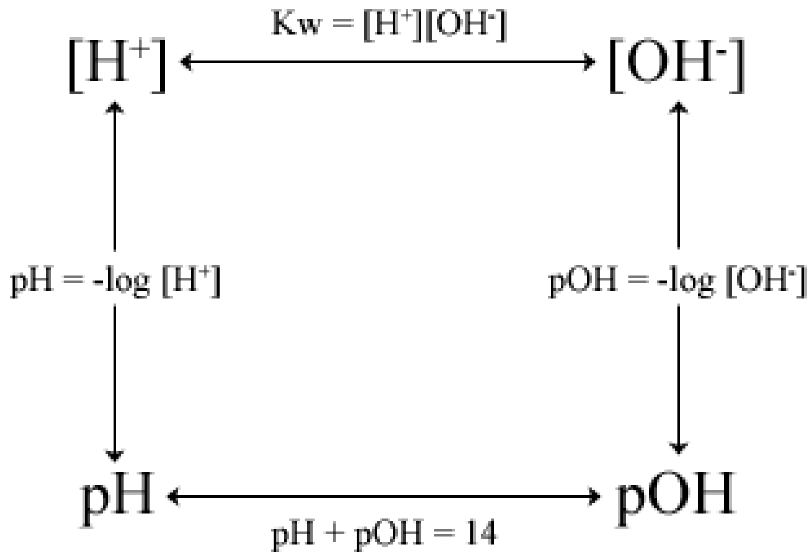
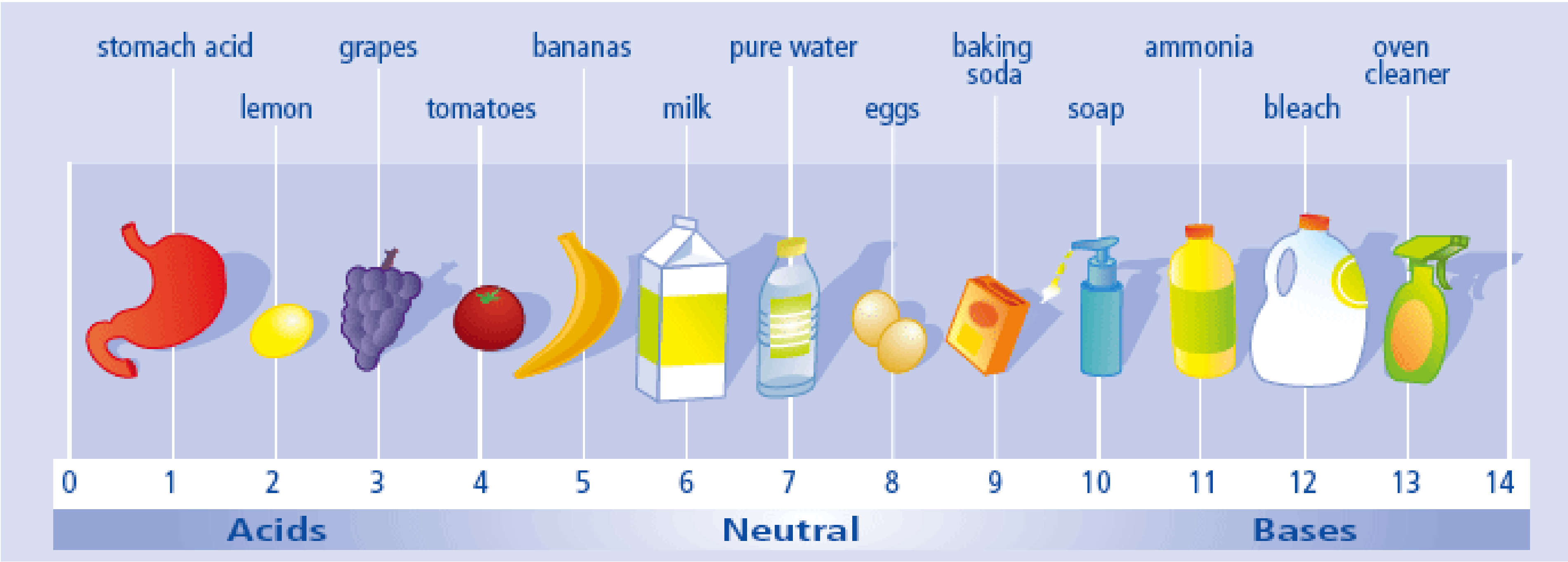


Unit 10: Acids and Bases



PROPERTIES OF ACIDS & BASES

H^+

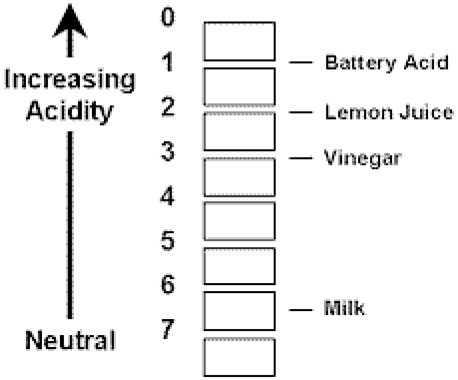
OH^-

Properties of an Acid: a substance which **dissociates** (ionizes, breaks apart in solution) in water to form **hydrogen ions**

Tastes sour

Turns blue litmus paper red

Electrolytes



Has a pH of less than 7

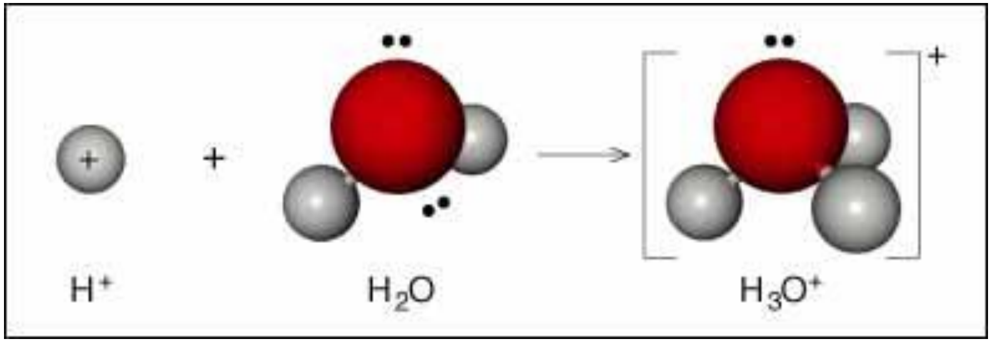
Produce hydrogen gas When they react with Metals

