Chemistry is really...

*Chem* is *try*

To do chemistry, you must:
- Practice
- Practice
- Practice

The Modern Periodic Table

The modern organization of the periodic table came about as a result of the work of Dimitri Mendeleyev

**Characteristics:**
- Ordered elements by atomic mass
- Repeating pattern of properties
- Elements with similar properties in the same column

**Periodic Law** – when the elements are arranged in order of increasing atomic mass, certain sets of properties recur periodically.

Patterns used to predict properties of undiscovered elements
The Periodic Table: Metals and Nonmetals

- Metals
- Nonmetals

The modern periodic table is defined by:

- Groups (families) (columns down)
- Periods (rows across)

Tin is in group 4A (14) in the 5th period.
Metals form cations. Non-metals form anions. Metalloids can do both.

Today’s Periodic table

Group 1A elements are also known as the “Alkali Metals” as they form basic salts.

Group 2A elements are also known as the “Alkaline earth Metals” as they are only found in the ground as metal salts (carbonates).

Group 2B – 8B elements are also known as the “Transition Metals”. They may be found in the earth as pure metals or as ores (salts).
Today's Periodic table

Group 7A elements are also known as the **Halogens**. They form acids with hydrogen and exist as diatomic molecules. (F₂, Cl₂,...)

Group 8A elements are also known as the **Noble Gasses**. They are inert to reaction for the most part. He is found underground!

The Representation of Matter:

In chemistry we use chemical formulas and symbols to represent matter.

**Why?**

We are “**macroscopic**”: large in size on the order of 100’s of cm

Atoms and molecules are “**microscopic**”:

- on the order of 10⁻¹² cm

Why do scientists use chemical symbols like C, Al and Fe to represent atoms?

Because atoms are really small!

Nucleus

\[ \sim 10^{-4} \text{Å} \]

1 Angstrom = 10⁻¹⁰ m
Chemical Symbols and Formulas:

What we observe... To what we can’t see!

Chemical symbols (H₂O) allow us to connect...

Elements:

<table>
<thead>
<tr>
<th>Element</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
</tr>
</tbody>
</table>

Molecules:

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>hydrogen</td>
</tr>
<tr>
<td>O₂</td>
<td>oxygen</td>
</tr>
<tr>
<td>H₂O</td>
<td>water</td>
</tr>
<tr>
<td>CH₄</td>
<td>methane</td>
</tr>
</tbody>
</table>

Some of the names are not systematic!

Atoms, Compounds, Molecules and Ions:

An atom is the smallest indivisible indistinguishable unit of a pure element.

An ion is an atom (or molecule) with a formal electrical charge.

An anion is an atom (or molecule) that has a negative charge.

The number of electrons > number of protons

A cation is an atom (or molecule) has a positive charge

The number of electrons < number of protons
Componds:

A compound is a distinct substance that contains two or more elements combined in a definite proportion by weight.

Atoms of the elements that constitute a compound are always present in simple whole number ratios.

They are never present as fractional parts.

**Examples:**  $\text{AB}$  $\text{A}_2\text{B}$  $\text{AB}_2$

Never:  $\text{A}_{\frac{1}{2}}\text{B}$

Molecules and Ionic Compounds:

A molecule is the smallest uncharged individual unit of a compound formed by two or more atoms.

Ionic compounds are made of positively and negatively charged ions.

A *molecule* can exist as an entity on its own.

An *ionic compound* is represented by a formula unit that describes the simplest ratio of *cations* to *anions*.

Componds fall into one of two classes:

<table>
<thead>
<tr>
<th>Inorganic Salts</th>
<th>Molecules</th>
</tr>
</thead>
<tbody>
<tr>
<td>metal cation</td>
<td>non-metal</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>non-metal or</td>
<td>non-metal</td>
</tr>
<tr>
<td>polyatomic anion</td>
<td>(no cations or anions)</td>
</tr>
</tbody>
</table>

The two use different formalisms for naming...
Molecular Compounds: Nonmetals and Nonmetals

Ion Charges:

Binary Compounds: Metal & non-Metal

Metal of fixed oxidation (charge) state combined with a non-metal.

