Chemical Reactions:

* A chemical reaction occurs when the atoms making up one or more chemical substance are rearranged to form produce new chemical substances.
* No new elements or atoms are created in a chemical reaction. However the rearranging of the atoms will produce new compounds/substances with new properties.
* The substances that you begin with are collectively called the ***reactants***.
* The substances that you end up with are called the ***products***.
* There is often a huge difference between the properties of the reactants and the products.

In classical chemistry there is no change to the nuclei of any of the atoms involved. Because there are no changes at the nuclear level, all chemical reactions obey ***The Law of Conservation of Mass***. This means that the total mass of all of the reactants must be equal to the total mass of all of the products. This law has been confirmed through millions of repeated experiments in carefully sealed containers that do allow for any materials to enter the system from outside, or for any materials to exit the system to the outside.

The law of conservation of mass can be explained by ***kinetic molecular theory***. KMT explains chemical reactions as simply the rearrangement of the atoms in the reactants to form products.

Chemical reactions involve changes in the valence electrons of atoms. These changes can cause ***chemical bonds*** to be formed and broken. The two most common types of bonds are ***ionic*** bonds and ***covalent*** bonds. Ionic bonds are formed when electrons are transferred from a metal to a non-metal. Ionic bonds are formed when electrons are shared between two (or more) non-metals.

The forming and breaking of chemical bonds can either absorb or release energy. Reactions that ***absorb energy*** from the surroundings are called ***Endothermic Reactions*** whereas reactions that ***release energy*** are called ***Exothermic 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.

It can be helpful in chemistry to understand what kind of reaction has occurred or will be likely to occur between certain reactants. One helpful tool to aid in this is the ability to classify chemical reactions in various ways. By knowing what classification a reaction is, it can be much simpler to predict the products.

One common method is to classify reactions according to how the atoms are rearranged:

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.

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 now 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.

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 take into account how many of each atom/molecule were involved.

In reality 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.

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 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_