Unit 4: Chemistry

Part 1: Definitions

**Pure Substance vs Mixture:**

**Pure Substance**

A pure substance is [matter](https://www.chemicool.com/definition/matter.html) which has a specific composition and specific properties. Every molecule of a pure substance has the same chemical composition. Every element is a pure substance. Every compound is a pure substance.

**Examples of pure substances**:

* [Iron](http://www.chemicool.com/elements/iron.html) is an element and hence is also a pure substance.
* Water is a compound and hence is also a pure substance. Although water is made of two different elements, each water molecule has the same structure (H2O).

**Mixture**

A mixture contains two or more [substances](https://www.chemicool.com/definition/substance.html) that are not chemically combined. The properties of a mixture can be altered by changing the ratios of the substances. A mixture contains different molecules of different pure substances.

**Examples of non-pure substances (mixtures)**:

* Salt water is not a pure substance. It is a mixture of two pure substances - sodium chloride and water. Its composition and therefore its properties are not fixed.
* Gasoline is not a pure substance. It is a mixture of hydrocarbons and, depending on the composition of the gasoline mixture, gasoline's properties can vary.
* Air is not a pure substance. Air is a mixture of many elements and compounds, including (but not limited to) oxygen, O2, hydrogen, H2, carbon dioxide, CO2 and many others.
* Brass is a mixture of copper and zinc. Mixtures of metals are often called alloys. Changing the amount of zinc can change the appearance, the malleability, the electrical conductivity and other properties.

**Element vs Compound**

**Element**

An element is a pure [substance](https://www.chemicool.com/definition/substance.html) whose atoms all have the same number of protons: another way of saying this is that all of a particular element's atoms have the same atomic number.

Elements are the simplest pure substances and cannot be broken down using chemical reactions. Elements can only be changed into other elements using nuclear methods.

Although an element’s [atoms](https://www.chemicool.com/definition/atom.html) must all have the same number of protons, they can have different numbers of neutrons or electrons. When atoms of the same element have different numbers of neutrons, they have different masses and are called [isotopes](https://www.chemicool.com/definition/isotopes.html). If atoms of the same element have different numbers of electrons, they will have different charges and are called ions.

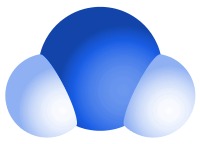
Atoms are generally neutral and have the same number of electrons as protons. If an atom gains extra electrons it will have a negative charge and be called an anion. If an atom loses electrons it will have a positive charge and be called a cation.

**Examples of Elements**

* All known elements are organized in the Periodic Table of the Elements

**Compound**

A compound is a pure substance formed when two or more chemical elements are chemically bonded together.



1 water molecule contain 3 atoms: 2 hydrogen atoms and 1 oxygen atom.

Every water molecule has this same structure.

The type of bonds holding elements together in a compound can vary: two common types are [covalent bonds](https://www.chemicool.com/definition/covalent_bond.html) and [ionic bonds](https://www.chemicool.com/definition/ionic_bonding.html).

