# Chemistry of Life

1. **Biology** (Bio)

* Science that deals with living organisms and vital processes

##### **Chemistry**

* Science that deals with the chemical compounds and processes occurring in living organisms
* Deals with structure, composition and properties of a substance and the changes these substances undergo
* *Gas, liquid, solid*
* *Hard, soft*

## Classification of Matter

* All living things are composed of matter
* Mass (measure of inertia) (*F = ma*) vs. weight (*W = mg*)
* Occupies space
* DEMO: Air is matter (funnel in beaker of water)
* All matter is composed of a limited number of basic substances called elements

### **Elements**

* A substance that cannot be decomposed into simpler substances by chemical reactions
* Compound: two or more elements
* Fission: nuclear reaction to split atoms by high speed bombardment
* Fusion: nuclear reaction to put two small elements together
  1. There are 92 naturally occurring elements. There are also 14 man-made elements. [Periodic Table of Elements}
  2. The basic unit of all elements is the atom. Atoms are the smallest unit or structure that still retains the characteristics of that element.
  3. There are SIX crucial elements to living organisms:

Millionaire game to get the right order of 6 elements

* + - 1. Man’s composition (CHON, PS)

Oxygen (62.87%) - O

Carbon (19.37%) - C

Hydrogen (9.31%) - H

Nitrogen (5.14%) - N

Phosphorus (0.63%) - P

Sulfur (0.63%) - S

* The “sulfa” is in the living room

DEMONSTRATION

H2 gas + O2 gas

* “sul far” so good
  + - 1. Most abundant compounds from simplest to most complex

H2O water (*2 elements*)

Use internet to find images of these compounds

Carbohydrates (*3 elements*) – C H O

* Cn H2n On 1:2:1 ratio
* C6 H12 O6 glucose, fructose, galactose

Proteins

* Amino acids as building blocks
* Amine group, carboxylic acid group

Fats

* Energy storage, insulation, “ugly”
* Fatty acid group, glycerol group
* Phosolipids in cell membrane

DNA, RNA, nucleotides

* Determine hereditary information
* Controls all cellular activity (body activity)

#### **Atom and Atomic Structure**

1. Atoms can be broken down into smaller particles, but they lose their chemical properties
2. Three basic subatomic particles composing an atom:

###### Charge Mass Symbol Location

* + 1. Protons +1 1 amu p or + nucleus
    2. Neutrons 0 1 amu n nucleus
    3. Electrons -1 1/1837 amu e or e- orbits
* protons – unique to every element
* neutron – interchangeable atoms called isotopes (used in radioactive dating or labelling)
* electron – determines the chemical characteristics of an atom or element

3. One Atomic Mass Unit = 1.66 x 10-24 g

* *453 g = 1 lb 1837 e- = 1 p of mass 220 lb. Male has 16 oz. of e-*

DEMONSTRATION – 7 stations

* Electroscopes with wool, silk, rubber / glass rods (4 stations)
* Van Der Graaf Generator
* Balloon with hole punches & wool
* Balloon, wool, hair, shirt and wall

#### **Bohr Model of the Atom**

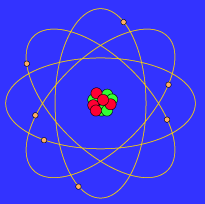
* *Gives us an image, model or picture to “handle” the concept of Atomic Structure*
  + - 1. **Nucleus**

Class Model of an Oxygen Atom

* Protons (8) sit down
* Neutrons (8) stand next to protons
* Electrons orbit around nucleus in 2 shells (2, 6)
* Composed of the particles protons and neutrons
* Constitute the heaviest portion of the atom
  + - 1. **Orbits or shells** - Composed of electrons
* Shell number 1 2 3 4 5 6 7
* Shell letter K L M N O P Q
* # of electrons 2 8 8 32 32 18 8

3. Modern Atomic Structure using an **electron cloud model**

* *E.g. place a golf ball on the fifty yard line and the electrons would orbit in the end zone*



#### **Periodic Chart of the Atoms (Elements)**

1. **Symbols**

* every element has its own symbol normally based on the first letter of its name
* indicate different aspects of the atom

1. **Atomic number** (“Z number”)

* the number of protons in the nucleus of an atom
* unique for every element
* written as a subscript in the nuclear or atomic symbol

