
Chemical
Reactions

Indicators of chemical reactions

- Emission of light or heat

- Formation of a gas

- Formation of a precipitate

- Color change

- Emission of odor

All chemical reactions:

- have two parts
- Reactants - the substances you start with
- Products- the substances you end up with
- The reactants turn into the products.
- Reactants $\rightarrow$ Products

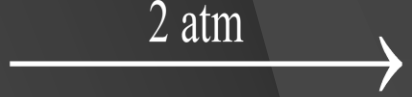
Describing chemical reaction

- The way atoms are joined is changed
- Atoms aren't created or destroyed.
- Can be described several ways
- In a sentence
- Copper reacts with chlorine to form copper (II) chloride.
- In a word equation
- Copper + chlorine $\rightarrow$ copper (II) chloride
- $Cu_{(s)} + Cl_{2(g)} \rightarrow CuCl_{2(aq)}$

Symbols used in equations

- (s) after the formula –solid $Cu_{(s)}$
- (g) after the formula –gas $H_{2\,(g)}$
- (l) after the formula -liquid $H_2O_{(l)}$
- (aq) after the formula - dissolved in water, an aqueous solution. $CaCl_{2\,(aq)}$
- used after a product indicates a gas (same as (g)) O_2
- ↓ used after a product indicates a solid (same as (s)) $CaCo_3 \downarrow$

Symbols used in equations

-  indicates a reversible reaction.
-  ,  shows that heat is supplied to the reaction.
-  , or  is used to indicate a catalyst used supplied, in this case, platinum.
-  ,  indicates a pressure other than STP

Summary of Symbols

Reactants and Products	
Symbol	***Meaning***
(*s*) or (*cr*)	solid or crystal
(*l*)	liquid
(*g*)	gas
(*aq*)	in aqueous solution (dissolved in water)
↓	solid precipitate product forms
↑	gaseous product forms

Reaction Conditions	
Symbol	***Meaning***
$\longrightarrow$	"produces" or "yields," indicating result of reaction
$\rightleftharpoons$	reaction in which products can re-form into reactants; final result is a mixture of products and reactants
$\xrightarrow{\Delta}$ or $\xrightarrow{\text{heat}}$	reactants are heated
$\xrightarrow{1.0 \times 10^8\ \text{kPa}}$	pressure at which reaction is carried out
$\xrightarrow{0°C}$	temperature at which reaction is carried out
$\xrightarrow{Pd}$	chemical formula of a catalyst added to speed up a reaction
$\xrightarrow{e^-}$	electrolysis

What is a catalyst?

- A substance that speeds up a reaction without being changed by the reaction.
- Enzymes are biological or protein catalysts.

Reaction Energy

- All chemical reactions are accompanied by a change in energy.
- **Exothermic** - reactions that release energy to their surroundings (usually in the form of heat)
  - oΔH (enthalpy) is negative – energy leaving system

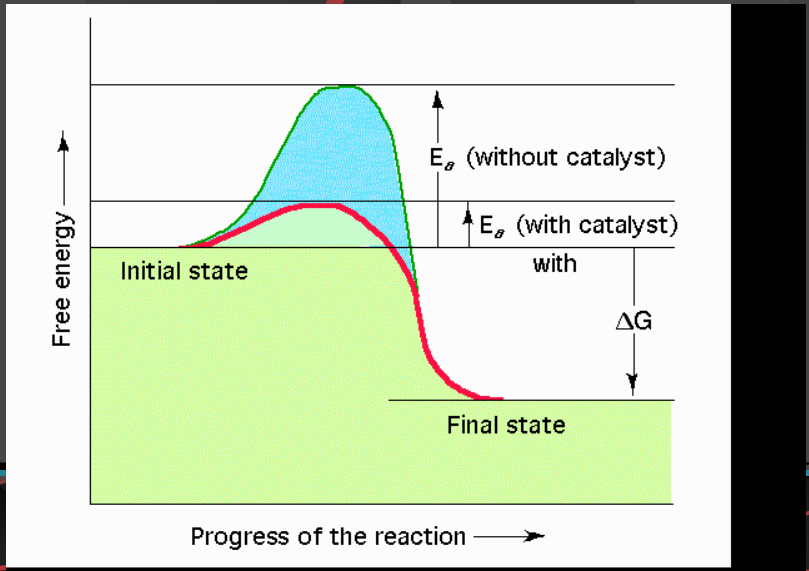
- **Endothermic** - reactions that need to absorb heat from their surroundings to proceed.
  - oΔH (enthalpy) is positive – energy coming into the system

