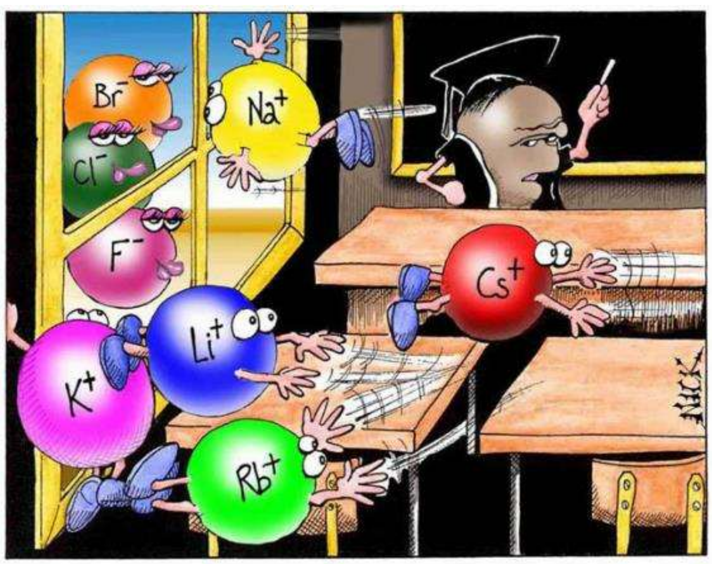
CHEMISTRY 30S

The Alchemist's Notebook

UNIT 1 – ELEMENTS & COMPOUNDS



"Perhaps one of you gentlemen would mind telling me just what it is outside the window that you find so attractive..?"

Cartoon courtesy of NearingZero.net

NAME:__________________________________

LET'S GET STARTED!

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

- ✓ Write large and small numbers in scientific notation and perform calculations on them.
- ✓ Round numbers to the correct degree of accuracy using significant digit rules.
- ✓ Convert between common units of measurement using unit analysis method.
- ✓ Evaluate the atomic structure of atoms, ions, and isotopes and calculate average atomic mass of them.
- ✓ Write formulas and names for a variety of chemical compounds including complex ionic.
- ✓ Describe the concept of the mole and calculate the molar mass of various substances.
- ✓ Solve problems requiring conversions between moles, mass, volume, and number of particles.
- ✓ Determine the % composition of elements in a compound
- ✓ Determine the empirical formula of a compound from the % composition.
- ✓ Determine the molecular formula of a compound from the empirical formula and molar mass.

THIS UNIT WILL TAKE APPROXIMATELY 20 LESSONS TO COMPLETE AND WILL COUNT 20% TOWARDS YOUR FINAL MARK.

1. SCIENTIFIC NOTATION

CH30S UNIT 1 WIEBE

1

SCIENTIFIC VALUES IN SCIENTIFIC NOTATION

Name	Symbol	Value
Universal gravitational constant	G	6.67×10^{-11} N•m²/kg²
Acceleration due to gravity	g	9.81 m/s²
Speed of light in a vacuum	c	3.00×10^{8} m/s
Speed of sound in air at STP		3.31×10^{2} m/s
Mass of Earth		5.98×10^{24} kg
Mass of the Moon		7.35×10^{22} kg
Mean radius of Earth		6.37×10^{6} m
Mean radius of the Moon		1.74×10^{6} m
Mean distance – Earth to the Moon		3.84×10^{8} m
Mean distance – Earth to the Sun		1.50×10^{11} m
Rest mass of the electron	m_e	9.11×10^{-31} kg
Rest mass of the proton	m_p	1.67×10^{-27} kg
Rest mass of the neutron	m_n	1.67×10^{-27} kg

3

DEALING WITH MEASUREMENTS

In chemistry, we deal with some very <u>LARGE</u> numbers:

1 mole = 602000000000000000000000

We also deal with some very <u>SMALL</u> numbers:

Mass of an electron = 0.00000000000000000000000000000091 kg

DEALING WITH MEASUREMENTS

Imagine the difficulty of calculating the mass of 1 mole of electrons!

0.00000000000000000000000000000091 kg
x 602000000000000000000000

???????????????????????????????????

SCIENTIFIC NOTATION

A method of representing very large or very small numbers in the form:

$$M \times 10^n$$

- M is a number between 1 and 10
- n is an integer

WRITING NUMBERS IN SCIENTIFIC NOTATION

Step #1: Insert an understood decimal point

Step #2: Decide where the decimal must end up so that one non-zero number is to its left

Step #3: Count how many places you bounce the decimal point

Step #4: Re-write in the form $M \times 10^n$

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

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

EXAMPLE #1

5732 grams

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

EXAMPLE #2

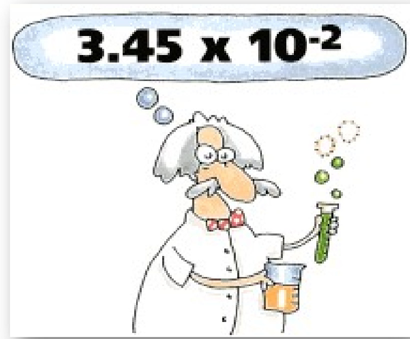
0.0050 m

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

CALCULATIONS IN SCIENTIFIC NOTATION

When multiplying and dividing two numbers in scientific notation, always do it in THREE STEPS!

1. Front numbers
2. Exponents
3. Units



$(1.0 \times 10^5 \text{ kg})(1.0 \times 10^{-2} \text{ kg})$

MULTIPLYING SCIENTIFIC NOTATION

EXAMPLE #1

$(3.0 \times 10^5 \text{cm})\ (2.0 \times 10^4 \text{cm})$

DIVIDING SCIENTIFIC NOTATION

EXAMPLE #2

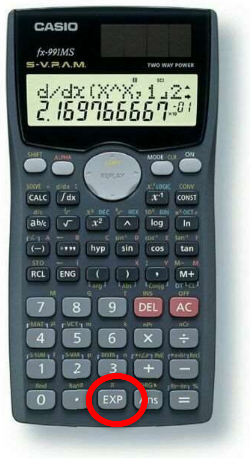
$$\frac{(9 \times 10^{7}\ kg)}{(3 \times 10^{3}\ s)}$$

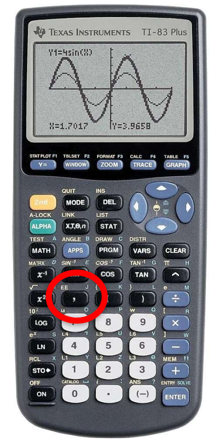
DIVIDING SCIENTIFIC NOTATION

EXAMPLE #3

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

SCIENTIFIC NOTATION ON YOUR CALCULATOR





CHALLENGE!

1 mole of anything:
600000000000000000000000

Mass of an electron
0.000000000000000000000000000000090 kg

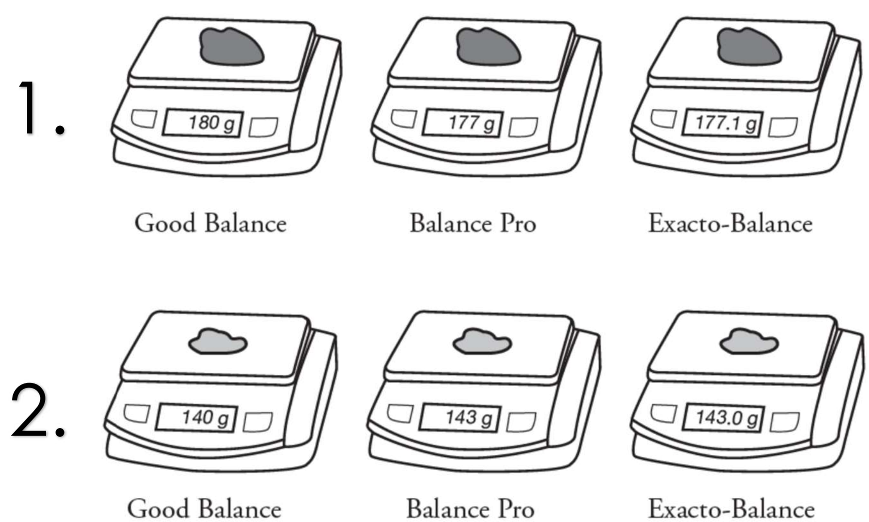
HOW MANY KILOGRAMS WOULD 1 MOLE OF ELECTRONS WEIGH?