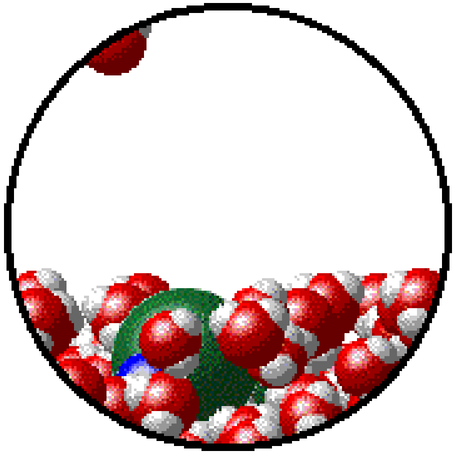
Acids dissociate in water to generates **[H_3O^+]** in solution

– can also be depicted as a **[H^+]**

– [H^+] known as a hydrogen ion or a proton

$$HCl(aq) + H_2O \rightarrow H_3O^+(aq) + Cl^-(aq)$$

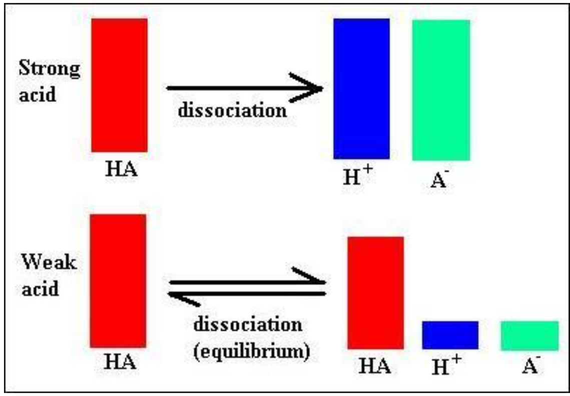




How do we classify as acid as weak or strong?

- We look at the degree to which they ionize in water.
  - Strong acids completely ionize:

    HCl, HBr, HI, HNO_3, H_2SO_4 and $HClO_4$
  - Weak acids only partially ionize
  - Look at K_a values to determine degree of dissociation



No.	Acid	K_a	pK_a
1	Hydroiodic acid (HI)	$3.16x10^9$	-9.5
2	Hydrobromic acid (HBr)	$1.0x10^9$	-9
3	Hydrochloric acid (HCl)	$1.0x10^6$	-6
4	Sulfuric acid (H_2SO_4)	$1.0x10^3$	-3
5	Hydronium ion (H_3O^+)	55	-1.74
6	Nitric acid (HNO_3)	28.2	-1.45
7	Trifluoroacetic acid (CF_3COOH)	$5.62x10^{-1}$	0.25
8	Oxalic acid (HOOC–COOH)	$5.37x10^{-2}$	1.27
9	Acetic acid (CH_3COOH)	$1.75x10^{-5}$	4.76

Strong Acids		HCl, HBr, HI, HNO_3, $HClO_3$, $HClO_4$, H_2SO_4
HCl	Hydrochloric	Strong, reacts quickly with tissue, found in stomach acid, used in fertilizer and explosives. Sometimes called muriatic acid.
H_2SO_4	Sulfuric	Strong, more damaging to tissue and clothing than HCl, gets hot when diluted. Gives up 1st hydrogen easily as a strong acid, gives up 2nd hydrogen as a weak acid.
HNO_3	Nitric	Strong, reacts quickly with tissue, used for fertilizer and explosives manufacturing. Reacts with many metals to form NO_2, a common component of city smog.
H_3PO_4	Phosphoric	Weak, even though it can give up to 3 H^+'s, it doesn't give them up easily. It dissociates poorly.
H_2CO_3	Carbonic	Weak, soft drink acid, easily decomposes into water and CO_2. H_2CO_3 $H_2O + CO_2$
$HC_2H_3O_2$ Or CH_3COOH	Acetic Acid	Weak. Vinegar is 5% acetic acid. Used to make plastics. An organic acid – the 2nd formula given to the left is the "organic" way to write the formula. The bolded hydrogen is the one that is released when it dissociates.

Monoprotic Acids – acids that only donate one hydrogen when they dissociate. Ex: HCl, HNO_3, $\mathbf{H}C_2H_3O_2$.

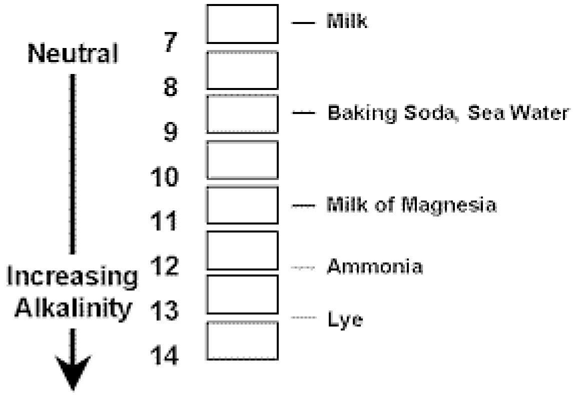
Polyprotic Acids – acids that give up more than one hydrogen. Typically the 1st dissociation is "strong" and the 2nd dissociation is "weak.

Properties of a Base (alkalis): a substance which dissolves in water to form hydroxide ions (OH^-).

Taste bitter and have a slippery feel

Turns red litmus paper **blue**

Electrolytes



Has a pH greater than 7

What's the Difference Between **Caustic** and **Corrosive**?

Neutralization

Chemical reaction between an acid and a base.

Products are a salt (ionic compound) and water.

