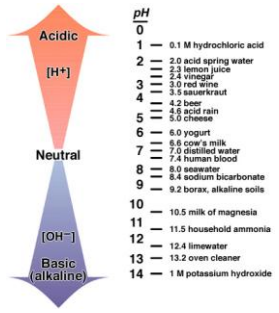
Unit 10 Acids, Bases and Salts



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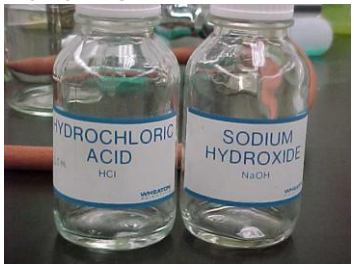
Behavior of many acids and bases can be explained by the Arrhenius theory.

Arrhenius acids and bases are electrolytes.



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An electrolyte is a substance which, when dissolved in water, forms a solution capable of conducting an electric current. The ability of a solution to conduct an electric current depends on the concentration of ions.

Properties of Acids and Bases

- Acids
  - Dissolve in water
  - Electrolytes
  - Taste sour
  - Neutralize bases
  - React with active metals to from hydrogen gas (H_2)
  - Have a pH less than 7
  - Turn blue litmus red
- Bases
  - Dissolve in water
  - Electrolytes
  - Taste Bitter
  - Neutralize acids
  - Emulsify fats and oils
  - Feel slippery
  - Have a pH more than 7
  - Turn red litmus blue

5

Regents Question: 01/03 #30

Which species can conduct an electric current?

(1) NaOH(s) — NaOH would conduct electricity if it was dissolved in water, not as a solid.

(2) CH_3OH(aq) — CH_3OH is an alcohol, a non-electrolyte

(3) H_2O(s) — Water is a non-electrolyte, even as a liquid.

☑ (4) HCl(aq) — HCl(aq), hydrochloric acid is an electrolyte.

6

Regents Question: 06/03 #29

Which 0.1 M solution contains an electrolyte?

(1) $C_6H_{12}O_6$ (aq)

☑ (2) CH_3COOH(aq)

(3) CH_3OH(aq)

(4) CH_3OCH_3 (aq)

7

Arrhenius acids yield H^+ (aq), hydrogen ion as the only positive ion in an aqueous solution.

The hydrogen ion may also be written as H_3O^+ (aq), hydronium ion.

8

Regents Question: 06/03 #31

An Arrhenius acid has

(1) only hydroxide ions in solution

(2) only hydrogen ions in solution

☑ (3) hydrogen ions as the only positive ions in solution

(4) hydrogen ions as the only negative ions in solution

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Regents Question: 08/02 #25

Which substance is an Arrhenius acid?

(1) LiF(aq)

☑ (2) HBr(aq)

(3) $Mg(OH)_2$ (aq)

(4) CH_3CHO

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Table K lists the names and formulas of some common acids.

Acids start with H

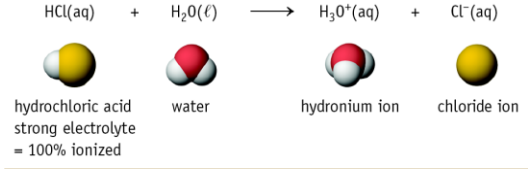
Table K
Common Acids

Formula	Name
HCl(aq)	hydrochloric acid
HNO_3(aq)	nitric acid
H_2SO_4(aq)	sulfuric acid
H_3PO_4(aq)	phosphoric acid
H_2CO_3(aq) or CO_2(aq)	carbonic acid
CH_3COOH(aq) or $HC_2H_3O_2$(aq)	ethanoic acid (acetic acid)

An organic chemist would write the formula for acetic acid this way.

A physical chemist would write the formula for acetic acid this way.

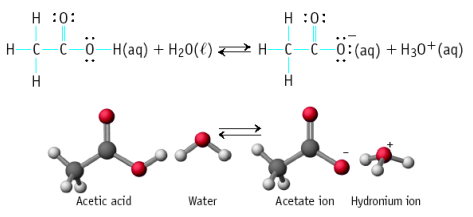
The strength of an acid (or base) is determined by the amount of IONIZATION.