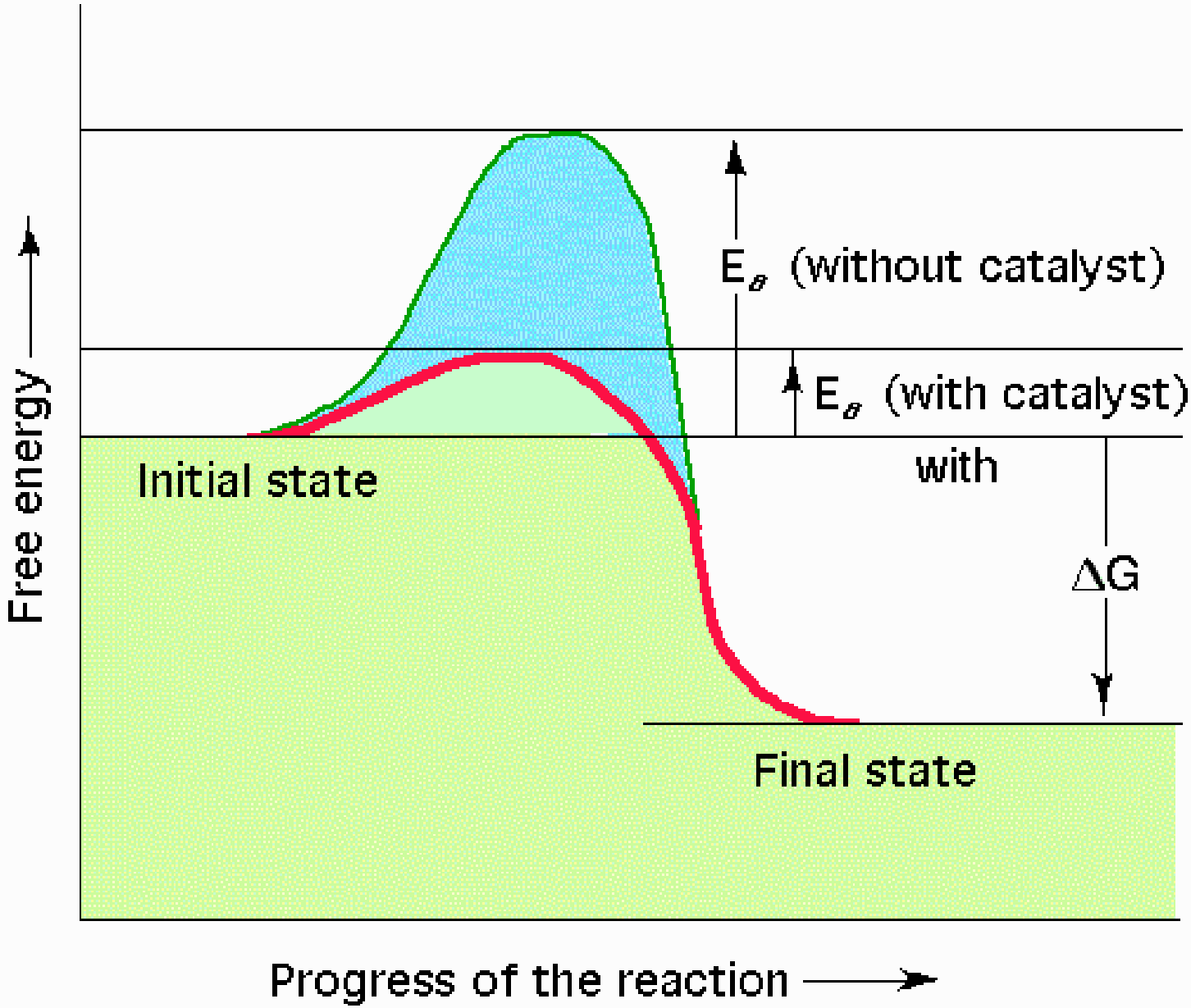
Reaction Energy

- **Spontaneous Reactions** - Reactions that proceed immediately when two substances are mixed together. Not all reactions proceed spontaneously.

- **Activation Energy** – the amount of energy that is required to start a chemical reaction.

  - Once activation energy is reached the reaction continues until you run out of material to react.




Free energy
E_a (without catalyst)
E_a (with catalyst)
with
Initial state
ΔG
Final state
Progress of the reaction

