

Formulas and Equations

I.Handout: Formulas and Equations Note Packet

II.Elements

I.The names of the elements are given on the periodic table.

II.Formulas are written differently depending on the element.

I.The formula for most elements is just its symbol. For example, Na for sodium or Xe for xenon.

II.Some elements naturally come in diatomic molecules. When expressing this element in its pure form we would write a formula indicating this state. There are seven diatomic elements: H₂, N₂, O₂, F₂, Cl₂, Br₂, and I₂. You should memorize these.

III.Compounds

I.Ionic Compounds

I.Ionic compounds are formed between oppositely charged ions usually consisting of a metal and one or more non-metals.

II.An ion can be a single charged atom or a small group of atoms (molecule) with a charge.

III.Binary Ionic Compounds (compounds composed of two single atom ions)

I.Naming

I.We can form ionic compounds from choosing a metal and a nonmetal, because they have a large difference in their electronegativity. This is best taught by example

II.Sodium and chlorine form Sodium Chloride.

III.Magnesium and oxygen form Magnesium Oxide.

IV.Calcium and sulfur form Calcium Sulfide.

V.Binary ionic compounds are named by removing the end of the name from the nonmetal and adding -ide.

II.Formula writing

I.To write the correct formula you must know the charges present on each ion. To determine this you would look on the periodic table or your common ion sheet.

II.The positive and negative charges must exactly balance each other in order to have the correct ratio of ions to form a neutral compound.

III. Sodium can form a +1 charged ion and is written: Na^{+1}

IV. Sulfur can form a -2 charged ion and is written: S^{-2}

V. The formula for Sodium Sulfide is Na_2S

VI. Some other common ions that you should memorize: K^{+1} , Ag^{+1} , Mg^{+2} , Zn^{+2} , Al^{+3} , Ca^{+2} , O^{-2} , Cl^{-1}

VII. Click here to see how binary ionic compounds dissolve compared to molecular compounds.

VIII. Try some examples below:

Calcium Fluoride =

Potassium Chloride =

Lithium Oxide =

Aluminum Sulfide =

IV. Polyatomic Ionic Compounds

I. Sometimes a group of atoms can have a charge. This is called a poly atomic ion.

II. Some common poly atomic ions which you should memorize are: nitrate NO_3^{-1} , sulfate SO_4^{-2} , carbonate CO_3^{-2} , bicarbonate (or hydrogen carbonate) HCO_3^{-1} , and hydroxide OH^{-1}

III. Notice that the names of these ions end in -ate.

IV. When you see a name ending in -ate it probably implies that it is a polyatomic ionic compound.

V. The groups of atoms can be thought of as a single entity with a charge, just like a single atom can have a charge. For example, Sodium Nitrate needs one +1 sodium ion to neutralize one -1 nitrate ion, so the formula is NaNO_3 .

VI. If you need more than one polyatomic ion then you put parenthesis around it in the formula. For example, Calcium Nitrate needs one +2 calcium ion to neutralize two -1 nitrate ions, so the formula is $\text{Ca}(\text{NO}_3)_2$.

VII. Click here to see how polyatomic ionic compounds dissolve.

VIII. Try some examples below:

Sodium Sulfate =

Zinc Phosphate =

Barium Hydroxide =

Ammonium Sulfate =

V. Ions with multiple charges

I. Some atoms can commonly form 2 or 3 different charges. These atoms are typically transition elements.

II. Copper, for example, usually forms +1 or +2 charged ions.

III. This can cause problems if a compound is named Copper Oxide. This could have the formula CuO or Cu₂O depending on the charge of the copper atom.

IV. To clear up this ambiguity we can name the ions by specifically adding on a number to their name. Cu⁺¹ is Copper(I) and Cu⁺² is Copper(II). So the names of the copper compounds listed above are Copper(II)Oxide for CuO and Copper(I)Oxide for Cu₂O.

V. Try some examples below:

Iron(II)Oxide =

= CuSO₄

Iron(III)Oxide =

= Cr(NO₃)₃

II. Handout: Solubility Rules and Common Ions

III. Homework: Binary Ionic Naming Sheet

IV. Homework: Binary Ionic With Roman Numerals.

V. Homework: Polyatomic Ion Sheet.

VI. Molecular Compounds

I. Molecular naming falls into two groups - organic and inorganic. We will talk about inorganic for now. Molecular compounds consist of non-metal atoms.

II. Prefixes which indicate the number of atoms of each element are used in the naming of inorganic molecular compounds. You should memorize the following:

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

III. When given a formula the prefixes above are applied to the words that would be used to name the compound as if it were ionic. For example, P₂O₃ would be named Phosphorous Oxide if it were ionic, but it consists of two nonmetals, so it would be named Diphosphorous Trioxide.

IV. Whenever there is only one atom of the first element in a formula we drop the term Mono-. For example CO is Carbon Monoxide, not Monocarbon Monoxide.

