CHEMISTRY 40S

The Alchemist's Notebook

UNIT 1 – AQUEOUS CHEMICAL REACTIONS

NAME:____________________________________

LET'S GET STARTED!

By the end of this unit, you should be able to:

- Explain examples of solubility and precipitation at the particulate and symbolic levels.
- Use a table of solubility rules to predict the formation of a precipitate in a precipitation reaction.
- Design and test a procedure to experimentally identify unknown ionic salts.
- Write a net ionic equation for a precipitation reaction.
- Explain the difference between strong and weak electrolytes.
- Write balanced neutralization reactions involving strong acids and bases
- Calculate the concentration or volume of an acid or a base from the concentration and volume of an acid or a base required for neutralization.
- Perform a titration and use the data collected to determine the molarity of an acid or base.
- Explain the process of oxidation and reduction in terms of electrons gained and lost as well as oxidizing and reducing agents.
- Determine the oxidation numbers for atoms in compounds and ions.
- Use oxidation numbers to identify reactions as redox or non-redox.
- Balance oxidation-reduction reactions using redox methods.

THIS UNIT WILL TAKE APPROXIMATELY 20 LESSONS TO COMPLETE AND WILL COUNT FOR 20% OF YOU MARK IN THIS COURSE.

REVIEW OF CH30

CH40S *MR. WIEBE*

1

SCIENTIFIC NOTATION

Put the following measurement into scientific notation.

5732 grams

If moving the decimal makes the number <u>smaller</u>, then the exponent gets <u>larger</u>.

2

SCIENTIFIC NOTATION

Put the following measurement into scientific notation.

0.0050 m

If moving the decimal makes the number **larger,** then the exponent gets smaller.

3

MULTIPLYING SCIENTIFIC NOTATION

$(3.0 \times 10^5 cm)\ (2.0 \times 10^4 cm) = ?$

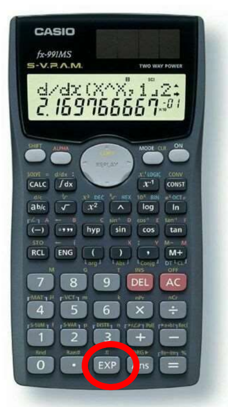
4

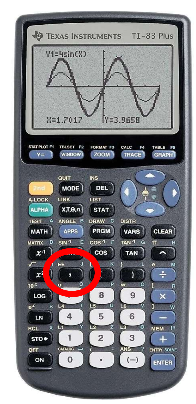
DIVIDING SCIENTIFIC NOTATION

$$\frac{(4 \times 10^{-3}\ s)}{(1 \times 10^{-5}\ s)}$$

5

SCIENTIFIC NOTATION ON YOUR CALCULATOR





Calculate the volume of a container with a length of 3.25×10^{3} m, width of 8.93×10^{5} m and height of 2.11×10^{-2} m.

6

UNIT ANALYSIS

In the far away country of Yrtsimehc, the monetary currency is based on "izzles" rather than "dollars". The following relationships are true in this currency:

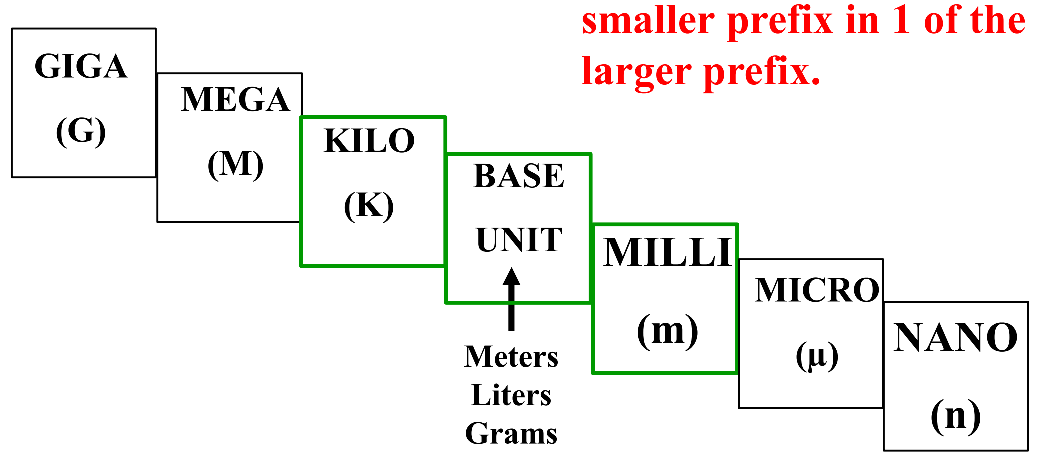
1 frizzle = 8 crizzles   6 drizzles = 0.5 sizzles   2 crizzles = 10 drizzles

If you have 75 frizzles in the bank, how many sizzles is this equivalent to?

7

Very big

There are 1000 or 10^3 of the smaller prefix in 1 of the larger prefix.



Very small

Gigantic **Mega**phones **Kil**led 1 **Milli**on **Micro**scopic **Nano**bots

8

Kinda big

There are 10 or 10^1 of the smaller prefix in 1 of the larger prefix.

KILO (k)	HECTO (h)	DECA (da)	BASE UNIT	DECI (d)	CENTI (c)	MILLI (m)

Meters
Liters
Grams

Pretty small

King Henry Died Drinking Chocolate Milk

9

UNIT ANALYSIS

Given that:

2.21 lb = 1.00 kg
1.00 atm = 101.3 kPa
14 lb = 1 stone
16 oz = 1 lb

4.54 L = 1.00 gal
1.61 km = 1.00 mile
2000 lb = 1 ton

Mr. Wiebe weighs 14.3 stone. How many kilograms is this?

10

UNIT ANALYSIS

Given that:

2.21 lb = 1.00 kg
1.00 atm = 101.3 kPa
14 lb = 1 stone
16 oz = 1 lb

4.54 L = 1.00 gal
1.61 km = 1.00 mile
2000 lb = 1 ton

A recipe calls for 4 oz of sugar. How many grams of sugar would this be?

11

IONIC COMPOUNDS

Example: Aluminum oxide

Example: $CaCl_2$

Example: Iron(III) chloride

Example: Cu_2S

12

12

IONIC COMPOUNDS

Example: barium nitrate

Example: Zinc hydroxide

Example: NH_4NO_3

Example: $Ca_3(PO_4)_2$

13

COVALENT MOLECULES

Some elements naturally exist in **molecule form** rather than atom form. They are called **diatomic elements**

H_2, N_2, F_2, O_2 , I_2, Cl_2, Br_2

"**H**ave **N**o **F**ear **O**f **I**ce **C**old **B**eer!"

