Writing & Naming Formulas of Ionic & Covalent Compounds

The Physical Science Series

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Review of the Periodic Table

Periods = number of e- energy levels.

Groups (families) = the number of valence electrons (A - groups)

Transition Metals

	IA	IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA
1	H non																	He non
2	Li metal	Be metal											B semi	C non	N non	O non	F non	Ne non
3	Na metal	Mg metal											Al metal	Si semi	P non	S non	Cl non	Ar non
4	K metal	Ca metal	Sc metal	Ti metal	V metal	Cr metal	Mn metal	Fe metal	Co metal	Ni metal	Cu metal	Zn metal	Ga metal	Ge semi	As semi	Se non	Br non	Kr non
5	Rb metal	Sr metal	Y metal	Zr metal	Nb metal	Mo metal	Tc metal	Ru metal	Rh metal	Pd metal	Ag metal	Cd metal	In metal	Sn metal	Sb semi	Te semi	I non	Xe non
6	Cs metal	Ba metal	La metal	Hf metal	Ta metal	W metal	Re metal	Os metal	Ir metal	Pt metal	Au metal	Hg metal	Tl metal	Pb metal	Bi metal	Po semi	At non	Rn non
7	Fr metal	Ra metal	Ac metal	Rf metal	Db metal	Sg metal	Bh metal	Hs metal	Mt metal	Uun metal	Uuu metal	Uub metal	113 metal	Uuq metal	115 metal	116 metal	117 non	118 non

6	Ce metal	Pr metal	Nd metal	Pm metal	Sm metal	Eu metal	Gd metal	Tb metal	Dy metal	Ho metal	Er metal	Tm metal	Yb metal	Lu metal
7	Th metal	Pa metal	U metal	Np metal	Pu metal	Am metal	Cm metal	Bk metal	Cf metal	Es metal	Fm metal	Md metal	No metal	Lr metal

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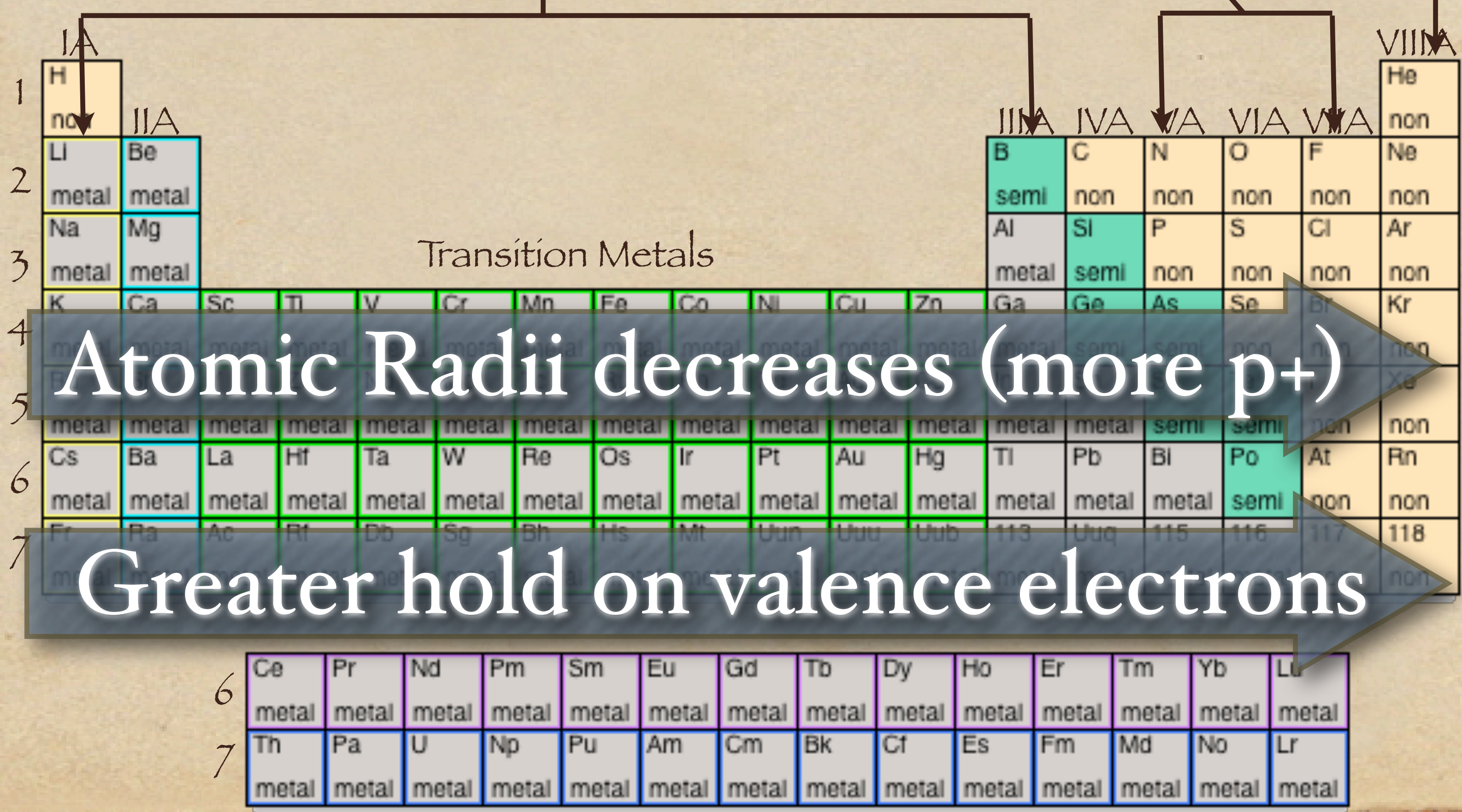
Metals have between 1 and 3 valence e-
and have a loose hold on them.

Nonmetals have between 5 and 7 valence e-
and have a tight hold on them.

Noble Gases

Very tight hold on valence e-.



Types of Compounds:

Ionic = Metal + Nonmetal

Covalent = 2 Nometals or Metalloid & Nonmetal

Metals

Metalloids

Nonmetals

Transition Metals

	IA	IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA
1	H non																	He non
2	Li metal	Be metal											B semi	C non	N non	O non	F non	Ne non
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6	Cs metal	Ba metal	La metal	Hf metal	Ta metal	W metal	Re metal	Os metal	Ir metal	Pt metal	Au metal	Hg metal	Tl metal	Pb metal	Bi metal	Po semi	At non	Rn non
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6	Ce metal	Pr metal	Nd metal	Pm metal	Sm metal	Eu metal	Gd metal	Tb metal	Dy metal	Ho metal	Er metal	Tm metal	Yb metal	Lu metal
7	Th metal	Pa metal	U metal	Np metal	Pu metal	Am metal	Cm metal	Bk metal	Cf metal	Es metal	Fm metal	Md metal	No metal	Lr metal

Chemical Compounds

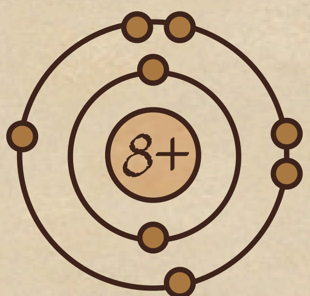
An atom consist of a positively charged nucleus (protons and neutrons) and orbiting electrons.

Very Important!

Atoms of elements are not chemically stable until they have 8 valence electrons (octet rule).

