Chem L111

• How will L111 work?
  - Every Tuesday, there will be a homework assignment due – you can’t do chemistry without problem solving
  - Most Thursdays, there will be a short quiz – 15 minutes, multiple choice
Consider This - Solution

- Amount of air in one breath
  \[ \sim 500 \text{ mL/breath} \]
- Breaths per minute
  \[ \sim 15 \text{ breaths/min} \]
- Breaths per day
  \[
  \frac{15 \text{ breaths}}{1 \text{ min}} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{24 \text{ hr}}{1 \text{ day}} = \frac{21,600 \text{ breaths}}{1 \text{ day}}
  \]
- Amount we breathe per day
  \[
  \frac{500 \text{ mL}}{1 \text{ breath}} \times \frac{21,600 \text{ breaths}}{1 \text{ day}} = \frac{10,800,000 \text{ mL}}{1 \text{ day}}
  \]
  \[
  \frac{10,800,000 \text{ mL}}{1 \text{ day}} \times \frac{1 \text{ L}}{1000 \text{ mL}} = \frac{10,800 \text{ L}}{1 \text{ day}} \approx 10,000 \text{ L/day} = 10^4 \text{ L/day}
  \]
Boston Air Quality

Brown Cloud Polluted Day
January 21, 1999

This is a typical "brown cloud" polluted day in Boston. Note how the brown cloud appears to envelop the city but quickly thins out at higher elevations. These events tend to occur on calm winter mornings during rush hour traffic. PM$_{2.5}$ and black carbon levels may be high; ozone will be low; RH may vary.

PM$_{2.5}$ = 40+ ug/m$^3$
RH = 69%
Risk Assessment

• Depends on two factors

  – **Toxicity** – the intrinsic health hazard of a substance
  – **Exposure** – the amount of the substance encountered
“Scientific notation” is used to represent numbers which are significantly larger or smaller than one, in order to eliminate the need to write a lot of zeroes.

In this table, the concentrations of CO are written in scientific notation:

\[
1 \times 10^4 = 10000 \\
4 \times 10^4 = 40000
\]
**SI Base Units**

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Unit of</th>
</tr>
</thead>
<tbody>
<tr>
<td>meter</td>
<td>m</td>
<td>length</td>
</tr>
<tr>
<td>kilogram</td>
<td>kg</td>
<td>mass</td>
</tr>
<tr>
<td>second</td>
<td>s</td>
<td>time</td>
</tr>
<tr>
<td>kelvin</td>
<td>K</td>
<td>thermodynamic temperature</td>
</tr>
<tr>
<td>mole</td>
<td>mol</td>
<td>amount of substance</td>
</tr>
</tbody>
</table>

SI = Système Internationale
## The Prefixes of the SI

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Base Value</th>
<th>Exponent</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exa</td>
<td>E</td>
<td>1 000 000 000 000 000 000</td>
<td>$10^{18}$</td>
<td>(one quintillion)</td>
</tr>
<tr>
<td>Peta</td>
<td>P</td>
<td>1 000 000 000 000 000 000</td>
<td>$10^{15}$</td>
<td>(one quadrillion)</td>
</tr>
<tr>
<td>Tera</td>
<td>T</td>
<td>1 000 000 000 000 000 000</td>
<td>$10^{12}$</td>
<td>(one trillion)</td>
</tr>
<tr>
<td>Giga</td>
<td>G</td>
<td>1 000 000 000 000 000 000</td>
<td>$10^{9}$</td>
<td>(one billion)</td>
</tr>
<tr>
<td>Mega</td>
<td>M</td>
<td>1 000 000 000 000 000 000</td>
<td>$10^{6}$</td>
<td>(one million)</td>
</tr>
<tr>
<td>Kilo</td>
<td>k</td>
<td>1 000 000 000 000 000 000</td>
<td>$10^{3}$</td>
<td>(one thousand)</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>1 000 000 000 000 000 000</td>
<td>$10^{0}$</td>
<td>(one)</td>
</tr>
<tr>
<td>Milli</td>
<td>m</td>
<td>0.000 000 000 000 000 000</td>
<td>$10^{-3}$</td>
<td>(one thousandth)</td>
</tr>
<tr>
<td>Micro</td>
<td>µ</td>
<td>0.000 000 000 000 000 000</td>
<td>$10^{-6}$</td>
<td>(one millionth)</td>
</tr>
<tr>
<td>Nano</td>
<td>n</td>
<td>0.000 000 000 000 000 000</td>
<td>$10^{-9}$</td>
<td>(one billionth)</td>
</tr>
<tr>
<td>Pico</td>
<td>p</td>
<td>0.000 000 000 000 000 000</td>
<td>$10^{-12}$</td>
<td>(one trillionth)</td>
</tr>
<tr>
<td>Femto</td>
<td>f</td>
<td>0.000 000 000 000 000 000</td>
<td>$10^{-15}$</td>
<td>(one quadrillionth)</td>
</tr>
<tr>
<td>Atto</td>
<td>a</td>
<td>0.000 000 000 000 000 000</td>
<td>$10^{-18}$</td>
<td>(one quintillionth)</td>
</tr>
</tbody>
</table>
Calculation