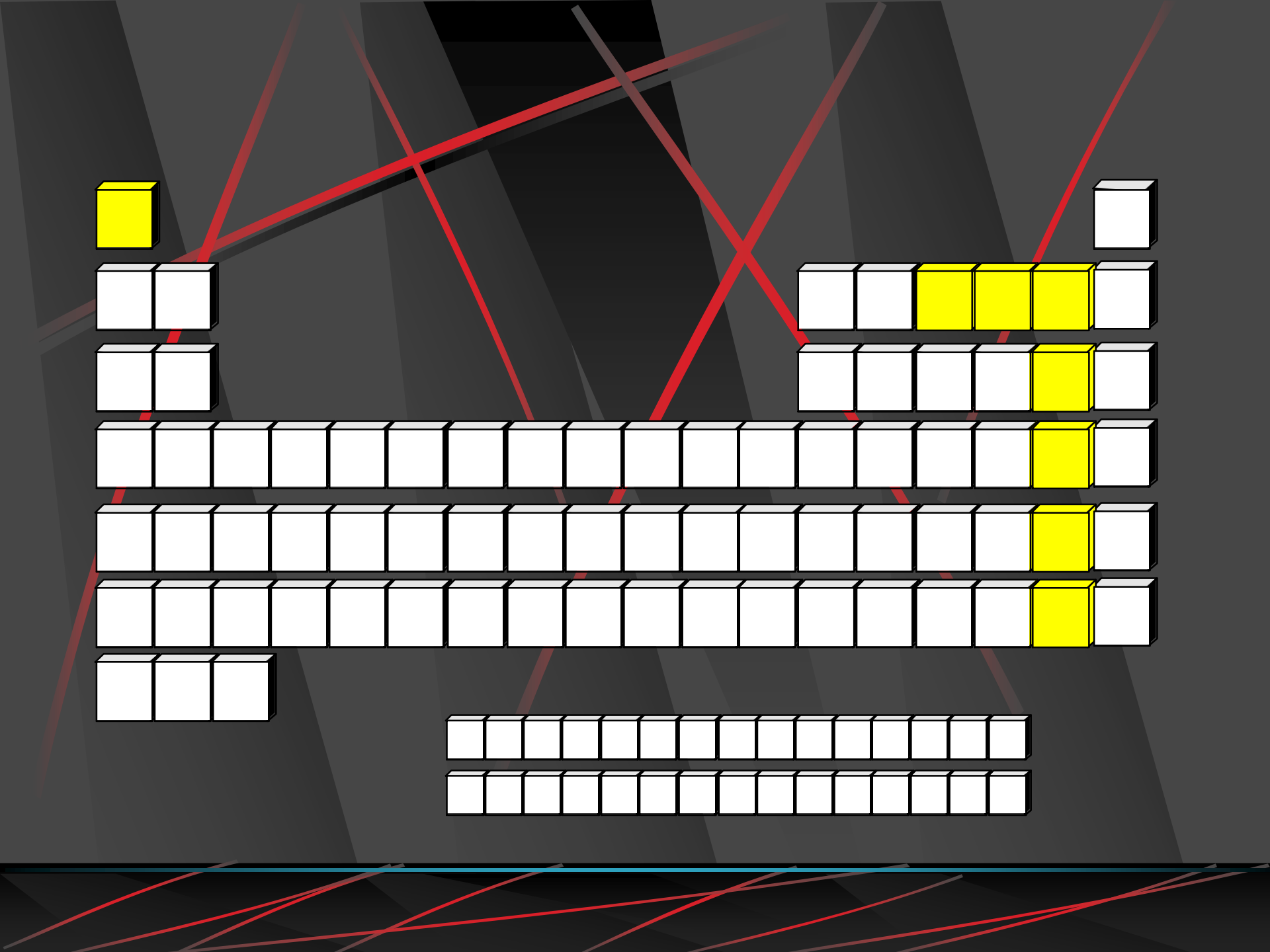
Formula Equation

- Uses formulas and symbols to describe a reaction
- doesn't indicate how many.
- All chemical equations are sentences that describe reactions.

Diatomic elements

- There are 8 elements that never want to be alone.
- They form diatomic molecules.
- H_2 , N_2 , O_2 , F_2 , Cl_2 , Br_2 , I_2 , and At_2
- The –ogens and the –ines
- 1 + 7 pattern on the periodic table

Element	Symbol	Molecular formula	Physical state at room temperature
Hydrogen	H	H_2	gas
Nitrogen	N	N_2	gas
Oxygen	O	O_2	gas
Fluorine	F	F_2	gas
Chlorine	Cl	Cl_2	gas
Bromine	Br	Br_2	liquid
