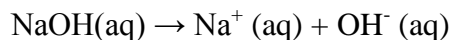


Chapter 15: 2, 6, 8, 10, 18, 26, 40, 52, 66, 72

15.2 Identify each substance as an acid or a base and write a chemical equation showing how it is an acid or a base according to the Arrhenius definition.

a. NaOH(aq)



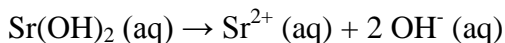
b. H₂SO₄ (aq)



c. HBr (aq)



d. Sr (OH)₂ (aq)



15.6 Write the formula for the conjugate acid of each base.

a. NH₃

b. ClO₄⁻

c. HSO₄⁻

d. CO₃²⁻

SOLUTION:

The conjugate acid is always just the base with a proton added.

e. NH₄⁺

f. HClO₄

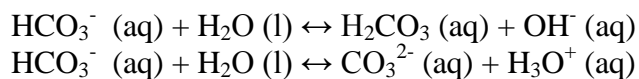
g. H₂SO₄

h. HCO₃⁻

15.8 HCO₃⁻ is amphoteric. Write equations that demonstrate both its acidic nature and its basic nature in aqueous solution.

SOLUTION:

If you are an acid in water, you give a proton to water. If you are a base in water, you get a proton from water.



15.10 Classify each acid as strong or weak. If the acid is weak, write an expression for the acid ionization constant (K_a)

- HF
- HCHO_2
- H_2SO_4
- H_2CO_3

SOLUTION:

The only strong acid in the list is H_2SO_4 . The other 3 are weak.

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{F}^-]}{[\text{HF}]}$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{CHO}_2^-]}{[\text{HCHO}_2]}$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]}$$

15.18 Calculate $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ for each solution.

- pH=8.55

$$\text{pOH} = 14 - \text{pH} = 14 - 8.55 = 5.45$$

So:

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

$$\text{pOH} = -\log[\text{OH}^-]$$

$$8.55 = -\log[\text{H}_3\text{O}^+]$$

$$[\text{H}_3\text{O}^+] = 10^{-8.55} = 2.82 \times 10^{-9}$$

$$5.45 = -\log[\text{OH}^-]$$

$$[\text{OH}^-] = 10^{-5.45} = 3.55 \times 10^{-6}$$

- pH=11.23

$$\text{pOH} = 14 - 11.23 = 2.77$$

$$11.23 = -\log[\text{H}_3\text{O}^+]$$

$$[H_3O^+] = 10^{-11.23} = 5.89 \times 10^{-12}$$

$$2.77 = -\log[OH^-]$$

$$[OH^-] = 10^{-2.77} = 1.70 \times 10^{-3}$$

- c. pH=2.87
pOH=14-2.87=11.13

$$2.87 = -\log[H_3O^+]$$

$$[H_3O^+] = 10^{-2.87} = 1.35 \times 10^{-3}$$

$$11.13 = -\log[OH^-]$$

$$[OH^-] = 10^{-11.13} = 7.41 \times 10^{-12}$$

15.26 Determine the pH of each solution.

- a. 0.028 M HI

HI is a strong acid, it completely dissociates.

$$pH = -\log(H_3O^+) = -\log(0.028) = 1.55$$

- b. 0.115 M HClO₄

Perchloric acid is a STRONG acid. It completely dissociates.

	HClO ₄ (aq)	+ H ₂ O (l)	↔	HClO ₃ ⁻ (aq)	+H ₃ O ⁺ (aq)
I	0.115 M	-		0	0
C	-0.115	-		+0.115	+0.115
E	0 M	-		0.115	0.115

$$pH = -\log(H_3O^+) = -\log(0.115) = 0.939$$

c. A solution that is 0.055 M in HClO₄ and 0.028 M in HCl

These are both strong acids. They both completely dissociate. They can be treated consecutively. First the perchloric acid dissociates:

	HClO ₄ (aq)	+ H ₂ O (l)	↔	HClO ₃ ⁻ (aq)	+H ₃ O ⁺ (aq)
I	0.055 M	-		0	0
C	-0.055	-		+0.055	+0.055
E	0 M	-		0.055	0.055

Then the HCl

	HCl (aq)	+ H ₂ O (l)	↔	Cl ⁻ (aq)	+H ₃ O ⁺ (aq)
I	0.028 M	-		0	0.055
C	-0.028	-		+0.028	+0.028
E	0 M	-		0.028	0.083

$$pH = -\log(H_3O^+) = -\log(0.083) = 1.08$$

d. A solution that is 1.85% HCl by mass. (Assume a density of 1.01 g/ml for the solution.)