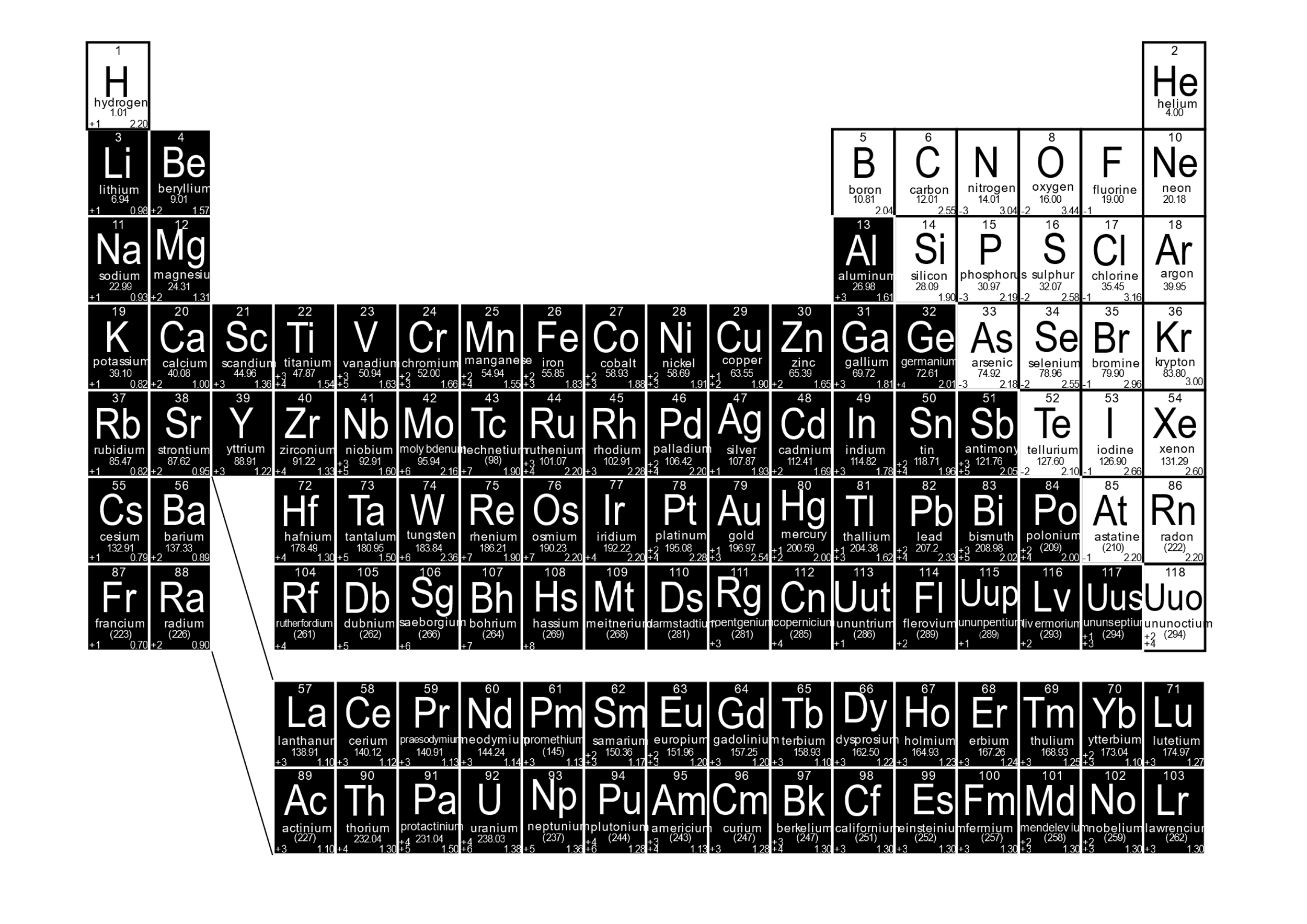
Ionic bonds are formed between a positively charged metal ion (cation) and a negatively charged non-metal ion (anion). The ratio of ions is always such that the molecule formed is neutral. Covalent bonds are formed between two (or more) non-metals. The non-metals share electrons such that each will have a full outer shell, or stable octet.

The elements in any compound are always present in fixed ratios. The molecules of a compound are nearly always neutral. The exception are the pol-atomic ions.

**Examples of Compounds**

* Pure water is a compound made from two elements - hydrogen and oxygen. The ratio of hydrogen to oxygen in water is always 2:1. Each molecule of water contains two hydrogen atoms bonded to a single oxygen atom. The chemical formula is H2O. Water is a covalent compound.
* Table salt is a compound made from two elements - sodium and chlorine. The ratio of sodium ions to chloride ions in sodium chloride is always 1:1. The chemical formula is NaCl. Sodium chloride is an ionic compound.
* Pure methane is a compound made from two elements - carbon and hydrogen. The ratio of hydrogen to carbon in methane is always 4:1. The chemical formula is CH4
* The nitrogenous base thymine, found in DNA, is a compound made from 4 elements-carbon, hydrogen, oxygen and nitrogen. The ration of carbon to hydrogen to oxygen to nitrogen is 5:6:2:2. the chemical formula is C5H6N2O2

Part 2: Types of Compounds (Review from Science 9)



Identifying Compounds

The first step in naming compounds is to recognize an element as a ***metal*** or a ***non-metal***. Luckily this is very simple with your periodic table.

Each element that appears as black is a metal, each element shown in white is a non-metal.

Hydrogen is the exception as it can behave as either a metal or a non-metal. We will deal with that a little later!

* An ***ionic compound*** consists of a metal and a non-metal, bound by an ionic bond. The metal will appear first in the chemical name and formula, while the non-metal will appear second in the name (with the ending “ide”) and formula.
* A ***covalent compound*** consists of two non-metals, bound by shared electrons; a co-valent bond.