11Na

8O

6C

1. **Atomic mass**
2. definition

* the number of neutrons in the nucleus of an atom
* Written as a superscript in the nuclear or atomic symbol

Na23

O16

C12

* Nuclear symbols

ZCAM

1. **Isotopes**
2. description

* An element whose weight differs by the addition or subtraction of neutrons
* Do not alter the chemical characteristics or properties of the atom
* Only effects the WEIGHT and MASS of an element or atom
* The atomic mass reflects the AVERAGE of all occurring isotopes for an element (*e.g hydrogen, deuterium, tritium*)

1. **Radioactive Isotopes**

* Unusual isotopes whose nucleus is unstable and breaks apart

1. results in the formation of a new element or elements
2. releases radiation

* alpha particles ( 2He4 ) 🡪 2 p and 2 n
* beta particles (e-)
* gamma radiation – penetrate bones (*unlike X-rays and is used for cancer treatment*)

1. releases tremendous amounts of energy

* Used to trace elements in a chemical reaction

CO2 + H2O 🡪 C6H12O6 + O2 Photosynthesis

**14C**O2 + H2O 🡪 **14C**6H12O6 + O2 How much C is involved?

CO2 + H2**O18** 🡪 C6H12O6 + **18O**2 Where does O go?

* Used for dating of living and non-living things

6C**12** 🡪 isotope 🡪 6C**14** used to date organic materials w/in 10,000 yrs

1. **Number of electrons**

* The # of e- = # of p in an electrically neutral atom
* All elements on the periodic table of elements are considered neutral
* Atoms react chemically based on the electrons in the outermost orbit or shell

1. **Atom diagrams**

1H**1** 2He**4**

e-

Pp

nn

p

e-

e-

* PRACTICE making Bohr Models for elements #1-20
* Hand out Periodic Table of Elements
* Atomic symbols and diagrams for each element
* COMPARE H2O to S2O located in the same column or period (6 valence e-)
* 8O**16** and 16S**32** atomic number? Mass number? p, n, e-?
* similar characteristics/properties

DEMONSTRATION

* Cotton Ball Trick
* Where are the electrons found?

III. Compounds and Chemical Bonds

1. Periodic Table of Elements

Well organized based on the number of protons and electrons in an element

**Periods** or Families – same valence (*# of e- in outermost shell*) – similar properties

* IA metals – extremely active (e.g. explosive in water)
* VIIA Halides (non-metals) – extremely active (poison gases)

**Rows** – increase atomic number until a valence shell is filled

1. Compounds / Molecules
2. A single substance made of two or more elements combined in definite proportions

* CO2 H2O NaCl C6H12O6
* Individual atoms are still independent, but are held by forces – they behave differently when together than when apart

1. FORMULAS

**Empirical** – shows the smallest proportion of atoms in a compound

**Molecular** – shows the actual composition of a compound or molecule

1. Classes of Compounds / Molecules

**Inorganic** – called “**compounds**”

CO2 H2O O2 minerals gases

**Organic** – C & H combinations – called “**molecules**”

CH4 (fuels) CH3OH (alcohols) CH2O (sugars)

1. Bonding

* Takes place between elements to form compounds or molecules

*C. Bonding continued*

* Atoms always attempt to become STABLE:

1. **Electrical neutrality**

* possess the same # of e- as p
* IONS – charged particles or atoms

1. **Complete outer shell of electrons** (VALENCE)

* atoms become charged based on how many e- they gain or lose

1. **Types of Bonds**

1. **Ionic Bonding** – electron **transfer**

* Weak bonds formed as the result of the attraction between ions or charged atoms
* Electrons are lost or gained by cells to make an atom more stable
* EXAMPLE using Sodium (Na) and Chlorine (Cl)

11Na**23** 17Cl**35**

**7 e-**

8 e-

**1 e-**

11 p

12 n

2 e-

2 e-

17 p

18 n

8 e-

Neutral (+11, -11) Neutral (+17, -17)

*Nucleus overburdened Not satisfied … hungry … needs one more*

*Guys: always giving girls: taking, greedy*

+11

-10

+1

* Na (metal) loses an electron to Cl and becomes an ion (Na**+1**) – OXIDATION (*loss of e-, gain charge*)
* Cl (non-metal) gains that electron from Na and becomes an ion (Cl**-1**) – REDUCTION (*gain of e-, loss of charge*)