HNO_3, HCl, HBr, HI, H_2SO_4 and $HClO_4$ are the strong acids.

Weak acids are much less than 100% ionized in water.

*One of the best known is acetic acid = CH_3CO_2H



Strong and Weak Acids

Table K
Common Acids

	Formula	Name
Strong acids	$HCl(aq)$	hydrochloric acid
	$HNO_3(aq)$	nitric acid
	$H_2SO_4(aq)$	sulfuric acid
	$H_3PO_4(aq)$	phosphoric acid
Weak acids	$H_2CO_3(aq)$ or $CO_2(aq)$	carbonic acid
	$CH_3COOH(aq)$ or $HC_2H_3O_2(aq)$	ethanoic acid (acetic acid)

Arrhenius bases yield $OH^-(aq)$, hydroxide ion as the only negative ion in an aqueous solution. (3.1ww)

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Regents Question: 06/02 #26

Which ion is produced when an Arrhenius base is dissolved in water?

(1) H^+ , as the only positive ion in solution

(2) H_3O^+ , as the only positive ion in solution

☑ (3) OH^- , as the only negative ion in solution

(4) H^- , as the only negative ion in solution

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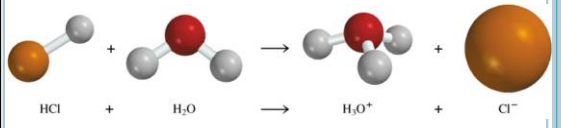
Acid/Base definitions

Definition 1: Arrhenius

Arrhenius acid is a substance that produces H^+ (H_3O^+) in water



Arrhenius base is a substance that produces OH^- in water

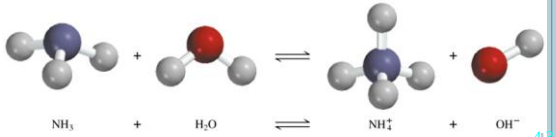


Table L lists the names and formulas of some common bases.

Table L
Common Bases

Formula	Name
$NaOH(aq)$	sodium hydroxide
$KOH(aq)$	potassium hydroxide
$Ca(OH)_2(aq)$	calcium hydroxide
$NH_3(aq)$	aqueous ammonia

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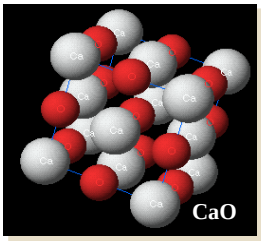
Strong Bases

Strong Base: dissociate 100% in water

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



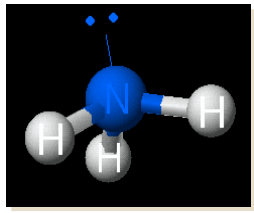
Other common strong bases include KOH and $Ca(OH)_2$.

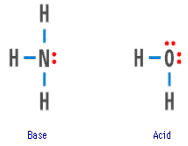
Weak Bases

Weak base: less than 100% ionized in water

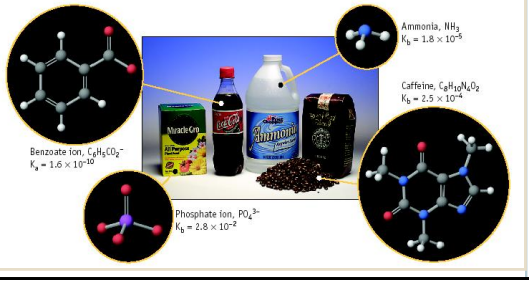
One of the best known weak bases is ammonia

$NH_3\ (aq) + H_2O\ (l) \leftrightarrow NH_4^+\ (aq) + OH^-$





Weak Bases



Ammonia is a base.

When it dissolves in water, it produces hydroxide ions.

$$NH_3(g) + H_2O(l) \longrightarrow NH_4^+(aq) + OH^-(aq)$$

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In the process of neutralization, an Arrhenius acid and an Arrhenius base react to form a salt and water.

The Nonmetal from the acid combines with the metal from the base to make a salt.

The H+ from the acid combines with the OH- from the base to make water (HOH = H_2O).