Examples:

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>K⁺</td>
<td>Cl⁻</td>
<td>KCl</td>
<td>Potassium chloride</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>O²⁻</td>
<td>CaO</td>
<td>Calcium Oxide</td>
</tr>
<tr>
<td>Na⁺</td>
<td>S²⁻</td>
<td>Na₂S</td>
<td>Sodium sulfide</td>
</tr>
<tr>
<td>Al³⁺</td>
<td>S²⁻</td>
<td>Al₂S₃</td>
<td>Aluminum sulfide</td>
</tr>
</tbody>
</table>
### Metals of variable charge (transition) with a non-metal

**Examples:** modify transition metal name with roman numeral

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb$^{2+}$</td>
<td>Cl$^-$</td>
<td>PbCl$_2$</td>
<td>lead (II) chloride</td>
</tr>
<tr>
<td>Pb$^{4+}$</td>
<td>Cl$^-$</td>
<td>PbCl$_4$</td>
<td>lead (IV) chloride</td>
</tr>
<tr>
<td>Fe$^{3+}$</td>
<td>O$^{2-}$</td>
<td>Fe$_2$O$_3$</td>
<td>Iron (III) oxide</td>
</tr>
</tbody>
</table>

pronounced: **lead - two - chloride**

### Some common polyatomic ions:

<table>
<thead>
<tr>
<th>Ion</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH$_4^+$</td>
<td>ammonium</td>
</tr>
<tr>
<td>H$_2$O$^+$</td>
<td>hydronium</td>
</tr>
<tr>
<td>CO$_3^{2-}$</td>
<td>carbonate</td>
</tr>
<tr>
<td>HCO$_3^{2-}$</td>
<td>hydrogen carbonate or bicarbonate</td>
</tr>
<tr>
<td>NO$_2^-$</td>
<td>nitrite</td>
</tr>
<tr>
<td>NO$_3^-$</td>
<td>nitrate</td>
</tr>
<tr>
<td>SO$_4^{2-}$</td>
<td>sulfate</td>
</tr>
<tr>
<td>SO$_3^{2-}$</td>
<td>sulfite</td>
</tr>
<tr>
<td>PO$_4^{3-}$</td>
<td>phosphate</td>
</tr>
<tr>
<td>C$_2$H$_3$O$_2^{-}$</td>
<td>acetate</td>
</tr>
</tbody>
</table>

### Ternary Compounds: Those with three different elements

**metal of fixed charge with a complex ion**

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>K$^+$</td>
<td>OH$^-$</td>
<td>KOH</td>
<td>Potassium hydroxide</td>
</tr>
<tr>
<td>Ca$^{2+}$</td>
<td>OH$^-$</td>
<td>Ca(OH)$_2$</td>
<td>Calcium hydroxide</td>
</tr>
<tr>
<td>Na$^+$</td>
<td>SO$_4^{2-}$</td>
<td>Na$_2$SO$_4$</td>
<td>Sodium sulfate</td>
</tr>
<tr>
<td>Al$^{3+}$</td>
<td>SO$_4^{2-}$</td>
<td>Al$_2$(SO$_4$)$_3$</td>
<td>Aluminum sulfate</td>
</tr>
</tbody>
</table>

### Metal of variable charge transition with a complex ion

<table>
<thead>
<tr>
<th>Cation</th>
<th>Anion</th>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe$^{3+}$</td>
<td>NO$_3^-$</td>
<td>Fe(NO$_3$)$_3$</td>
<td>Iron (III) nitrate</td>
</tr>
<tr>
<td>Fe$^{2+}$</td>
<td>NO$_2^-$</td>
<td>Fe(NO$_2$)$_2$</td>
<td>Iron (II) nitrite</td>
</tr>
</tbody>
</table>
Non-metal with a non-metal

When non-metals combine, they form molecules. They may do so in multiple forms:

- CO
- $CO_2$

Because of this we need to specify the number of each atom by way of a prefix.

