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REVIEW OF GENERAL CHEMISTRY

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Nomenclature

There are 3 systems for naming of chemical compounds, depending on the type of molecule:

Ionic compounds
Covalent compounds
Organic molecules (a subtype of covalent compounds)

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Ionic Compounds

Formed from a metal (left side of the periodic table) and a non-metal (right side of the periodic table) or a polyatomic anion. The metal has a "+" charge (it is called a cation), the non-metal has a "-" charge (it is called an anion)

It is very simple to name an ionic compound:

1. Name the metal first
2. Name the non-metal second
3. Add "-ide" to the root of the non-metal

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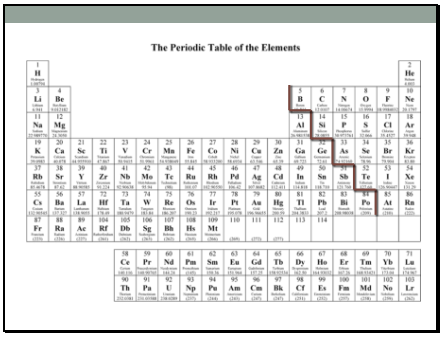

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Some examples…

sodium + chlorine
NaCl – sodium chloride

magnesium + fluorine
MgF_2 – magnesium fluoride

iron + nitrogen
Fe_2N_3 – iron nitride

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Some examples…

But, iron is a transition metal, it has more than one possible oxidation state (charge when an ion)

Fe_2N_3 – iron (III) nitride

The (III) indicates the CHARGE OF THE IRON (not how many there are.

Fe_3N_2 – iron (II) nitride

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How do you know the charge?

Some are easy, some are hard.

Certain groups (columns) in the periodic table are predictable. Start with those as knowns and you can sometimes figure out the unknowns based on the total charge of the molecule or ion.

The total of all the atoms charges must equal the total of the entire species.

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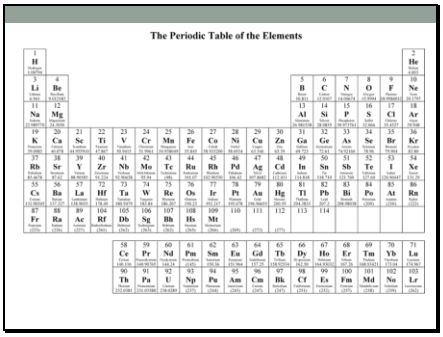

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Group I (H and everything underneath it) Almost always +1

Group II (Be and everything underneath it)
Almost always +2

Group VI (oxygen and friends). Usually -2

Group VII (fluorine and friends). Usually -1

The ones in the middle ("transition metals") have multiples and those you usually figure out based on what they are bonded to.

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For example…

CrS_3

Chromium is a transition metal, it has multiple possible "oxidation states" (charges) including +3, +4, +6. So you can't tell just by looking at it.

But sulfur…

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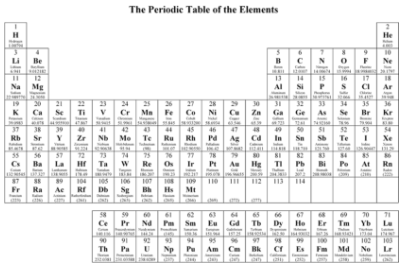

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CrS_3

Sulfur is under oxygen in Group VI. So it is almost always…
-2

There are 3 S atoms in the molecule:
3*(-2) = -6

For the whole molecule to be neutral, the total charge must be zero, so chromium must be a +6

Chromium (VI) sulfide

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Naming Ionic Compounds

It is very simple to name an ionic compound:

1. Name the metal first
2. Indicate the oxidation state of the metal
3. Name the non-metal second
4. Add "-ide" to the root of the non-metal

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Some atoms really like each other…

…so they are always hanging out together.

These are called "polyatomic ions" and are treated as single units rather than as individual atoms.

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For polyatomic ions…

You need to know the ions name. Some common ones are:

OH^- = hydroxide
PO_4^{3-} = phosphate
SO_4^{2-} = sulfate
ClO_3^- = chlorate
ClO_2^- = chlorite
CO_3^{2-} = carbonate
NO_3^- = nitrate
NO_2^- = nitrite

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Some examples of compounds…

Sodium + hydroxide
NaOH – sodium hydroxide

Magnesium + sulfate
$MgSO_4$ – magnesium sulfate

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Types of ionic compounds

These are still considered ionic compounds:

1) Metal and non-metal (e.g., NaCl)
2) Metal and polyatomic (e.g., $NaNO_3$)
3) Polyatomic and polyatomic (e.g., NH_4NO_3)
4) Polyatomic and non-metal (e.g., NH_4Cl)

The hard part is recognizing the polyatomic ion as a polyatomic ion…practice makes perfect!

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Covalent compounds

Unlike ionic compounds, covalent compounds aren't made up of cations and anions.

Covalent compounds are compounds formed by atoms sharing electrons rather than sticking together due to having opposite charges.

