A-Level Chemistry

Transition Metals

Mark Scheme

Time available: 65 minutes
Marks available: 63 marks

1. (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

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2. (a) Variable oxidation state

1

eg Fe(II) and Fe (III)

Any correctly identified pair

Allow two formulae showing complexes with different oxidation states even if oxidation state not given

1

(Characteristic) colour (of complexes)

1

eg Cu^{2+}(aq) / $[Cu(H_2O)_6]^{2+}$ is blue

Any correct ion with colour scores M3 and M4

Must show (aq) or ligands OR identified coloured compound e.g. $CoCO_3$)

1

(b) Tetrahedral

1

$[CuCl_4]^{2-}$ / $[CoCl_4]^{2-}$

Any correct complex

(Note charges must be correct)

1

Square planar

1

$(NH_3)_2PtCl_2$

Any correct complex

1

Linear

Do not allow linear planar

1

$[Ag(NH_3)_2]^+$

$[AgCl_2]^-$ etc

1

(c) (i) $[Ca(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [CaEDTA]^{2-} + 6H_2O$

If equation does not show increase in number of moles of particles CE = 0/3 for (c)(ii)

If no equation, mark on

1

(ii) 2 mol of reactants form 7 mol of products

Allow more moles/species of products

Allow consequential to (c)(i)

1

Therefore disorder increases

1

Entropy increases / +ve entropy change / free-energy change is negative

1

(iii) Moles EDTA = 6.25 × 0.0532 / 1000 = (3.325×10^{-4})

1

Moles of Ca^{2+} in 1 dm^3 = $3.325 \times 10^{-4} \times 1000 / 150 = (2.217 \times 10^{-3})$

Mark is for M1 × 1000 / 150 ***OR*** *M1 × 74.1*

If ratio of Ca^{2+} : EDTA is wrong or 1000 / 150 is wrong, CE and can score M1 only

This applies to the alternative

1

Mass of $Ca(OH)_2$ = $2.217 \times 10^{-3} \times 74.1 = 0.164$ g

M1 × 74.1 × 1000 / 150

Answer expressed to 3 sig figs or better

Must give unit to score mark

Allow 0.164 to 0.165

1

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3.

(a) Same phase/state

1

(b) Because only exist in one oxidation state

Allow do not have variable oxidation states

1

(c) $2I^- + S_2O_8^{2-} \rightarrow I_2 + 2SO_4^{2-}$

Ignore state symbols
Allow multiples

1

(d) Both (ions)have a negative charge

Or both have the same charge
Or (ions) repel each other
Do not allow both molecules have the same charge (contradiction)

1

(e) $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$

1

$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$

1

Equations can be in any order

Positive and negative (ions)/oppositely charged (ions)

Mark independently

1

(f) Equations 1 and 2 can occur in any order

Allow idea of Fe^{3+} converted to Fe^{2+} then Fe^{2+} converted back to Fe^{3+}

1

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4. (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

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5. (a) [Ar] $4s^2\ 3d^7$ or $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$

Allow 4s and 3d in either order

1

[Ar] $3d^7$ or $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$

1

Any 3

Variable oxidation state

Act as catalysts

Form complexes

Form coloured ions/compounds

3

(b) Two atoms that each donate a lone pair (of electrons) / coordinate bonds from two atoms

1

Formula of ethane-1,2- diamine: $NH_2CH_2CH_2NH_2$

M2 gained from equation or structure

1

$[Co(H_2O)_6]^{2+} + 3NH_2CH_2CH_2NH_2 \longrightarrow [Co(NH_2CH_2CH_2NH_2)_3]^{2+} + 6H_2O$

Equation must be balanced inc charges

Allow en or $C_2H_8N_2$ in equation for ethane-1,2-diamine

1

There is an increase in the number of particles / the reaction goes from 4 moles to 7 moles

Allow increase number of molecules/moles. Allow numbers that match an incorrect equation

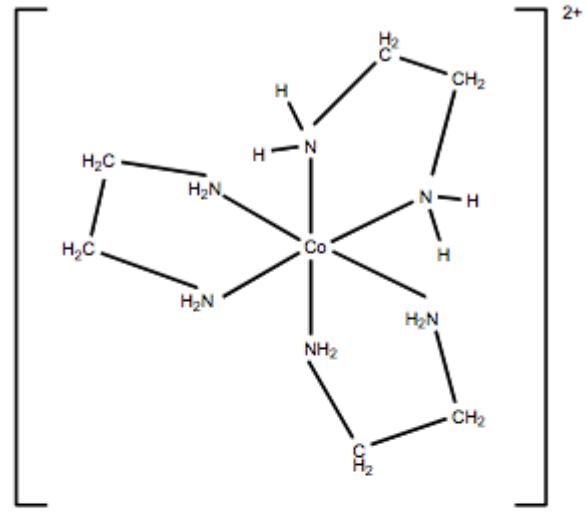
1

Disorder/entropy increases / ΔS is positive

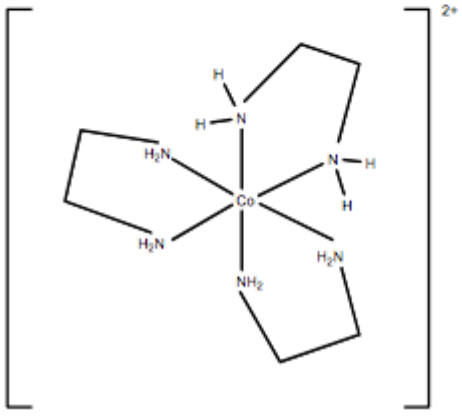
1

ΔG negative

1



Or



Mark for correct structure (ignore charges -even if wrong)

NH_2 can be shown in either way – see structure

1

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