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + HOH$$

$$H_2SO_4(aq) + Ca(OH)_2(aq) \longrightarrow CaSO_4(aq) + 2H_2O$$

Acid + Base ⟶ Salt + Water

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Regents Question: 06/02 #25

Given the reaction:

$HCl(aq) + LiOH(aq) \longrightarrow HOH(l) + LiCl(aq)$

The reaction is best described as

☑ (1) neutralization

(2) synthesis

(3) decomposition

(4) oxidation-reduction

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Regents Question: 06/03 #30

Which equation represents a neutralization reaction?

(1) $Na_2CO_3 + CaCl_2 \longrightarrow 2\ NaCl + CaCO_3$

(2) $Ni(NO_3)_2 + H_2S \longrightarrow NiS + 2HNO_3$

(3) $NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$

☑ (4) $H_2SO_4 + Mg(OH)_2 \longrightarrow MgSO_4 + 2\ H_2O$

25

Titration is a laboratory process in which a volume of solution of known concentration is used to determine the concentration of another solution. (3.1zz)

$$M_aV_a = M_bV_b$$

Ma = Molarity of H^+ Mb = Molarity of OH^-

Va = Volume of Acid Vb = Volume of Base

At the equivalence point, the moles of H^+ equals the moles of OH^-

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Regents Question: 08/02 #45

When 50. milliliters of an HNO_3 solution is exactly neutralized by 150 milliliters of a 0.50 M solution of KOH, what is the concentration of HNO_3 ?

(1) 1.0 M

☑ (2) 1.5 M

(3) 3.0 M

(4) 0.5 M

Use $M_aV_a=M_bV_b$

$M_a=X$

$V_a=50.\ mL$

$M_b=0.50M$

$V_b=150\ mL$

27

Regents Question: 06/02 #45

If 5.0 milliliters of a 0.20 M HCl solution is required to neutralize exactly 10. milliliters of NaOH, what is the concentration of the base?

☑ (1) 0.10 M

(2) 0.20 M

(3) 0.30 M

(4) 0.40 M

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Regents Question: 01/03 #71

A titration setup was used to determine the unknown molar concentration of a solution of NaOH. A 1.2 M HCl solution was used as the titration standard. The following data were collected.

	Trial 1	Trial 2	Trial 3	Trial 4
Amount of HCl Standard Used	10.0 mL	10.0 mL	10.0 mL	10.0 mL
Initial NaOH Buret Reading	0.0 mL	12.2 mL	23.2 mL	35.2 mL
Final NaOH Buret Reading	12.2 mL	23.2 mL	35.2 mL	47.7 mL

35.2 mL

- 23.2 mL

12.0 mL

Calculate the volume of NaOH solution used to neutralize 10.0 mL of the standard HCl solution in trial 3. Show your work.

29

Regents Question: 01/03 #72-74

According to Reference Table M, what indicator would be most appropriate in determining the end point of this titration? Give one reason for choosing this indicator.

Bromthymol Blue because it changes color at a neutral pH (7)

Phenolphthalein because it changes color right after being neutral.

Calculate the average molarity of the unknown NaOH solution for all four trials. Your answer must include the correct number of significant figures and correct units.

MaVa=MbVb

1.2Mx10.0mL = X x 12.2mL X=1.0 M

1.2Mx10.0mL = X x 11.0mL X=1.1 M

1.2Mx10.0mL = X x1 2.0mL X=1.0 M

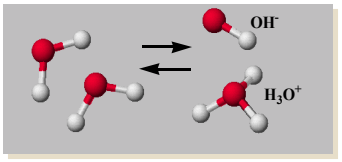
1.2Mx10.0mL = X x1 2.5mL X=0.96 M

(1.0 + 1.1 + 1.0 + 0.96)/4 = 1.015=1.0 M

	Trial 1	Trial 2	Trial 3	Trial 4
Amount of HCl Standard Used	10.0 mL	10.0 mL	10.0 mL	10.0 mL
Initial NaOH Buret Reading	0.0 mL	12.2 mL	23.2 mL	35.2 mL
Final NaOH Buret Reading	12.2 mL	23.2 mL	35.2 mL	47.7 mL

Alternate Acid-Base Theory

Bronsted-Lowry Theory



Water can act as an acid or a base. (amphoteric)

Alternate Theory has a new set of definitions for acids and bases so we can figure out if Water is acting as an acid or a base.

