Stoichiometric Relationships

Introduction to the Particulate Nature of Matter and Chemical Change

The Mole Concept

Reacting Masses and Volumes

Ms. Thompson - SL Chemistry
Wooster High School

Topic 1.1
Introduction to the Particulate Nature of Matter and Chemical Change

- Atoms of different elements combine in fixed ratios to form compounds, which have different properties from their component elements.
- Mixtures contain more than one element and/or compound that are not chemically bonded together and so retain their individual properties.
- Mixtures are either homogeneous or heterogeneous.

Introduction to the Particulate Nature of Matter and Chemical Change

The Atomic Theory

- ***Scientists now know all matter is made up of atoms***
  - ***Was not always the belief - Phlogiston***
- ***Antoine Lavoisier showed that some reactions gained mass, not lost, during combustion***
- ***$Mg_{(s)} + 0_{2(g)} \rightarrow MgO_{(s)}$***
- ***Atoms cannot be created or destroyed, rearranged during chemical reactions***

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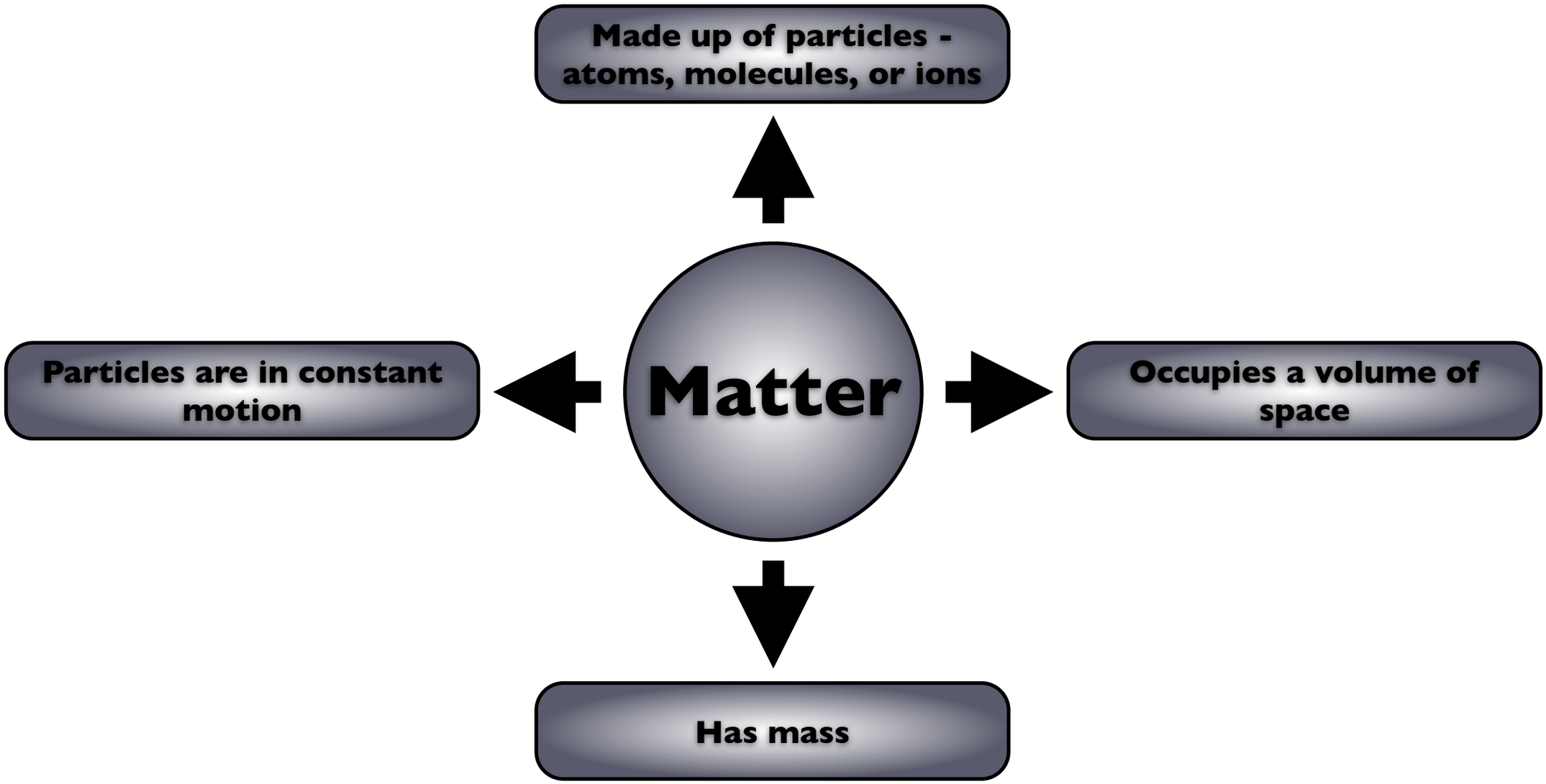
What is Matter?



