Solution Chemistry

Solutions for a Mixed Up World

The Physical Science Series

Solution Chemistry Index

Florida Sunshine State Standards

SC.C.2.4.2 know that electrical forces exist between any two charged objects.

SC.A.2.4.2 know the difference between an element, a molecule, and a compound.

SC.H.3.4.3 know that scientists can bring information, insights, and analytical skills to matters of public concern and help people understand the possible causes and effects of events.

SC.A.1.4.2 know that the vast diversity of the properties of materials is primarily due to variations in the forces that hold molecules together

SC.A.1.4.3 know that a change from one phase of matter to another involves a gain or loss of energy.

SC.A.1.4.5 know that connections (bonds) form between substances when outer-shell electrons are either transferred or shared between their atoms, changing the properties of substances.

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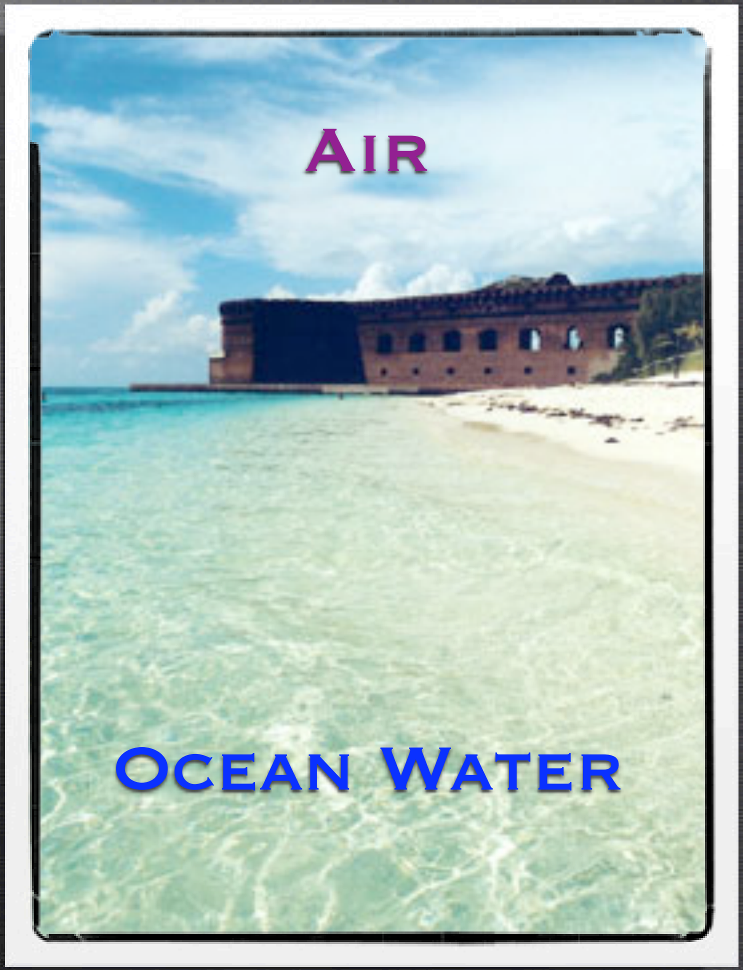
What is a Solution?

- A homogenous mixture. It is the same throughout - all parts are evenly mixed. A sample from the top would be the same as from the bottom of the solution.
- Made of a solvent and one or more solutes. Solvent > Solute
- Does not settle upon standing, scatter light or filter out. Cannot see the particles.
- Particles are less than 1 x 10 -9 m in size: composed of atoms, ions or molecules.

Solutions are homogeneous mixtures. What solutions can be found in this picture?

What are the solvents and solutes?



Solutions: Solvents & Solutes

Name of Solution	Solvent	Solute
Ocean Water	Water	Salt, O_2, CO_2...
Filtered Air	N_2 (78%)	O_2 (21%), H_2O, CO_2
Colas	Water	Sugar, CO_2, flavoring
Alcoholic Beverages	Water	Ethyl Alcohol
14 K Gold	Gold (58%)	Copper (42%)

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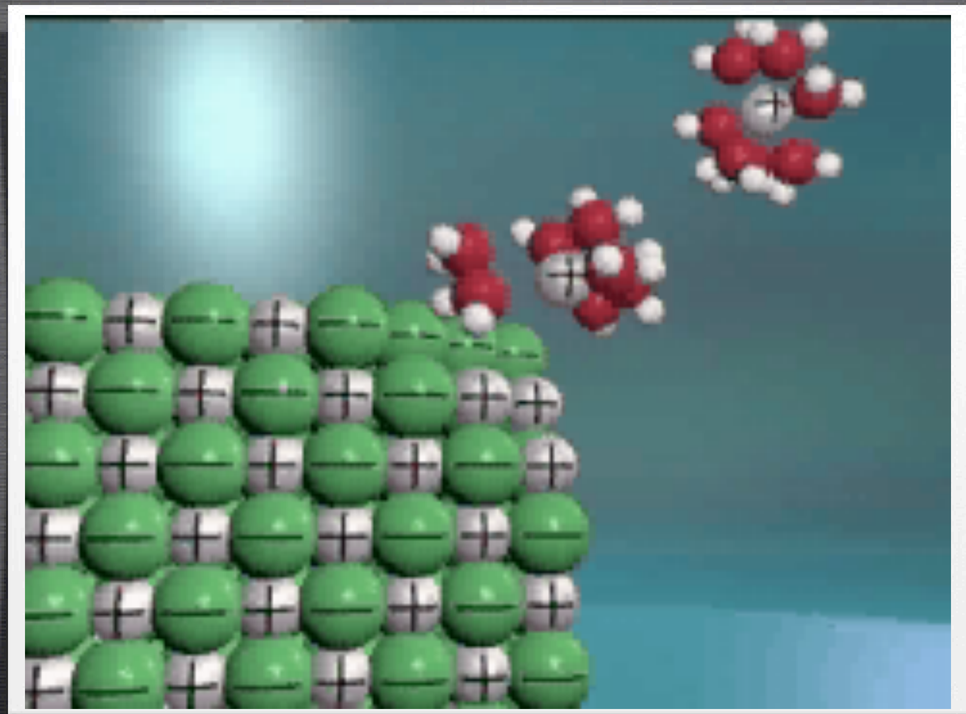
What happens when ionic compounds dissolve in water to make a solution?



The crystalline lattice breaks apart and individual ions go out into the water. This is the reason why the solute disappears.

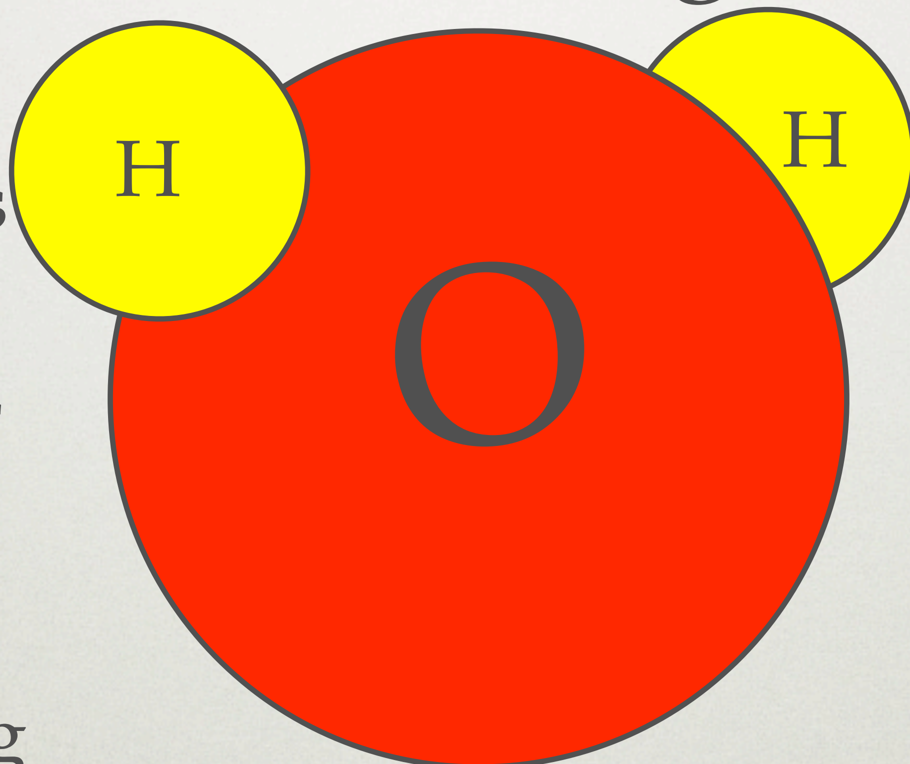
This process is called **Dissociation**.

Water: A Polar Molecule

Polar covalent compounds have a partial charge at each end of the molecule.

A water molecule is polar because the 8 protons in the oxygen nucleus pull the 10 electrons closer to the oxygen end of the molecule, giving it a partial negative charge.

δ + charge



δ - charge

The hydrogen end of the molecule becomes charged partial positive. This is due to the protons of the hydrogen atoms sticking out near that end of the molecule.

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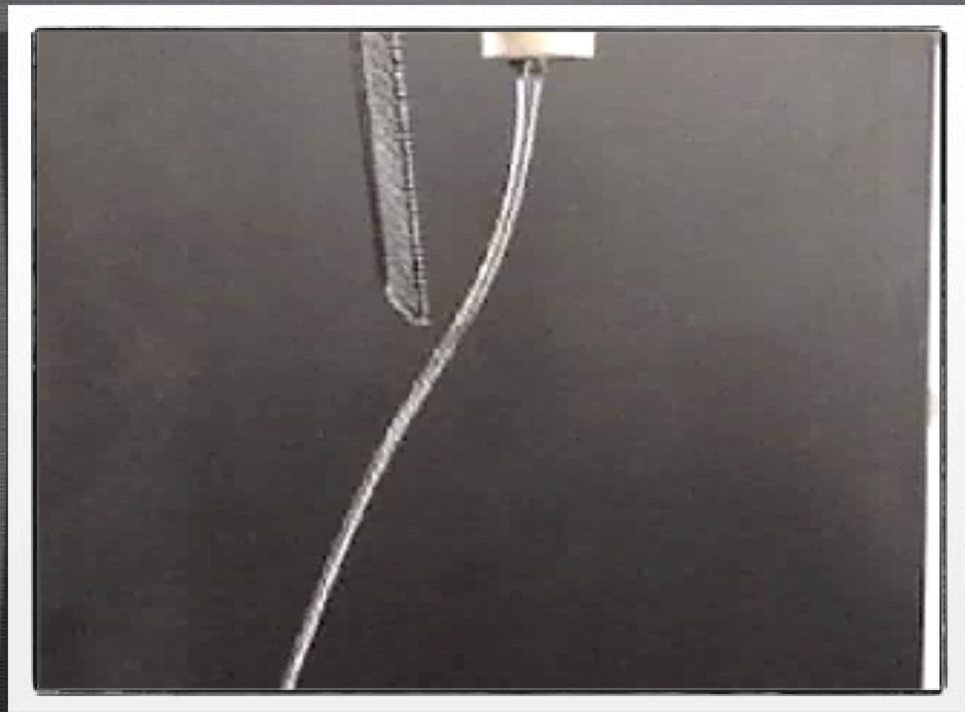
Water: A Polar Molecule

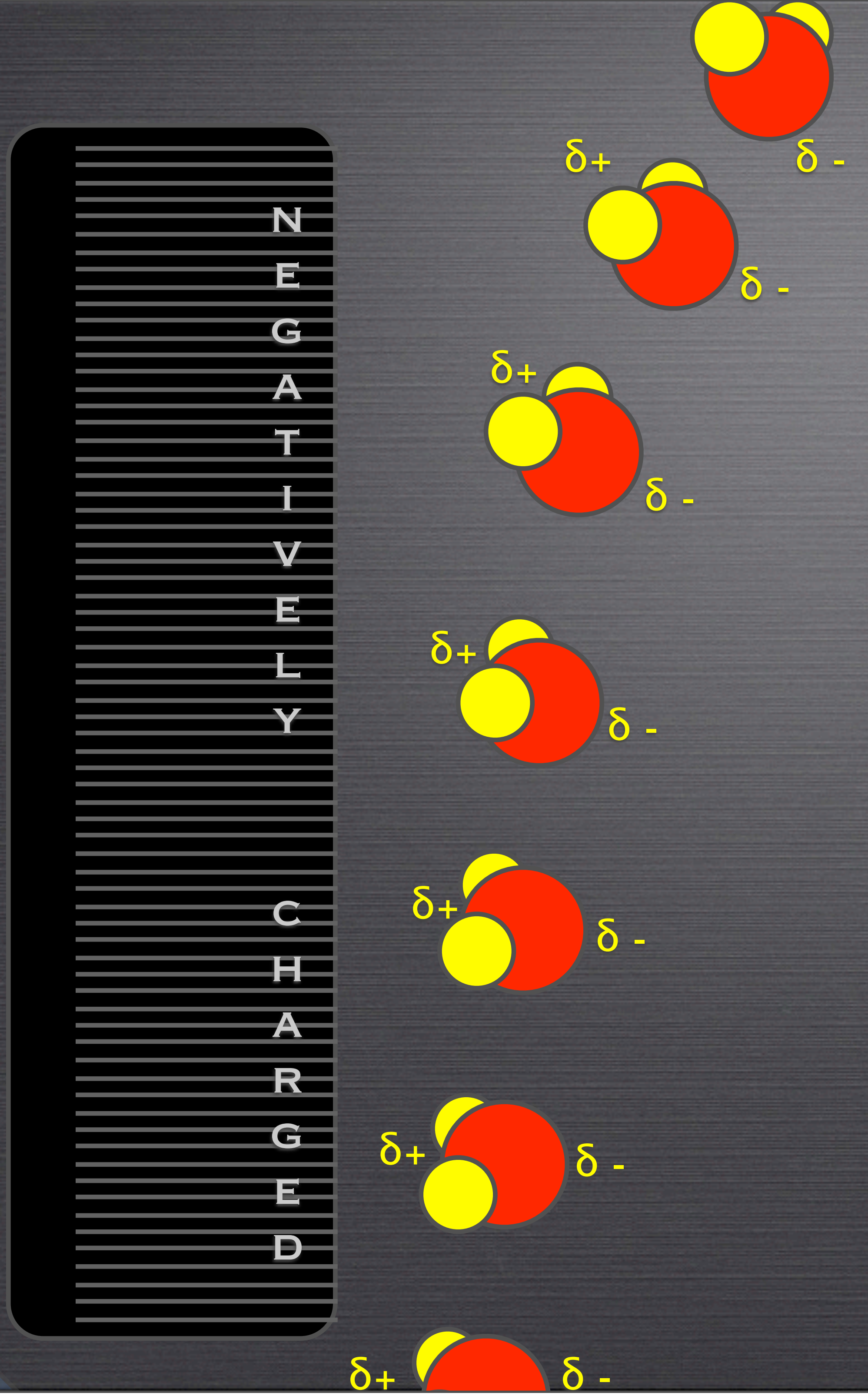


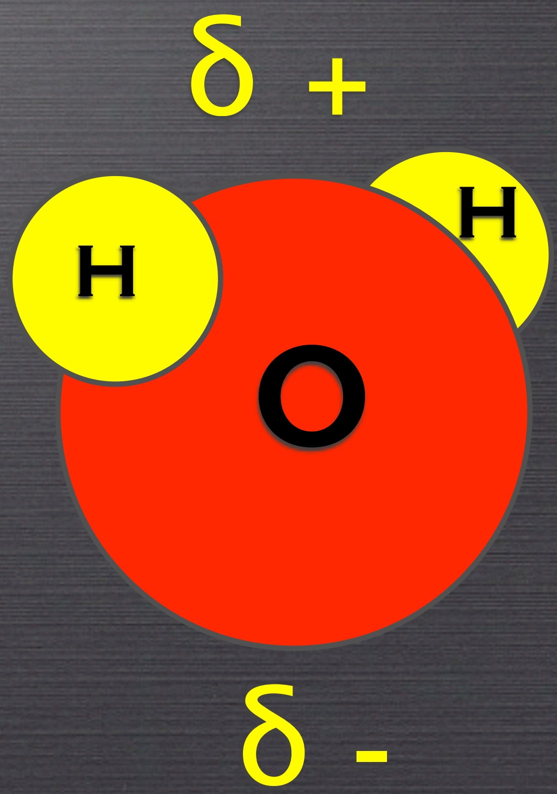
Explanation:

As you comb your hair you strip electrons off your hair. Your comb, collecting these electrons, becomes negatively charged.

when you place a negatively charged comb near a stream of water, the partial positively charged end (hydrogen end) of a water molecule are attracted and pulled towards the comb.