ACID + BASE → SALT + WATER

What salt is produced?

$$\mathbf{HCl + NaOH \rightarrow NaCl + H_2O}$$

strong strong neutral

- Write out the balanced equation for the neutralization reaction between sulfuric acid and sodium hydroxide.

- Phosphoric acid and potassium hydroxide

- Ammonia and hydrochloric acid

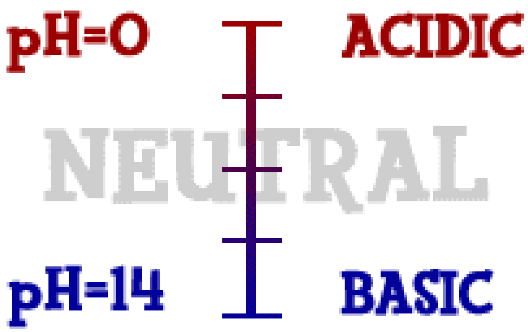
Neutralization

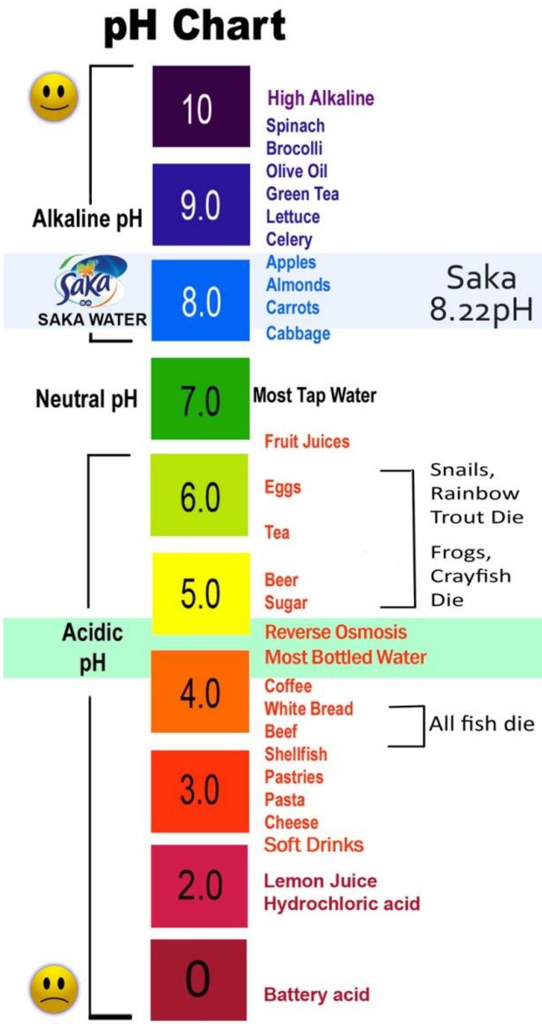
Salts can be neutral, acidic, or basic.

Neutralization does not mean pH = 7.

$$HC_2H_3O_2 + NaOH \rightarrow NaC_2H_3O_2 + H_2O$$

weak strong ?





So…

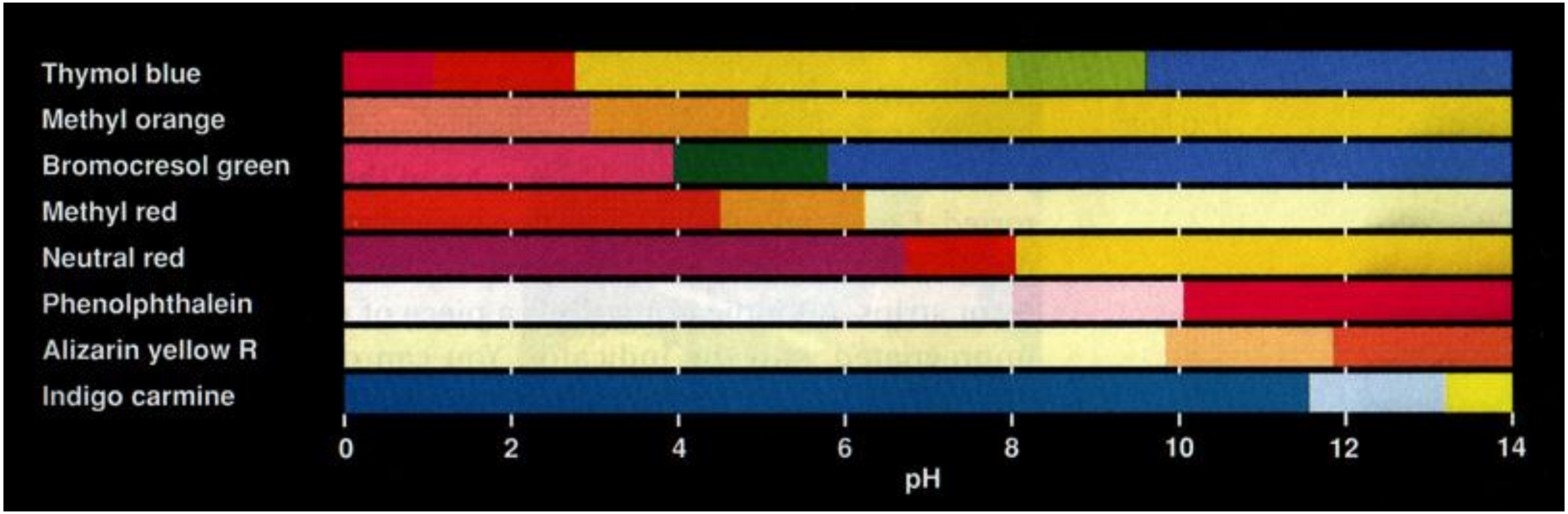
Orange juice, with a pH of 3 has 10 times as much free H^+ as tomato juice with a pH of 4

Lemon juice, with a pH of 2 has _______ times as many H^+ as black coffee with a pH of 5

Indicators

These are chemicals that change color in the presence of an acid or a base.

There are a number of different indicators that change color at different pH's.