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States of Matter

Solid

- *Fixed volume*
- *Fixed shape*
- *Cannot be compressed*
- *Attractive forces between particles hold the particles in a close-packed arrangement*
- *Particles vibrate in fixed positions*

Liquid

- *Fixed volume*
- *no fixed shape - takes shape of container it occupies*
- *Cannot be compressed*
- *Attractive forces between particles are weaker than in solids*
- *Particles vibrate, rotate, and translate (move)*

Gas

- *No fixed volume*
- *No fixed shape - expands to occupy space available*
- *Can be compressed*
- *Forces between particles are taken as zero*
- *Particles vibrate, rotate, and translate faster than in a liquid*

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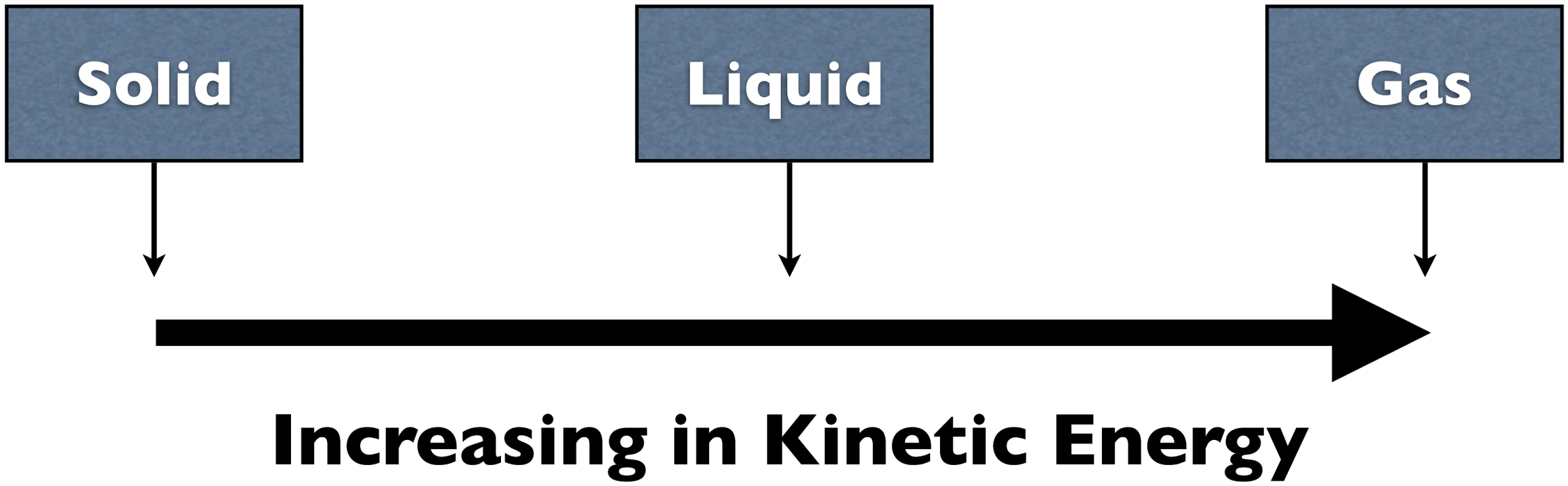
States of Matter