Practice:

Identify each compound below as ionic (I) or covalent (C).

A. NaCl B. CaF2 C. SiCl4 D. CuCl2 E. N2O2

F. P2Cl G. CO2 H. K2O I. MgBr2 J. B2F3

Beyond this there are other more complex classifications of compounds like ***acids, bases*** and ***salts***. There is also the distinction between ***organic*** and ***inorganic*** compounds, within organic compounds there are ***hydrocarbons, alcohols, sugars, proteins, aromatics, benzenes, polymers*** and more. This will be explored in more detail in Science 10.

Naming Ionic Compounds

**Rule 1:**  a. Write the name of the **metal element** first.

b. If the metal is a **transition metal** (group 3-12) include a roman numeral to indicate ion charge.

**Rule 2:**  Write the name of the poly atomic ion or non-metal element next. For non-metal elements

change the ending to **“ide”**

Practice:

Write the chemical name for each of the following ionic compounds. Don’t forget to write the correct roman numeral for transition metals!

A. NaCl B. Na2O C. MgO D. MgCl2 E. KI F. CuCl2 G. FeBr3

H. CrN I. K2S J. Li2O K. CuF L. FeBr2 M. CuCl N. MnO2

Naming Covalent Compounds

* **Rule 1:**  The element with the lower group (family) number is written first in the name; the element with

the higher group (family) number is written second in the name.

***Exception: when the compound contains oxygen and a halogen, the name of the halogen is the first word in the name.***

* **Rule 2:**  If both elements are in the same group, the element with the higher period number is written

first in the name.

* **Rule 3:** The second element in the name is named as if it were an anion, i.e., by adding the suffix *-ide* to

the name of the element.

* **Rule 4:**  Greek prefixes (see the table below) are used to indicate the number of atoms of each nonmetal

element in the chemical formula for the compound.

* **Rule 5:** The Greek prefix is written ***before*** the name of each element. That’s why it’s called a ***pre***-fix!

***Exception: if the compound contains one atom of the element that is written first in the name, the prefix "mono-" is not used.***

Prefixes:

|  |  |  |  |
| --- | --- | --- | --- |
| **Number** | Prefix | **Number** | Prefix |
| 1 |  | 6 |  |
| 2 |  | 7 |  |
| 3 |  | 8 |  |
| 4 |  | 9 |  |
| 5 |  | 10 |  |

|  |
| --- |
|  |

*Note: when the addition of the Greek prefix places two vowels adjacent to one another, the "a" (or the"o") at the end of the Greek prefix is usually dropped; e.g., "nonaoxide" would be written as "nonoxide", and "monooxide" would be written as "monoxide". The "i" at the end of the prefixes "di-" and "tri-" are never dropped.*

Practice:

A. P2Cl4 B. CO2 C. CO D. N2O2 E. Si2O3 F. ClF

G. NO H. SeF2 I. B2S3 J. CCl4 K. AsN L. Si3N5

Part 3: Types of Chemical Compounds:

As we know one of the primary ways that science organizes and analyzes data is through ***classification***. Classification is the process of grouping objects/events according to similarities. Classification is a major prat of chemistry. Elements are classified on the periodic table into groups/families according to valence structure, into periods depending on the number of electron shells. The elements are separated into metal and non-metals.

More detailed classifications of the elements lead to categories such as: transition metals, metalloids, halogens, alkalis, alkalines, noble gases, diatomics, lanthanides, actinides and more!

Compounds can also be classified in different ways. We have already seen one major classification of compounds into ***ionic*** and ***covalent*** compounds. Now will next discuss some other ways that chemical compounds can be classified.

Acids and Bases (and Salts):

Acids are a group of compounds with the following properties:

* sour taste
* react with metals to produce H2 gas
* react with carbonates to form CO2 gas
* corrosive
* turn blue litmus red (pink)
* pH below 7

Acids are very common in nature. Most fruits are high in acid; citric acid gives lemons and limes their characteristic sour taste. Your stomach contains a strong acid (hydrochloric acid, HCl) that helps to digest the food you eat. Bee stings are acidic in nature. When you exercise the “burn” you may feel in your muscles is caused by a buildup of lactic acid. Acids have many used in industry as well.

Bases are a group of compounds with the following properties:

* bitter taste
* feel slippery
* react with some metals to produce H2 gas
* corrosive
* turn red (pink) litmus blue
* pH above 7

Bases are also common in nature. We generally find bitter flavours unpleasant, this is because most poisons produced by plants are highly basic (or alkaline). Bile is a fluid formed by our livers and used in the digestion of fats. Wasp stings are basic. Most household cleaners and soaps are also basic.

