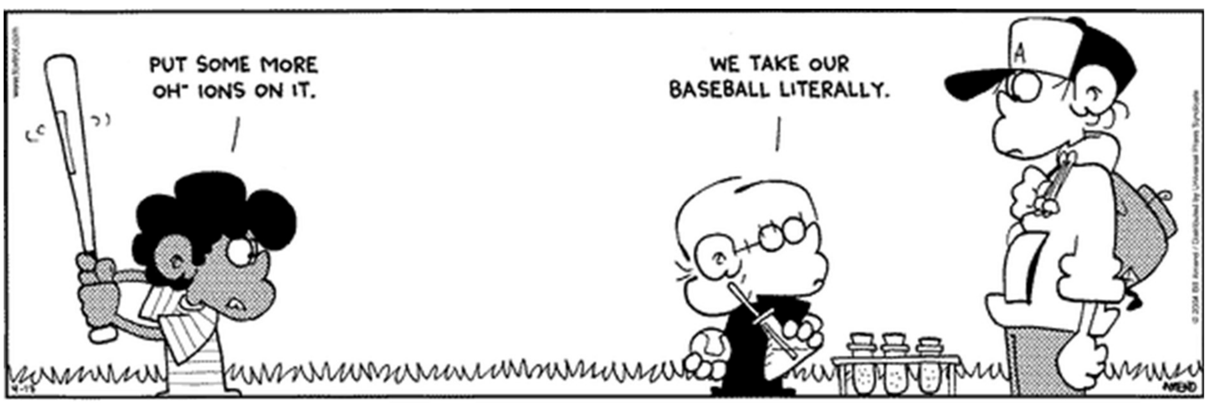
CHEMISTRY 40S

The Alchemist's Notebook

UNIT 4 – ACIDS & BASES



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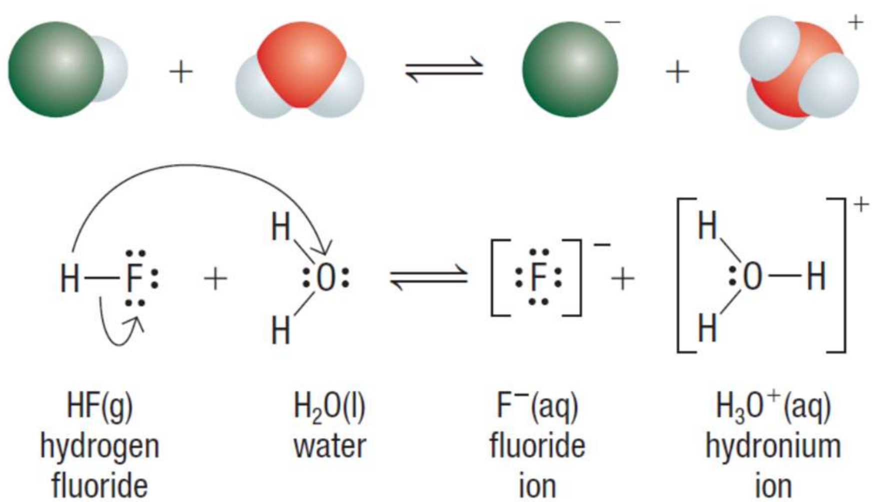
1. BRONSTED-LOWRY ACIDS & BASES

CH40S UNIT 4 – ACID BASE EQUILIBRIUM

1

BRONSTED LOWRY ACIDS

An acid is a hydrogen ion donor.



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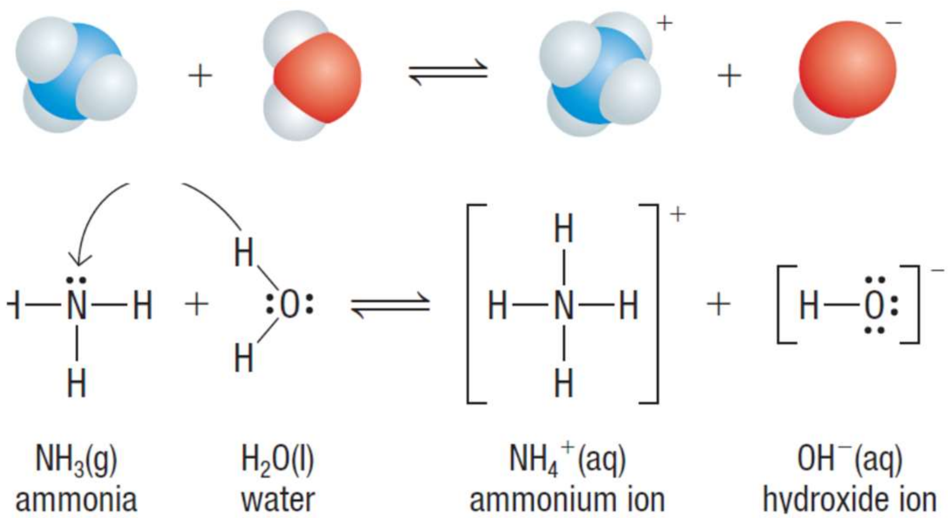
BRONSTED LOWRY BASES

A base is a hydrogen ion acceptor.



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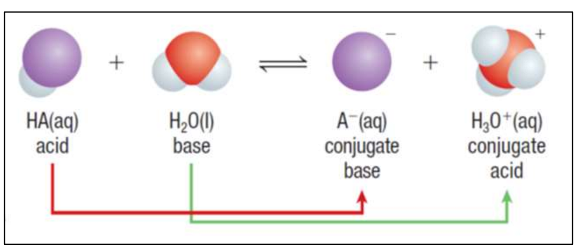
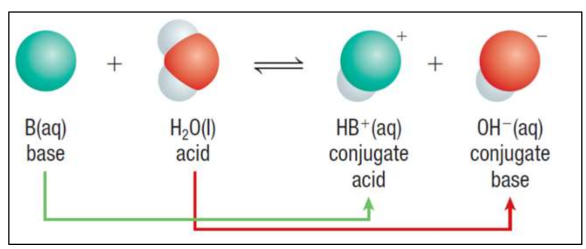
CONJUGATE ACID BASE PAIRS

LEARNING TIP
The conjugate acid always contains one more H^+ than the conjugate base.





conjugate acid the substance that forms when a base, according to the Brønsted–Lowry theory, accepts a hydrogen ion (proton)

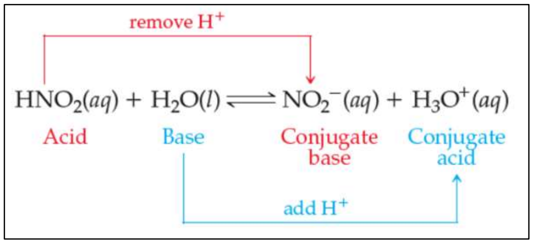
conjugate base the substance that forms when an acid loses a hydrogen ion (proton)

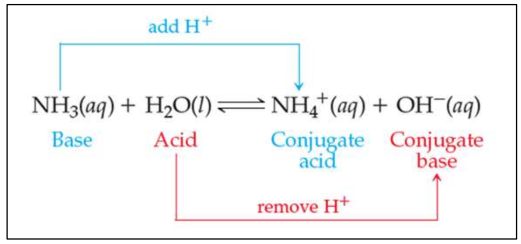
4

CONJUGATE ACID BASE PAIRS

LEARNING TIP

The conjugate acid always contains one more H^+ than the conjugate base.





- Conjugates act as the acid and base for the reverse reaction.
- The bases that are the best at taking protons dictate eq'm position.

5

A SUBSTANCE CAN BE BOTH?

amphiprotic (amphoteric) able to donate or accept a hydrogen ion (proton) and thus act as both a Brønsted–Lowry acid and a Brønsted–Lowry base

$$HCO^-_{3(aq)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)} + OH^-_{(aq)}$$

base — acid

$$HCO^-_{3(aq)} + H_2O_{(l)} \rightleftharpoons CO^{2-}_{3(aq)} + H_3O^+_{(aq)}$$

acid — base

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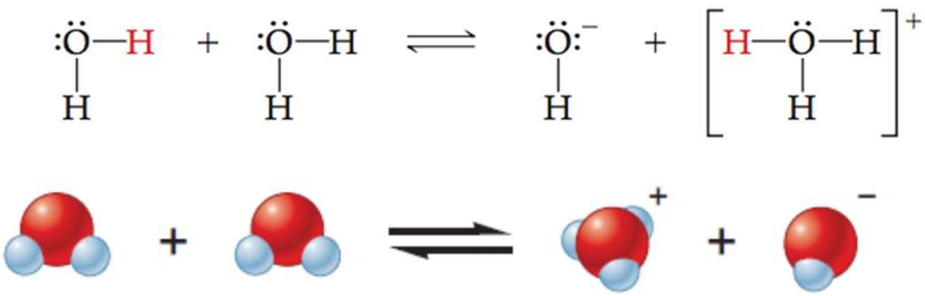
AMPHOTERIC CHEMICALS

Water is amphoteric

$$H_2O(l) + H_2O(l) \rightleftharpoons OH^-(aq) + H_3O^+(aq)$$



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FOR EXAMPLE

Write the Bronsted-Lowery equations for the following acids in aqueous solution and identify the conjugate acid-base pairs:

Hydrochloric acid (HCl)

