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

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

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(1 mark)

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

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(1 mark)

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

4 (c) (i) a linear complex

(1 mark)

4 (c) (ii) a square planar complex

(1 mark)

4 (c) (iii) a tetrahedral complex

(1 mark)

Question 4 continues on the next page

4 (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.

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

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(1 mark)

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

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(1 mark)

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

Equation 1 .....

Equation 2 .....

(2 marks)

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

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(2 marks)

4 (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}

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

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(1 mark)

4 (e) (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.

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

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

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(2 marks)

4 (e) (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

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(2 marks)

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