14

14

COVALENT COMPOUNDS

Example: P_2O_5

Example: N_2O

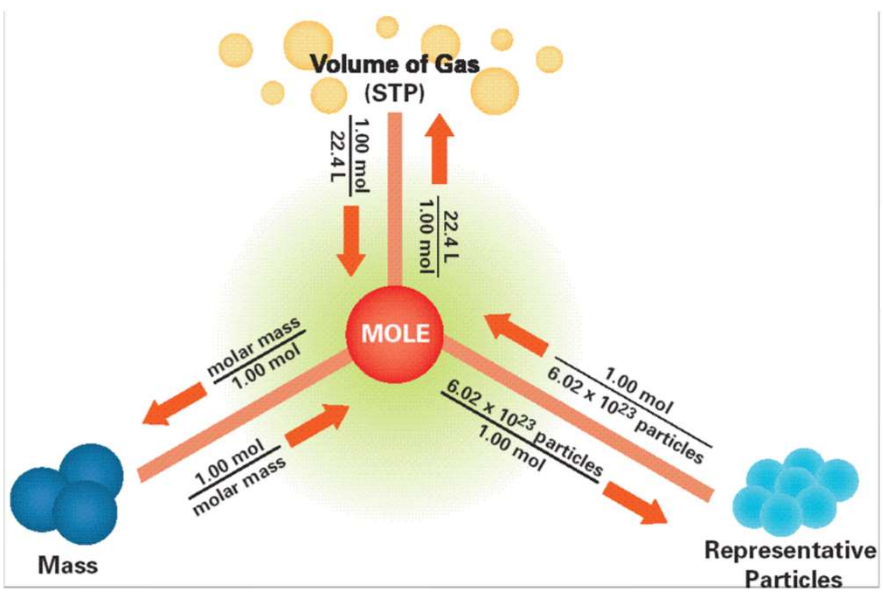
Example: carbon monoxide

Example: nitrogen triiodide

15

15

THE MOLE



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MOLAR MASS

He

CO_2

lithium nitrate

$Ni_2(CO_3)_3$

Molar mass is used as a conversion factor between the mass of a chemical and the number of moles of that chemical.

17

EXAMPLE #1

A liter of regular gasoline typically contains about **19 moles** of octane molecules (C_3H_8).

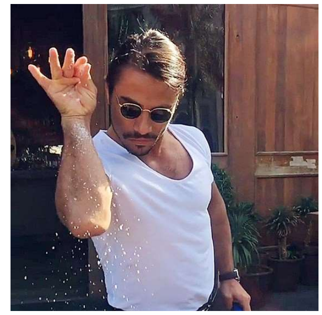
How many **grams** of octane would this be?

How many **molecules** of octane are present?

18

EXAMPLE #2

It is recommended that a person eat no more than **6.0 g** of table salt (sodium chloride) per day.



How many **moles** of salt would this be?

How many **molecules** of salt is this?

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BALANCING CHEMICAL EQUATIONS

___ Al + ___ O_2 → ___ Al_2O_3

___ Na(OH) + ___ $Fe(NO_3)_3$ → ___ $Na(NO_3)$ + ___ $Fe(OH)_3$

___ C_2H_6 + ___ O_2 → ___ CO_2 + ___ H_2O

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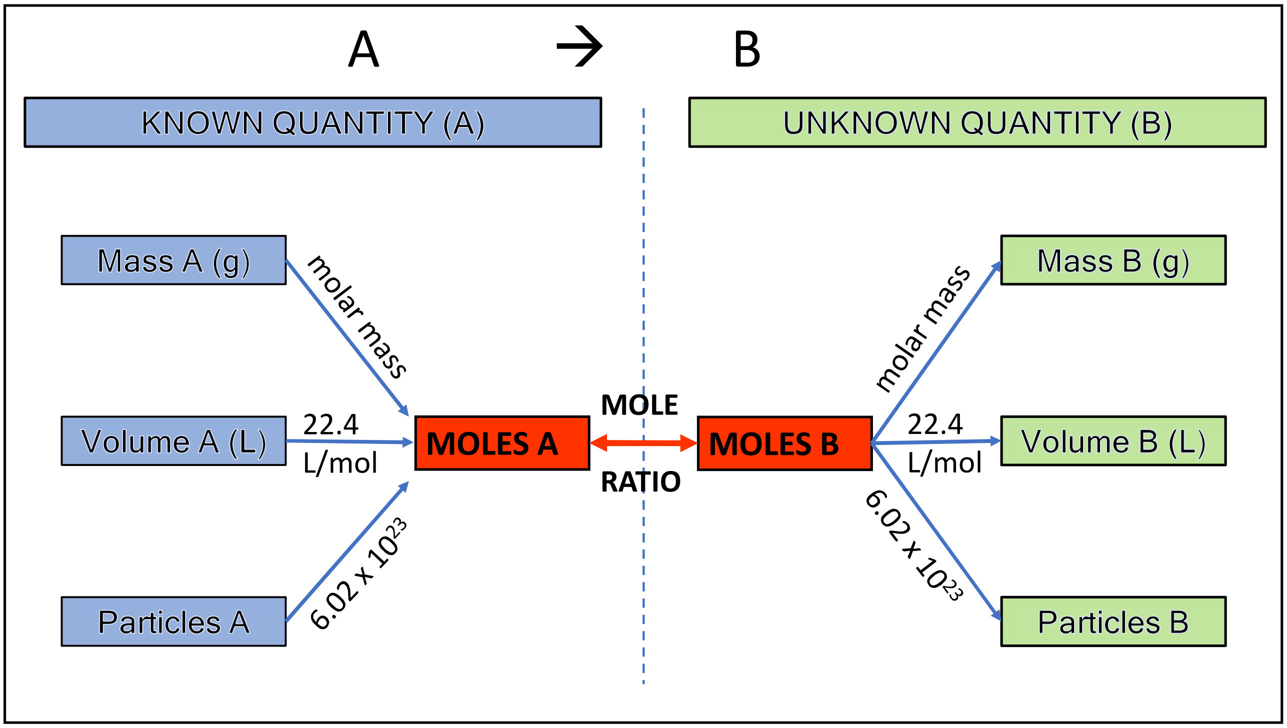
BALANCED FORMULA EQUATIONS

A piece of iron reacts with oxygen gas to produce rust, Fe_2O_3.

Words			
Formulas			
Pictures			
Balanced Equation			

21



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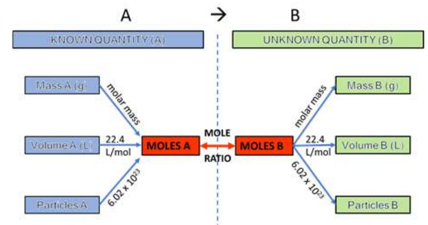
STOICHIOMETRY



Balanced Equation:

What mass of iron must have been present to produce 25.0 g of rust?