Acetic acid (CH_3COOH)

Anilinium ion ($C_6H_5NH_3^+$)

8

FOR EXAMPLE

Write the Bronsted-Lowery equations for the following <u>bases</u> in aqueous solution and identify the <u>conjugate acid-base pairs</u>:

Methylamine (CH_3NH_2)

Ammonia (NH_3)

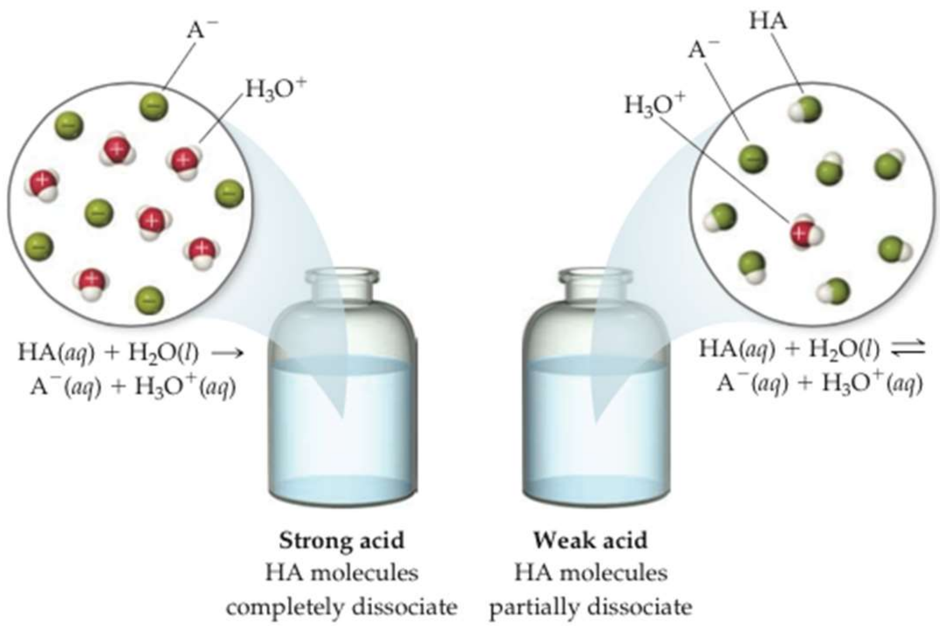
9

2. STRONG VS. WEAK ACIDS & BASES

CH40S UNIT 4 – ACID BASE EQUILIBRIUM

1

STRONG VS. WEAK



2

STRONG ACIDS REVISED

A strong acid is a forceful H^+ donor. It must give an H^+ to someone! Once a strong acid donates H^+, the H^+ will **never** come back.

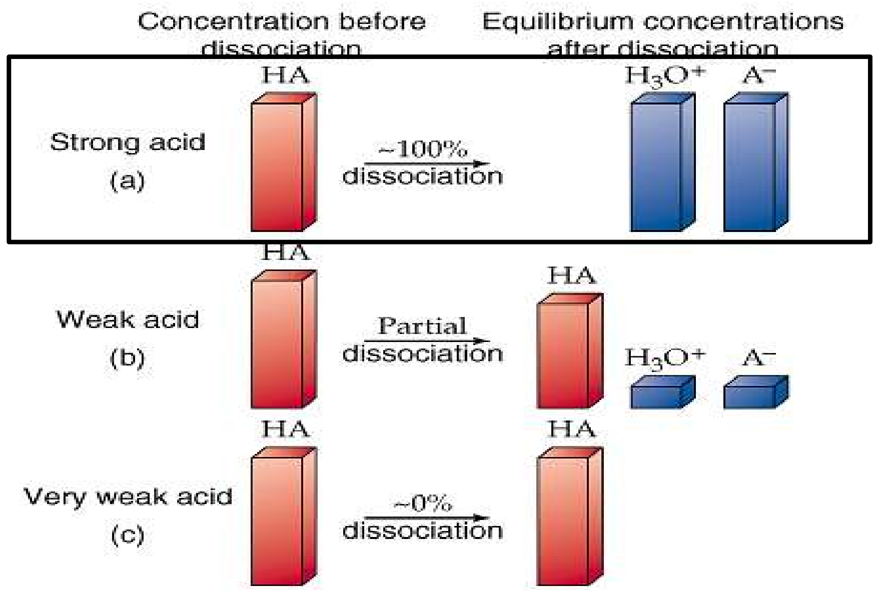
- Acid chart top six
- Not equilibrium…stoichiometric relationships…No ICE table!
- Use a "→" and not "⇄"

$HCl(aq) + H_2O(l)$

1.0M

3

RELATIVE ACID STRENGTH



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STRONG ACIDS

STRONG ↑ STRENGTH OF ACID

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	→	$H^+ + ClO_4^-$	very large
Hydriodic	HI	→	$H^+ + I^-$	very large
Hydrobromic	HBr	→	$H^+ + Br^-$	very large
Hydrochloric	HCl	→	$H^+ + Cl^-$	very large
Nitric	HNO_3	→	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	→	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	⇄	$H^+ + H_2O$	1.0
Iodic	HIO_3	⇄	$H^+ + IO_3^-$	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	⇄	$H^+ + HC_2O_4^-$	5.9×10^{-2}
Sulphurous ($SO_2 + H_2O$)	H_2SO_3	⇄	$H^+ + HSO_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	⇄	$H^+ + SO_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	⇄	$H^+ + H_2PO_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	⇄	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
Citric	$H_3C_6H_5O_7$	⇄	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	⇄	$H^+ + NO_2^-$	4.6×10^{-4}
Hydrofluoric	HF	⇄	$H^+ + F^-$	3.5×10^{-4}
Methanoic, formic	$HCOOH$	⇄	$H^+ + HCOO^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	⇄	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}
Benzoic	C_6H_5COOH	⇄	$H^+ + C_6H_5COO^-$	6.5×10^{-5}
Hydrogen oxalate ion	$HC_2O_4^-$	⇄	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	⇄	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	⇄	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}

WEAK STRENGTH

5

WEAK ACIDS REVISED

A weak acid is a wishy-washy H⁺ donor. It can give away its H^+, but may regain the H^+ a few seconds later. Every acid that is not a strong acid is a weak acid.

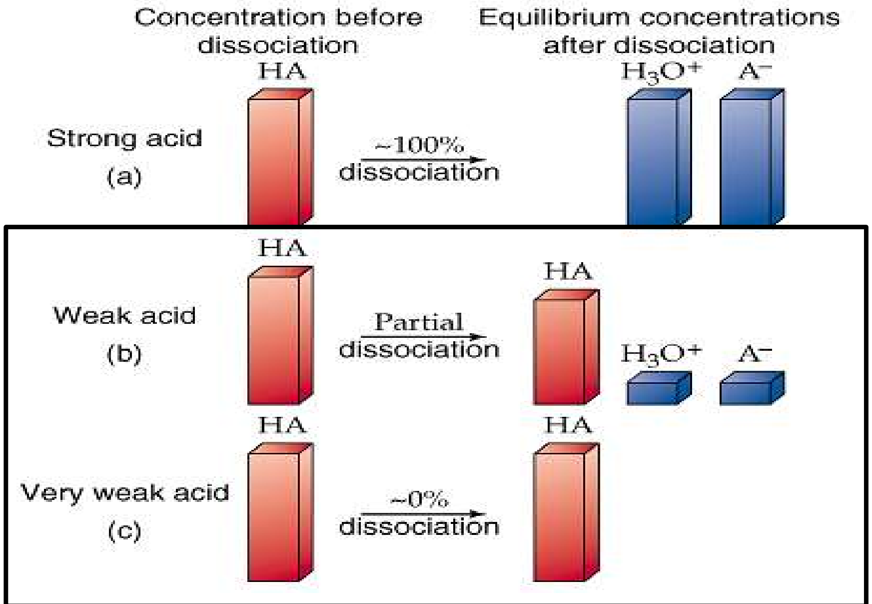
- Produce small amounts of H^+ / H_3O^+.
- Equilibriums…equilibrium constants (K_a' s)…need ICE tables .
- Use a "⇄" and not "→"

$$HF(aq) + H_2O(l)$$

1.0M

6

RELATIVE ACID STRENGTH



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STRONG ACIDS

WEAK ACIDS

STRENGTH OF ACID: STRONG ↑

WEAK BASE STRENGTH ↓

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	→	$H^+ + ClO_4^-$	very large
Hydriodic	HI	→	$H^+ + I^-$	very large
Hydrobromic	HBr	→	$H^+ + Br^-$	very large
Hydrochloric	HCl	→	$H^+ + Cl^-$	very large
Nitric	HNO_3	→	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	→	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	⇄	$H^+ + H_2O$	1.0
Iodic	HIO_3	⇄	$H^+ + IO_3^-$	1.7×10^{-1}
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Nitrous	HNO_2	⇄	$H^+ + NO_2^-$	4.6×10^{-4}
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Ethanoic, acetic	CH_3COOH	⇄	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	⇄	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}

8

DON'T FORGET LAST LESSON!

- In order to have a reaction, both an acid (H^+ donor) and a base (H^+ acceptor) are required!
- The reaction itself is an **H^+ transfer** (sometimes called a **proton transfer**) from the acid to the base (like tossing a football from quarterback to receiver).
- Many acid-base reactions are reversible, so the H^+ (the "football") may be passed back and forth.