1 = mono 2 = di 3 = tri 4 = tetra

5 = penta 6 = hexa 7 = hepta

Examples:

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCl$_3$</td>
<td>boron trichloride</td>
</tr>
<tr>
<td>SO$_3$</td>
<td>sulfur trioxide</td>
</tr>
<tr>
<td>NO</td>
<td>nitrogen monoxide</td>
</tr>
<tr>
<td>NO</td>
<td>nitrogen monoxide</td>
</tr>
<tr>
<td>N$_2$O$_4$</td>
<td>dinitrogen tetraoxide</td>
</tr>
</tbody>
</table>

We don’t write: nitrogen monoxide or mononitrogen monoxide.

Writing formulas for acids and Bases

- An **acid** is a substance that produces $H^+$ when dissolved in water.
- Certain gaseous molecules become acids when dissolved in water.

- A **base** produces $OH^-$ when dissolved in water.
- Bases often are Group I and Group II hydroxide salts.
**Type I Acids:** Acids derived from \(-ide\) anions.

The names for these acids follows the formula:

“hydro” + the root of the \(ide\) anion + \(ic\) “acid”

<table>
<thead>
<tr>
<th>Anion</th>
<th>Acid</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>chloride</td>
<td>HCl</td>
<td>hydrochloric acid</td>
</tr>
<tr>
<td>fluoride</td>
<td>HF</td>
<td>hydrofluoric acid</td>
</tr>
</tbody>
</table>

**Examples: Oxy Acids:** Those derived from \(-ate\) anions.

<table>
<thead>
<tr>
<th>Anion</th>
<th>Acid</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>(nitrate)</td>
<td>(NO_3^-)</td>
<td>HNO(_3)     nitric acid</td>
</tr>
<tr>
<td>(chlorate)</td>
<td>(ClO_3^-)</td>
<td>HClO(_3)     chloric acid</td>
</tr>
<tr>
<td>(sulfate)</td>
<td>(SO_4^{2-})</td>
<td>H(_2)SO(_4) sulfuric acid</td>
</tr>
<tr>
<td>(acetate)</td>
<td>(C_2H_3O_2^-)</td>
<td>HC(_2)H(_3)O(_2) acetic acid</td>
</tr>
</tbody>
</table>

**Oxy Acids:** Those derived from \(-ite\) anions.

root name of the anion with \(-ous\) replacing the \(-ite\)

<table>
<thead>
<tr>
<th>Anion</th>
<th>Acid</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>(nitrite)</td>
<td>(NO_2^-)</td>
<td>HNO(_2)  nitrous acid</td>
</tr>
<tr>
<td>(chlorite)</td>
<td>(ClO_2^-)</td>
<td>HClO(_2)  chlorous acid</td>
</tr>
<tr>
<td>(sulfite)</td>
<td>(SO_3^{2-})</td>
<td>H(_2)SO(_3)  sulfurous acid</td>
</tr>
</tbody>
</table>

\[H^+ \text{ and } S^{2-} \quad \downarrow \quad \text{it takes } 2H^+ \text{ to cancel one } S^{2-}\]

\[H_2S \quad \text{hydro sulfuric acid}\]
Bases:

- \( \text{Ba(OH)}_2 \) barium hydroxide
- sodium hydroxide NaOH
- \( \text{NH}_4\text{OH} \) ammonium hydroxide

Common Names:

- \( \text{H}_2\text{O} \) water
- ammonia \( \text{NH}_3 \)
- \( \text{CH}_4 \) methane
- NO nitric oxide
- \( \text{N}_2\text{O} \) nitrous oxide

Practice:

- \( \text{N}_2\text{SO}_4 \) sodium sulfate
- barium carbonate \( \text{BaCO}_3 \)
- FeO Iron (II) oxide
- zinc phosphide \( \text{Zn}_3\text{P}_2 \)
- \( \text{NiBr}_2 \) nickel (II) bromide

Modern Atomic Theory:

- Atoms are made of protons, neutrons and electrons.
- The nucleus of the atom carries most of the mass.
- It consists of the protons and neutrons surrounded by a cloud of electrons.
  - The charge on the electron is \(-1\)
  - The charge on the proton is \(+1\)
  - There is no charge on the neutron

The **Atomic Number** or number of protons in the nucleus defines an element.
The Composition of an Atom:

The atom is mostly empty space

- protons and neutrons in the nucleus.
- the number of electrons is equal to the number of protons.
- electrons in space around the nucleus.