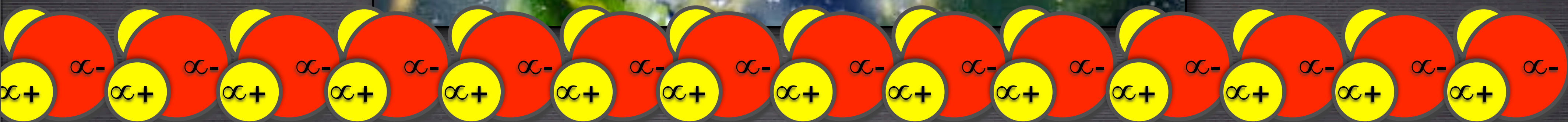
WHY DOES A COMB ATTRACT A STREAM OF WATER?





Surface Tension

Jump to Acids



The partially + charged hydrogen end of a water molecule is attracted to the partially - charged oxygen end of another molecule. At the surface this causes surface tension. To enter the water, one must break apart this attraction.

What animal makes use of surface tension?

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Some substances, such as carbon tetrachloride (CCl_4) do not dissolve in water.

Carbon tetrachloride is **immiscible** in water. Ionic Iodine is soluble in carbon tetrachloride, but is immiscible in water.

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Molarity:
A Solution's
Concentration

The Concentration of Solutions

- Concentration is the amount of solute dissolved in a fixed amount of solution.
- The concentration of a solution is measured in Molarity - the number of moles of solute dissolved in one liter of solution. In aqueous solutions, the solvent is water.

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{liter of solution}}$$

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How can you make 250 mL of a 0.350 M Copper(II) Nitrate Solution?

1) Write the formula & molar mass of the solute.

Formula: $Cu(NO_3)_2$ Molar Mass: 187.56 grams

2) Calculate the amount of solute need to make 1.00 L of 0.350 M Copper Nitrate solution.

$$\frac{0.350\ \cancel{M}}{1} \Big| \frac{187.56\ \text{grams}}{1\ \cancel{\text{mole}}} = 65.6\ \text{grams}$$

3) Set up a proportion to calculate how much solute is needed to make 250 mL of the solution.

$$\frac{65.6\ \text{grams}}{1.00\ \text{L}} = \frac{X}{0.250\ \text{L}}$$

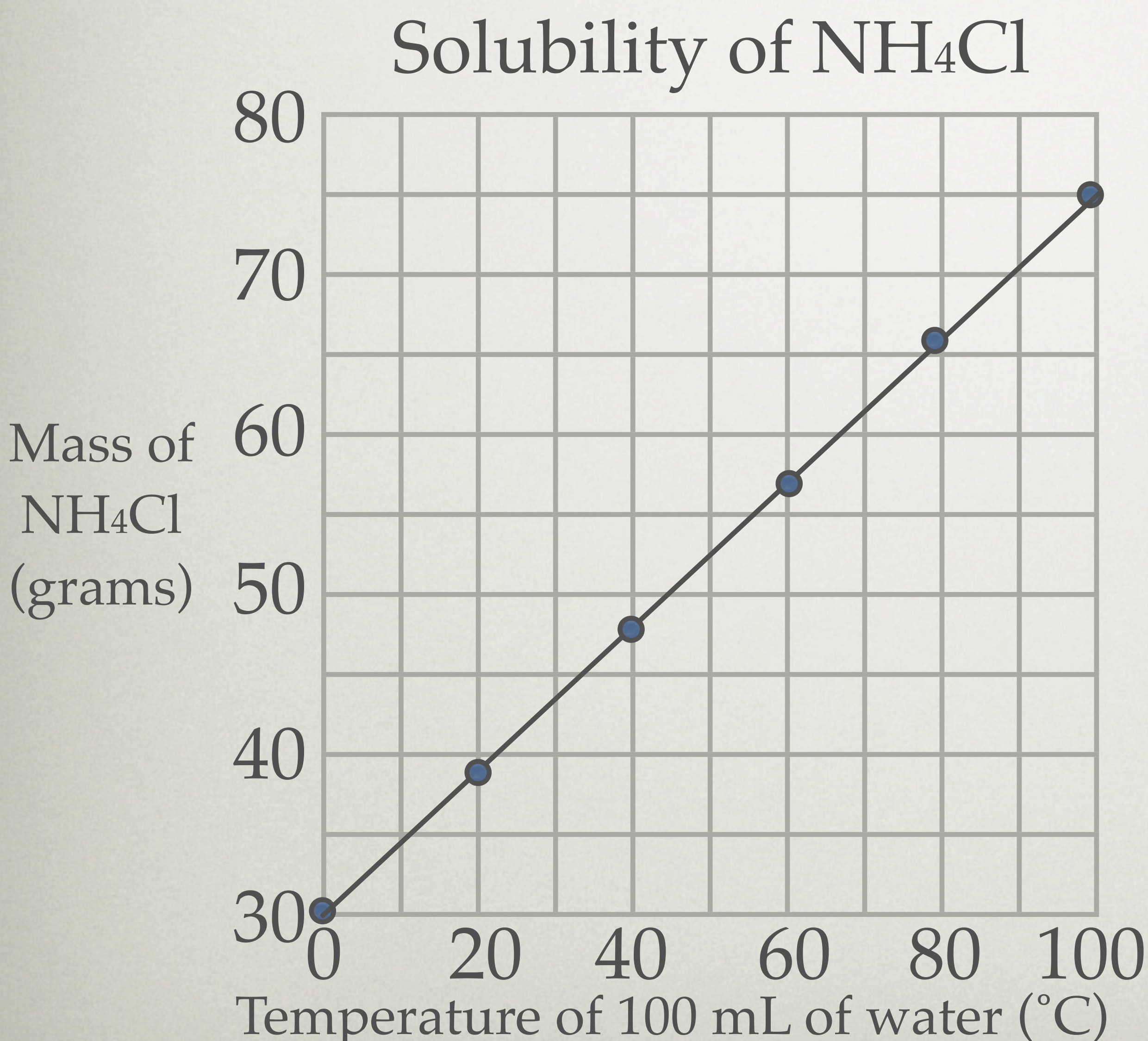
$$X = \frac{65.6\ \text{grams} \times 0.250\ \cancel{\text{L}}}{1.00\ \cancel{\text{L}}} = 16.4\ \text{grams}$$

Solubility of Salt in 100 ml of Water

Temperature	Mass of Salt able to dissolve
0° C	34 g
20° C	35 g
40° C	36 g
60° C	37 g
80° C	38 g
100° C	39 g

The solubility of most ionic compounds increases with an increase in temperature.

Solubility: How much solute will dissolve in a solvent.



Temperature effects the amount of solute you can dissolve in a fixed amount of solvent. Below is a table showing the maximum amount of ammonium chloride one can dissolve in 100 mL of water at various temperatures.

temperature	mass of NH_4Cl
0˚ C	30 g
20˚ C	38 g
40˚ C	45 g
60˚ C	56 g
80˚ C	66 g
100˚ C	75 g

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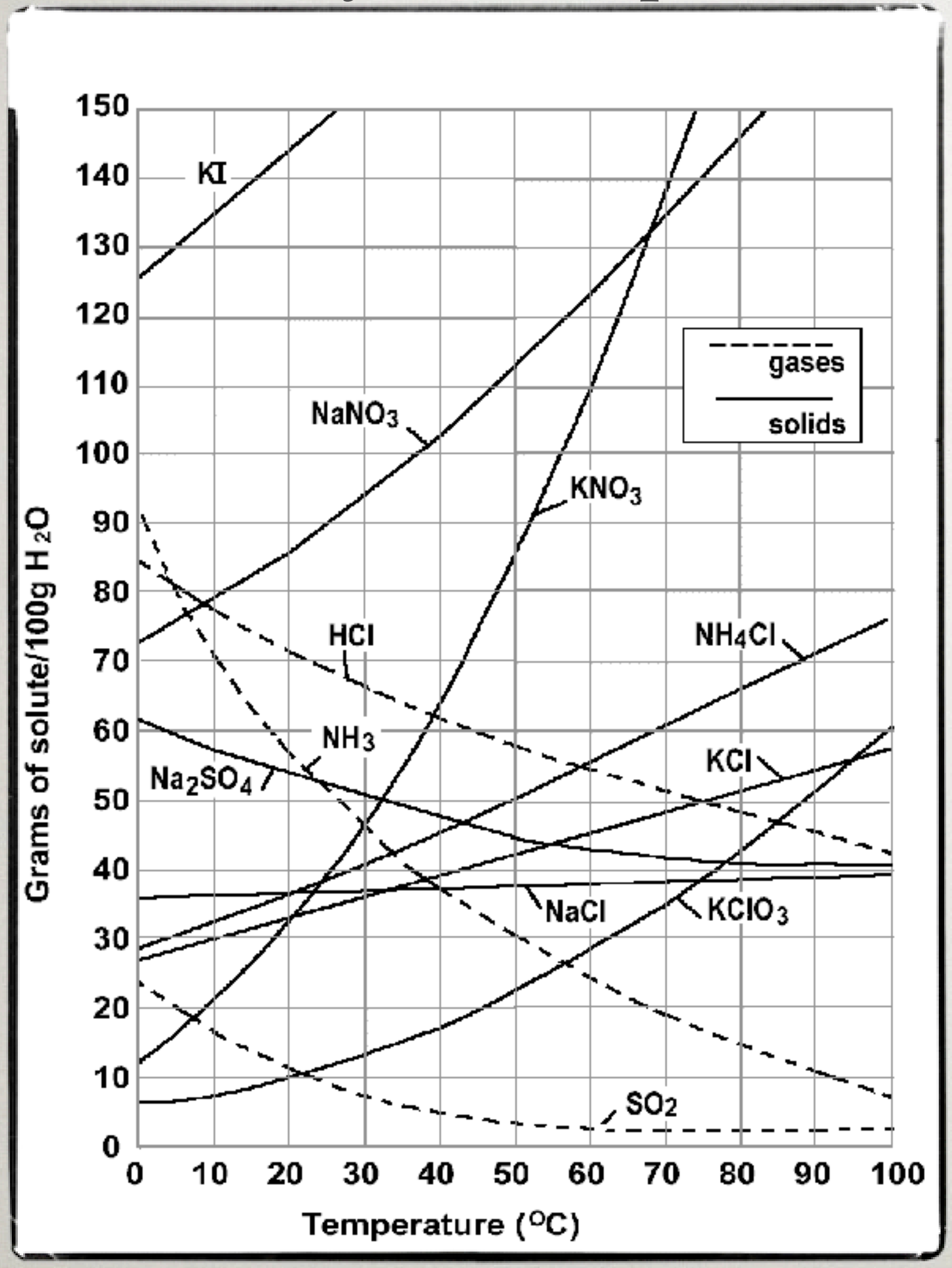
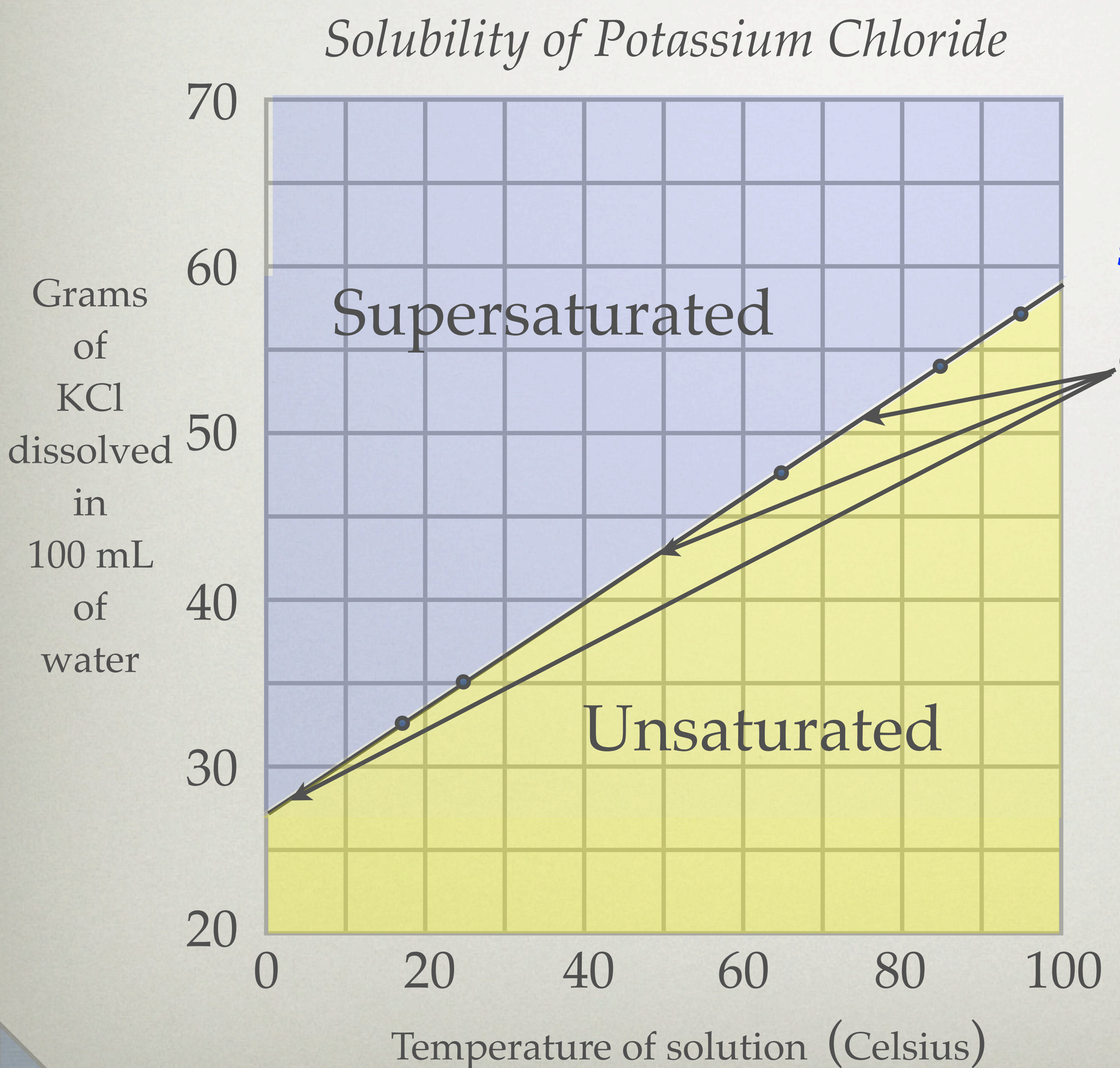
Solubility of Compounds



Solubility Curve

A solubility curve shows how temperature effects the amount of solute that can be dissolved in 100 mL of water.

