

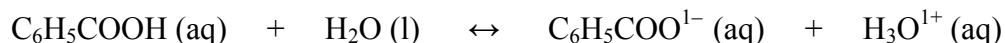
Unit 7, Lesson 05: Answers to Working with Ka, Kb and Kw

4. For each of the following acids:

- write the ionization reaction in water and the Ka expression
- write the ionization reaction for its conjugate base and Kb expression
- calculate the value of Kb for the conjugate base

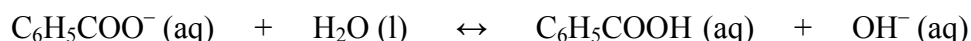
a) benzoic acid

The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$K_a = \frac{[C_6H_5COO^{1-}][H_3O^{1+}]}{[C_6H_5COOH]}$$
$$= 6.3 \times 10^{-5} \quad (\text{from page 597})$$

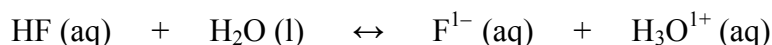
The K_b equation shows the ionization and dissociation of the base to form OH^- in water:



$$K_b = \frac{[C_6H_5COOH][OH^{1-}]}{[C_6H_5COO^-]}$$
$$= K_w / K_a$$
$$= 1.0 \times 10^{-14} / 6.3 \times 10^{-5}$$
$$= 1.6 \times 10^{-10}$$

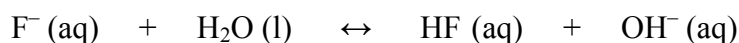
b) hydrofluoric acid

The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$K_a = \frac{[F^{1-}][H_3O^{1+}]}{[HF]}$$
$$= 6.3 \times 10^{-4} \quad (\text{from page 597})$$

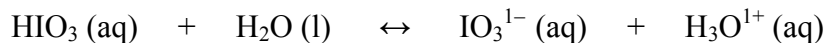
The K_b equation shows the ionization and dissociation of the base to form OH^- in water:



$$K_b = \frac{[HF][OH^{1-}]}{[F^-]}$$
$$= K_w / K_a$$
$$= 1.0 \times 10^{-14} / 6.3 \times 10^{-4}$$
$$= 1.6 \times 10^{-11}$$

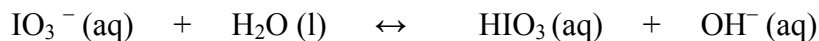
c) iodic acid HIO_3

The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$\begin{aligned} K_a &= \frac{[\text{IO}_3^{1-}][\text{H}_3\text{O}^{1+}]}{[\text{HIO}_3]} \\ &= 1.7 \times 10^{-1} \quad (\text{from page 597}) \end{aligned}$$

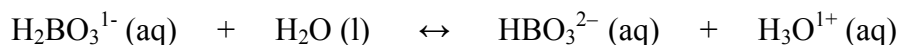
The K_b equation shows the ionization and dissociation of the base to form OH^- in water:



$$\begin{aligned} K_b &= \frac{[\text{HIO}_3][\text{OH}^{1-}]}{[\text{IO}_3^{-}]} \\ &= K_w / K_a \\ &= 1.0 \times 10^{-14} / 1.7 \times 10^{-1} \\ &= 5.9 \times 10^{-14} \end{aligned}$$

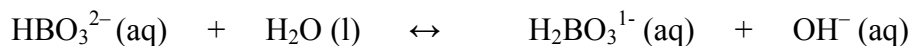
d) $\text{H}_2\text{BO}_3^{1-}(\text{aq})$

The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$\begin{aligned} K_a &= \frac{[\text{HBO}_3^{2-}][\text{H}_3\text{O}^{1+}]}{[\text{H}_2\text{BO}_3^{1-}]} \\ &< 1.0 \times 10^{-14} \quad (\text{from table E.10 on page 597}) \end{aligned}$$

