Unit 7: Chemical Equations

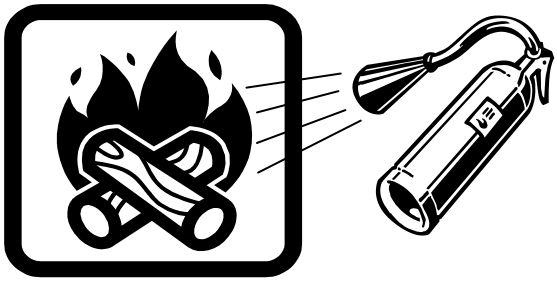
Evidence of a chemical reaction:

heat, light, sound, gas emitted, color change, odor

A reaction has occurred if the chemical and physical properties of the reactants and products differ.

For a reaction to occur, particles of reactants must collide, and with sufficient energy → collision theory





activation energy: energy needed to start a reaction

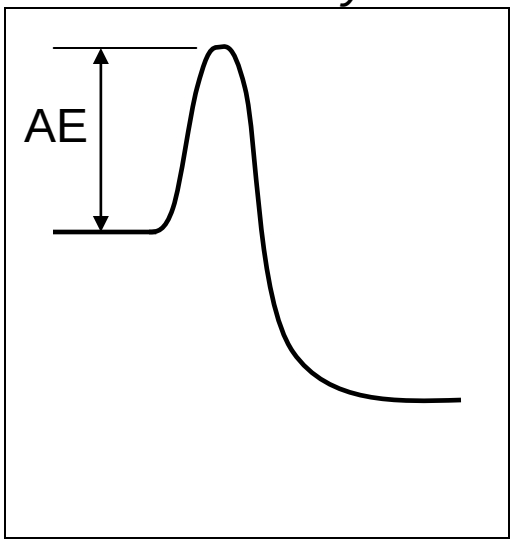
Chemical reactions release or absorb energy.

exothermic reactions endothermic reactions

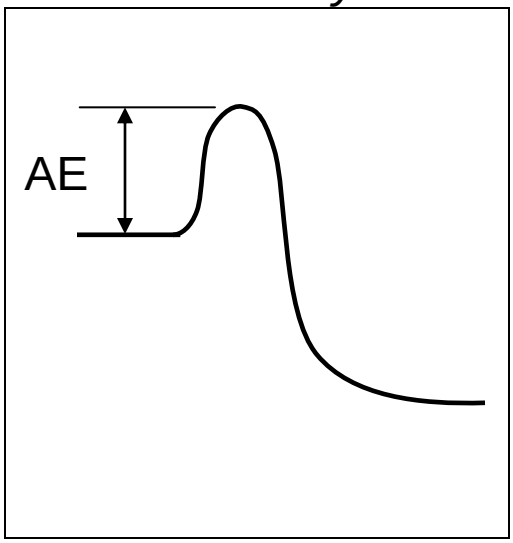
catalyst: speeds up reaction ^{wo}/being consumed

…it lowers the activation energy (AE)

Without catalyst



With catalyst



Examples:

enzymes catalyze biochemical reactions

catalytic converters convert CO into CO_2

Reaction Conditions and Terminology

Certain symbols give more info about a reaction.

(s) = solid

(l) = liquid

(g) = gas

(aq) = aqueous (dissolved in H_2O)

NaCl(s)   NaCl(aq)

More on aqueous…

-- “soluble” or “in solution” also indicate that a substance is dissolved in water (usually)

-- acids are aqueous solutions

Other symbols…

$\longrightarrow$ means “yields” or “produces”

Δ means heat is added to the reaction

$$MgCO_3(s) \xrightarrow{\Delta} MgO(s) + CO_2(g)$$

Temp. at which we perform rxn. might be given.

$$C_6H_5Cl + NaOH \xrightarrow{400^oC} C_6H_5OH + NaCl$$

The catalyst used might be given.

$$C_2H_4(g) + H_2(g) \xrightarrow{Pt} C_2H_6(g)$$

<u>precipitate</u>: a solid product that forms in an aqueous solution reaction

$$NaI(aq) + Pb(NO_3)_2(aq) \longrightarrow PbI_2(s) + NaNO_3(aq)$$

Factors that influence the rate of a reaction	To make reaction rate increase…
concentration of reactants	↑
particle size	↓
temperature	↑
mechanical mixing	↑
pressure	↑
catalyst	use one
nature of reactants	N/A