V. To write formulas you just interpret the prefixes on the names and write the appropriate symbolic representation. For example, Sulfur Dioxide is SO_2 .

VI. Try some of the following examples:

Carbon Tetrachloride = CCl_4

Trinitrogen Pentoxide = N_2O_5

VII. There are special cases where we use common names for molecular compounds. The only two that I want you to memorize are: Water = H_2O and Ammonia = NH_3 (not to be confused with the ammonium ion = NH_4^{+1})

VII. Ban dihydrogen monoxide! DMHO Fact Sheet- Join the movement by clicking here.

VIII. Acids

I. Binary Acids

I. As a general rule the formula for an acid starts with hydrogen.

II. If acid consists of just two elements, then it is named Hydro-_____-ic Acid.

III. For example HCl is Hydrochloric Acid.

IV. And the formula for Hydrobromic Acid is HBr.

II. Other Acids

I. For all other acids common names are used that cannot be deduced from the formula and vice versa.

II. You should memorize the following:

I. H_2SO_4 = Sulfuric acid

II. HNO_3 = Nitric Acid

III. $\text{HC}_2\text{H}_3\text{O}_2$ = acetic acid

IX. Homework: Naming Various Chemicals Sheet

X. Get some extra practice on naming substances at the ChemTeam website.

IV. General naming and formula writing strategy

I. General naming strategy

- I. Determine if the formula depicts an ionic compound (metal and nonmetal), a molecular compound (two nonmetals), or an acid (begins with hydrogen).
- II. If ionic, determine the names of the ions and write the name putting the metal first.
- III. If molecular, determine the names of the nonmetals and add the appropriate prefixes before writing the name.
- IV. If an acid, it is either in the form hydro-____-ic acid or it is one of the ones you memorized.

II. General formula writing strategy

- I. Determine if the name depicts an ionic compound (metal and nonmetal), a molecular compound (two nonmetals), or an acid (has the word acid in its name).
- II. If ionic, determine the charges on the ions and write a formula that will yield a neutral compound.
- III. If molecular, write a formula using the prefixes in the name to determine the subscripts in the formula.
- IV. If an acid, then it is either one of the ones you memorized or it's H____.
(hydrogen followed by some single element)

V. Writing Chemical Equations

- I. A chemical equation is a symbolic representation of what happens during a chemical reaction.
- II. To describe the reaction you did between baking soda and hydrochloric acid in words you would write: Sodium Bicarbonate reacts with Hydrochloric Acid to produce Carbon Dioxide, Water, and Sodium Chloride.
- III. In symbolic form we would write: $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{NaCl}$
- IV. Everything to the left of the arrow is called the reactants, everything to the right, the products.

V. One can even add the state of each substance in the reaction.

(s) = solid (l) = liquid

(g) = gas (aq) = aqueous (dissolved in water)

Using the above, the reaction becomes: $\text{NaHCO}_3(\text{s}) + \text{HCl}(\text{aq}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) + \text{NaCl}(\text{aq})$

VI. Reactions with only ionic compounds as reactants.

I. Typically ionic compounds won't react with each other unless they are dissolved in water. Therefore, most of our reactions with ionic compounds will be in the aqueous phase.

II. A reaction only occurs if one of the products formed would be insoluble in water. When an insoluble compound is formed from a reaction between two aqueous solutions, we call this compound a precipitate. See the Precipitation Rules Sheet to learn if an insoluble compound would form.

III. When combining two aqueous ionic compounds you basically have four different ions floating around in solution. The positive and negative ions from each compound have the opportunity to come in contact and react. If the new compound formed is insoluble then a precipitate forms.

IV. We can write the reaction between Sodium Chloride and Lead(II) Nitrate in several ways.

I. In words it would be:

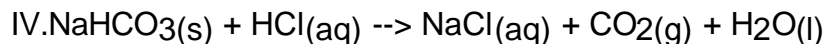
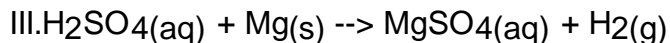
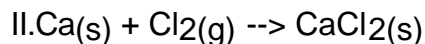
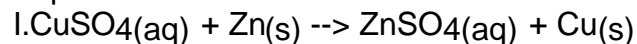
Sodium Chloride + Lead(II) Nitrate \rightarrow Sodium Nitrate + Lead(II) Chloride

II. In formulas it would be

$\text{NaCl}(\text{aq}) + \text{Pb}(\text{NO}_3)_2(\text{aq}) \rightarrow \text{NaNO}_3(\text{aq}) + \text{PbCl}_2(\text{s})$ (see an illustration of this below)

III. Notice that the NaNO_3 is still dissolved. Basically, the sodium and nitrate ions did not really do anything. They were floating around dissolved in solution before and after the reaction.