Atoms gain, lose or share electrons with other atoms to be come chemically stable (have 8 valence electrons).

Six valence electrons. Not chemically stable.



Oxygen Atom

Eight valence electrons. Chemically stable.

Oxide Ion

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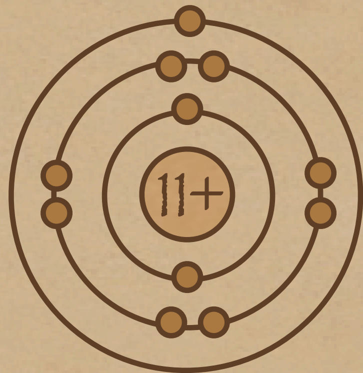
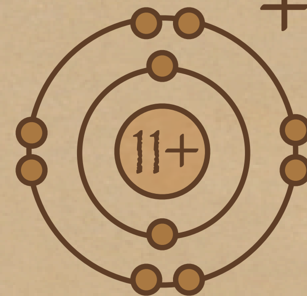
Atoms & Ions:

Not Stable	to become stable will:	Stable
Sodium Atom	Lose 1 e-	+1 Sodium Ion
Nitrogen Atom	Gain 3 e-	-3 Nitride Ion
Aluminum Atom	Lose 3 e-	+3 Aluminum Ion

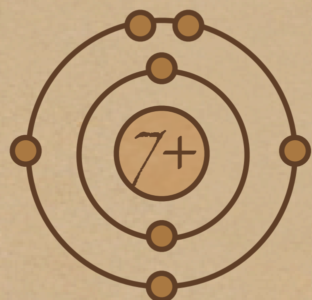
Sodium Atom



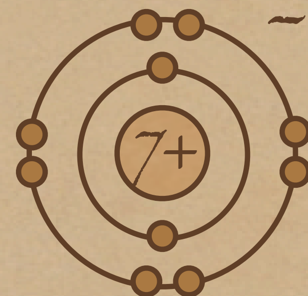
Sodium Ion



Nitrogen Atom



Nitride Ion



Aluminum Atom

Aluminum Ion

Two Types of Compounds

- I o n i c - occurs when a metal loses all its valence electrons to a nonmetal. The metal becomes a cation (+ion), while the nonmetal becomes an anion (- ion).
- C o v a l e n t - two nonmetals share electrons. Neither loses or gains electrons - they share electrons. Neither atom becomes an ion.

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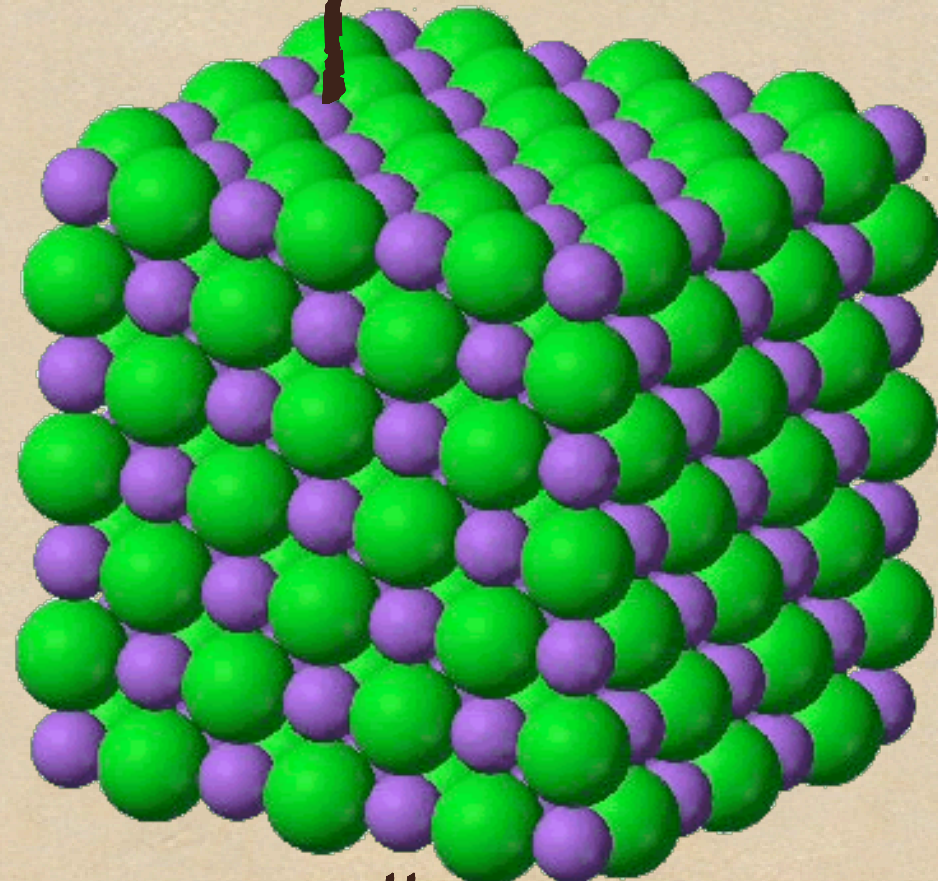
Ionic Compounds



Crystalline Lattice

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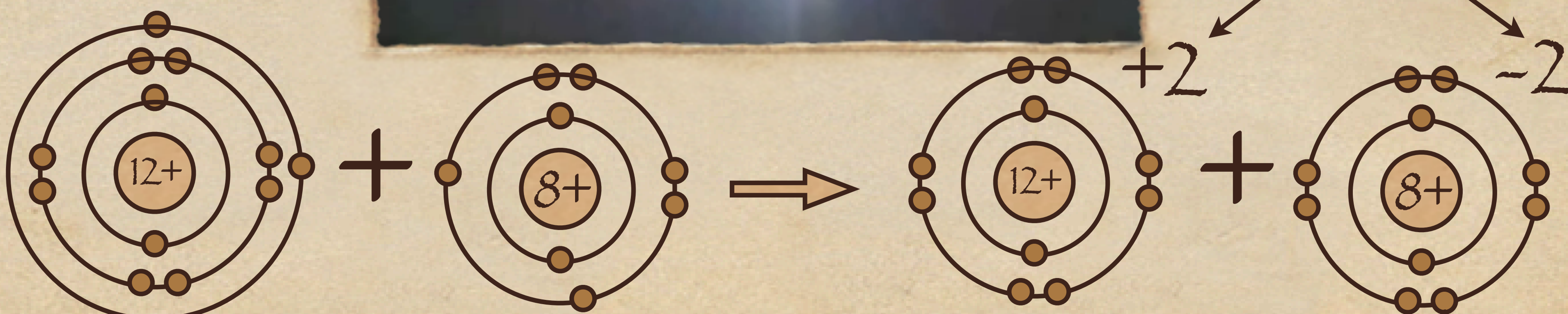
Oxidizing Magnesium

$$2Mg + O_2 \rightarrow 2MgO$$

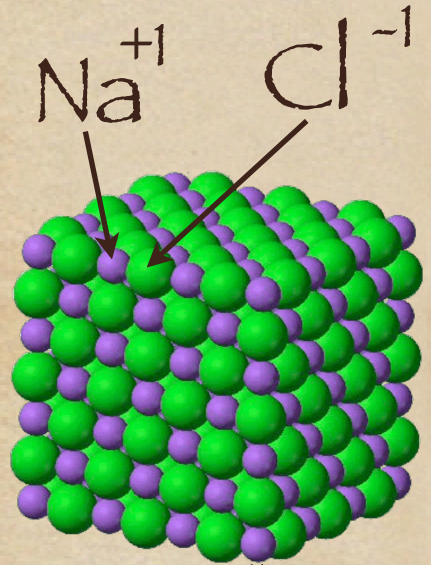
Opposite charges hold the compound together.