Iodine	I	I_2	solid



Convert this to an equation

Solid iron (III) sulfide reacts with gaseous hydrogen chloride to form iron (II) chloride and hydrogen sulfide gas.

$$Fe_2S_{3\,(s)} + HCl_{(g)} \rightarrow FeCl_{2\,(s)} + H_2S_{(g)}$$

Convert this to an equation

Nitric acid dissolved in water reacts with solid sodium carbonate to form liquid water and carbon dioxide gas and sodium nitrate dissolved in water.

$$HNO_{3\,(aq)} + Na_2CO_{3\,(s)} \rightarrow NaNO_{3\,(aq)} + H_2O_{(l)}$$

The other way

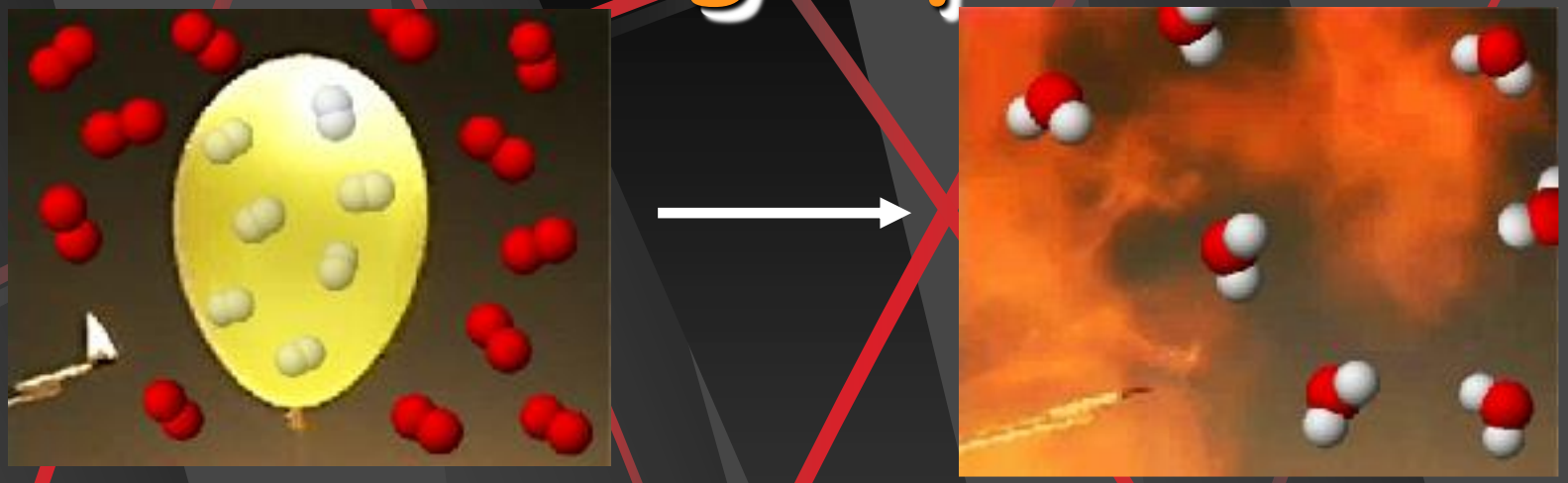
$$Fe_{(s)} + O_{2(g)} \rightarrow Fe_2O_{3(s)}$$