Methyl orange

Bromthymol blue

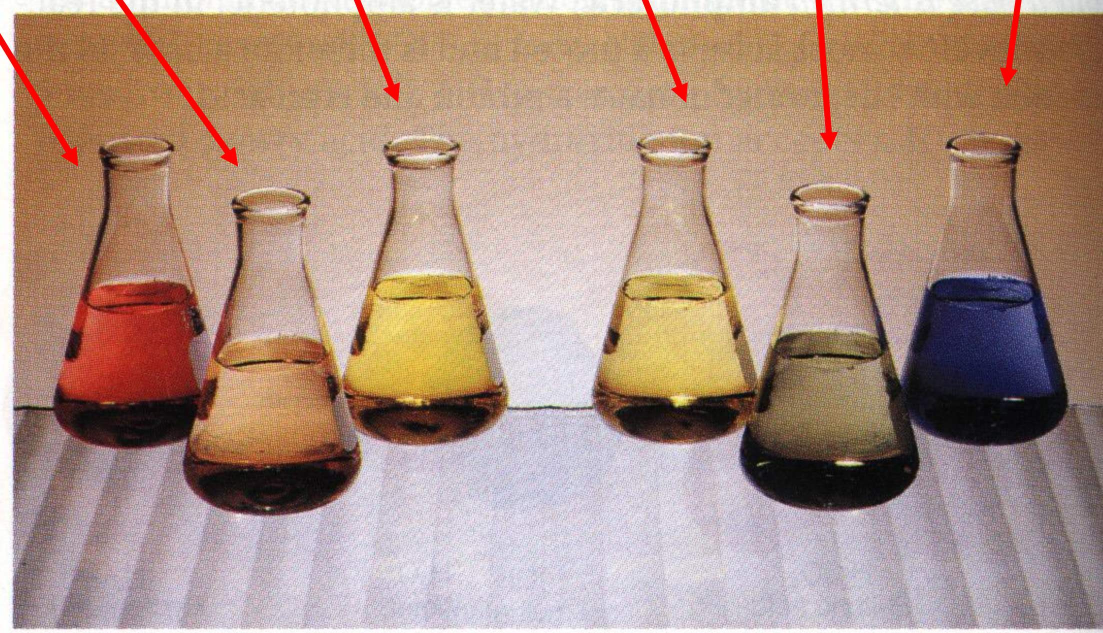


Figure 19.11 Acid-base indicators respond to pH changes over a specific range. Methyl orange (left group) is shown at pH 2, 4, and 6 (left to right). Bromthymol blue (right group) is shown at pH 5, 7, and 9.

Theories of acids and bases

Arrhenius Acid - compounds that **contain hydrogen** and can dissolve in water to release hydrogen

$HCl \rightarrow H^+ (aq) + Cl^- (aq)$

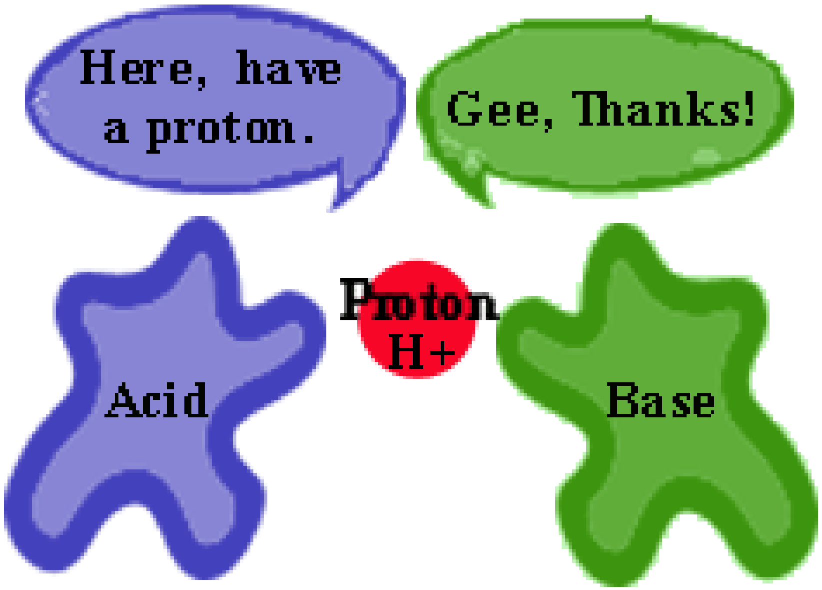
Arrhenius Base- compounds that **contain hydroxide** and can dissolve in water to release hydroxide

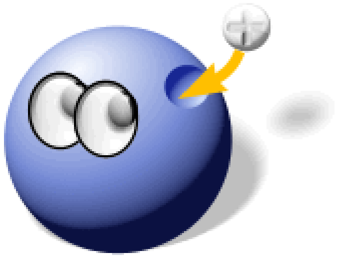
$NaOH \rightarrow Na^+ (aq) + OH^- (aq)$

Bronsted-Lowry Definition

Acid - any substance that can donate a hydrogen ion (proton)

Base-any substance that can accept a hydrogen ion (proton).