9

SOME COMMON WEAK ACIDS

Acetic acid, CH_3COOH $K_a = 1.8 \times 10^{-5}$

Nitrous acid, HNO_2 $K_a = 4.5 \times 10^{-4}$

Write the Bronsted Lowry equation for each acid in water and identify the acids and bases.

Write the Ka expression for each acid. Which acid is stronger? Why?

10

STRONG BASES REVISED

<u>A strong base is a forceful H^+ grabber</u>. If an acidic hydrogen is anywhere to be found, the strong base will take it and keep it! There is <u>only 1 strong base </u>that you will see in this class:

- Produce large amounts of OH^-.
- Not equilibrium…stoichiometric relationships…no ICE tables
- Use a "$\rightarrow$" and not "$\rightleftarrows$"

$$OH^-(aq) + H_2O(l)$$

1.0M

11

STRONG BASES

<u>Soluble Hydroxides</u>

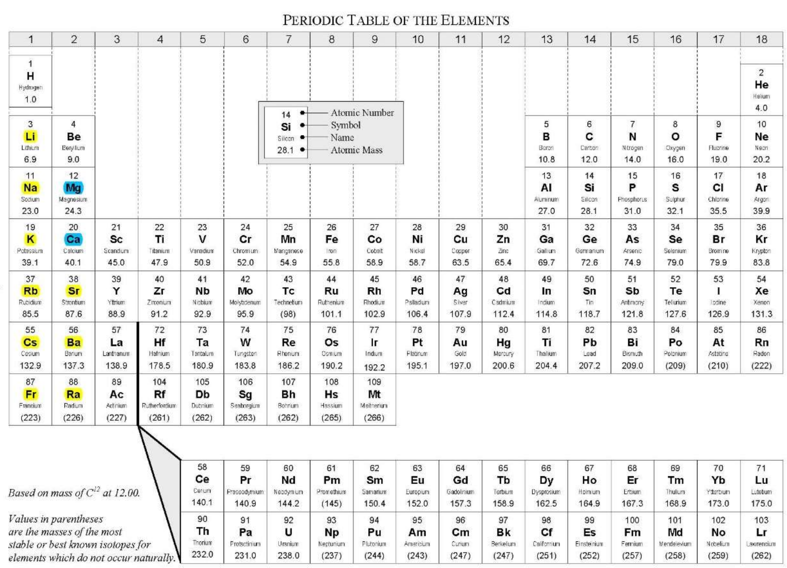
LiOH

NaOH

KOH

$Sr(OH)_2$

$Ba(OH)_2$



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WEAK BASES REVISED

A weak base is a wishy-washy H^+ acceptor. It can take an H^+, but may relinquish the H^+ a few seconds later. Every base that is NOT hydroxide is a weak base.

- Produce small amounts of OH^-.
- Equilibriums…equilibrium constants (K_b' s)…need ICE tables .
- Use a "⇄" and not "→"

$NH_3(aq) + H_2O(l)$

1.0M

13

SOME COMMON WEAK BASES

Bicarbonate ion, HCO_3^-	$K_b = 2.3 \times 10^{-8}$
Ammonia, NH_3	$K_b = 1.8 \times 10^{-5}$

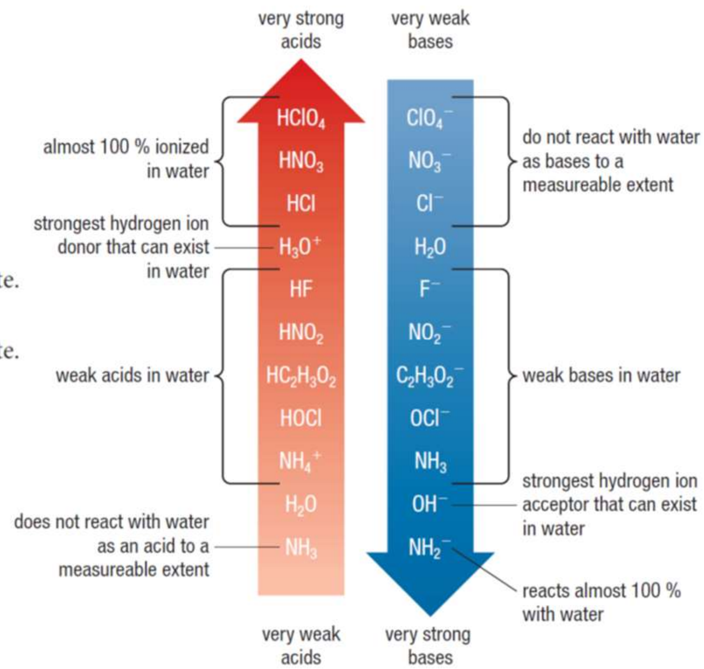
Write the Bronsted Lowry equations for each base in water and identify the acids and bases.

Write the K_b expression for each acid. Which base is stronger? Why?

14

INVERSE RELATIONSHIPS

- A strong acid or base has a very weak conjugate.
- A weak acid or base has a weak conjugate.
- A very weak acid or base has a strong conjugate.



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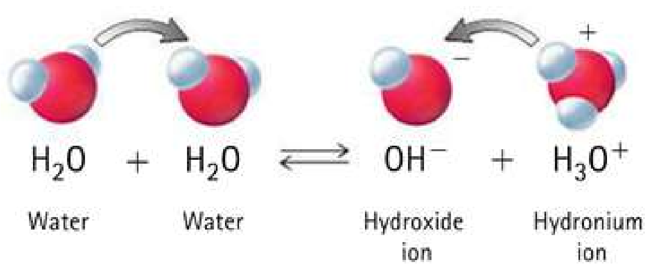
3. AN INTRODUCTION TO pH

UNIT 4 CH40S WIEBE

1

WATER IS AMPHOTERIC



$K_w =$

- In a sample of pure water, occasionally molecules collide effectively and a H^+ transfer occurs.
- This equilibrium is **VERY** reactant favoured.
- All aqueous solutions contain both H_3O^+ and OH^-.

2

AQUEOUS SOLUTION RELATIONSHIPS

In neutral solutions	$[H^+_{(aq)}] = [OH^-_{(aq)}]$
In acidic solutions	$[H^+_{(aq)}] > [OH^-_{(aq)}]$
In basic solutions	$[H^+_{(aq)}] < [OH^-_{(aq)}]$

3

WORKING WITH K_W

	$[H_3O^+]$	WORK	$[OH^-]$	Acid Base Neutral
1.	1.0×10^{-8} M			
2.			1.0×10^{-10} M	
3.	1.0×10^{-7} M			

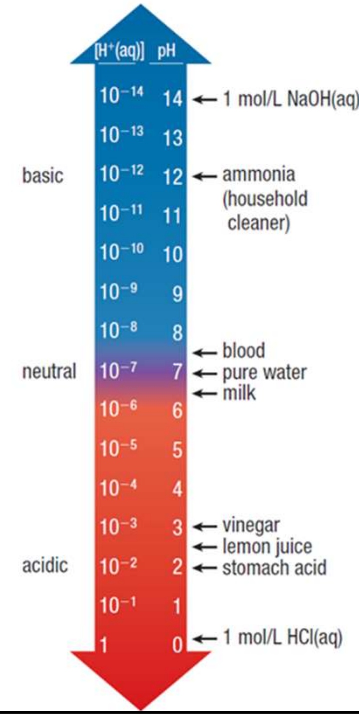
Note that in an acid, the $[H_3O^+]$ is LARGE and the $[OH^-]$ is small.

4

THE pH SCALE

- pH is used to represent the hydrogen/hydronium ion concentration in a solution.
- pOH is used to represent the hydroxide ion concentration in a solution.
- In every solution, the **pH + pOH = 14**.

pAnything = logarithm of that thing



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USING LOGS TO SIMPLIFY THINGS

pH the negative logarithm of the concentration of hydrogen ions in an aqueous solution

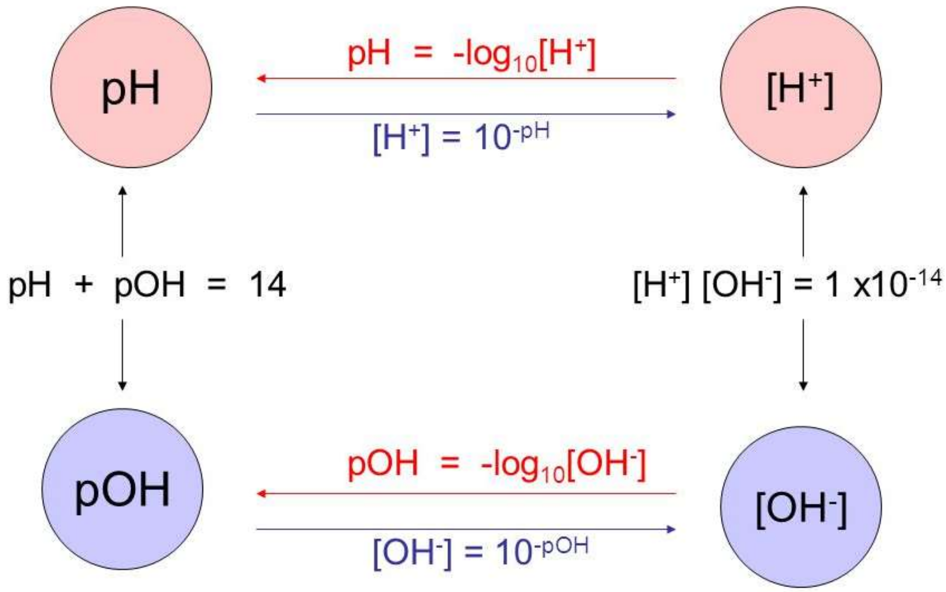
$$pH = -\log[H^+(aq)]$$

pOH the negative logarithm of the concentration of hydroxide ions in an aqueous solution

$$pOH = -\log[OH^-(aq)]$$

6

A HANDY TOOL…



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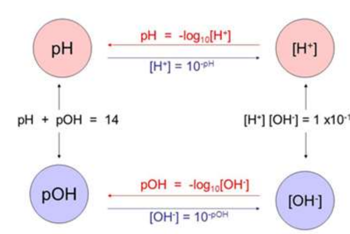
WORKING WITH pH