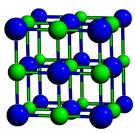
+17

-18

-1

* The “electrostatic” attraction between these charged atoms is the **ionic bond – WEAK** compared to the covalent bonds (shared e-)

Na**+1** + Cl**-1** ions

 NaCl Crystal Lattice

Demonstration:

* Dramatize the Na**+1** and Cl**-1** and how they want to become STABLE
* A*dd a piece of Potassium or Sodium to water [ K + H*2*O 🡪 KOH ]*

PRACTICE: Have students make diagrams

* Do Li & Cl as a class
* *show atom diagrams, ion charges, formula*
* *Oxygen gains TWO electrons from the lithium atoms (each give up 1 e-)*
* Have students discover that Li & O must become 🡪 Li2O
* Give students the elements and have them find the atom diagram, ion charges and formula for the following:
* MgO, MgCl2, AlF3, HCl, HF, LiOH, Al2O3,

**The chemical nature of atoms is determined by the valence e-**

1. **Three classes of ionic compounds –** based on water’s ability to ionize (*water has covalent bonds*)

*H*2*O 🡪 [*H**+***] [OH* **-***]*

# **Acids**

* Any substance that increases the concentration of Hydrogen ions *[*H**+***]* in a solution of water (donates H**+** ions)
* *Chemically speaking, it is any species that accepts an electron pair*
* EXAMPLES - HCl, H2SO4, HNO3,
* Taste sour
* Corrosive to many metals

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 4.8 – 7.6 | 6.6 | 3.0 | 2.5 | 2.0 - 0.9 |
| Urine | Saliva | Citric Acid | Car Battery | Stomach Acid |
|  |  | Vinegar, lemon, fruit, Coca Cola |  |  |

Demonstration:

* Add 3 M HCl to a test tube or Erlenmeyer Flas
* Add chips or pieces of Mg metal
* Observe the bubbles (gas formation)

1. **Bases - Alkaline**

* Any substance that increases the concentration of Hydroxide ions *[O*H**-***]* in a solution of water (accepts H**+** ions)
* *Chemically speaking, it is any species that donates an electron pair (decreases the [*H**+***] ions)*
* EXAMPLES - NaOH, LiOH, KOH,
* Taste bitter

|  |  |  |  |
| --- | --- | --- | --- |
| 7.4 | 8.0 | 9.0 | 12.0 – 13.00 |
| Blood | Egg white | Cocoa | Drano |
| Tears | Soap | Alum, lye | NaOH |

Demonstration:

* Make a weak NaOH (aq) solution
* Dip fingers into the weak base and feel the slippery
* Soap is slippery because it is “basic” (saponification: skin becomes soap)

\*\*A measurement of acidity or alkalinity (base) is accomplished using a pH scale

1 7 14

Strongly Acidic Neutral Strongly Basic3. **Salts**

* The result of a reaction between an acid and a base
* “*a salt is something you get arrested for*”

Acid + Base 🡪 Salt + Water

* EXAMPLES

NaOH + HCl 🡪 NaCl + Water

KOH + H2SO4 🡪 K2SO4 + HOH

1 7 14

# Strongly Acidic **Salt** / Neutral Strongly Basic

***[*H+*]*** *> [OH* **-***] < [*H**+***] = [OH* **-***] [*H**+***] <* ***[OH* -*]*** *>*

**Demonstrate** Mix 1 M NaCl + 1 M HCl taste the saltwater

# 

* + - * 1. **Instruments to measure pH**

**DEMONSTRATE**

# Litmus Paper

# Hydrion Paper

# PH meter

# Use HCl, NaOH

1. Litmus Paper

* Red to blue 🡪 basic
* Blue to red 🡪 acidic

1. Hydrion Paper

* Indicates actual pH (1 to 14)
* Different Hydrion papers are used for different pH ranges

1. pH meter

**DEMONSTRATE**

# Place water and PHENOLPHTHALEIN indicator in a large, flat container

* Add a small piece of K or Na
* Turns water blue (KOH)

1. Indicators

* Phenolpthalein
* Bromthymol Blue

Almost all chemical reactions in living organisms take place at pH of 6 –8 (*exception: stomach ~2*)