Magnesium Atom + Oxygen Atom → Magnesium Ion + Oxide Ion

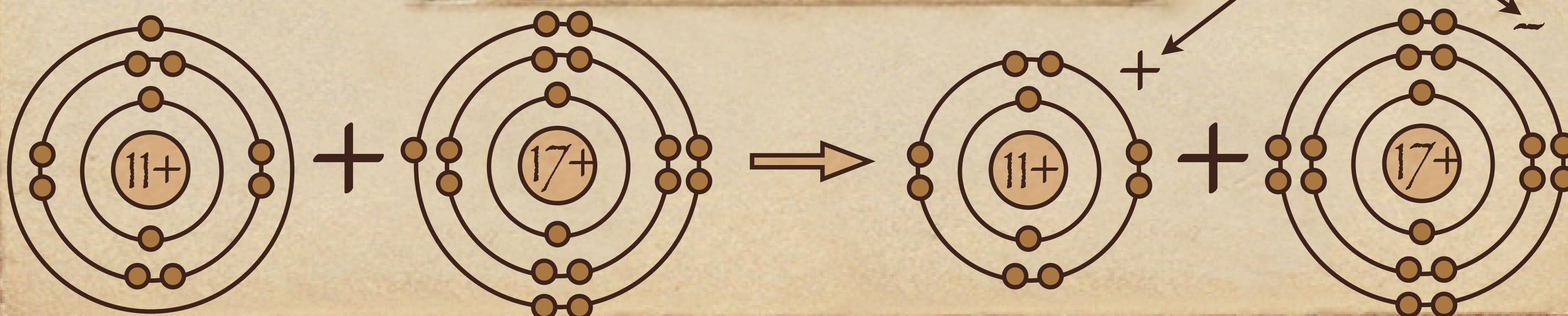
Formation of Sodium Chloride

$$2Na + Cl_2 \rightarrow 2NaCl$$



Crystalline Lattice

Opposite charges hold the compound together.



Sodium Atom + Chlorine Atom → Sodium Ion + Chloride Ion

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Ionic Compounds

- Contain a metal and a nonmetal.
- The Metal loses e- and becomes a cation (+).
- The Nonmetal gains e- and becomes an anion(-).
- Metal is listed first, followed by nonmetal.
- Change the name of the nonmetal to -ide. Examples: nitride, sulfide, fluoride, oxide, bromide, iodide, chloride, telluride, phosphide.

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Valence (Oxidation Number)

The valence of an elements is the charge an atom takes when it loses or gains electrons and becomes an ion.

Metal atoms lose 1, 2 or 3 electrons and become + ions (cations)

Nonmetals gain 1,2 or 3 electrons and become - ions (anions)

Transition Metals
Multiple valences

+1	+2											+3	-4	-3	-2	-1	0
H non																	He non
Li metal	Be metal											B semi	C non	N non	O non	F non	Ne non
Na metal	Mg metal											Al metal	Si semi	P non	S non	Cl non	Ar non
K metal	Ca metal	Sc metal	Ti metal	V metal	Cr metal	Mn metal	Fe metal	Co metal	Ni metal	Cu metal	Zn metal	Ga metal	Ge semi	As semi	Se non	Br non	Kr non
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Th metal	Pa metal	U metal	Np metal	Pu metal	Am metal	Cm metal	Bk metal	Cf metal	Es metal	Fm metal	Md metal	No metal	Lr metal

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The 5 Steps for writing an ionic compound formula:

(I) Write the symbols of the two elements.

(II) Write the valence of each as superscripts.

(III) Drop the positive and negative signs.

(IV) Crisscross the superscripts so they become subscripts.

(V) Reduce when possible.

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Formula for boron oxide

1. Write the symbols of the two elements.

B O

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Formula for boron oxide

2. Write the valence for each element.

$$B^{+3} \quad O^{-2}$$

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Formula for boron oxide

3. Drop the positive & negative sign.

$$B^{+3} \quad O^{-2}$$

Formula for boron oxide

4. Crisscross the superscripts so they become subscripts.

$$B^{3}\quad O^{2}$$

Formula for boron oxide

4. Crisscross the superscripts so they become subscripts.

$$B_2O_3$$

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Formula for boron oxide

5. Reduce subscripts when possible.

(not possible here)

$$B_2O_3$$

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Examples of Reduction of Subscripts:

Sr_2O_2 → Reduces to → SrO

Al_3P_3 → Reduces to → AlP

Pb_2O_4 → Reduces to → PbO_2

Ba_3N_2 → Reduces to → Doesn't Reduce

Most Transition metals have two valences. Roman numerals are used in the name of the transition metal in the compound to show the valence on the cation.

Period 4 Transition Metals

Sc	Tl	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
+3	+4	+5	+6	+4	+2	+2	+2	+2	+2
	+3	+4	+3	+6	+3	+3	+3	+1	

Examples:

Mn^{+4} Manganese(IV) Mn^{+6} Manganese(VI)

Fe^{+2} Iron(II) Fe^{+3} Iron(III)

Cu^{+1} Copper(I) Cu^{+2} Copper(II)

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Examples of Transition Metals