$[H_3O^+]$	$[OH^-]$	pH	pOH
1.0 x 10^{-4} M			



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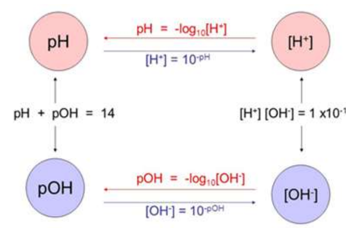
WORKING WITH pH

$[H_3O^+]$	$[OH^-]$	pH	pOH
2.3×10^{-2} M			



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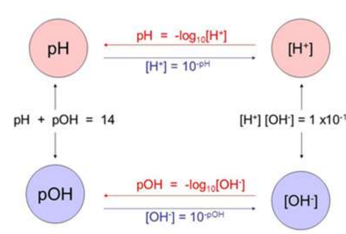
WORKING WITH pH

$[H_3O^+]$	$[OH^-]$	pH	pOH
	1.0×10^{-6} M		



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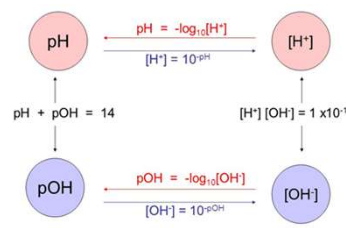
WORKING WITH pH

$[H_3O^+]$	$[OH^-]$	pH	pOH
	7.2×10^{-5} M		



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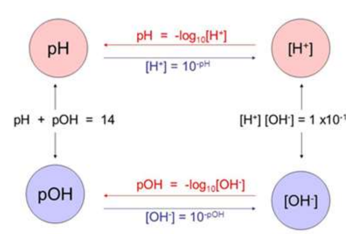
WORKING WITH pH

$[H_3O^+]$	$[OH^-]$	pH	pOH
		3.00	



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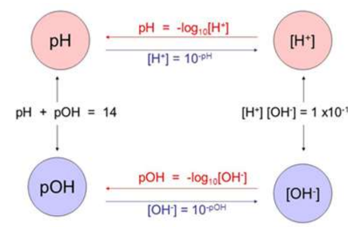
WORKING WITH pH

$[H_3O^+]$	$[OH^-]$	pH	pOH
		8.35	



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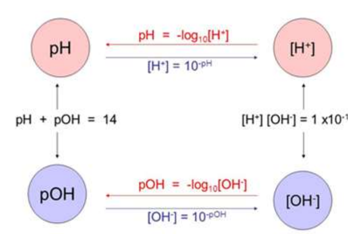
WORKING WITH pH

$[H_3O^+]$	$[OH^-]$	pH	pOH
			11.00



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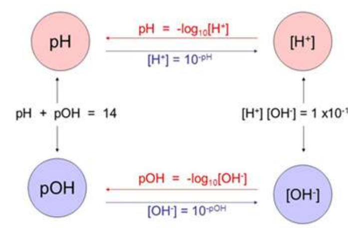
WORKING WITH pH

$[H_3O^+]$	$[OH^-]$	pH	pOH
			5.73



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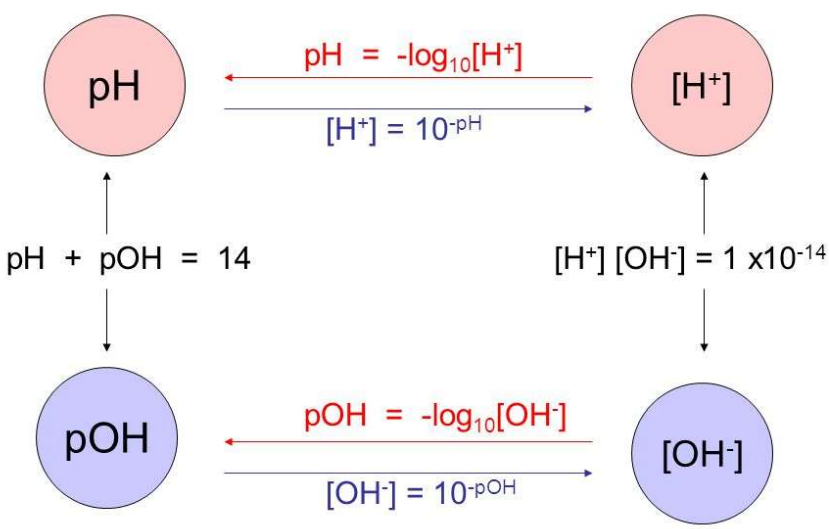
4. pH OF STRONG ACIDS & BASES

UNIT 4 CH40S WIEBE

1

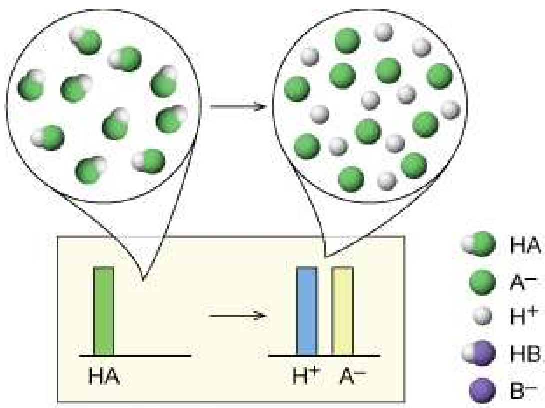
DON'T FORGET…



2

STRONG ACIDS

- Ionize completely in water therefore **not equilibriums.**
- Use B/L or dissociation equation and stoichiometry



$[H_3O^+] = [ACID]$

3

HAVE A PLAN OF ACTION!

What type of solution am I dealing with?

Acid

What type of acid am I dealing with?

- *Strong*: Use **basic stoichiometry** to determine $[H_3O^+]$ and the 4-corners diagram to determine pH/pOH
- *Weak*: Use an **ICE table** to determine $[H_3O^+]$ and the 4-corners diagram to determine pH/pOH

Base

What type of base am I dealing with?

- *Strong*: Use **basic stoichiometry** to determine $[OH^-]$ and the 4-corners diagram to determine pH/pOH
- *Weak*: Use an **ICE table** to determine $[OH^-]$ and the 4-corners diagram to determine pH/pOH

4

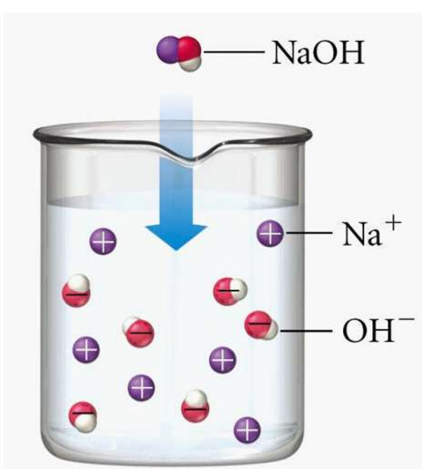
FOR EXAMPLE

Nitric acid is used in the production of agricultural fertilizers, explosives such as TNT, and dyes. Determine pH of a 0.25 M solution of HNO_3.

5

STRONG BASES

- Soluble hydroxides → dissociate completely in water
- **Not equilibriums**…use dissociation equations and stoichiometry



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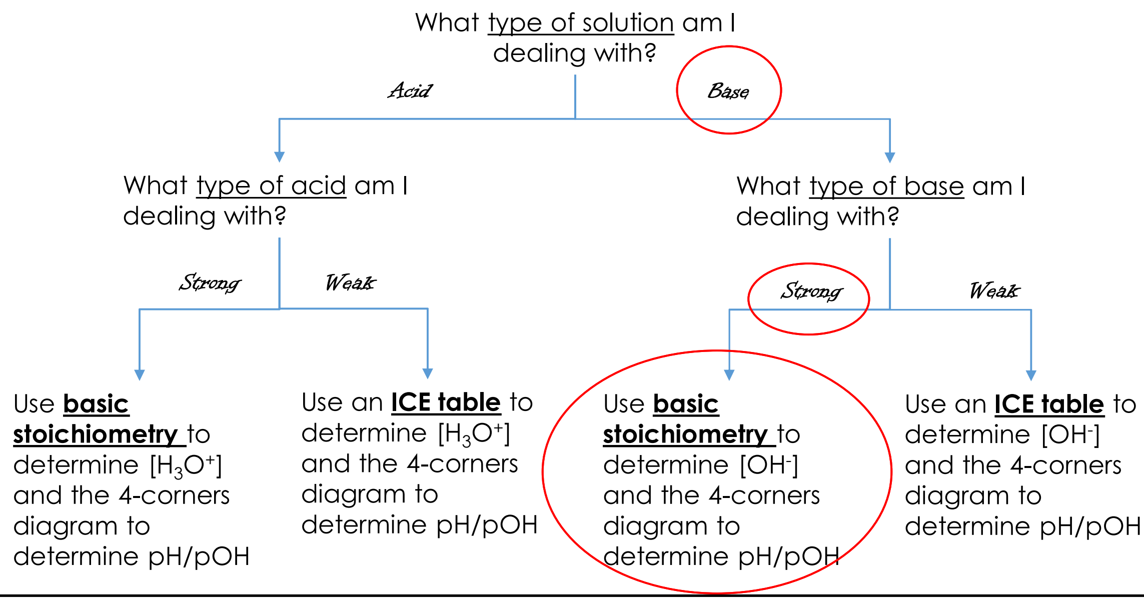
HAVE A PLAN OF ACTION!