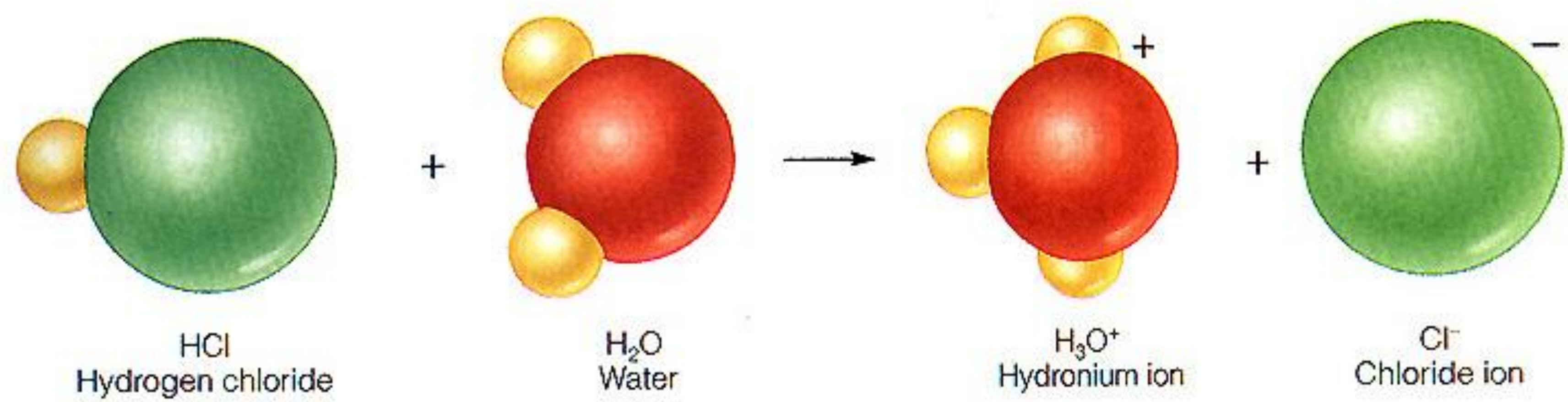


Bronsted-Lowry Definition

Acids are proton (H^+) donors

Bases are proton (H^+) acceptors

$$\underset{\text{acid}}{HA_{(aq)}} + \underset{\text{base}}{H_2O_{(l)}} \Leftrightarrow H_3O^+_{(aq)} + A^-_{(aq)}$$



Bronsted-Lowry Definition

The acid on one side reacts to become the base on the other side.

$$HCl + NH_3 \rightarrow NH_4^+ + Cl^-$$

HCl	NH_3	NH_4^+	Cl^-
Acid 1	Base 1	Acid 2	Base 2
Donor	**(Acceptor)**	**Donor**	**(Acceptor)**
		CA	**CB**

Acid 1 (HCl) and Base 2 (Cl^-) are conjugate pairs

Acid 2 (NH_4^+) and Base 1 (NH_3) are also conjugate pairs

The only difference between and acid and its conjugate base is a proton (H+).

Bronsted-Lowry Definition

What are the acid/base pairs in these equations?

$HBr_{(aq)}$ +	$H_2O_{(l)}$ ⇔	$H_3O^+_{(aq)}$ +	$Br^-_{(aq)}$
acid	**base**	**Conjugate acid**	**Conjugate base**
$NH_{3\,(aq)}$ +	$H_2O_{(l)}$ ⇔	$NH_4^+_{(aq)}$ +	$OH^-_{(aq)}$
base	**acid**	**Conjugate acid**	**Conjugate base**

Water can act as either an acid or a base…it's called amphoteric

Bronsted-Lowry Definition

Label the acid/base pairs.

$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$

$HSO_3^- + H_2O \rightarrow H_2SO_3 + OH^-$

$OH^- + HC_2H_3O_2 \rightarrow H_2O + C_2H_3O_2$

Bronsted-Lowry Definition

Practice

Write the conjugate base for the following acids:

a. $HClO_4$ ClO_4^-

b. H_3PO_4 $H_2PO_4^-$

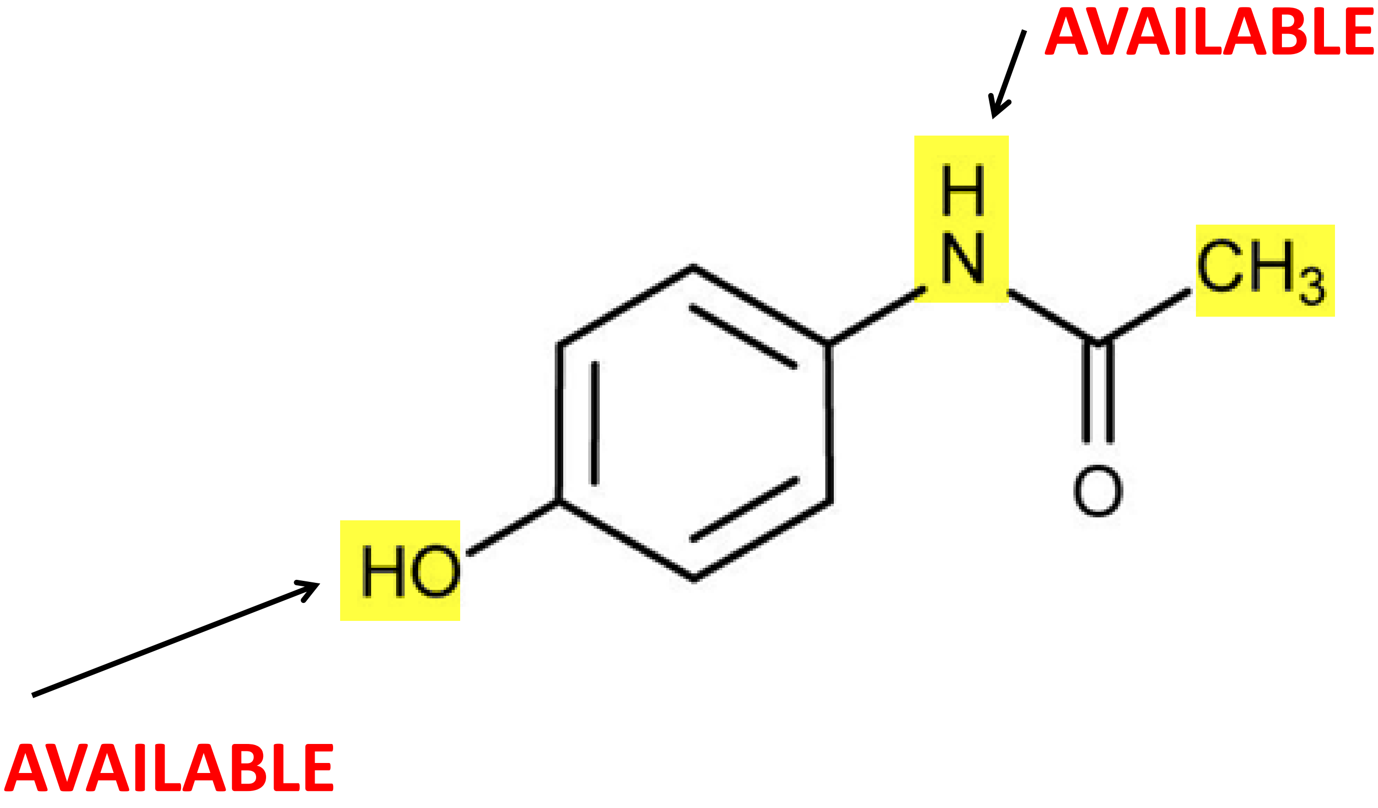
c. $CH_3NH_3^+$ CH_3NH_2

Write the conjugate acid for the following bases:

