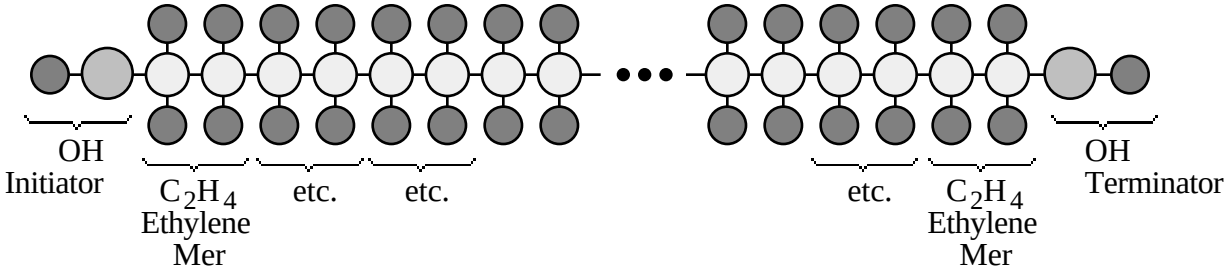
Example 15-6. Polymer molecular weights

1 g of Hydrogen Peroxide, H2O2, is added to 10000 g (1 kilogram) of ethylene to serve as the initiator and terminator (i.e., we assume that the cains are terminated by combination). Calculate the average molecular weight of the polymer if all the hydrogen peroxide is consumed and is 100% effective.

To solve this problem, it is necessary to understand that the completed polymer molecule consists of a backbone of ethylene monomers, with one OH group on each end, as shown in the sketch below. Hence, one molecule of H2O2 will be needed for each polymer molecule. Of course, not all of the molecules will have the exact same length (degree of polymerization) or molecular weight, but it is easy to determine the average value.



First, we will calculate the number of H2O2 molecules that are present in our 1 gram. We know (or should, from our basic chemistry courses) that one mole of a substance contains Avagadro's number of molecules. The atomic weights of C, H and O are 12, 1 and 16, respectively. Hence:

$N_A = 6.023 \cdot 10^{23}$

$\text{wt}_{H_2O_2} = 2 \cdot 1 + 2 \cdot 16$

$\text{wt}_{H_2O_2} = 34$

$\text{wt}_{C_2H_4} = 2 \cdot 12 + 4 \cdot 1$

$\text{wt}_{C_2H_4} = 28$

$N_{H_2O_2} = 1 \dfrac{N_A}{\text{wt}_{H_2O_2}}$

$N_{H_2O_2} = 0.17715 \cdot 10^{23}$

This is the number of H2O2 molecules present, which must be equal to the number of polymer molecules produced. Now we will use the same procedure to determine the number of ethylene molecules present, since this will give us the total number of mers that form the polymer molecules.

$N_{C_2H_4} = \dfrac{10000}{\text{wt}_{C_2H_4}} N_A$

$N_{C_2H_4} = 2151.1 \cdot 10^{23}$

This is the number of mers. For the average polymer molecule, the number of mers (the degree of polymerization) is just the ratio of the number of C2H4 mers to the number of molecules, which in turn is equal to the number of H2O2 molecules. Hence:

$\text{DegPolymerization} = \dfrac{N_{C_2H_4}}{N_{H_2O_2}}$

△ DegPolymerization = 12143 This is the average degree of polymerization. Multiplying this by the weight of the mer gives the molecular weight of the polymer. We really should add the weight of the H2O2 hanging on the ends, but this is really negligible in terms of the rest of the molecule and is often ignored.

▢ $wt_{polymer}$ = DegPolymerization$wt_{C_2H_4}$

△ $wt_{polymer}$ = 340000 Molecular weight of the polymer in grams per gram-mole