\[
10,800 \text{ L air per day} \times \frac{1 \text{ m}^3}{1000 \text{ L}} = 10.8 \text{ m}^3 \text{ air per day}
\]

\[
\text{PM}_{2.5} = \frac{40 \mu\text{g}}{\text{m}^3}
\]

\[
10.8 \text{ m}^3 \text{ air per day} \times \frac{40 \mu\text{g PM}_{2.5}}{\text{m}^3} = 432 \mu\text{g PM}_{2.5} \text{ per day}
\]
Calculation

10,800 L air per day $\times \frac{1 \text{ m}^3}{1000 \text{ L}} = 10.8 \text{ m}^3$ air per day

$\text{PM}_{2.5} = \frac{40 \mu\text{g}}{\text{m}^3}$

$10.8 \text{ m}^3$ air per day $\times \frac{40 \mu\text{g} \text{ PM}_{2.5}}{\text{m}^3} = 432 \mu\text{g} \text{ PM}_{2.5}$ per day

During Rush Hour - duration of 2.5 hours - so how much breathed in?
Calculation

10,800 L air per day \times \frac{1 \text{ m}^3}{1000 \text{ L}} = 10.8 \text{ m}^3 \text{ air per day}

PM_{2.5} = \frac{40 \mu\text{g}}{\text{m}^3}

10.8 \text{ m}^3 \text{ air per day} \times \frac{40 \mu\text{g} \text{ PM}_{2.5}}{\text{m}^3} = 432 \mu\text{g} \text{ PM}_{2.5} \text{ per day}

During Rush Hour - duration of 2.5 hours - so how much breathed in?

2.5 \text{ hours} \times \frac{1 \text{ day}}{24 \text{ hours}} \times \frac{432 \mu\text{g} \text{ PM}_{2.5}}{1 \text{ day}} = 45 \mu\text{g} \text{ PM}_{2.5} \text{ breathed during 'rush hour'}

Is this safe?
A publication of the ACS, *Chemical Risk: A Primer*, states:

“The general public is uncomfortable with uncertainties. Too often we think in terms of absolutes and demand that the scientists and decision makers be held accountable for their risk decisions.”

Do you agree or disagree with these statements?
• **Exosphere**: above the ionosphere, where the atmosphere thins out into space.
• **Thermosphere**: from 80–85 km to 640+ km, temperature increasing with height.
  – **Ionosphere**: the region containing ions: approximately the mesosphere and thermosphere up to 550 km.
• **Mesopause**: Boundary
• **Mesosphere**: from about 50 km to the range of 80 km to 85 km, temperature decreasing with height.
• **Stratopause**: Boundary
• **Stratosphere**: from that 7–17 km range to about 50 km, temperature increasing with height.
  – **Ozone Layer**: approximately 10 - 50 km, where stratospheric ozone is found. Note that even within this region, ozone is a minor constituent by volume
• **Tropopause**: Boundary
• **Troposphere**: The troposphere is the lowest layer of the atmosphere starting at the surface going up to between 7 km at the poles and 17 km at the equator with some variation due to weather factors. In the troposphere, on average, temperature decreases with height due to expansive cooling.

