NUCLEOPHILIC ADDITION: C=O and HCN

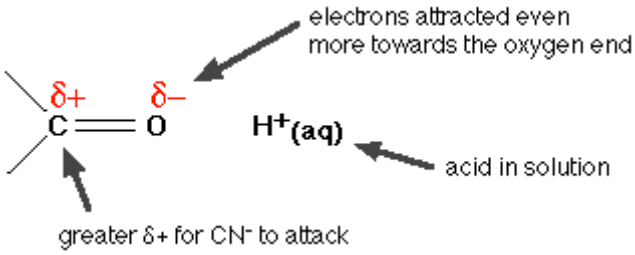
1. a) Because oxygen is more electronegative than carbon, the carbon-oxygen double bond is strongly polarised, with the oxygen being fairly negative and the carbon fairly positive. The lone pair on the negatively charged carbon in the cyanide ion is attracted to the carbon end of the carbon-oxygen double bond.

   The lone pair electrons form a new bond between the two carbon atoms, forcing the pi bond electrons in the carbon-oxygen double bond to move entirely on to the oxygen atom, giving it a negative charge.

   In the second stage, a lone pair on the oxygen moves to form a bond with a hydrogen atom from an HCN molecule. This forces the bonding pair between the hydrogen and carbon in the HCN completely on to the carbon, producing a cyanide ion.

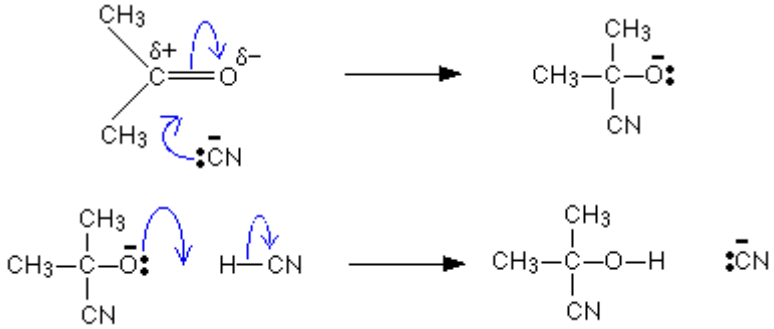
   b) Either water or hydroxonium ions, H_3O^+.

   c) (i) The hydrogen ions in solution help to increase the polarity of the carbon-oxygen double bond by attracting electrons even more strongly towards the oxygen end of the bond:



   (ii) HCN is a very weak acid, which means it hardly ionises at all. The more acidic you make the solution, the more cyanide ions will be converted into HCN. Since the first step of the reaction involves attack by cyanide ions, having fewer of them will slow the reaction down.

   d)



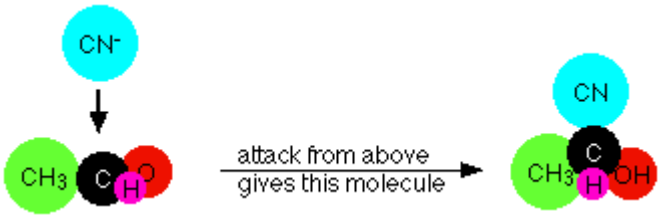
   (It doesn't matter if you have arranged the various groups around in the central carbon in a different order. As long as you have shown the carbon attached to two CH_3 groups, a CN group and an OH group, that's fine.)

2. a) It has a carbon atom attached to four different groups – an asymmetric carbon atom. It is possible to have two different isomers of this which are non-superimposable mirror images.

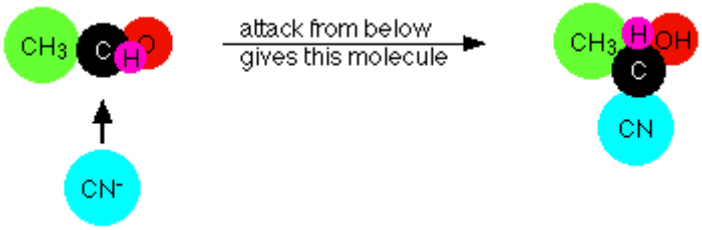
b) A racemic mixture is a 50/50 mixture of two optical isomers of a compound. Because they each rotate the plane of polarisation of plane polarised light in opposite directions, overall the mixture has no effect on plane polarised light.

c) Ethanal is a planar molecule which has an equal chance of being attacked by a cyanide ion either from above or from below:

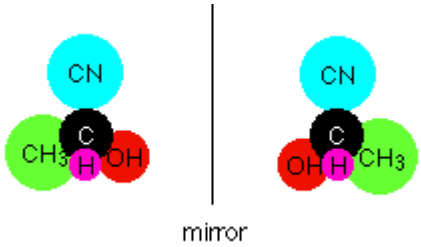
Attack from above:



and attack from below:



Rotating the second one in space, and lining it up with the first one shows that they are non-superimposable mirror images of each other:



Therefore, by chance, you get a 50/50 mixture of the two isomers – a racemic mixture.