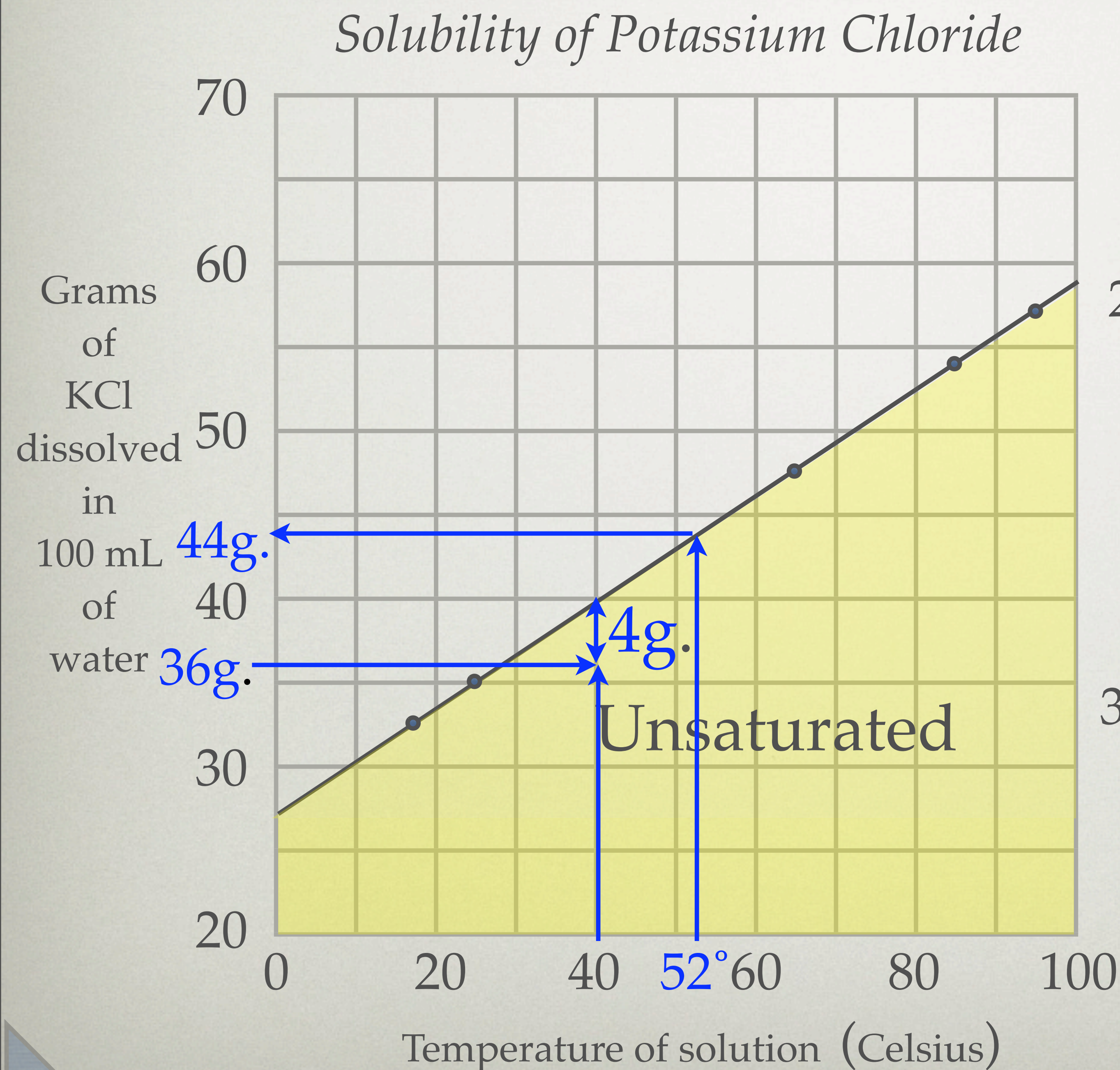
Solubility Curve



A solution that is saturated has the maximum amount of solute dissolved in the solvent at that temperature.

- Any point below the curve: the solution is unsaturated.
- Any point on the curve: the solution is saturated.
- Any point above the curve: the solution is supersaturated.

Extrapolating & Interpolating with a Solubility Curve



1. How much KCl can be dissolved in 100 mL of water at 52˚C?

44 grams

2. Is 36 g of KCl dissolved in 100 mL of water at 40˚ C saturated, unsaturated or supersaturated?

Unsaturated

3. How many more grams of KCl can be dissolved in the solution at that temperature?

4 grams

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Acids

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Acids

Acids are polar covalent compounds that ionize in solution to produce hydronium ions.

$$HX_{(g)} + H_2O_{(l)} \longrightarrow H_3O^{+}_{(aq)} + X^{-}_{(aq)}$$

Binary Acids

$HCl_{(aq)}$ - hydrochloric acid

$HF_{(aq)}$ - hydrofluoric acid

$HBr_{(aq)}$ - hydrobromic acid

$HI_{(aq)}$ - hydroiodic acid

Ternary Acids

$HNO_3\,_{(aq)}$ - nitric acid

$HNO_2\,_{(aq)}$ - nitrous acid

$H_2SO_4\,_{(aq)}$ - sulfuric acid

$H_2SO_3\,_{(aq)}$ - sulfurous acid

$H_2CO_3\,_{(aq)}$ - carbonic acid

$H_3PO_4\,_{(aq)}$ - phosphoric acid

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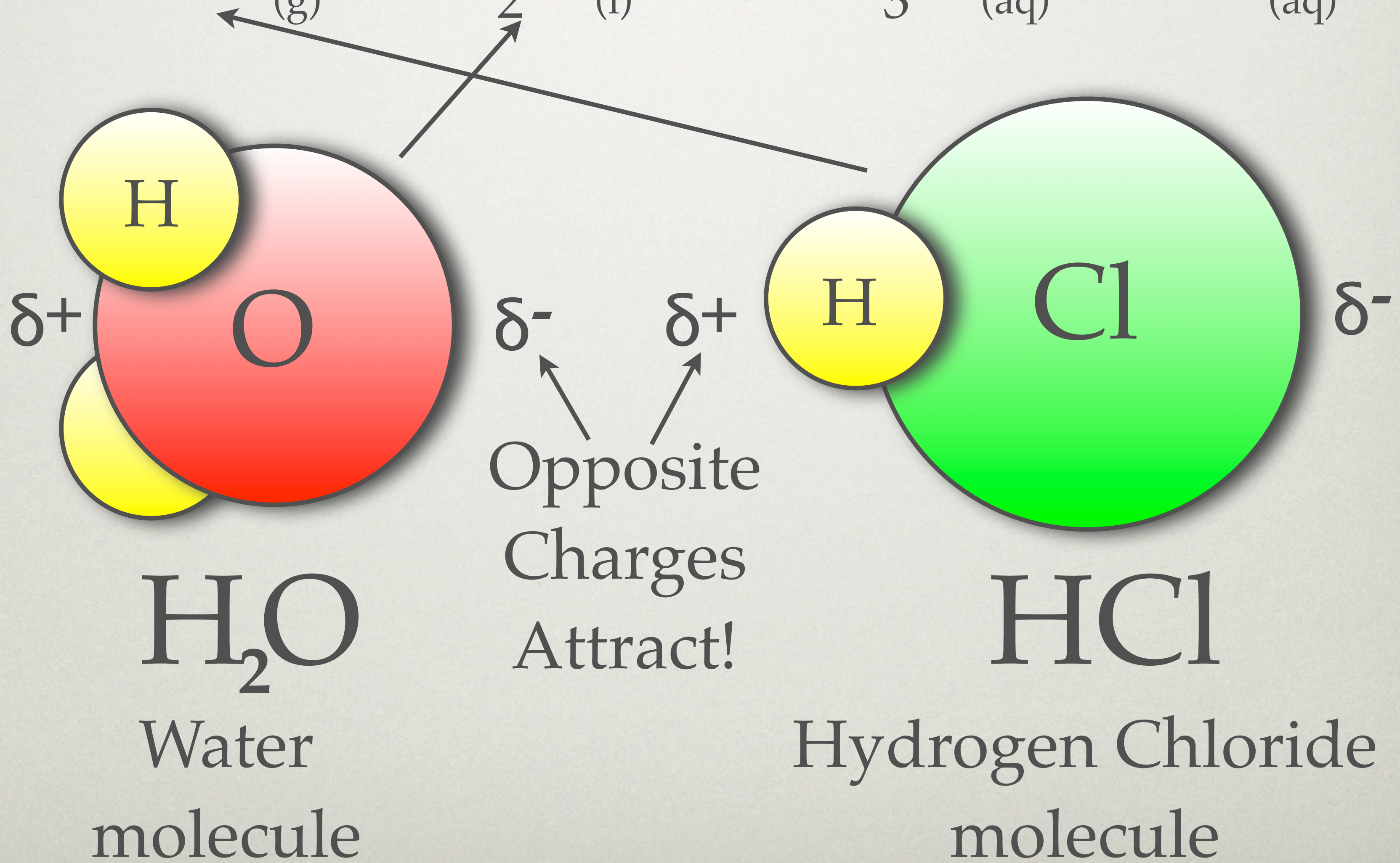
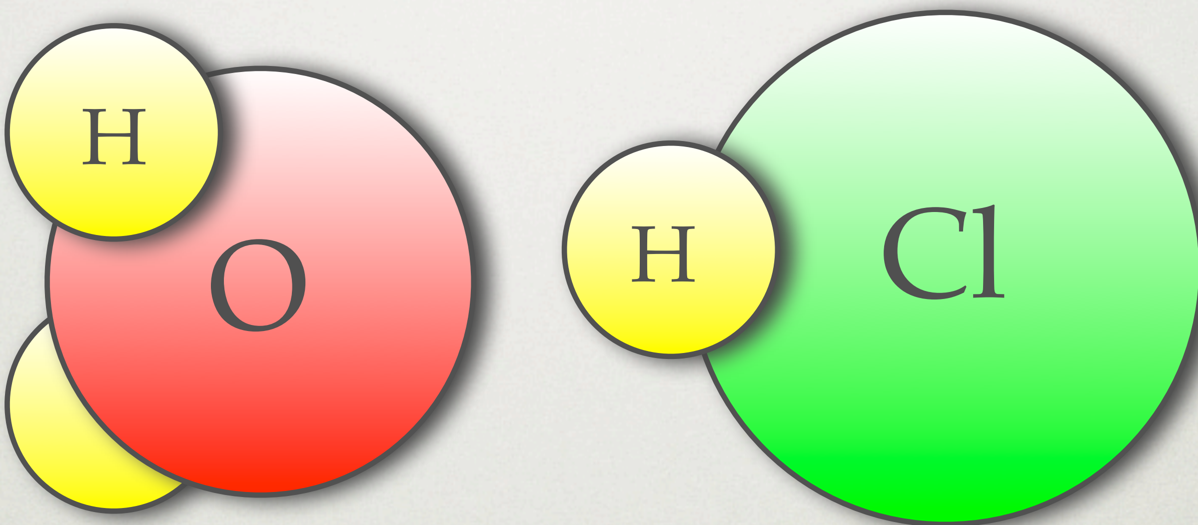
Ionization of an Acid: Hydrogen Chloride

