Objective

After completing this section, you should be able to

- use pK_a values to calculate K_{eq}
- use pK_a values to predict the equilibrium direction of an acid-base reaction.

Key Terms

Make certain that you can define, and use in context, the key term below.

- pK_a

Using pK_a values to predict reaction Equilibria

Edit section

By definition, the pK_a value tells us the extent to which an acid will react with water as the base, but by extension, we can also calculate the equilibrium constant for a reaction between any acid-base pair. Mathematically, it can be shown that:

$$K_{eq} \text{ (for the acid base reaction in question)} = 10^{\Delta pK_a}$$

where $\Delta pK_a$ is the $pK_a$ of product acid minus $pK_a$ of reactant acid

Consider a reaction between methylamine and acetic acid:

First, we need to identify the acid species on either side of the equation. On the left side, the acid is of course acetic acid, while on the right side the acid is methyl ammonium. The specific pK_a values for these acids are not on our very generalized pK_a table, but are given in the figure above. Without performing any calculations, you should be able to see that this equilibrium lies far to the right-hand side: acetic acid has a lower pK_a, is a stronger acid, and thus it wants to give up its proton more than methyl ammonium does. Doing the math, we see that

$$[K_{eq}] = 10^{\Delta pK_a} = 10^{(10.6 - 4.8)} = 10^{5.8} = 6.3 \times 10^5$$

So $[K_{eq}]$ is a very large number (much greater than 1) and the equilibrium lies far to the right-hand side of the equation, just as we had predicted.

If you had just wanted to approximate an answer without bothering to look for a calculator, you could have noted that the
difference in pKₐ values is approximately 6, so the equilibrium constant should be somewhere in the order of $10^6$, or one million. Using the pKₐ table in this way, and making functional group-based pKₐ approximations for molecules for which we don’t have exact values, we can easily estimate the extent to which a given acid-base reaction will proceed.

Example \(\PageIndex{1}\))

Show the products of the following acid-base reactions, and estimate the value of $K_{eq}$. Use the pKₐ table from Section 2.8 and/or from the Reference Tables.

**Answer:**

Exercises
Questions
Q2.9.1

In the following reactions give the resulting products and label the conjugate acid and bases.

\[
\text{CH}_3\text{CH}_2\text{OH} + \text{NO}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}
\]

Solutions
S2.9.1

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{OH} & + \text{NO}_2 \rightarrow \text{Conjugate base} \quad \text{Conjugate acid} \\
\text{CH}_3\text{OH} & + \text{H}_2\text{O} \rightarrow \text{Conjugate base} \quad \text{Conjugate acid}
\end{align*}
\]

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