Iron(II) Fe^{+2}

Iron(III) Fe^{+3}

Copper(I) Cu^{+1}

Copper(II) Cu^{+2}

Manganese(II) Mn^{+2}

Manganese(IV) Mn^{+4}

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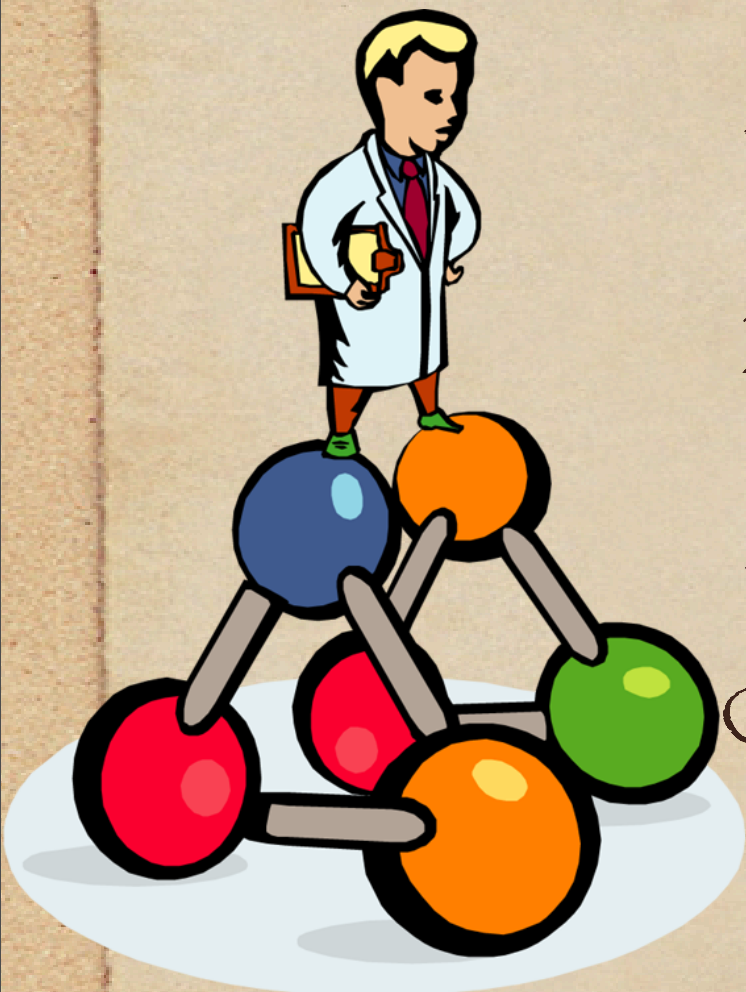
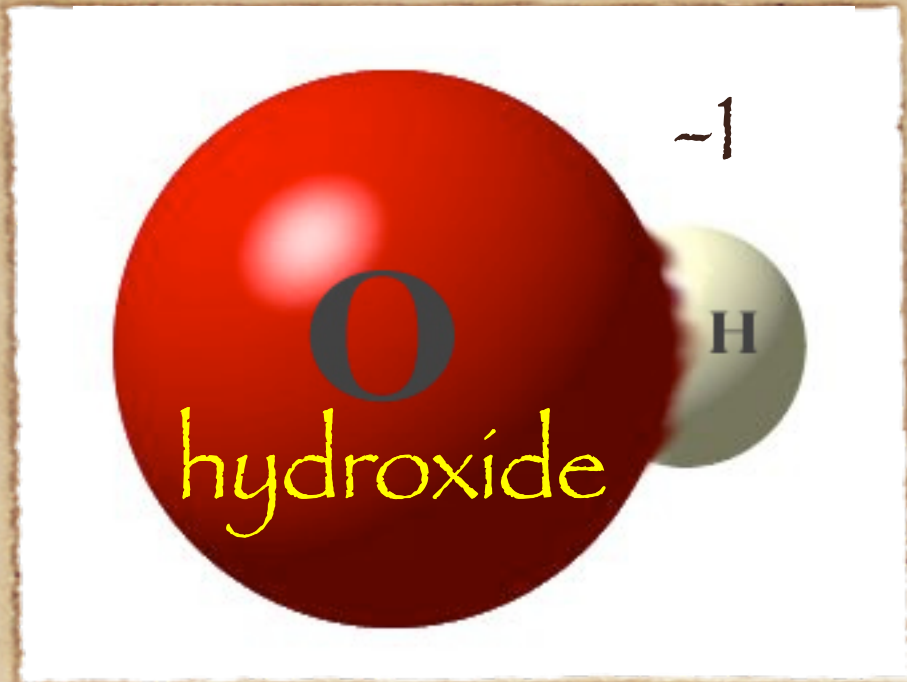
Naming binary compounds containing a transition metal.



formula	name
Fe_2O_3	Iron(III) oxide
$ZnCl_2$	Zinc(II) chloride
$AgCl$	Silver(I) chloride
Cu_3P_2	Copper(II) phosphide
PbS_2	Lead(IV) sulfide
MnO_2	Manganese(IV) oxide

Polyatomic Ions



Polyatomic (many atom) ions are covalent molecules with a charge. They behave as if they were a one-atom ion.

Polyatomic Ions

NH_4^{+1}	Ammonium	SO_3^{-2}	Sulfite
OH^{-1}	Hydroxide	SO_4^{-2}	Sulfate
NO_2^{-1}	Nitrite	CO_3^{-2}	Carbonate
NO_3^{-1}	Nitrate	PO_4^{-3}	Phosphate

Note: ammonium is the only polyatomic ion with a + charge.

Treat polyatomic ions as you would any ion - crisscross to determine the formula. The only difference is that when you have more than one of a specific polyatomic ion in a formula you must encase it in parenthesis.

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Writing Ternary Formulas

(Ternary compounds have 3 elements in them.)

Cation	Anion	Compound
Ca^{+2}	NO_3^{-1}	$Ca(NO_3)_2$
Mg^{+2}	PO_4^{-3}	$Mg_3(PO_4)_2$
Ba^{+2}	OH^{-1}	$Ba(OH)_2$
Ba^{+2}	SO_4^{-2}	$BaSO_4$

As in all ionic compounds you must reduce subscripts, but you cannot change the formula of the polyatomic ion. You can only reduce subscripts outside the parenthesis.

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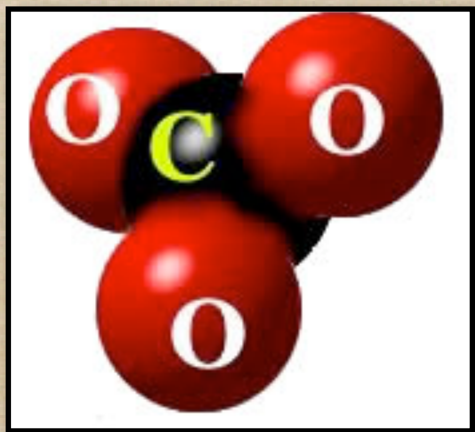
Compounds with Polyatomic ions

