

## Lecture 3: Basic Chemistry of Life: What are you made of?

"B bec poot commas"  
Or...

*Betty Boop Eats Creamy Club Panini's  
Outdoor on our Terrace. Cartoons offer  
magical moments almost secretly.*

BIOSPHERE   
 BIOME   
 ECOSYSTEM   
 COMMUNITY   
 POPULATION   
 ORGANISM   
 ORGAN SYSTEM   
 ORGAN   
 TISSUE   
 CELL   
 ORGANELLE   
 MACROMOLECULE   
 MOLECULE   
 ATOM   
 SUBATOMIC PARTICLES

---

---

---

---

---

---

---

---

---

---

---

---

### Which is the main element you are made of?

## Periodic Table of Elements

For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

Design and Interface Copyright © 1997 Michael Dayah (micheal@dayah.com) <http://www.ptable.com/>

---

---

---

---

---

---

---

---

---

---

---

---

## Elements

- Basic unit of matter
- Characterized by specific properties
- **Elements** are composed of **only one type of atom**
  - 92 occur naturally on Earth
  - 25 essential to life
    - Recommended APP: NOVA Elements!

Figure 2.2

---

---

---

---

---

---

---

---

---

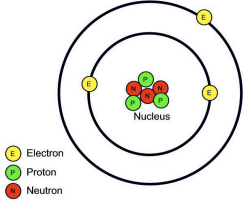
---

---

---

### What Are Atoms?

- Smallest units of matter
- Made up of subatomic particles:
  - Protons (+)
  - Electrons (-)
  - Neutrons (no charge)




---

---

---

---

---

---

---

---

### Nucleus is made of Protons and Neutrons

2 + Protons  
 2 ● Neutrons  
 2 - Electrons

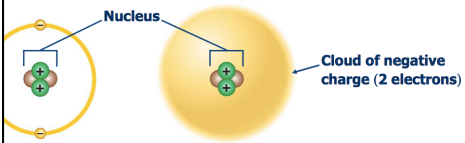


Figure 2.4

---

---

---

---

---

---

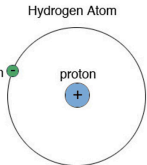
---

---

### Charge in Atoms

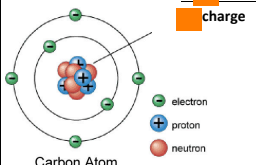
# protons (+) = # electrons (-)  
therefore atoms have no net charge

**Hydrogen**

$$\begin{array}{r} 1 \text{ p}^+ \\ + \\ 1 \text{ e}^- \\ \hline 0 \text{ charge} \end{array}$$


Hydrogen Atom

**Carbon**

$$\begin{array}{r} 6 \text{ p}^+ \\ + \\ 6 \text{ e}^- \\ \hline 0 \text{ charge} \end{array}$$


Carbon Atom

---

---

---

---

---

---

---

---

### Atomic Number

- Atomic number = number of protons
- Number of protons determines the type of element
- All atoms of an element have the same number of protons

$H = 1 \text{ proton} \rightarrow \text{atomic\#} = 1$   
 $C = 6 \text{ proton} \rightarrow \text{atomic\#} = 6$

1  
**H**  
Hydrogen  
1

Periodic Table of the Elements

6  
**C**  
Carbon  
12

---

---

---

---

---

---

---

---

### For Each Element

- The number of protons, the **atomic number**, determines which element it is.
- An atom's **mass number** is the sum of the number of protons and neutrons.

1  
**H**  
Hydrogen  
1

Hydrogen Atom

Carbon Atom

6  
**C**  
Carbon  
12

---

---

---

---

---

---

---

---

### Isotopes

- Isotopes are **alternate mass** forms of an element.
- Isotopes have the **same number of protons** and electrons, but they have a **different number of neutrons**.

**Carbon**

6 Protons  
6 Neutrons

Nuclear number  
= 6 + 6  
= 12

**Carbon-13**

6 Protons  
7 Neutrons

Nuclear number  
= 6 + 7  
= 13

**Carbon-14**

6 Protons  
8 Neutrons

Nuclear number  
= 6 + 8  
= 14

C-12

C-14

---

---

---

---

---

---


---

---


### Isotopes Make Cents

- Isotopes are **alternate mass** forms of an element.
- Isotopes have the **same number of protons** and electrons, but they have a **different number of neutrons**.