HCl is a strong acid, it completely dissociates. But to get the pH, we need M not % by mass.

$$\frac{1.85 \text{ g HCl}}{100 \text{ g solution}} \frac{1 \text{ mol HCl}}{35.453 \text{ g HCl}} \frac{1.01 \text{ g HCl solution}}{1 \text{ mL solution}} \frac{1000 \text{ mL}}{1 \text{ L}} = 0.527 \text{ M HCl}$$

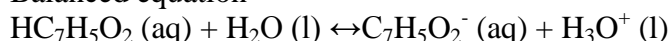
$$pH = -\log(H_3O^+) = -\log(0.527) = 0.278$$

15.40 Determine the percent ionization of a 0.225 M solution of benzoic acid.

SOLUTION: It's a weak acid, $K_a = 6.5 \times 10^{-5} M$.

Equilibrium problems have how many parts...? 1? 2? No, no, I'm pretty sure it's 3. 3 parts!

1. Balanced equation



2. Equilibrium constant expression

$$K_a = 6.5 \times 10^{-5} M = \frac{[\text{C}_7\text{H}_5\text{O}_2^-][\text{H}_3\text{O}^+]}{[\text{HC}_7\text{H}_5\text{O}_2]}$$

3. ICE chart

	$\text{HC}_7\text{H}_5\text{O}_2 (\text{aq})$	$+ \text{H}_2\text{O} (\text{l})$	\leftrightarrow	$\text{C}_7\text{H}_5\text{O}_2^- (\text{aq})$	$+ \text{H}_3\text{O}^+ (\text{aq})$
I	0.225 M	-		0	0
C	-x	-		+x	+x
E	0.225 - x	-		x	x

$$6.5 \times 10^{-5} M = \frac{[\text{C}_7\text{H}_5\text{O}_2^-][\text{H}_3\text{O}^+]}{[\text{HC}_7\text{H}_5\text{O}_2]} = \frac{(x)(x)}{(0.225 - x)}$$

Might as well try the assumption: $x \ll 0.225$

$$6.5 \times 10^{-5} M = \frac{(x)(x)}{(0.225)}$$

$$x^2 = 1.4625 \times 10^{-5}$$

$$x = 3.82 \times 10^{-3}$$

I check the assumption:

$$\frac{0.00382}{0.225} \times 100 = 1.7\% - \text{good assumption!}$$

	$\text{HC}_7\text{H}_5\text{O}_2 (\text{aq})$	$+ \text{H}_2\text{O} (\text{l})$	\leftrightarrow	$\text{C}_7\text{H}_5\text{O}_2^- (\text{aq})$	$+ \text{H}_3\text{O}^+ (\text{aq})$
I	0.225 M	-		0	0
C	-0.00382	-		+0.00382	+0.00382
E	0.221	-		0.00382	0.00382

Percent ionization is just what it sounds like: what percent of the original acid dissociated (ionized)?

$$\frac{0.00382 \text{ M ionization}}{0.225 \text{ M benzoic acid}} \times 100 = 1.7\% \text{ ionization}$$

15.52 For each strong base solution, determine $[\text{OH}^-]$, $[\text{H}_3\text{O}^+]$, pH, and pOH

- $8.77 \times 10^{-3} \text{ M LiOH}$
- $0.0112 \text{ M Ba(OH)}_2$
- $1.9 \times 10^{-4} \text{ M KOH}$
- $5.0 \times 10^{-4} \text{ M Ca(OH)}_2$

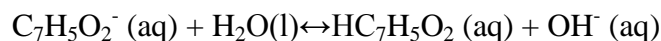
SOLUTION:

Since these are all strong bases, it takes all the equilibrium fun out of it. They each completely dissociate.