2. SIGNIFICANT DIGITS

CH30S UNIT 1 WIEBE

1

WHICH SCALE IS MOST RELIABLE?



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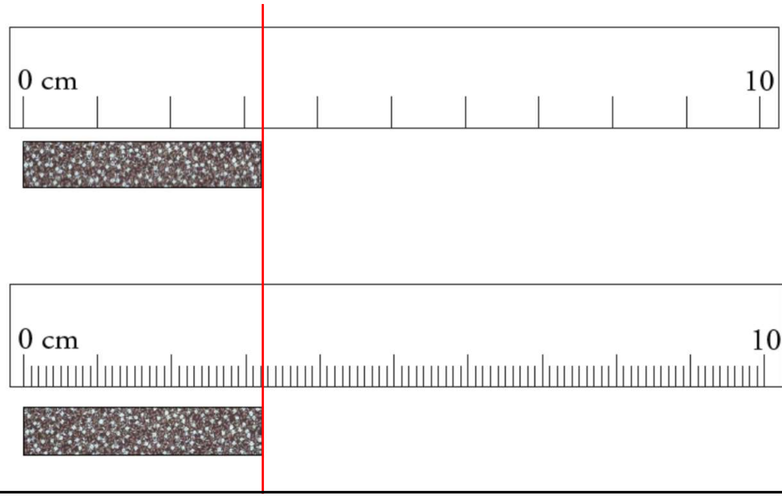
COMMUNICATING RELIABILITY

When measuring with ANY device, write all the certain values PLUS ONE ESTIMATE!



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WHAT ARE SIGNIFICANT DIGITS?

- A set of rules that communicate the reliability of a measurement.
- By following the rules, you ensure that your answer to a calculation that uses measurements is as reliable as it should be.
- In other words, they allow you to round your answer to a calculation correctly.

4

ANALOGY:

Attempting to Locate Your Friends in 2004 (before smartphones)

Me: Where are you guys?

Friend #1: Uh…we are on a road with buildings on it.

Friend #2: Yah…we're standing near a blue car.

Me: Oh cool. Sounds like you are on the southwest corner of Manitoba Avenue and Main Street. I'll be right there.

YOUR CONCLUSION FROM THIS INFORMATION IS TOO DETAILED AND THEREFOR UNRELIABLE. THE SAME IS TRUE OF MEAUREMENTS!

5

THE RULES

1. Leading Zeros are **NOT** significant.

0.00245 L

6

THE RULES

2. Trailing Zeros in a non-decimal number are **NOT** significant.

5500 g

7

THE RULES

3. ALL other zeros and numbers are significant.

10.25 g   3.00 mL 1.0×10^{-7}

8

THE RULES

4. Round your answer to the number of sig digs in the <u>least accurate measurement</u> you started with.

$$\frac{3.0 \times 10^{-3}\ g}{1.50 \times 10^{4}\ cm^3}$$

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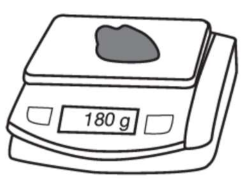
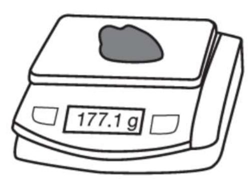
EXAMPLE:



Good Balance

Volume of rock:
$9.52\ cm^3$



Exacto-Balance

Density of Rock Using Good Balance:

Density of Rock Using Exacto-Balance:

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3. UNIT ANALYSIS

CH30S UNIT 1 WIEBE

1

REVIEW

A rectangular parcel of land has the dimensions of 14500 m long and 2000 m wide.

1. Convert each of these values into scientific notation.
2. How many significant digits are each of these values measured to?
3. Without using a calculator, calculate the area of the land. Round your answer correctly.

3

BASIC UNIT ANALYSIS

In the far away country of Yrtsimehc, the monetary currency is based on “izzles” rather than “dollars”. The following equivalencies 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?

4

EXAMPLE #1

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?

5

EXAMPLE #2

Given that:

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

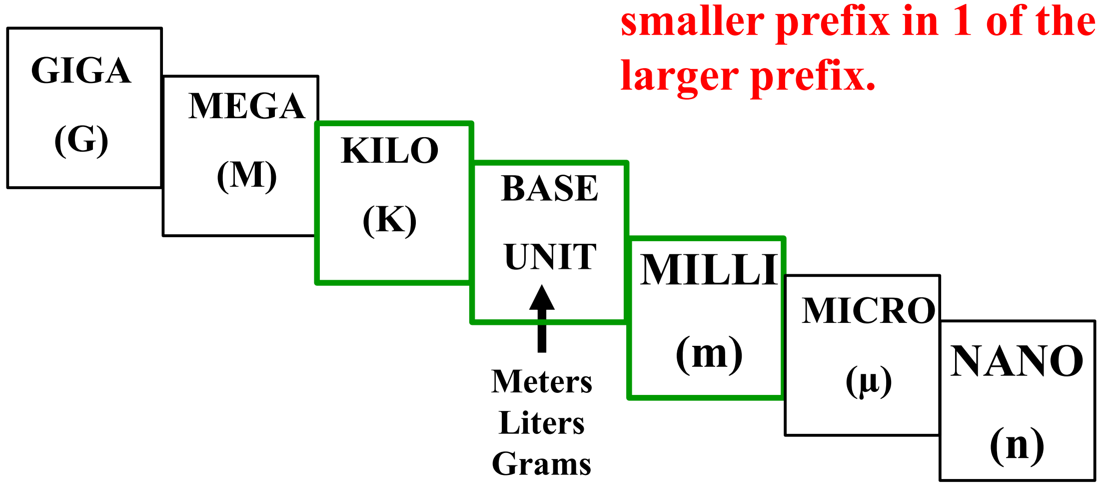
4.54 L = 1.00 gal
1.61 km = 1.00 mile
2000 lb = 1 ton

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

6

Very big

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

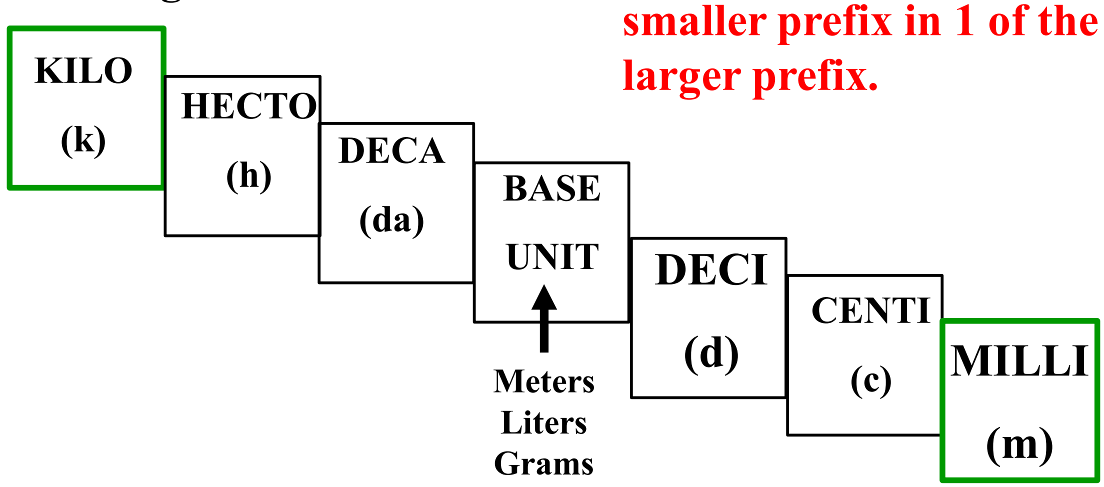


Very small

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

7

Kinda big



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

Pretty small

King Henry Died Drinking Chocolate Milk

8

EXAMPLE #3

Visible light, as well as ultraviolet, infrared, X-ray, and other radiation, is characterized by what is called wavelength. The wavelength of certain infrared light is 30 micrometers.