1. acids and bases often carry nutrients or wastes in the bloodstream to various parts of the body
2. An organism will resist sudden changes in pH because chemical reactions are greatly effected by small pH changes
3. PH of stomach ~2 intestines (~7.4) pancreas (~7.4) blood, tears (~7.4) **…. How is this possible**?
   * + - 1. **Buffers**

Special salts that resist changes in pH

Especially important for “Homeostasis”

Neutralization reactions

a) Acid + BASE 🡪 Buffer salt + H2O

b) ACID + base 🡪 Buffer salt + H2O

4. Common buffer reaction in the human body 🡪 “soaks” up acids or bases

**H2CO3 🡪 H+ + HCO3-**

*Carbonic Acid Bicarbonate*

*(*H**+** *Donor) (*H**+** *acceptor)*

* Carbonic Acid is weak and can flow in the bloodstream
* If one adds HCl (stomach) 🡪 bicarbonate (HCO3-) accepts the H**+** from the acid (HCl) to form carbonic acid (H2CO3)
* If NaOH (base) is added 🡪 carbonic acid (H2CO3) donates its H**+** to form bicarbonate (HCO3-) and water

**CO2 + H2O 🡪 H2CO3**

* Carbonic Acid converts back to CO2 + H2O
* The body gets rid of carbon dioxide through the lungs
* Water increases this exchange by moisturizing the surface area in the alveoli

2. **Covalent Bonding**

“Covalent” (*sharing of electrons*) – water goes into and out of pool filter back into pool

“Ionic” (*Transfer of electrons*) – lost contact in pool; pool broke and water runs out

1. Characteristics

* Cooperate “CO” or share
* “Valence” 🡪 the outermost e- shell
* Strong bonds formed as a result of sharing electrons between atoms.
* Covalently bonded atoms are called MOLECULES

1. Formulas
2. **molecular formula**

* identifies the atoms and number of each as a proportion

H2O CO2 ionic compounds: MgCl2 AlF3

1. conventions for molecular formulas

* the + atom is listed first in a molecular formula
* the – atom is listed second in a molecular formula

1. **structural formula**

* shows the relative position of the atoms to each other
* shows the type of bonds between atoms (single, double, triple covalent)

H – O – H O = C = O

1. Examples of molecules showing covalent bonds
2. Hydrogen gas **H2** (*Molecular Formula*)

Electron Cloud Model

1H**1** 1H**1**

Structural Formula

**1 e-**

H - H

1 p

1 p

**1 e-**

* “Reeses” Cups: Chocolate & Peanut Butter “You got your \_\_ in my \_\_”
* Both atoms are STABLE: 1) electrical neutral and 2) have a complete outer shell
* Single Covalent Bond (*shares 1 pair of e-*)

1. Oxygen gas **O2** (*Molecular Formula*)

8O**16** 8O**16**

Structural Formula

8 p

8 n

O = O

**2 e-**

**2 e-**

8 p

8 n

* Both atoms are STABLE: 1) electrical neutral and 2) have a complete outer shell
* DOUBLE Covalent Bond (*shares 2 pairs of e-*)

1. Nitrogen gas **N2** (*Molecular Formula*)

7N**14** 7N**14**

Structural Formula

7 p

7 n

N = N

**2 e-**

**2 e-**

7 p

7 n

* Both atoms are STABLE: 1) electrical neutral and 2) have a complete outer shell
* TRIPLE Covalent Bond (*shares 3 pairs of e-*)

ACTIVITY: molecular model kits, make those elements

CH4 NH3 C2H2 CCl4 CH3(OH) H2S

* Show structural formulas
* Make model of molecule using the kits

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **e- in outer shell** | **# bonds** | **Type of Bonds** |
| C | 4 | 4 | 1 triple, 1 single – 2 double – 1 double, 2 single – 4 single |
| N | 3 | 3 | 1 triple – 1 double, 1 single -- 3 single |
| O | 2 | 2 | 1 double – 2 single |
| H | 1 | 1 | 1 single |

3. **Hydrogen Bonding**

* Inter-molecular attractions between “polar molecules”
* Weak “bond” formed by smaller atoms
* The best known example is in water

N

-

+

a. Polar molecule

Earth

Battery

* A molecule that has an unequal distribution of electrons around it

S

* Appears to have “poles” of charge

b. Water

DEMONSTRATION

* Use **lycopodium powder** or sulfur powder
* Use a petri dish or large pan of water
* Sprinkle the powder evenly over water
* Secretly put a **drop of soap** on index finger
* Tell story of one of the students going swimming with the rest of the class and diving in
* Molecules quickly get “polarized”