Atomic Number, Z

An element’s identity is defined by the number of protons in the nucleus: \( Z \)

Example: Selenium-75

Isotopes, Atomic Numbers, and Mass Numbers

Elemental Isotopic Symbols: For a given element “X”, an isotope is written by:

Atomic number \( (Z) = \) number of protons in the nucleus.

Mass number \( (A) = \) total number of nucleons in the nucleus (i.e., protons and neutrons).

One nucleon has a mass of 1 amu (Atomic Mass Unit) a.k.a “Dalton” or u

\[ A \]
\[ Z \]

Isotopes have the same Z but different total number of nucleons (A).
The **average weighted** atomic mass is determined by the following mathematical expression:

\[
\text{m Cl (u)} = \frac{\text{mass of a Cl-35 atom} \times \text{fraction that are Cl-35}}{\text{abundance of Cl-35}} + \frac{\text{mass of a Cl-37 atom} \times \text{fraction that are Cl-37}}{\text{abundance of Cl-37}}
\]

\[35.45 \text{ u} = 34.96885 \times 0.7553 + 36.96590 \times 0.2447\]

This is the value that is reported on the periodic table.

Note that: \(0.7553 + 0.2447 = 1.0000\) (100%)

---

**Avogadro's Number**

Since one mole of \(^{12}\text{C}\) has a mass of 12g (exactly), 12g of \(^{12}\text{C}\) contains \(6.022142 \times 10^{23}\) C-12 atoms.

But carbon exists as 3 isotopes: C-12, C-13 & C-14

The average atomic mass of carbon is 12.011 u.

From this we conclude that 12.011g of carbon contains \(6.022142 \times 10^{23}\) C-atoms. *Is this a valid assumption?*

Yes, since \(N_A\) is so large, the statistics hold.

---

**Avogadro's Number and the Mole**

The concept of a mole is defined so that we may equate the amount of matter (mass) to the number of particles (mole).

The Standard is based upon the C-12 isotope.

The mass of one \(^{12}\text{C}\)-atom is \(1.99265 \times 10^{-23}\) g.

The atomic mass of \(^{12}\text{C}\) is defined as exactly 12 u.

Therefore: \(1\text{u} = (\text{the mass of one }^{12}\text{C atom} \div 12)\)

\[= 1.66054 \times 10^{-24}\text{ g}\]

\[= 1.66054 \times 10^{-27}\text{ kg}\]

---

**Molar Masses**

Since we can equate mass (how much matter) with moles (how many particles) we now have a **conversion factor** that relates the two.

\[
\text{mols} \times \text{molar mass (g/mol)} = \text{grams}
\]

The Molar Mass of a substance is the amount of matter that contains one-mole or \(6.022 \times 10^{23}\) particles. *aka: Avogadro's number \((N_A)\)*

The atomic masses on the Periodic Table also represent the molar masses of each element in grams per mole (g/mol).
So if you have 12.011 g of carbon...
   you have $6.022 \times 10^{23}$ carbon atoms!

So if you have 39.95 g of argon...
   you have $6.022 \times 10^{23}$ argon atoms!

if you have a mole of dollar bills... you are Bill Gates...
   you have 6.022 x $10^{23}$ bucks!

and if you have $6.022 \times 10^{23}$ avocados...
   you have... a “guacamole”

---

**Question:** How many magnesium atoms are there in 150.0 g of magnesium?

**Solution:** Use the molar mass of Mg from the periodic table.

\[
150.0 \text{ g Mg} \times \frac{1 \text{ mol Mg}}{24.305 \text{ g Mg}} \times \frac{6.022 \times 10^{23} \text{ Mg atoms}}{1 \text{ mol Mg}}
\]

\[
= 3.717 \times 10^{24} \text{ Mg atoms}
\]

*(4 sig figs) big number as expected!