Salts are a group of compounds with the following properties:

* white solid
* crystalline structure
* taste salty
* soluble in water
* formed from the reaction of an acid with a base

Naming of Acids and Bases:

For the following discussion we shall be using the simple ***Arrhenius*** theory of acids and bases. Be aware that there are other more advanced theories including the ***Lewis*** theory and the ***Bronstead-Lowry*** theory.

**ACIDS**

Acids are ionic compounds, in solution with water, with H+ acting as the metal, in solution with water. Examples include *Hydrochloric Acid (HCl), Hydrofluoric Acid (HF), Hydronitric Acid (H3N), Sulfuric Acid (H2SO4) and Chlorous Acid (HClO2).* When these compounds are dissolved in water the H+ ions are released into solution. Although acids are simply ionic compounds, when they are dissolved in water (aqueous solution) they are named differently than typical ionic compounds. There are 3 general rules for naming acids:

**1. If the non-metal part of the acid is an *element* (Cl-, N3-, Br-…) the name of the acid is:**

Hydro \_\_\_\_\_\_\_\_\_\_ ic Acid

where the blank is the beginning of the element’s name:

EX: HCl : Hydro\_\_\_\_\_\_\_\_\_\_ic Acid

HBr : Hydro\_\_\_\_\_\_\_\_\_\_ic Acid

H2S : Hydro\_\_\_\_\_\_\_\_\_\_ic Acid

**2. If the non-metal is a polyatomic ion ending in “ATE” (CO32- carbonate, SO42- sulfate…) the name of the acid is:**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ic Acid

where the blank is the beginning of the name of the polyatomic ion.

\*NO HYDRO AT THE START

EX: H2CO3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ic Acid

H3PO4: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ic Acid

HMnO4: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ic Acid

**3. If the non-metal is a polyatomic ion ending in “ITE” (ClO2- chlorite, SO32- sulfite…) the name of the acid is:**

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ous Acid

where the blank is the beginning of the name of the polyatomic ion.

\*NO HYDRO AT THE START

EX: H2SO3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ous Acid

H3PO3: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ous Acid

HNO2: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ous Acid

**BASES:**

Bases are ionic compounds with hydroxide, OH-, acting as the non-metal, in solution with water. When in aqueous solution the hydroxide ions are liberated. There is no special rule for naming them, we just name them as an ionic compound.

EX: NaOH : sodium hydroxide

Mg(OH)2 : magnesium hydroxide

Al(OH)3 : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**NEUTRALIZATION and SALTS:**

When an acid and a base are mixed a special sort of double replacement reaction occurs. The H+ cation from the acid and the OH- anion from the base combine to form water (HOH=H2O). The cation from the base and the anion from the acid then combine to form an ionic compound known as a salt.

The result is that the acid and base both disappear to become water and salt (depending, of course on the relative amount of each present), this is known as an acid/base neutralization reaction.

This reaction is outlined as reaction type 6 in the notes you were given on classifying reactions.

The salt is named as any ionic compound.

Examples:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **ACID** | **+** | **BASE** | **→** | **WATER** | **+** | **SALT** |
| HCl | + | NaOH | → | H2O | + | NaCl |
| HBr | + | Mg(OH)2 | → | H2O | + | MgBr2 |
| H2SO4 | + | KOH | → | H2O | + | K2SO4 |
| H3PO3 | + | Ca(OH)2 | → | H2O | + | Ca3(PO3)2 |

Part 4: Chemical Reactions

**Chemical vs Physical Change**

**Physical Change**

A physical change is a change to a substance that does not alter the molecules of the substance. The molecules may be rearranged but no chemical bonds are broken and the molecules maintain their chemical composition.

**Examples of Physical Change:**

* Changes of state, like freezing/melting and boiling/condensation.
* Crystallization
* Magnetization. Certain materials can be magnetized by aligning the molecules in the material using a strong magnetic field.
* Dissolving. If you mix sugar into coffee (or tea or whatever) the sugar molecules remain intact. You simple break the crystals down until they are so small they cannot be seen.
* Alloy formation. Metals can be melted and mixed to form alloys that have desirable properties. The individual molecules from each metal do not join; no compounds are formed.

**Chemical Change**

A chemical change is a change in which the atoms of the molecules are rearranged. Chemical bonds are broken or formed or both. NO NEW ATOMS ARE FORMED AND NO ATOMS ARE DESTROYED. In chemical reactions new materials with new properties are created.

