Did you read chapter 19 before coming to class?
A. Yes
B. No

Chapter 19: Atoms, Molecules, and Extended-Bonding Substances

Elements vs Compounds
- Elements: only one kind of atom
- Compounds: two or more kinds of atoms
- Which are elements?
- Which are compounds?

Chemical Bonds
- The constituent atoms in molecules are held together by "bonds". A bond is usually a pair of electrons.
  - Strong Bonds: Metallic, Ionic, Covalent
  - Weak Bonds: van der Waals, Hydrogen
- The quantum model explains them all
- In our visual models we often use sticks to represent bonds, and balls to represent atoms

Chemical matter is classified into a number of types

How does bonding work?
- Atoms give up, obtain, or share electrons and in the process combine to form the substances around us.
- Bonding involves only the electrons in the outermost, unfilled orbitals: the valence electrons. All other inner electrons don’t matter as far as bonding is concerned.
- All bonding involves atoms sharing or exchanging electrons in a “stable” way.

Stability means:
- To fall to a lower energy state and thus be more tightly bound.
- To completely fill an orbital set.
Writing chemical formulas for molecular matter

- Identify atoms in a molecule
- Give the number of each atom type
- Examples
  - \( \text{H}_2\text{O} \)
  - \( \text{S}_8 \)
  - \( \text{CH}_4 \)

Molecules have shapes

- How many ways can you arrange Carbon and Hydrogen?
- Guess the shape of Benzene
  - \( \text{C}_6\text{H}_6 \)

The shape of a molecule is determined by molecular orbitals

- When \( \text{H}_2 \) was formed from \( \text{H} \), energy was released as heat.
- So in \( \text{H}_2 \) each electron needs more energy than before to escape.
- \( \text{H} \) has a different discrete spectrum than \( \text{H}_2 \). This allows astronomers to tell the temperature of hydrogen gas.

Molecules belong to families -- Hydrocarbons

- Methane -- \( \text{CH}_4 \)
- Propane -- \( \text{CH}_3\text{CH}_2\text{CH}_3 \) (or \( \text{C}_3\text{H}_8 \))
- Octane -- \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3 \) (or \( \text{C}_8\text{H}_{18} \))

What elements are present?

- All react to form \( \text{CO}_2 \) and \( \text{H}_2\text{O} \)

methane, propane, octane belong to hydrocarbon family
all three are used as fuels
What formula represents this family of molecules?

A. \((\text{CH}_2)_n\)
B. \(\text{C}_n\text{H}_{2n+2}\)
C. \(\text{C}_n\text{H}_{2n+2}\)
D. \(\text{C}_{2n}\text{H}_n\)

where \(n\) is an integer starting with 1.

Another molecular family – Organic acids

\(\text{CH}_3\text{CO}_2\text{H} \rightarrow \text{Acetic acid (gives vinegar its taste)}\)

\(\text{CH}_3(\text{CH}_2)_{10}\text{CO}_2\text{H} \rightarrow \text{Lauric acid – in coconut milk}\)

\(\text{CH}_3(\text{CH}_2)_{10}\text{CO}_2\text{H} \rightarrow \text{Palmitic acid (palm oils, and animals)}\)

family of organic acids – all three are in foods we eat

Amino Acids, the building blocks for proteins

What elements are present?

- NH\(_2\)
- CH\(_3\)
- CH\(_2\)
- CO\(_2\)H

Formulas?

- \(\text{NH}_2\text{CH}_2\text{CO}_2\text{H}\)
- \(\text{NH}_2\text{CHCH}_3\text{CO}_2\text{H}\)
- \(\text{NH}_2\text{C}_{10}\text{H}_9\text{NHCO}_2\text{H}\)

family of amino acids – acid group + amine group – also in foods we eat

Deducing molecular formulae and structures:

**Time-of-Flight Mass Spectrometer**

![Diagram of mass spectrometer with positive fragments and length of flight path](image)

kinetic energy = \(\frac{1}{2} (\text{mass})(\text{speed})^2\)

If all fragments are given the same kinetic energy, which ones get to the detector first?

Deducing molecular structure with a mass spectrometer

Nitric oxide

What molecule does this mass spectrum represent?

- \(\text{CO}\)
- \(\text{H}_2\text{O}\)
- \(\text{NO}\)
- \(\text{CO}_2\)

What elements are present?

- \(\text{NH}_2\)
- \(\text{CH}_2\)
- \(\text{CO}_2\)H

Formulas?

- \(\text{NH}_2\text{CH}_2\text{CO}_2\text{H}\)
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Mass Spectroscopy

**Mass Spectroscopy**

Parent peak: Mass of the molecule 180 amu

**Electronic Spectroscopy**

- Each element has a unique electronic spectrum
- Visible absorption spectrum of the parent characterised

**A simplified view of infrared (vibrational) spectroscopy**

- Infrared Source
- Sample
- Detector
- Absorption IR spectrum (continuous with dark bands)
- Analogous visible continuous spectrum
- Analogous visible absorption spectrum

**IR spectroscopy can be used to deduce chemical formulas and structures**

- IR Vibrational Spectroscopy
- Different molecular groups vibrate in different regions

**Motion within a molecules**

- Bonds are not rigid
  - lengths change
  - Bond angles bend - angle opens and closes
- The various types of stretches and bends occur with different energies and frequencies
- Energy depends on how stiff the bond is and the atomic masses that are moving
- Most frequencies are in the infrared frequency range

**Deducing molecular structure with a mass spectrometer**

- Mass of molecular fragments
- C9O4H8 Aspirin

**A portion of the IR spectrum for each molecule is shown. Formulate a hypothesis about what portion of the molecule gives rise to the sharp set of peaks labeled P?**

- A. OH group
- B. Hydrocarbon part

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**Additional Image Descriptions:**

- **Electron Spectroscopy:**
  - Visible absorption spectrum of the giant star Arcturus
  - Each element has a unique electronic spectrum

- **Mass Spectroscopy Diagram:**
  - C9O4H8 Aspirin
  - Parent peak: Mass of the molecule 180 amu
How do we deduce chemical formulas and structures?

Crystallography