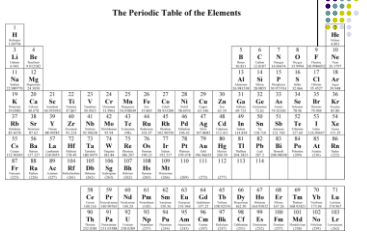
Slide 1

Chemical Compounds

Sticking atoms together

1

Slide 2



2

Slide 3

Chemistry is Reactions

"Doing Chemistry" is all about creating materials by rearranging atoms.

Chemical Reactions are the central processes in chemistry – a very experiential science.

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Slide 4

Chemical Symbols

The symbols in the periodic table are just abbreviations for the names of the different elements. It is easier to write “C” than “carbon”.

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Molecular symbols

Water, for example, is made up of 2 hydrogen atoms stuck together with 1 oxygen atom, so it is written:

H_2O

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Chemical Reactions

I could describe a chemical reaction using words:

Hydrogen and oxygen react to form water.

I can even be more specific:

Two diatomic hydrogen molecules and one diatomic oxygen molecule will react under XYZ conditions to form 2 molecules of water

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Chemical Shorthand

It is more concise to use chemical shorthand and write a **chemical equation**:

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

$2\ H_2 + O_2 \xrightarrow{xyz} 2\ H_2O$

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Chemical Compounds

In order for this to work, we need a language for naming compounds that we all understand.

Chemical nomenclature is the systematic naming of chemical compounds so that chemical symbols can be translated into names and names can be translated into symbols.

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Naming Chemical Compounds

In order to name chemical compounds, it is helpful to know your way around the periodic table.

Identifying metals and non-metals is very helpful in constructing and naming molecules. Compounds formed between a metal and non-metal are different from compounds formed between two non-metals.

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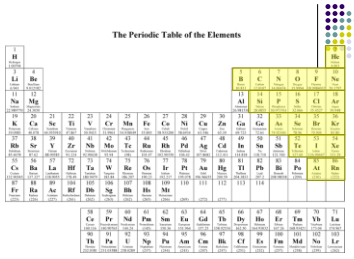

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Metals vs. Non-metals

Metals tend to be “electropositive” – they form positive ions. They also tend to be “electron-poor”.

Non-metals tend to be “electronegative” – they form negative ions. They are also electron-rich in their valence shells, so they don’t need to form ions at all.

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It’s really a continuum

There’s nothing magical about crossing the imaginary line between “metals” and “non-metals”. The properties gradually change.

For this reason, sometimes the “border elements” are called “metalloids” or “semi-metals”. Their properties are a mix of metal-like and non-metal-like.

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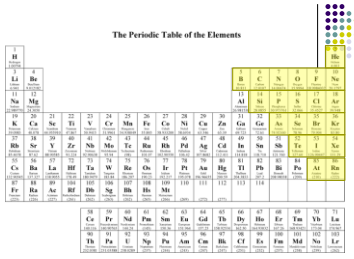

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Metal/Non-metal Compounds

When a metal (electropositive) and a non-metal (electronegative) form a compound, the easiest way to do so is by the metal giving up its electrons to the non-metal.

The transfer of electrons results in the formation of two ions which are then electrostatically attracted to each other.

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MgO

MgO is a perfect example of a metal/non-metal compound.

Mg gives up 2 electrons to form Mg^{2+}

O accepts 2 electrons to form O^{2-}

Mg^{2+} and O^{2-} are attracted to each other.

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MgO

Because it is formed by joining oppositely charged ions together, MgO is called an **ionic compound**.

Ionic compounds tend to be "less molecular" and are simply piles of ions. As a result ionic compounds tend to conduct electricity and be soluble in water.

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Naming Ionic Compounds

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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Examples

NaF – sodium fluoride
NaCl – sodium chloride
Na_2O – sodium oxide

Fe_2O_3 - ?
FeO - ?

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Multiple Oxidation States

Some atoms can form more than one possible ion. For example, iron. Iron can be either a +2 or +3. These possible ionic states are also called "oxidation states" for reasons that will be clearer when we discuss electrochemistry.

Since there is more than one possible ion, there is more than one possible compound.

