Q15.

An equation for the decomposition of hydrogen peroxide is

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

(a) The rate of reaction can be determined by collecting the oxygen formed and measuring its volume at regular intervals.

Draw a diagram to show the apparatus that you would use to collect and measure the volume of the oxygen formed.

(2)

(b) Explain how you could use your results from the experiment in part (a) to determine the initial rate of this reaction.

_____

_____

_____

_____

_____

(2)

(c) The rate of decomposition of hydrogen peroxide is increased by the addition of cobalt(II) ions.

Outline the essential features of an additional experiment to show that the rate of decomposition is increased by the addition of cobalt(II) chloride. Use the same method and the same apparatus as in part (a).

_____

_____

_____

_____

_____

(2)

(Total 6 marks)

Q16.

Transition metal compounds have a range of applications as catalysts.

(a) State the general property of transition metals that allows the vanadium in vanadium(V) oxide to act as a catalyst in the Contact Process.

_____

(1)

(b) Write **two** equations to show how vanadium(V) oxide acts as a catalyst in the Contact Process.

Equation 1

_____

Equation 2

_____

(2)

(c) In the Contact Process, vanadium(V) oxide acts as a heterogeneous catalyst.

(i) Give the meaning of the term *heterogeneous*.

_____

_____

_____

(1)

(ii) Give **one** reason why impurities in the reactants can cause problems in processes that use heterogeneous catalysts.

_____

_____

_____

(1)

(d) The oxidation of $C_2O_4^{2-}$ ions by MnO_4^- ions in acidic solution is an example of a reaction that is autocatalysed.

(i) Give the meaning of the term *autocatalysed*.

_____

_____

_____

(1)

(ii) Identify the autocatalyst in this reaction.

_____

(1)

(iii) Write **two** equations to show how the autocatalyst is involved in this oxidation of $C_2O_4^{2-}$ ions.

Equation 1

_____

Equation 2

_____

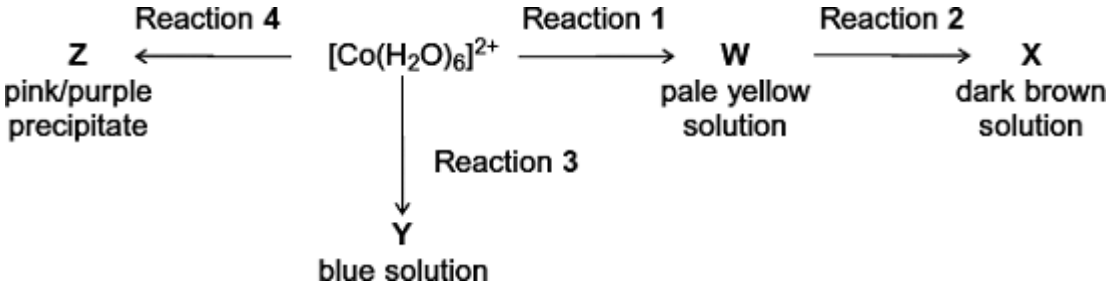
(2)

(Total 9 marks)

Q17.

This question is about cobalt chemistry.

(a) Consider the following reaction scheme that starts from $[Co(H_2O)_6]^{2+}$ ions.
W, **X** and **Y** are ions and **Z** is a compound.



For each of the reactions **1** to **4**, identify a suitable reagent.

Identify **W**, **X**, **Y** and **Z** and write an equation for each of reactions **1** to **4**.

(12)

(b) A flue-gas desulfurisation process involves the oxidation, by oxygen, of aqueous sulfate(IV) ions (SO_3^{2-}) into aqueous sulfate(VI) ions (SO_4^{2-}). This reaction is catalysed by Co^{2+} ions in an acidic aqueous solution.

Write an equation for the overall reaction of sulfate(IV) ions with oxygen to form sulfate(VI) ions.

Suggest why this overall reaction is faster in the presence of Co^{2+} ions.

Suggest a mechanism for the catalysed reaction by writing **two** equations involving Co^{2+} and Co^{3+} ions. You will need to use H^+ ions and H_2O to balance these two equations.