Carbonate CO_3^{-2}

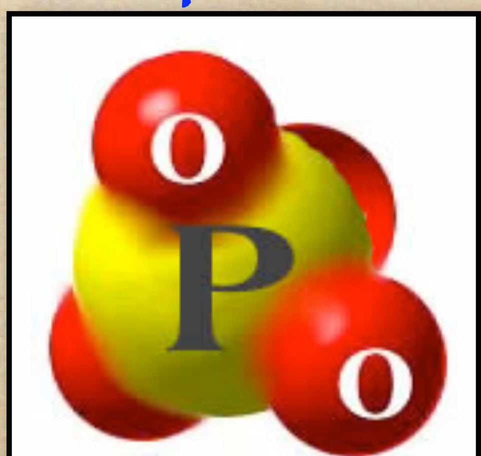


Sodium carbonate Na_2CO_3

Calcium carbonate $CaCO_3$

Aluminum carbonate $Al_2(CO_3)_3$

Phosphate PO_4^{-3}

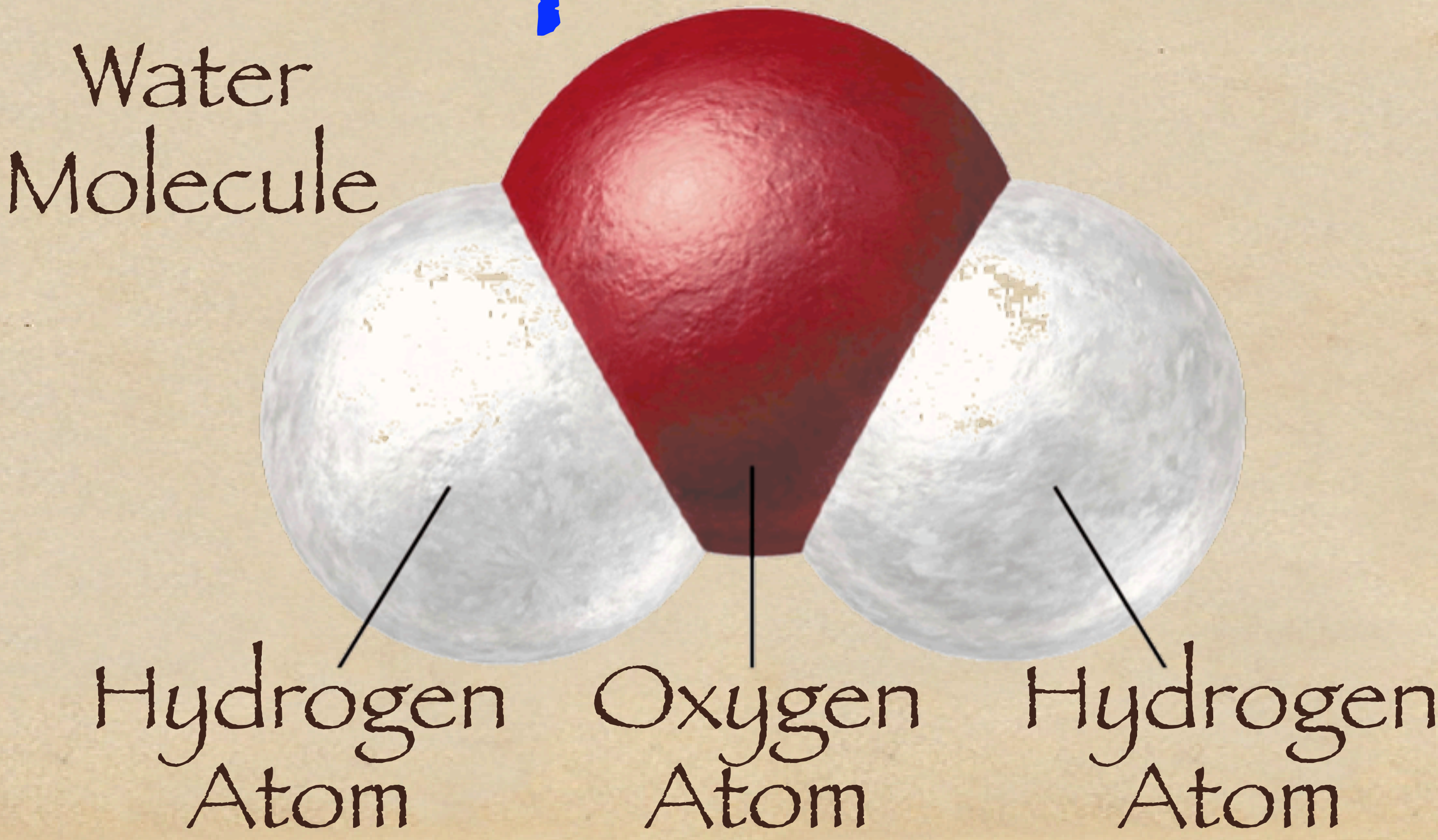


Sodium phosphate Na_3PO_4

Calcium phosphate $Ca_3(PO_3)_2$

Aluminum phosphate $AlPO_3$

Covalent Compounds



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Covalent Compounds

- Two nonmetals share electrons so both have 8 valence electrons. Exception: H
- Neither takes on a charge - no valence. Do not crisscross to determine formula.
- Must use prefixes in the name.
- Name tells you the formula. Example: N_2O_4 is dinitrogen tetroxide.
- You cannot reduce the formulas!!!

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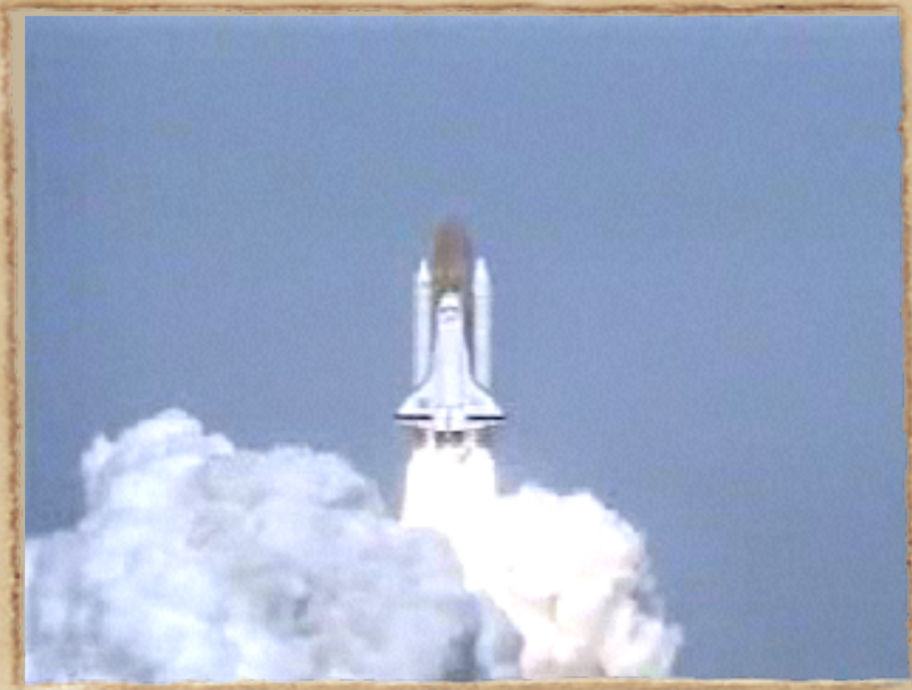
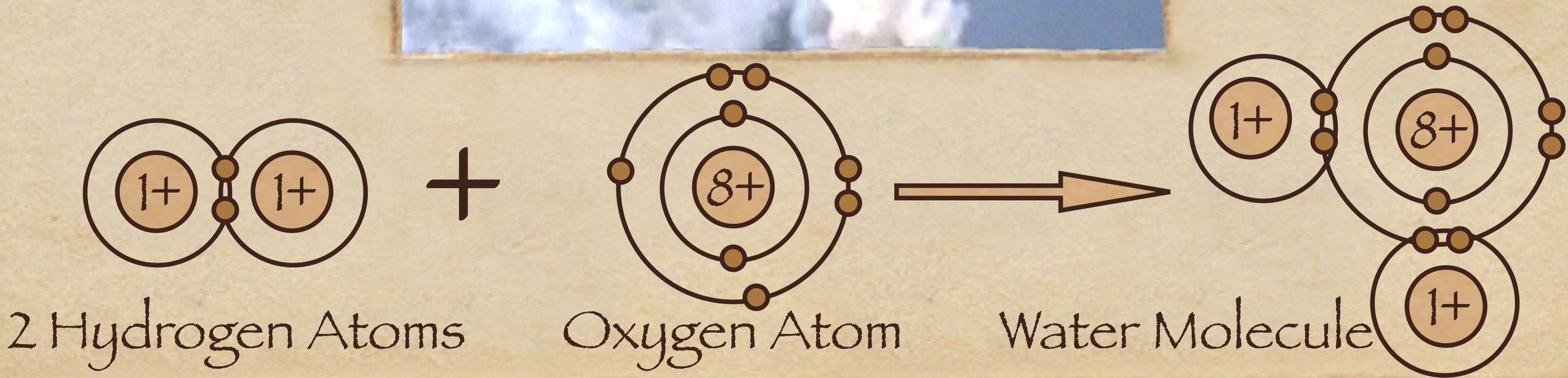
Reaction between hydrogen + oxygen