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Specifying the oxidation state

To differentiate the oxidation state, we specifically write it out as a Roman Numeral after the metal's name

Fe_2O_3 – iron (III) oxide
FeO – iron (II) oxide

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(#) – The number is the charge on the metal NOT NOT NOT NOT THE NUMBER OF ATOMS

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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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How do you know the oxidation state?

The periodic table is organized in a manner that makes determining the oxidation state of many atoms to be very simple.

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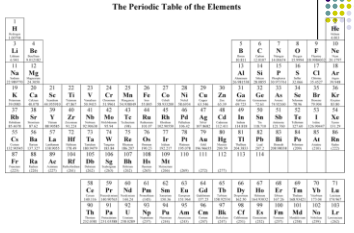

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Columns in the Periodic Table

1st – Alkali metals +1 oxidation state
2nd – Alkali earth metals +2 oxidation state
Last – Noble gases 0 oxidation state
2nd to last – Halogens -1 oxidation state
3rd to last – chalcogenides -2 oxidation state
In between – Transition metals – MULTIPLE oxidation states

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Another example

MnO_2
What would you name it?

Mn = manganese

So it is manganese (?) oxide

Oxygen is a chalcogenide – usually -2 (peroxides have -1 charge), so Mn must be +4

Manganese (IV) oxide

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Some other examples

$FeCl_3$

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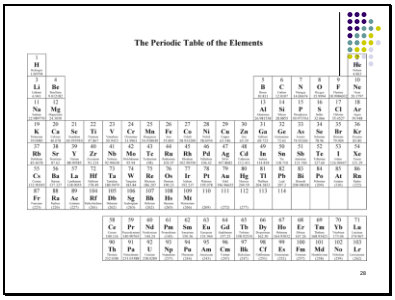

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Some other examples

$FeCl_3$
Iron (III) chloride

Chlorine is usually -1
3x(-1) = -3
So, Fe must supply +3 to balance the -3 from the chlorine

How about NaF?

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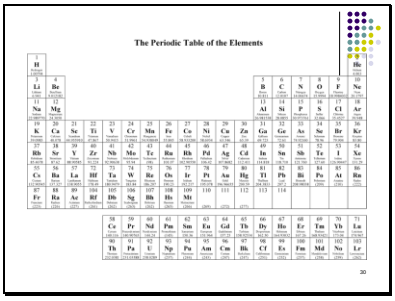

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Some other examples

NaF

Sodium fluoride or Sodium (I) fluoride

Sodium only has 1 possible oxidation state

CrO_3?

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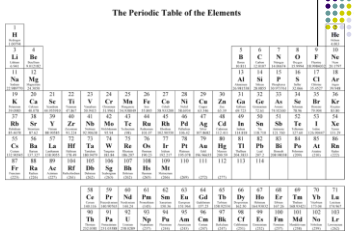

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Some other examples

CrO_3

Oxygen is almost always -2

3*(-2) = -6

So, Cr must supply +6 to balance the -6 from the oxygens

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What is the name of the following compound?
NiO_2

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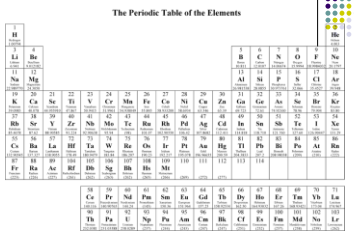

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What is the name of the following compound?
NiO_2

A. Nickel oxide
B. Nickel (II) oxide
C. Nickel (IV) oxide
D. Nickel dioxide

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What is the name of the following compound?

NiO_2

Nickel (IV) oxide

Oxygen is almost always -2. 2x-2=-4 Nickel must be a +4 to balance the charge.

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It works both ways:

If I have the name, I can turn it into a molecular formula.

For example, what is the molecular formula of nickel (IV) fluoride?

Well, right away, I know the nickel has a +4 charge: "nickel (IV)".

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What about fluorine?

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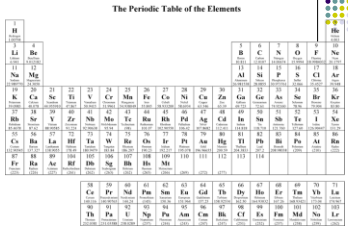

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What is the molecular formula of nickel (IV) fluoride?