$$HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$



Ionization of an Acid: Hydrogen Chloride

$$HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$$

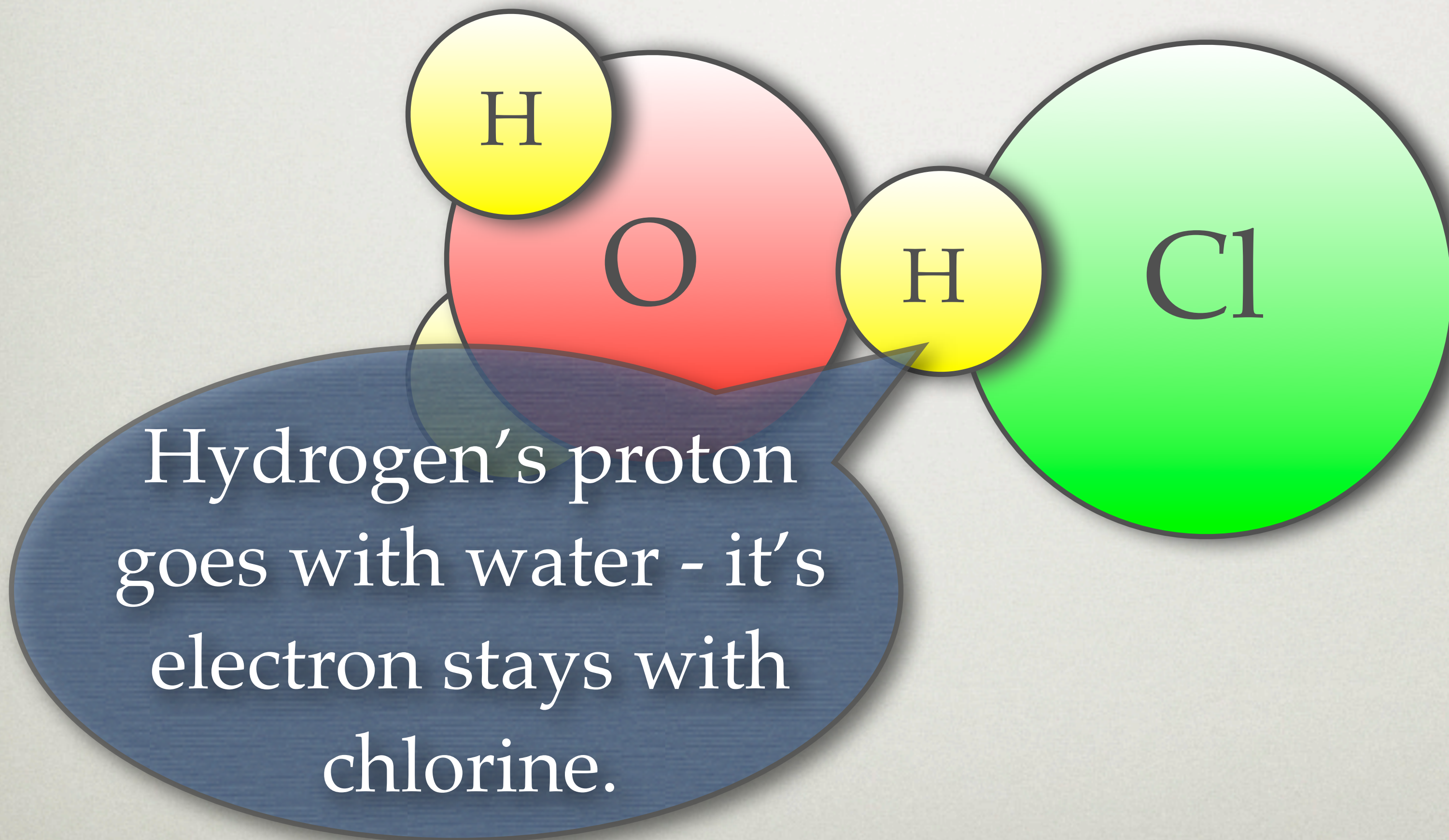


Water molecule

Hydrogen Chloride molecule

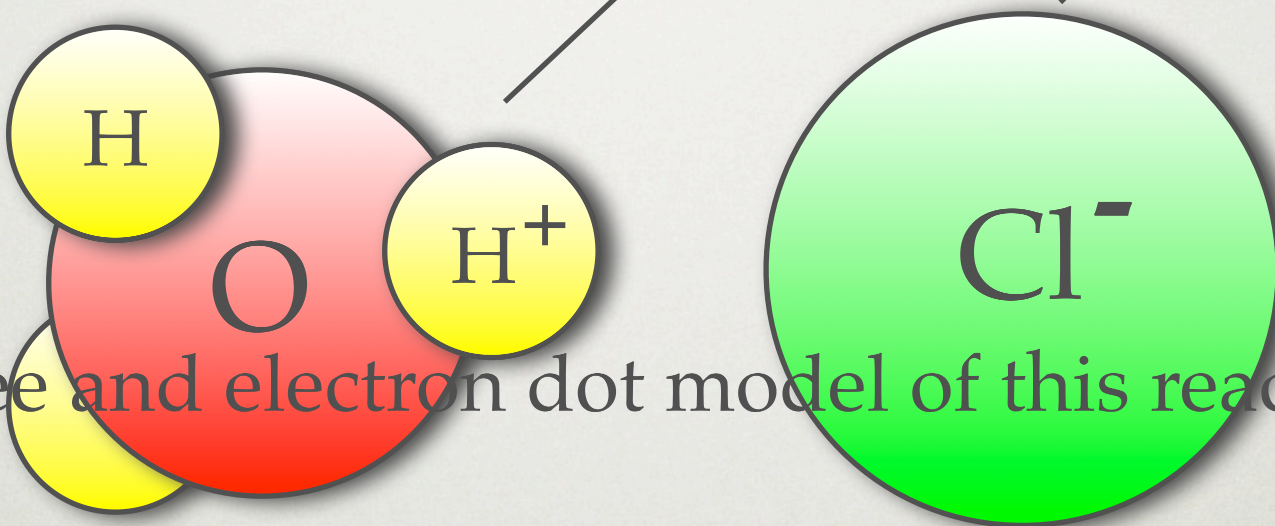
Ionization of an Acid: Hydrogen Chloride

$$HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^{+}_{(aq)} + Cl^{-}_{(aq)}$$



Ionization of an Acid: Hydrogen Chloride

$$HCl_{(g)} + H_2O_{(l)} \rightarrow H_3O^{+}_{(aq)} + Cl^{-}_{(aq)}$$



Let’s see and electron dot model of this reaction.

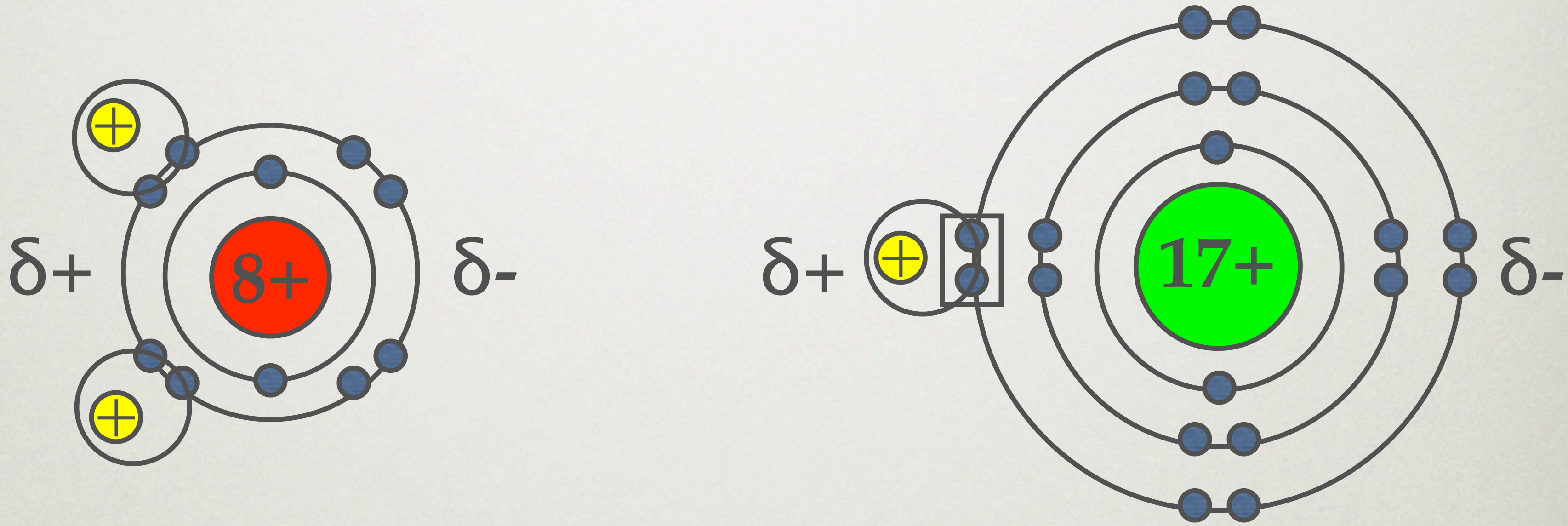
H_3O^+

Hydronium ion

Cl^-

Chloride ion

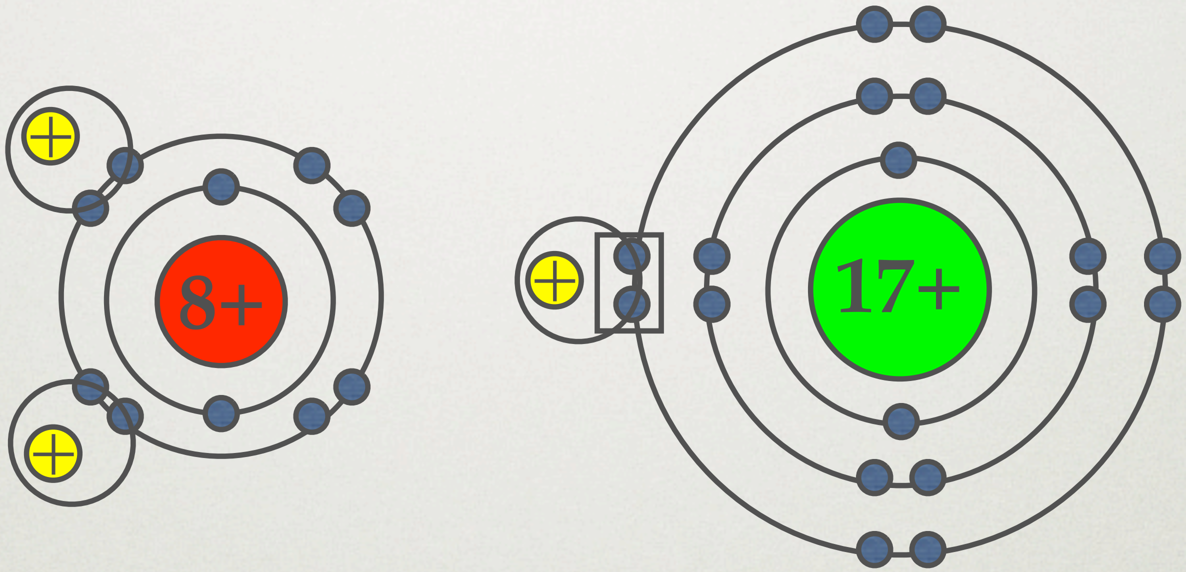
Ionization of an Acid: Hydrogen Chloride



Water molecule

Hydrogen Chloride molecule

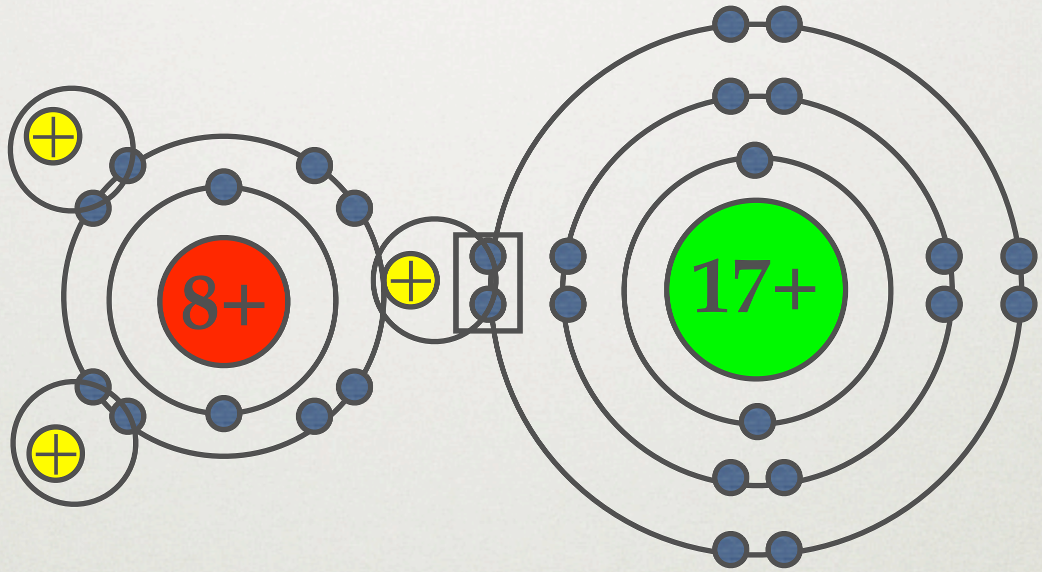
Ionization of an Acid: Hydrogen Chloride



Water molecule

Hydrogen Chloride molecule

Ionization of an Acid: Hydrogen Chloride



Water molecule

Hydrogen Chloride molecule

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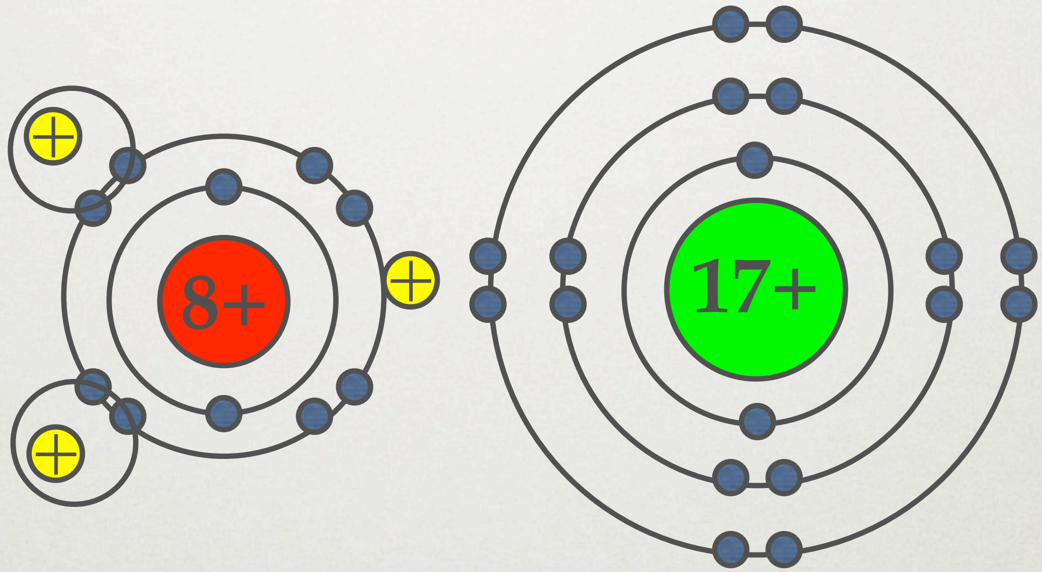
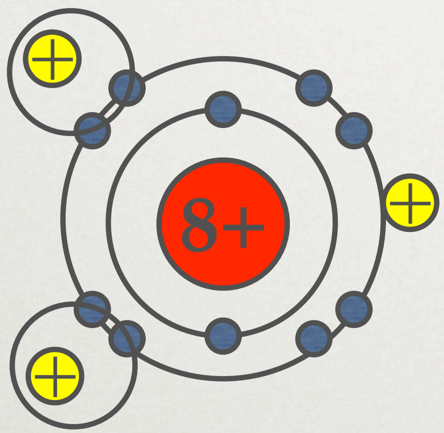
Ionization of an Acid: Hydrogen Chloride



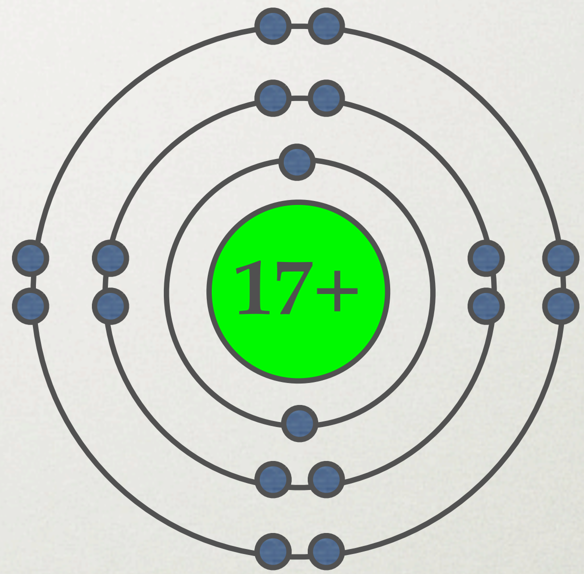
Ionization of an Acid: Hydrogen Chloride

11 +
10 -
1 +



H_3O^+

Hydronium ion



17 +
18 -
1 -

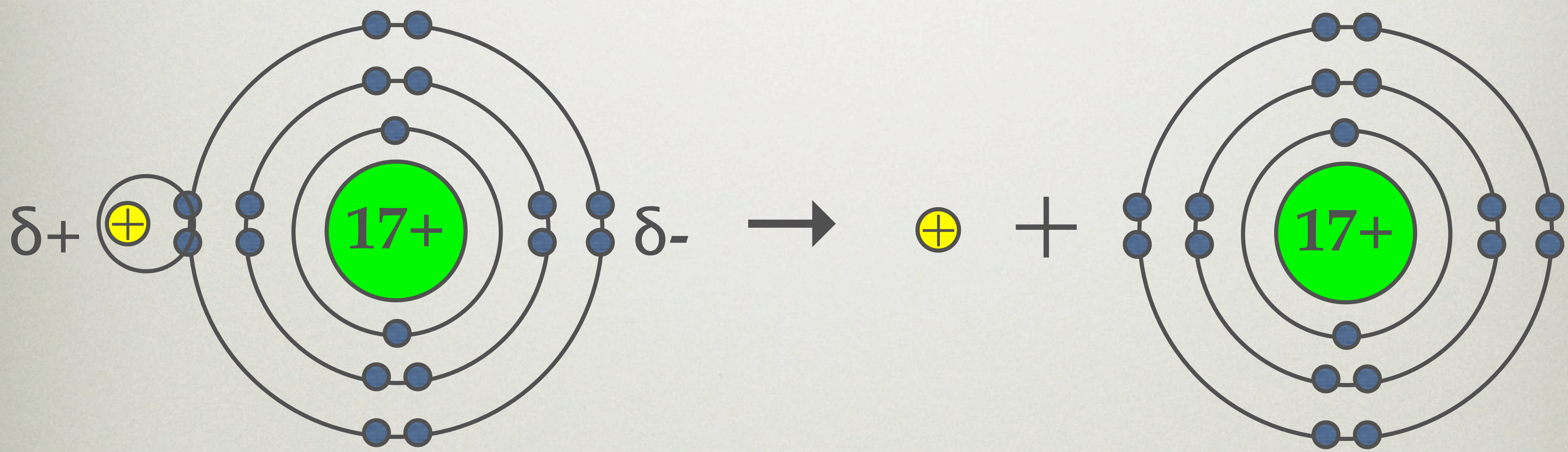
Cl^-

Chloride ion

Go back

Looking at just the Hydrogen Chloride Molecule

$$HCl_{(g)} \rightarrow H^{+}_{(aq)} + Cl^{-}_{(aq)}$$



Hydrogen Chloride molecule → Hydrogen ion + Chloride ion

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Ionization of some Binary Acids

hydrogen fluoride + water → hydronium ion + fluoride

$$HF_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + F^-_{(aq)}$$

hydrogen bromide + water → hydronium ion + bromide

$$HBr_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Br^-_{(aq)}$$

hydrogen iodide + water → hydronium ion + iodide

$$HI_{(g)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + I^-_{(aq)}$$

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Bases

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Bases

Bases are ionic compounds that, when dissolved in water, produce hydroxide ions (OH^-).