23

STOICHIOMETRY

$$\text{Percentage Yield} = \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \times 100\%$$

5.0 g of iron is completely reacted with excess oxygen and forms 6.29 g of rust. What is the % yield of this reaction?

24

MOLARITY

The number of **moles** of the chemical solute per **litre of solution**.

mol/L = M

For example:

1.8 M HCl means 1.8 moles of HCl per litre of solution.

Table 1 Amount Concentrations of Common Stock Acid Solutions

Stock acid	Amount concentration (mol/L)
hydrochloric acid, $HCl(aq)$	12
nitric acid, $HNO_3(aq)$	16
sulfuric acid, $H_2SO_4(aq)$	18

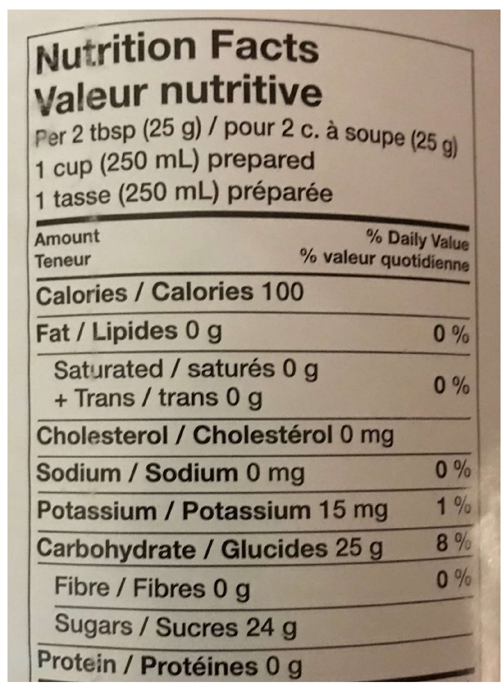
$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}}$$

25

CALCULATING MOLARITY

A student makes some iced tea as per the instructions on the container. Calculate the molarity of **sugar** in the juice. (Assume the sugar in powdered drinks is all **sucrose** $C_{12}H_{22}O_{11}$

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}}$$



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WORKING WITH MOLARITY

Household chlorine bleach is a 0.067 M solution of sodium hypochlorite. What mass of NaClO solute is required to prepare 225 mL of bleach solution?

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DILUTION

Concentrated solutions have a relatively **high** molarity.

Dilute solutions have a relatively **low** molarity.

It is often **faster** to prepare a standard solutions by **diluting** a more concentrated solution.

The following **equation** can be used to solve **dilution problems** – when **water** is **added** or **removed** from a solution.

$$M_1V_1 = M_2V_2$$

M_1 = the initial molarity M_2 = the final molarity

V_1 = the initial volume V_2 = the final volume

28

DILUTION

A student measures 100.0 mL of a 5.0 M potassium chloride solution and adds enough water to it to make the volume 2.0 L. What will be the molarity of this new solution?

29

DILUTION

How much water would you need to add to 200.0 mL of a 1.50 M sodium nitrate solution to dilute it down to 0.250 M?

30

DILUTION

If you were to mix 200.0 mL of a 0.750 M NaCl solution with 300.0 mL of a 0.250 M NaCl solution, what would the final molarity of the solution be?

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1. PROPERTIES OF SOLUTIONS

UNIT 1 AQUEOUS CHEMICAL REACTIONS

CH40S MR. WIEBE

1

SOLUTIONS

Solutions are defined as homogeneous mixtures of two or more pure substances.

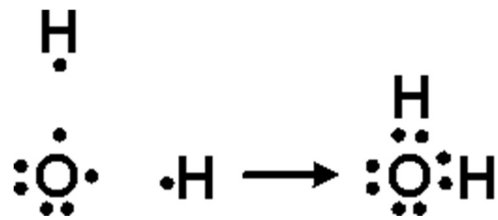
The solvent is present in greatest abundance.

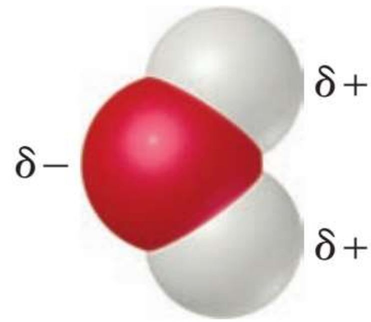
All other substances are solutes.

2

WATER IS POLAR

- Water is a covalent compound.
- Each atom of hydrogen and oxygen are bonded together with a shared pair of electrons.
- Oxygen pulls the pair of electrons closer to its nucleus.
- This creates a slight negative charge on each oxygen atom and a slight positive charge on the hydrogen atom.





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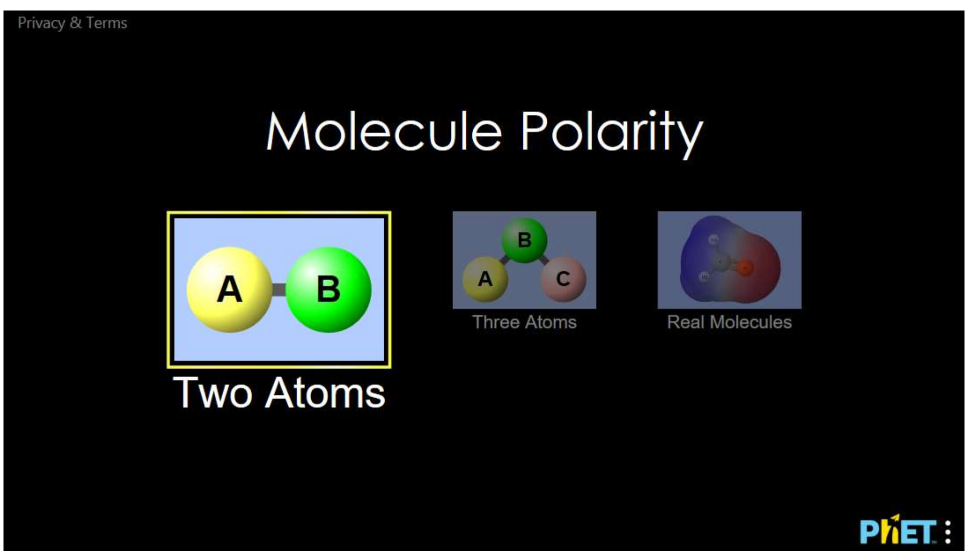
VISUALIZING POLARITY