## Are these both pennies?



- What if I told you that they weigh different amounts?



Pennies minted before 1982 were solid copper and have a heavier mass than the zinc/copper pennies minted after 1982. They are all pennies and all worth \$0.01, but they have different masses. Just like isotopes.

<http://aleverandaplacetostand.blogspot.com/2014/10/isotopes-make-cents.html>

---

---

---

---

---

---

---

---

---

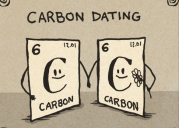
---

---

---

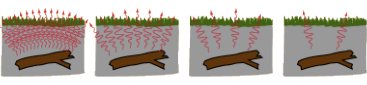
### Radioactive isotopes are very useful in biology. We'll discuss them in more detail in our Anatomy and Physiology and/or evolution sections.....stay tuned!

#### CARBON DATING



Measurement of the beta decay activity of a buried piece of wood provides a measurement of the time elapsed since it was living and in equilibrium with the atmosphere.

| Age           | 100% | 50% | 25% | 12.5% |
|---------------|------|-----|-----|-------|
| Age 0         | 100% |     |     |       |
| Age 5730 yr   |      | 50% |     |       |
| Age 11,460 yr |      |     | 25% |       |
| Age 17,190 yr |      |     |     | 12.5% |




---

---

---

---

---

---

---

---

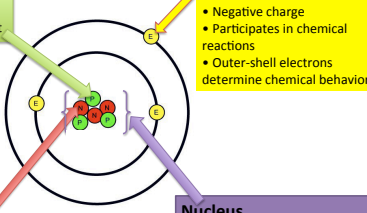
---

---

---

---

### Atom Review



**Proton**

- Positive charge
- Determines element

**Electron**

- Negative charge
- Participates in chemical reactions
- Outer-shell electrons determine chemical behavior

**Neutron**

- No charge
- Determines isotope

**Nucleus**

- Consists of neutrons and protons

Figure UN2-5

---

---

---

---

---

---

---

---

---

---

---

---

### Electron Shells

- Electrons occur at certain energy levels at a fixed distance from the nucleus
- Electrons are drawn to the nucleus by the positive charge of the proton
- The number of shells differs with the number of electrons

Atomic Structure 1

---

---

---

---

---

---

---

---

### Electron Shells

Outermost electron shell (can hold 8 electrons)  
First electron shell (can hold 2 electrons)

Electron

HYDROGEN (H)  
Atomic number = 1

CARBON (C)  
Atomic number = 6

NITROGEN (N)  
Atomic number = 7

OXYGEN (O)  
Atomic number = 8

© Addison Wesley Longman, Inc.

---

---

---

---

---

---

---

---

### Electron Vacancies

- Unfilled shells make atoms likely to **react**
- H, C, O, and N - have **vacancies** in their outer shells

Outermost electron shell (can hold 8 electrons)  
First electron shell (can hold 2 electrons)

Electron

HYDROGEN (H)  
Atomic number = 1

CARBON (C)  
Atomic number = 6

NITROGEN (N)  
Atomic number = 7

OXYGEN (O)  
Atomic number = 8

© Addison Wesley Longman, Inc.

---

---

---

---

---

---

---

---

**Chemical Bonding and Molecules**

---

- Chemical reactions enable atoms to give up or acquire electrons to complete their outer shells.
- Leads to Ionic or Covalent Bonds

---

---

---

---

---



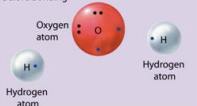

---

---

---

**Chemical Bonds & Molecules**

- Atoms form bonds that fill outer electron shell
- Molecules contain two or more atoms bonded together
- Examples:

| $O_2$   | $N_2$   | $H_2O$   |  |
|---|---|--|--|
| <br>$\cdot\ddot{O}::\ddot{O}\cdot$<br>$O=O$<br>Oxygen, $O_2$ | <br>$:\ddot{N}::\ddot{N}:$<br>$N\equiv N$<br>Nitrogen, $N_2$ | <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p style="font-size: small;">Before bonding</p>  <p style="font-size: x-small;">Oxygen atom</p> <p style="font-size: x-small;">Hydrogen atom</p> </div> <div style="text-align: center;"> <p style="font-size: small;">Covalent bonds formed</p>  <p style="font-size: x-small;">Water molecule, <math>H_2O</math></p> </div> </div> |  |