In a reaction: atoms are rearranged

AND mass, charge, energy } are conserved

Balancing Chemical Equations

law of conservation of mass = same # of atoms of each type on each side of equation

solid iron reacts with oxygen gas to yield solid iron (III) oxide

Fe^{3+} O^{2-}

___Fe(s) + ___O_2(g) → ___Fe_2O_3(s)

If all coefficients are 1…

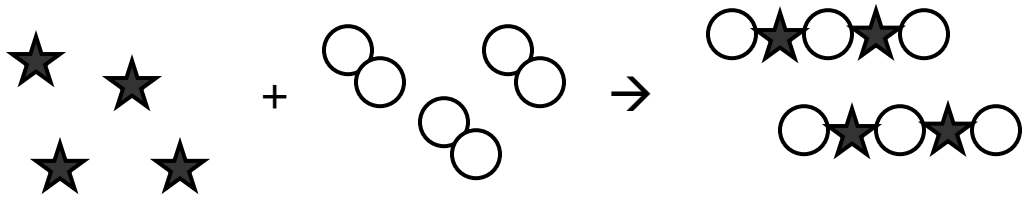
_1_Fe(s) + _1_O_2(g) → _1_Fe_2O_3(s)

If we change subscripts…

_1_Fe_2(s) + _1_O_3(g) → _1_Fe_2O_3(s)

Changing a subscript changes the substance. To balance, only modify coefficients. Right now, superscripts don't enter into our "balancing" picture.

4 Fe(s) + **3** O_2(g) → **2** Fe_2O_3(s)

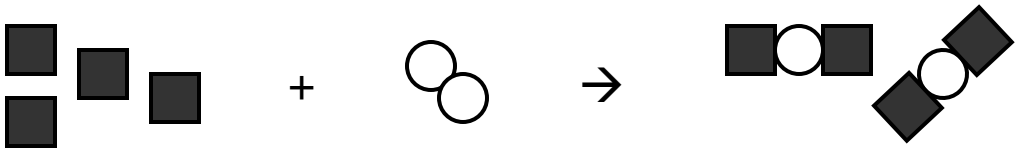


Hint: Start with most complicated substances first and leave simplest substances for last.

solid sodium reacts w/oxygen to form solid sodium oxide

Na^{1+} O^{2-}

___Na(s) + ___O_2(g) → ___Na_2O(s)



4 Na(s) + **1** O_2(g) → **2** Na_2O(s)

Aqueous aluminum sulfate reacts w/aqueous calcium chloride to form a white precipitate of calcium sulfate. The other compound remains in solution.

Al^{3+} SO_4^{2-} Ca^{2+} Cl^{1-}

_ $Al_2(SO_4)_3$(aq) + _ $CaCl_2$(aq) → _ $CaSO_4$(s) + _ $AlCl_3$(aq)

1 $Al_2(SO_4)_3$(aq) + **3** $CaCl_2$(aq) → **3** $CaSO_4$(s) + **2** $AlCl_3$(aq)

Methane gas (CH_4) reacts with oxygen to form carbon dioxide gas and water vapor.

_ CH_4(g) + _ O_2(g) → _ CO_2(g) + _ H_2O(g)

1 CH_4(g) + **2** O_2(g) → **1** CO_2(g) + **2** H_2O(g)

___$CaC_2(s)$ + ___$H_2O(l)$ → ___$C_2H_2(g)$ + ___$CaO(s)$

___$CaSi_2$ + ___SbI_3 → ___Si + ___Sb + ___CaI_2

___Al + ___CH_3OH → ___$Al(CH_3O)_3$ + ___H_2

** ___$C_2H_2(g)$ + ___$O_2(g)$ → ___$CO_2(g)$ + ___$H_2O(l)$

** ___C_3H_8 + ___O_2 → ___CO_2 + ___H_2O

** ___C_5H_{12} + ___O_2 → ___CO_2 + ___H_2O

** complete combustion of a <u>hydrocarbon</u>
yields CO_2 and H_2O

Write equations for combustion of C_7H_{16} and C_8H_{18}.