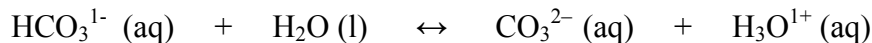
The K_b equation shows the ionization and dissociation of the base to form OH^- in water:



$$\begin{aligned} K_b &= \frac{[\text{H}_2\text{BO}_3^{1-}][\text{OH}^{1-}]}{[\text{HBO}_3^{2-}]} \\ &= K_w / K_a \\ &= 1.0 \times 10^{-14} / < 1.0 \times 10^{-14} \\ &> 1 \quad (\text{so } \text{HBO}_3^{2-} \text{ is a very strong base}) \end{aligned}$$

e) $\text{HCO}_3^{1-} (\text{aq})$

The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$\begin{aligned} K_a &= \frac{[\text{CO}_3^{2-}][\text{H}_3\text{O}^{1+}]}{[\text{HCO}_3^{1-}]} \\ &= 4.7 \times 10^{-11} \quad (\text{from table E.10 on page 597}) \end{aligned}$$

The K_b equation shows the ionization and dissociation of the base to form OH^- in water:



$$\begin{aligned} K_b &= \frac{[\text{HCO}_3^{1-}][\text{OH}^{1-}]}{[\text{CO}_3^{2-}]} \\ &= K_w / K_a \\ &= 1.0 \times 10^{-14} / 4.7 \times 10^{-11} \\ &= 2.1 \times 10^{-4} \end{aligned}$$

5. For each of the following bases:

- write the ionization reaction in water and the K_b expression
- write the ionization reaction for its conjugate acid and K_a expression
- calculate the value of K_a for the conjugate acid

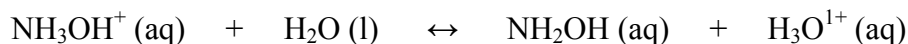
a) hydroxylamine

The K_b equation shows the ionization and dissociation of the base to form OH^- in water. Add a hydrogen ion (H^+) to the original compound:



$$\begin{aligned} K_b &= \frac{[\text{NH}_3\text{OH}^+][\text{OH}^{1-}]}{[\text{NH}_2\text{OH}]} \\ &= 8.8 \times 10^{-9} \quad (\text{from table E.11 on page 597}) \end{aligned}$$

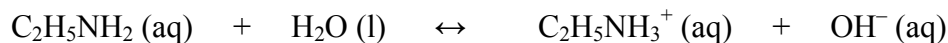
The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$\begin{aligned} K_a &= \frac{[\text{NH}_2\text{OH}][\text{H}_3\text{O}^{1+}]}{[\text{NH}_3\text{OH}^+]} \\ &= K_w / K_b \\ &= 1.0 \times 10^{-14} / 8.8 \times 10^{-9} \\ &= 1.1 \times 10^{-6} \end{aligned}$$

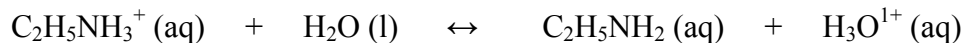
b) ethanamine

The K_b equation shows the ionization and dissociation of the base to form OH^- in water. Add a hydrogen ion (H^+) to the original compound:



$$\begin{aligned} K_b &= \frac{[\text{C}_2\text{H}_5\text{NH}_3^+][\text{OH}^{1-}]}{[\text{C}_2\text{H}_5\text{NH}_2]} \\ &= 4.5 \times 10^{-4} \quad (\text{from table E.11 on page 597}) \end{aligned}$$

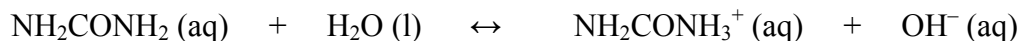
The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$\begin{aligned} K_a &= \frac{[\text{C}_2\text{H}_5\text{NH}_2][\text{H}_3\text{O}^{1+}]}{[\text{C}_2\text{H}_5\text{NH}_3^+]} \\ &= K_w / K_b \\ &= 1.0 \times 10^{-14} / 4.5 \times 10^{-4} \\ &= 2.2 \times 10^{-11} \end{aligned}$$