Solid iron reacts with oxygen gas to form solid iron oxide (rust).

A silver spoon tarnishes. The solid silver reacts with sulfur in the air to make solid silver sulfide, the black material we call tarnish.

$$Ag_{(s)} + H_2S_{(g)} + O_{2\,(g)} \rightarrow Ag_2S_{(s)} + H_2O$$

Balancing Equations



2 $H_2(g)$ + ___ $O_2(g)$ ---> 2 $H_2O(l)$

- What Happened to the Other Oxygen Atom?
- This equation is not balanced!
- Two hydrogen atoms from a hydrogen molecule (H_2) combines with one of the oxygen atoms from an oxygen molecule (O_2) to form H_2O. Then, the remaining oxygen atom combines with two more hydrogen atoms (from another H_2 molecule) to make a second H_2O molecule.

Translate Equation

Aluminum metal reacts with liquid bromine to form solid aluminum bromide

$$\underline{\;2\;}\ Al(s) + \underline{\;3\;}\ Br_2(l) \rightarrow \underline{\;2\;}\ AlBr_3(s)$$

Translate some more!

1. calcium fluoride and sulfuric acid make calcium sulfate and hydrofluoric acid

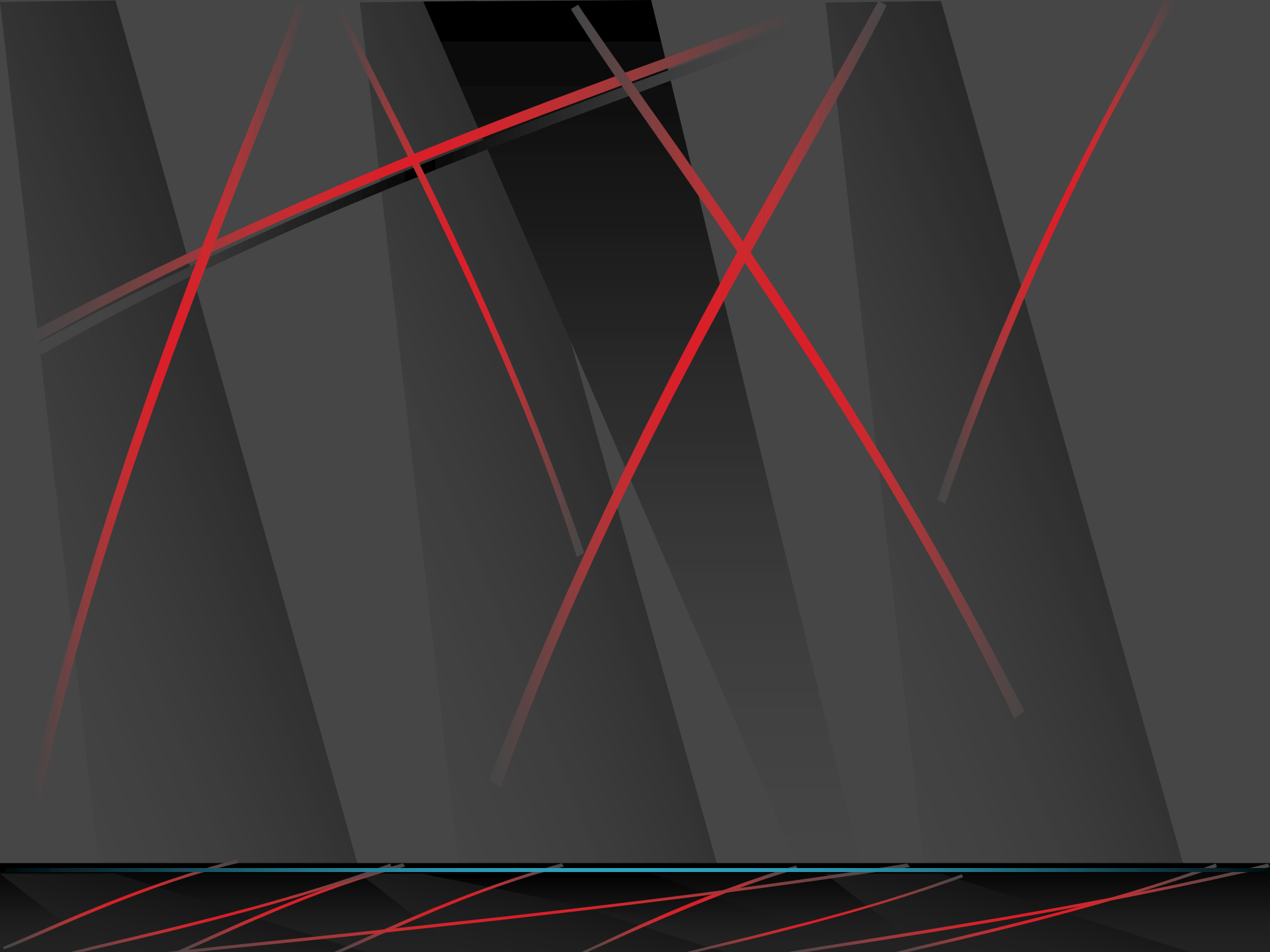
2. calcium carbonate will come apart when you heat it to leave calcium oxide and carbon dioxide.

3. ammonia gas when it is pressed into water will make ammonium hydroxide.

4. aluminum sulfate and calcium hydroxide become aluminum hydroxide and calcium sulfate.

5. copper metal and silver nitrate react to form silver metal and copper (II) nitrate.

6. sodium metal and chlorine react to make sodium chloride.