___C_7H_{16} + ___O_2 → ___CO_2 + ___H_2O

___C_8H_{18} + ___O_2 → ___CO_2 + ___H_2O

2 C_8H_{18} + **25** O_2 → **16** CO_2 + **18** H_2O

Classifying Reactions → four types

synthesis: simpler substances combine to form more complex substances

$\overbrace{A + B \rightarrow AB}$ $\overbrace{AB + C \rightarrow ABC}$ $\overbrace{A + B + C \rightarrow ABC}$

oxygen + rhombic sulfur → sulfur dioxide

$\_\_\_O_2 + \_\_\_S_8 \rightarrow \_\_\_SO_2$

$\mathbf{8}\ O_2 + \mathbf{1}\ S_8 \rightarrow \mathbf{8}\ SO_2$

sodium + chlorine gas → sodium chloride

$\_\_\_Na + \_\_\_Cl_2 \rightarrow \_\_\_NaCl$

$\mathbf{2}\ Na + \mathbf{1}\ Cl_2 \rightarrow \mathbf{2}\ NaCl$

decomposition: complex substances are broken down into simpler ones

$\overbrace{AB \rightarrow A + B}$ $\overbrace{ABC \rightarrow AB + C}$ $\overbrace{ABC \rightarrow A + B + C}$

lithium chlorate → lithium chloride + oxygen

$\_\_\_LiClO_3 \rightarrow \_\_\_LiCl + \_\_\_O_2$

$\mathbf{2}\ LiClO_3 \rightarrow \mathbf{2}\ LiCl + \mathbf{3}\ O_2$

water → hydrogen gas + oxygen gas

$\_\_\_H_2O \rightarrow \_\_\_H_2 + \_\_\_O_2$

$\mathbf{2}\ H_2O \rightarrow \mathbf{2}\ H_2 + \mathbf{1}\ O_2$

single-replacement: one element replaces another

$AB + C \rightarrow A + CB$

chlorine + sodium bromide → sodium chloride + bromine

___Cl_2 + ___NaBr → ___NaCl + ___Br_2

1 Cl_2 + **2** NaBr → **2** NaCl + **1** Br_2

aluminum + copper (II) sulfate → ?

Cu^{2+} SO_4^{2-}
(Al^{3+})

___Al + ___$CuSO_4$ → ___Cu + ___$Al_2(SO_4)_3$

2 Al + **3** $CuSO_4$ → **3** Cu + **1** $Al_2(SO_4)_3$

double-replacement: $AB + CD \rightarrow AD + CB$

iron (III) chloride + potassium hydroxide → ?

Fe^{3+} Cl^{1-}
K^{1+} OH^{1-}

___$FeCl_3$ + ___KOH → ___KCl + ___$Fe(OH)_3$

1 $FeCl_3$ + **3** KOH → **3** KCl + **1** $Fe(OH)_3$

lead (IV) nitrate + calcium oxide → ?

Pb^{4+} NO_3^{1-}
Ca^{2+} O^{2-}

___$Pb(NO_3)_4$ + ___CaO → ___PbO_2 + ___$Ca(NO_3)_2$

1 $Pb(NO_3)_4$ + **2** CaO → **1** PbO_2 + **2** $Ca(NO_3)_2$

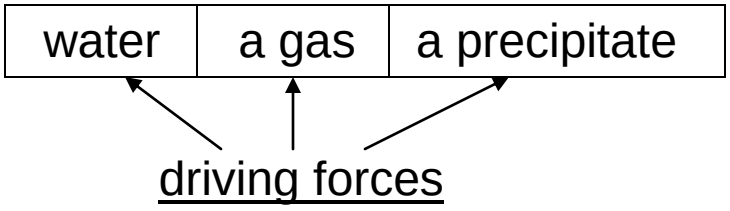
How do we know if a reaction will occur?

For single-replacement reactions, use Activity Series.

In general, elements above replace elements below.