Examples of bases are:
sodium hydroxide - $NaOH$
calcium hydroxide - $Ca(OH)_2$
strontium hydroxide - $Sr(OH)_2$
iron(II) hydroxide - $Fe(OH)_2$
ammonium hydroxide NH_4OH

Dissociation of Common Bases

Sodium hydroxide → sodium ion + hydroxide ion

$$NaOH_{(s)} \rightarrow Na^{+}_{(aq)} + OH^{-}_{(aq)}$$

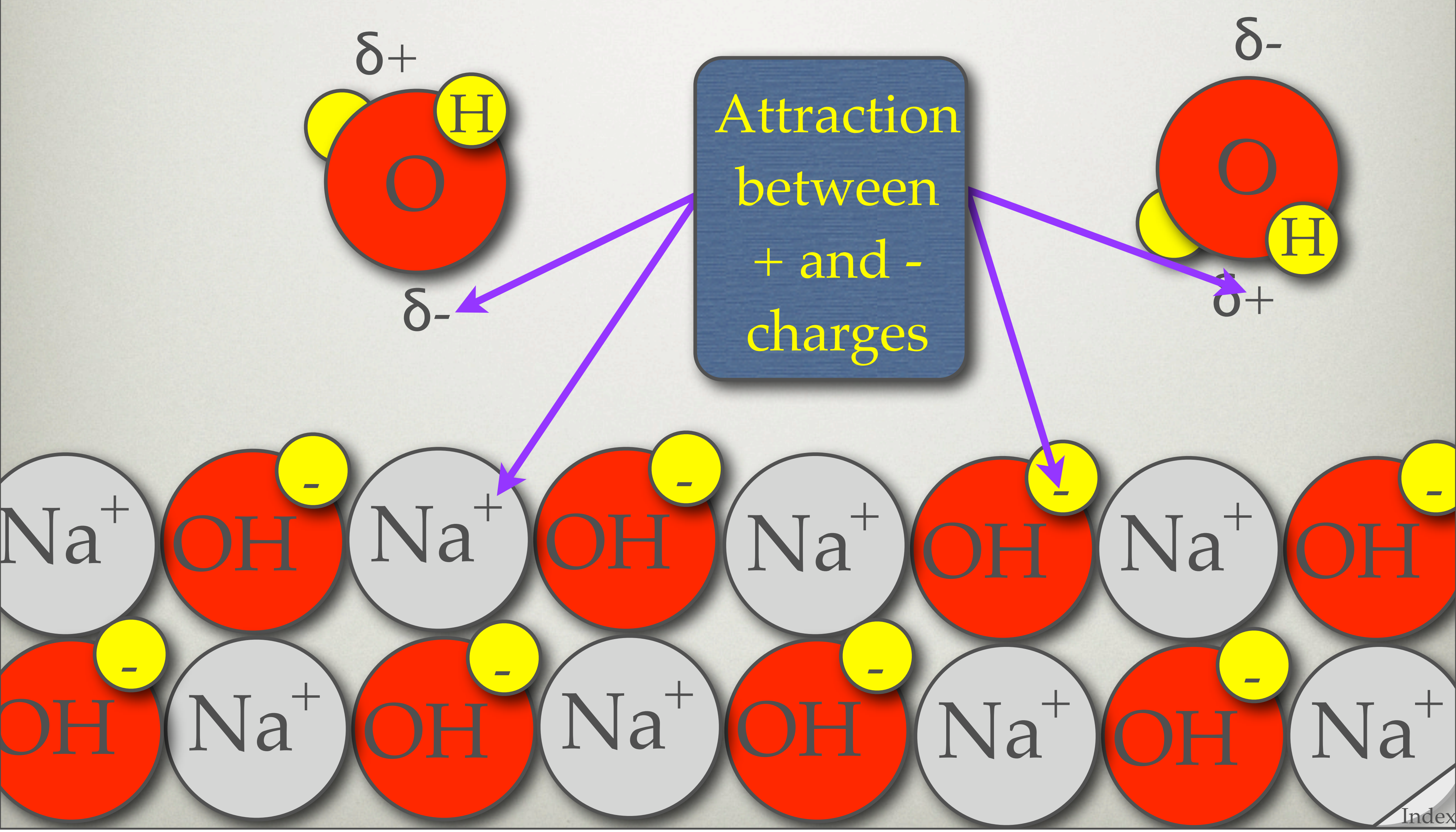
Potassium hydroxide → potassium ion + hydroxide ion

$$KOH_{(s)} \rightarrow K^{+}_{(aq)} + OH^{-}_{(aq)}$$

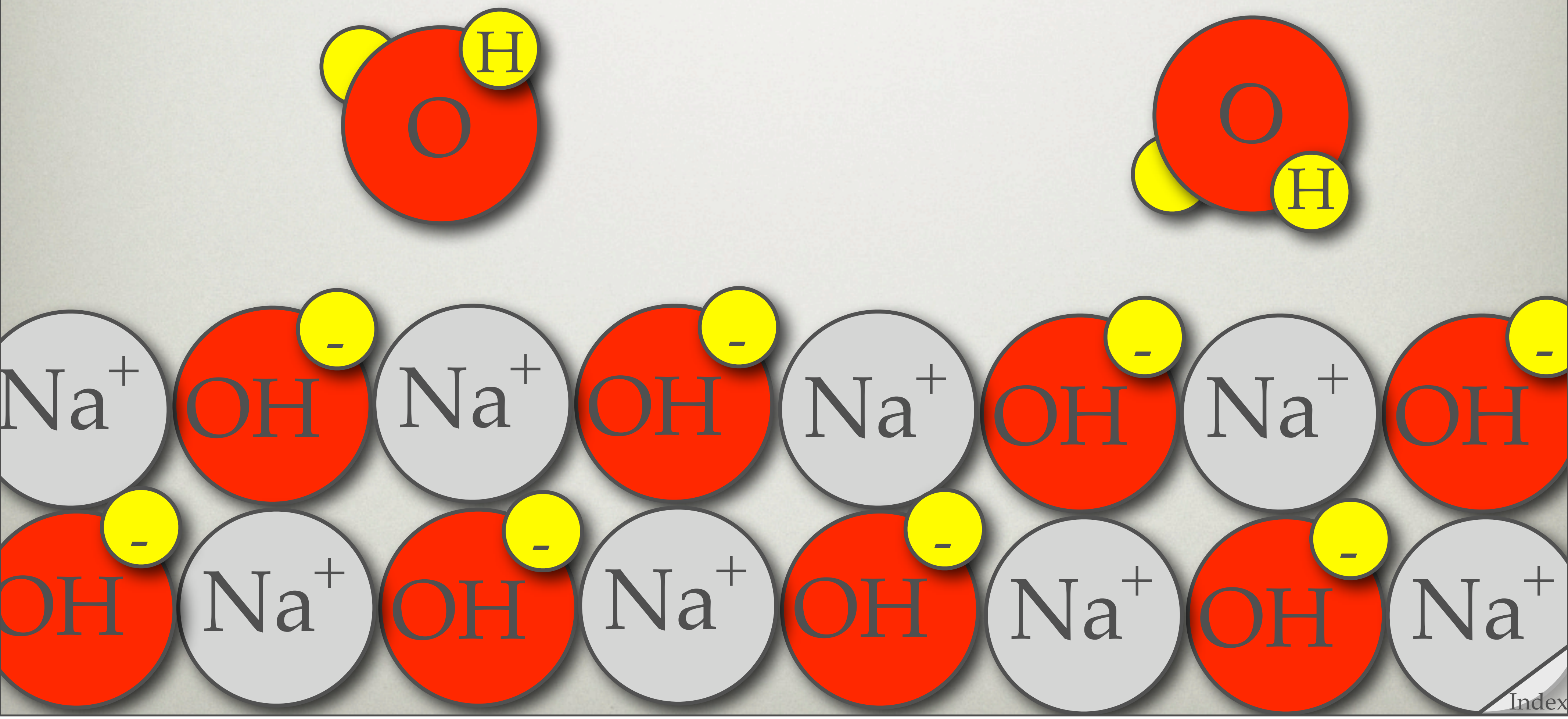
Lithium hydroxide → lithium ion + hydroxide ion

$$LiOH_{(s)} \rightarrow Li^{+}_{(aq)} + OH^{-}_{(aq)}$$

Dissociation of Sodium Hydroxide



Dissociation of Sodium Hydroxide



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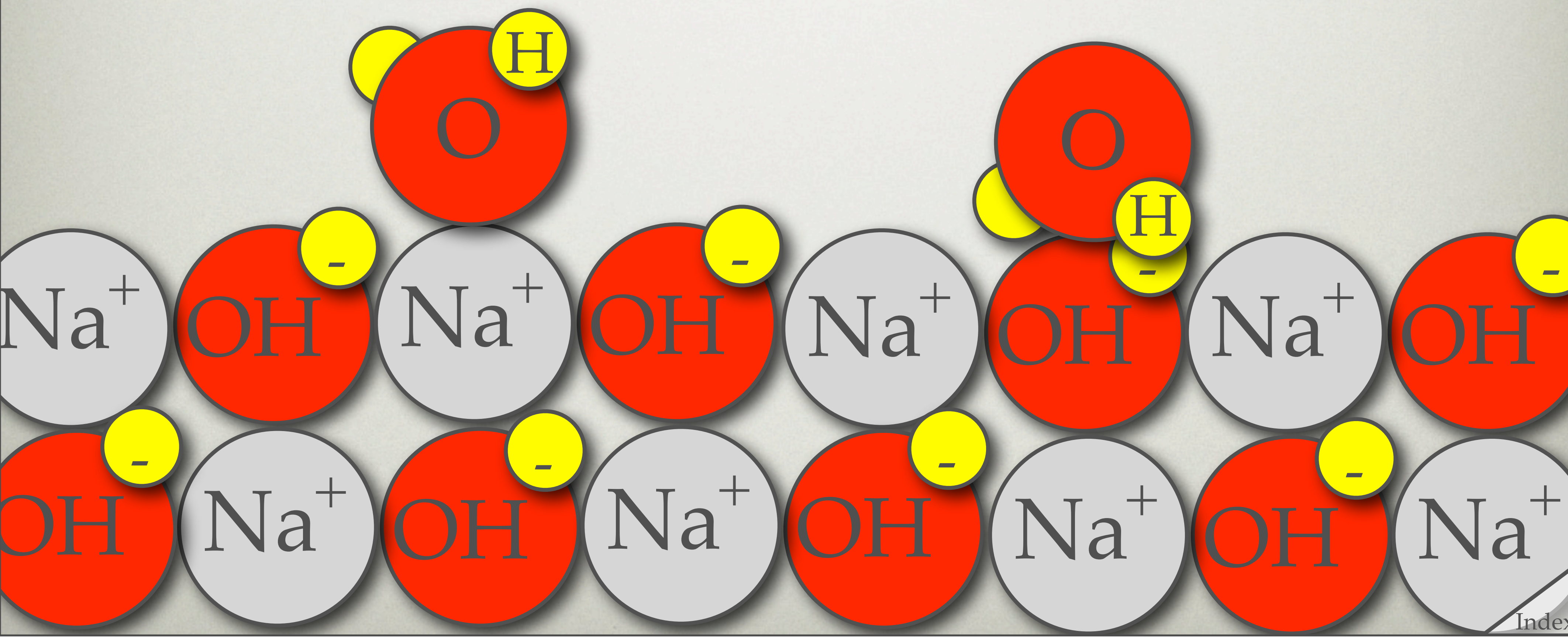
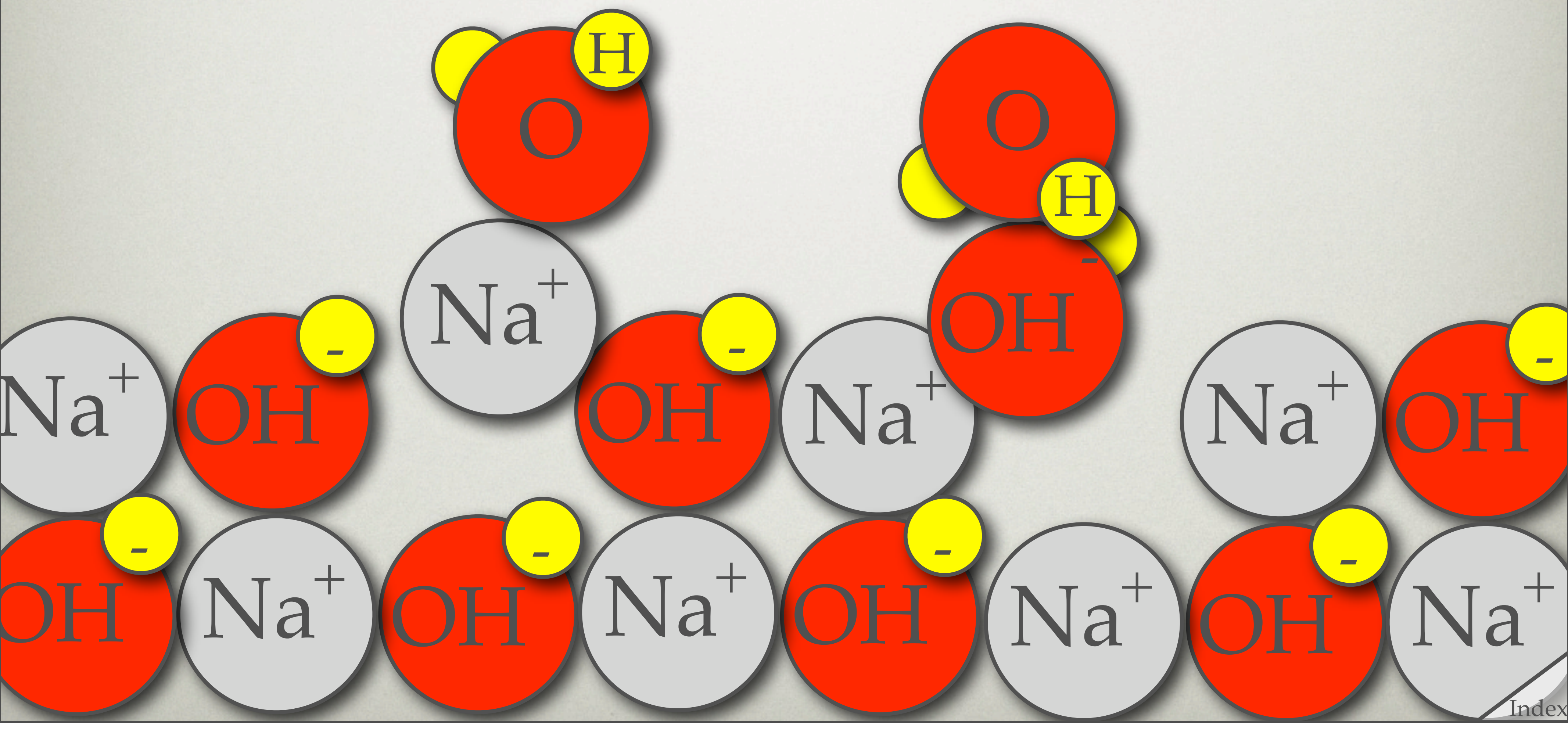
Dissociation of Sodium Hydroxide