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Temperature

- **SI (Système International) unit for temperature is kelvin (K).**

- **Absolute zero is zero on the Kelvin scale, 0K (which is -273°C)**

- **All movement of particles in matter stop moving at 0K**

Temperature (K) = Temperature (C) + 273.15

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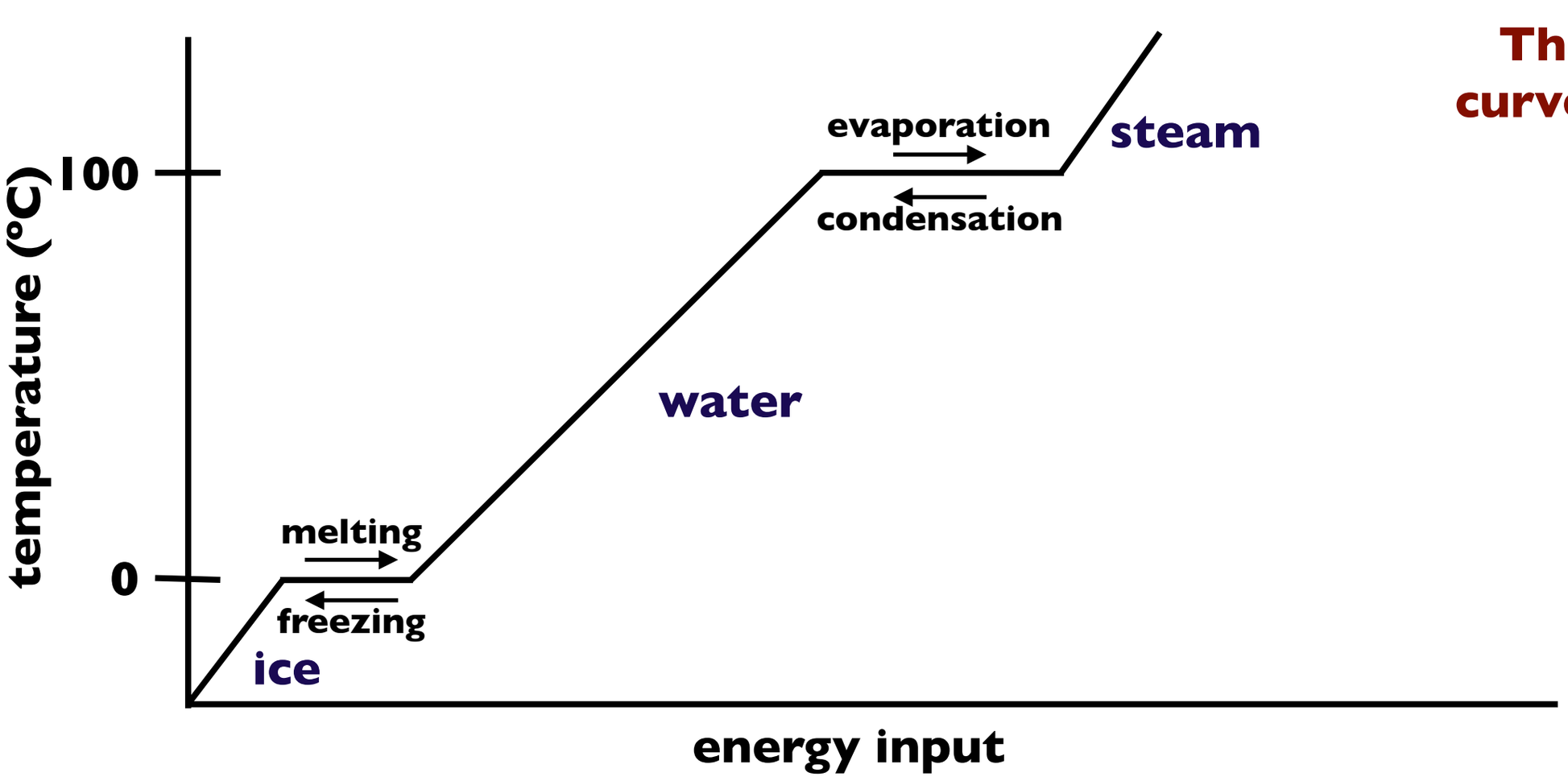
Changes of State

- ***Increase in kinetic energy leads to a change of state in matter (solid - liquid - gas)***



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Changes of State Key Terms

- **Melt:** solid - liquid equilibrium is set up
- **Boil:** liquid - gas equilibrium is set up
- **Endothermic:** Energy is transferred from the surroundings to the system
- **Condensation:** gas to liquid
- **Freezing:** liquid to solid
- **Exothermic:** Energy is transferred from the system to the surroundings
- **Vaporization:** liquid to gas (boiling)
- **Evaporation:** liquid to gas (below boiling point)
- **Sublimation:** solid to gas (skips liquid phase)
- **Deposition:** gas to solid (skips liquid phase)

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Elements and Compounds

- **Elements** only contain one type of atom (H, Na, Cl, or Mg) and can combine to form **compounds** (H_2O, NaCl, or H_2SO_4).

- Compounds react differently than their constituent parts
  - i.e. Na metal reacts violently with water and Cl_2 is an extremely poisonous gas but as NaCl, they combine to form table salt.