How many nanometers is this?

9

EXAMPLE #4

A sample of an unknown metal has a volume of 125 m^3

How many cubic kilometers (km^3) is this?

10

EXAMPLE #5

Ethanol, the alcohol found in beer, wine, and spirits, has a density of 0.789 g/mL.

What is this density in mg/kL?

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4. ATOMIC STRUCTURE

CH30S UNIT 1 – ELEMENTS & COMPOUNDS

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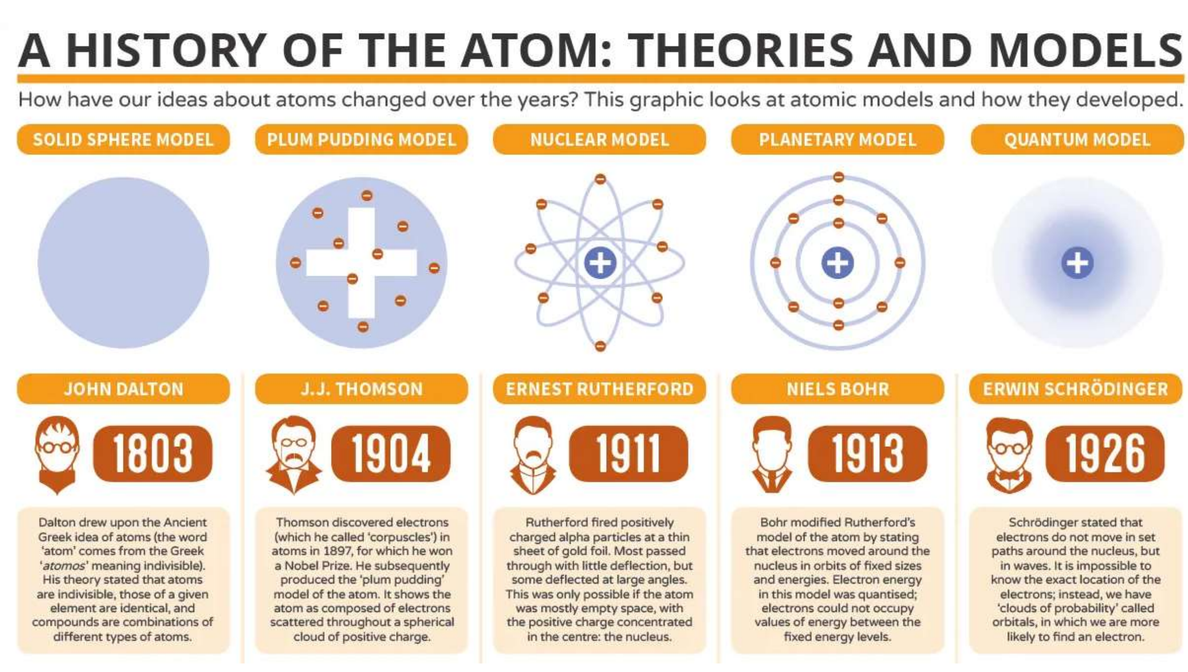

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THE ATOMIC MODEL

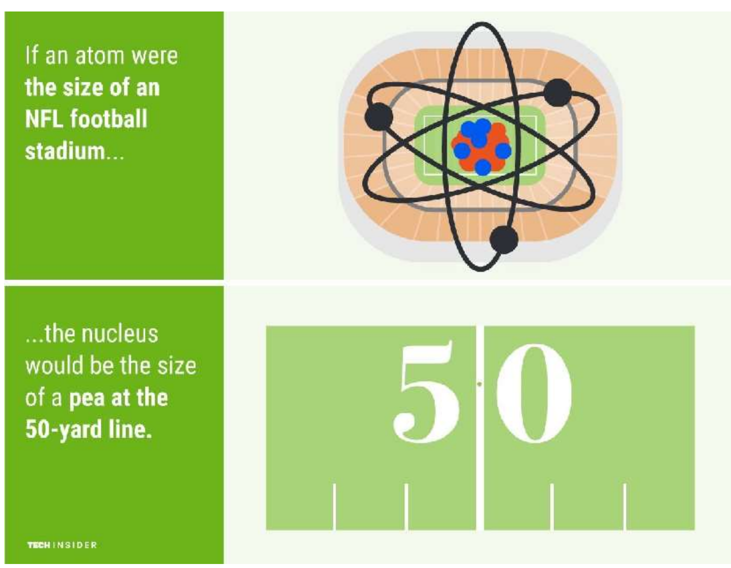
The most common model of the atom is like a mini solar system. While this is not truly accurate, it works for now!

THE <u>MASS</u> OF THE ATOM IS DUE TO THE SIZE OF THE NUCLEUS.

THE <u>SIZE</u> OF THE ATOM IS DUE TO THE NUMBER OF ELECTRONS.

3

PUTTING IN TO PERSPECTIVE



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WHAT MAKES UP AN ATOM?

Most people already know that the atom is made up of three main parts, the protons and neutrons in the **nucleus** and the electrons somewhere outside of the **nucleus**.

	PROTONS	NEUTRONS	ELECTRONS
SYMBOL			
CHARGE			
LOCATION			

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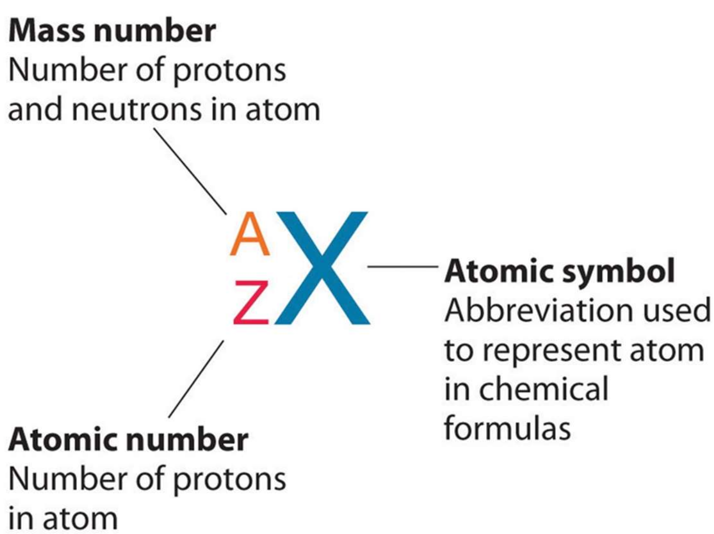
ATOMIC NOTATION



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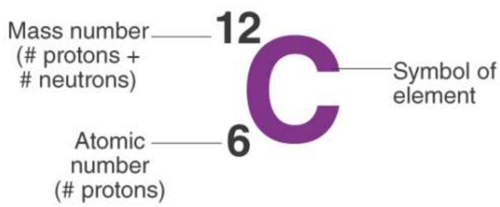
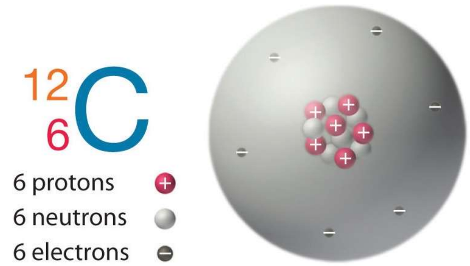
ATOMIC NOTATION





CARBON - 12

7

ATOMIC NUMBER (Z)

The proton is the particle that determines the identity of the element.