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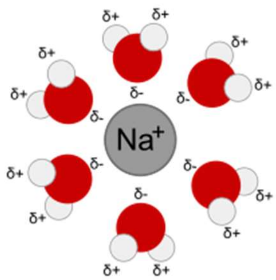
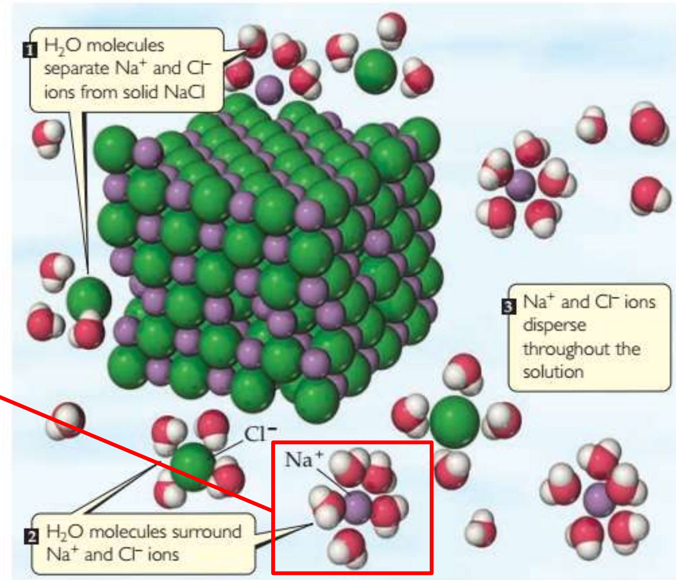
DISSOCIATION





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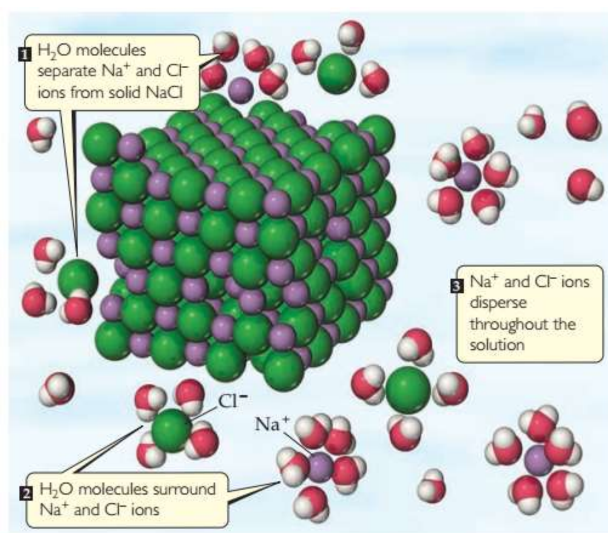
ELECTROLYTES

When a solute dissolves and ions are produced, the solution conducts electricity.

This type of solution is called an electrolyte.



All soluble ionic compounds dissolved in water are electrolytes!

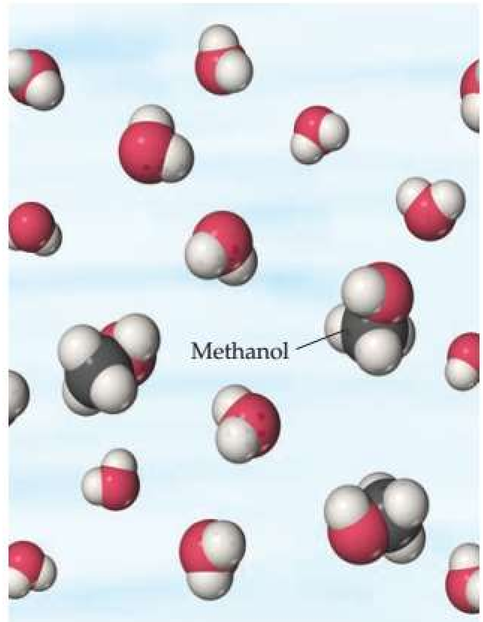
6

NON-ELECTROLYTES

A non-electrolyte may dissolve in water, but it does not dissociate into ions when it does so.

Examples of this are:

- Low soluble ionic compounds
- Aqueous covalent compounds



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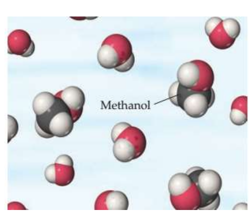
ELECTROLYTES

Pure water does not conduct electricity

Pure water, $H_2O(l)$

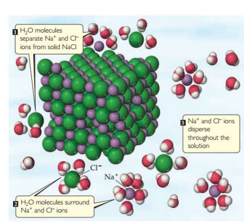
An **nonelectrolyte solution** does not conduct electricity

Sucrose solution, $C_{12}H_{22}O_{11}(aq)$



An **electrolyte solution** conducts electricity

Sodium chloride solution, $NaCl(aq)$



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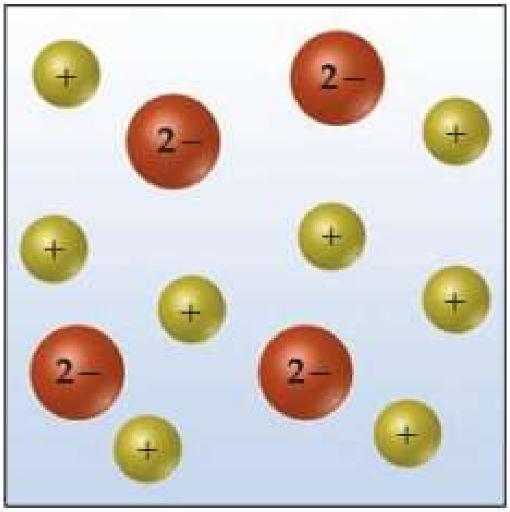
THINK ABOUT IT…



Which of the following soluble salts, when dissolved in water do you think would produce the model on the left? Why?

- Magnesium chloride
- Potassium chloride
- Potassium sulphate

9

DISSOCIATION EQUATIONS

Write the dissociation equation for the dissolving of *sodium carbonate* in water.

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	CH_3COO^-	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}

10

DISSOCIATION EQUATIONS

Write the dissociation equation for the dissolving of *aluminum sulphate* in water.

Soluble Ionic Compounds		Important Exceptions
Compounds containing	NO_3^-	None
	CH_3COO^-	None
	Cl^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	Br^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	I^-	Compounds of Ag^+, Hg_2^{2+}, and Pb^{2+}
	SO_4^{2-}	Compounds of Sr^{2+}, Ba^{2+}, Hg_2^{2+}, and Pb^{2+}

11

THINK ABOUT IT…

If you had a solution with 1.5 moles of $CaCl_2$ dissolved in it, how many moles of each ion would be present in the solution?

12

2. PRECIPITATION RXNS

UNIT 1 AQUEOUS CHEMICAL REACTIONS

CH40S MR. WIEBE

1

REVIEW

Write the dissociation equations for the following solutions and draw a diagram to model the process:

1. Lead(II) nitrate is dissolved in water.

2. Potassium chloride is dissolved in water.

WHAT WOULD HAPPEN IF YOU MIXED THESE TWO SOLUTIONS TOGETHER?