Dissociation of Sodium Hydroxide



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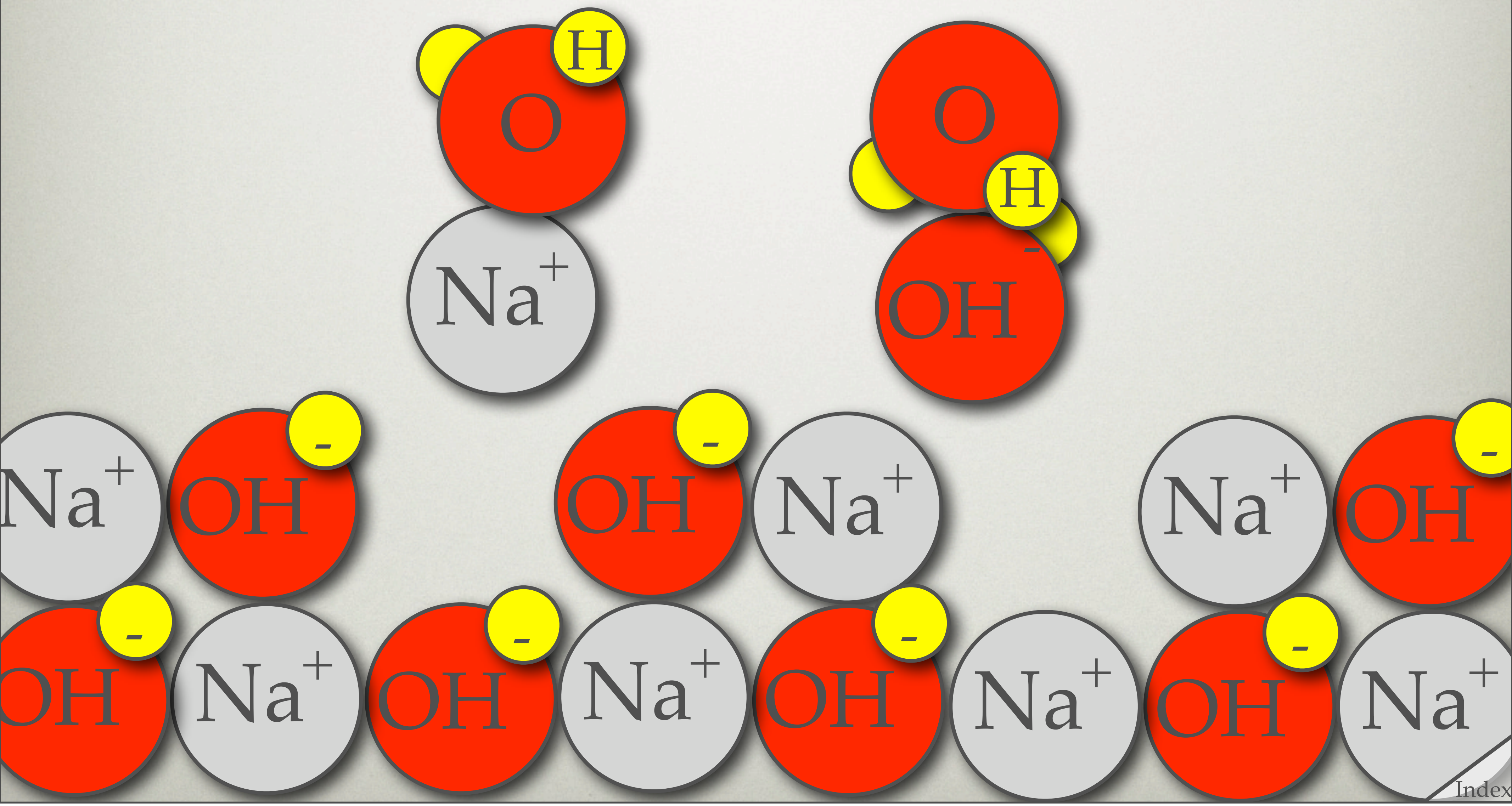
Dissociation of Sodium Hydroxide



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Ionization Vs. Dissociation

- Ionization of a acids produces hydrogen ions. A hydrogen atom loses an electron to become a hydrogen ion. H atoms → H+ ions
- Dissociation of bases occurs when the crystalline lattice, composed of ions, breaks apart into individual ions. Ions already existed in the lattice so we cannot say that bases ionize in solution - instead they dissociate (break apart).

Acid-Base Indicators

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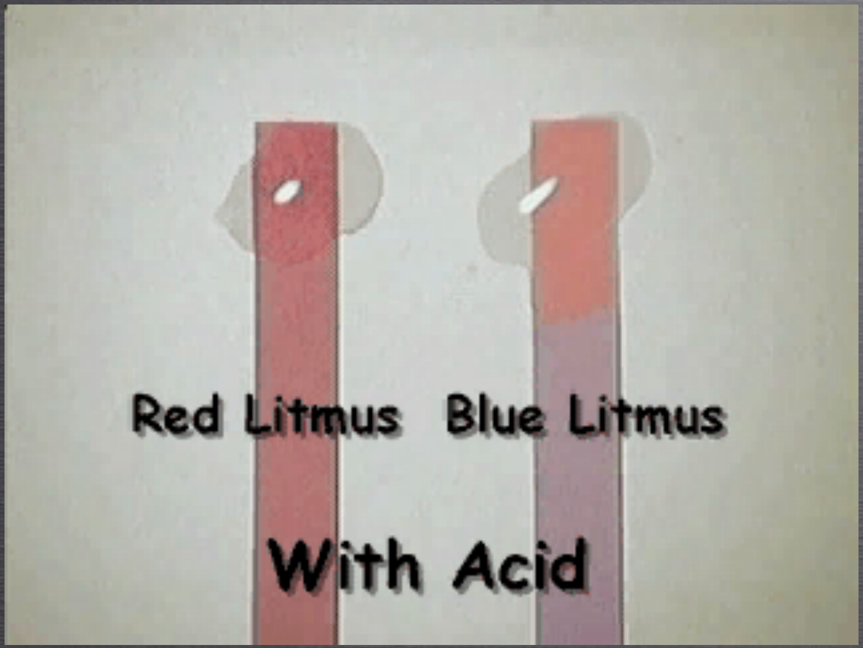
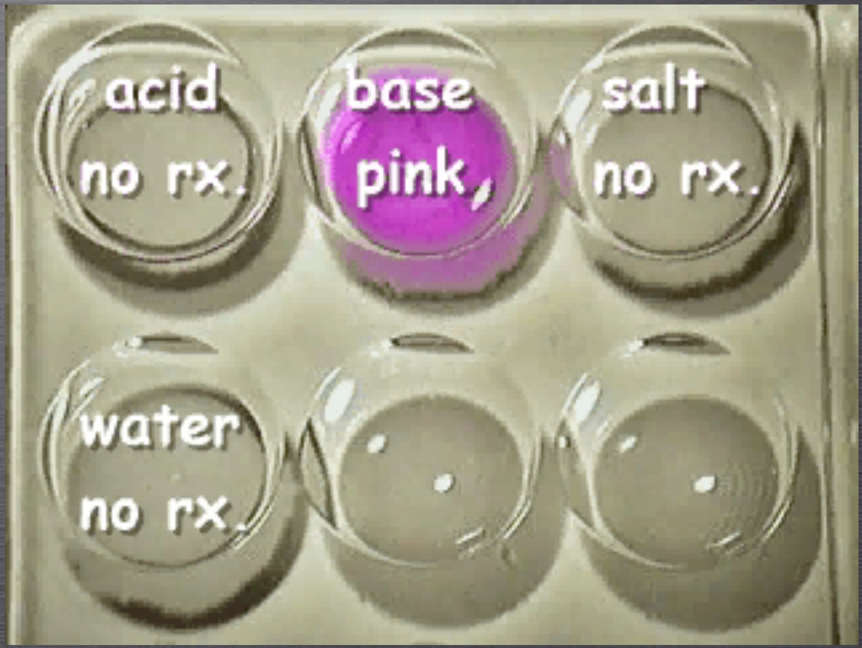
Acid-Base Indicators

Litmus Paper



Phenolphthalein



While there are many indicators to identify acids and bases the two we will be using in the lab are litmus paper, phenolphthalein and pH paper.

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Strong & Weak Acids and Base

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Strong & Weak Acids

- Compounds that ionize completely in water are strong acids.
- Compounds that ionize only slightly in water are weak acids.
- Binary acids with a halogen are strong acids.
- Ternary acids in which the hydrogen outnumber the oxygen by 2 or more are strong acids.

Strong & Weak Bases

- Bases that completely dissociate in water are strong bases.
- Bases that are only slightly soluble in water are weak bases.
- Bases containing an alkali metal or an alkaline earth metal are strong bases. All other bases are weak.

Strong or weak?	$Cu(OH)_2$	KOH	$Mg(OH)_2$	NH_4OH
	Weak	Strong	Strong	Weak

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Neutralization Reactions

Acid + Base → Salt + Water

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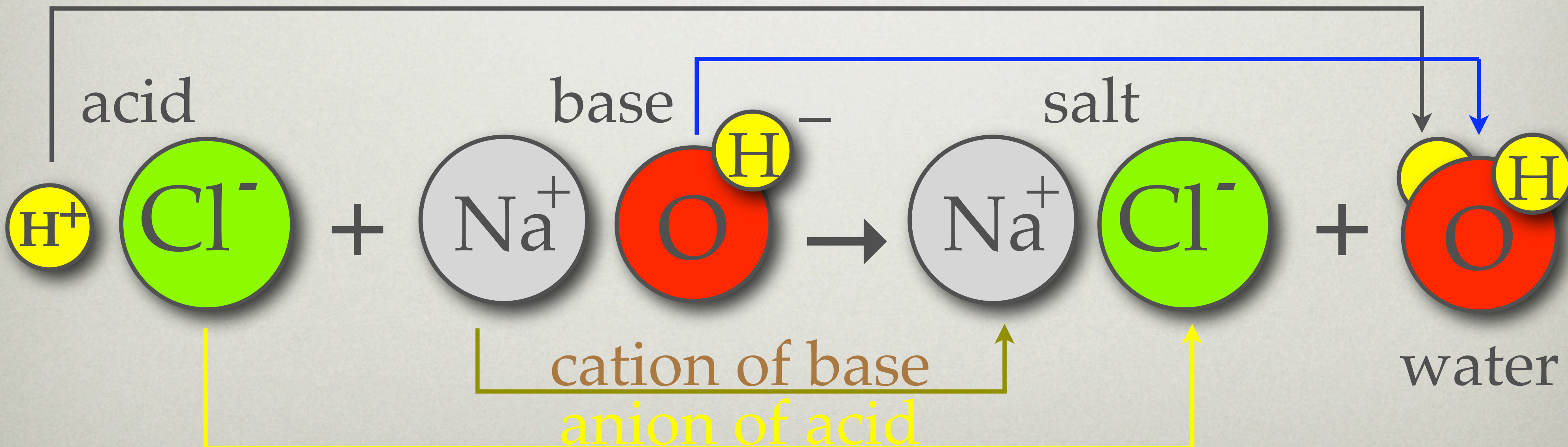
Neutralization Reaction

- In a neutralization reaction, an acid and a base react in a double replacement reaction to produce a salt and water.
- The salt is formed from the *cation of the base* and the *anion of the acid*.
- The water is formed from the *hydrogen ion of the acid* and the *hydroxide ion of the base*.
- The properties of both the acid and base are destroyed in the reaction to produce a neutral salt solution.

Neutralization Reactions

Acid + Base → Salt + Water

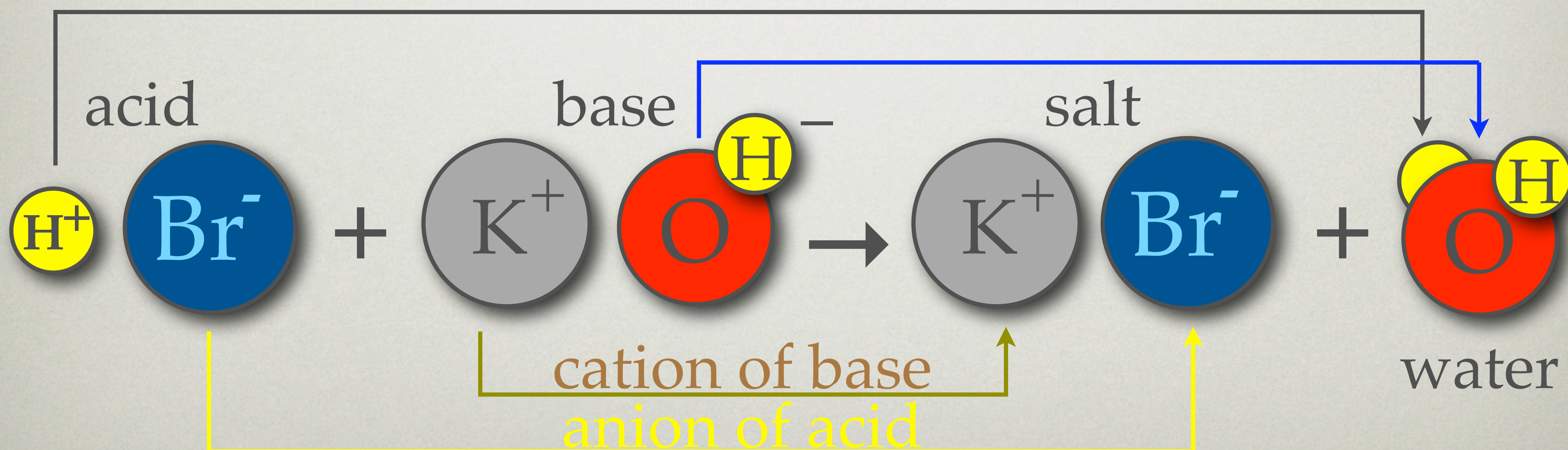
$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$



Neutralization Reactions

Acid + Base → Salt + Water

$$HBr_{(aq)} + KOH_{(aq)} \rightarrow KBr_{(aq)} + H_2O_{(l)}$$



What Salt is formed in these reactions:

