Mark Scheme - 3.4 Chemistry of the d-block Transition Metals

1.

(a) (i) Number of moles of EDTA $= \frac{19.20 \times 0.010}{1000} = 1.92 \times 10^{-4}$ / 0.000192 [1]

- error carried forward throughout (a)

(ii) 1.92×10^{-4} / 0.000192 [1]

(iii) Concentration $= \frac{1.92 \times 10^{-4} \times 1000}{50} = 3.84 \times 10^{-3}$ / 0.00384 $mol\ dm^{-3}$ (1)

Concentration $= 3.84 \times 10^{-3} \times 63.5 = 0.244\ g\ dm^{-3}$ (1) [2]

(iv) % Cu $= \frac{0.244 \times 100}{11.56} = 2.11$ [1]

(b) Transition elements have either a partly filled 3d sub-shell or form ions that have a partly filled 3d sub-shell (1)
However copper forms Cu^{2+} ions that are '$3d^9$' / partly filled 3d sub-shell (1)
whereas Zn^{2+} ions are '$3d^{10}$' / full 3d sub-shell (1) - any 2 from 3 [2]

QWC Organisation of information clearly and coherently; use of specialist vocabulary where appropriate. [1]

(c)

Complex ion	Shape	Colour
$[CuCl_4]^{2-}$	tetrahedral	yellow / lime green
$[Cu(NH_3)_4(H_2O)_2]^{2+}$	octahedral	deep blue

Any two correct (1) all correct (2) [2]

(d) The more negative the ΔH_f value the more stable the oxide (1)
PbO is relatively the more stable / CuO is relatively the less stable (1) [2]
- must have the first mark to get second

(e) (i) Any TWO from
variable oxidation states
partially filled 3d energy levels
ability to adsorb 'molecules'
ability to form complexes with reacting molecules / temporary / co-ordinate bonds

One mark for each correct response [2]

(ii) e.g. to allow lower pressures / temperatures
use recyclable catalysts - needs qualifying [1]
longer lasting / less toxic catalysts

Total [15]

2.

(a) H : O : O : H (with lone pairs shown as dots above and below each O) [1]

(b) 20 dm^3 oxygen = 0.83 mol (1)

Moles H_2O_2 = 1.67 and $[H_2O_2]$ = 1.67 mol dm^{-3} (1) [2]

(c) (i) Variable oxidation states / partially filled 3d energy levels /ability to adsorb 'molecules' / form complexes (or temporary bonds) with reacting molecules
(Accept any two answers)
Do not accept 'empty / unfilled d-orbitals' [2]

(ii) 3d orbitals split by ligands (1)

Three d-orbitals have lower energy, two have higher energy (1)

Electrons absorb (visible light) energy to jump from lower level to higher level (1)

The colour is that due to the remaining / non-absorbed frequencies (1)
(Appropriate diagrams are acceptable alternatives)
[4]

QWC Legibility of text; accuracy of spelling, punctuation and grammar, clarity of meaning [1]

(d) (i) $MnO_4^- + 8H^+ + 5e^- \longrightarrow Mn^{2+} + 4H_2O$ [1]

(ii) $5H_2O_2 + 6H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 5O_2 + 8H_2O$ [2]

(Mark consequentially from (i) – 1 mark if formulae correct but equation not balanced properly)

(iii) Moles $MnO_4^- = \frac{0.02 \times 14.8}{1000} = 2.96 \times 10^{-4}$ (1)

Moles H_2O_2 = 7.40×10^{-4} (1)

Concentration $H_2O_2 = \frac{7.40 \times 10^{-4}}{0.020} = 0.037$ mol dm^{-3} (1) [3]

(e) Oxidation state of oxygen starts at –1 (in peroxide) (1)
Oxidation state in water is –2 (reduced)
oxidation state in oxygen is 0 (oxidised) (1) [2]

Total [18]

3.

