Q16.

Due to their electron arrangements, transition metals have characteristic properties including catalytic action and the formation of complexes with different shapes.

(a) Give **two other** characteristic properties of transition metals. For each property,illustrate your answer with a transition metal of your choice.

(4)

(b) Other than octahedral, there are several different shapes shown by transition metal complexes. Name **three** of these shapes and for each one give the formula of a complex with that shape.

(6)

(c) It is possible for Group 2 metal ions to form complexes. For example, the $[Ca(H_2O)_6]^{2+}$ ion in hard water reacts with $EDTA^{4-}$ ions to form a complex ion in a similar manner to hydrated transition metal ions. This reaction can be used in a titration to measure the concentration of calcium ions in hard water.

(i) Write an equation for the equilibrium that is established when hydrated calcium ions react with $EDTA^{4-}$ ions.

(1)

(ii) Explain why the equilibrium in part (c)(i) is displaced almost completely to the right to form the EDTA complex.

(3)

(iii) In a titration, 6.25 cm^3 of a 0.0532 mol dm^{-3} solution of EDTA reacted completely with the calcium ions in a 150 cm^3 sample of a saturated solution of calcium hydroxide.
Calculate the mass of calcium hydroxide that was dissolved in 1.00 dm^3 of the calcium hydroxide solution.

(3)

(Total 17 marks)

Q17.

Transition metals and their complexes have characteristic properties.

(a) Give the electron configuration of the Zn^{2+} ion.
Use your answer to explain why the Zn^{2+} ion is **not** classified as a transition metal ion.

Electron configuration _____

Explanation _____

_____

(2)

(b) In terms of bonding, explain the meaning of the term *complex*.

_____

_____

_____

_____

(2)

(c) Identify **one** species from the following list that does **not** act as a ligand. Explain your answer.

H_2 O^{2-} O_2 CO

Not a ligand _____

Explanation _____

(2)

(d) The element palladium is in the d block of the Periodic Table. Consider the following palladium compound which contains the sulfate ion.

$[Pd(NH_3)_4]SO_4$

(i) Give the oxidation state of palladium in this compound.

_____

(1)

(ii) Give the names of two possible shapes for the complex palladium ion in this compound.

Shape 1 _____

Shape 2 _____

(2)

(Total 9 marks)

Q18.

(a) Some metal ions are toxic to humans. A substance that can be used to treat such poisoning contains the ion $EDTA^{4-}$.
$EDTA^{4-}$ forms very stable complexes with metal ions. These complexes are **not** toxic.

(i) Write an equation for the reaction of $EDTA^{4-}$ with aqueous copper(II) ions, $[Cu(H_2O)_6]^{2+}$.

_____

(1)

(ii) A solution containing $EDTA^{4-}$ can also be used in a titration to determine the concentration of metal ions in solution.
A river was polluted with copper(II) ions. When a 25.0 cm^3 sample of the river water was titrated with a 0.0150 mol dm^{-3} solution of $EDTA^{4-}$, 6.45 cm^3 were required for complete reaction.
Calculate the concentration, in mol dm^{-3}, of copper(II) ions in the river water.
Show your working.

_____

_____

_____

_____

(2)

(b) The determination of the concentration of copper(II) ions in a single sample of river water gives an unreliable value for the copper(II) ion pollution in the river.
Give one reason why this value is unreliable.

_____

_____

(1)

(c) Silver complexes can be used to identify a particular organic functional group.
Give **one** example of a silver complex that can be used in this way and state the organic functional group it identifies.

Silver complex _____

Organic functional group _____

(2)

(Total 6 marks)

Q19.

Transition elements form complex ions with a range of colours and shapes.

(a) By considering its electron arrangement, state how an element can be classified as a transition element.

_____

_____

(1)

(b) Explain the meaning of the term *complex ion*.

_____

_____

_____

(2)

(c) In terms of electrons, explain why an aqueous solution of cobalt(II) sulfate has a red colour.

_____

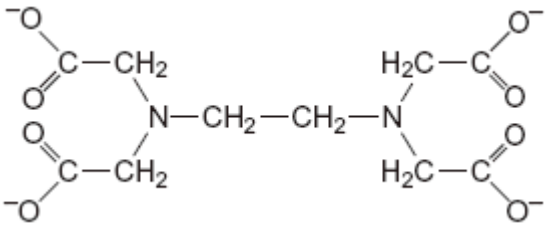
_____

_____

_____

(3)

(d) The ligand $EDTA^{4-}$ is shown below.