ACID	BASE	SALT
hydrofluoric	magnesium hydroxide	magnesium fluoride
nitric	barium hydroxide	barium nitrate
sulfuric	sodium hydroxide	sodium sulfate
hydrochloric	ammonium hydroxide	ammonium chloride
carbonic	lithium hydroxide	lithium carbonate

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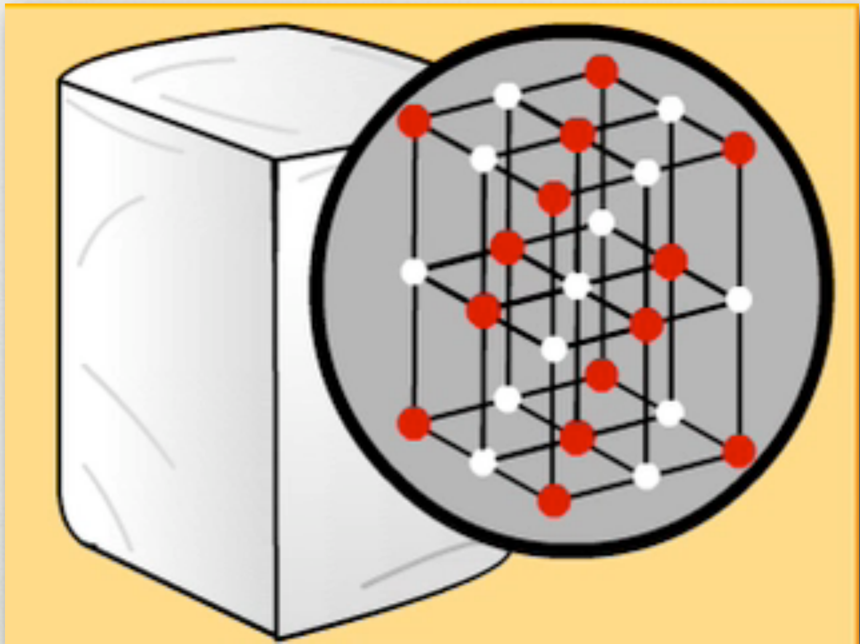
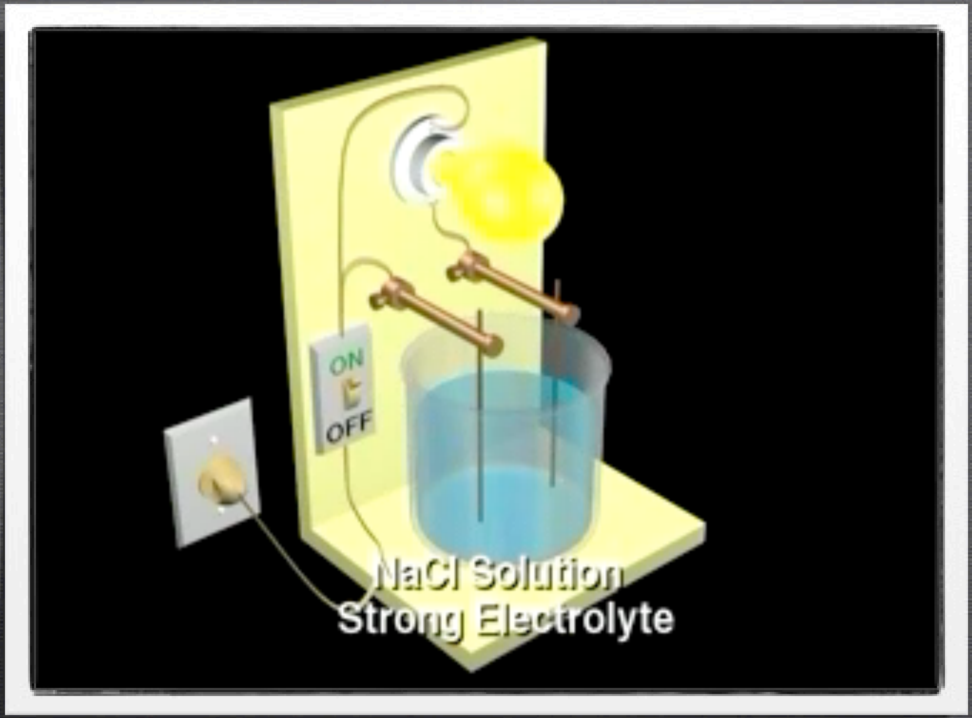
An Important Salt: Sodium Chloride



Sodium chloride (NaCl) is a common salt that comes from underground mines that were once part of the ocean. When the water evaporated, salt deposits thousands of feet thick were left behind.

Electrolytes



Electolytes are solutions that carry an electrical current.

Substances that produce ions in solution such as acids, bases, and salts are electrolytes.

Nonpolar covalent compounds, such as sugar do not produce ions in solution and are not electrolytes.

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Titration

The process of neutralizing an acid with a known molarity of a base to determine the molarity of the acid.

the formula used is:

$$M_A \times V_A = M_B \times V_B$$

where M=molarity, V= volume, A=acid, B=base.

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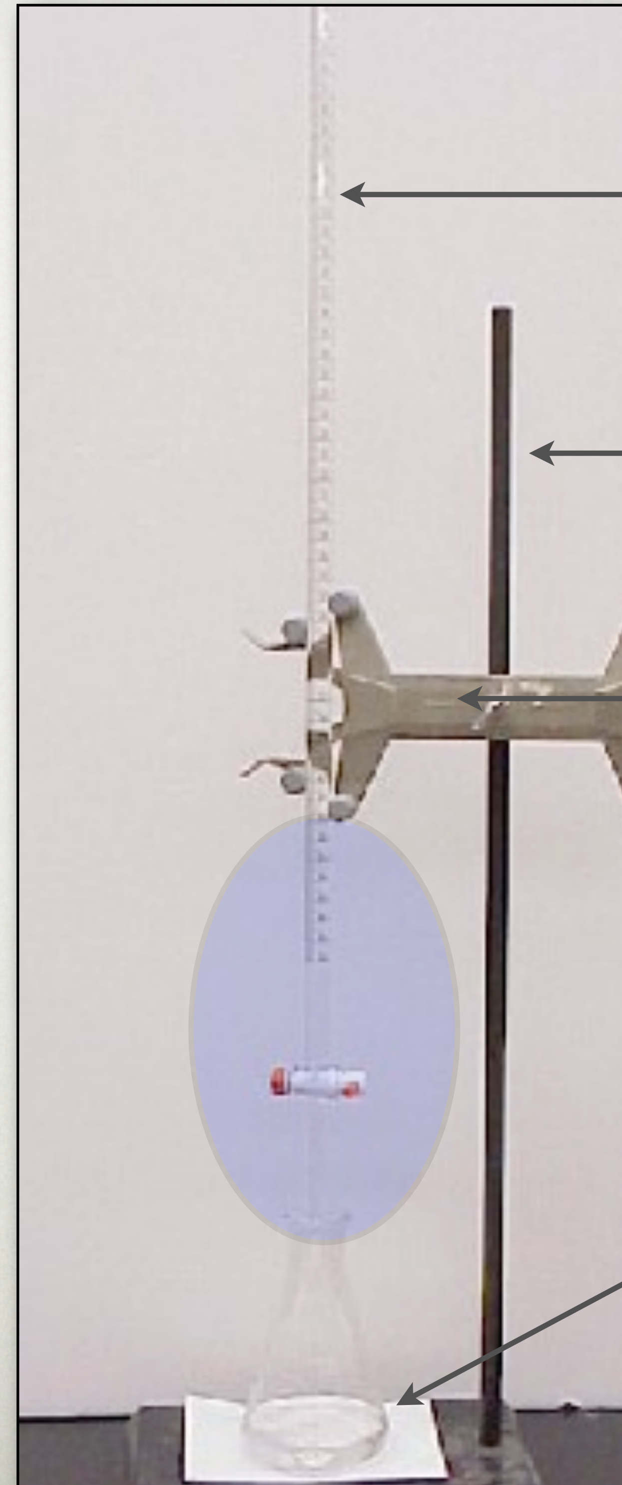
TITRATION

Graduations increase in value as you go down (opposite of a graduate). Read burets from the top down.

Stopcock Controls the flow of base. When lined up with buret the stopcock is open. When horizontal it is off.



buret filled with 0.100 M NaOH

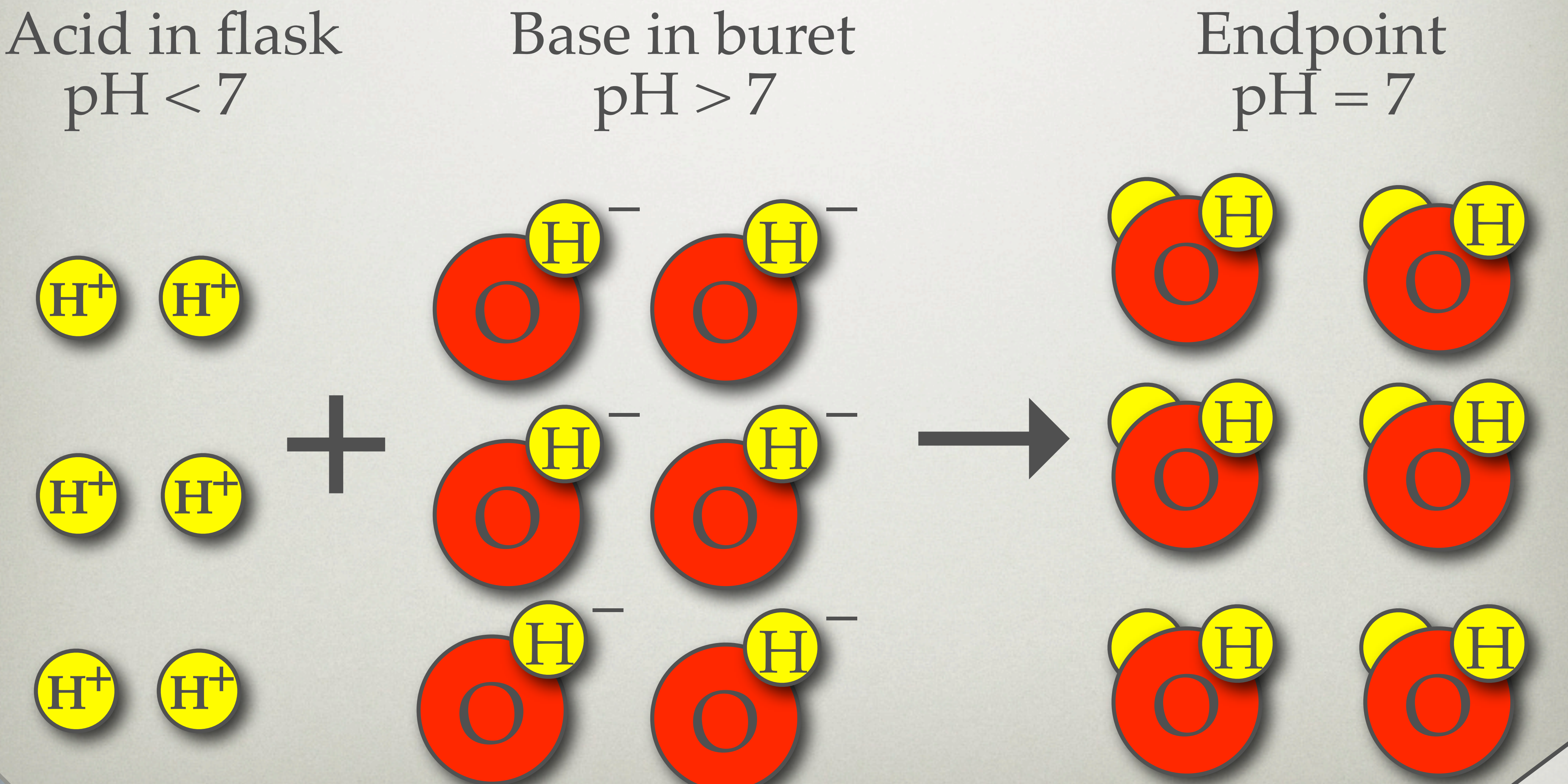
ring stand

buret clamp

Flask with 4.00 mL of acid, stir bar, water & phenolphthalein

Neutralization Reaction

When titrating, you are neutralizing an acid by adding a base. The point at which the acid is neutralized (pH = 7) is called the endpoint. A drop of base later the phenolphthalein turns pink.



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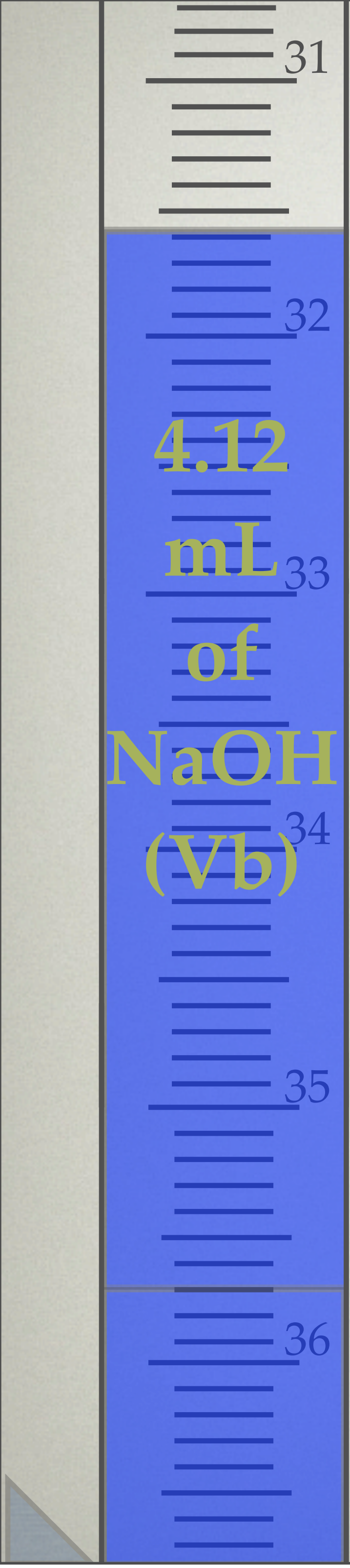

Initial Volume
31.58 mL

How to Read a Buret

When reading a buret,

read from the top down.

This is due to pouring *out* of a buret as opposed to pouring *into* a graduate.

To determine the volume of NaOH used:

Final volume of NaOH

<u>- Initial volume NaOH</u>

Volume of NaOH used

Final volume of NaOH: 35.70 mL

<u>- Initial volume NaOH: 31.58 mL</u>

Volume of NaOH used: 4.12 mL

35.70 mL
Final Volume

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Formula for calculating the Molarity of the Acid

$$M_a \times V_a = M_b \times V_b$$

Molarity acid x Volume acid = Molarity base x Volume base

10.00 mL 0.100 M 13.89 mL

$$M_a = \frac{M_b \times V_b}{V_a}$$

$$M_a = \frac{0.100\text{ M} \times 13.89\text{ }\cancel{\text{mL}}}{10.00\text{ }\cancel{\text{mL}}} = 1.39\text{ M}$$

The acid's molarity is 1.39 M

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Things to Remember:

1) Fill the buret each time you use it. Be sure to add 0.100 M NaOH (base) and not water to your buret.