- $8.77 \times 10^{-3} \text{ M}$ will create $8.77 \times 10^{-3} \text{ M OH}^-$ ions.
 $\text{pOH} = -\log(\text{OH}^-) = -\log(8.77 \times 10^{-3}) = 0.826$
 $\text{pH} = 14 - \text{pOH} = 14 - 0.826 = 13.17$
 $[\text{H}_3\text{O}^+] = 10^{-13.17} = 6.76 \times 10^{-14} \text{ M}$
- $0.0112 \text{ M Ba(OH)}_2 \frac{2 \text{ mol OH}^-}{1 \text{ mol Ba(OH)}_2} = 0.0224 \text{ M OH}^-$
 $\text{pOH} = -\log(\text{OH}^-) = -\log(0.0224) = 1.64$
 $\text{pH} = 14 - \text{pOH} = 14 - 1.64 = 12.36$
 $[\text{H}_3\text{O}^+] = 10^{-12.36} = 4.37 \times 10^{-13} \text{ M}$
- $1.9 \times 10^{-4} \text{ M KOH}$ will create $1.9 \times 10^{-4} \text{ M OH}^-$
 $\text{pOH} = -\log(\text{OH}^-) = -\log(1.9 \times 10^{-4}) = 3.72$
 $\text{pH} = 14 - \text{pOH} = 14 - 3.72 = 10.28$
 $[\text{H}_3\text{O}^+] = 10^{-10.28} = 5.25 \times 10^{-11} \text{ M}$
- $5.0 \times 10^{-4} \text{ M Ca(OH)}_2 \frac{2 \text{ mol OH}^-}{1 \text{ mol Ca(OH)}_2} = 1.0 \times 10^{-3} \text{ M OH}^-$
 $\text{pOH} = -\log(\text{OH}^-) = -\log(0.0010) = 3$
 $\text{pH} = 14 - \text{pOH} = 14 - 3 = 11$
 $[\text{H}_3\text{O}^+] = 10^{-11} = 1.0 \times 10^{-11} \text{ M}$

15.66 Classify each anion as basic or neutral. For the anions that are basic, write an equation that shows how the anion acts as a base.

- $\text{C}_7\text{H}_5\text{O}_2^-$
 Conjugate base of a weak acid (benzoic), so it is basic.



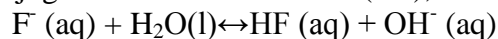
- I^-
 Conjugate base of a weak acid (HI), so it is basic.
 $\text{I}^- (\text{aq}) + \text{H}_2\text{O}(\text{l}) \leftrightarrow \text{HI} (\text{aq}) + \text{OH}^- (\text{aq})$

c. NO_3^-

Conjugate base of a strong acid (HNO_3) so it is neutral.

d. F^-

Conjugate base of a weak acid (HF), so it is basic.



15.72 Determine whether each salt will form a solution that is acidic, basic, or pH-neutral.

a. $\text{Al}(\text{NO}_3)_3$

Al^{3+} is the conjugate acid of $\text{Al}(\text{OH})_3$ – a weak base

NO_3^- is the conjugate base of HNO_3 – a strong acid

The NO_3^- will do nothing, so the solution will be acidic due to the Al^{3+}

b. $\text{C}_2\text{H}_5\text{NH}_3\text{NO}_3$

$\text{C}_2\text{H}_5\text{NH}_3^+$ is the conjugate acid of ethylamine – a weak base

NO_3^- is the conjugate base of HNO_3 – a strong acid

The NO_3^- will do nothing, so the solution will be acidic due to the ethylamine

c. K_2CO_3

K^+ is the conjugate of a strong base (KOH) so we ignore it.

CO_3^{2-} is the conjugate of a weak acid (H_2CO_3) so the solution will be basic.

e. RbI

Rb^+ is the conjugate of a strong base (RbOH) so we ignore it.

I^- is the conjugate of a strong acid (HI), so we ignore it.

The resulting solution will, as a result, be pH-neutral.

f. NH_4ClO

NH_4^+ is the conjugate acid of a weak base, NH_3 , $K_b = 1.76 \times 10^{-5}$

ClO^- is the conjugate base of a weak acid, HClO , $K_a = 2.9 \times 10^{-8}$

If you calculate the corresponding K_a of NH_4^+ $K_a = \frac{1 \times 10^{-14}}{1.76 \times 10^{-5}} = 5.68 \times 10^{-10}$

And the K_b of ClO^- + $K_b = \frac{1 \times 10^{-14}}{2.9 \times 10^{-8}} = 3.45 \times 10^{-7}$

You can see that ClO^- is a better base than NH_4^+ is an acid. The resulting solution should be basic.