2

DOUBLE REPLACEMENT REACTIONS FORM PRECIPITATES

When two soluble ionic compounds are mixed together in solution, the ions of the compounds exchange places to form two new compounds.

$$AX + BY \rightarrow AY + BX$$

One of the compounds formed is usually either:

1. a **precipitate** (an insoluble solid), or
2. an **insoluble gas** that bubbles out of solution.

3

OBSERVE A PRECIPITATION REACTION…

1. Place your Petri dish on a white piece of paper and fill it about half full of distilled water.
2. Have one person place a small amount of **lead(II) nitrate** to one side of the dish. At the same time, have your partner add about the same amount of **potassium chloride** to the other side of the Petri dish.
3. Observe. Be patient! Write down what you see.

4

WRITING NET IONIC EQUATIONS

Lead(II) nitrate + potassium chloride →

1. Balanced Formula Equation (Grade 10 style!)

2. Complete ionic equation (show soluble salts as aqueous ions)

3. Net ionic equation (eliminate the spectator ions)

5

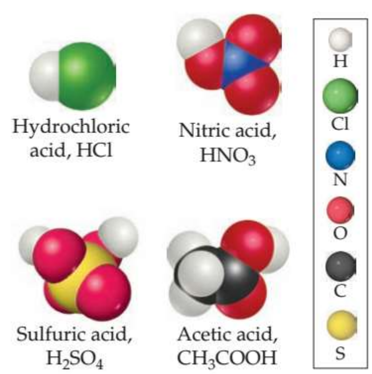
3. REACTIONS OF ACIDS & BASES

UNIT 1 REACTIONS IN AQUEOUS SOLUTIONS
CH40S
MR. WIEBE

1

PROPERTIES OF ACIDS

1. Acids contain H^+
2. Acids have a pH lower than 7
3. Acids taste sour
4. Acids affect indicators (Blue litmus turns red)
5. Acids react with active metals, producing H_2
6. Acids react with carbonates, producing CO_2
7. Acids neutralize bases



▲ Figure 4.6 Molecular models of four common acids.

2

PROPERTIES OF BASES

1. Many bases contain OH^-
2. Bases have a pH greater than 7
3. Bases taste bitter
4. Bases effect indicators (Red litmus turns blue)
5. Solutions of bases feel slippery
6. Bases neutralize acids

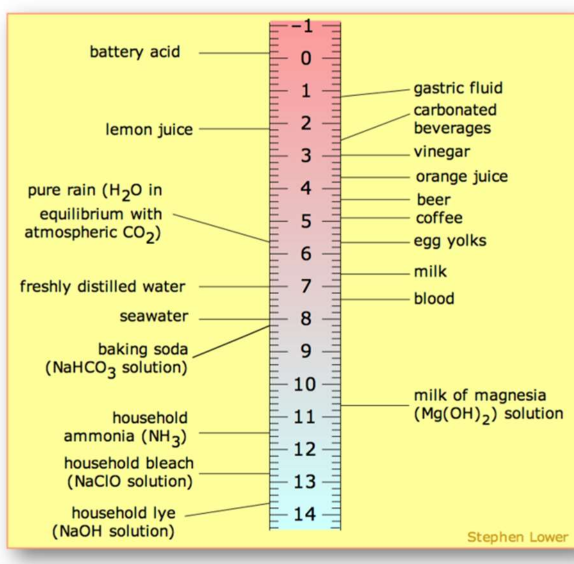
3

THE pH SCALE

Acids have a pH < 7

Bases have a pH > 7

pH = 7 = Neutral



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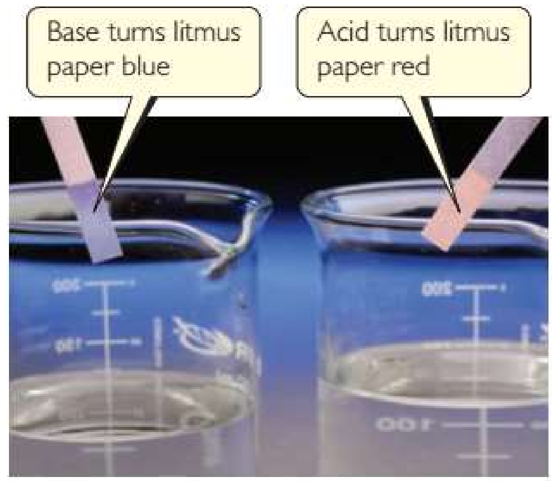
INDICATORS

Indicators are chemicals that change their colour as pH changes.

There are many different types of chemical indicators. We will learn more about them in a later unit.

You may be familiar with litmus paper.



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REACTIONS OF ACIDS

1. Acids react with active metals to form salts and hydrogen gas.

A piece of magnesium is placed in a test tube of hydrochloric acid.

6

REACTIONS OF ACIDS

2. Acids react with carbonate salts to produce carbon dioxide gas.

Vinegar (acetic acid) is mixed with washing soda (sodium carbonate).

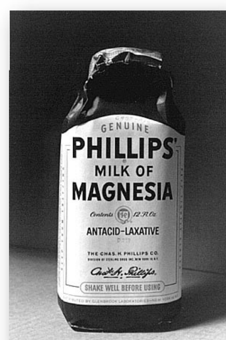
7

REACTIONS OF ACIDS

Acids react with bases to produce a soluble ionic salt and water.

This is called a neutralization reaction.

Milk of Magnesia contains magnesium hydroxide, $Mg(OH)_2$, which neutralizes stomach acid, HCl.



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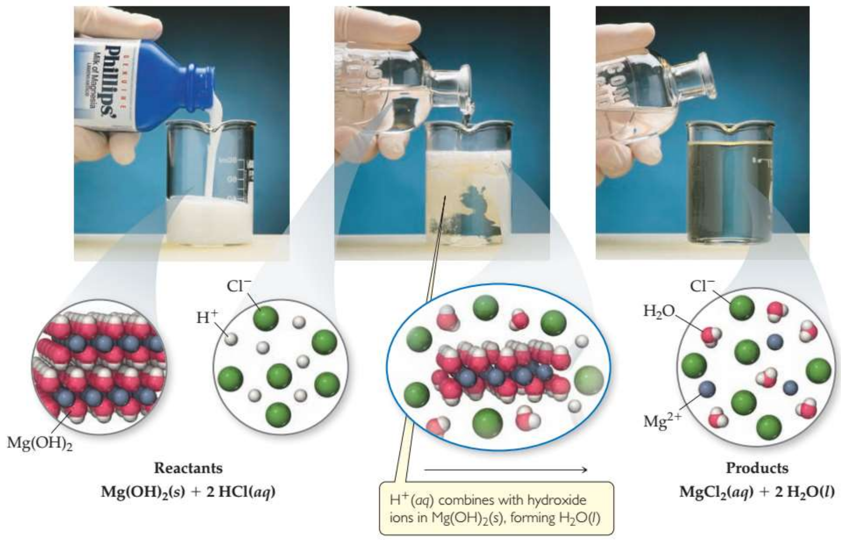
NEUTRALIZATION DEEP DIVE

Adding just a few drops of hydrochloric acid would not be sufficient to dissolve all the $Mg(OH)_2(s)$. Why not?



