Reminder: My Office Hours
HELD 104A & CHEM 330

• Tuesdays & Thursdays, 4:00 - 5:30 (That’s the 90 min. before each class) in HELD 104A.
• Fridays, 1:30 - 3:00 in CHEM 330
• Other times as available or by appointment.
• Also, see the scheduled review sessions.

Instructional Assistant (IA)

Nicki Hogan nhogan@tamu.edu

Nicki will be conducting weekly help/recitation sessions:
5:15 – 6:15 PM on Wednesdays in HELD 107

Supplemental Instruction (SI)

We don’t have an SI instructor specifically assigned to this class, but SI instructors for other Chem 107 sections that you can attend as given in the next slide.

Chem 107 Supplemental Instruction (SI)

- Goodey Eli
  - Sunday 6 to 7 HECC 105
  - Tuesday 6 to 7 BLOC 120
  - Thursday 6 to 7 BLOC 120
- Leung Andrew
  - Sunday 8 to 9 HECC 204
  - Tuesday 8 to 9 HECC 204
  - Thursday 8 to 9 HECC 201

Homework update
As of 9:40 this morning:

- ALEKS enrollment was 143 (34 missing!)
  - First objective due date: Sept. 6th
- OWL enrollment was 26 (150 missing!)
  - First due date: Sept. 5th & 8th

Matter, Atoms & Molecules

CHEM 107
T. Hughbanks
Atomic Theory of Matter

- All matter is composed of atoms.
- All atoms of a given element have identical chemical properties.
- Atoms of different elements have different properties.
- Atoms combine in whole number ratios to form compounds.
- Atoms are neither created nor destroyed in chemical reactions.

Atoms

- Atoms contain protons, neutrons, electrons
- Nucleus = protons + neutrons
- Electrons surround nucleus
- protons: + charge
- electrons: – charge
- neutrons: no charge

Isotopes

- Chemical behavior of atoms ultimately controlled by electrostatic attraction between nuclei and electrons
- Therefore, atoms with different number of protons, but the same number of neutrons, and the same number of electrons have essentially identical chemistry
- Examples: ¹²C, ¹³C, ¹⁴C; ³⁵Cl, ³⁷Cl

Atomic Weights

- Atoms have measurable masses.
- “mass spectrometer”
- “Atomic weight” of an element is the average mass of an atom of the element. (Why average?)
- Units:
  \[ 1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg} \]

(Average) Mass of C atom

Find mass of an average carbon atom in grams. (atomic weight = 12.011 amu)

\[
12.011 \text{ amu} \times \frac{1.6606 \times 10^{-27} \text{ kg}}{\text{amu}} \times \frac{1.000 \text{ g}}{1 \text{ kg}} = 1.9945 \times 10^{-23} \text{ g}
\]

Isotopes of Carbon & Chlorine

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Abundance</th>
<th>Mass (amu)</th>
<th>Isotope</th>
<th>Abundance</th>
<th>Mass (amu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>¹²C</td>
<td>98.9%</td>
<td>¹²</td>
<td>³⁵Cl</td>
<td>75.77%</td>
<td>34.9685268</td>
</tr>
<tr>
<td>¹³C</td>
<td>1.1%</td>
<td>³⁵Cl</td>
<td>³⁷Cl</td>
<td>24.23%</td>
<td>36.9690259</td>
</tr>
<tr>
<td>¹⁴C</td>
<td>trace†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Exactly, by definition
†terrestrial ¹⁴C abundance is decreasing as a result of burning ¹²C-rich fossil fuels

\[
\begin{align*}
\text{¹n (neutron) mass} & = 1.0086649158(5) \text{ amu} \\
\text{¹p (proton) mass} & = 1.007276469(1) \text{ amu} \\
\text{e (electron) mass} & = 5.4857991(1) \times 10^{-4} \text{ amu}
\end{align*}
\]
An example
- Chlorine is a mixture of two isotopes: $^{35}\text{Cl}$, 75.8%, and $^{37}\text{Cl}$, 24.2%. Chlorine occurs as Cl$_2$ molecules.
- A mass spectrometer can be used to measure the mass of molecules - not bulk samples. In this case, this is done by making Cl$_2^+$ ions and using their charge-to-mass ratios to distinguish the masses of isotopically different Cl$_2^+$ ions (like Thomson’s expt.).
- How many different masses can Cl$_2^+$ ions have? What are the masses? What are the relative numbers of each?

Example!
- Bromine is a mixture of two isotopes: $^{79}\text{Br}$ and $^{81}\text{Br}$. Bromine occurs as Br$_2$ molecules.
- A high-precision mass spectrometer measures the mass of Br$^+$ ions and two masses are determined to be 78.91834 and 80.91629 amu. From analytical chemistry we can determine the molar mass of bromine to be 79.904(1) g/mol.
- What are the % abundances of each isotope?