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





The Space Shuttle

Oxygen

Hydrogen

Water Vapor

Exothermic Reaction

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

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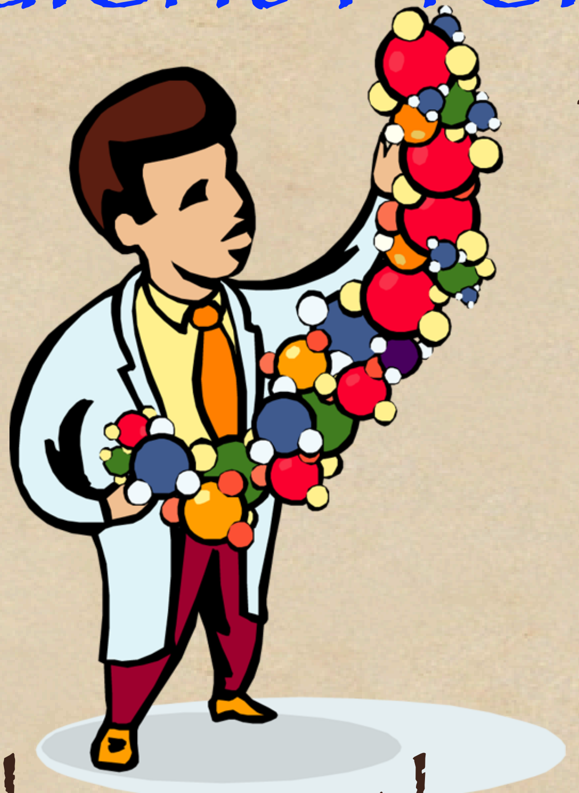
Covalent Prefixes

Mon - 1

Di - 2

Tri - 3



Tetra - 4

Pent - 5

Hex - 6

A prefix tells you the number of atoms of that element in the compound.

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Naming Covalent Compounds

N_2O_3 Dinitrogen trioxide

CH_4 Carbon tetrahydride

PO_5 Phosphorus pentoxide

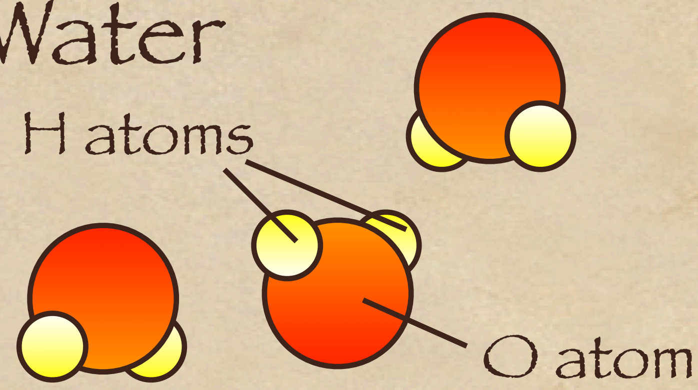
S_2F_3 disulfur trifluoride

Ionic and Covalent Structure

Ionic compounds form a crystalline lattice - a repeating pattern of ions.

Boron nitride

Water



Covalent compounds form individual molecules that are not connected to each other.

Naming Binary Compounds

Does the compound have a metal?

Yes

Ionic

(Metal cation + Nonmetal anion)

Place metal first followed by nonmetal ending in -ide

Contain a Transition Metal?

Yes

Use Roman Numerals to tell the valence of the metal.

Examples:
iron(III) oxide
copper(II) chloride
manganese(IV) oxide
silver(I) chloride

No

Do not use Roman Numerals

Examples:
sodium chloride
magnesium nitride
aluminum fluoride
beryllium oxide

No

Covalent

(Two Nonmetals)

Place the nonmetal furthest to the left on the periodic table first, then the other nonmetal ending in -ide.

Use prefixes to tell the number of atoms in the compound
mon(o)-1, di-2, tri-3, tetr(a)-4, pent(a)-5, hex-6

Examples:
dinitrogen trioxide, nitrogen trichloride, phosphorus pentoxide, sulfur dioxide carbon tetrachloride, dihydrogen oxide

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Name these compounds:

CoF_2	cobalt(II) fluoride
PCl_3	phorphorus trichloride
Sr_3N_2	strontium nitride
KOH	potassium hydroxide
NH_3	nitrogen trihydride

Write formulas for these compounds:

Zn_3N_2	zinc(II) nitride
$LiBr$	lithium bromide
N_2O_5	dinitrogen pentoxide
MnS_2	manganese(IV) sulfide
H_2O	dihydrogen oxide

Summing up: Ionic

- Ionic bonding occurs between a metal and a nonmetal. Metals lose all their valence e- and become cations. Nonmetals gain enough e- to fill their valence level and become anions.
- Always crisscross valences and reduce to determine the formulas of ionic compounds
- Do not use prefixes in the names.
- Ions form a crystalline lattice.

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Summing up: Covalent

- Covalent bonding occurs when two nonmetals share electrons to fill their valence energy level.
- Never use valence to determine the formula - there isn't any valence. Since the two atoms share electrons, they do not take on a charge.
- Always use prefixes in the names.
- Atoms combine to form individual molecules.