---

---

---

---

---

---

---

---

**Bonds in Biological Molecules**

1. Ionic Bonds – *“Theft”*
  - *Strongest*
2. Covalent Bonds – *“Sharing”*
  - *Second Strongest*
3. Hydrogen Bonds – *“Partial Charge Sharing”*
  - *Weakest*

---

---

---

---

---

---

---

---

### Ionic Bonds

- Atoms: #e<sup>-</sup> = #p<sup>+</sup>  
– no net charge
- Ion: an atom that gains or loses e<sup>-</sup>(s)
- Charge difference attracts the two ions to each other

---

---

---

---

---

---

---

---

### Formation of NaCl

- Sodium atom (Na)  
– Outer shell has one e<sup>-</sup>
- Chlorine atom (Cl)  
– Outer shell has seven e<sup>-</sup>
- Na transfers e<sup>-</sup> to Cl forming Na<sup>+</sup> and Cl<sup>-</sup>

---

---

---

---

---

---

---

---

■ **Opposite charges attract**  
Na<sup>+</sup> Cl<sup>-</sup>

■ **Ions remain together as NaCl**

Do not post photos to Internet **Figure 2.3a(2)**

---

---

---

---

---

---

---

---

### Covalent Bonding

- Atoms **share** a pair or pairs of **electrons** to fill outermost shell

---

---

---

---

---

---

---

---

### Types of Covalent Bonds

**Non-Polar Covalent**

- Atoms **share** electrons **equally**
- No charge difference** between atoms
- Example:
  - Hydrogen gas (H-H)

**Polar Covalent**

- Unequal sharing** of electrons
  - One atom is stronger
  - Electrons spend more time near nucleus with the most protons
- Example:
  - Water: Electrons are more attracted to O nucleus than to H nuclei

---

---

---

---

---

---

---

---

### Polar Covalent Bonding

- Polar covalent bonding creates atoms with **opposite charges**
- Oppositely charged** atoms with polar covalent bonds are **attracted to each other**

---

---

---

---

---

---

---

---



### Hydrogen Bonding in Water

- A hydrogen bond is the electrostatic attraction between polar molecules.
- This Happens when a Hydrogen (H) atom bound to a highly electronegative atom

Figure 3.22-8

---

---

---

---

---

---

---

---

### Hydrogen Bond of H<sub>2</sub>O

---

---

---

---

---

---

---

---

### Bonds in Biological Molecules

1. Ionic Bonds – *“Theft”*
  - *Strongest*
2. Covalent Bonds – *“Sharing”*
  - *Second Strongest*
3. Hydrogen Bonds – *“Partial Charge Sharing”*
  - *Weakest*

---

---

---

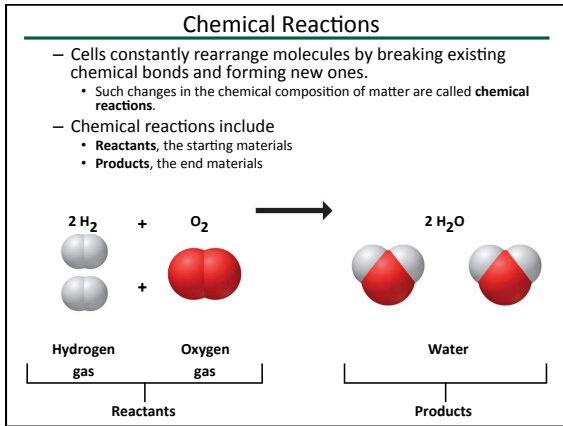
---

---

---

---

---



---

---

---

---

---

---

---

---

### WATER AND LIFE

- Life on Earth began in water and evolved there for 3 billion years.
  - Modern life remains tied to water.
  - Your cells are composed of 70%–95% water.
- The abundance of water is a major reason Earth is habitable.

