2O$ **(1)**

<u>or</u> $[Ga(H_2O)_6]^{3+} + 3H_2O$ (as above), then $H_3O^+ + OH^- \rightarrow 2H_2O$

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

<u>or</u> $+ 3OH^- \rightarrow [Ga(OH)_6]^{3-} + 3H_2O$

<u>or</u> $+OH^- \rightarrow [Ga(OH)_4]^- + 3H_2O$

<u>or</u> $Ga(OH)3 + OH^- \rightarrow [Ga(OH)_4]^-$ etc **(1)** 8

[12]

19. (a) electron donor **(1)**
electron pair acceptor **(1)** 2

(b) $CH_3CH_2CH_2CH_2CH_3$ **(1)**
no lone pair or not a Lewis base **(1)** 2

(c) (i)

Zn or Sn or Fe/HCl	HCl or H_2SO_4 or HNO_3	$BaCl_2$/Hcl	
			(1)
nothing	nothing	white ppt	**(1)**
colour seen	colour seen	nothing	**(1)**

(ii)

NaOH or NH_3 or Na_2CO_3	$KMnO_4/H^+$ ($K_2Cr_2O_7/H^+$) (green)	Na_2CO_3	
			(1)
green ppt	decolourised	no fizz	**(1)**
brown ppt	nothing no	fizz	**(1)**

alternatives:–

conc HCl	KI
nothing	nothing
yellow	red/brown

6

[13]

20. (i) green–blue or pink ppt **(1)**
$[Co(OH)_2(H_2O)_4]$ or $Co(OH)_2$ **(1)**

(ii) goes brown **(1)**
$[Co(OH)_3(H_2O)_3]$ or $Co(OH)_3$ **(1)**
or $CoO(OH)$ 4

[10]

21. (a) (i) Conc or xs NH_3 **(1)** air or O_2 or H_2O_2 **(1)**

(ii) Conc **(1)** HCl **(1)**

(iii) NaOH **(1)** H_2O_2 **(1)**

(iv) Zn **(1)** HCl or dil H_2SO_4 8

(b) Dissolve in dil HCl or dil H_2SO_4 **(1)**
add xs **(1)** Na_2CO_3 **(1)**
filter off ppt **(1)**
or $FeCO_3$ precipitates

Acid must be present to score last 3 marks 4

[12]

22.

Formula of P	$[CO(H_2O)_6]^{2+}$ **(1)**	
Shape of P	octahedral **(1)**	
Formula of B	$[CoCl_4]^{2-}$ **(1)**	
Shape of B	tetrahedral **(1)**	
Equation	$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$ **(1)**	5

[5]

23. (a) (i) *Formula of precipitate* $[Co(OH)_2(H_2O)_4]$ or $Co(OH)_2$ **(1)**

Equations

$[Co(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Co(OH)_2(H_2O)_4] + 2NH_4^+$ **(2)**
or $[Co(H_2O)_6]^{2+} + 2OH^-$ $(2H_2O) \rightarrow [Co(OH)_2(H_2O)_4] + 2H_2O$ $(2H_3O^+)$ **(1)**,
H_2O (H_3O^+) $+ NH_3 \rightarrow NH_4^+ + OH^-$ (H_2O) **(1)**

(ii) $[Co(NH_3)_6]^{2+}$ **(1)**

$[Co(OH)_2(H_2O)_4] + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 4H_2O + 2OH^-$ **(2)**

(iii) darkness or goes brown **(1)**

$[Co(NH_3)_6]^{3+}$ **(1)** 8

[8]

24. (a) (i) LB = electron pair donor **(1)**
RA = electron donor **(1)**

(ii) Any rn in which Br^- donates lone pair **(1)**
e.g. $[Co(H_2O)_6]^{2+} + 4Br^- \rightarrow CoBr_4^{2-} + 6H_2O$
$H^+ + Br^- \rightarrow HBr$; $CH_3^+ + Br^- \rightarrow CH_3Br$; $AlBr_3 + Br^- \rightarrow AlBr_4^-$

Any rn in which Br^- acts as RA **(1)**
e.g. $2Br^- + Cl_2 \rightarrow Br_2 + 2Cl^-$; $2HBr + H_2SO_4 \rightarrow Br_2 + SO_2 + 2H_2O$ 4

(b) $FeSO_4/SO_2/H_2O_2$/Fe/stated aldehyde 1^y or 2^y ROH **(1)**
acid or dil H_2SO_4 (above) **(1)**
$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$ **(2)**
or two half-equations

Zn **(1)** HCl or dil H_2SO_4 **(1)**
absence of air **(1)**
$Cr_2O_7^{2-} + 14H^+ + 4Zn \rightarrow 2Cr^{2+} + 7H_2O + 4Zn^{2+}$ **(2)**
or two half-equations 9

(c) green ppt **(1)** effervescence **(1)**

$[Cr(OH)_3(H_2O)_3]$ or $Cr(OH)_3$ **(1)**

ppt **(1)**

$CrCO_3$ **(1)** 5

[18]

25. (a) Ligand: -
atom, ion or molecules which can donate a pair of electrons to a metal ion. 1

co-ordinate bond:-
a covalent bond 1
in which both electrons are donate by one atom 1

(b) (i) Two correct complex ions 1
Balanced equation 1
Two correct colours 2

(ii) Complex with a bidentate ligand 1
Balanced equation 1
NB en *not allowed as a ligand unless structure also given*

More molecules/ions formed 1
Increase in entropy 1
more stable complex formed 1

Max 2

(c) ΔE; energy absorbed by electron, ground to excited state (Q o L) 1
h; Planck's constant or a constant 1
Change in