__Ba + __$FeSO_4$ →	YES	__$BaSO_4$ + __Fe
__Mg + __$Cr(ClO_3)_3$ →	YES	__$Mg(ClO_3)_2$ + __Cr
__Pb + __Al_2O_3 →	NR	
__NaBr + __Cl_2 →	YES	__NaCl + __Br_2
__$FeCl_3$ + __I_2 →	NR	
__$CoBr_2$ + __F_2 →	YES	__CoF_2 + __Br_2

For double-replacement reactions, reaction will occur if any product is:



_$Pb(NO_3)_2$(aq) + _KI(aq) → _PbI_2(s) + _KNO_3(aq)

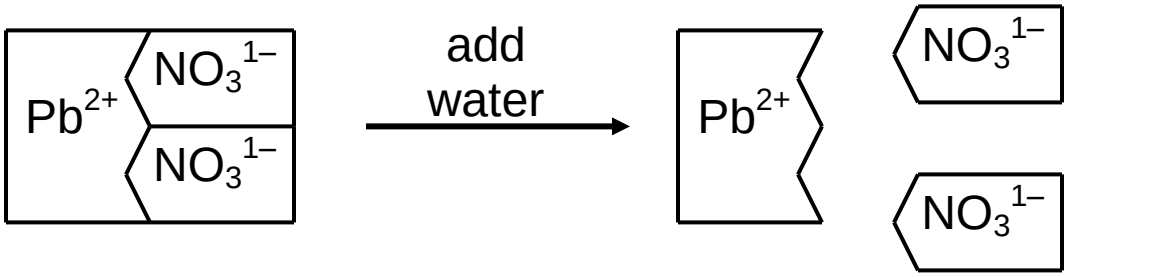
_KOH(aq) + _H_2SO_4(aq) → _K_2SO_4(aq) + _H_2O(l)

_$FeCl_3$(aq) + _$Cu(NO_3)_2$(aq) → NR

Ions in Aqueous Solution

$Pb(NO_3)_2(s)$ $\qquad$ $Pb(NO_3)_2(aq)$

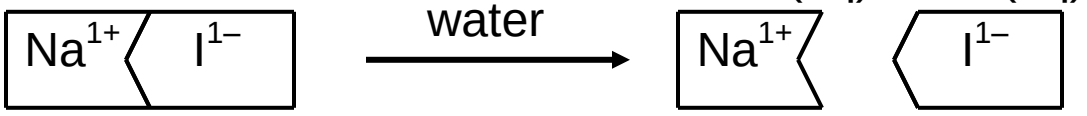
$Pb^{2+}(aq) + 2\ NO_3^{1-}(aq)$



dissociation: "splitting into ions"

$NaI(s)$ $\qquad$ $NaI(aq)$

$Na^{1+}(aq) + I^{1-}(aq)$



Mix them and get the boxed products…

$\_\_Pb^{2+}(aq) + \_\_NO_3^{1-}(aq) + \_\_Na^{1+}(aq) + \_\_I^{1-}(aq) \rightarrow$

$\boxed{\_\_PbI_2(s) + \_\_NO_3^{1-}(aq) + \_\_Na^{1+}(aq)}$

Balance to get overall ionic equation…

1 $Pb^{2+}(aq)$ + **2** $NO_3^{1-}(aq)$ + **2** $Na^{1+}(aq)$ + **2** $I^{1-}(aq) \rightarrow$

1 $PbI_2(s)$ + **2** $NO_3^{1-}(aq)$ + **2** $Na^{1+}(aq)$

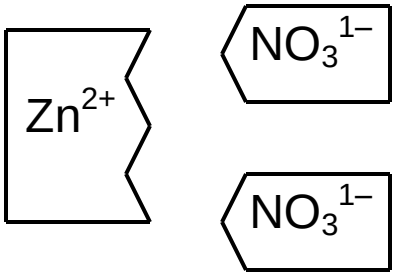
Cancel spectator ions to get net ionic equation…

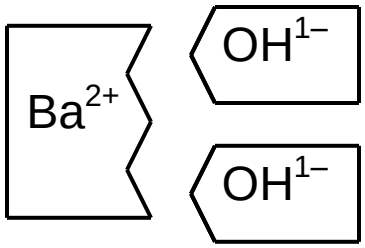
1 $Pb^{2+}(aq)$ + **2** $I^{1-}(aq) \rightarrow$ **1** $PbI_2(s)$