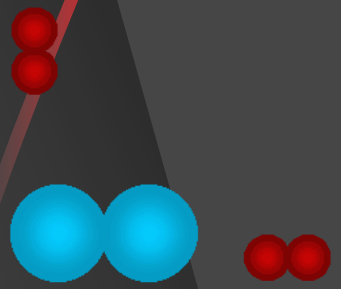


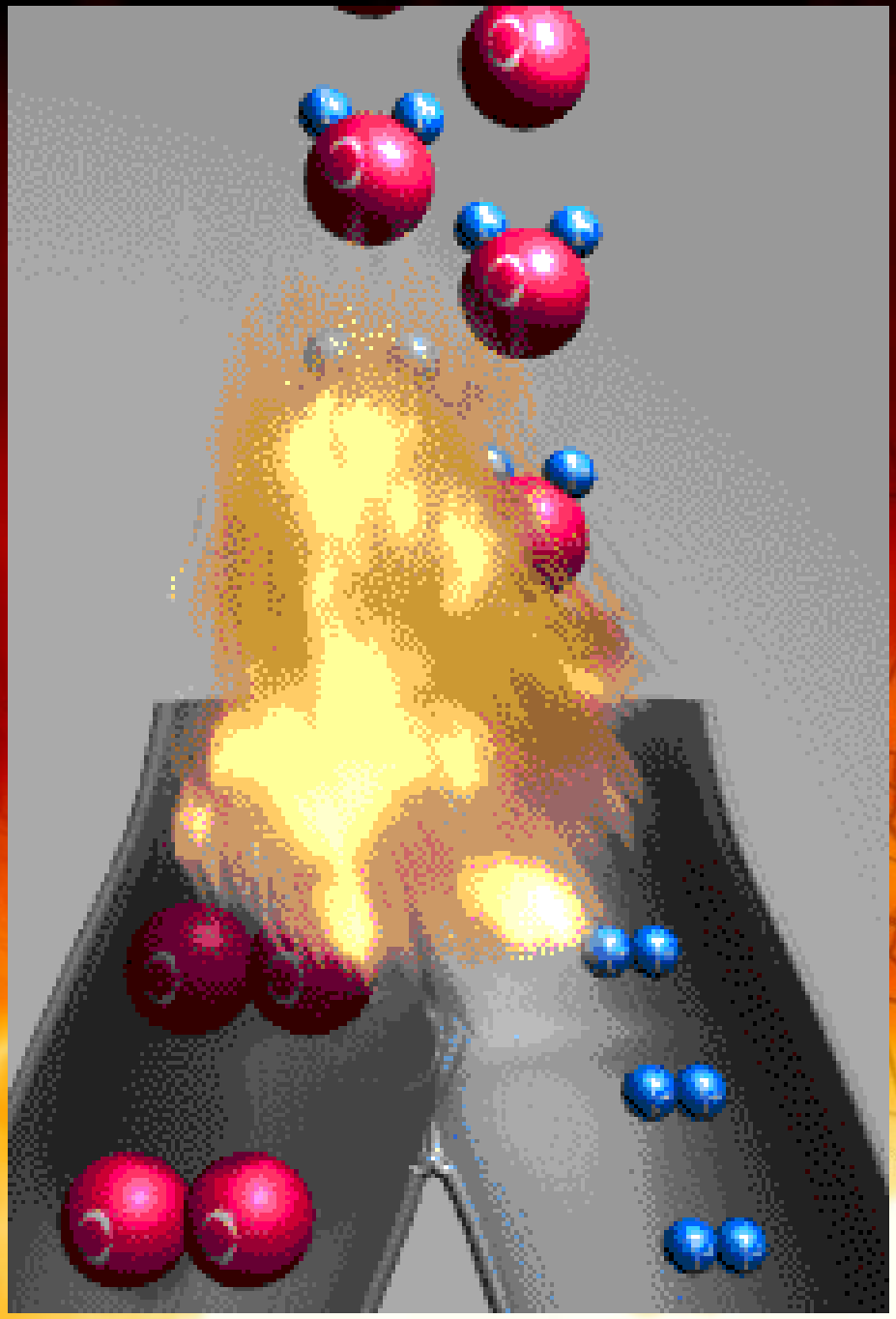
Types of Reactions

- There are millions of reactions.
- Can't remember them all
- Fall into several categories.
- We will learn 6 types.
- We will be able to predict the products.
- For some we will be able to predict whether they will happen at all.
- We will recognize them by the reactants

Synthesis Reactions

- Also called combination reactions
- 2 elements, or compounds combine to make one compound.
- A + B → AB
- $Na_{(s)} + Cl_{2(g)} \rightarrow NaCl_{(s)}$
- $Ca_{(s)} + O_{2(g)} \rightarrow CaO_{(s)}$
- $SO_{3(s)} + H_2O_{(l)} \rightarrow H_2SO_{4(s)}$
- We can predict the products if they are two elements.
- $Mg_{(s)} + N_{2(g)} \rightarrow Mg_3N_{2(s)}$