The atomic number of an element is the number of protons found in the nucleus of the atom.

ATOMIC NUMBER (Z)	NUMBER OF PROTONS	IDENTITY OF ELEMENT
23		
92		
		Chlorine
		Magnesium

8

ATOMIC NUMBER (Z)

Atoms (as opposed to ions) are electrically neutral, meaning they have one electron for every proton.

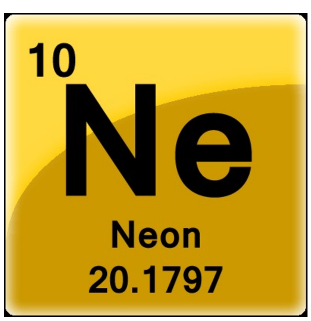
ELEMENT	NUMBER OF PROTONS	NUMBER OF ELECTRONS
sodium		
potassium		
sulphur		
bromine		

9

MASS NUMBER (A)

The mass of an atom is found in its nucleus.

The mass number of an atom is the sum of its protons and neutrons.



Determining Neutrons:

10

EXAMPLE #1

Determine the number of protons, electrons, and neutrons in:

a) ^{210}Pb

b) ^{34}S

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IONS

Chemical changes involve the gaining or losing of electrons only.

Ions are atoms (or groups of atoms) that have gained or lost electrons during a reaction to become electrically charged.

$^{24}_{12}Mg^{2+}$

Magnesium Cation
Lost 2 electrons

$^{31}_{15}P^{3-}$

Phosphide Anion
Gained 3 electrons

12

EXAMPLE #2

Determine the number of protons, neutrons, and electrons present in the following substances:

$^{207}_{82}Pb$ $^{209}_{82}Pb$ $^{207}_{82}Pb^{2+}$

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YOUR TURN!

NASA has just discovered a delicious new element on Mars that smells and tastes like lunch meat. The have called it Bolognium (Bo). Determine the number of protons (p^+), neutrons (n^0) and electrons (e^-) in the following atomic notation of Bolognium.

$^{293}_{115}Bo$ $^{296}_{115}Bo$ $^{294}_{115}Bo^{2-}$

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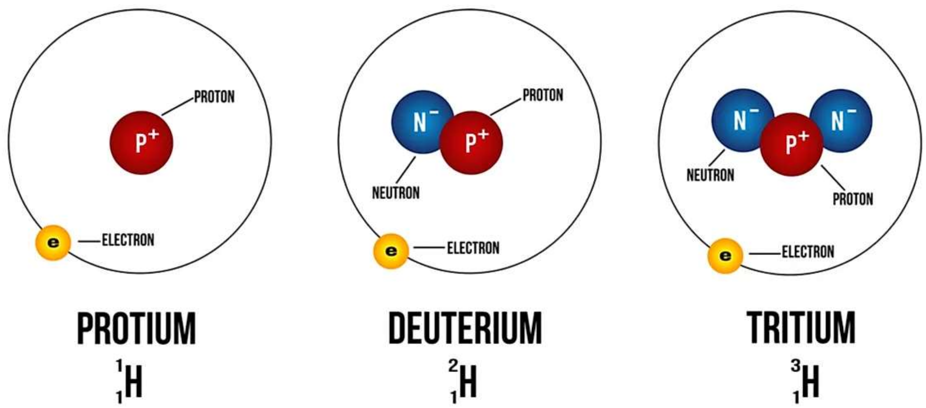
ISOTOPES

<u>Isotopes</u> are atoms of the same element having different masses due to **varying numbers of neutrons.**



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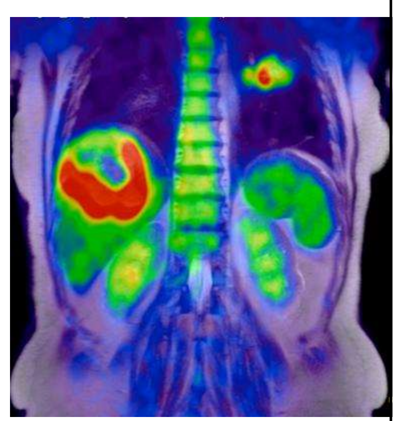
COMMON MEDICAL ISOTOPES

Radioactive Isotope	Applications in Medicine
Cobalt-60	Radiation therapy to prevent cancer
Iodine-131	Locate brain tumors, monitor cardiac, liver and thyroid activity
Carbon-14	Study metabolism changes for patients with diabetes, gout and anemia
Carbon-11	Tagged onto glucose to monitor organs during a PET scan
Sodium-24	Study blood circulation
Thallium-201	Determine damage in heart tissue, detection of tumors



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AVERAGE ATOMIC MASS

- The average mass of all the naturally occurring isotopes of that element.
- This explains why atomic masses on your periodic table are decimals and not whole numbers, as you might expect.

Isotope	Symbol	Composition of the nucleus	% in nature
Carbon-12	^{12}C	6 protons 6 neutrons	98.89%
Carbon-13	^{13}C	6 protons 7 neutrons	1.11%
Carbon-14	^{14}C	6 protons 8 neutrons	<0.01%

19

19

EXAMPLE # 3

Use the mass spectrometry data below to calculate the average atomic mass of iron.

Table 2. Stable Isotopes of Iron

Isotope	Mass (amu)	% Abundance
^{54}Fe	53.94	5.845
^{56}Fe	55.93	91.75
^{57}Fe	56.94	2.119

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YOUR TURN

Use the mass spectrometry data below to calculate the average atomic mass of neon.

Strontium		
Isotope	Mass (amu)	Abundance
Sr-84	83.913428	0.56%
Sr-86	85.909273	9.86%
Sr-87	86.908902	7.00%
Sr-88	87.905625	82.58%

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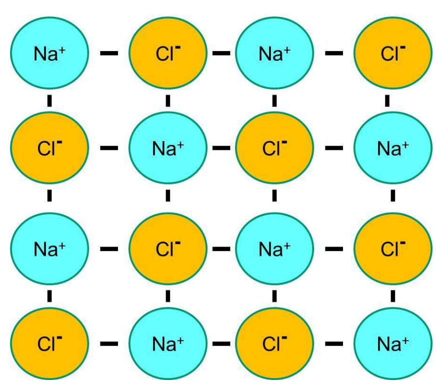
5. CHEMICAL COMPOUNDS

CH30S UNIT 1 – ELEMENTS & COMPOUNDS

1

IONIC COMPOUNDS

- Ionic compounds contain positive ions called **cations.** and negative ions called **anions**.
- **Cations** usually form when **metal** atoms **lose electrons** and **anions** usually form when **non-metal** atoms **gain electrons**.
- These ions combine in specific ratios to form **solid crystal lattices**.



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2

BINARY IONIC COMPOUNDS

HOW DO I RECOGNIZE THESE?

Example: Aluminum oxide

Example: $CaCl_2$

3

3

MULTIVALENT IONIC COMPOUNDS

HOW DO I RECOGNIZE THESE?

Example: Iron(III) chloride

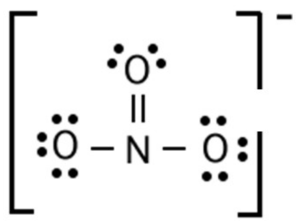
Example: Cu_2S

4

4

POLYATOMIC IONIC COMPOUNDS

- Many ionic compounds, such as baking soda (sodium bicarbonate) and battery acid (hydrogen sulphate) contain more than 2 different elements.
- These compounds contain a **POLYATOMIC ION**, a group of non-metal atoms that bond together and have a negative charge.



nitrate - NO_3^-

5

5

POLYATOMIC IONIC COMPOUNDS

HOW DO I RECOGNIZE THESE?