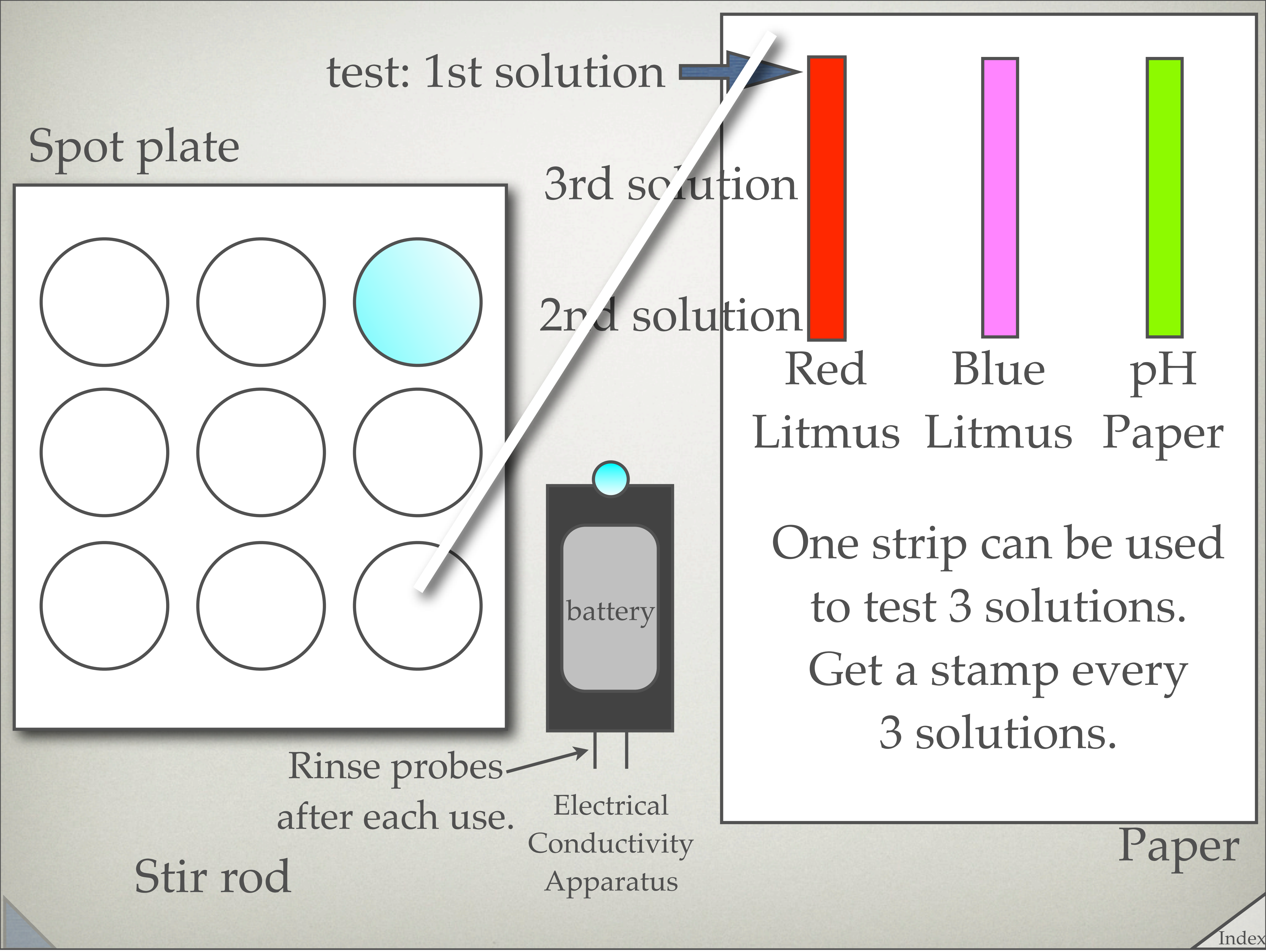
2) Make accurate readings with your buret.

3) Rinse your flask and stir bar each time you use it.

4) Get eye level with the menisus when you read it.

5) Hold the buret in front of you when you go to fill it up. Hold the buret securely in your hand.

6) Have the following when you go to the lab:
Lab, Calculator, pencil and paper.


test: 1st solution
Spot plate
3rd solution
2nd solution
Red Litmus
Blue Litmus
pH Paper
One strip can be used to test 3 solutions.
Get a stamp every 3 solutions.
battery
Rinse probes after each use.
Electrical Conductivity Apparatus
Stir rod
Paper
Index

Formulas:

Methyl Alcohol: $CH_3OH_{(l)}$

Soda Pop: $H_2CO_{3(aq)}$

---Unknown solutions----

Even lab stations: A, I, J

Odd lab stations: B, E, G

correction: phenolphthalein instead of No Rx on top of data table.

Note:
Bases turn Red Litmus blue.
Phenolphthalein will turn pink
in bases only with a
pH greater than 8.5.

So....

If your Red Litmus turns blue, you have a base even if phenolphthalein doesn't turn pink.
Very weak bases are also very weak electrolytes so cup your hand over the light to see if it produces a very dim light.

Also antacids, in some cases, will produce results of both an acid and base. If this occurs write acid/base.

Litmus Indicator

- Litmus is a plant dye extracted from the plant lichen *Roccella tinctoria.*
- When exposed to an *acid* litmus turns *red*, a *base* turns litmus *blue*.

Roccella tinctoria.

Dry Ice: Solid Phase of Carbon Dioxide

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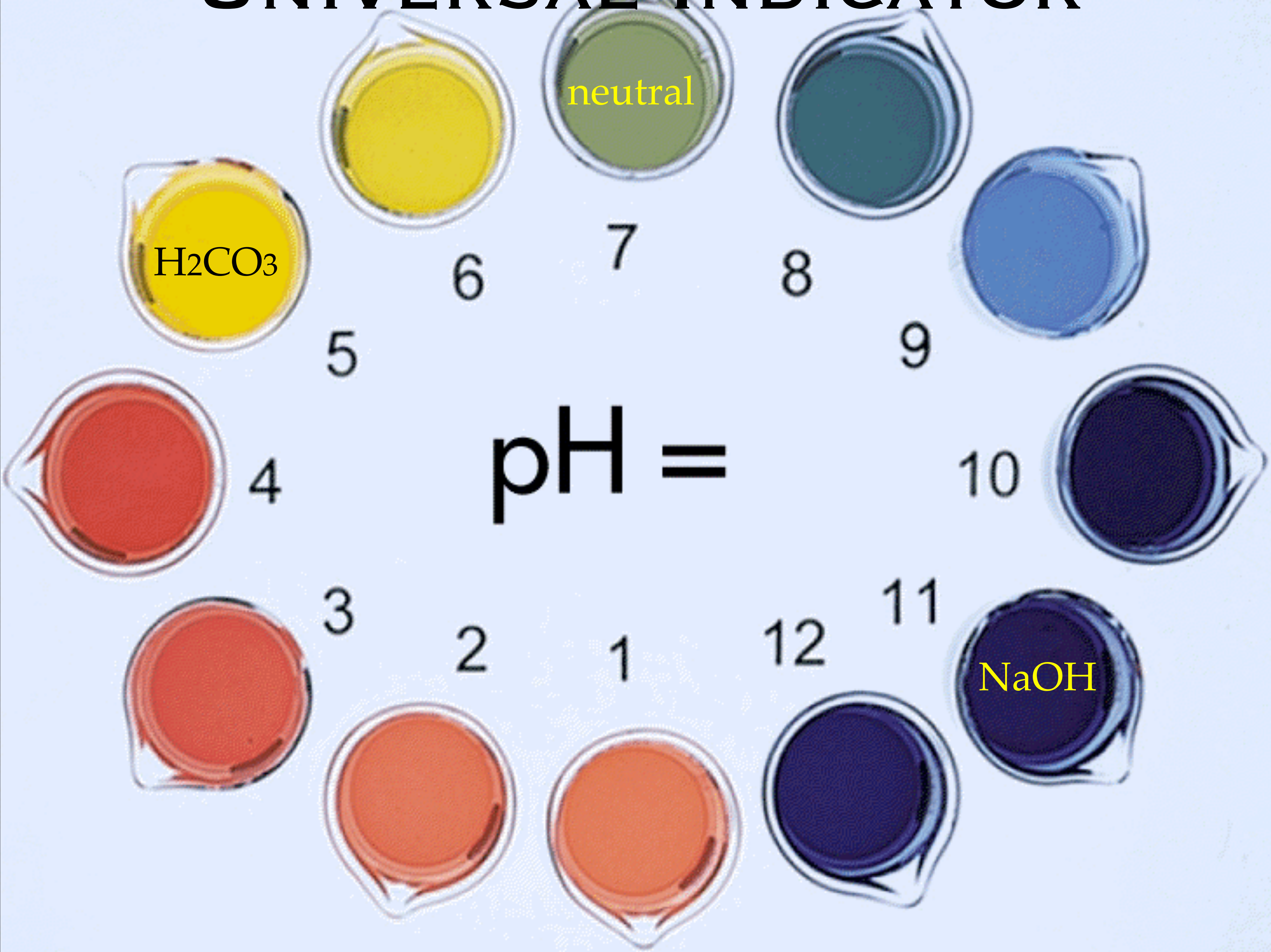
- Dry ice is frozen carbon dioxide (CO_2).
- Carbon dioxide goes through sublimation - it goes directly from solid to gas, or gas to solid.
- Carbon dioxide freezes at -78.5˚C (-109.3˚F).
- Dry ice uses include refrigeration of packages and fog machines.

Universal Indicator



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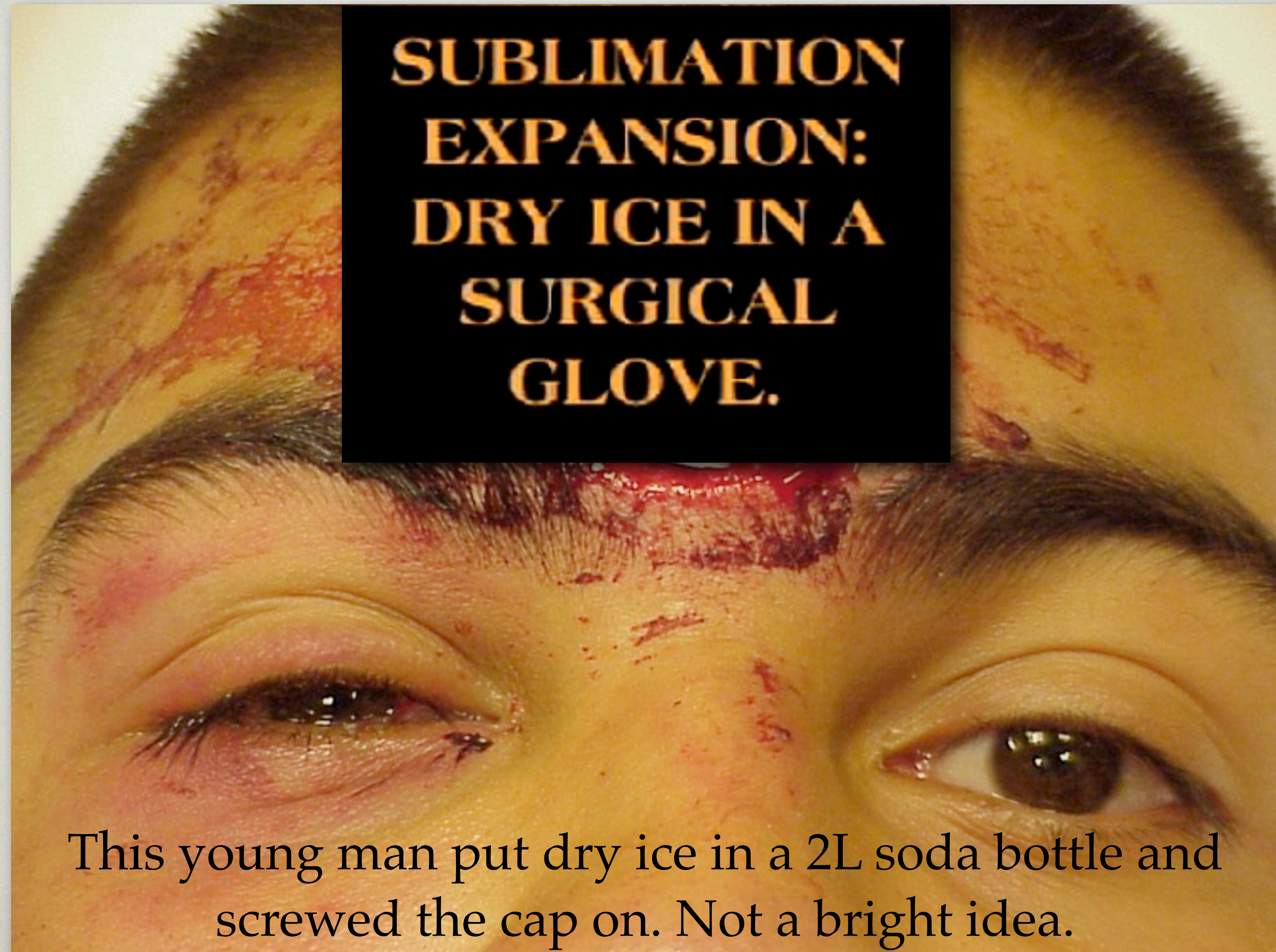
When going from solid to gas, CO_2 expands.



This young man put dry ice in a 2L soda bottle and screwed the cap on. Not a bright idea.

Acids & Bases Review

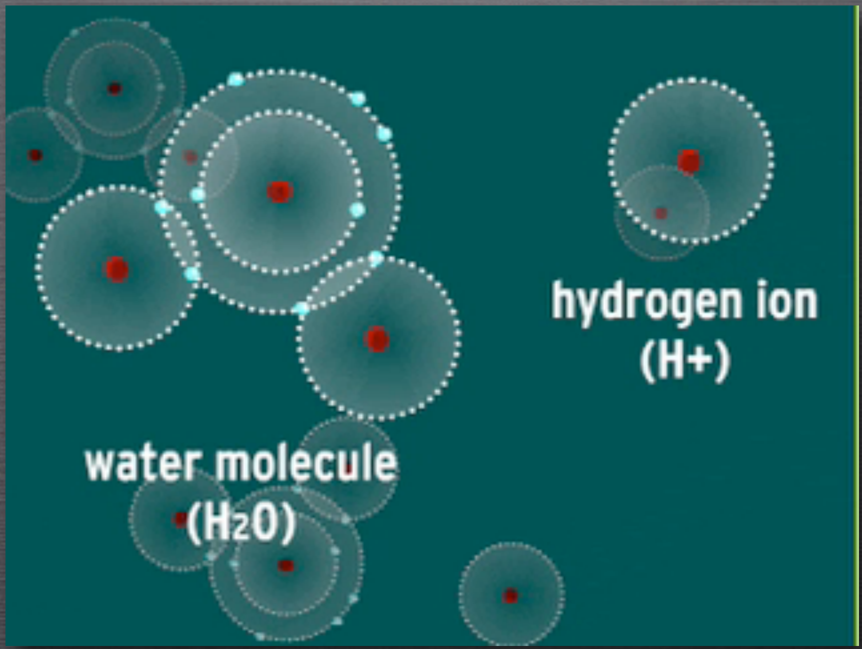
Acids

Have a pH < 7

Taste Sour

Turn Blue litmus Red

Example: Soft Drinks



Bases

Have a pH > 7

Taste Bitter

Turn Red litmus Blue

Example: Cleansers

Acids are Proton donors.
They produce hydrogen ions (H^+).

Bases are Proton Acceptors.
They produce hydroxide ions (OH^-).

$$H^+ + OH^- \rightarrow H_2O$$

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