I know the nickel has a +4 charge: "nickel (IV)".

What about fluorine?
It's a halogen, so it's -1.

I have 4 positive charges from nickel, I need 4 negative charges from the fluorine. Each fluoride is -1, so I need 4 of them!
NiF_4

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Polyatomic Ions

There are some common ions formed from multiple atoms (poly-atomic) and are therefore viewed as a single unit.

NO_2^- - nitrite
NO_3^- - nitrate
ClO_4^- - perchlorate
ClO_3^- - chlorate
ClO_2^- - chlorite
ClO^- - hypochlorite

$Cr_2O_7^{2-}$ - dichromate
CrO_4^{2-} - chromate
MnO_4^- - permanganate

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Ionic compounds of polyatomic ions

Same rules as metal/non-metal compounds, but you keep the polyatomic ions name:

$KMnO_4$ – potassium permanganate
$Fe(NO_3)_3$ – iron (III) nitrate
$Mg(ClO)_2$ – magnesium hypochlorite

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Covalent Compounds

Ionic compounds are formed from metals and nonmetals. [Or, polyatomic ions.]

Two metal ions are both (+) and would repel.

Two non-metal ions are both (-) and would repel.

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Covalent Compounds

For electron-rich atoms (non-metals), it is possible to simply share electrons to form a bond rather than transfer electrons to form ions.

A **covalent compound** is a molecule formed from 2 non-metals by sharing ("co") valence electrons.

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Metal-Metal compounds?

You can't form a covalent compound between 2 electron-poor atoms.

Two poor people don't have enough money between them buy a cup of coffee!

Two electron poor atoms don't have enough electrons to make a bond!

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Naming Covalent Compounds

Even easier than naming ionic compounds.

1. Start with “leftmost” (in periodic table) element. In cases of ties, go “downmost”.
2. Use Greek prefixes to designate the number of each element – although a leading “mono” is usually dropped.
3. End with “-ide”

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Greek prefixes

One – “mono”
Two – “di”
Three – “tri”
Four – “tetra”
Five – “penta”
Six – “hexa”
Seven – “hepta”
Eight – “octo”
Nine – “nona”
Ten – “deca”
Eleven – “undeca”
Twelve – “dodeca”
Thirteen – “trideca”

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Sample names

H_2O
dihydrogen monoxide

N_2O_5
dinitrogen pentoxide

CO_2
carbon dioxide (note that it isn’t monocarbon dioxide)

N_3O_5
trinitrogen pentoxide

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Sample names

Diphosphorous tetroxide
P_2O_4

Trisulfur hexoxide
S_3O_6

Nitrogen monoxide
NO

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Scientific Shorthand

This allows us to write chemical reactions in both long-hand and short-hand:

$4\ NO_2 + 6\ H_2O \rightarrow 4\ NH_3 + 7\ O_2$

Four moles of nitrogen dioxide and 6 moles of dihydrogen monoxide (water) react **to yield** four moles of nitrogen trihydride (ammonia) and seven moles of oxygen.

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Scientific Shorthand

This allows us to write chemical reactions in both long-hand and short-hand:

$4\ NO_2 + 6\ H_2O \xrightarrow[45\ min]{850\ ^\circ C} 4\ NH_3 + 7\ O_2$

Four moles of nitrogen dioxide and 6 moles of dihydrogen monoxide (water) are reacted for 45 minutes at 850 degrees Celsius **to yield** four moles of nitrogen trihydride (ammonia) and seven moles of oxygen.

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Scientific Shorthand

Even more information is sometimes included

$4\ NO_2\ (g) + 6\ H_2O\ (g) \xrightarrow[45\ min]{850\ ^\circ C} 4\ NH_3\ (g) + 7\ O_2\ (g)$

Four moles of nitrogen dioxide gas and 6 moles of dihydrogen monoxide gas (steam) are reacted for 45 minutes at 850 degrees Celsius **to yield** four moles of nitrogen trihydride (ammonia) gas and seven moles of oxygen gas.