Example: **barium nitrate**

Example: **ammonium sulfate**

Example: **Zinc hydroxide**

6

POLYATOMIC IONIC COMPOUNDS (cont'd)

HOW DO I RECOGNIZE THESE?

7

Example: $CaCO_3$

Example: $Ca_3(PO_4)_2$

Example: NH_4NO_3

7

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!"

8

8

COVALENT COMPOUNDS

Some covalent compounds have **common names** like :

H_2O	=	water	=	dihydrogen monoxide
NH_3	=	ammonia	=	nitrogen trihydride
CH_4	=	methane	=	carbon tetrahydride
H_2O_2	=	hydrogen peroxide	=	dihydrogen dioxide
O_3	=	ozone	=	trioxide

9

9

COVALENT COMPOUNDS

First element:

- Keeps its element name
- **Gets a prefix if there is a subscript on it**

Second element:

- Use the root of the element name plus the *-ide* suffix
- **Always use a prefix on the second element**

Number	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-
8	octa-
9	nona-
10	deca-

10

10

COVALENT COMPOUNDS

HOW DO I RECOGNIZE THESE?

Example: P_2O_5

Example: N_2O

Example: carbon monoxide

Example: nitrogen triiodide

6. THE MOLE

CH30S UNIT 1 - ELEMENTS & COMPOUNDS

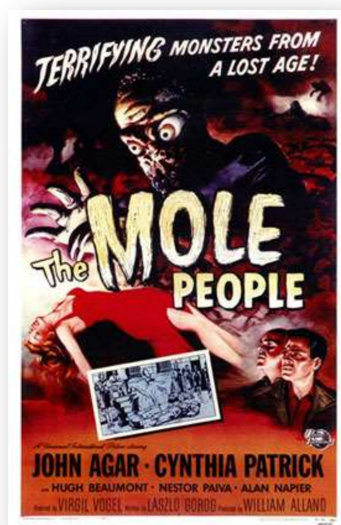
1

QUANTIFYING ATOMS & MOLECULES

Atoms and molecules are extremely small.

If they are so small and so light, how can we weigh them?

We weigh large numbers of them.



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THE MOLE CONCEPT

1 dozen = 12
1 gross = 144
1 ream = 500
1 mole = 6.02×10^{23}

This is called **Avogadro's number**

3

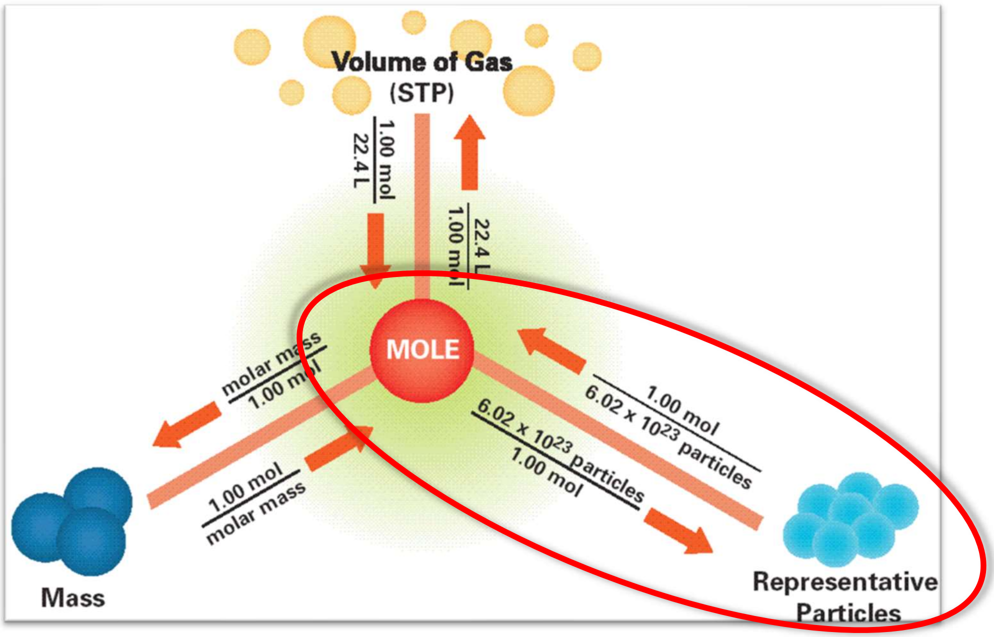
A MOLE IS A BIG, BIG NUMBER!

The mole is a **large number** of particles. The following conversion factor can be used to convert between particles and moles of any substance.

$$\frac{6.02 \times 10^{23} \text{ particles}}{1 \text{ mole}} \quad \text{OR} \quad \frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ particles}}$$

4

THE MOLE MAP



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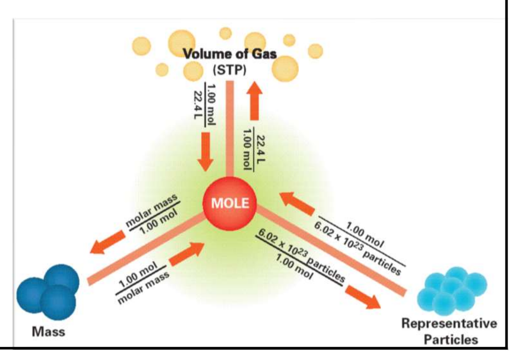
EXAMPLE #1

If your pencil contained 9.5 x 10^{23} **atoms** of carbon in the form of graphite, how many **moles** of carbon does your pencil contain?



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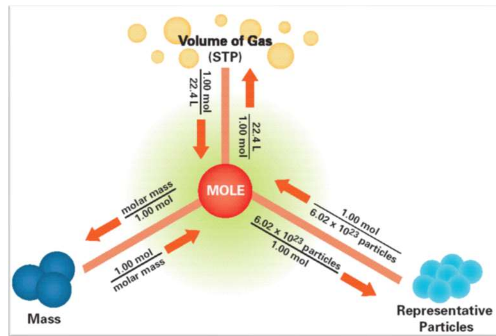
EXAMPLE #2

If you breath out 4.5 X 10^{-3} **moles** of CO_2 every breath, how many **molecules** of carbon dioxide are you exhaling?



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MOLAR MASS

- The **atomic mass** of an element/compound is the sum of the number of protons & neutrons in the nucleus of the atom(s).

- The **molar mass** of an element/compound is the mass of one mole of particles and the unit is grams/mole.

ATOMIC MASS = MOLAR MASS!

8

MOLAR MASS

He

CO_2

lithium nitrate

$Ni_2(CO_3)_3$

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

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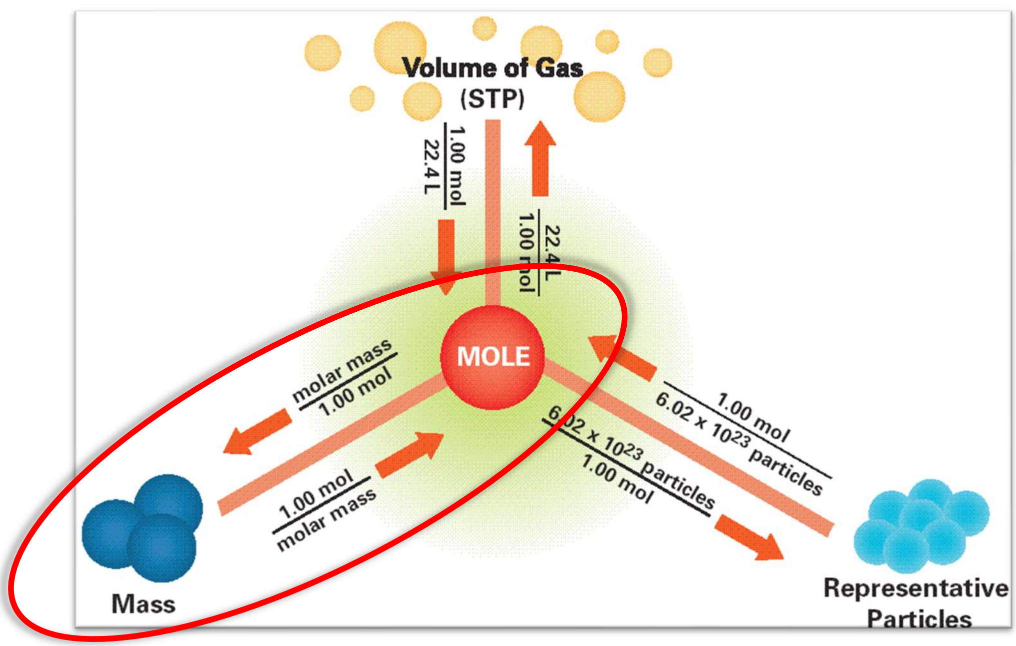
THE MOLE MAP