Covalent compounds are typically made up of only non-metals.

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Rules for naming covalent compounds

Covalent compounds are named by using Latin prefixes to indicate the exact number of each atom present, starting with the furthest left in the periodic table.

The name ends in "-ide".

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Latin prefixes

Latin prefixes:

1 = mono	4 = tetra	7 = hepta
2 = di	5 = penta	8 = octa
3 = tri	6 = hexa	9 = nona

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Some examples…

CO_2 = carbon dioxide (the opening "mono" is often omitted.
CO = carbon monoxide
P_2O_5 = diphosphorous pentoxide
NO = nitrogen monoxide
NO_2 = nitrogen dioxide
N_2O_5 = dinitrogen pentoxide

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Organic compounds

Organic molecules are mixtures of carbon (a non-metal) and other non-metals. As a result, they are covalent compounds. However, organic molecules have their own nomenclature based on their functional groups.

We will discuss this later when we talk about organic contaminants.

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What would you call…?

MnS_2

Manganese (IV) sulfide

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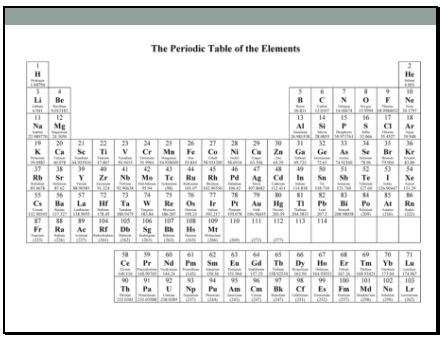

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What would you call…?

AsO_3

Arsenic trioxide

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What would you call…?

$SiCl_2$

Silicon dichloride

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Nomenclature is IMPORTANT

If we can't speak the language, we can't communicate.

Once we know what to call things, then we can start doing things with the molecules.

Like measure them…

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UNITS! UNITS! UNITS!

Joe's 1st rule of Physical Sciences

The ability to convert units is fundamental, and a useful way to solve simple problems.

Having the appropriate units is a consistency check on your answer: if it has units of inches, you have not calculated the mass of an object!

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What's in a number?

11

That's a perfectly nice number – but so what?

11 what?

11 is good for craps, bad for an IQ, OK for a shoe size.

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Numbers are good, Data are better

A number with a unit is a datum – a piece of information:

11 dogs
11 inches of cloth
11 pounds of cheese

Now we know something!

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Systems Internationale

SI units are the standard system of units in the physical sciences.

They are internally consistent. If you use SI units in a calculation, you always get an SI unit in the result.

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Pure Units

Mass – kilograms – “kg”
Length – meters – “m”
Time – seconds – “s”

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Derived units:

Combinations of pure units:

Volume – m^3

Energy – Joules – $\frac{kg\ m^2}{s^2}$

Density – $\frac{kg}{m^3}$

If you use SI units in a calculation, you always get the proper SI unit in the result.

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Dimensional Analysis

Also called the "factor-label method"

You can convert quantities into other quantities by using conversion factors. The entire goal of dimensional analysis is to convert the units (the dimensions) of the quantity.

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Conversion Factors

The Power of 1

Conversion factors are just fancy ways of writing the number 1.

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Relationships beget ratios

For example, 12 inches = 1 foot
This is a statement of fact

This can be rearranged algebraically:

$\frac{12 \text{ inches}}{1 \text{ foot}} = 1$

This is now a conversion factor!

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The multiplicative identity

$\frac{12 \text{ inches}}{1 \text{ foot}} = 1$

1 is the "multiplicative identity": you can multiply any number by 1 without changing its value (2x1=2, 3x1=3, etc.)

So, you can also multiply any number or datum by $\frac{12\ inches}{1\ foot}$ without changing its value

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Dumb example

My dog weighs 118 pounds.

$118 \text{ pounds} * \frac{12 \text{ inches}}{1 \text{ foot}} = 1416$

1416 what?

1416 $\frac{pound\ inch}{foot}$, of course!

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Dumb example continued!

What's a $\frac{pound\ inch}{foot}$?

I have no frigging idea!

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Consistency check

Since the unit is meaningless, so is the datum.

If I'm trying to calculate an energy, I MUST get Joules as a unit, not pound inches/foot.

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Proper use of dimensional analysis

I have 26.5 liters of water, what is its mass at 25°C?

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Proper use of dimensional analysis

I have 26.5 liters of water, what is its mass (in grams) at 25°C?

Two questions for you:

1) If I know a volume (liters) and I want to know a mass, what do I need to know?
2) Does the temperature matter?

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$$26.5 liters \times \frac{?}{?} = ??? \, g$$

I'm looking for a conversion factor that will "convert" my units.

$$26.5 liters \times \frac{? \, g}{? \, liters} = ??? \, g$$

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Density

Density has units of $\frac{mass}{volume}$

($\frac{kg}{m^3}$ or $\frac{g}{cm^3}$ or $\frac{g}{L}$ or…)

Density is a physical property of a material, but it is also simply a conversion factor between mass and volume or, equivalently, between volume and mass.