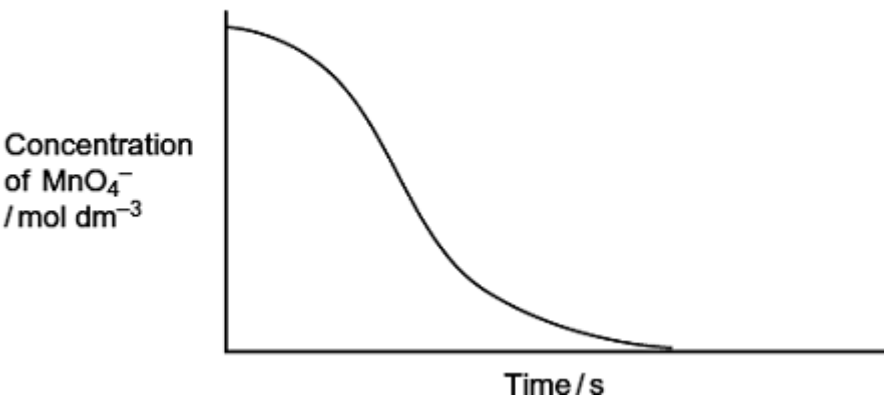
(4)

(Total 16 marks)

Q18.

An acidified solution of potassium manganate(VII) was reacted with a sample of sodium ethanedioate at a constant temperature of 60 °C. The concentration of the manganate(VII) ions in the reaction mixture was determined at different times using a spectrometer to measure the light absorbed.

The following results were obtained.



(a) Write an equation for the reaction between manganate(VII) ions and ethanedioate ions in acidic solution.

(2)

(b) By considering the properties of the reactants and products, state why it is possible to use a spectrometer to measure the concentration of the manganate(VII) ions in this reaction mixture.

(2)

(c) This reaction is autocatalysed. Give the meaning of the term *autocatalyst*.
Explain how the above curve indicates clearly that the reaction is autocatalysed.

Meaning of *autocatalyst*

Explanation

(3)

(d) Identify the autocatalyst in this reaction.

(1)

(e) Write **two** equations to show how the autocatalyst is involved in this reaction.

Equation 1

Equation 2

(2)

(Total 10 marks)

Q19.

Iron is an important element in living systems. It is involved in redox and in acid–base reactions.

(a) Explain how and why iron ions catalyse the reaction between iodide ions and $S_2O_8^{2-}$ ions. Write equations for the reactions that occur.

(5)

(b) Iron(II) compounds are used as moss killers because iron(II) ions are oxidised in air to form iron(III) ions that lower the pH of soil.

(i) Explain, with the aid of an equation, why iron(III) ions are more acidic than iron(II) ions in aqueous solution.

(3)

(ii) In a titration, 0.321 g of a moss killer reacted with 23.60 cm^3 of acidified 0.0218 mol dm^{-3} $K_2Cr_2O_7$ solution.

Calculate the percentage by mass of iron in the moss killer. Assume that all of the iron in the moss killer is in the form of iron(II).

(5)

(c) Some sodium carbonate solution was added to a solution containing iron(III) ions. Describe what you would observe and write an equation for the reaction that occurs.

(3)

(Total 16 marks)

Q20.

Three characteristic properties of transition metals are complex formation, coloured ions and catalytic activity.

(a) State the feature of transition metals that gives rise to these characteristic properties.

_____

(1)

(b) State a fourth characteristic property of transition metals.

_____

(1)

(c) For each of the following shapes of complex, identify an appropriate example by drawing its structure.

(i) a linear complex

(1)

(ii) a square planar complex

(1)

(iii) a tetrahedral complex

(1)

(d) The chemical industry makes use of the catalytic activity of transition metal compounds. For example, vanadium(V) oxide is used as a heterogeneous catalyst in the Contact Process.

(i) Write an equation for the overall reaction in the Contact Process.

_____

(1)

(ii) Explain the meaning of the term *heterogeneous* as applied to a catalyst.

_____

(1)

(iii) Write two equations to illustrate how vanadium(V) oxide acts as a catalyst in the Contact Process.

Equation 1 _____

Equation 2 _____

(2)

(iv) Suggest what is done to a heterogeneous catalyst such as vanadium(V) oxide to maximise its efficiency and how this is achieved.

_____

_____

_____

(2)

(e) The porphyrin ring is a multidentate ligand that is found in living systems complexed with iron(II) ions in haemoglobin and with cobalt(II) ions in vitamin B_{12}

(i) Give the meaning of the term *multidentate*.

_____

_____

(1)

(ii) A porphyrin ring can be represented by the symbol PR. It reacts with aqueous iron(II) ions as shown in the equation below.
The enthalpy change for this reaction is approximately zero.

$$PR(aq) + [Fe(H_2O)_6]^{2+}(aq) \rightarrow [FePR(H_2O)_2]^{2+}(aq) + 4H_2O(l)$$

Explain why the free-energy change for this reaction is negative.