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EXAMPLE #3

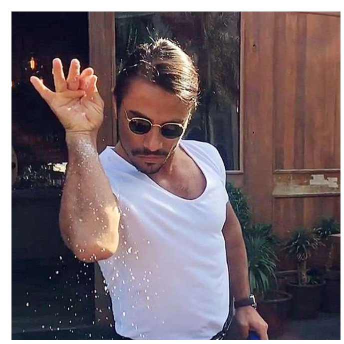
A liter of regular gasoline typically contains about **19 moles** of octane molecules (C_3H_8).

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

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

11

EXAMPLE #4



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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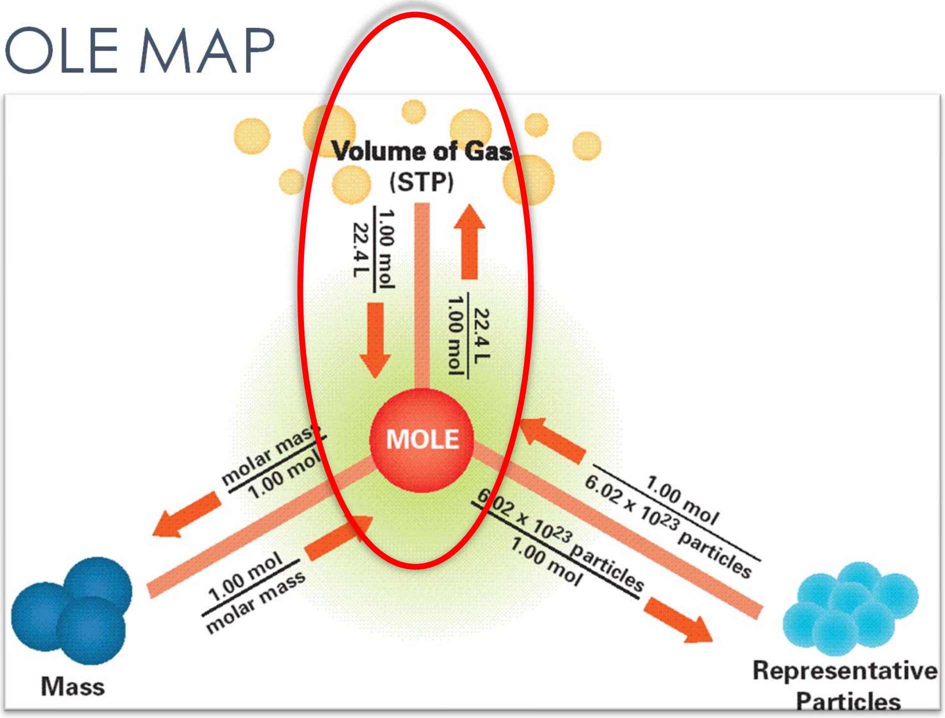
THE MOLE MAP



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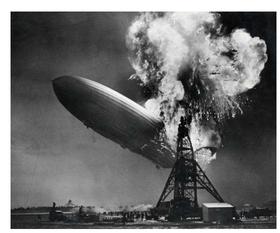
EXAMPLE #5



The Hindenburg was a hydrogen filled airship that exploded spectacularly in 1937. It contained approximately **2×10^8 liters** of hydrogen gas.

How many **moles** of hydrogen was this?

How many **molecules** of hydrogen was this?

14

EXAMPLE #6

A pop bottle rocket contains 4.5 x 10^{-2} **mol** of hydrogen gas at STP (standard temperature and pressure: 0°C and 1 atmosphere…more on this later).

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

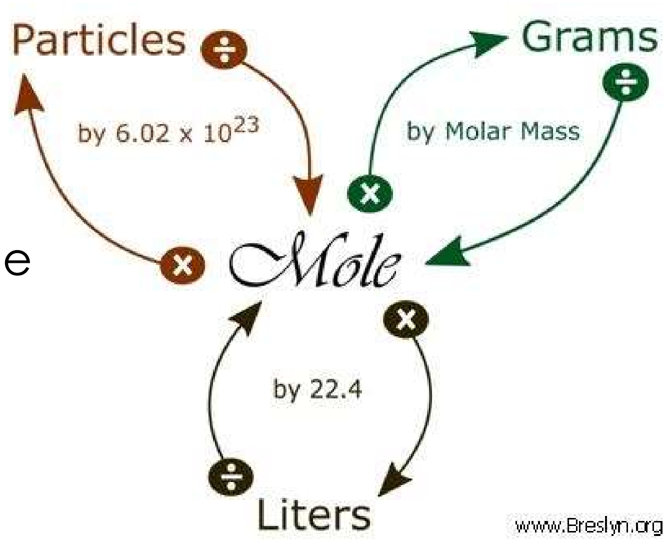
What is the **volume** of hydrogen in the bottle?

15

SUMMARY

1 <u>mole</u> of anything!

= **molar mass** of substance
= **6.02 x 10^{23}** particles
= **22.4 L of gas** @ STP



16

7. PERCENT COMPOSITION

CH30S UNIT 1 – ELEMENTS & COMPOUNDS

1

LAW OF DEFINITE PROPORTIONS

Joseph-Louis Proust

$2H_2O \rightarrow 2H_2 + O_2$

100 g → 11 g + 89 g

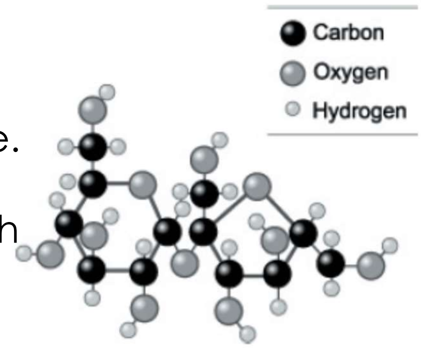
In other words…

- Waters mass composition is ALWAYS 11% H : 89% O
- Waters mole composition is ALWAYS 2 moles H : 1 mole O

2

Sucrose is the form of sugar found in soda & candy. Excess sucrose in your diet has been linked to obesity, diabetes, and heart disease.

Detemine the % composition by mass of each element in a mole of sucrose.

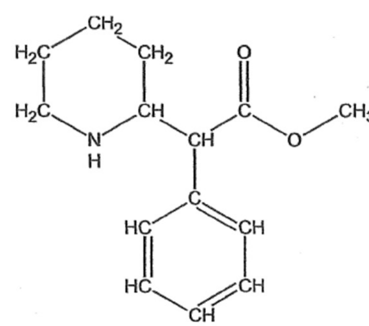


1. Determine the formula.
2. Calculate the molar mass.
3. Find proportions.

3

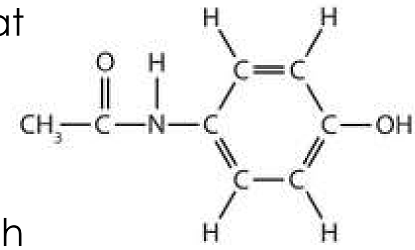
Ritalin© is a medication used to treat Attention Deficit Hyperactivity Disorder (ADHD). Is has the molecular structure shown here.

