CHM 12600 Concept Problems  
March 21, 2016

1. In organic chemistry, pK_a values (rather than K_a values) are used to indicate relative strengths of acids. Consider the organic molecules I - III shown below (the acidic proton for each molecule is shown in bold).

\[
\begin{align*}
\text{I} & : \begin{array}{c}
\text{F} \\
\text{F}
\end{array} \\
\text{O} & \\
\text{O} & \\
\text{H} & \\
\text{F} & \\
\text{F}
\end{align*}
\]

\[
\begin{align*}
\text{II} & : \begin{array}{c}
\text{O} \\
\text{C} & \\
\text{O} & \\
\text{H}
\end{array}
\end{align*}
\]

\[
\begin{align*}
\text{III} & : \begin{array}{c}
\text{\_\_}\text{O} \\
\text{\_\_}\text{H}
\end{array}
\end{align*}
\]

Which molecule would be expected to have the smallest pK_a value, and which would be expected to have the largest pK_a value? Explain your reasoning.

2. Sodium amide, NaNH_2, is a salt that contains the very strong base, amide ion (NH_2^-). Considering the fact that amide ion is a much stronger base than hydroxide ion, OH^-, describe what will happen when sodium amide is dissolved in water. Support your argument(s) with appropriate chemical equations, Lewis structures, and “arrow-pushing”.

3. You have just invented a new device called a "microscopometer" which allows you to see solute particles (but not solvent particles) in aqueous solutions on the atomic scale. You are on the spot, in the limelight, poised to win the Nobel Prize. In order to prove that your new device works, the Nobel Prize Selection Committee gives you three bottles, each containing an aqueous solution of an acid. All you have to do is use your microscopometer to identify which of the following three acids is in each of the bottles!

\[
\begin{align*}
\text{H—Br} & : \\
\text{hydrogen bromide} & \\
\text{H—C≡N} & : \\
\text{hydrogen cyanide} & \\
\text{H—C} & :
\end{align*}
\]

\[
\begin{align*}
\text{O} & : \\
\text{H} & \\
\text{C} & \\
\text{O} & \\
\text{H}
\end{align*}
\]

\[
\begin{align*}
\text{formic acid} & \\
\end{align*}
\]
a. Draw three atomic-scale diagrams that illustrate what your microscopometer shows for each of the three solutions.

b. To further substantiate your claim for the Nobel Prize Selection Committee, write a balanced, chemical equation for the reaction of each acid with water. For each reaction, identify the Bronsted acid, the Bronsted base, the conjugate acid, and the conjugate base, and then illustrate the transfer of $\text{H}^+$ from the Bronsted acid to the Bronsted base by using “arrow-pushing”.

4. Baking powder is used in making many baked goods, pastries, pancakes and pizza because it is a good leavening agent (it lightens a dough or batter via the production of a gas). Most baking powders contain: 26-30% sodium bicarbonate (baking soda, $\text{NaHCO}_3$), the "active ingredient", an acid, and inert ingredients. One of the acids that is commonly used in baking powder is potassium acid tartrate ($\text{KHC}_4\text{H}_4\text{O}_6$, "Cream of Tartar"), which is a weak, monoprotic acid.

\[
\begin{align*}
\text{bicarbonate ion, } & \text{HCO}_3^- \\
\text{acid tartrate ion, } & \text{HC}_4\text{H}_4\text{O}_6^-
\end{align*}
\]

When baking powder is dissolved in a liquid, such as water or milk, a reaction occurs and a gas is produced. Write a balanced, chemical equation for the reaction, and identify the Bronsted acid, the Bronsted base, the conjugate acid, and the conjugate base. Illustrate the transfer of $\text{H}^+$ from the Bronsted acid to the Bronsted base using the “arrow-pushing” symbolism. What is the gas that is produced in the reaction?