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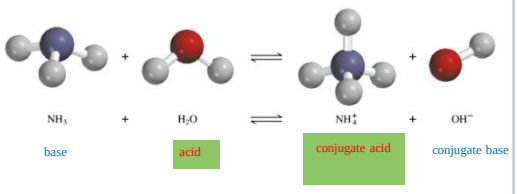
A Brønsted-Lowry acid is a proton donor

A Brønsted-Lowry base is a proton acceptor

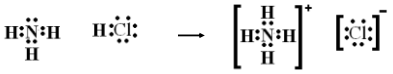


There are alternate acid-base theories.

One theory states that an acid is an H^+ (proton) donor and a base is an H^+ (proton) acceptor.

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

When NH_3 reacts with HCl, the HCl donates a proton (H^+) and NH_3 accepts a proton (H^+)



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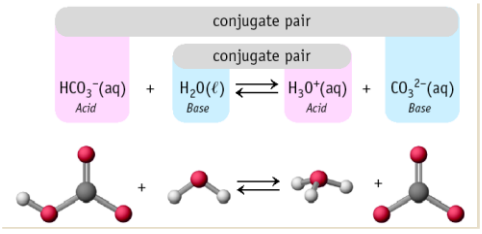
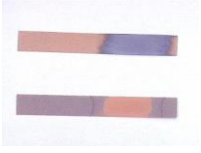
Conjugate pairs



The acidity or alkalinity of a solution can be measured by its pH value. The relative level of acidity or alkalinity of a solution can be shown by using indicators.

Red Litmus turns Blue in Base

Blue Litmus turns Red in Acid



35

Table M lists some common acid-base indicators.

Table M
Common Acid–Base Indicators

Indicator	Approximate pH Range for Color Change	Color Change
methyl orange	3.2–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8.2–10	colorless to pink
litmus	5.5–8.2	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

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Color of Indicators at different pHs

Indicator	pH 3	pH 5	pH7	pH 9
Methyl Orange	red	yellow	yellow	yellow
Bromthymol Blue	yellow	yellow	green	blue
litmus	red	red	??????	blue
Bromcresol Green	yellow	green	blue	blue
Thymol blue	yellow	yellow	yellow	green

Table M
Common Acid–Base Indicators

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methyl orange	3.2–4.4	red to yellow
bromthymol blue	6.0–7.6	yellow to blue
phenolphthalein	8.2–10	colorless to pink
litmus	5.5–8.2	red to blue
bromcresol green	3.8–5.4	yellow to blue
thymol blue	8.0–9.6	yellow to blue

When the pH is lower than the lower number in the range, the color is the color on the left.

When the pH is higher than the higher number in the range, the color is the color on the right.

When the pH is between the two numbers in the range, the color is changing.

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Regents Question: 01/03 #34

A compound whose water solution conducts electricity and turns phenolphthalein pink is

(1) HCl

(2) $HC_2H_3O_2$

☑ (3) NaOH

(4) CH_3OH

38

Regents Question: 06/03 #48

A student was given four unknown solutions. Each solution was checked for conductivity and tested with phenolphthalein. The results are shown in the data table below

Solution	Conductivity	Color with Phenolphthalein
A	Good	Colorless
B	Poor	Colorless
C	Good	Pink
D	Poor	Pink

Based on the data table, which unknown solution could be 0.1 M NaOH?

(1) A (2) B ☑ (3) C (4) D

39

Regents Question: 06/02 #54

A student is given two beakers, each containing an equal amount of clear, odorless liquid. One solution is acidic and the other is basic.

a State *two* safe methods of distinguishing the acid solution from the base solution.

1- Test with litmus paper 2- Use a pH meter

b For *each* method, state the results of both the testing of the acid solution *and* the testing of the base solution.

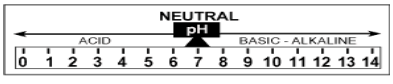
1- Red litmus paper would turn blue in base. Blue litmus paper would turn red in acid.

2- The pH of the acid would be below 7. The pH of the base would be above 7.

40

On the pH scale, each decrease of one unit of pH represents a tenfold increase in hydronium ion concentration.

$$[H_3O^+] = 1 \times 10^{-pH}$$



An acid with a pH of 2 has 10x the $[H_3O^+]$ hydronium ion concentration as an acid with a pH of 3.