Chemical changes occur all around us all of the time. A chemical change is sometimes obvious but is often not. Evidence of chemical change includes: colour change, gas formation, precipitate formation, energy release in the form of light, heat or sound.

**Examples of Chemical Change:**

* A campfire. As the wood burns heat and light are produced. The wood is transformed into ash. The process cannot be reversed.
* Rotting of food.
* Digestion of food.
* Photosynthesis in plants.
* Rusting of metal.
* Batteries create electricity via chemical reactions.

Evidence that a chemical reaction has occurred/is occurring includes, but is not limited to:

* Change in odour
* Change in colour
* Change in composition (paper or wood turning to ash in a fire)
* Production of a precipitate
* Formation of gases
* Change of state without heating/cooling
* Release of heat/light/sound

These are evidence of chemical change, but none are conclusive.

Part 5: Classifying Chemical Reactions:

We will be looking at 6 types of chemical reaction. You will be expected to look at a chemical reaction and determine what type of reaction it is. You will also be expected to spot patterns and use these to predict what the products of a reaction will be.

1. SYNTHESIS

A synthesis reaction is one in which simple parts (often elements) join to form more complex molecules (compounds). **Usually** a synthesis reaction will begin with 2 reactants and end with 1 product. The reaction has the following BASIC FORM:

A + B → AB

\*Here if this is an ionic compound, A is representing the metal and B is representing the non-metal. The following equations could also represent a synthesis:

A+B→BA; B+A→BA; B+A→AB; AB +C→ABC…

2. DECOMPOSITION

A decomposition reaction is one in which a complex molecule breaks apart into simpler molecules. **Usually** a decomposition reaction will begin with 1 reactants and end with 2 product. The reaction has the following BASIC FORM:

AB → A + B

\*What other equations could represent a decomposition?

3. SINGLE REPLACEMENT

In a single replacement reaction a SINGLE part of an ionic compound is REPLACED with another element (or polyatomic ion). **Usually** there is one single element and one compound on both the reactant and the product side of the equation. The equation will have one of 2 BASIC FORMS, depending on whether A is a metal or non-metal:

A + BC → B + AC

A + BC → C + BA

4. DOUBLE REPLACEMENT

In a double replacement reaction two compounds switch or trade their metal and non-metal parts. There are two compounds on both the reactant and the product side of the equation.

AB + CD → AD + CB

5. COMBUSTION of a HYDROCARBON

This is the easiest type of reaction to identify.

A ***hydrocarbon*** is a compound consisting of only carbon and hydrogen. There is an infinite number of possible arrangements. Examples include: CH4 (methane), C2H6 (ethane), C3H8 (propane), C4H10 (butane)…

CxHy + O2 → CO2 + H2O

Notice that this is VERY different from the above examples as all of the elements involved are known (Carbon, Hydrogen and Oxygen). In fact three of the four *compounds* are known (Oxygen gas, Carbon dioxide and water). The only unknowns (x,y) are the numbers of carbon atoms and hydrogen atoms in the original hydrocarbon.

If any other elements are present, the combustion becomes more complex, and there can be, and usually are toxic by-products. This is why most fires produce smoke and fumes.

6. Neutralization Reaction

This is a special case of a double replacement reaction in which one of the reactants is an ***acid*** and the other is a ***base***.

An ***acid*** is any ionic compound whose metal (or cation) is hydrogen (HCl, HBr, H3N, H2S, H2SO4…). These compounds give off H+ ions (or protons) in solution.

A ***base*** is any ionic compound whose anion is the polyatomic ion hydroxide (OH-) (NaOH, Ca(OH)2, KOH, Al(OH)3…). These compounds give off the OH- ions in solution.

HnX + Y(OH)m → YX + H2O

acid base salt water

An acid plus a base yields salt and water.

Part 6: Balancing Chemical Equations

One of the most important aspects of chemical reactions is that chemical reactions do not create or destroy matter. There is never any change in the atoms themselves, instead atoms are only rearranged as chemical bonds are broken and new bonds are formed. Unlike nuclear reactions no new elements are formed and chemical reactions always obey the *law of conservation of mass*.

This means that in a chemical process, ***the total number of atoms of each element must be the same before and after the reaction.*** However, when chemicals combine, they don’t always match up in nice one to one ratio.