http://en.wikipedia.org/wiki/Earth's_atmosphere
Layers of Atmosphere leading to space. (NOAA) from U.S. National Weather Service (NOAA)
Matter

Pure substances
- Elements

Mixtures
- Compounds
• Matter - commonly referred to as the substance of which physical objects are composed
  – Mixtures (the atmosphere)
  – Pure Substances

• Elements – substances that cannot be broken down into simpler ones by any chemical means

• Chemical symbols – one- or two-letter abbreviations for the elements

• Periodic Table – an orderly arrangement of all the elements base on similarities of their properties
The 1–18 group designation has been recommended by the International Union of Pure and Applied Chemistry (IUPAC) but is not yet in wide use. In this text we use the standard U.S. notation for group numbers (1A–8A and 1B–8B). No names have been assigned for elements 111–115. Elements 116–118 have not yet been synthesized.
• Horizontal Columns – Periods
• Vertical Columns – Groups
  – Alkali Metals
  – Alkaline Earth Metals
  – Halogens
  – Noble gases – inert
• Metals – elements that are shiny and conduct electricity and heat well
• Nonmetals – elements that have varied appearances and don’t conduct well
Pure Substances

• Elements – pure substances made up of a single element
  – Only ~100 exist

• Compounds – pure substances made up of two or more elements in a fixed, characteristic chemical combination
  – Over 20 million compounds have been isolated, identified and characterized.
Your Turn 1.15

- Classifying Pure Substances
  - Using your everyday knowledge of materials, classify each of these as an element, a compound, or as a mixture.
  a. Rubbing Alcohol (Isopropanol)
  b. Copper
  c. U.S. penny coin
  d. 14kt gold
  e. Nitrogen dioxide
  f. Shampoo
Atoms and Molecules

• An **atom** (Greek from *non* and *divisible*) is a submicroscopic structure found in all ordinary matter around us.
  - The word *atom* originally meant a smallest possible particle of matter, not further divisible.
  - Later, those objects to which the name atom had been assigned were found to be further divisible into smaller subatomic particles, but the word atom nonetheless continues to refer to them.
  - Atoms are canonically distinguished from ions by their balanced electrical charge. When this charge is disrupted, the particle is then considered to be an atomic ion rather than an atom.

• Most atoms are composed of 3 types of massive subatomic particles which govern their external properties:
  - electrons, which have a negative charge;
  - protons, which have a positive charge; and
  - neutrons, which have no charge.
• Pure elements have all the same kind of atom.
  – Pure elements can also be made up of molecules.
  – Ar (g), Fe (s), Hg (l), N₂ (g)
  – N₂ (g), O₂ (g), and H₂ (g) are examples of elements made up of diatomic molecules.

• Pure compounds have different kinds of atoms, but all the same kind of molecules.
  – Molecule – a combination of a fixed number of atoms held together in a certain spatial arrangement.
  – Chemical formula – a symbolic way to represent the elementary composition of a substance
  – H₂O, CH₄, NO₂, CO₂, CO
Your Turn 1.16

• Elements and Compounds
  – Name the element(s) present in each of these substances. Identify each substance as an element or a compound.
    a. Water, $\text{H}_2\text{O}$
    b. Methane, $\text{CH}_4$
    c. Iodine, $\text{I}_2$
    d. Nitrogen dioxide, $\text{NO}_2$
    e. Glucose, $\text{C}_6\text{H}_{12}\text{O}_6$
    f. Methyl bromide, $\text{CH}_3\text{Br}$
# Most Prominent Gases in the Air

<table>
<thead>
<tr>
<th>Name</th>
<th>Chemical Formula</th>
<th>Element or Compound</th>
<th>Atom or Molecule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>H₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>CO₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Krypton</td>
<td>Kr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Naming Binary Compounds

• The name of the more metallic element comes first, followed by the name of the less metallic element, modified to end in the suffix “ide”.