d. CN^- HCN

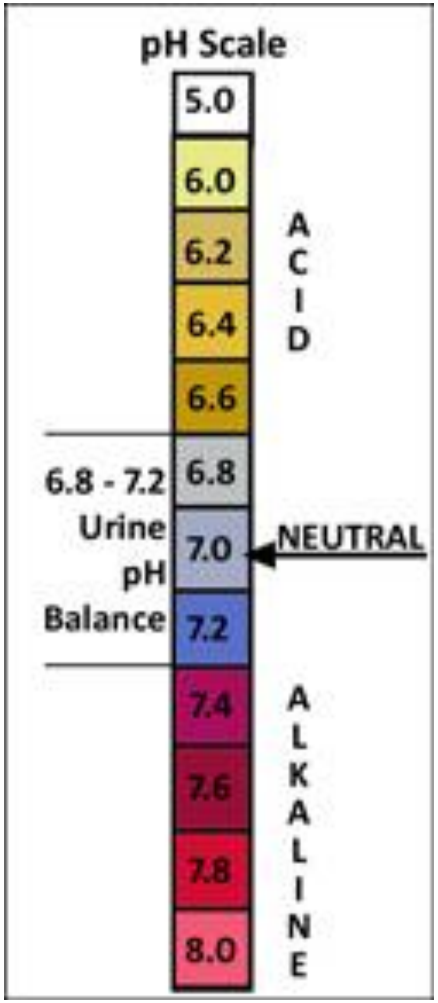
e. H_2O H_3O^+

Which of the highlighted atoms or group of atoms makes acetaminophen a **Brønsted-Lowry** acid? Why?



Calculating pH and pOH

pH scale



We measure the strength of acids and bases using the pH scale.

pH = power of hydrogen

Each change on the pH scale is a power of ten.

pH scale goes from 0 to 14

0 to 7 – acid

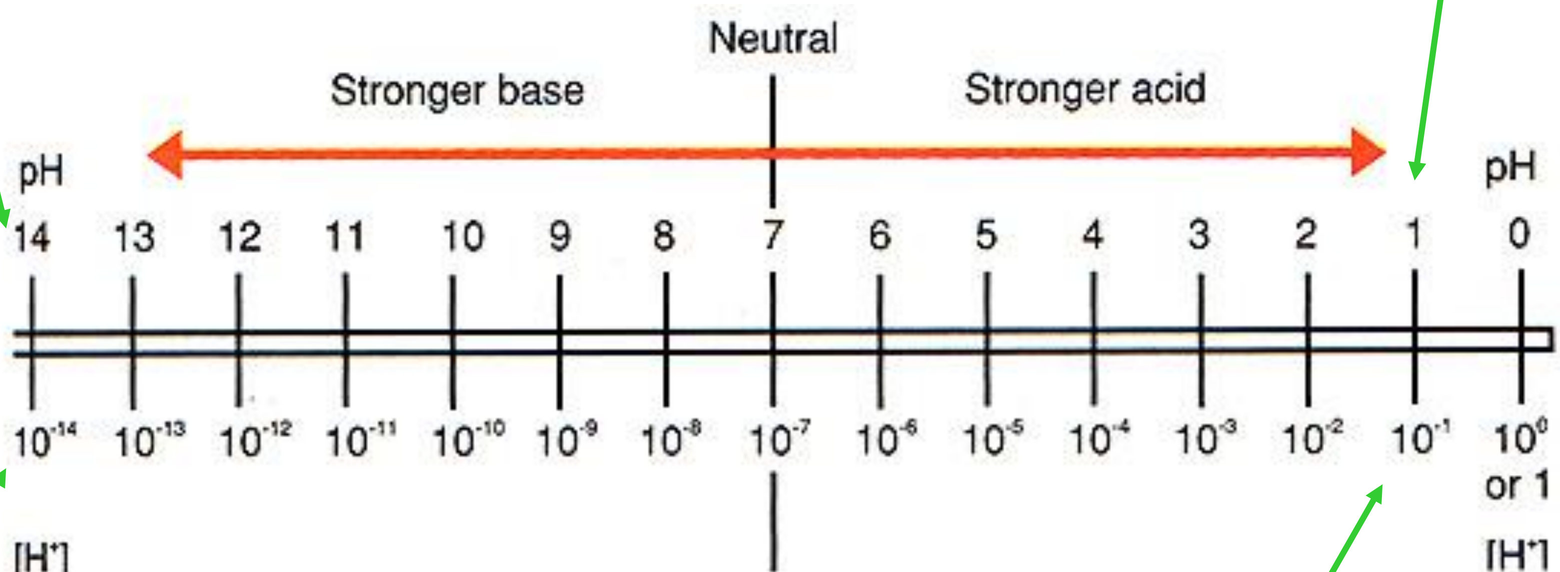
7 – neutral

7 to 14 - base

The pH Scale

pH = -log [H$^+$] = 14

pH = -log [H$^+$] = 1



[H$^+$] = 1 × 10 $^{-14}$

= 0.00000000000001 mol L^{-1}

[H$^+$] = 1 × 10 $^{-1}$

= 0.1 mol L^{-1}

You can convert the concentrations of [H^+] and [OH^-] in solutions in terms of **pH** and **pOH**