**Example 1:** Consider the following synthesis reaction between sodium and sulfur:

Na + S → Na2S

We should be able to see the problem here, there is only one sodium atom (Na) on the reactant side, but there are 2 sodium atoms (Na2) in the resulting compound. Where did the extra sodium come from? Did we create a new atom from nowhere? No, we did not. The extra sodium was always there.

The reaction above is known as a *skeleton reaction* and simply shows what molecules were involved before and after the reaction. A skeleton reaction does not consider how many of each atom/molecule were involved.

This reaction is occurring between billions and billions and billions of atoms. There are plenty of sodiums to go around. What we will be doing next is ***balancing*** the skeleton equation to show the correct proportion of each molecule in the reaction. When balancing it is important to remember that we cannot change the chemical composition of any of the reactants or products, nor can we introduce any new products or reactants. All we can do is determine *how many of each molecule* must be present for the reaction to occur.

The example above is extremely simple, you simply need 2 Na atoms for each S atom, so to balance we will write:

2 Na + 1 S → 1 Na2S

|  |  |  |
| --- | --- | --- |
| Reactants |  | Products |
| 2 | Na | 2 |
| 1 | S | 1 |

The reaction is balanced when there is the same number of each atom in the reactants and products.

**Example 2:** Consider this more difficult example:

MgO + AgCl3 → MgCl2 + Ag2O3

Let’s balance this beast!

**1. Count the number of each element (or polyatomic ion) in the product and reactant side:**

MgO + AgCl3 → MgCl2 + Ag2O3

|  |  |  |
| --- | --- | --- |
| Reactants |  | Products |
| 1 | Mg | 1 |
| 1 | O | 3 |
| 1 | Ag | 2 |
| 3 | Cl | 2 |

**2. Identify which elements/ions need to be balanced.** In this case the oxide, silver and chloride are all

unbalanced.

**3. Pick an ion to start with.** There is no rule, but I usually start with the ion that is the most unbalanced.

In this case that is oxide.

**4. Start balancing.** Determine which side has less of the ion you are balancing. In this case there are 3

oxides in the products, but only 1 in the reactants. Place a coefficient in front of the compound that will

result in the same number of your chosen ion on both sides. In this case we need a coefficient of 3 in

front of the MgO to end up with 3 oxides on both sides. Then recount.

3 MgO + AgCl3 → MgCl2 + Ag2O3

|  |  |  |
| --- | --- | --- |
| Reactants |  | Products |
| 3 | Mg | 1 |
| 3 | O | 3 |
| 1 | Ag | 2 |
| 3 | Cl | 2 |

Notice that now the oxides are balanced, but the magnesium ions become unbalanced. Don’t panic, this

is a process and everything will work out the end.

**5. Repeat step 4 for the next ion.** Now the magnesium ions are the most unbalanced. A coefficient of 3

in front of the MgCl2 will balance the magnesium ions. Recount.

3 MgO + AgCl3 → 3 MgCl2 + Ag2O3

|  |  |  |
| --- | --- | --- |
| Reactants |  | Products |
| 3 | Mg | 3 |
| 3 | O | 3 |
| 1 | Ag | 2 |
| 3 | Cl | 6 |

**6. Repeat step 4 for the next ion.** Now the chloride ions are the most unbalanced. A coefficient of 2 in

front of the AgCl3 will balance the chloride ions. Recount.

3 MgO + 2 AgCl3 → 3 MgCl2 + Ag2O3

|  |  |  |
| --- | --- | --- |
| Reactants |  | Products |
| 3 | Mg | 3 |
| 3 | O | 3 |
| 2 | Ag | 2 |
| 6 | Cl | 6 |

**7. Stop when it balances.** We are done. Finally add the coefficient 1 in front of all remaining compounds.

3 MgO + 2 AgCl3 → 3 MgCl2 + 1 Ag2O3

Balancing is a process that takes practice. Believe it or not, after a while you can balance most of these in your head. But for now, please go through the steps. Below is a list of tips that can assist you in your journey.

**Balancing Rules and Tips:**

1. **RULE:** You can’t change the molecules themselves. You must follow the rules for ionic compounds, and you can’t change the subscripts!

2. **RULE:** You can only change the coefficients.

Remember, there are literally billions of billions of atoms in a single drop. Coefficients are just a way of determining how many of each molecule participate in a reaction.

3. **TIP:** Often it is easier if polyatomic ions are grouped and treated like single “atoms”

This will not always work, but usually it will.

4. **TIP:** Balance compounds first. Leave elements (even diatomic elements) until the end.

