COMPLEX IONS - INTRODUCTION

1. a) Ligands are molecules or ions which surround and are bonded to the central atom or ion in a complex. In this case, the water molecules are ligands.

   b) An active lone pair of electrons at the bonding level.

   c) Coordinate (dative covalent) bonding

   d) 6

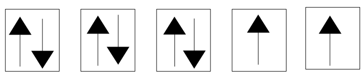
   e) The fact that they are all arrows shows the coordinate bonds. Simple arrows show bonds in the plane of the paper or screen. Dotted arrows show bonds lying behind the plane of the paper or screen. Wedge-shaped arrows show bonds coming out towards you.

   f) $1s^2 2s^2 2p^6 3s^2 3p^1$

   g) $1s^2 2s^2 2p^6$

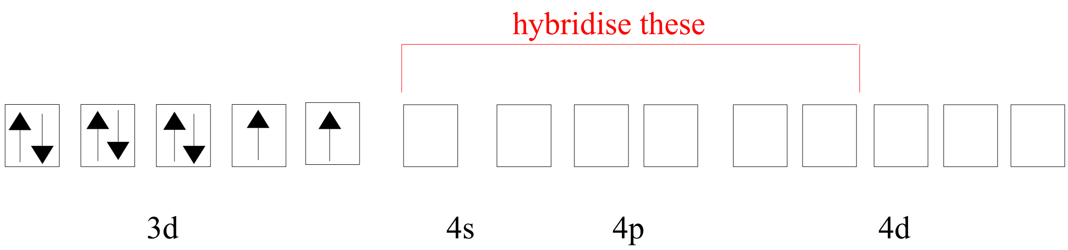
   h) In order to form six coordinate bonds, there have to be six empty orbitals on the aluminium ion. The ones used are the 3s orbital, the three 3p orbitals, and two of the 3d orbitals. These hybridise to give six hybrid orbitals with the same energy. Each of these then accepts a lone pair from one of the six water molecules to form a coordinate bond.

2. When nickel forms an ion, the two electrons in the 4s orbital are lost leaving an ion with the structure $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$. Each of the 3d orbitals has at least one electron in it, and you are told in the question that these don't rearrange when the ammonia attach:

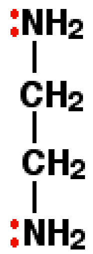


Each ammonia molecule has an active lone pair on the nitrogen atom.

To get six empty orbitals to accept the lone pairs from six ammonia molecules and form coordinate (dative covalent) bonds, the 4s orbital, the three 4p orbitals, and two of the 4d orbitals are hybridised:



The shape will be identical to the aluminium ion in question 1.

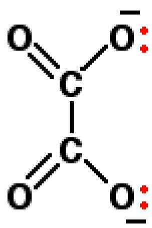
3. a) 

You could perfectly well draw this horizontally. I have drawn it vertically because using the diagram from the Chemguide page saved time. You also needn't draw the lone pairs of electrons at this stage.

b) A bidentate ligand is one which can form two coordinate bonds to the central atom or ion. 1,2-diaminoethane is bidentate because it has two nitrogen atoms and so two lone pairs. (Notice also that the two lone pairs are far enough apart for the molecule to bend in such a way as both lone pairs can approach empty orbitals on whatever it is joining to.)

c) $[Cr(NH_2CH_2CH_2NH_2)_3]^{3+}$
(You weren't given permission to write this using the abbreviation "en"! It is usual to include the square brackets around the whole ion apart from the charge, but for now don't worry whether you have written them or not.)

d) Ethanedioate (oxalate) ions:



The lone pairs shown are responsible for its ligand activity.

4. a) Haem (US: heme)

b) The water ligand at the bottom of the complex is easily replaced by oxygen. in the lungs The oxyhaemoglobin (haemoglobin now carrying oxygen) travels around the body in the blood, and the oxygen is removed where it is needed. The haemoglobin then returns to the lungs to pickup more oxygen.

c) Carbon monoxide can replace the water ligand to form a very stable complex. Since the site is now blocked, it can no longer pick up oxygen molecules.

5. a) $[Cr(EDTA)]^-$. The chromium carried 3+ charges, and the $EDTA^{4-}$ carries 4-. That leaves a net charge of 1-.

b) $[Ag(EDTA)]^{3-}$