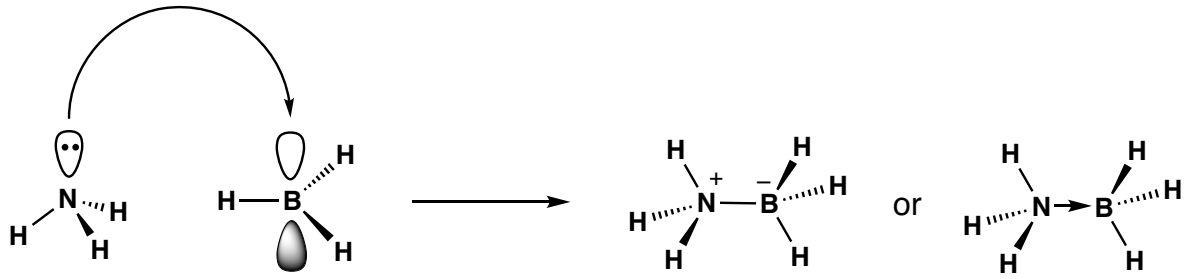
Chapter 6 Exercises

1. Predict the structure of and describe the bonding in the product formed from the reaction between diborane, B_2H_6, and ammonia, NH_3.

Answer. This is a simple Lewis acid-Lewis base reaction in which the lone pair on the ammonia acts as the Lewis base through donation to the empty orbital on borane (BH_3) which acts as the Lewis acid. This is shown graphically below. Remember that B_2H_6 effectively acts as a source of BH_3.

The product formed, H_3BNH_3 or ammonia-borane, is isoelectronic with ethane (C_2H_6) and the B–N bond can be represented in either of the ways shown in the graphic.



2. Write down the reactions expected between K_2O and water and between Cl_2O and water and comment on the acidity or basicity of the resulting solutions.

Answer. K_2O reacts with water to give 2 KOH which is a source of $[OH]^-$ so that solutions are basic.

$$K_2O + H_2O \rightarrow 2\ KOH$$

Cl_2O reacts with water to form ClOH which dissociates to form H^+ and the ClO^- anion so solutions are acidic.

$$Cl_2O + H_2O \rightarrow 2\ ClOH$$

Dissociation of the E–O–H unit(s) where E = K or Cl is in accordance with charge separation due to element electronegativity differences.

3. Consider whether SF_4 violates the octet rule.

Answer. We can start by using VSEPR to predict the structure of SF_4 from which we deduce that it has 5 electron pairs which point towards the vertices of a trigonal bipyramid. There are 4 S–F bond pairs and one lone pair so the lone pair goes equatorial and SF_4 therefore has the structure shown in the diagram below with two axial S–F bonds and two equatorial S–F bonds.

The simplest way to consider the bonding is to assign sp^2 hybridisation to the S centre such that the two equatorial S–F bonds and the lone pair involve these three sp^2 hybrid orbitals. The remaining unhybridized p orbital then forms part of a three-centre, four-electron interaction (3c,4e) with the two axial fluorines. An MO description of this 3c,4e interaction is exactly in accord with that described for the I_3^- anion and XeF_2 in the text. An MO diagram is shown below. The key point to appreciate is that the bonding F–S–F orbital has a contribution from all three atoms whereas the non-bonding F–S–F orbital is localized exclusively on the two fluorines. The total number of electrons associated with the S centre is therefore 8: the F–S–F bonding orbital referred to above, the two equatorial S–F bond pairs and the S lone pair. On this basis, SF_4 can be said not to violate the octet rule as it only has a total of 8 electrons associated with the S centre.