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FOR EXAMPLE

Calcium hydroxide is an important component of cement, plasters, and mortars. It is also sometimes used to make your pickles extra crunchy! Calculate the pH of a 0.125 M $Ca(OH)_2$ solution.

8

PUTTING IT ALL TOGETHER!

Calculate the pH of each of the following solutions and ranks them from most to least acidic.

Solution	Volume and Molarity	Calculations
X	100.0 mL of 0.10 M HCl	
Y	200.0 mL of 0.20 M NaOH	
Z	300.0 mL of distilled water	

9

PUTTING IT ALL TOGETHER!

What would the new pH values be for each of the solutions after they are diluted by adding 100.0 mL of distilled water?

Solution	Original Solution	New Solution	Calculations
X	V_1 = 100.0 mL M_1 = 0.10 M HCl pH =		
Y	V_1 = 200.0 mL M_1 = 0.20 M NaOH pH =		
Z	V_1 = 300.0 mL distilled water pH = 7.00		

10

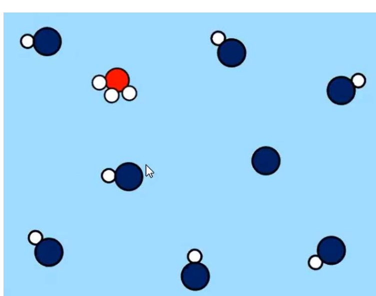
5. pH OF WEAK ACID SOLUTIONS

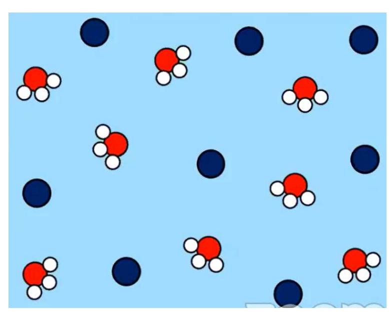
UNIT 4 CH40S WIEBE

1

REVIEW

Which of the following diagrams shows a strong acid dissolved in water? Justify your answer.





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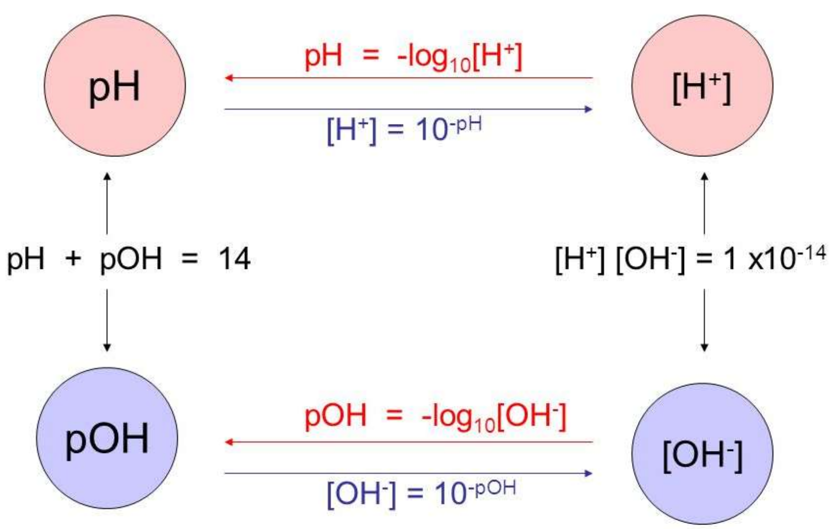
REVIEW

Which of the following acids is a strong acid? Justify your answer.

Concentration (*M*)	pH of Acid 1	ph of Acid 2	ph of Acid 3	pH of Acid 4
0.010	3.44	2.00	2.92	2.20
0.050	3.09	1.30	2.58	1.73
0.10	2.94	1.00	2.42	1.55
0.50	2.69	0.30	2.08	1.16
1.00	2.44	0.00	1.92	0.98

3

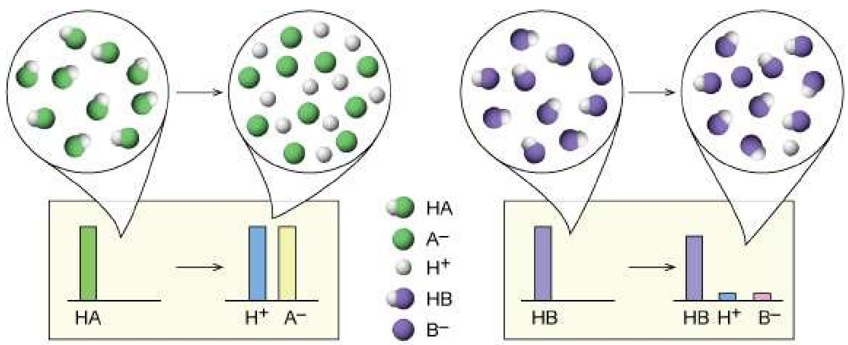
DON'T FORGET…



4

WEAK ACIDS…

- Are reactant favored equilibriums
- Have K_a values to represent equilibrium position
- Require ICE tables to determine $[H_3O^+]$ and pH



(a) Strong acid (b) Weak acid

5

HAVE A PLAN OF ACTION!

What type of solution am I dealing with?

Acid | *Base*

Acid → What type of acid am I dealing with?

- *Strong* → Use **basic stoichiometry** to determine $[H_3O^+]$ and the 4-corners diagram to determine pH/pOH
- *Weak* → Use an **ICE table** to determine $[H_3O^+]$ and the 4-corners diagram to determine pH/pOH

Base → What type of base am I dealing with?

- *Strong* → Use **basic stoichiometry** to determine $[OH^-]$ and the 4-corners diagram to determine pH/pOH
- *Weak* → Use an **ICE table** to determine $[OH^-]$ and the 4-corners diagram to determine pH/pOH

6

FOR EXAMPLE

Hydrofluoric acid is used industrially for etching glass, cleaning metals, and manufacturing electronic parts. Determine the pH and the % ionization of a 0.10 M solution of HF.

7

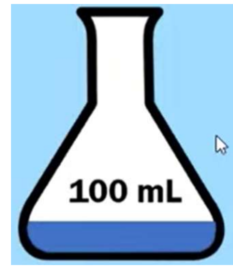
FOR EXAMPLE

Hypochlorous acid is the active sanitizer used in swimming pools. Determine the equilibrium constant (K_a) of a 0.100 M sample of acid if it has a pH of 4.23.

8

PUTTING IT ALL TOGETHER!

1. Calculate the pH and % ionization of the solution shown.

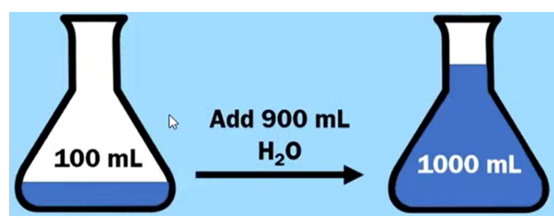


0.10 M solution of acetic acid (CH_3COOH).

9

PUTTING IT ALL TOGETHER!

2. Calculate the pH and % ionization of the solution after it has been diluted according to the picture.



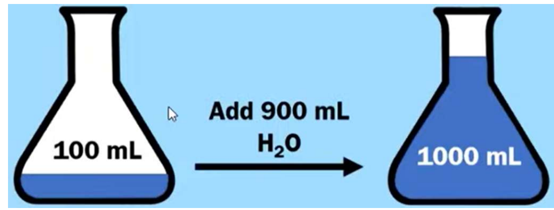
0.10 M solution of acetic acid (CH_3COOH).

??? M solution of acetic acid (CH_3COOH).

10

PUTTING IT ALL TOGETHER – CHALLENGE!

3. What happened to the pH and % ionization of the weak acid when it was diluted?



0.10 M solution of acetic acid (CH_3COOH).

??? M solution of acetic acid (CH_3COOH).