(i) Draw circles around the atoms of **two** different elements that link to a transition metal ion by a co-ordinate bond when $EDTA^{4-}$ behaves as a ligand.

(2)

(ii) Write an equation for the reaction between $EDTA^{4-}$ and a $[Co(H_2O)_6]^{2+}$ ion. Use the abbreviation $EDTA^{4-}$ in your equation.

_____

(1)

(iii) Explain why the complex ion, formed as a product of the reaction in part (d) (ii), is more stable than the $[Co(H_2O)_6]^{2+}$ ion.

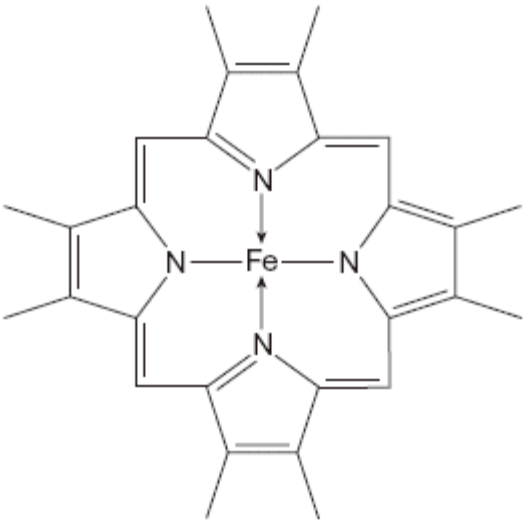
_____

_____

_____

(2)

(e) The diagram below shows part of the structure of haemoglobin.



Haemoglobin contains an iron(II) ion bonded to five nitrogen atoms and one other ligand. The fifth nitrogen atom and the additional ligand are not shown in this diagram.

(i) In this diagram, bonds between nitrogen and iron are shown as N→Fe and as N—Fe.

State the meaning of each of these symbols.

Meaning of → _____

Meaning of — _____

(2)

(ii) State the function of haemoglobin in the blood.

_____

(1)

(iii) With reference to haemoglobin, explain why carbon monoxide is toxic.

_____

_____

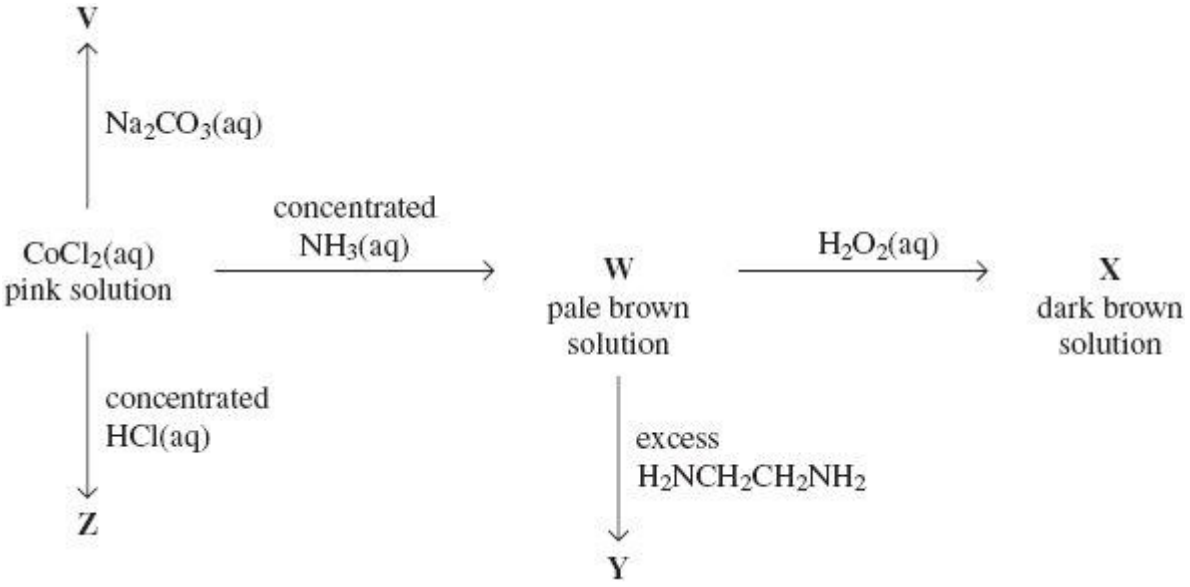
_____

(2)

(Total 16 marks)

Q20.

This question is about some reactions of cobalt compounds.