5. **TIP:** If an element appears in *MORE THAN 2* molecules in the reaction, it is usually best to balance it last.

6. BE PATIENT.

It’s a virtue!

7. BE PERSISTENT.

Classify the following Reactions. ***When finished***, try to balance them.

1. \_\_\_\_CaCO3 🡪 \_\_\_\_\_Ca + \_\_\_\_\_CO3 Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. \_\_\_P4 + \_\_\_O2 🡪 \_\_\_P2O3 Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. \_\_\_RbNO3 +\_\_\_BeF2 🡪\_\_\_Be(NO3)2 +\_\_\_RbF Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
4. \_\_\_AgNO3 + \_\_\_Cu 🡪 \_\_\_Cu(NO3)2 + \_\_\_Ag Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
5. \_\_\_C3H8 + \_\_\_O2 🡪 \_\_\_CO2 + \_\_\_H2O Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
6. \_\_\_C5H5 + \_\_\_Fe 🡪 \_\_\_Fe(C5H5)2 Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
7. \_\_\_SeCl6 + \_\_\_O2 🡪 \_\_\_SeO2 + \_\_\_Cl2 Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
8. \_\_\_MgI2 + \_\_\_Mn(SO3)2 🡪 \_\_\_MgSO3 + \_\_\_MnI4 Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
9. \_\_\_O3 🡪 \_\_\_O + \_\_\_O2 Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
10. \_\_\_NO2 🡪 \_\_\_O2 + \_\_\_N2 Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
11. \_\_\_C3H5N3O9 🡪 \_\_N2 + \_\_O2 + \_\_CO2 + \_\_H2O Reaction Type \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Part 7: Energy in Chemical Reactions:

Remember that atoms are made up of protons, neutrons and electrons. Protons and electrons have charge and can therefor apply forces to one another.

proton – proton: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_)

electron – electron: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_)

proton – electron: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_)

Because of this, chemical compounds have energy stored up within the bonds between atoms. Some reactions require energy to create bonds, other reactions release energy by the breaking of bonds. In general, larger molecules store more energy than smaller ones.

Chemical reactions always involve the breaking and/or forming of bonds and so energy is always involved. There are two basic types of chemical reaction, classified according to energy:

**Endothermic Reactions** are reactions in which the *chemical potential energy of the products is greater than the chemical potential energy of the reactants*. In other words, this reaction has absorbed energy from the surroundings. Remember, energy cannot be created, so the extra energy stored in the products had to come from somewhere. In most cases, this means the reaction will cause the surroundings to get colder. An instant cold pack is an example of an endothermic reaction.

**Exothermic Reactions** are reactions in which the *chemical potential energy of the reactants is greater than the chemical potential energy of the products*. In other words, this reaction has released energy to the surroundings. In most cases, this means the reaction will cause the surroundings to get warmer. In highly exothermic reactions there may also be a release of light and sound. An explosion is an example of a highly exothermic reaction.

**Activation Energy:** For a chemical reaction to occur, the molecules must collide. Furthermore, they must collide with enough *energy*; that is, they need to hit hard enough. How much energy the molecules need to hit with is called the activation energy. This is the extra energy, beyond what is stored in the molecules that must be present (think temperature) for the reaction to proceed.

**Activated Complex:** In chemical reactions there is usually an *intermediate* step between the reactants and the products, called the *activated complex*. The energy within this activated complex determines the activation energy of the reaction.

***Δ*H:** Virtually every chemical reaction involves some change in the amount of chemical energy within the reactants and the products. This change in energy is known as ΔH (pronounced “*delta* H”). Very simply it is the difference between the energy of the products and the energy of the reactants. Change is, by definition, the difference between the final value and the initial value of some quantity. Therefor:

***ΔH= final energy – initial energy***

***ΔH = energy of products – energy of reactants***

***ΔH = Hp - Hr***

For endothermic reactions ΔH will be positive.

For exothermic reactions ΔH will be negative.

**Notation:** Energy is an important part of a chemical reaction and, as such, it is often included in the chemical equation. There are 2 common ways to do this.