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4. MOLARITY & TITRATION

UNIT 1 REACTIONS IN AQUEOUS SOLUTIONS
CH40S
MR. WIEBE

1

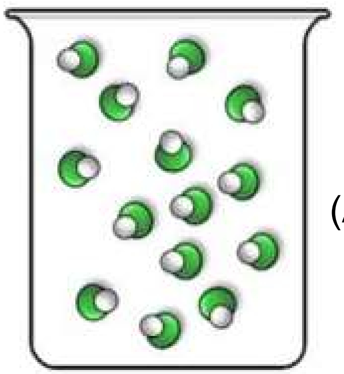
REVIEW - MOLARITY

- Two solutions can contain the same solute and solvent but be quite different because the proportions of those compounds are different.
- Molarity is one way to measure the concentration of a solution.

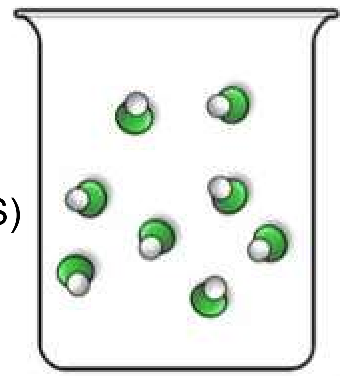
$$\text{Molarity } (M) = \frac{\text{moles of solute}}{\text{volume of solution in liters}}$$

2

REVIEW - CONCENTRATED VS. DILUTE ACIDS



CONCENTRATED ACIDS CONTAIN MORE SOLUTE (ACID MOLECULES) THAN DILUTE ACIDS)



CONCENTRATED
(i.e. 5.0 mol/L)

DILUTE
(i.e. 3.0 mol/L)

3

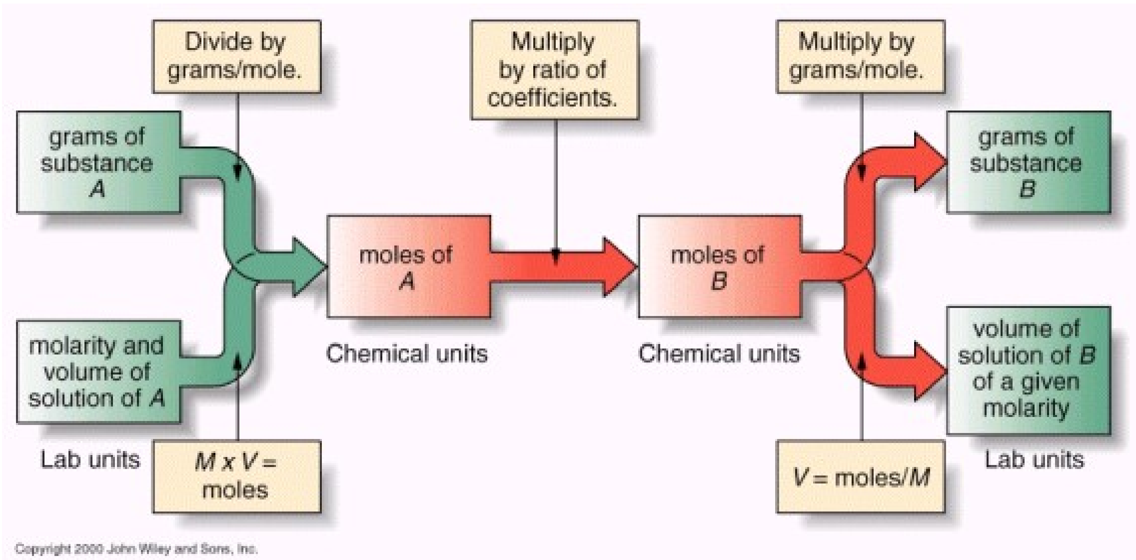
REVIEW - CALCULATING MOLARITY

What is the molarity of a solution made by dissolving 23.4 g of sodium hydroxide in enough water to form 125 mL of solution? What is the molarity of each of the ions present in the solution?

Slide 4

4

REVIEW - USING MOLARITY IN STOICHIOMETRY



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STOICHIOMETRY OF NEUTRALIZATION REACTIONS

Calculate the volume of 0.250 M strontium hydroxide solution (base) required to react fully neutralize 125.0 mL of 0.150 M hydrochloric acid (HCl).

6

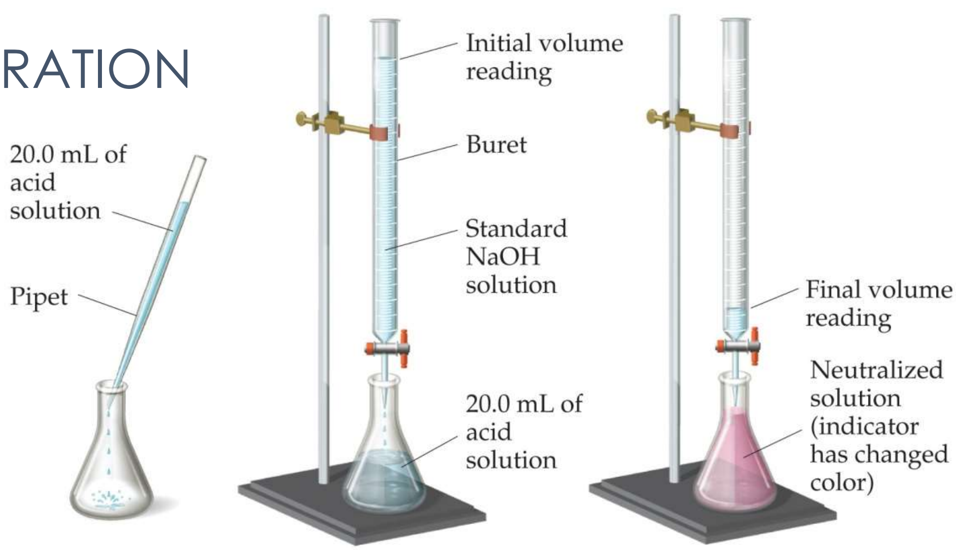
STOICHIOMETRY OF NEUTRALIZATION REACTIONS

125 mL of sodium hydroxide base is mixed with 175 ml of 0.200 M sulfuric acid (H_2SO_4). The resulting solution is completely neutral. What is the concentration of the sodium hydroxide?

Slide 7

7

TITRATION



Titration is a technique in which one can calculate the unknown concentration of a solution from the known concentration of another solution.

