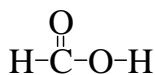


Chapter 16

Acids and Bases

Concept Check 16.1

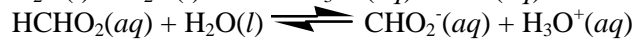
Chemists in the seventeenth century discovered that the substance that gives red ants their irritating bite is an acid with the formula HCHO_2 . They called this substance formic acid after the ant, whose Latin name is *Formica rufus*. Formic acid has the following structural formula and molecular model.



Write the acid-base equilibria connecting all components in the aqueous solution. Now list all of the species present.

Solution

In any aqueous solution, you should consider the autoionization of water. And because we have a solution of a weak acid in water, you should also consider the equilibrium between this acid and water. Here are the two equilibria:



The species present in these equilibria are: $\text{H}_2\text{O}(l)$, $\text{H}_3\text{O}^+(aq)$, $\text{OH}^-(aq)$, $\text{HCHO}_2(aq)$, and $\text{CHO}_2^-(aq)$.

Concept Check 16.2

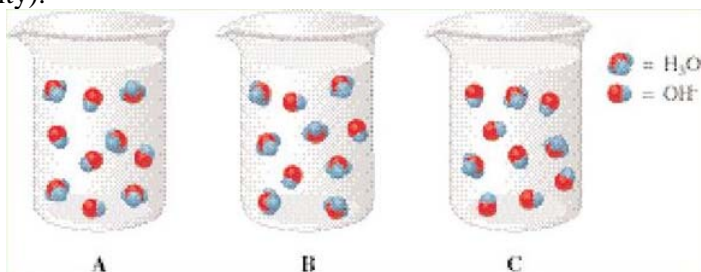
Formic acid, HCHO_2 , is a stronger acid than acetic acid, $\text{HC}_2\text{H}_3\text{O}_2$. Which is the stronger base, formate ion, CHO_2^- , or acetate ion, $\text{C}_2\text{H}_3\text{O}_2^-$?

Solution

The stronger acid gives up its proton more readily, and therefore its conjugate base ion holds onto a proton less strongly. In other words, the stronger acid has the weaker conjugate base. Because formic acid is the stronger acid, the formate ion is the weaker base. Acetate ion is the stronger base.

Concept Check 16.3

Rank the following solutions from most acidic to most basic (water molecules have been omitted for clarity).



Solution

Look at each solution, and determine whether it is acidic, basic, or neutral. In solution A, the numbers of H_3O^+ and OH^- ions are equal, so the solution is neutral. For solution B, the number of H_3O^+ ions is greater than the number of OH^- ions, so the solution is acidic. In solution C, the number of H_3O^+ ions is less than the number of OH^- ions, so the solution is basic. Therefore, ranking from most acidic to least acidic (most basic) is $\text{B} > \text{A} > \text{C}$.

Concept Check 16.4

You have solutions of NH_3 , HCl , NaOH , and $\text{HC}_2\text{H}_3\text{O}_2$ (acetic acid), all with the same solute concentrations. Rank these solutions in order of pH, from the highest to lowest.

Solution

In order to qualitatively answer this problem, it is essential that all of the solutions have the same solute concentrations. Bases produce solutions of pH greater than 7 where acids produce solutions of pH less than 7. NH_3 and NaOH are bases, and HCl and $\text{HC}_2\text{H}_3\text{O}_2$ are acids. NaOH is a stronger base than NH_3 , so the NaOH solution would have the highest pH followed by the NH_3 solution. $\text{HC}_2\text{H}_3\text{O}_2$ is a much weaker acid than HCl so the $\text{HC}_2\text{H}_3\text{O}_2$ solution would have a higher pH than the HCl solution. Therefore, the ranking from highest to lowest pH for solutions with the same solute concentrations is: $\text{NaOH} > \text{NH}_3 > \text{HC}_2\text{H}_3\text{O}_2 > \text{HCl}$.

Conceptual Problem 16.15

Aqueous solutions of ammonia, NH_3 were once thought to be solutions of an ionic compound ammonium hydroxide, NH_4OH , in order to explain how solutions could contain hydroxide ion. Using the Brønsted-Lowry concept, show how NH_3 yields hydroxide ion in aqueous solution without involving the species NH_4OH .

Solution

It is not necessary to have the species NH_4OH in order to have OH^- in the solution. When ammonia reacts with water, hydroxide ion forms in the reaction.



Conceptual Problem 16.16

Blood contains several substances that minimize changes in its acidity by reacting with either an acid or a base. One of these is the hydrogen phosphate ion, HPO_4^{2-} . Write one equation showing this species acting as a Brønsted-Lowry acid and another in which the species acts as a Brønsted-Lowry base.

Solution

A reaction where HPO_4^{2-} acts as an acid is



A reaction where HPO_4^{2-} acts as a base is



Conceptual Problem 16.17

Self-contained environments, such as that of a space station, require that the carbon dioxide exhaled by people be continuously removed. This can be done by passing the air over solid alkali hydroxide, in which carbon dioxide reacts with hydroxide ion. What ion is produced by the addition of OH^- ion to CO_2 ? Use the Lewis concept to explain this.

Solution

The hydroxide ion acts as a base and donates a pair of electrons to the O atom, forming a bond with CO_2 to give HCO_3^- .

Conceptual Problem 16.18

Compare the structures of HNO_2 and H_2CO_3 . Which would you expect to be the stronger acid? Explain your choice.

Solution

Nitrogen has greater electronegativity than carbon. You would expect the H—O bond in the H—O—N group to be more polar (with the H atom having a positive partial charge) than the H—O bond in the H—O—C group. Thus, based on their structure, you would expect HNO_2 to be the stronger acid.

Conceptual Problem 16.19

The value of the ion-product constant for water, K_w , increases with temperature. What will be the effect of lowering the temperature on the pH of pure water?

Solution

When you lower the temperature of pure water, the value of K_w decreases. In pure water, the hydronium ion concentration equals the hydroxide ion concentration, so $K_w = [\text{H}_3\text{O}^+]^2$. When K_w decreases, the hydronium ion decreases, and the corresponding pH increases.

Conceptual Problem 16.20

You make solutions of ammonia and sodium hydroxide by adding the same moles of each solute to equal volumes of water. Which solution would you expect to have the higher pH?

Solution

Sodium hydroxide is a strong base, whereas ammonia is weak. As a strong base, NaOH exists in solution completely as ions, whereas NH_3 exists in solution as an equilibrium in which only part of the NH_3 has reacted to produce ions. Thus, a sodium hydroxide solution has a greater OH^- concentration than the same concentration solution of NH_3 . At the same concentrations, the pH of the NaOH solution is greater (more basic) than the NH_3 solution.