1. In *standard notation* the energy is written directly into the equation:

***A + B + 1000J → C+ D*** *(endothermic)*

***A + B → C + D + 1000J*** *(exothermic)*

2. In ΔH notation energy is shown to the side. It is positive for endothermic and negative for exothermic.

***A + B → C + D ΔH=1000J*** *(endothermic)*

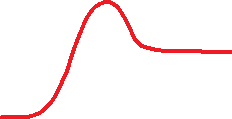
***A + B → C + D ΔH=-1000J*** *(exothermic)*

Potential Energy Diagrams:

Understanding energy in chemical reactions is incredibly important. It is essential to designing safe and efficient engines, furnaces, stoves and power plants. On smaller scales it is critical to understanding cellular processes in order to help diagnose disease, screen for and treat cancers. Understanding energy in chemical processes is essential to nutrition and diet in modern society where the majority of our food is purchased from a supermarket, rather than grown or raised or hunted.

To help understand energy in chemical reactions chemists make use of *potential energy diagrams*.

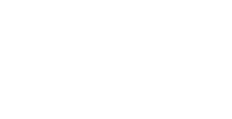
Energy



Reaction Progress



Energy



Reaction Progress

Part 8: Collision Theory and Reaction Rates:

In order to understand collision theory, we must first recall *Kinetic Molecular Theory.*

**Kinetic Molecular Theory** is a theory with many applications. It can be used to explain the properties of the three basic states of matter (solid, liquid, gas), diffusion, conduction, convection, evaporation, diffusion as well as reaction rates.

**Kinetic Molecular Theory:**

1. All matter is composed of molecules.

2. The molecules are in continuous motion.

3. The spaces between the molecules are empty.

4. The speed of the molecules increases with temperature.

**Collision Theory:**

In order for a reaction to occur molecules must collide:

1. with a sufficient amount of energy.

2. with the correct orientation.

The majority of collisions between molecules will not result in a reaction.

What this means is that the molecules must hit each other hard enough, and they have to hit at the right angle and position.

Example: Consider the reaction shown. Imagine that in order to react the reactants must form a product, like shown:

+ →

* It should be clear that they can`t just bump into each other in any way, they must align properly and there must be sufficient energy for them to lock together.
* ***This is only an analogy***, molecules are not actually puzzle pieces.

In order to make a reaction occur more quickly it is necessary to do one (or more) of the following

* Increase the number of collisions.
* Increase the energy of the collisions.
* Improve the orientation of the collisions.

**Reaction Rate:** The reaction rate is measure of how much time is required for a reaction to proceed from reactants to products. In other words, it is a measure of how quickly a reaction proceeds. A higher reaction rate means a faster reaction, a lower reaction rate means a slower reaction.

**Factors Affecting Reaction Rate:**

1. Temperature: As temperature increases the speed of the molecules increases. If the molecules in a chemical reaction move more quickly, there will be *more collisions* AND the collisions will occur with *more energy*.

***Increased Temperature ⇒ Increased Reaction Rate***

2. Stirring/Physical Agitation: If the reactants are stirred together or shaken or agitated in some way, the speed of the molecule will increase and the chemicals can have more contact, especially for powdered solids. Again, there will be *more collisions* AND the collisions will occur with *more energy*.

***Increased Agitation ⇒ Increased Reaction Rate***

3. Surface Area: A reaction can only occur if the molecules of a reactant can collide. If a cube of solid zinc is placed into hydrochloric acid, only the zinc molecules on the surface of the cube can react; the molecules inside the cube cannot interact with the acid. If you were to cut the cube into smaller pieces more surface would be exposed, and so more zinc atoms would be able to be hit by acid molecules to react. This is also true for a reaction between a gas and a solid or a gas and a liquid. More surface area will result in *more collisions*.

***Increased Surface Area ⇒ Increased Reaction Rate***

4. Concentration: Concentration is a measure of how many molecules are in a certain amount of space. Higher concentration means more molecules in the same space. The higher the concentration of the reactants, the more likely it is they will collide. A simple analogy is to think of how crowded a room is. If you have a classroom with only 5 people walking around in it, it will be fairly easy to move around without bumping into anyone. If the same classroom is now packed with 40 people, all walking around, collisions will be very difficult to avoid. Increasing the concentration will result in *more collisions.*

***Increased Concentration ⇒ Increased Reaction Rate***

5. Catalysts: A catalyst is a chemical substance which participates in a chemical reaction, but is not used up in the reaction. In other words the catalyst is involved, and may even be altered, in the reaction, however it is present in equal amounts before and after the reaction. The roll of the catalyst is to make the reaction occur more efficiently by helping the reactants to align properly. The details of how catalysts work can be incredibly complex, however the overall effect is that *catalysts lower activation energy*. This means a *higher percentage of successful collisions.*

***Catalyst ⇒ Increased Reaction Rate***