Detemine the % composition by mass of each element in a mole of Ritalin.



4

Acetaminophen is an analgesic molecule that reduces pain by inhibiting the transmission of pain signals to your brain.



Determine the % composition by mass of each element in a mole of acetaminophen.

5

8. EMPIRICAL FORMULAS

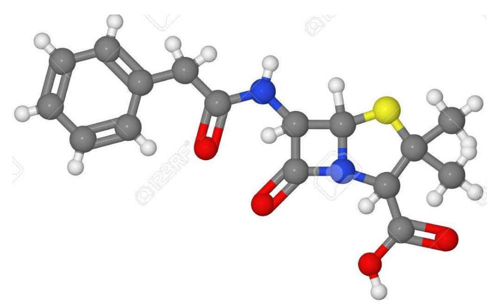
CH30S UNIT 1 – ELEMENTS & COMPOUNDS

1

REVIEW

Penicillin is an antibiotic molecule that has saved millions of lives from bacterial infection. Alexander Fleming accidentally discovered it in 1928, when he came back from a vacation and found that a green mold called *Pennicilium notatum* had contaminated Petri dishes in his lab and were killing some of the bacteria he'd been growing.

Black = Carbon
Blue = Nitrogen
Yellow = Sulphur
White = Hydrogen
Red = Oxygen



1. Write the chemical formula of penicillin.
2. Determine the molar mass.
3. What is the percent composition of penicillin?
4. A vet gives your dog 75 mg of penicillin. How many moles is this? How many molecules are in the dose?

2

REVIEW ANSWERS

3

TYPES OF CHEMICAL FORMULAS

Every compound has 3 formulas that represent it:

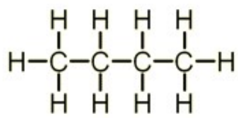
1. Empirical formula: the lowest whole number ratio of atoms or moles of atoms in a compound.
2. Molecular formula: the true number of atoms or moles of atoms of each element in the formula of a compound.
3. Structural formula: a diagram of the arrangement of the atoms in a molecule of that chemical.

4

FOR EXAMPLE

BUTANE

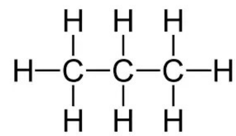
- Structural Formula:



- Molecular Formula:
- Empirical Formula:

PROPANE

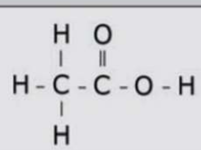
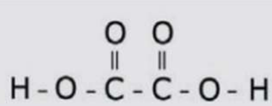
- Structural Formula:



- Molecular Formula:
- Empirical Formula:

5

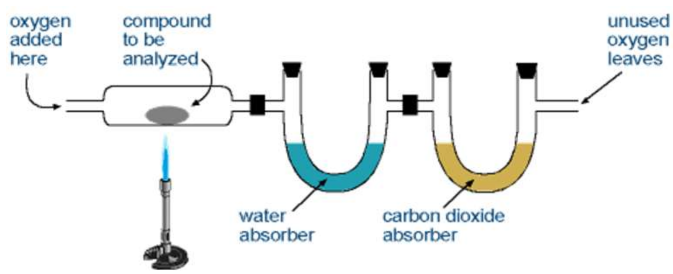
QUICK CHECK…

Structural Formula	Molecular Formula	Empirical Formula
		
		

6

EMPIRICAL FORMULAS

- Chemists can take an unknown compound and determine the % composition of each element in the compound through a process called combustion analysis.
- From these % compositions, the empirical formula can be determined, and the compound can be identified.



7

EXAMPLE #1

RDX is an organic explosive used extensively in World War II in combination with TNT. It is still used today by the military in many countries.

The percent composition of RDX was found to be 16.2% carbon, 2.73% hydrogen, 37.8% nitrogen, and the remainder is oxygen. Determine the empirical formula of RDX.

8

EXAMPLE #2

Nicotine is an addictive ingredient found in tobacco products. It is linked to many different health problems, including cancer, lung disease, and aneurysms. The percent composition of nicotine was found to be 74.02 % carbon, 8.71% hydrogen, and the remainder is nitrogen. Determine the empirical formula of nicotine.

9

9. MOLECULAR FORMULAS

CH30S UNIT 1 WIEBE

1

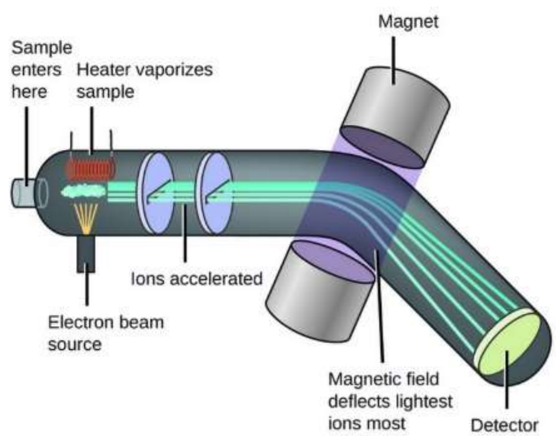
REVIEW

- We can use a variety of methods to find the **% composition** of an unknown compound (ie. combustion analysis, elemental analysis)
- From the % composition, we can determine the **empirical formula** of a compound (last lesson)
- The empirical formula of a compound is the **lowest whole number ratio** of elements in the compound.

2

MOLECULAR FORMULA DETERMINATION

- Using a **mass spectrometer**, we can determine the **molar mass** of an unknown compound.
- If we compare this measured molar mass with the molar mass of the empirical formula, we can determine the molecular formula of the unknown compound!



3

RELATING EMPIRICAL TO MOLECULAR

	EMPIRICAL FORMULA	E.F. MOLAR MASS	M.F. MOLAR MASS	MOLECULAR FORMULA
EXAMPLE #1	**C_4H_8NO**		**258.24 g/mol**	
EXAMPLE #2	**C_7H_{12}**		**192.24 g/mol**	

4

EXAMPLE #1

Caffeine is the component of coffee and tea that stimulates the cerebral cortex. A typical cup of coffee or tea contains about 0.10 g of caffeine. Combustion analysis indicates that caffeine is 49.47% carbon, 5.20% hydrogen, 16.48% oxygen, and the remainder nitrogen. If the molar mass of caffeine is 194.22 g/mol, what is the empirical and molecular formula of caffeine?

5

EXAMPLE #2

Serotonin is a compound that conducts nerve impulses in the brain and influences the moods we experience. It is composed of 68.2% carbon, 6.86% hydrogen, 15.9% nitrogen, and 9.08% oxygen. Its molar mass is 176 g/mol. Determine the empirical and molecular formula for serotonin.