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Mixtures

- A **pure substance** is matter that has constant composition throughout.
  - i.e. NaCl, graphite, H_20
- A **mixture** is made up from combined pure substances.
  - i.e. sea water is a mixture of NaCl and H_2O (contains other minerals and salts too)
- A **homogenous mixture** has uniform composition and properties throughout the mixture.
  - i.e. metal alloys (stainless steel), coffee, urine
- A **heterogenous mixture** has a non-uniform composition and hence their properties vary throughout the mixture.
  - i.e. stew, water/sand

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Mixtures

matter: any substance that occupies space and has mass

mixture: a combination of two or more pure substances that retain their individual properties

- **homogenous**: has both uniform composition and properties throughout
- **heterogenous**: has non-uniform composition and varying properties throughout

pure substance: has a definite and constant composition

- **element**: made up of elements that have the same atomic number
- **compound**: made up of a combination of atoms or ions in a fixed ratio and having different properties from the constituent elements

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Language of Chemistry

- International Union of Pure and Applied Chemistry (**IUPAC**) is an organization that develops and monitors a system of standardized nomenclature (naming) for both organic and inorganic compounds.
  - Provides consistency in naming compounds
  - Needs no translation; transcends national borders and languages
  - Lends to a deeper knowledge and meaning
  - i.e. Benzene

USEFUL RESOURCE:
The IUPAC Gold Book (http://goldbook.iupac.org/index.html) is IUPAC's compendium of chemical terminology.

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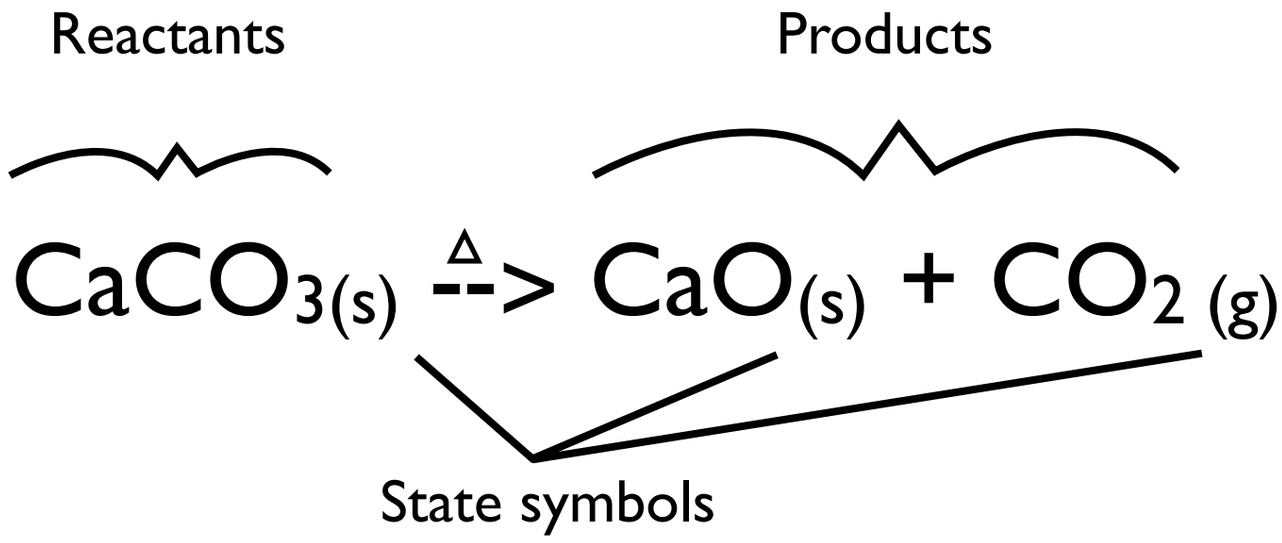
Combining elements & writing equations

- *An **ion** is a charged species (atom/molecule). **Anions** are negatively charged and **cations** are positively charged.*
- *Writing balanced chemical equations is central to chemistry*
- *Reactants are on left side along with their state symbols (s), (l), (g), or (aq) and those for products on the right side.*
- *Arrow represents boundary between reactants and products*



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Common Polyatomic Ions

Name of polyatomic ion	Formula	Name of polyatomic ion	Formula
ammonium ion	NH_4^+	**phosphate (V) ion**	PO_4^{3-}
carbonate ion	CO_3^{2-}	**phosphonate ion**	PO_3^{3-}
hydrogencarbonate ion	HCO_3^-	**sulfate (VI) ion**	SO_4^{2-}
hydroxide ion	OH^-	**sulfate ion**	SO_3^{2-}
nitrate (V) ion	NO_3^{2-}	**ethanedioate ion**	$C_2O_4^{2-}$
nitrate (III) ion	NO_2^-	**peroxide ion**	O_2^{2-}