(a) Give the formula of the complex responsible for the pink colour in aqueous $CoCl_2$ and name its shape.

Formula _____

Name of shape _____

(2)

(b) Give the formula of the cobalt-containing compound **V** and describe its appearance.

Formula _____

Appearance _____

(2)

(c) Write an equation for the reaction that occurs when the pink solution is converted into **W**.

_____

(2)

(d) Give the formula of the cobalt-containing complex in **X** and state the role of the H_2O_2 in this reaction.

Formula _____

Role of H_2O_2 _____

(2)

(e) Give the formula of the cobalt-containing complex in **Y** and explain why this complex is more stable than the cobalt-containing complex in **W**.

Formula _____

Explanation _____

_____

_____

(3)

(f) Identify the cobalt-containing complex in solution **Z** and explain why its co-ordination number is different from that in the pink solution of $CoCl_2$

Complex _____

Explanation _____

_____

(2)

(Total 13 marks)

Mark Scheme

Q16.

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

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

[17]

Q17.

(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$

allow [He] $2s^2$. or [Ne] $3s^2$.or [Ar]$3d^{10}$

1

d sub-shell / shell / orbitals / sub-level full (or not partially full)

can only score M2 if d^{10} in M1 correct

allow 'full d orbital' if d^{10} in M1

do not allow d block

1

(b) atom or ion or transition metal bonded to / surrounded by one or more ligands

Allow Lewis base instead of ligand

1

by co–ordinate / dative (covalent) bonds / donation of an electron pair

can only score M2 if M1 correct

1

(c) H_2 / hydrogen

do not allow H

1

no lone / spare / non-bonded pair of electrons

only score M2 if M1 correct or give 'H' in M1

1

(d) (i) +2 or 2+ or Pd^{2+} or II or +II or II+ or two or two plus

1

(ii) tetrahedral

these shapes can be in any order

1

square planar

allow phonetic spelling e.g. tetrahydral

1

[9]

Q18.

(a) (i) $EDTA^{4-} + [Cu(H_2O)_6]^{2+} \rightarrow [Cu(EDTA)]^{2-} + 6H_2O$

1

(ii) (Mol EDTA = (6.45/1000) ×0.015 =)9.68×10^{-5} mol Cu(II)

1

Conc. Cu(II) = ((9.68×10^{-5}) / 0.025 =) 0.00387 mol dm^{-3}

Correct answer without working gains M2 only.

1

(b) Samples may not be consistent throughout the river
OR
Concentration may vary over time

Ignore comments on technique.

1

(c) $[Ag(NH_3)_2]^+$

Accept name eg diamminesilver(I) ion.

1

aldehyde

Allow CHO.

1

[6]

Q19.

(a) Partially filled/incomplete d sub-shell/orbital/shell

Ignore reference to f orbitals
*Do **not** allow d block*
*Do **not** allow half-filled d orbitals*

1

(b) Has ligand(s)

Allow molecules/ions with lone pairs

1

linked by co-ordinate bonds

Allow dative/donation of lone pair

1

(c) (Blue) light is absorbed (from incident white light)

1

Due to electrons moving to higher levels/electrons excited

Allow d → d transitions

1

Red light (that) remains (is transmitted)/light that remains (transmitted light) is the colour observed

Allow red light reflected

1

(d) (i) Circle round any O^-

List principle

1

Circle round either N

1

(ii) $EDTA^{4-} + [Co(H_2O)_6]^{2+} \rightarrow [CoEDTA]^{2-} + 6H_2O$

Allow missing square brackets
Ignore state symbols

1

(iii) Increase in entropy/Δ*S* positive

Or increase in disorder

1

Because 2 mol (of particles/molecules/species/entities) form 7 mol

Allow 'increase in number' as stated in words or as shown by any numbers deduced correctly from an incorrect equation

Do not allow increase in ions/atoms

1

(e) (i) Co-ordinate/dative/dative covalent bond

Allow pair of electrons donated by nitrogen/ligand
Do not allow pair of electrons donated from Iron/Fe

1

Covalent bond

Shared electron pair

1

(ii) Transport of oxygen/O_2

Allow any statement that implies oxygen carried (around the body)

Do not allow transport of carbon dioxide (CO_2). This also contradicts the mark (list principle)

1

(iii) Because it bonds to the iron/haemoglobin

Allow blocks site
/CO has greater affinity for haemoglobin
/carboxyhaemoglobin more stable than oxyhaemoglobin

1

Displaces oxygen

Or prevents transport of oxygen
QoL

1

[16]

Q20.

(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]