Oxidation state 1
Ligand 1
Co-ordination number 1
Apply list principle to incorrect additional answers

[16]

26. (a) replacement of 1 ligand by another **(1)**

<u>$CuSO_4$</u>

blue ppt **(1)** deep blue (blue violet) solution **(1)**

$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(OH)_2(H_2O)_4] + 2NH_4^+$ **(1)**

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

$[Cu(OH)_2(H_2O)_4] + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^-$
formula **(1)** $+ 2H_2O$ **(1)**

<u>$Cr_2(SO_4)_3$</u>

green ppt (grey–green) **(1)** purple (lilac, mauve) solution **(1)**

$[Cr(H_2O)_6]^{3+} + 3NH_3 \rightarrow [Cr(OH)_3(H_2O)_3] + 3NH_4^+$ **(1)**

<u>or</u> $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$ }
$[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow [Cr(OH)_3(H_2O)_3] + 3H_2O$}

$[Cr(OH)_3(H_2O)_3] + 6NH_3 \rightarrow [Cr(NH_3)_6]^{3+} + 3OH^- + 3H_2O$
formula **(1)** **(1)** 11

(b) (i) $[Cu(NH_2CH_2CH_2NH_2)_2(H_2O)_2]^{2+}$
(or 'en')
(1) **(1)**

(ii) $[Co(NH_2CH_2CH_2NH_2)_3]^{3+}$ 4
(1) **(1)**

[15]

27. A $CuBr_2$ **(1)**

B $[Cu(H_2O)_6]^{2+}$ **(1)**

C Br^- **(1)**

D $[Cu(OH)_2(H_2O)_4]$ <u>or</u> $Cu(OH)_2$ **(1)**

E $[Cu(NH_3)_4(H_2O)_2]^{2+}$ **(1)**

F $[CuCl_4]^{2-}$ **(1)**

G AgBr **(1)**

H $[Ag(NH_3)_2]^+$ **(1)**

I $Ag(S_2O_3)_2]^{3-}$ **(1)** 9

$CuBr_2 + 6H_2O \rightarrow [Cu(H_2O)_6]^{2+} + 2Br^-$ **(1)**
$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Cu(OH)_2(H_2O)_4] + 2NH_4^+$ **(1)**
(or 2 equations, form^n OH^-, use of OH^-)
$[Cu(OH)_2(H_2O)_4] + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^- + 2H_2O$ **(1)**
$[Cu(H_2O)_6]^{2+} + 4Cl^-$ (4HCl) $\rightarrow [CuCl_4]^{2-} + 6H_2O$ $(+4H^+)$ **(1)**

$Ag^+ + Br^- \rightarrow AgBr$ <u>or</u> $AgNO_3 + Br^- \rightarrow AgBr + NO_3^-$ (*) **(1)**

$AgBr + 2NH_3 \rightarrow [Ag(NH_3)_2]^+ + Br^-$ (*) **(1)**

$AgBr + 2S_2O_3^{2-} \rightarrow [Ag(S_2O_3)_2]^{3-} + Br^-$ (*) **(1)**

(*) allow AgCl here if C given as Cl^- max 6

[15]

28. (a) H_2O or O–H broken **(1)** H^+ formed **(1)**

$[M(H_2O)_6]^{2+} + H_2O \rightarrow [M(H_2O)_5(OH)]^+ + H_3O^+$ **(1)**

↑ any metal ↓ ↑ any base ↓ ↑ protonated base ↓

$[M(H_2O)_6]^{3+} + H_2O \rightarrow [M(H_2O)_5(OH)]^{2+} + H_3O^+$ **(1)**

M^{3+} more acidic than M^{2+} **(1)** higher charge/size rated **(1)** or charge density

M^{3+} polarises H_2O more **(1)** O–H bond weakened **(1)**

$M^{2+} \rightarrow MCO_3$ **(1)** M3+ $\rightarrow [M(OH)_3(H_2O)3]$ **(1)**

M^{2+} weaker acid than H_2CO_3 or not enough H_3O^+ to react with CO_3^{2-} **(1)**

M^{3+} stronger than or displaces H_2CO_3 or more H_3O^+ so can react with CO_3^{2-} **(1)**

or eq^n showing $CO_3^{2-} \rightarrow CO_2$ 12

(b) green ppt is $[Cu(H_2O)_5(OH)]^+$ or $[Cu(H_2O)_5(OH)]_2SO_4$ **(1)**

$[Cu(H_2O)_6]^{2+} + H_2O$ (or OH^-) $\rightarrow [Cu(H_2O)_5(OH)]^+ + H_3O^+$ (H_2O) **(1)**

OH^- removes H_3O^+ or pushes eq^n to RHS **(1)**

blue ppt is $[Cu(H_2O)_4(OH)_2]$ **(1)**

$[Cu(H_2O)_6]^{2+} + 2H_2O$ (OH^-) $\rightarrow [Cu(H_2O)_4(OH)_2] + 2H_3O^+$ (H_2O) **(1)**

or $[Cu(H_2O)_5(OH)]^+ + H_2O$ (OH^-) $\rightarrow [Cu(H_2O)_4(OH)_2] + H_3O^+$ (H_2O)

OH^- removes H_3O^+ or pushes eq^n to RHS **(1)**

blue solution is $[Cu(OH)_4]^{2-}$ or $[Cu(OH)_4(H_2O)_2]^{2-}$ or $[Cu(OH)_3(H_2O)_3]^-$ **(1)**

$[Cu(H_2O)_4(OH)_2] + 2OH^- \rightarrow [Cu(OH)_4]^{2-}$ (or other) $+ 4H_2O$ **(1)**

substitution or amphoterism or must be an ion **(1)** Max 8

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