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If I want to change…

…volume into mass, I use density.
…mass into volume, I use density.

Conversion factors are ratios, you can always use them to go both ways.

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Does the Temperature Matter?

Density is temperature dependent?

Why?

Matter expands/contracts when heated/cooled, so volume changes when the temperature changes…

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Returning to my problem:

I have 26.5 liters of water, what is its mass at 25°C?

Suppose I tell you that the density of water at 25 °C is 0.97 $\frac{g}{cm^3}$, does that help…?

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Where am I trying to go

26.5 liters …….. grams

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What do I know?

26.5 liters …… $\frac{g}{cm^3}$ …… grams

What do I still need to know?

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What do I know?

26.5 liters …… $\frac{g}{cm^3}$ …… grams

What do I still need to know?
Liters to cm^3

Does anyone know?

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Volume conversions

1 cm^3 = 1 mL
1000 mL = 1 L

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Doing the problem

$$26.5 \text{ liters} * \frac{1000 \text{ mL}}{1 \text{ L}} * \frac{1 \text{ cm}^3}{1 \text{ mL}} * \frac{0.97 \text{ g}}{\text{cm}^3} = 25{,}705 \text{ grams}$$

Right units! Right answer!

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It's all about water…

This is a class about water, so all of the chemicals will be in water.

So, this is a class about "mixtures" – combinations of chemical compounds (water + A + B + C + …)

Mixtures, unlike "pure compounds" are not unique.

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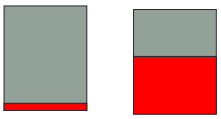
Consider the following…

2 containers, each contain 1 liter of water:



Put a teaspoon of sugar into the 1st one and a pound of sugar into the second one – what's the difference?

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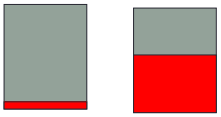
Syrup vs. water

The 1st container will barely even taste sweet.



The 2nd container will be VERY SWEET and a little thick. The moral of the story…

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The Moral of the Story

Not all mixtures of sugar and water are created equal!

But they are both sugar & water…how do I specify the difference?

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Concentration

"Concentration" is the metric for specifying different relative amounts of the species in a mixture.

There are many different ways of specifying concentration, depending on the units.

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Concentration

You could simply specify the relative amounts based on how the solution was made:

1 teaspoon sugar/ 1 liter of water
1 pound sugar/ 1 liter of water

Is this okay?

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YES – it's fine.

Is it the best way….???

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Consistency of units

Ideally, we would like to express the concentration in units that we can all accept as standard.

For example, we could express weight in “Joes” but not everyone knows how much a Joe weighs.

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Common units of concentration

% by mass
% by volume
% by mass-volume
Molarity
Molality
Normality
ppt – parts per thousand
ppm – parts per million
ppb – parts per billion
lb/million gallons

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Common units of concentration

% by mass – $\frac{g\ solute}{100\ g\ solution}$

% by volume $\frac{mL\ solute}{100\ mL\ solution}$

% by mass-volume $\frac{g\ solute}{100\ mL\ solution}$

Molarity – $\frac{moles\ solute}{L\ solution}$

Molality – $\frac{moles\ solute}{kg\ solvent}$

Normality $\frac{equivalent\ moles\ solute}{L\ solution}$

ppt – $\frac{g\ solute}{1000\ g\ solution}$

ppm – $\frac{g\ solute}{1{,}000{,}000\ g\ solution}$

ppb – $\frac{g\ solute}{1{,}000{,}000{,}000\ g\ solution}$

lb/million gallons - $\frac{lb\ solute}{1{,}000{,}000\ gal\ solution}$

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Solute? Solvent? Solution?

What's the difference?

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Some definitions

Solution – mixture of substances
Solvent – the majority substance
Solute – a minority substance

Aqueous solution – solution where water is the solvent.

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Common units of concentration

% by mass – $\frac{g\ solute}{100\ g\ solution}$

% by volume $\frac{mL\ solute}{100\ mL\ solution}$

% by mass-volume $\frac{g\ solute}{100\ mL\ solution}$

Molarity – $\frac{moles\ solute}{L\ solution}$

Molality – $\frac{moles\ solute}{kg\ solvent}$

Normality $\frac{equivalent\ moles\ solute}{L\ solution}$

ppt – $\frac{g\ solute}{1000\ g\ solution}$

ppm – $\frac{g\ solute}{1{,}000{,}000\ g\ solution}$

ppb – $\frac{g\ solute}{1{,}000{,}000{,}000\ g\ solution}$

lb/million gallons - $\frac{lb\ solute}{1{,}000{,}000\ gal\ solution}$

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Context, Convenience & History

Often, the choice between units comes down to context.

If I'm talking about the concentration of sugar in my soda, pounds in a million gallons is way too big a unit.

If I'm talking about waste in a lake, grams per 100 mL is way too small.

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What is this thing called moles?

That is Joe's 2nd rule of chemistry!