4. Explain why this happens using Le Chatelier's Principle.

$CH_3COOH + H_2O \leftrightarrow$

11

6. pH OF WEAK BASE SOLUTIONS

UNIT 4 CH40S MR. WIEBE

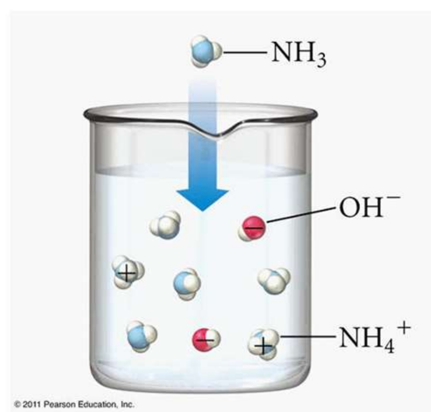
1

WEAK BASES

- Are reactant favored equilibriums
- Have K_b values to represent equilibrium position
- Require ICE tables to determine $[OH^-]$ and pOH/pH

$$B + H_2O \leftrightarrows BH^+ + OH^-$$

$$K_b = \frac{[BH^+][OH^-]}{[B]} = ???$$



2

BE CAREFUL WITH WEAK BASES!

- Weak bases are the conjugate bases of weak acids!
- They are created by dissolving a soluble salt containing the weak base in water.

<u>For example:</u>

Weak Acid	Conj. Base (Weak Base)	Soluble Salt Containing Weak Base
HCN	CN-	NaCN
HF	F-	NaF
CH_3COOH	CH_3COO-	$NaCH_3COO$

TWO COMMON WEAK BASES TO RECOGNIZE:

1. Ammonia (NH_3)
2. Methyamine (CH_3NH_2)

$NaCN(s) \leftrightarrow Na^+(aq) + CN^-(aq)$ ⟶ $CN^- + H_2O \leftrightarrow OH^- + HCN$

3

K_b's OF WEAK BASES

The K_b of a weak base is related to the K_a of the conjugate acid of that base.

$(Ka)(Kb) = K_w$

$(Ka)(Kb) = 1.0 \times 10^{-14}$

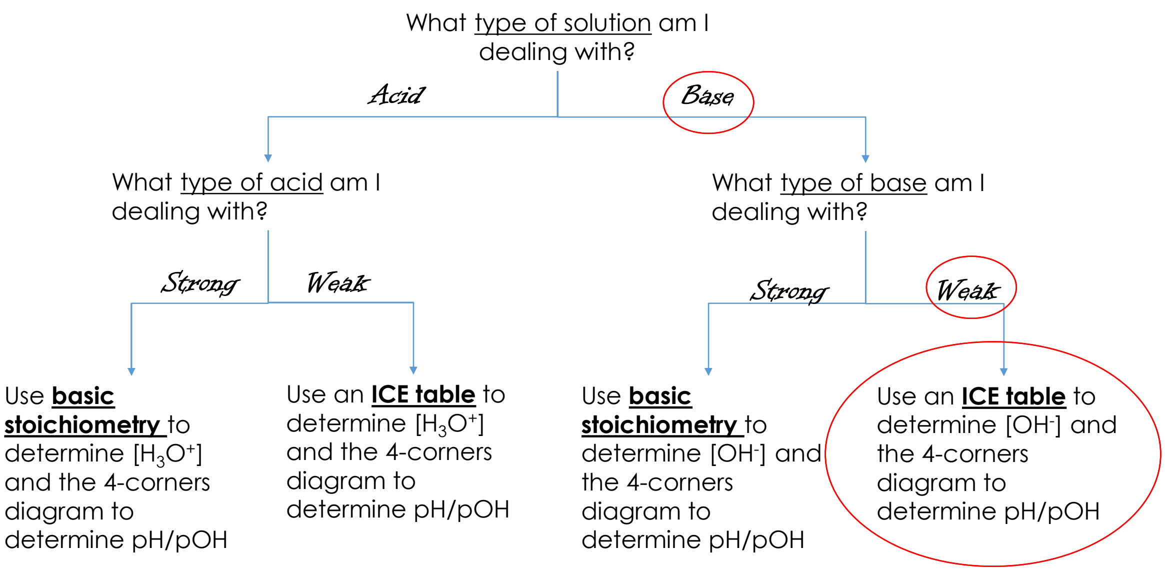
K_b NH_3 =

Ionization Constants for Some Acids and Their Conjugate Bases at 25°C

Acid Name	Formula	Ka	Formula	Kb	Base name
Perchloric acid	$HClO_4$	large	ClO_4^-	very small	Perchlorate ion
Sulfuric acid	H_2SO_4	large	HSO_4^-	very small	Hydrogen sulfate ion
Hydrochloric acid	HCl	large	Cl^-	very small	Chloride ion
Nitric acid	HNO_3	large	NO_3^-	very small	Nitrate ion
Hydronium ion	H_3O^+	1.0	H_2O	1.0×10^{-14}	Water
Sulfurous acid	H_2SO_3	1.2×10^{-2}	HSO_3^-	8.3×10^{-13}	Hydrogen sulfite ion
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}	SO_4^{2-}	8.3×10^{-13}	Sulfate ion
Phosphoric acid	H_3PO_4	7.5×10^{-3}	$H_2PO_4^-$	1.3×10^{-12}	Dihydrogen phosphate ion
Hexaaquairon(III) ion	$[Fe(H_2O)_6]^{3+}$	6.3×10^{-3}	$[Fe(H_2O)_5OH]^{2+}$	1.6×10^{-12}	Pentaaquahydroxoiron(III) ion
Hydrofluoric acid	HF	7.2×10^{-4}	F^-	1.4×10^{-11}	Fluoride ion
Nitrous acid	HNO_2	4.5×10^{-4}	NO_2^-	2.2×10^{-11}	Nitrite ion
Formic acid	HCO_2H	1.8×10^{-4}	HCO_2^-	5.6×10^{-11}	Formate ion
Benzoic acid	$C_6H_5CO_2H$	6.3×10^{-5}	$C_6H_5CO_2^-$	1.6×10^{-10}	Benzoate ion
Acetic acid	CH_3CO_2H	1.8×10^{-5}	$CH_3CO_2^-$	5.6×10^{-10}	Acetate ion
Propanoic acid	$CH_3CH_2CO_2H$	1.3×10^{-5}	$CH_3CH_2CO_2^-$	7.7×10^{-10}	Propanoate ion
Hexaaquaaluminium ion	$[Al(H_2O)_6]^{3+}$	7.9×10^{-6}	$[Al(H_2O)_5OH]^{2+}$	1.3×10^{-9}	Pentaaquahydroxoaluminum ion
Carbonic acid	H_2CO_3	4.2×10^{-7}	HCO_3^-	2.4×10^{-8}	Hydrogen carbonate ion
Hexaaquacopper(II) ion	$[Cu(H_2O)_6]^{2+}$	1.6×10^{-7}	$[Cu(H_2O)_5OH]^+$	6.3×10^{-8}	Pentaaquahydroxocopper(II) ion
Hydrogen sulfide	H_2S	1.0×10^{-7}	HS^-	1.0×10^{-7}	Hydrogen sulfide ion
Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}	HPO_4^{2-}	1.6×10^{-7}	Hydrogen phosphate ion
Hydrogen sulfite ion	HSO_3^-	6.2×10^{-8}	SO_3^{2-}	1.6×10^{-7}	Sulfite ion
Hypochlorous acid	HClO	3.5×10^{-8}	ClO^-	2.9×10^{-7}	Hypochlorite ion
Hexaaqualead(II) ion	$[Pb(H_2O)_6]^{2+}$	1.5×10^{-8}	$[Pb(H_2O)_5OH]^+$	6.7×10^{-7}	Pentaaquahydroxolead(II) ion
Hexaaquacobalt(II) ion	$[Co(H_2O)_6]^{2+}$	1.3×10^{-9}	$[Co(H_2O)_5OH]^+$	7.7×10^{-6}	Pentaaquahydroxocobalt(II) ion
Boric acid	$B(OH)_3(H_2O)$	7.3×10^{-10}	$B(OH)_4^-$	1.4×10^{-5}	Tetrahydroxoborate ion
Ammonium ion	NH_4^+	5.6×10^{-10}	NH_3	1.8×10^{-5}	Ammonia
Hydrocyanic acid	HCN	4.0×10^{-10}	CN^-	2.5×10^{-5}	Cyanide ion
Hexaaquairon(II) ion	$[Fe(H_2O)_6]^{2+}$	3.2×10^{-10}	$[Fe(H_2O)_5OH]^+$	3.1×10^{-5}	Pentaaquahydroxoiron(II) ion
Hydrogen carbonate ion	HCO_3^-	4.8×10^{-11}	CO_3^{2-}	2.1×10^{-4}	Carbonate ion
Hexaaquanickel(II) ion	$[Ni(H_2O)_6]^{2+}$	2.5×10^{-11}	$[Ni(H_2O)_5OH]^+$	4.0×10^{-4}	Pentaaquahydroxonickel(II) ion
Hydrogen phosphate ion	HPO_4^{2-}	3.6×10^{-13}	PO_4^{3-}	2.8×10^{-2}	Phosphate ion
Water	H_2O	1.0×10^{-14}	OH^-	1.0	Hydroxide ion
Hydrogen sulfide ion	HS^-	1.0×10^{-19}	S^{2-}	1.0×10^{5}	Sulfide ion
Ethanol	C_2H_5OH	very small	$C_2H_5O^-$	large	Ethoxide ion
Ammonia	NH_3	very small	NH_2^-	large	Amide ion
Hydrogen	H_2	very small	H^-	large	Hydride ion

4

HAVE A PLAN OF ACTION!