VII. Reactions can occur with all different kinds of substances. The one described above is typical of how ionic substances react with each other. However, elements and compounds (ionic, molecular, and acid) also react together, although in more or less predictable ways. For example:



I. Demo: Precipitation of NaCl and $\text{Pb}(\text{NO}_3)_2$

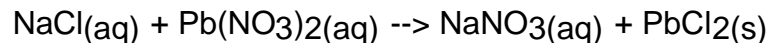
II. Lab: Predicting Precipitates

III. Homework: Seven Solution Practice

VI. Balancing Equations

I. Remember Lavoisier's Law of Conservation of Mass? So far the chemical equations we have written have not taken this law into consideration.

II. Let's recall the reaction between Sodium Chloride and Lead(II) Nitrate:

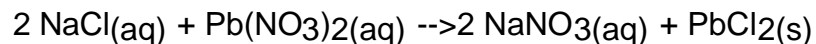


Where did the second chloride ion come from, and where did the other nitrate ion go?

III. Every atom that appears on the left side of the arrow must also appear on the right side. It might be tempting to fix this problem by rewriting PbCl_2 as PbCl , but that would be the

incorrect formula for Lead(II) Chloride. Pb^{+2} must pair up with two Cl^{-1} s.

IV. We resolve this by placing coefficients in front of the formulas indicating that you can have different ratios of the substances reacting to form different ratios of products. To fix the above reaction we would rewrite it as:



V. The 2 in front of NaCl give you 2 Na's and 2 Cl's. The 2 in front of the NaNO₃ gives you 2 Na, 2 N, and 6 O. If you count up all the atoms on the left and right of the arrows you will have the same number of each element. The equation is now balanced.

VI. An unbalanced equation is like having a recipe with no quantities for each ingredient.

VII. Click here to see a visual representation of balancing equations by C.H. Mak at Virginia Tech.

I. Homework: Balance Practice

II. If you want even more practice on balance equations click here to see the ChemTeam's set of problems.

III. Lab: Seven Solution Lab

VII. Types of Reactions

I. Reactions can be placed in broad categories.

I. Synthesis

I. This occurs when the number of products is fewer than the number of reactants.

II. In symbolic form: $A + B \rightarrow AB$

III. An example of this is the formation of water: $2 \text{H}_2\text{(g)} + \text{O}_2\text{(g)} \rightarrow 2 \text{H}_2\text{O(l)}$

II. Decomposition

I. This occurs when the number of products is more than the number of reactants.

II. In symbolic form: $AB \rightarrow A + B$

III. Concrete example: $2 \text{H}_2\text{O(l)} \rightarrow 2 \text{H}_2\text{(g)} + \text{O}_2\text{(g)}$

III. Single Replacement (or Displacement)

I. This occurs when one element replaces another element in a compound.

II. In symbolic form: $A + BC \rightarrow AC + B$ or $A + BC \rightarrow BA + C$

III. Concrete example: $\text{Zn(s)} + \text{CuSO}_4\text{(aq)} \rightarrow \text{ZnSO}_4\text{(aq)} + \text{Cu(s)}$

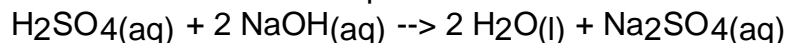
IV. Double Replacement (or Displacement)

I. This occurs when two sets of elements switch places in a reaction.

II. In symbolic form: $AB + CD \rightarrow AD + CB$

III. Concrete example: $2 \text{NaCl(aq)} + \text{Pb(NO}_3)_2\text{(aq)} \rightarrow 2 \text{NaNO}_3\text{(aq)} + \text{PbCl}_2\text{(s)}$

IV. When the reaction is between an acid and a base (any compound that forms hydroxide ions), water is formed as one of the products. This is called Neutralization. For example:



V. Combustion

I. Typically combustion occurs when a hydrocarbon reacts with oxygen to produce carbon dioxide and water. Hydrocarbons are a class of compounds that primarily consist of hydrogen and carbon.

II. In symbolic form: $\text{C}_x\text{H}_y + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$

III. Concrete example: $2 \text{C}_2\text{H}_6 + 7 \text{O}_2 \rightarrow 4 \text{CO}_2 + 6 \text{H}_2\text{O}$

II. Some common chemical reactions that you should be familiar with:

I. acid + base \rightarrow water + ionic compound

II. metal + oxygen \rightarrow ionic compound

III. metal + acid \rightarrow hydrogen gas + ionic compound

IV. ionic compound1 + ionic compound2 \rightarrow ionic compound3 + ionic compound4

V. acid + carbonate \rightarrow carbon dioxide + water + ionic compound

VI. metal1 + ionic compound1 \rightarrow metal2 + ionic compound2

VII. hydrocarbon + oxygen \rightarrow carbon dioxide + water

I. Homework: Types of Reactions

II. Lab: Common Chemical Reactions

III. Lab: Copper Conversion Lab