6

Fundamental Constants

Name	Symbol	Value
Speed of light in a vacuum	c	3.00×10^{8} m/s
Magnitude of charge of electron	e	1.602×10^{-19} C
Planck's constant	h	6.626×10^{-34} J·s
Boltzmann constant	k	1.381×10^{-23} J/K
Avogadro's number	N_A	6.022×10^{23} particles/mol
Gas constant, SI	R	8.314 L·kPa/mol·K
Gas constant	R	0.08206 L·atm/mol·K
Mass of electron	m_e	9.109×10^{-31} kg
Mass of proton	m_p	1.673×10^{-27} kg
Mass of neutron	m_n	1.675×10^{-27} kg
Faraday constant	$\mathscr{F}$ or F	96 485 C/mol e^-

International System (SI) Units

Physical Quantity	Name of Unit	Symbol
	base units	
Length (l)	Meter	m
Mass (m)	Kilogram	kg
Time (t)	Second	s
Temperature (T)	Kelvin	K
Electric Current (I)	Ampere	A
Luminous Intensity (φ)	Candela	cd
Amount of Substance	Mole	mol
	derived units	
Area (A)	square meter	m^2
Volume (V)	cubic meter	m^3
Frequency (ν)	Hertz	Hz [s^{-1}]
Speed, velocity (v)	meter per second	m/s
Force (F)	Newton	N [kg·m/s^2]
Pressure (P)	Pascal	Pa [N/m^2]

Common SI Prefixes

Factor	Prefix	Symbol	Factor	Prefix	Symbol
10^{12}	tera	T	10^{-2}	centi	c
10^{9}	giga	G	10^{-3}	milli	m
10^{6}	mega	M	10^{-6}	micro	μ
10^{3}	kilo	k	10^{-9}	nano	n
			10^{-12}	pico	p
			10^{-15}	femto	f

e.g. 1 km = 1 x 10^3 m

e.g. 1 μg = 1 x 10^{-6} g

PERIODIC TABLE OF IONS

KEY: 26 Fe^{3+} iron (III) / Fe^{2+} iron (II) — atomic number; ion charge; symbol; ion name (IUPAC)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H^+ hydrogen																1 H^- hydride	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^{3+} vanadium(III) V^{5+} vanadium (V)	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+} technitium	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_2^{2+} 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															

58 Ce^{3+} cerium	59 Pr^{3+} praseodymium	60 Nd^{3+} neodymium	61 Pm^{3+} promethium	62 Sm^{3+} samarium(III) Sm^{2+} samarium(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^{3+} 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 Lr^{3+} lawrencium

TABLE OF POLYATOMIC IONS

acetate	CH_3COO^-	dihydrogen phosphate	$H_2PO_4^-$	oxalate	$C_2O_4^{2-}$
arsenate	AsO_4^{3-}	hydrogen carbonate	HCO_3^-	perchlorate	ClO_4^-
arsenite	AsO_3^{3-}	hydrogen oxalate	$HC_2O_4^-$	periodate	IO_4^-
benzoate	$C_6H_5COO^-$	hydrogen sulfate	HSO_4^-	permanganate	MnO_4^-
borate	BO_3^{3-}	hydrogen sulfide	HS^-	peroxide	O_2^{2-}
bromate	BrO_3^-	hydrogen sulfite	HSO_3^-	phosphate	PO_4^{3-}
carbonate	CO_3^{2-}	hydroxide	OH^-	pyrophosphate	$P_2O_7^{4-}$
chlorate	ClO_3^-	hypochlorite	ClO^-	sulfate	SO_4^{2-}
chlorite	ClO_2^-	iodate	IO_3^-	sulfite	SO_3^{2-}
chromate	CrO_4^{2-}	monohydrogen phosphate	HPO_4^{2-}	thiocyanate	SCN^-
cyanate	CNO^-	nitrate	NO_3^-	thiosulfate	$S_2O_3^{2-}$
cyanide	CN^-	nitrite	NO_2^-	POSITIVE POLYATOMIC IONS	
dichromate	$Cr_2O_7^{2-}$	orthosilicate	SiO_4^{4-}	ammonium	NH_4^+
				hydronium	H_3O^+

The Periodic Table of the Elements

Average relative masses are rounded to two decimal places.

Element name → Mercury
Atomic # → 80
Symbol → Hg
Avg. Mass → 200.59

1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hydrogen 1 H 1.01																		Helium 2 He 4.00
Lithium 3 Li 6.94	Beryllium 4 Be 9.01												Boron 5 B 10.81	Carbon 6 C 12.01	Nitrogen 7 N 14.01	Oxygen 8 O 16.00	Fluorine 9 F 19.00	Neon 10 Ne 20.18
Sodium 11 Na 22.99	Magnesium 12 Mg 24.31												Aluminum 13 Al 26.98	Silicon 14 Si 28.09	Phosphorus 15 P 30.97	Sulfur 16 S 32.07	Chlorine 17 Cl 35.45	Argon 18 Ar 39.95
Potassium 19 K 39.10	Calcium 20 Ca 40.08		Scandium 21 Sc 44.96	Titanium 22 Ti 47.88	Vanadium 23 V 50.94	Chromium 24 Cr 52.00	Manganese 25 Mn 54.94	Iron 26 Fe 55.85	Cobalt 27 Co 58.93	Nickel 28 Ni 58.69	Copper 29 Cu 63.55	Zinc 30 Zn 65.39	Gallium 31 Ga 69.72	Germanium 32 Ge 72.61	Arsenic 33 As 74.92	Selenium 34 Se 78.96	Bromine 35 Br 79.90	Krypton 36 Kr 83.80
Rubidium 37 Rb 85.47	Strontium 38 Sr 87.62		Yttrium 39 Y 88.91	Zirconium 40 Zr 91.22	Niobium 41 Nb 92.91	Molybdenum 42 Mo 95.94	Technetium 43 Tc (97.91)	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 102.91	Palladium 46 Pd 106.42	Silver 47 Ag 107.87	Cadmium 48 Cd 112.41	Indium 49 In 114.82	Tin 50 Sn 118.71	Antimony 51 Sb 121.76	Tellurium 52 Te 127.60	Iodine 53 I 126.90	Xenon 54 Xe 131.29
Cesium 55 Cs 132.91	Barium 56 Ba 137.33	57-70 *	Lutetium 71 Lu 174.97	Hafnium 72 Hf 178.49	Tantalum 73 Ta 180.95	Tungsten 74 W 183.84	Rhenium 75 Re 186.21	Osmium 76 Os 190.23	Iridium 77 Ir 192.22	Platinum 78 Pt 195.08	Gold 79 Au 196.97	Mercury 80 Hg 200.59	Thallium 81 Tl 204.38	Lead 82 Pb 207.20	Bismuth 83 Bi 208.98	Polonium 84 Po (208.98)	Astatine 85 At (209.99)	Radon 86 Rn (222.02)
Francium 87 Fr (223.02)	Radium 88 Ra (226.03)	89-102 **	Lawrencium 103 Lr (262.11)	Rutherfordium 104 Rf (265.12)	Dubnium 105 Db (268.13)	Seaborgium 106 Sg (271.13)	Bohrium 107 Bh (270)	Hassium 108 Hs (277.15)	Meitnerium 109 Mt (276.15)	Darmstadtium 110 Ds (281.16)	Roegentium 111 Rg (280.16)	Copernicium 112 Cn (285.17)	Nihonium 113 Nh (284.18)	Flerovium 114 Fl (289.19)	Moscovium 115 Mc (288.19)	Livermorium 116 Lv (293)	Tennessine 117 Ts (294)	Oganesson 118 Og (294)

*lanthanides	Lanthanum 57 La 138.91	Cerium 58 Ce 140.12	Praseodymium 59 Pr 140.91	Neodymium 60 Nd 144.24	Promethium 61 Pm (145)	Samarium 62 Sm 150.36	Europium 63 Eu 151.97	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.93	Dysprosium 66 Dy 162.50	Holmium 67 Ho 164.93	Erbium 68 Er 167.26	Thulium 69 Tm 168.93	Ytterbium 70 Yb 173.05
**actinides	Actinium 89 Ac (227.03)	Thorium 90 Th 232.04	Protactinium 91 Pa 231.04	Uranium 92 U 238.03	Neptunium 93 Np (237.05)	Plutonium 94 Pu (244.06)	Americium 95 Am (243.06)	Curium 96 Cm (247.07)	Berkelium 97 Bk (247.07)	Californium 98 Cf (251.08)	Einsteinium 99 Es (252.08)	Fermium 100 Fm (257.10)	Mendelevium 101 Md (258.10)	Nobelium 102 No (259.10)