A simulation of the reaction:

$2H_2 + O_2 \rightarrow 2H_2O$

Decomposition Reactions

- decompose = fall apart
- one compound (reactant) falls apart into two or more elements or compounds.
- Usually requires energy
- **AB $\rightarrow$ A + B**
- $NaCl \xrightarrow{\text{electricity}} Na + Cl_2$
- $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$

Decomposition Reactions

- Can predict the products if it is a binary compound
- Made up of only two elements
- Falls apart into its elements
- $H_2O \xrightarrow{\text{electricity}} H_{2\,(g)} + O_2$
- $HgO \xrightarrow{\Delta} Hg_{(s)} + O_{2\,(g)}$

Decomposition Reactions

- If the compound has more than two elements you must be given one of the products
- The other product will be from the missing pieces
- $NiCO_{3\,(aq)} \xrightarrow{\Delta} CO_{2\,(g)} + Ni_{\,(s)}$
- $H_2CO_{3(aq)} \rightarrow H_{2\,(g)} + CO_{2\,(g)}$

Single Replacement

- Also referred to as single displacement
- One element replaces another
- Reactants must be an element and a compound.
- Products will be a different element and a different compound.
- **A + BC → AC + B**
- $2Na + SrCl_2 \rightarrow Sr + 2NaCl$
- $F_2 + LiCl \rightarrow LiF + Cl_2$

Single Replacement

- We can tell whether a reaction will happen
- Some are more active than other
- More active replaces less active

Double Replacement

- Two things replace each other.
- Reactants must be two ionic compounds or acids.
- Usually in aqueous solution

$$AB + CD \rightarrow AD + CB$$

$$ZnS + 2HCl \rightarrow ZnCl + H_2S$$

$$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$$

Combustion

- A reaction in which a compound (often carbon) reacts with oxygen
- $CH_4 + O_2 \rightarrow CO_2 + H_2O$
- $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
- $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$

- The charcoal used in a grill is basically carbon. The carbon reacts with oxygen to yield carbon dioxide. The chemical equation for this reaction is $C + O_2 \rightarrow CO_2$

Acid/Base Reaction

- An acid and a base react to form a salt and water.
- Always in aqueous solution
- **Acid (H^+) + Base (OH^-) → Salt + H_2O**

$$NaOH + HCl \rightarrow NaCl + H_2O$$

$$NH_4OH + H_2SO_4 \rightarrow (NH_4)_2SO_4 + H_2O$$

How to recognize which type

- Look at the reactants
  - Element(E), Compound(C)
- E + E — Synthesis
- C — Decomposition
- E + C — Single replacement
- C + C — Double replacement
- Acid + Base — Acid/Base reaction

Redox

- Look at the Products — Combustion
- $CO_2 + H_2O$

Examples

- $H_2 + O_2 \rightarrow$ Synthesis
- $H_2O \rightarrow$ Decomposition
- $AgNO_3 + NaCl \rightarrow$ Double replacement
- $Zn + H_2SO_4 \rightarrow$ Single replacement
- $HgO \rightarrow$ Decomposition
- $KBr + Cl_2 \rightarrow$ Single replacement
- $Mg(OH)_2 + H_2SO_3 \rightarrow$ Double replacement

Examples

- $HNO_3 + KOH \rightarrow$ Acid/Base
- $CaPO_4 \rightarrow$ Decomposition
- $AgBr + Cl_2 \rightarrow$ Single replacement
- $Zn + O_2 \rightarrow$ Synthesis
- $HgO + Pb \rightarrow$ Single replacement
- $HBr + NH_4OH \rightarrow$ Acid/Base
- $Cu(OH)_2 + KClO_3 \rightarrow$ Double replacement

Summary

An equation:

- Describes a reaction
- Must be balanced because to follow Law of Conservation of Energy
- Can only be balanced by changing the coefficients.
- Has special symbols to indicate state, and if catalyst or energy is required.
- Can describe 5 different types of reactions.