5

FOR EXAMPLE

Ammonia acts as a weak base in solution. It is commonly found in household cleaning solutions such as Windex and toilet bowl cleaners. What is the pH of a 0.050 M solution of ammonia?

6

WORKING BACKWARDS

Calculate the K_b of 0.20 M weak base that has a pH of 11.30. What is the identity of this substance?

7

7. ACIDIC & BASIC SALTS

UNIT 4 – ACIDS & BASES CH40S MR. WIEBE

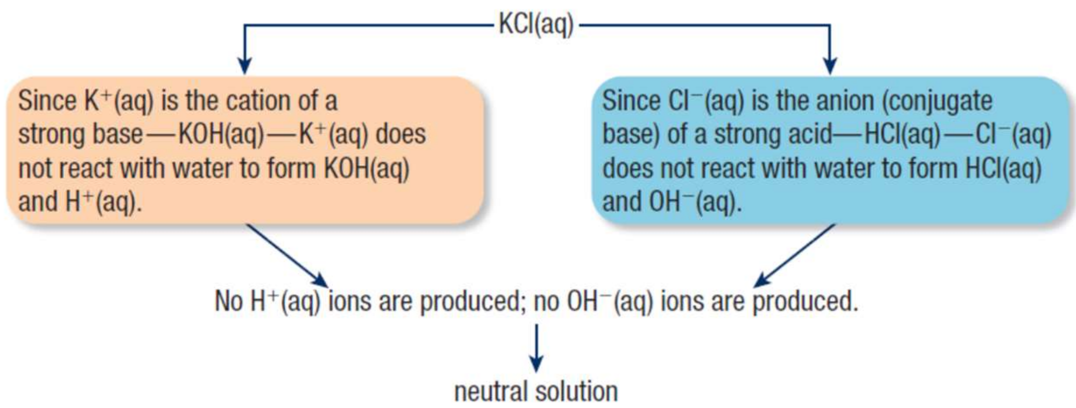
1

ALL SALTS ARE NOT CREATED EQUALLY

- Soluble salts are ionic compounds that readily dissolve in water.
- Soluble salts can create acidic, basic, or neutral solutions when they dissolve, depending on their make-up.
  - Acidic salts increase the [H_3O^+] in solution when they dissolve.
  - Basic salts increase the [OH^-] in solution when they dissolve.
  - Neutral salts do not alter either [H_3O^+] or [OH^-] when they dissolve.

2

NEUTRAL SALTS



When the **acid** and **base** parents are both **strong** the salt is always **neutral**.

3

NEUTRAL SALTS

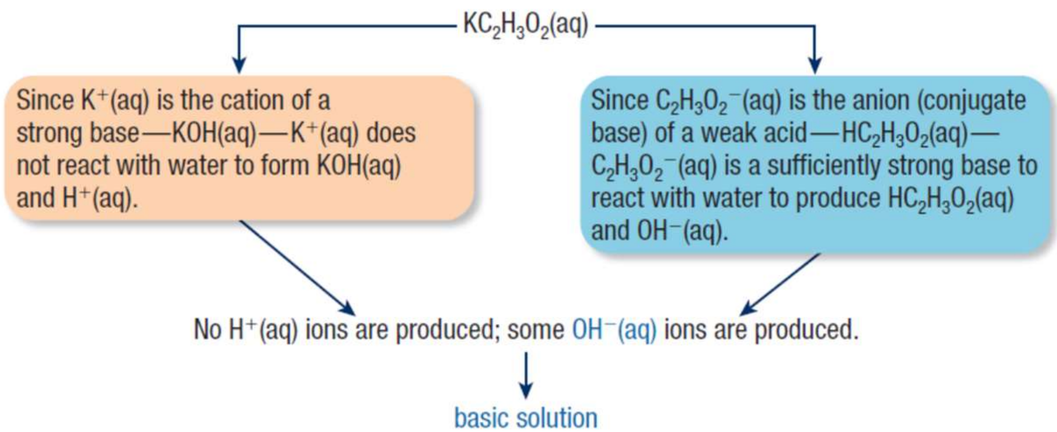
Type of Salt	Examples	Comment	pH of solution
Cation is from a strong base, anion from a strong acid	KCl, KNO_3 $NaCl$ $NaNO_3$	Both ions are neutral	Neutral

These salts simply dissociate in water:

KCl(s) →

4

BASIC SALTS



When the **acid** parent is **weak** and the **base** parent is **strong** the salt is always **basic.**

5

BASIC SALTS

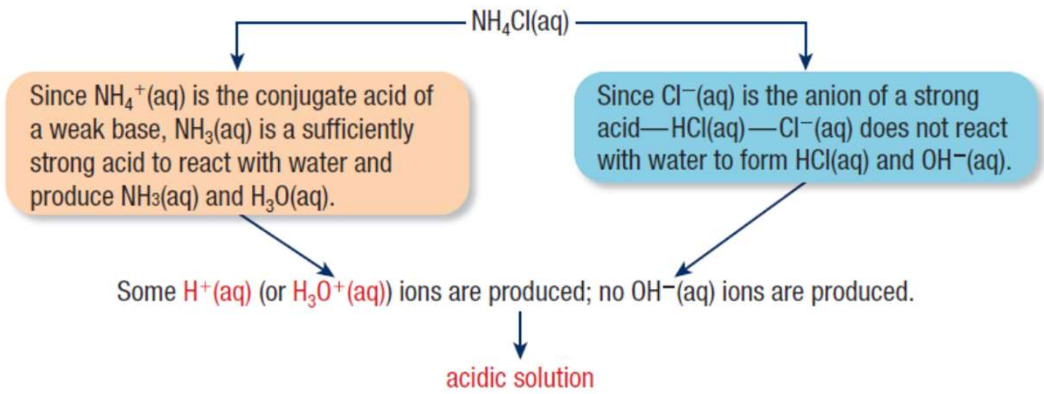
Type of Salt	Examples	Comment	pH of solution
Cation is from a strong base, anion from a weak acid	$NaC_2H_3O_2$ KCN, NaF	Cation is neutral, Anion is basic	Basic

The basic anion can accept a proton from water:

$$C_2H_3O_2^- + H_2O \leftrightarrows$$

6

ACIDIC SALTS



When the **acid** parent is **strong** and the **base** parent is **weak** the salt is always **acidic**.

7

ACIDIC SALTS

Type of Salt	Examples	Comment	pH of solution
Cation is the conjugate acid of a weak base, anion is from a strong acid	NH_4Cl, NH_4NO_3	Cation is acidic, Anion is neutral	Acidic

The acidic cation can act as a proton donor:

$NH_4^+(aq) + H_2O \leftrightarrows$

8

EXAMPLE #1

A chemist dissolves a mass of sodium nitrite in distilled water. Will the resulting aqueous solution be acidic, basic, or neutral? Support your claim.

9

EXAMPLE #2

A chemist dissolves a mass of ammonium nitrate in distilled water. Will the resulting aqueous solution be acidic, basic, or neutral? Support your claim.

10

RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature.

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large
Hydriodic	HI	$\rightarrow$	$H^+ + I^-$	very large
Hydrobromic	HBr	$\rightarrow$	$H^+ + Br^-$	very large
Hydrochloric	HCl	$\rightarrow$	$H^+ + Cl^-$	very large
Nitric	HNO_3	$\rightarrow$	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	$\rightarrow$	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	$\rightleftarrows$	$H^+ + H_2O$	1.0
Iodic	HIO_3	$\rightleftarrows$	$H^+ + IO_3^-$	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	$\rightleftarrows$	$H^+ + HC_2O_4^-$	5.9×10^{-2}
Sulphurous $(SO_2 + H_2O)$	H_2SO_3	$\rightleftarrows$	$H^+ + HSO_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	$\rightleftarrows$	$H^+ + SO_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	$\rightleftarrows$	$H^+ + H_2PO_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
Citric	$H_3C_6H_5O_7$	$\rightleftarrows$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	$\rightleftarrows$	$H^+ + NO_2^-$	4.6×10^{-4}
Hydrofluoric	HF	$\rightleftarrows$	$H^+ + F^-$	3.5×10^{-4}
Methanoic, formic	$HCOOH$	$\rightleftarrows$	$H^+ + HCOO^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}
Benzoic	C_6H_5COOH	$\rightleftarrows$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}
Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftarrows$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	$\rightleftarrows$	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftarrows$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}
Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}
Carbonic $(CO_2 + H_2O)$	H_2CO_3	$\rightleftarrows$	$H^+ + HCO_3^-$	4.3×10^{-7}
Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftarrows$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}
Hydrogen sulphite ion	HSO_3^-	$\rightleftarrows$	$H^+ + SO_3^{2-}$	1.0×10^{-7}
Hydrogen sulphide	H_2S	$\rightleftarrows$	$H^+ + HS^-$	9.1×10^{-8}
Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftarrows$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}
Boric	H_3BO_3	$\rightleftarrows$	$H^+ + H_2BO_3^-$	7.3×10^{-10}
Ammonium ion	NH_4^+	$\rightleftarrows$	$H^+ + NH_3$	5.6×10^{-10}
Hydrocyanic	HCN	$\rightleftarrows$	$H^+ + CN^-$	4.9×10^{-10}
Phenol	C_6H_5OH	$\rightleftarrows$	$H^+ + C_6H_5O^-$	1.3×10^{-10}
Hydrogen carbonate ion	HCO_3^-	$\rightleftarrows$	$H^+ + CO_3^{2-}$	5.6×10^{-11}
Hydrogen peroxide	H_2O_2	$\rightleftarrows$	$H^+ + HO_2^-$	2.4×10^{-12}
Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftarrows$	$H^+ + PO_4^{3-}$	2.2×10^{-13}
Water	H_2O	$\rightleftarrows$	$H^+ + OH^-$	1.0×10^{-14}
Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small
Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	very small