8

TITRATION – DEEP DIVE

$$H^+(aq) + OH^-(aq) \rightarrow H_2O_{(l)}$$

- In every neutralization reaction, the H^+ from the acid reacts in a 1:1 ratio with the OH^- from the base.
- If you add 5 moles of H^+ from an acid, it will react with 5 moles of OH^- from a base.
- If you can determine the moles of H^+/OH^- in your known, you can calculate the moles of H^+/OH^- present in the unknown.

9

TITRATION DATA ANALYSIS

Table 1: The Titration of 10.0 mL of HCl(aq) with 0.100 M NaOH			
Titration Trial #	**Final Volume NaOH (mL)**	**Initial Volume NaOH (mL)**	**Volume NaOH Used (mL)**
1	12.2	0.0	
2	23.7	12.2	
3	35.1	23.7	
Average Volume of NaOH Used to Neutralize the HCl (mL):			

AT LEAST TWO TRIALS WITHIN 0.20 mL OF EACH OTHER

IGNORE OTHERS

10

SUMMARY PROBLEM

One commercial method of peeling potatoes is to soak them in sodium hydroxide solution for a short time, then spray off the loosened peel. The [NaOH] is normally in the range of 3M to 6M. To ensure the range is consistant, periodic titrations are done on the lye. In one titration, it was found that 45.7 mL of 0.500M H_2SO_4 was needed to neutralize a 20.0 mL sample of NaOH. What was the [NaOH]?

11

5. REDOX REACTIONS

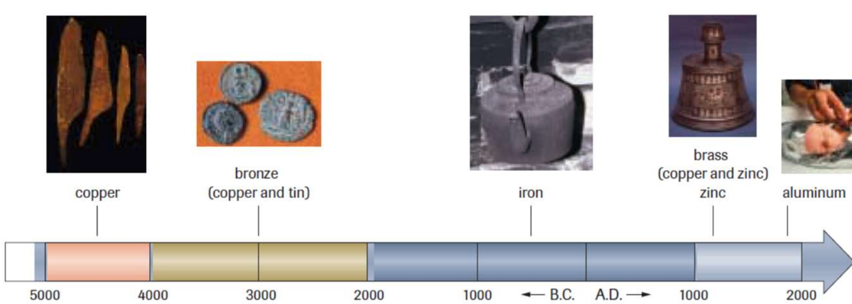
UNIT 1 REACTIONS IN AQUEOUS SOLUTIONS
CH40S
MR. WIEBE

1

REDOX = REDUCTION + OXIDATION

The historic definitions:

REDUCTION: reducing the volume of a naturally occuring metal ore (ie. $CuO_{(s)}$) into its components and extracting the metal (ie. $Cu_{(s)}$)



2

REDOX = REDUCTION + OXIDATION

The historic definitions:

OXIDATION: The reaction of a metal with oxygen in the air, resulting in corrosion.



These definitions are still somewhat true, but not nearly detailed enough for us!

3

OBSERVE…

A piece of copper wire, Cu(s), is placed in an aqueous solution of silver nitrate, $AgNO_3(aq)$.

Observations:

4

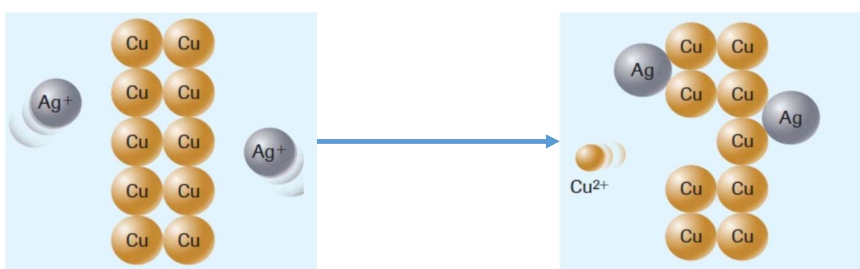
WHAT'S GOING ON?

Write the balanced chemical equation for this reaction:

Write the complete ionic equation for this reaction:

Write the net ionic equation for this reaction:

WHAT'S GOING ON?



Losing electrons = oxidation

$$2Ag^{+} + Cu \rightarrow 2Ag + Cu^{2+}$$

Gaining electrons = reduction

REDOX…

Losing **E**lectrons **O**xidation

Gaining **E**lectrons **R**eduction

Oxidation **I**s **L**osing

Reduction **I**s **G**aining

7

PREDICTING REDOX REACTIONS

- An element can only steal electrons from another element if it is "strong" enough.
- The ranking of a chemicals ability to steal electrons is called an Activity Series.
- The lower the element, the better it is at stealing electrons. The higher the element, the better it is at losing electrons.

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
Sodium	$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$
Magnesium	$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$
Aluminum	$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$
Manganese	$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$
Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
Iron	$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$
Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
Hydrogen	$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$
Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$

Ease of oxidation increases

8

PREDICT A REDOX REACTION

Use the Activity Series to predict the spontaneity of the following reaction.

$\_\_Al_{(s)} + \_\_Fe_2O_{3(aq)}$

Metal	Oxidation Reaction
Lithium	$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$
Potassium	$K(s) \longrightarrow K^{+}(aq) + e^{-}$
Barium	$Ba(s) \longrightarrow Ba^{2+}(aq) + 2e^{-}$
Calcium	$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$
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Zinc	$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$
Chromium	$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$
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Cobalt	$Co(s) \longrightarrow Co^{2+}(aq) + 2e^{-}$
Nickel	$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$
Tin	$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$
Lead	$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$
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Copper	$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$
Silver	$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$
Mercury	$Hg(l) \longrightarrow Hg^{2+}(aq) + 2e^{-}$
Platinum	$Pt(s) \longrightarrow Pt^{2+}(aq) + 2e^{-}$
Gold	$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$

Ease of oxidation increases

9

PREDICT A REDOX REACTION

Write the balanced chemical equation, the complete ionic equation, and the net ionic equation for the reaction:

$\_\_Al_{(s)} + \_\_Fe_2O_{3(aq)} \rightarrow$

10

THE THERMITE REACTION

CAUTION: This reaction will reach a temperature of about 3000°C!

$2\ Al + Fe_2O_3 \rightarrow$

Identify the substance being reduced. Prove it!

Identify the substance being oxidized. Prove it!

Thermite Rail Welding

11

6. OXIDATION NUMBERS

UNIT 1 REACTIONS IN AQUEOUS SOLUTIONS
CH40S
MR. WIEBE

1

OXIDATION NUMBERS

When polyatomic ions and covalent compounds are involved in a redox reaction, it can be difficult to tell if electrons are being lost or gained.

$$CrO_4^{2-} \rightarrow Cr_2O_7^{2-}$$

- ☐ Are any electrons being lost or gained here?
- ☐ Which element(s) is being oxidized/reduced?

Oxidation numbers are assigned numbers that are used to determine if oxidation or reduction has occurred.