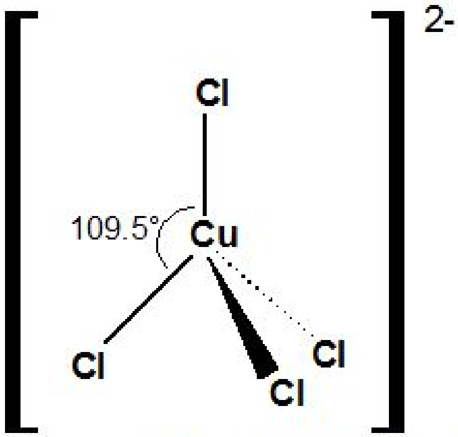
Provides an alternative pathway (1)
with lower activation energy / more particles have energy above E_A (1) **[2]**

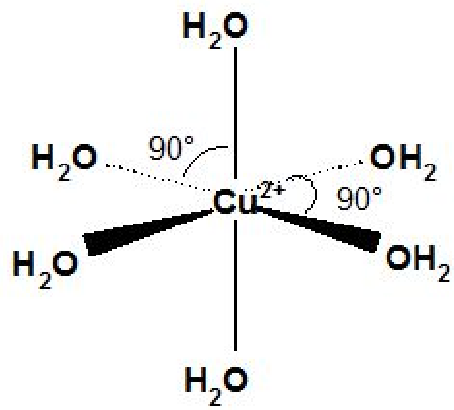
any example e.g. [1]
iron for Haber process / manufacture of ammonia
vanadium(V) oxide in Contact process / manufacture of sulfuric acid
platinum / palladium / rhodium in catalytic converters / to remove toxic gases from exhaust fumes
nickel in hydrogenation of alkenes / unsaturated oils

4.

(a) (i) Species with lone pair that can bond to a metal atom/ion (1) [1]

(ii) Must clearly show which atoms are bonded and the 3D structure
1 mark each (2) [2]





(iii) Ligands cause d-orbitals to split into three lower and two higher (1)
Electrons move from lower level to higher level by absorbing some frequencies (1)
Light not absorbed gives colour seen (1) [3]

(iv) $[Cu(NH_3)_4(H_2O)_2]^{2+}$ (1) Royal blue (1) [2]

(b) (i) $K_p = \frac{p_{PCl_3} p_{Cl_2}}{p_{PCl_5}}$ do not accept if [ ] included [1]

(ii) I. 1.3×10^5 (Pa) [1]

II. $P_{PCl5} = 3.0 \times 10^5 - 1.3 \times 10^5 = 1.7 \times 10^5$ (1) (ecf from part I)

$K_p = (1.3 \times 10^5 \times 1.3 \times 10^5) / 1.7 \times 10^5 = 9.9 \times 10^4$ (1)

Pa (1) [3]

III. Endothermic as equilibrium shifts to products when temperature increases [1]

(c) $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ OR

$SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$ (1)

Silicon has available empty d-orbitals whilst carbon does not /
Silicon can expand its octet whilst carbon cannot (1) [2]

Total [16]

5.

(a)	Name of any commercially/ industrially important chlorine containing compound e.g. (sodium) chlorate(I) as bleach/ (sodium) chlorate(V) as weedkiller/ aluminium chloride as catalyst in halogenation - do not accept CFCs			**[1]**
(b)	(i)	$K_c = \frac{[HI]^2}{[H_2][I_2]}$	must be square brackets	**[1]**
	(ii)	$K_c = \frac{0.11^2}{3.11^2} = 1.25 \times 10^{-3}$	follow through error (ft)	**[1]**
	(iii)	K_c has no units	ft	**[1]**
	(iv)	when temperature increases K_c increases (1) this means equilibrium has moved to RHS / increasing temperature favours endothermic reaction (1) therefore ΔH for forward reaction is +ve (1) (mark only awarded if marking point 2 given)		**[3]**
(c)	(i)	+2		**[1]**
	(ii)	co-ordinate/ dative (covalent)		**[1]**
	(iii)	pink is $[Co(H_2O)_6]^{2+}$ **and** blue is $[CoCl_4]^{2-}$ (1) (ligand is) Cl^- (1) (addition of HCl sends) equilibrium to RHS (1)		**[3]**
	(iv)	$[Co(H_2O)_6]^{2+}$ shown as octahedral [with attempt at 3D] (1) $[CoCl_4]^{2-}$ shown as tetrahedral/ square planar (1)		**[2]**

Total [14]