_____

_____

_____

_____

(2)

(iii) In vitamin B_{12} the cobalt(II) ion is co-ordinated to a porphyrin ring, a cyanide (CN^-) ion and an additional unidentate ligand. The cyanide ion is very toxic.

Predict the co-ordination number of the cobalt ion in vitamin B_{12}
Suggest why vitamin B_{12} is **not** toxic.

Co-ordination number _____

Reason why vitamin B_{12} is **not** toxic

_____

_____

(2)

(Total 16 marks)

Mark Scheme

Q15.

(a) Stoppered flask or similar with side arm

Allow gas outlet through stopper.

1

Calibrated container for collection eg gas syringe

Allow collection over water, but must use calibrated vessel for collection.

Lose 1 mark if apparatus is not gas tight.

1

(b) Plot a graph of 'volume (of gas)' against 'time'

1

Determine the slope (gradient) at the beginning

1

(c) Repeat with same volume **or** concentration of hydrogen peroxide and at the same temperature

Ignore references to results.

Do not allow 'keep everything the same' or words to that effect.
Must mention volume or concentration and temperature.

1

Add cobalt(II) chloride to one experiment

1

[6]

Q16.

(a) Variable / many oxidation states

1

(b) $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$

Equations can be in either order

Allow multiples

1

$V_2O_4 + ½O_2 \rightarrow V_2O_5$

1

(c) (i) In a different phase / state from reactants

1

(ii) Impurities poison / deactivate the catalyst / block the active sites

Allow (adsorbs onto catalyst AND reduces surface area)

1

(d) (i) The catalyst is a reaction product

1

(ii) Mn^{2+} / Mn^{3+} ion(s)

1

(iii) $4Mn^{2+} + MnO_4^- + 8H^+ \rightarrow 5Mn^{3+} + 4H_2O$

Equations can be in either order

1

$2Mn^{3+} + C_2O_4^{2-} \rightarrow 2Mn^{2+} + 2CO_2$

1

[9]

Q17.

(a) *For reactions 1 to 3 must show complex ions as reactants and products*

Take care to look for possible identification on flow chart

Reaction 1

ammonia solution

1

W is $[Co(NH_3)_6]^{2+}$

1

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

Correct equation scores all 3 marks

1

Reaction 2

Allow oxygen, Do not allow air

H_2O_2

1

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

1

$2[Co(NH_3)_6]^{2+} + H_2O_2 \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$

Allow $2[Co(NH_3)_6]^{2+} + ½O_2 + H_2O \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$

Correct equations score all 3 marks

1

Reaction 3

HCl

Do not allow Cl^- but mark on

1

Y is $[CoCl_4]^{2-}$

1

$[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$/

Correct equation scores previous mark

$[Co(H_2O)_6]^{2+} + 4HCl \rightarrow [CoCl_4]^{2-} + 6H_2O + 4H_+$

This equation scores all three marks

1

Reaction 4

Na_2CO_3 Or $NaOH/NH_3$

Do not allow $CaCO_3$ as a reagent but mark on

1

Z is $CoCO_3$ $Co(OH)_2/Co(H_2O)_4(OH)_2$

1

$[Co(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CoCO_3 + 6H_2O$ $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(H_2O)_4(OH)_2 + 2H_2O$ etc

Allow waters to stay co-ordinated to Co. This mark also previous mark

Or $[Co(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow CoCO_3 + 6H_2O + 2Na^+$

Allow $Co^{2+} + CO_3^{2-} \rightarrow CoCO_3$

1

(b) $SO_3^{2-} + ½O_2 \rightarrow SO_4^{2-}$

Allow multiples

1

The activation energy is lower (for the catalysed route)

Or Co^{3+} attracts SO_3^{2-}/Co^{2+} attracts SO_3^{2-}/oppositely charged ions attract

1

$½O_2 + 2Co^{2+} + 2H^+ \rightarrow H_2O + 2Co^{3+}$

1

$2Co^{3+} + SO_3^{2-} + H_2O \rightarrow 2Co^{2+} + SO_4^{2-} + 2H^+$

Allow these equations in either order

1

[16]

Q18.