Figure 2.9

---

---

---

---

---

---

---

---

### Water's Life-Supporting Properties

- The polarity of water molecules and the hydrogen bonding that results explain most of water's life-supporting properties.
  - Water molecules stick together.
  - Water has a strong resistance to change in temperature.
  - Frozen water floats.
  - Water is a common solvent for life.

---

---

---

---

---

---

---

---

### The Cohesion of Water

- Water molecules stick together as a result of hydrogen bonding.
  - This is called **cohesion**.
  - Cohesion is vital for water transport in plants.

**PLAY** Animation: Water Transport

---

---

---


---

---

---

---

- Surface tension is the measure of how difficult it is to stretch or break the surface of a liquid.
  - Hydrogen bonds give water an unusually high surface tension.



---

---

---

---

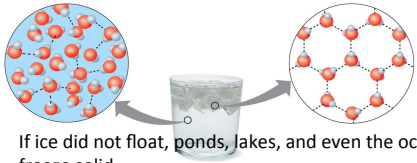
---

---

---

### The Biological Significance of Ice Floating

- When water molecules get cold enough, they move apart, forming ice.
- A chunk of ice has fewer molecules than an equal volume of liquid water.
- Ice floats because it is less dense than the liquid water around it.



- If ice did not float, ponds, lakes, and even the oceans would freeze solid.
- Life in water could not survive if bodies of water froze solid.

---

---

---

---

---

---

---

### Water as the Solvent of Life

– A **solution** is a liquid consisting of a homogeneous mixture of two or more substances.

- The dissolving agent is the **solvent**.
- The dissolved substance is the **solute**.

– When water is the solvent, the result is an **aqueous solution**.

The diagram illustrates the process of a salt crystal dissolving in water. On the left, a salt crystal is shown as a lattice of sodium ions (Na<sup>+</sup>) and chloride ions (Cl<sup>-</sup>). As it dissolves, the ions separate and become surrounded by water molecules. Labels indicate 'Sodium ion in solution' (Na<sup>+</sup>) and 'Chloride ion in solution' (Cl<sup>-</sup>). A glass of water with a salt crystal is shown to the right, with an arrow pointing to the dissolved ions.

---

---

---

---

---

---

---

---

---

---

---

---

### Acids, Bases, and pH

– A chemical compound that releases H<sup>+</sup> to solution is an **acid**.

– A compound that accepts H<sup>+</sup> and removes it from solution is a **base**.

– To describe the acidity of a solution, chemists use the **pH scale**.

The pH scale ranges from 0 to 14. Values below 7 are acidic, 7 is neutral, and values above 7 are basic. Examples include: 0 (Acidic solution), 1 (Lemon juice, gastric juice), 2 (Grapefruit juice, soft drink), 3 (Tomato juice), 4 (Urine), 5 (Human blood), 6 (Pure water), 7 (Neutral pH=7), 8 (Seawater), 9 (Household ammonia), 10 (Milk of magnesia), 11 (Household bleach), 12 (Household ammonia), 13 (Household bleach), 14 (Oven cleaner).

© 2013 Pearson Education, Inc. Figure 2.16

---

---

---

---

---

---

---

---

---

---

---

---

The diagram shows three beakers representing different solutions. The first beaker (blue) contains many OH<sup>-</sup> ions and a few H<sup>+</sup> ions, labeled 'solution'. The second beaker (white) contains equal numbers of OH<sup>-</sup> and H<sup>+</sup> ions, labeled 'solution'. The third beaker (pink) contains many H<sup>+</sup> ions and a few OH<sup>-</sup> ions, labeled 'solution'.

© 2013 Pearson Education, Inc. Figure 2.16a

---

---

---

---

---

---

---

---

---

---

---

---

— **Buffers** are substances that resist pH change.

— Buffers

- Accept  $H^+$  ions when they are in excess
- Donate  $H^+$  ions when they are depleted

— Increases in global  $CO_2$  concentrations may lead to the acidification of the oceans.

---

---

---

---

---

---

---