• Example: sodium and chlorine combine to give the common compound
  – sodium chloride or NaCl or table salt.
Your Turn 1.17

• Naming Simple Compounds
  – Name the compound that contains each pair of elements.
    a. Chlorine and Calcium
    b. Oxygen and Magnesium
    c. Potassium and Iodine
    d. Hydrogen and Sulfur
Your Turn 1.18

• More Naming Exercises
  – Name the compound that has each of these formulas.
    a. AgCl
    b. Fe\textsubscript{2}O\textsubscript{3}
    c. NaH
    d. CuCl\textsubscript{3}
Naming Compounds

Table 1.7
Prefixes Used in Naming Compounds

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Meaning</th>
<th>Prefix</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mono</td>
<td>One</td>
<td>Hexa-</td>
<td>Six</td>
</tr>
<tr>
<td>Di- or Bi-</td>
<td>Two</td>
<td>Hepta-</td>
<td>Seven</td>
</tr>
<tr>
<td>Tri-</td>
<td>Three</td>
<td>Octa-</td>
<td>Eight</td>
</tr>
<tr>
<td>Tetra-</td>
<td>Four</td>
<td>Nona-</td>
<td>Nine</td>
</tr>
<tr>
<td>Penta-</td>
<td>Five</td>
<td>Deca-</td>
<td>Ten</td>
</tr>
</tbody>
</table>

- CO: carbon monoxide
- CO₂: carbon dioxide
- NO₂: nitrogen dioxide
- N₂O₄: dinitrogen tetraoxide
- NO:  
- SO₂:
Chemical Reactions

– A process whereby substances described as *reactants* are transformed into different substances called *products*.

\[
\text{Reactant(s)} \rightarrow \text{Product(s)}
\]

carbon + oxygen $\rightarrow$ carbon dioxide

– Represented by a *chemical equation* which uses the chemical formulas of the reactants and products.

\[
C + O_2 \rightarrow CO_2
\]
Combustion

- The rapid combination of oxygen with a substance.
- A major type of chemical reaction.
- When elemental carbon or carbon-containing compounds burn in air, oxygen combines with the carbon to form CO$_2$ or CO (or both).
\[
C (s) + O_2 (g) \rightarrow CO_2 (g)
\]

\[
S (s) + O_2 (g) \rightarrow SO_2 (g)
\]
The **law of conservation of mass and matter** states that the mass of a system of substances is constant, regardless of the processes acting inside the system.

An equivalent statement is that matter changes form, but cannot be created or destroyed.

This implies that for any chemical process in a closed system, the mass of the reactants must equal the mass of the products.
# Table 1.8 Characteristics of Chemical Equations

## Always Conserved
- Identity of atoms in reactants = Identity of atoms in products
- Number of atoms in reactants = Number of atoms in products
- Mass of all reactants = Mass of all products

## May Change
- Number of molecules in reactants may differ from number of molecules in products
- Physical states (s, l, or g) of reactants may differ from physical states of products
Balancing Chemical Reactions

Carbon and oxygen combine to give carbon monoxide
Carbon = C (s)
Oxygen = O₂ (g)
Carbon Monoxide = CO (g)
C (s) + O₂ (g) → CO (g)
Is this reaction Mass Balanced?
Balancing Chemical Reactions

\[ \text{C (s) + O}_2 (g) \rightarrow \text{CO (g)} \]

Reactants : 1 atom of carbon and 2 atoms of oxygen
Products : 1 atom of carbon and 1 atom of oxygen

Where does the other oxygen atom go?
Balancing Chemical Reactions

\[ C (s) + O_2 (g) \rightarrow 2 \text{ CO (g)} \]

Reactants still: 1 atom of carbon and 2 atoms of oxygen

Now products: 2 atoms of carbon and 2 atoms of oxygen

Now the Oxygens match, but what about the Carbon?
Balancing Chemical Reactions

\[ 2 \text{ C (s)} + \text{O}_2 \text{ (g)} \rightarrow 2 \text{ CO (g)} \]

**Now reactants:** 2 atoms of carbon and 2 atoms of oxygen

**Products:** 2 atoms of carbon and 2 atoms of oxygen

Now the both the Oxygens and the Carbon match.
\[
C + C + O_2 \rightarrow CO + CO
\]