STRONG — STRENGTH OF ACID — WEAK

WEAK — STRENGTH OF BASE — STRONG

ACID-BASE INDICATORS

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

Solubility Product Constants at 25°C

Name	Formula	K_{sp}
Barium carbonate	$BaCO_3$	2.6×10^{-9}
Barium chromate	$BaCrO_4$	1.2×10^{-10}
Barium sulphate	$BaSO_4$	1.1×10^{-10}
Calcium carbonate	$CaCO_3$	5.0×10^{-9}
Calcium oxalate	CaC_2O_4	2.3×10^{-9}
Calcium sulphate	$CaSO_4$	7.1×10^{-5}
Copper(I) iodide	CuI	1.3×10^{-12}
Copper(II) iodate	$Cu(IO_3)_2$	6.9×10^{-8}
Copper(II) sulphide	CuS	6.0×10^{-37}
Iron(II) hydroxide	$Fe(OH)_2$	4.9×10^{-17}
Iron(II) sulphide	FeS	6.0×10^{-19}
Iron(III) hydroxide	$Fe(OH)_3$	2.6×10^{-39}
Lead(II) bromide	$PbBr_2$	6.6×10^{-6}
Lead(II) chloride	$PbCl_2$	1.2×10^{-5}
Lead(II) iodate	$Pb(IO_3)_2$	3.7×10^{-13}
Lead(II) iodide	PbI_2	8.5×10^{-9}
Lead(II) sulphate	$PbSO_4$	1.8×10^{-8}
Magnesium carbonate	$MgCO_3$	6.8×10^{-6}
Magnesium hydroxide	$Mg(OH)_2$	5.6×10^{-12}
Silver bromate	$AgBrO_3$	5.3×10^{-5}
Silver bromide	$AgBr$	5.4×10^{-13}
Silver carbonate	Ag_2CO_3	8.5×10^{-12}
Silver chloride	$AgCl$	1.8×10^{-10}
Silver chromate	Ag_2CrO_4	1.1×10^{-12}
Silver iodate	$AgIO_3$	3.2×10^{-8}
Silver iodide	AgI	8.5×10^{-17}
Strontium carbonate	$SrCO_3$	5.6×10^{-10}
Strontium fluoride	SrF_2	4.3×10^{-9}
Strontium sulphate	$SrSO_4$	3.4×10^{-7}
Zinc sulphide	ZnS	2.0×10^{-25}

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

Periodic Chart of Ions

Table of Polyatomic Ions

acetate	CH_3COO^-	dichromate	$Cr_2O_7^{2-}$	dihydrogen phosphate	$H_2PO_4^-$
ammonium	NH_4^+	cyanide	CN^-	silicate	SiO_3^{2-}
benzoate	$C_6H_5COO^-$	hydroxide	OH^-	sulphate	SO_4^{2-}
borate	BO_3^{3-}	iodate	IO_3^-	sulphite	SO_3^{2-}
carbonate	CO_3^{2-}	nitrate	NO_3^-	hydrogen sulphide	HS^-
hydrogen carbonate	HCO_3^-	nitrite	NO_2^-	hydrogen sulphate	HSO_4^-
chlorate	ClO_3^-	oxalate	$OOCCOO^{2-}$	hydrogen sulphite	HSO_3^-
hypochlorite	ClO^-	permanganate	MnO_4^-	thiocyanate	SCN^-
chromate	CrO_4^{2-}	phosphate	PO_4^{3-}	thiosulphate	$S_2O_3^{2-}$
		hydrogen phosphate	HPO_4^{2-}		

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H^+ hydrogen																	2 He helium
3 Li^+ lithium	4 Be^{2+} Beryllium											5 B boron	6 C carbon	7 N^{3-} nitride	8 O^{2-} oxide	9 F^- fluoride	10 Ne neon
11 Na^+ sodium	12 Mg^{2+} magnesium											13 Al^{3+} aluminum	14 Si silicon	15 P^{3-} phosphide	16 S^{2-} sulfide	17 Cl^- chloride	18 Ar argon
19 K^+ potassium	20 Ca^{2+} calcium	21 Sc^{3+} scandium	22 Ti^{4+} titanium (IV) / Ti^{3+} titanium (III)	23 V^{5+} vanadium (V) / V^{4+} vanadium (IV)	24 Cr^{3+} chromium (III) / Cr^{2+} chromium (II)	25 Mn^{2+} manganese (II) / Mn^{4+} manganese (IV)	26 Fe^{3+} iron (III) / Fe^{2+} iron (II)	27 Co^{2+} cobalt (II) / Co^{3+} cobalt (III)	28 Ni^{2+} nickel (II) / Ni^{3+} nickel (III)	29 Cu^{2+} copper (II) / Cu^+ copper (I)	30 Zn^{2+} zinc	31 Ga^{3+} gallium	32 Ge^{4+} germanium	33 As^{3-} arsenide	34 Se^{2-} selenide	35 Br^- bromide	36 Kr krypton
37 Rb^+ rubidium	38 Sr^{2+} strontium	39 Y^{3+} yttrium	40 Zr^{4+} zirconium	41 Nb^{5+} niobium (V) / Nb^{3+} niobium (III)	42 Mo^{6+} molybdenum	43 Tc^{7+} technetium	44 Ru^{3+} ruthenium (III) / Ru^{4+} ruthenium (IV)	45 Rh^{3+} rhodium	46 Pd^{2+} paladium (II) / Pd^{4+} paladium (IV)	47 Ag^+ silver	48 Cd^{2+} cadmium	49 In^{3+} indium	50 Sn^{4+} tin (IV) / Sn^{2+} tin (II)	51 Sb^{3+} antimony (III) / Sb^{5+} antimony (V)	52 Te^{2-} telluride	53 I^- iodide	54 Xe xenon
55 Cs^+ cesium	56 Ba^{2+} barium	57 La^{3+} lanthanum	72 Hf^{4+} hafnium	73 Ta^{5+} tantalum	74 W^{6+} tungsten	75 Re^{7+} rhenium	76 Os^{4+} osmium	77 Ir^{4+} iridium	78 Pt^{4+} platinum (IV) / Pt^{2+} platinum (II)	79 Au^{3+} gold (III) / Au^+ gold (I)	80 Hg^{2+} mercury (II) / Hg^+ mercury (I)	81 Tl^+ thallium (I) / Tl^{3+} thallium (III)	82 Pb^{2+} lead (II) / Pb^{4+} lead (IV)	83 Bi^{3+} bismuth (III) / Bi^{5+} bismuth (V)	84 Po^{2+} polonium (II) / Po^{4+} polonium (IV)	85 At^- astatide	86 Rn radon
87 Fr^+ francium	88 Ra^{2+} radium	89 Ac^{3+} actinium															

KEY

26 Fe^{3+} iron (III) / Fe^{2+} iron (II)

atomic number → 26; ion charge → Fe^{3+}; stock name (IUPAC) → iron (III); symbol → Fe

58 Ce^{3+} cerium	59 Pr^{3+} praseodymium	60 Nd^{3+} neodymium	61 Pm^{3+} promethium	62 Sm^{3+} samarium (III) / Sm^{2+} samium(II)	63 Eu^{3+} europium (III) / Eu^{2+} europium(II)	64 Gd^{3+} gadolinium	65 Tb^{3+} terbium	66 Dy^{3+} dysprosium	67 Ho^{3+} holmium	68 Er^{3+} erbium	69 Tm^{3+} thulium	70 Yb^{3+} ytterbium (III) / Yb^{2+} ytterbium (II)	71 Lu lutetium
90 Th^{4+} thorium	91 Pa^{5+} protactinium (V) / Pa^{4+} protactinium(IV)	92 U^{6+} uranium (VI) / U^{4+} uranium (IV)	93 Np^{5+} neptunium	94 Pu^{4+} plutonium (IV) / Pu^{6+} plutonium (VI)	95 Am^{3+} americium (III) / Am^{4+} americium (IV)	96 Cm^{3+} curium	97 Bk^{3+} berkelium (III) / Bk^{4+} berkelium (IV)	98 Cf^{3+} californium	99 Es^{3+} einsteinium	100 Fm^{3+} fermium	101 Md^{2+} mendelevium(II) / Md^{3+} mendelevium (III)	102 No^{2+} nobelium (II) / No^{3+} nobelium (III)	103 Gd^{3+} lawrencium

PERIODIC TABLE OF THE ELEMENTS

14	Atomic Number
Si	Symbol
Silicon	Name
28.1	Atomic Mass

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4	63 **Eu** Europium 152.0	64 **Gd** Gadolinium 157.3	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0	71 **Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.