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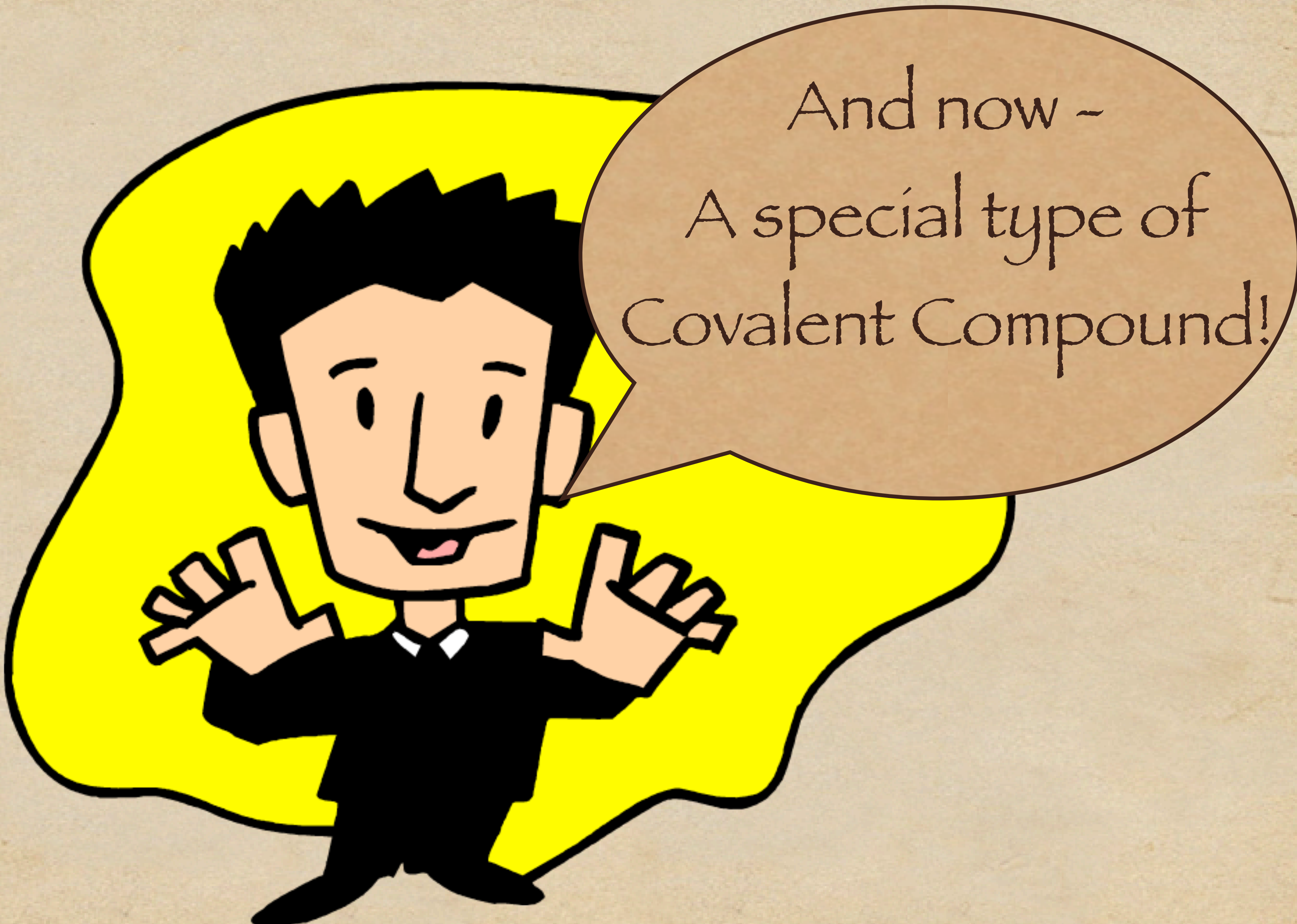
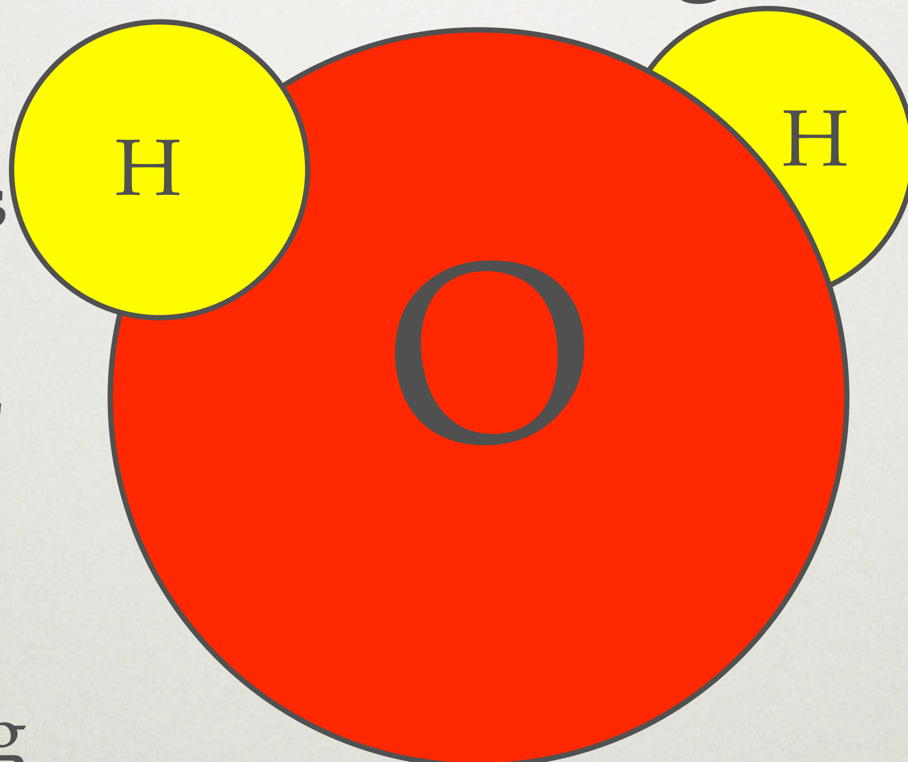

And now -
A special type of
Covalent Compound!

Water: A Polar Molecule

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

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

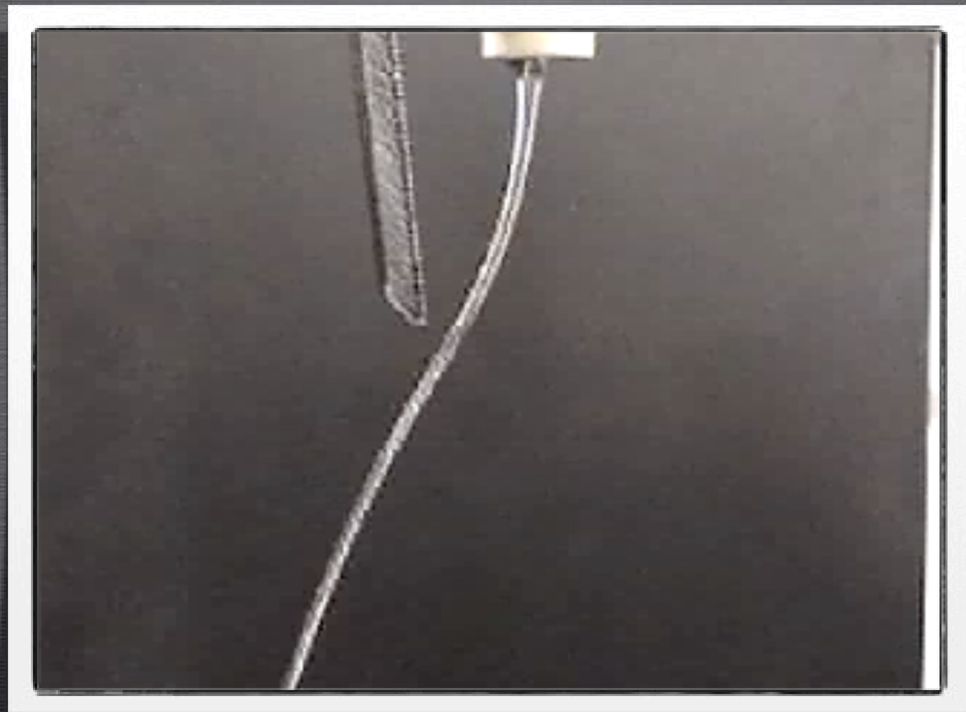
δ + charge



δ - charge

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

Water: A Polar Molecule



Explanation:

