M1.(a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression from stage 1 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct chemistry to gain a mark.

Level 0
0 marks

Indicative chemistry content

Stage 1: Electrons round P

- P has 5 electrons in the outside shell
- With 3 electrons from 3 fluorine, there are a total of 8 electrons in outside shell
- so 3 bond pairs, 1 non-bond pair

Stage 2: Electron pair repulsion theory

- Electron pairs repel as far as possible
- Lone pair repels more than bonding pairs

Stage 3: Conclusions

- Therefore, tetrahedral / trigonal pyramidal shape

- With angle of 109(.5)° decreased to 107°

6

(b) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$

Allow correct numbers that are not superscripted

1

(c) Too many electrons in d sub-shell / orbitals

1

(d) Tetrahedral (shape)

1

109.5°

Allow 109°

1

[10]

M2.(a) Percentage of oxygen is 42.5% **(M1)**

Allow if shown clearly in the calculation.

1

Co 13.0 / 58.9 = 0.221, N 18.6 / 14 = 1.329,

K 25.9 / 39.1 = 0.662, O 42.5 / 16 = 2.656 **(M2)**

Allow alternative method if chemically correct.

*If A_r has been divided by the percentage, chemical error, lose **M2** and **M3**.*

1

$CoN_6K_3O_{12}$ **(M3)**

Allow in any order.

Correct answer without working scores this mark only.

1

(b) $Co(NO_2)_6^{3-}$

Allow a correct diagram bonding through N or O

Do not allow $CoN_6O_{12}^{3-}$

Must have correct overall charge.

Allow consequential answer from part(a) if the charge on the anion is correct.

1

[4]

M3. (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]

M4.(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+}<u>(aq)</u> / $[Cu(H_2O)_6]^{2+}$ is blue

Any correct ion with colour scores M3 and M4

Must show (aq) or ligands OR identified coloured compounde.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]

M5.(a) A ligand is an electron pair / lone pair donor

Allow uses lone / electron pair to form a co-ordinate bond

1

A bidentate ligand donates two electron pairs (to a transition metal ion) from different atoms / two atoms (on the same molecule / ion)

QoL

1

(b) $CoCl_4^{2-}$ diagram

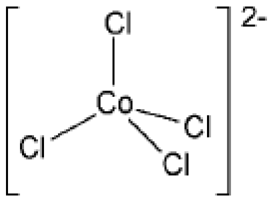
1

Tetrahedral shape

1

109°28'

1



Four chlorines attached to Co with net 2− charge correct

Charge can be placed anywhere, eg on separate formula

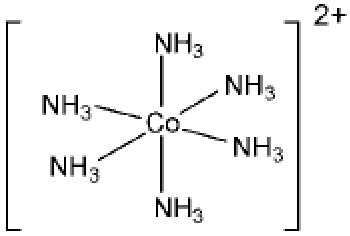
Penalise excess charges

Allow 109° to 109.5°

$[Co(NH_3)_6]^{2+}$ diagram 1

Octahedral shape 1

90° 1



Six ammonia / NH_3 molecules attached to Co with 2+ charge correct

Allow 180° if shown clearly on diagram

CE= 0 if wrong complex but mark on if only charge is incorrect

(c) In different complexes the d orbitals / d electrons (of the cobalt) will have different energies / d orbital splitting will be different 1

Light / energy is absorbed causing an electron to be excited 1

Different frequency / wavelength / colour of light will be absorbed / transmitted / reflected 1

(d) 1 mol of H_2O_2 oxidises 2 mol of Co^{2+}

Or $H_2O_2 + 2Co^{2+} \rightarrow 2OH^- + 2Co^{3+}$ 1

M_r $CoSO_4.7H_2O$ = 281

If M_r wrong, max 3 for M1, M4, M5 1

Moles Co^{2+} = 9.87 / 281 = 0.03512

1

Moles H_2O_2 = 0.03512 / 2 = 0.01756

M4 is method mark for (M3) / 2 (also scores M1)

1

Volume H_2O_2 = (moles × 1000) / concentration
= 0.01756 × 1000) / 5.00

= 3.51 cm^3 / (3.51 × 10^{-3} dm^3)

Units essential for answer

M5 is method mark for (M4) x 1000 / 5
Allow 3.4 to 3.6 cm^3

If no 2:1 ratio or ratio incorrect Max 3 for M2, M3 & M5

Note: Answer of 7 cm^3 scores 3 for M2, M3, M5 (and any other wrong ratio max 3)

Answer of 16.8 cm^3 scores 3 for M1, M4, M5 (and any other wrong M_r max 3)

Answer of 33.5 cm^3 scores 1 for M5 only (so wrong M_r AND wrong ratio max 1)

1

[16]