---

**Grams, Moles and Molar Mass:**

The molar mass of an atom is a conversion factor that relates *mass* (grams) to *moles* and vice versa.

\[
\text{(how much matter)} \quad \text{(number of atoms)}
\]

\[
\text{grams} \div \text{molar mass} = \text{moles}
\]

\[
\frac{\text{grams}}{\text{mol}} \times \frac{\text{mol}}{\text{atoms}} = \frac{\text{mol}}{\text{grams}}
\]

**Avogadro's number** ($N_A$) relates moles numbers of individual particles:

\[
1 \text{ mol} \times \frac{6.022 \times 10^{23} \text{ particles}}{1 \text{ mol}} = 6.022 \times 10^{23} \text{ particles}
\]

---

**The molar mass of an ionic compound** is the molar mass of one formula unit of the compound.

For the compound $\text{Al}_2(\text{SO}_4)_3$, the molar mass would be:

\[
\begin{align*}
2 \times (26.98 \text{ g/mol}) & \quad 2 \text{ Al’s} \\
+ 3 \times (32.07 \text{ g/mol}) & \quad 3 \text{ S’s} \\
+ 3 \times 4 \times (16.00 \text{ g/mol}) & \quad 3 \times 4 \text{ O’s}
\end{align*}
\]

\[
342.17 \text{ g/mol}
\]
How many oxygen atoms are there in 25.1 g of chromium (III) acetate?

**step 1:** write the correct chemical formula...

\[ \text{Cr}^{3+} \& \text{C}_2\text{H}_3\text{O}_2^- \rightarrow \text{Cr(C}_2\text{H}_3\text{O}_2)_3 \]

**step 2:** calculate the molar mass...

229.13 g/mol

**step 3:** use dimensional analysis to solve the problem...

\[
\frac{25.1 \, \text{g} \, \text{Cr(C}_2\text{H}_3\text{O}_2)_3}{229.13 \, \text{g/mol}} \times \frac{1 \, \text{mol} \, \text{Cr(C}_2\text{H}_3\text{O}_2)_3}{6 \, \text{mol} \, \text{O}} \times 6.022 \times 10^{23} \, \text{O-atoms} = 3.96 \times 10^{23} \, \text{O-atoms}
\]

How many grams of nitrogen are needed to completely react with 0.525 g of hydrogen in the formation of ammonia?

To answer this question, one must go through moles.

\[ \text{N}_2(g) + 3 \, \text{H}_2(g) \rightarrow 2 \, \text{NH}_3(g) \]

The equation relates moles, not mass.

\[
g \, \text{H}_2 \rightarrow \text{mols} \, \text{H}_2 \rightarrow \text{mols} \, \text{N}_2 \rightarrow g \, \text{N}_2
\]

(a) How many grams of nitrogen will be needed to produce 0.384 mols of ammonia?

\[
\text{N}_2(g) + 3 \, \text{H}_2(g) \rightarrow 2 \, \text{NH}_3(g)
\]

\[
0.384 \, \text{mols} \, \text{NH}_3 \times \frac{1 \, \text{mol} \, \text{N}_2}{2 \, \text{mol} \, \text{NH}_3} \times \frac{28.02 \, \text{g} \, \text{N}_2}{1 \, \text{mol} \, \text{N}_2} = 5.38 \, \text{g} \, \text{N}_2
\]

(b) How many moles of hydrogen are needed to combine with 5.84 g of nitrogen?

\[
5.84 \, \text{g} \, \text{N}_2 \times \frac{1 \, \text{mol} \, \text{N}_2}{28.02 \, \text{g} \, \text{N}_2} \times \frac{3 \, \text{mol} \, \text{H}_2}{1 \, \text{mol} \, \text{N}_2} = 0.625 \, \text{mols} \, \text{H}_2
\]