A base with a pH of 10 has **100x** the $[H_3O^+]$ hydronium ion concentration as a base with a pH of 12.

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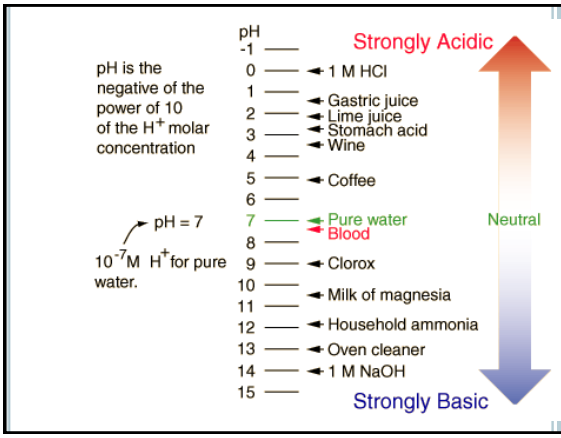

Regents Question: 01/03 #23

Which of these 1 M solutions will have the highest pH?

☑ (1) NaOH — NaOH is a base

(2) CH_3OH — CH_3OH is an alcohol

(3) HCl — HCl is an acid

(4) NaCl — NaCl is a salt

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$[H_3O^+]$ in decimal (mol/Liter)	$[H_3O^+]$ in scientific notation (mol/Liter)	pH
1.0	1×10^{0}	0
0.1	1×10^{-1}	1
0.01	1×10^{-2}	2
0.001	1×10^{-3}	3
0.0001	1×10^{-4}	4
0.00001	1×10^{-5}	5
0.000001	1×10^{-6}	6
0.0000001	1×10^{-7}	7
0.00000001	1×10^{-8}	8
0.000000001	1×10^{-9}	9
0.0000000001	1×10^{-10}	10
0.00000000001	1×10^{-11}	11
0.000000000001	1×10^{-12}	12
0.0000000000001	1×10^{-13}	13
0.00000000000001	1×10^{-14}	14

Acid — Neutral — Base

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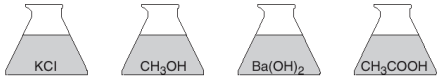
Regents Question: 08/02 #59

Four flasks each contain 100 milliliters of aqueous solutions of equal concentrations at 25°C and 1 atm.



a Which solutions contain electrolytes? KCl, $Ba(OH)_2$ and CH_3COOH

b Which solution has the *lowest* pH? CH_3COOH

c What causes some aqueous solutions to have a low pH? They are acids, they have dissolved hydrogen ions

d Which solution is most likely to react with an Arrhenius acid to form a salt and water? $Ba(OH)_2$

45

Regents Questions June 2011

25 Which compounds can be classified as electrolytes?

(1) alcohols
(2) alkynes
(3) organic acids
(4) saturated hydrocarbons

28 According to one acid-base theory, an acid is an

(1) H^+ acceptor
(2) H^+ donor
(3) OH^- acceptor
(4) OH^- donor

46

Regents Questions June 2011

27 In which laboratory process is a volume of solution of known concentration used to determine the concentration of another solution?

(1) deposition
(2) distillation
(3) filtration
(4) titration

48 Which volume of 2.0 M NaOH(aq) is needed to completely neutralize 24 milliliters of 1.0 M HCl(aq)?

(1) 6.0 mL
(2) 12 mL
(3) 24 mL
(4) 48 mL

47

Regents Questions June 2011

Base your answers to questions 80 through 82 on the information below.

Some carbonated beverages are made by forcing carbon dioxide gas into a beverage solution. When a bottle of one kind of carbonated beverage is first opened, the beverage has a pH value of 3.

80 State, in terms of the pH scale, why this beverage is classified as acidic. [1]

81 Using Table *M*, identify *one* indicator that is yellow in a solution that has the same pH value as this beverage. [1]

82 After the beverage bottle is left open for several hours, the hydronium ion concentration in the beverage solution decreases to $\frac{1}{1000}$ of the original concentration. Determine the new pH of the beverage solution. [1]

48