M1. (a) $[Co(H_2O)_6]^{2+}$

1

octahedral

Only allow if species has 6 ligands
but allow if M1 not given because charge missing

1

(b) $CoCO_3$

Mark independently

1

Purple solid (allow pink)

Allow pink precipitate

1

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

Allow $[Co(NH_3)_5H_2O]^{3+}$

Formula of product

1

Balanced equation

1

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

Allow $[Co(NH_3)_5H_2O]^{3+}$

1

Oxidising agent

1

(e) $[Co(H_2NCH_2CH_2NH_2)_3]^{2+}$

Allow use of en $[Coen_3]^{2+}$

1

Entropy change for reaction is positive

Mark independently

1

Because 4 mol reactants form 7 mol products
(or increase in number of particles)

Or bidentate replaces unidentate

1

(f) $[CoCl_4]^{2-}$

1

Cl^- ligand too big to fit more than 4 round Co^{2+}

Allow Cl^- is bigger
Allow chlorine and Cl but NOT chlorine molecules.

1

[13]

M2. (a) Ti(IV) [Ar]

Or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

1

Ti(III) $[Ar]3d^1$

Or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1$

1

Ti(III) has a d electron that can be excited to a higher level

Allow idea that d electrons can be excited to another level (or move between levels)

1

Absorbs one colour of light from white light

Allow idea that light is absorbed

1

Ti(IV) has no d electron so no electron transition with energy equal to that of visible light

Allow Ti(IV) has no d electrons

1

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

1

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

1

$[CuCl_4]^{2-}$

1

(c) (i) Rapid determination of concentration

Or easy to get many readings

1

Does not use up any of the reagent/does not interfere with the reaction

Or possible to measure very low concentrations

1

(ii) Curve starts with small gradient (low rate)

1

Because negative ions collide so E_a high

1

Curve gets steeper

1

Because autocatalyst (Mn^{2+}) formed

1

Curve levels out approaching time axis

Can score this mark and next one ONLY with simple curve (that is curve with gradually decreasing gradient)

1

Because MnO_4^- ions used up

5 max

1

[15]

M3. (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]

M4. (a) Equation:

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

Species

1

Balance

1

Colours:
e.g $[Cu(H_2O)_6]^{2+}$ blue

1

e.g. $[CuCl_4]^{2-}$ yellow/green

1

(b) (i) ΔE: The energy absorbed

1

h: Planck's constant

1

(ii) Factor 1 Change of ligand

1

Factor 2 Change in oxidation state

1

Factor 3 Change in co-ordination number

1

[9]