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

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

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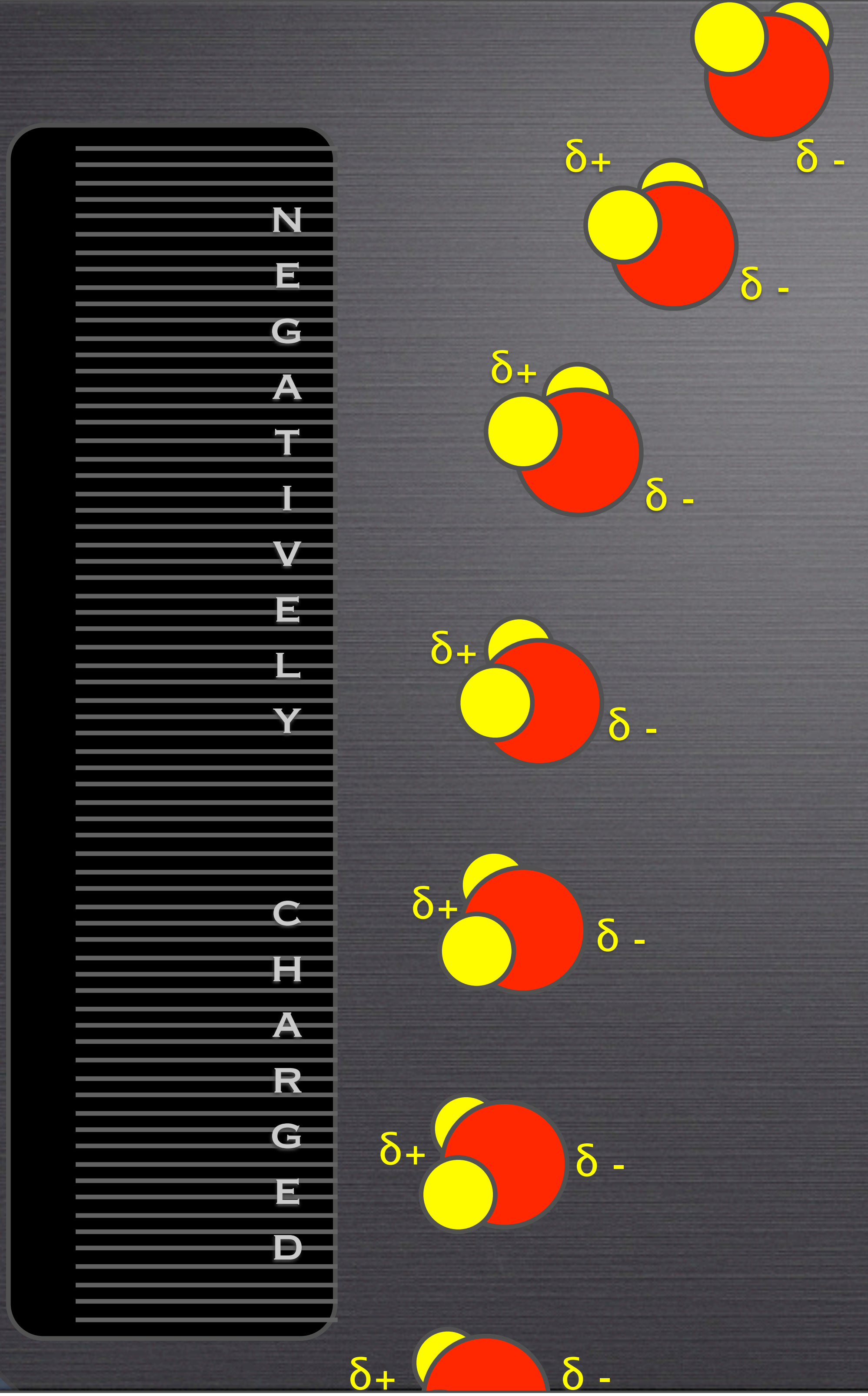
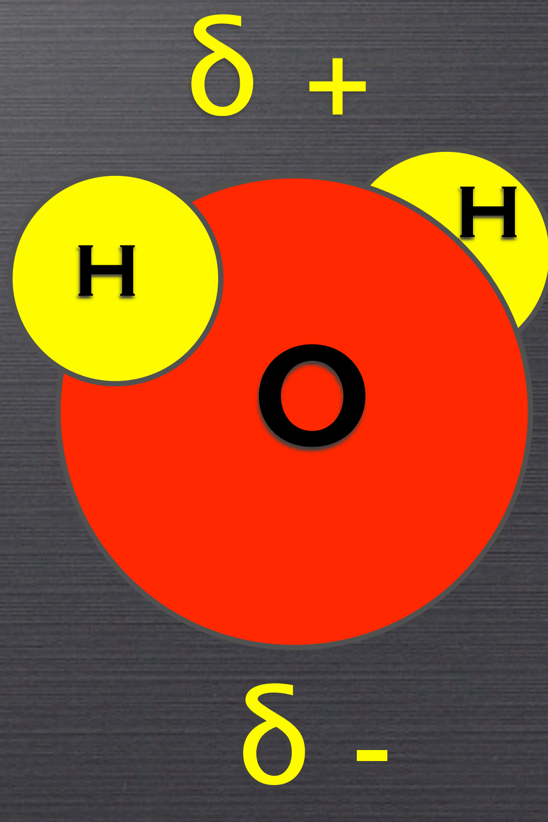


WHY DOES A COMB ATTRACT A STREAM OF WATER?



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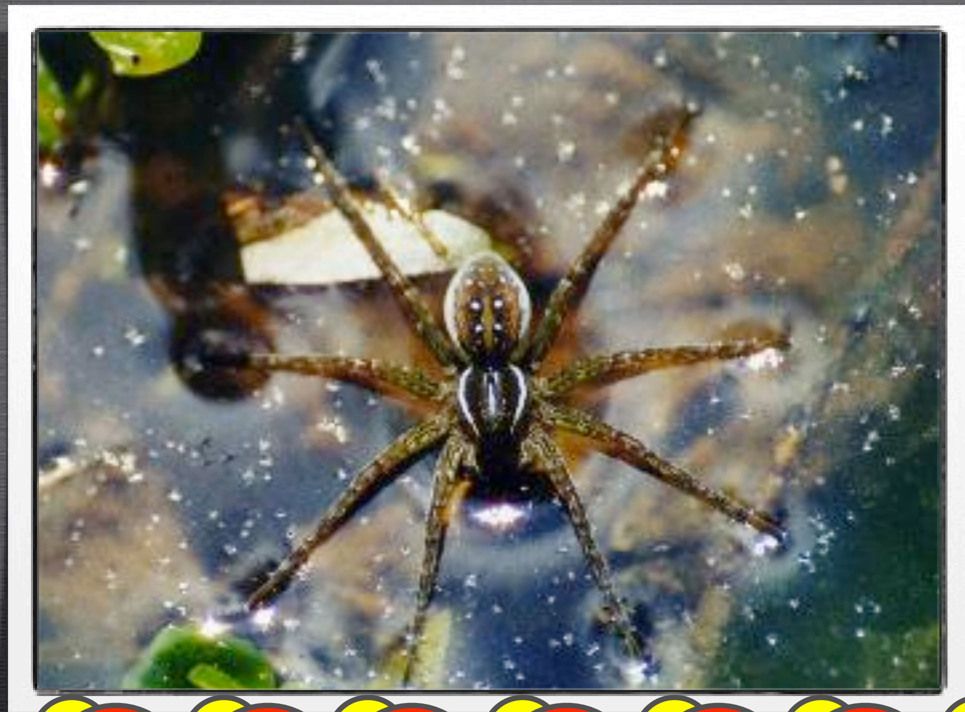
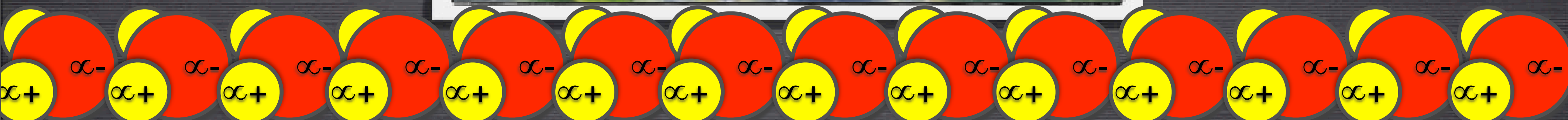
Surface Tension





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

What animal makes use of surface tension?

Chemical Formulas Index

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Ionic Compounds

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Summing Up