$pH = -\log[H^+]$

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

$pH + pOH = 14$

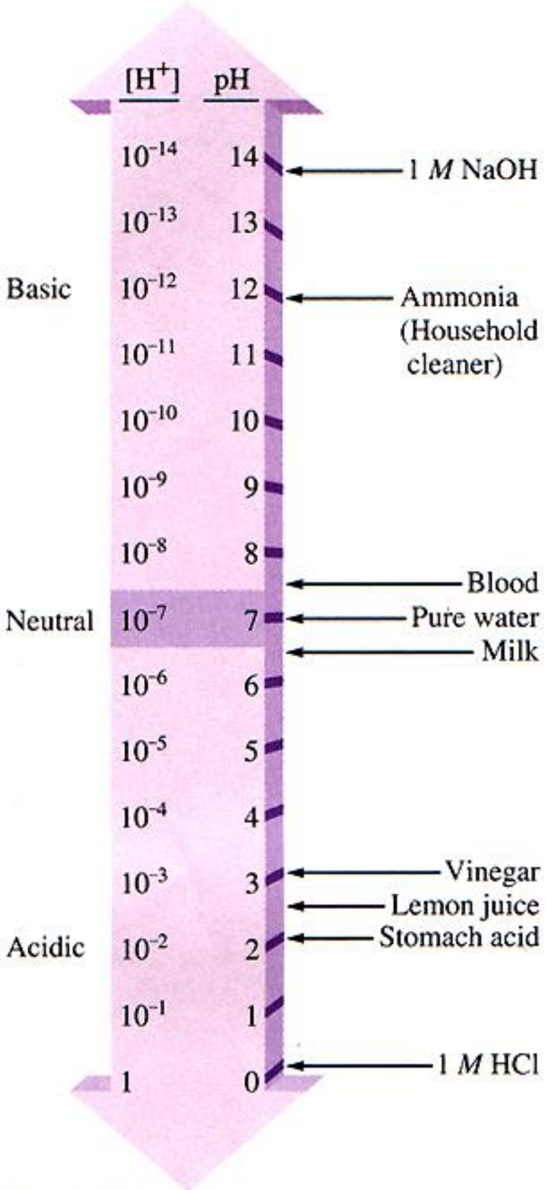


Figure 14.3
The pH scale and pH values of some common substances.

Calculating the pH using a calculator:

1. What is the pH of a solution where $[H^+] = 1.0 \times 10^{-4}$

Step 1: Push the **-** key	-
Step 2: Push the **log** key	- log
Step 3: Enter the number	- log (1.0 E -4)

pH = 4.00

Find the pH:
[H+] = 3.5 x 10-3 M

[H+] = 5.5 x 10-14 M

Table 20.2

Relationship among $[H^+]$, $[OH^-]$, and pH

	$[H^+]$ (mol/L)	$[OH^-]$ (mol/L)	pH	Aqueous system
Increasing acidity ↑	1×10^{0}	1×10^{-14}	0.0	$1\,M$ HCl
	1×10^{-1}	1×10^{-13}	1.0	$0.1\,M$ HCl; Gastric juice
	1×10^{-2}	1×10^{-12}	2.0	Lemon juice
	1×10^{-3}	1×10^{-11}	3.0	
	1×10^{-4}	1×10^{-10}	4.0	Tomato juice
	1×10^{-5}	1×10^{-9}	5.0	Black coffee
	1×10^{-6}	1×10^{-8}	6.0	Milk
Neutral	1×10^{-7}	1×10^{-7}	7.0	Pure water; Blood
Increasing basicity ↓	1×10^{-8}	1×10^{-6}	8.0	Sodium hydrogen carbonate, sea water
	1×10^{-9}	1×10^{-5}	9.0	
	1×10^{-10}	1×10^{-4}	10.0	Milk of magnesia
	1×10^{-11}	1×10^{-3}	11.0	Household ammonia
	1×10^{-12}	1×10^{-2}	12.0	Washing soda
	1×10^{-13}	1×10^{-1}	13.0	$0.1\,M$ NaOH
	1×10^{-14}	1×10^{0}	14.0	$1\,M$ NaOH

You can convert the concentrations of $[H^+]$ and $[OH^-]$ in solutions in terms of **pH** and **pOH**

$$pH = -\log[H^+]$$

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

$$pH + pOH = 14$$

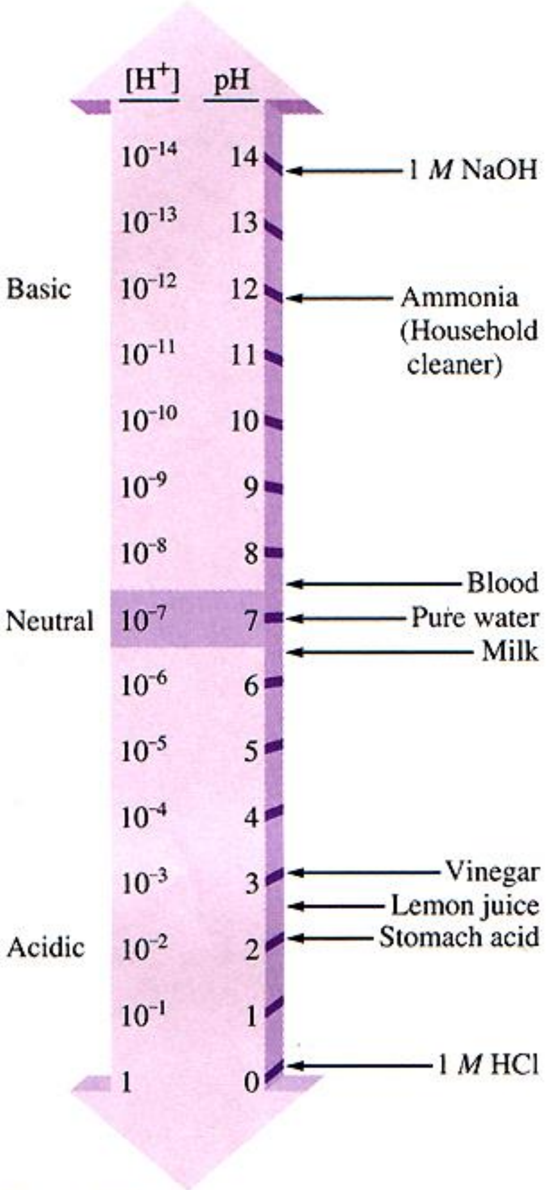


Figure 14.3
The pH scale and pH values of some common substances.