How many grams of nitrogen are needed to completely react with 0.525 g of hydrogen in the formation of ammonia?

\[ \text{N}_2(g) + 3 \, \text{H}_2(g) \rightarrow 2 \, \text{NH}_3(g) \]

\[
0.525 \, \text{g} \, \text{H}_2 \times \frac{1 \, \text{mol} \, \text{H}_2}{2.02 \, \text{g} \, \text{H}_2} \times \frac{1 \, \text{mol} \, \text{N}_2}{3 \, \text{mol} \, \text{H}_2} \times \frac{28.02 \, \text{g} \, \text{N}_2}{1 \, \text{mol} \, \text{N}_2} = 2.43 \, \text{g} \, \text{N}_2
\]

How many grams of ammonia form?

\[
0.525 \, \text{g} \, \text{H}_2 \times \frac{1 \, \text{mol} \, \text{H}_2}{2.02 \, \text{g} \, \text{H}_2} \times \frac{2 \, \text{mol} \, \text{NH}_3}{3 \, \text{mol} \, \text{H}_2} \times \frac{17.04 \, \text{g} \, \text{NH}_3}{1 \, \text{mol} \, \text{NH}_3} = 2.95 \, \text{g} \, \text{NH}_3
\]
How many grams of $O_2$ will result from the decomposition of 15.6g of potassium chlorate?

Step 1. Write the chemical equation

$2 \text{ KClO}_3(s) \rightarrow 3 \text{ O}_2(g) + 2\text{ KCl}(s)$

Step 2: Balance

Step 3: Set up the solution

$\text{g KClO}_3 \rightarrow \text{mols KClO}_3 \rightarrow \text{mols O}_2 \rightarrow \text{g O}_2$

How many grams of $O_2$ will result from the decomposition of 15.6g of potassium chlorate?

$2 \text{ KClO}_3(s) \rightarrow 3 \text{ O}_2(g) + 2\text{ KCl}(s)$

$15.6 \text{ g KClO}_3 \times \frac{1\text{ mol KClO}_3}{122.55\text{ g KClO}_3} \times \frac{3\text{ mol O}_2}{2\text{ mol KClO}_3} \times \frac{32.00\text{ g O}_2}{1\text{ mol O}_2}

= 61.1\text{ g O}_2$

Chemical Reactions

A chemical reaction can be described by a chemical equation. All chemical equations have three parts:

Reactants $\rightarrow$ Products

When a chemical changes occurs:

Atoms, Compounds or Molecules $\rightarrow$ New Compounds, Molecules or atoms

How does one know when a reaction has occurred? Generally, what you end up with looks nothing like what you started with.
Indicators of a Chemical Reaction:

Gas Evolution

Temperature change

Color Change

Precipitate Formation
Quantitative Information About Chemical Reactions

Mass must be conserved in a chemical reaction.

Total mass of reactants = Total mass of products

Chemical equations must therefore be balanced for mass.

Numbers of atoms on the reactant side = Numbers of atoms on the product side

The chemical equation for the formation of water can be visualized as two hydrogen molecules reacting with one oxygen molecule to form two water molecules:

\[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]

Balancing Chemical Reactions: Example

\[ \text{C}_2\text{H}_6 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

Balance H first

\[ 2\text{C}_2\text{H}_6 + 7\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O} \]

Balance C next

\[ 2\text{C}_2\text{H}_6 + 3\text{O}_2 \rightarrow 4\text{CO}_2 + 6\text{H}_2\text{O} \]

Balance O

When writing chemical reactions one starts with:

Reactants \[ \rightarrow \] products

\[ \text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \rightarrow 2\text{NH}_3\text{(g)} \]

Some reactions can also run in reverse:

\[ 2\text{NH}_3\text{(g)} \rightarrow \text{N}_2\text{(g)} + 3\text{H}_2\text{(g)} \]

Under these conditions, the reaction can be written:

\[ 3\text{H}_2\text{(g)} + \text{N}_2\text{(g)} \rightleftharpoons 2\text{NH}_3\text{(g)} \]

Dynamic Equilibrium!