Molecules
- 2 or more atoms joined by chemical bonds
- molecular formula → composition: number of atoms of each element present
- molecular mass = sum of masses of atoms
- representations: formula, structure, etc.

Molecules & Moles
- Typical samples contain huge numbers of molecules.
- Use moles as a unit of quantity.
- 1 mole $\approx 6.02 \times 10^{23}$ (“Avogadro’s Number”) This is an experimentally measured number.

Avogadro’s Number
- Defined by setting 1 mole $^{12}\text{C} = 12$ g (exactly)
- With this definition $N_A = 6.022137(4) \times 10^{23}$
- Definition of the amu is 1 atom $^{12}\text{C} = 12$ amu (exactly)
- For any element or compound, the average mass of one atom or molecule in amu is numerically equal to the mass of one mole of atoms or molecules in grams.

Mass, moles, # molecules, ...
- Converting between these is essentially a manipulation of units.
- Use atomic & molecular weights, densities, etc. as needed.
Representing Organic Molecules (Chapter 2: Section 2.6)

- **names** ethanol or ethyl alcohol
- **formulas** (with or without some clues about structure)
  - ethanol: \( C_2H_6O \), \( C_2H_5OH \), \( CH_3CH_2OH \)
- **structural drawings**
- **models**

Isomers: Same Molecular formula and composition, but different arrangement of atoms

- **diethyl ether**
  \[
  \text{diethyl ether} = C_2H_5OCH_2 = \\
  \begin{array}{c}
  \text{CH}_3 \\
  \text{H} \\
  \text{H} \\
  \text{H} \\
  \text{H}
  \end{array}
  \]

- **ethanol**
  \[
  \text{ethanol} = CH_3CH_2OH = \\
  \begin{array}{c}
  \text{CH}_3 \\
  \text{CH}_2 \text{OH}
  \end{array}
  \]

Representing Organic Molecules

- **structural drawings**

Ways to depict molecules

- Acrylic acid
  \[
  \text{Acrylic acid} = C_3H_4O_2 \\
  \begin{array}{c}
  \text{CH}_3 \text{C} \text{C} \text{O} \\
  \text{OH}
  \end{array}
  \]

- Dimethyl ether
  \[
  \text{dimethyl ether} = C_2H_6O \\
  \begin{array}{c}
  \text{CH}_3 \text{CH}_2 \text{OH}
  \end{array}
  \]

- Caffeine
  \[
  \text{Caffeine} = C_8H_{10}N_4O_2
  \]

Line Drawings

- Ethanol
  \[
  \text{ethanol} = C_2H_6O = \\
  \begin{array}{c}
  \text{H} \\
  \text{H} \\
  \text{H} \\
  \text{H}
  \end{array}
  \]

  - Shorthand notation for organic molecules
  - Carbons, and hydrogens attached to carbons, are not shown
  - Each line is a bond.
  - Every carbon has 4 bonds, nitrogen has 3 bonds, oxygen has two.

Example: Line structure/formula

- **N-acetyl-para-aminophenol** (tylenol)
  \[
  \text{N-acetyl-para-aminophenol} = \\
  \begin{array}{c}
  \text{OH} \\
  \text{OH} \\
  \text{N} \\
  \text{O}
  \end{array}
  \]

  - Find molecular formula
  - Find molar mass
Clicker Question

What is the chemical formula of the molecule depicted?

1. C₉H₉O₂N
2. C₆H₇O₂N
3. C₆H₈O₂N
4. C₆H₁₀O₂N

Formulas & % composition

Given a chemical formula, it is easy to calculate the mass % for each element. Just find molar mass of molecule and the amount contributed by each element. As an example, we’ll calculate mass % of each element in the “tylenol molecule”

Composition & formulas

The reverse process is useful in analyzing unknown substances. Instruments are available which can tell us the elemental composition of a substance (“elemental analysis”). We can convert this info into a molecular formula.

Composition & formulas: example

Nicotine contains 74.0% C, 8.65% H, and 17.35% N. If the molar mass of nicotine is 162, what is the chemical formula of nicotine? Atomic weights are 12, 1, and 14 for C, H, and N. (More precisely, they are 12.01, 1.008, and 14.01 g/mol, respectively.)

Nicotine structure

Nicotine
C₁₀H₁₄N₂
Empirical vs. Molecular formula

- Last example shows difference between empirical and molecular formulas.
- **Empirical formula:** simplest possible formula with correct ratios of atoms
- **Molecular formula:** formula showing the actual composition of a molecule
- Can find molecular formula from empirical formula if we know molar mass

Formulas from % composition; more examples

- Hydrogen peroxide is 5.93% hydrogen and 94.07% oxygen by weight. What is its chemical formula?
- An unknown sample of a pure substance is 43.7% P and 56.3% O by weight. What is its chemical formula?

Note: mass ratios do **not** give mole ratios, since atomic masses are not the same.