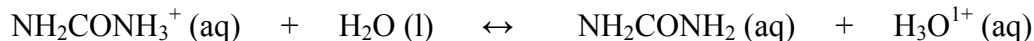
c) urea

The K_b equation shows the ionization and dissociation of the base to form OH^- in water. Add a hydrogen ion (H^+) to the original compound:



$$\begin{aligned} K_b &= \frac{[\text{NH}_2\text{CONH}_3^+][\text{OH}^{1-}]}{[\text{NH}_2\text{CONH}_2]} \\ &= 1.3 \times 10^{-14} \quad (\text{from table E.11 on page 597}) \end{aligned}$$

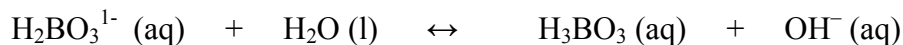
The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$\begin{aligned} K_a &= \frac{[\text{NH}_2\text{CONH}_2][\text{H}_3\text{O}^{1+}]}{[\text{NH}_2\text{CONH}_3^+]} \\ &= K_w / K_b \\ &= 1.0 \times 10^{-14} / 1.3 \times 10^{-14} \\ &= 0.77 \quad (\text{quite a strong acid}) \end{aligned}$$



The K_b equation shows the ionization and dissociation of the base to form OH^- in water. Add a hydrogen ion (H^+) to the original compound:



$$K_b = \frac{[\text{H}_3\text{BO}_3][\text{OH}^{1-}]}{[\text{H}_2\text{BO}_3^{1-}]}$$

We only know the K_a for $\text{H}_3\text{BO}_3 \text{ (aq)} = 5.4 \times 10^{-10}$ (from table E.10 on page 597), so we can calculate K_b using this value:

$$\begin{aligned} K_b &= K_w / K_a \\ &= 1.0 \times 10^{-14} / 5.4 \times 10^{-10} \\ &= 1.85 \times 10^{-5} \quad \text{or} \quad 1.9 \times 10^{-5} \text{ (2 sd)} \end{aligned}$$

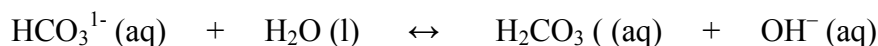
The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$\begin{aligned} K_a &= \frac{[\text{H}_2\text{BO}_3^{1-}][\text{H}_3\text{O}^{1+}]}{[\text{H}_3\text{BO}_3]} \\ &= 5.4 \times 10^{-10} \quad \text{(from table E.10 on page 597)} \end{aligned}$$



The K_b equation shows the ionization and dissociation of the base to form OH^- in water. Add a hydrogen ion (H^+) to the original compound:



$$K_b = \frac{[\text{H}_2\text{CO}_3][\text{OH}^{1-}]}{[\text{HCO}_3^{1-}]}$$

We only know the K_a for $\text{H}_2\text{CO}_3 \text{ (aq)} = 4.5 \times 10^{-7}$ (from table E.10 on page 597), so we can calculate K_b using this value:

$$\begin{aligned} K_b &= K_w / K_a \\ &= 1.0 \times 10^{-14} / 4.5 \times 10^{-7} \\ &= 2.2 \times 10^{-8} \end{aligned}$$

The K_a equation shows the ionization and dissociation of the acid to form H_3O^+ in water:



$$\begin{aligned} K_a &= \frac{[\text{HCO}_3^{1-}][\text{H}_3\text{O}^{1+}]}{[\text{H}_2\text{CO}_3]} \\ &= 4.5 \times 10^{-7} \quad \text{(from table E.10 on page 597)} \end{aligned}$$

6. Given the relationship $K_a \cdot K_b = K_w$, complete the following statements:

- a) If the K_a for an acid is large, the K_b for its conjugate base is: small
- b) If the K_a for an acid is small, the K_b for its conjugate base is: **large**
- c) If the K_b for a base is large, the K_a for its conjugate acid is: **small**
- d) If the K_b for a base is small, the K_a for its conjugate acid is: **large**