Calculating the pOH using a calculator:

What is the pOH of a solution where $[OH^-] = 3.4 \times 10^{-4}$

Find the pOH:
$[OH-] = 6.7 \times 10^{-13}$ M

$[OH-] = 5.5 \times 10^{-2}$ M

Calculating $[H^+]$ and $[OH^-]$ from pH and pOH

What is the $[H^+]$ of a solution with a pH of 6.7?

Step 1: Push the **inv log** key (2nd log) 10^

Step 2: Push the **-** key 10^-

Step 3: Enter the pH 10^- 6.7

$[H^+] = 2.0 \times 10^{-7}$

pOH = 2.5 [OH-]=?

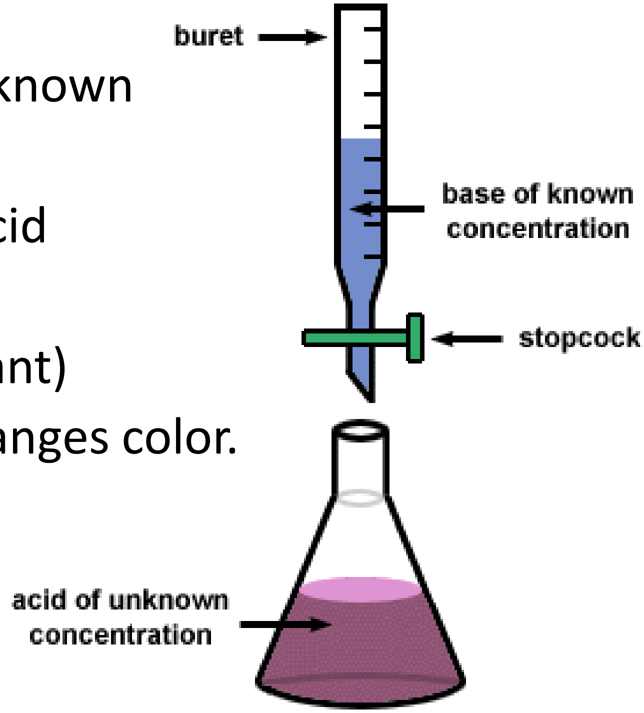
pH = 9.9 [H+] =?

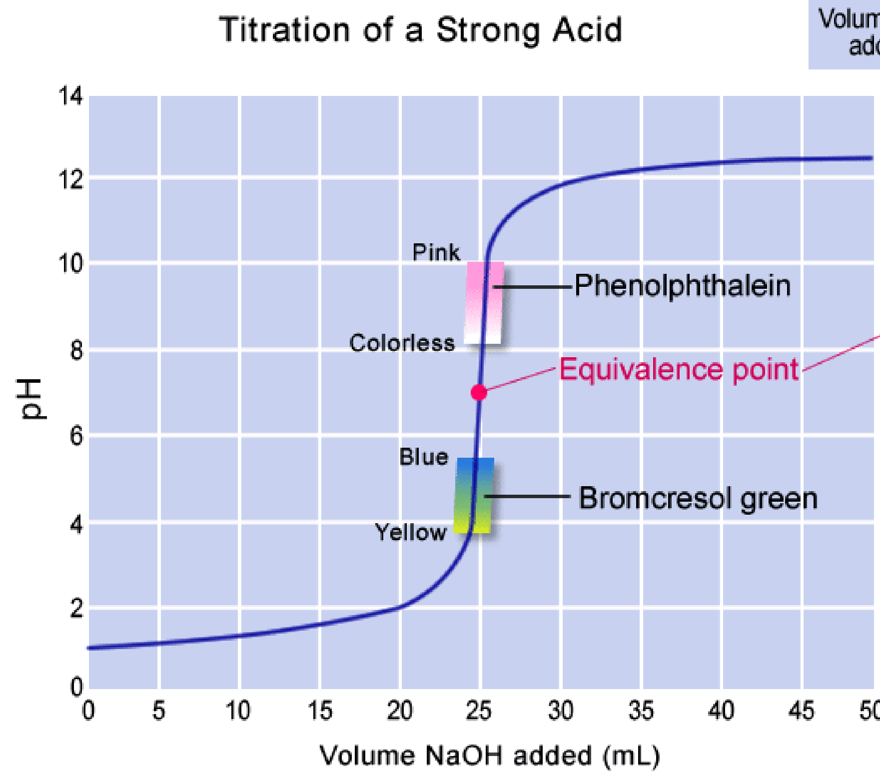
$[H^+]$	pH	$[OH^-]$	pOH
2.09×10^{-3}			
	8.00		
		9.0×10^{-3}	
			5.67
			12.9
4.98×10^{-12}			
		6.799×10^{-9}	
	7.9		
	13.85		

Titrations

- Using a neutralization reaction to determine the concentration of an acid or base.
  - Steps for titration:

1. Have a measured volume of acid of unknown concentration in flask (analyte).
2. Add several drops of indicator to the acid and swirl gently.
3. Add base of known concentration (titrant) dropwise into acid until indicator barely changes color.
4. The indicator changes color at the end point of the titration (should coincide with equivalence point).





Volume NaOH added (mL)	pH
0	1.00
5	1.18
10	1.37
15	1.60
20	1.95
21	2.06
22	2.20
23	2.38
24	2.69
25	**7.00**
26	11.29
27	11.59
28	11.75
29	11.87
30	11.96
35	12.22
40	12.36
45	12.46
50	12.52

In a titration, 33.21 mL of 0.3020 M rubidium hydroxide solution is required to exactly neutralize 20.00 mL of hydrofluoric acid solution. What is the molarity of the hydrofluoric acid solution?

A 35.00 mL sample of NaOH solution is titrated to an endpoint by 4.76 mL of 0.4122 M HBr solution. What is the molarity of the NaOH solution?