HL Answers to Lewis acids & bases questions

1. BF_3 is accepting a pair of electrons and thus acting as a Lewis acid. F^- is donating the pair of electrons and thus is acting as a Lewis base. (It is worth noting that BF_3 is an 'electron deficient compound' as there are only three pairs of electrons around the central boron atom. It can readily accept one more pair of electrons to complete the octet.)
BF_3 : trigonal planar, 120°. BF_4^- : regular tetrahedron, 109.5°.

2. $AlCl_3$ only contains three electron pairs around the central aluminium atom. When it acts as a halogen carrier it completes its octet by accepting a pair of electrons from one of the chlorine atoms in the chlorine molecule causing the Cl—Cl bond to break and form $AlCl_4^-$ and Cl^+. It is therefore acting as a Lewis acid and the chlorine molecule is acting as a Lewis base.

3. All ligands and all nucleophiles possess at least one pair of non-bonding electrons and they react by donating this pair of electrons and are thus acting as Lewis bases. Ligands donate them to transition metal ions and nucleophiles donate them to an electron poor (δ^+) carbon atom.

4. i. Both the carbon and the nitrogen atoms in the cyanide ion possess a non-bonding pair of electrons. The formal charge on the carbon atom = 4 − 2 − (½ x 6) = −1; the formal charge on the nitrogen atom = 5 − 2 − (½ x 6) = 0. Since the carbon atom has a more negative formal charge it is more likely to donate its non-bonding pair of electrons to the transition metal ion.

ii. From the spectrochemical series it can be seen that cyanide ion ligands are more electron dense than water ligands as they causes greater splitting of the d orbitals. Because the cyanide ion is more electron dense it is a stronger ligand than water. If aqueous iron(II) ions, $[Fe(H_2O)_6]^{2+}$, are added to cyanide ions the cyanide ions replace the six water ligands irreversibly to form $[Fe(CN)_6]^{4-}$. This means the cyanide are no longer free to form coordinate bonds with other transition metal ions in the body.

5. The aluminium atom in $AlCl_3$ is electron deficient as it only has six electrons in its outer shell. It can therefore act as a Lewis acid accepting a non-bonding pair of electrons from one of the chlorine atoms from another molecule of aluminium chloride. At the same time one of its own chlorine molecules also donates a pair of electrons to the other aluminium atom. $AlCl_3$ is therefore acting as both a Lewis acid and a Lewis base.