(a) $2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \longrightarrow 2Mn^{2+} + 8H_2O + 10CO_2$

For all species correct / moles and species correct but charge incorrect

1

For balanced equation including all charges (also scores first mark)

1

(b) <u>Manganate(VII) ions</u> are <u>coloured</u> (purple)

1

All other reactants and products are **not** coloured (or too faintly coloured to detect)

Allow (all) other species are colourless

Allow Mn^{2+} are colourless / becomes colourless / pale pink

1

(c) The catalyst for the reaction is a reaction product

1

Reaction starts off slowly / gradient shallow

1

Then gets faster/rate increases / gradient increases

Allow concentration of MnO_4^- decreases faster / falls rapidly

1

(d) Mn^{2+} ions

Allow Mn^{3+} ions

1

(e) $MnO_4^- + 8H^+ + 4Mn^{2+} \longrightarrow 5Mn^{3+} + 4H_2O$

Allow multiples

1

$2Mn^{3+} + C_2O_4^{2-} \longrightarrow 2Mn^{2+} + 2CO_2$

1

[10]

Q19.

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

1

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

1

two negative ions repel / lead to reaction that is slow / lead to reaction that has high E_a

1

iron able to act because changes its oxidation state

allow iron has variable oxidation state

1

With iron ions have alternative route / route with lower activation energy

1

(b) (i) $[Fe(H_2O)_6]^{3+} \rightarrow [Fe(H_2O)_5OH]^{2+} + H^+$

can have H_2O on LHS and H_3O^+ on R

do not penalise further hydrolysis equations

allow high charge density

1

Fe^{3+} ion has higher charge (to size ratio) (than Fe^{2+})

1

increases polarisation of co-ordinated water / attracts O releasing an H^+ ion / weakens O–H bond

1

(ii) $Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$

or 6 mol Fe(II) react with 1 mol dichromate

If factor of 6 not used max = 3 for M2, M4 and M5

e.g. 1:1 gives ans= 8.93 to 8.98% (scores 3)

1

moles dichromate = $23.6 \times 0.218/1000 = 5.14 \times 10^{-4}$

1

moles iron = $5.14 \times 10^{-4} \times 6 = 0.00309$

M3 also scores M1

1

mass iron = $0.00309 \times 55.8 = 0.172$

Mark is for moles of iron × 55.8 conseq

Allow use of 56 for iron

1

% by mass of iron = $0.172 \times 100/0.321 = 53.7\%$

Answer must be to at least 3 sig figures allow 53.6 to 53.9

Mark is for mass of iron × 100/0.321 conseq

1

(c) brown precipitate / solid

Allow red-brown / orange solid

Not red or yellow solid

1

bubbles (of gas) / effervescence/ fizz

Allow gas evolved / given off

Do not allow just gas or CO_2 or CO_2 gas

1

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

Allow

$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(OH)_3 + 3CO_2 + 9H_2O$

Use of Na_2CO_3

e.g. … + $3Na_2CO_3 \rightarrow$ .. + .. + .. + $6Na^+$

1

[16]

Q20.

(a) Incomplete (or partially filled) d orbitals/sub-shells

Do not allow d shell

1

(b) Variable oxidation states

1

(c) (i) $[H_3N–Ag–NH_3]^+$

Allow $[Cl–Ag–Cl]^-$ or similar Cu(I) ion

Allow compounds in (i), (ii) and (iii) (eg Cl-Be-Cl)

Allow no charge shown, penalise wrong charge(s)

1

(ii) Cis platin drawn out as square planar

Allow NiX_4^{2-} etc

1

(iii) $[CuCl_4]^{2-}$ drawn out as tetrahedral ion

Or $[CoCl_4]^{2-}$ drawn out

1

(d) (i) $SO_2 + 1/2O_2 \rightarrow SO_3$

Allow multiples

Allow $SO_2 + 1/2O_2 + H_2O \rightarrow H_2SO_4$

ignore state symbols

1

(ii) In a different phase/state (from the reactants)

1

(iii) $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$

can be in either order

1

$V_2O_4 + 1/2O_2 \rightarrow V_2O_5$

allow multiples

1

(iv) Surface area is increased

1

By use of powder or granules or finely divided

Allow suspending/spreading out onto a mesh or support

1

(e) (i) Forms two or more co-ordinate bonds

Allow more than one co-ordinate bond or donates more than 1 electron pair.

Do not allow "has more than one electron pair"

Allow uses more than one atom to bond (to TM)

1

(ii) Number of product particles > Number of reactant particles

Allow molecules/entities instead of particles

Penalise incorrect numbers (should be 2→5)

1

Disorder increases or entropy increases
(or entropy change is positive)

Allow ΔG must be negative because ΔH = 0 and ΔS is +ve

1

(iii) 6

1

Cyanide strongly bound to Co (by co-ordinate/covalent bond)

1

[16]