2

RULES FOR ASSIGNING NUMBERS

1. All elements are zero

OXIDATION #

N_2

Pb

Na

O_2

3

RULES FOR ASSIGNING NUMBERS

2. Monatomic Ions are their charge

OXIDATION #

Na^+

Br^-

$\underline{Mg}SO_4$

$Al_2\underline{S}_3$

4

RULES FOR ASSIGNING NUMBERS

3. **O** in a compound is **-2**

OXIDATION #

$Na_2\underline{O}$

$C\underline{O}_2$

$\underline{O}_2$

$CH_3C\underline{O}OH$

5

RULES FOR ASSIGNING NUMBERS

4. **H** in a compound is **+1**

OXIDATION #

$\underline{H}_2O$

$C_{12}\underline{H}_{22}O_{11}$

$\underline{H}_2$

$\underline{H}NO_3$

6

RULES FOR ASSIGNING NUMBERS

5. The **sum** of the **oxidation numbers** must **equal** the **charge**

oxidation #s →

$\underline{S}O_4^{2-}$

Total charge →

7

EXAMPLE

oxidation #s →

$\underline{P}O_4^{3-}$

Total charge →

8

EXAMPLE

oxidation #s →

$\underline{Si}_2O_3^{2-}$

Total charge →

9

TRY A FEW…

$\underline{C}_6H_{12}O_6$ $H_3\underline{P}O_3$ $Al(\underline{N}O_3)_3$

10

USING OXIDATION NUMBERS

If the oxidation number of the central atom increases going from left to right, oxidation has occurred.

$$ClO_2^- \rightarrow ClO_4^-$$

11

USING OXIDATION NUMBERS

If the oxidation number of the central atom decreases going from left to right, reduction has occurred.

$$NO_3^- \rightarrow HNO_2$$

12

BACK TO THE START…

CrO_4^{2-} → $Cr_2O_7^{2-}$

Is the chromium in the above equation undergoing oxidation **or** reduction?

13

NOT ALL REACTIONS ARE REDOX

Reactions in which there has been no change in oxidation number are **not** redox rxns.

Examples:

$$\overset{+1}{Ag}\,\overset{+5}{N}\,\overset{-2}{O_3}(aq) + \overset{+1}{Na}\,\overset{-1}{Cl}(aq) \rightarrow \overset{+1}{Ag}\,\overset{-1}{Cl}(s) + \overset{+1}{Na}\,\overset{+5}{N}\,\overset{-2}{O_3}(aq)$$

Precipitation reactions are NOT redox!

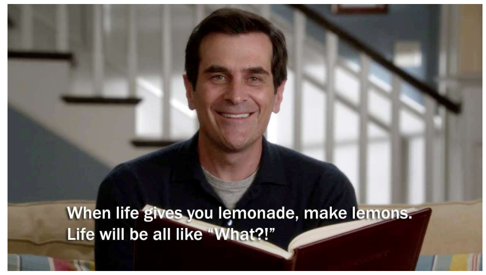
$$2\,\overset{+1}{Na}\,\overset{-2}{O}\,\overset{+1}{H}(aq) + \overset{+1}{H_2}\,\overset{+6}{S}\,\overset{-2}{O_4}(aq) \rightarrow + \overset{+1}{Na_2}\,\overset{+6}{S}\,\overset{-2}{O_4}(aq) + \overset{+1}{H_2}\,\overset{-2}{O}(l)$$

Neutralization reactions are NOT redox!

14

OXIDIZING & REDUCING AGENTS

Agents always HELP ANOTHER PARTY.



Eg) Real Estate Agents HELP OTHERS find real estate.

15

Oxidizing Agents cause oxidation…

…by undergoing reduction.

They gain electrons, causing the other reactant to lose electrons.

Reducing Agents cause reduction…

…by undergoing oxidation.

They lose electrons, causing the other reactant to gain electrons.

16

THE CHEMICAL BATTLEFIELD

$MnO_4^-(aq) + H^+(aq) + CH_3OH(l) \rightarrow Mn^{2+}(aq) + H_2O(l) + CH_2O(aq)$

1. Is this reaction a redox reaction or not? Prove it using oxidation numbers.
2. Identify the reactant being oxidized and the reactant being reduced.
3. Identify the oxidizing agent and the reducing agent.

17

7. BALANCING REDOX REACTIONS

UNIT 1 REACTIONS IN AQUEOUS SOLUTIONS
CH40S
MR. WIEBE

1

BALANCING REDOX EQUATIONS

- Redox reactions are often quite complicated and difficult to balance because you must account for all the electrons as well as the atoms!
- The method we will use to balance redox reactions is called the Half Reaction Method.

2

THE HALF-REACTION METHOD:

1. Write the unbalanced net equation.
2. Split the equation into it's LEO and GER ½ reactions.
3. Balance all elements **<u>except</u>** "H" and "O".
4. Balance the "O's" by **<u>adding water</u>**, H_2O.
5. Balance the "H's" by **<u>adding hydrogen ions</u>**, H^+.
6. Balance the electric charge by **<u>adding electrons</u>**, e^-.
7. Multiply the two equations by appropriate coefficients to make the # of electrons in the equations equal.
8. Re-combine the two equations, canceling if needed.

3

BALANCING <u>NEUTRAL</u> REDOX REACTIONS

Redox reactions that **<u>don't</u>** involve oxygen and hydrogen can be balanced fairly simply…

$Cu^+(aq) \quad + \quad Fe(s) \quad \rightarrow \quad Fe^{3+}(aq) \quad + \quad Cu(s)$

4

BALANCING ACIDIC REDOX REACTIONS

Redox reactions that **do** involve oxygen and hydrogen are a different beast…

MnO_4^{-} + $C_2O_4^{2-}$ → MnO_2 + CO_3^{2-} (ACIDIC)

5

WHAT IF IT'S BASIC?

Notice that the method has assumed the solution was **acidic** - we added H^+ to balance the equation. The $[H^+]$ in a basic solution is very small. The $[OH^-]$ is much greater.

For this reason, we will add enough OH^- ions to both sides of the equation to neutralize the H^+ in the overall reaction.

The hydrogen and hydroxide ions will combine to make water, and you may have to do some canceling before you're done.

6

BALANCING A BASIC REACTION

Balance the reaction as if acidic, then tweak it like this…

$2MnO_4^- + 3C_2O_4^{2-} + \mathbf{2H_2O} \rightarrow 2MnO_2 + 6CO_3^{2-} + \mathbf{4H^+}$

7

ALWAYS CHECK YOUR ANSWER!

Count charges on both sides. If they are equal, you are golden!

$2MnO_4^- + 3C_2O_4^{2-} + 4OH^- \rightarrow 2MnO_2 + 6CO_3^{2-} + 2\,H_2O$

8

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			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

atomic number → 26; symbol → Fe^{3+} (ion charge) iron (III) (stock name (IUPAC)); Fe^{2+} iron (II)

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

Key	
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.