M1. (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) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$;

1

(ii) role of Cu: a reducing agent;

1

[17]

M2. (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

NB en not allowed as a ligand unless structure also given

1

More molecules/ions formed

1

Increase in entropy

1

more stable complex formed

1

Max 2

(c) Δ*E;* energy absorbed by electron, ground to excited state (QoL)

1

h; Planck's constant or a constant

1

Change in

Oxidation state

1

Ligand

1

Co-ordination number

Apply list principle to incorrect additional answers

1

[16]

M3. (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**

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]

M4. (a) $C_2O_4^{2-}$ or $H_2NCH_2CH_2NH_2$ **(1)**

1

(b) $[AgCl_2]^-$ or $[Ag(CN)_2]^-$ or $[Ag(NH_3)_2]^+$ **(1)**

1

(c) e.g. $[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$
Correct complex species **(1),** Balanced **(1),** Only allow if species correct

2

(d) e.g. $[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$
Correct complex species **(1),** Balanced **(1),** Only allow if species correct

2

(e) *Equation:* $[Co(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [Co(EDTA)]^{2-} + 6H_2O$ **(1)**
Explanation: More molecules on right hand side **(1)**
Entropy increases **(1)**

3

[9]