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Common acids

Name of acid	Formula
hydrochloric acid	HCl
nitric (V) acid	HNO_3
phosphoric (V) acid	H_3PO_4
sulfuric (VI) acid	H_2SO_4
ethanoic acid	CH_3COOH

Naming anions

Name of Anion	Formula	Naming Suffix
sulfide ion	S^{2-}	-ide
sulfate (VI) ion	SO_4^{2-}	-ate
sulfate (IV)	SO_3^{2-}	-ate

Practice Problem

... I Do ...

Magnesium burns in oxygen to form a white powder known as magnesium oxide. Write a chemical equation to represent this change, including state symbols.

Practice Problem

... We Do ...

The alkaline earth metal calcium reacts with water to produce an alkaline solution. Hydrogen gas is evolved from the reaction.

Practice Problem

15 mins

... You Do ...

Write equations for the following chemical reactions, including state symbols and be sure to balance them. Refer to the working method handout if you need assistance.

1. *Zinc metal reacts with hydrochloric acid to form the salt zinc chloride. Hydrogen gas is evolved.*
2. *Hydrogen gas and oxygen gas react together to form water.*
3. *At a high temperature, calcium carbonate decomposes into calcium oxide and carbon dioxide.*

http://users.wfu.edu/ylwong/balanceeq/balanceq.html

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Some reaction types

- ***Combination*** *or* ***Synthesis*** *reactions involve the combination of two or more substances to produce a single product:*

$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

- ***Decomposition*** *reactions involve a single reactant being broken down into two or more products:*

$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

- ***Single Replacement*** *reactions occur when one element replaces another in a compound. An example of this type of reaction is a redox reaction:*

$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(s)} + H_{2(g)}$

- ***Double Replacement*** *reactions occur between ions in solution to form insoluble substances and weak non-electrolytes, also termed* ***metathesis*** *reactions:*

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

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The atom economy

- *As population grows, so does our need for resources.*
- *Scientists are trying to conserve the use of raw resources and therefore find ways to increase efficiency in synthetic reactions and industrial processes.*
- ***Atom economy** was developed by Professor Barry Trost of Stanford University*
    - *Focuses on the level of efficiency of chemical reactions by comparing the molecular mass of atoms in the reactants with the molecular mass of useful compounds.*

$$\textbf{percentage atom economy} = \frac{\textbf{Molecular mass of atoms in desired product}}{\textbf{Molecular mass of atoms in reactants}} \times 100\%$$

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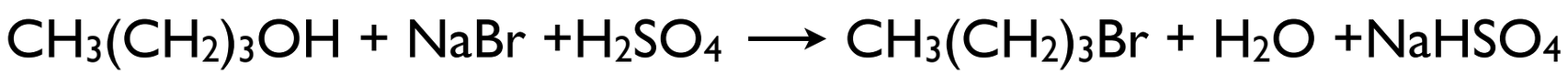
Homework

Short Response:

1. Suggest why even if a chemical reaction has a yield close to 100%, the atom economy may be poor. Carry out some research into this aspect.

2. Deduce the percentage atom economy for the nucleophilic substitution reaction.



$$CH_3(CH_2)_3OH + NaBr + H_2SO_4 \longrightarrow CH_3(CH_2)_3Br + H_2O + NaHSO_4$$

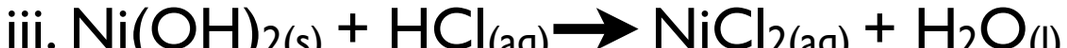
3. Identify the type of reaction and then copy and balance the equation, using the smallest possible whole number coefficients.

i. 

$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}$$

ii. 

$$NCl_{3(g)} + N_{2(g)} \rightarrow Cl_{2(g)}$$

iii. 

$$Ni(OH)_{2(s)} + HCl_{(aq)} \rightarrow NiCl_{2(aq)} + H_2O_{(l)}$$

iv. 

$$AgNO_{3(aq)} + Cu_{(s)} \rightarrow Cu(NO_3)_{2(aq)} + Ag_{(s)}$$

v. 

$$Ca(OH)_{2(s)} \rightarrow CaO_{(s)} + H_2O_{(l)}$$

vi. 

$$KClO_{3(s)} \rightarrow KCl_{(s)} + O_{2(g)}$$