Mix together $Zn(NO_3)_2(aq)$ and $Ba(OH)_2(aq)$:

$Zn(NO_3)_2(aq)$ $\qquad$ $Ba(OH)_2(aq)$

$Zn^{2+}(aq) + 2\ NO_3^{1-}(aq)$ $\qquad$ $Ba^{2+}(aq) + 2\ OH^{1-}(aq)$





Mix them and get the boxed products…

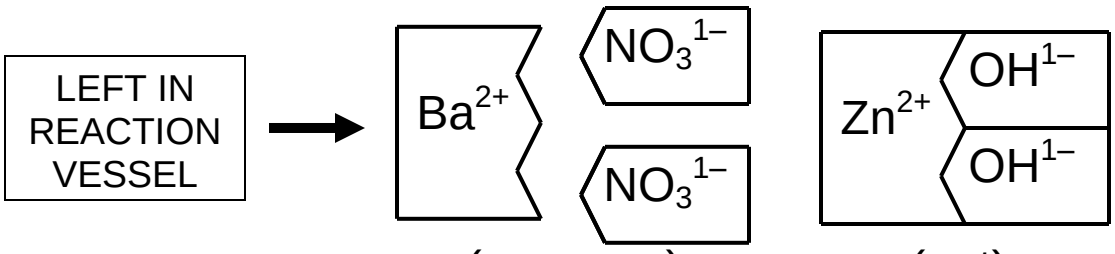
$\_\_Zn^{2+}(aq) + \_NO_3^{1-}(aq) + \_Ba^{2+}(aq) + \_\_OH^{1-}(aq) \rightarrow$

$\boxed{\_\_Zn(OH)_2(s) + \_\_NO_3^{1-}(aq) + \_\_Ba^{2+}(aq)}$

Balance to get <u>overall ionic equation</u>…

1 $Zn^{2+}(aq)$ + **2** $NO_3^{1-}(aq)$ + **1** $Ba^{2+}(aq)$ + **2** $OH^{1-}(aq) \rightarrow$

1 $Zn(OH)_2(s)$ + **2** $NO_3^{1-}(aq)$ + **1** $Ba^{2+}(aq)$



(aqueous) $\qquad$ (ppt)

SPECTATOR IONS

Cancel spectator ions to get <u>net ionic equation</u>…

1 $Zn^{2+}(aq)$ + **2** $OH^{1-}(aq) \rightarrow$ **1** $Zn(OH)_2(s)$

Polymers and Monomers

polymer: a large molecule (often a chain) made of many smaller molecules called monomers

Polymers can be made more rigid if the chains are linked together by way of a cross-linking agent.

Monomer	**Polymer**
amino acids	protein
nucleotides (^{w}/N-bases A,G,C,T/U)	nucleic acids
styrene	polystyrene
PVA	"slime"

Quantitative Relationships in Chemical Equations

$$4\ Na(s) + O_2(g) \rightarrow 2\ Na_2O(s)$$

Particles	4 atoms	1 m'cule	2 m'cules
Moles	4 mol	1 mol	2 mol
Grams	4 g	1 g	2 g

**Coefficients of a balanced equation represent # of particles OR # of moles, but NOT # of grams.

When going from moles of one substance to moles of another, use coefficients from balanced equation.

$$4\ Na(s) \ + \ O_2(g) \ \rightarrow \ 2\ Na_2O(s)$$

How many moles oxygen will react with 16.8 moles sodium?

$$X\,mol\,O_2 = 16.8\,mol\,Na\left(\frac{1\,mol\,O_2}{4\,mol\,Na}\right) = \boxed{4.2\,mol\,O_2}$$

How many moles sodium oxide are produced from 87.2 moles sodium?

$$X\,mol\,Na_2O = 87.2\,mol\,Na\left(\frac{2\,mol\,Na_2O}{4\,mol\,Na}\right) = \boxed{43.6\,mol\,Na_2O}$$

How many moles sodium are required to produce 0.736 moles sodium oxide?

$$X\,mol\,Na = 0.736\,mol\,Na_2O\left(\frac{4\,mol\,Na}{2\,mol\,Na_2O}\right) = \boxed{1.47\,mol\,Na}$$