+

+

Molecular Formula

H2O

+

-

1 p

-

-

-

-

Structural Formula

H - H

-

-

-

**2 e-**

8 p

8 n

-

1 p

+

-

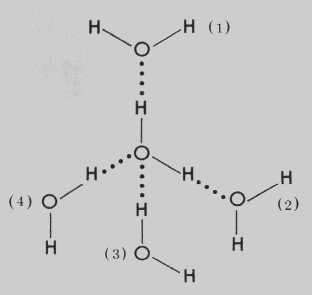
Electron Cloud Model

* The oxygen atom attracts e- more than the hydrogen atom
* The electrons are traveling around O more than around hydrogen
* These intermolecular attractions account for water’s “stickiness” (*e.g cohesion, adhesion, capillary action*)

ANALOGY

# Non-polar Polar

# *Evenly distributed molecules Unevenly distributed molecules*



III. Important Inorganic Molecules

1. Water
   1. Living things are composed of between 50% to 90% water
   2. Nearly all chemical reactions of living organisms occur in water
   3. Water is a **universal solvent** capable of dissolving many other substances

“polar” molecules tend to be good solvents

Alcohol is a better solvent but water is more stable and useful

* 1. Water is used to transport substances internally and externally
  2. Special Properties of water

a. high specific heat

1) e.g. vegetables stay hot a long time

2) ocean & lake temperatures are more moderate than in-land temperatures

3) liquid ammonia has a higher specific heat than water

b. high surface tension

1) e.g. water striders, water skiing on top of the water

2) liquid Mercury has a greater surface tension than water

c. high boiling point

1) water normally boils at 100 C

2) other molecules with similar size of water are gases which boil around –78 C or lower (-200 F) - *e.g. O2, N2, H2, NH3* *all need extreme cold to exist as liquids*

d. ice is less dense than liquid water

1) most solids are more dense than their liquid

2) water actually freezes at 4 C

3) ice molecules expand (*rather than contract like other solids*) and therefore, becomes less dense and floats

4) critical for all life to exist – imagine if ice sank!!!!! All the earth would be a solid block of ice

5) ice insulates the earth’s surface to prevent “permafrost” conditions for all the soil

1. Carbon dioxide
   1. Constitutes a small fraction of the atmosphere (0.03 %)
   2. Carbon is the principal structural element of living organisms and CO*2* is the source of this carbon

* CO*2* is produced or released from most metabolic reactions in living organisms
  1. Carbon is incorporated into living organisms by plants through the process of photosynthesis

**C**O2 + H2O + light energy 🡪 **C**6H12O6 + O2

DEMONSTRATION - “Bad breath test”

* **Limewater**
* Half fill one beaker with water and another with limewater
* Have a girl breath into the beaker of water
* Have a guy breath into the beaker of limewater
* The CO*2* in the breath turns limewater cloudy
* Use a straw and blow bubbles into the limewater

1. Oxygen

1) Constitutes ~20% of the atmosphere

2) Necessary for respiration (to produce energy) in most living organisms

3) Used by aquatic animals (*gills*) and plants because O*2* will dissolve in water

a) released by plants during photosynthesis

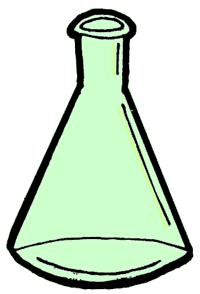
CO2 + H2**O** + light energy 🡪 C6H12O6 + **O**2

b) utilized by animals during aerobic respiration

C6H12O6 + O2 🡪 CO2 + H2O + ATP

DEMONSTRATION - producing O2

* Add 3M HCl to an Erlenmeyer Flask
* Add pieces of Zn metal to the flask
* Cover flask with a gallon milk container and plug top with rubber stopper and dropper pipette
* Allow H2 gas to collect in the container
* Uncover dropper and ignite the gas with a splint on end of meter stick



**Zn**

* O2 gas aids in the combustion reaction

IV. Biochemical (Organic) Compounds Important to Living Organisms

1. Carbohydrates
2. simple sugars
3. glucose
4. galactose
5. fructose
6. double sugars
7. dehydration synthesis
8. hydrolysis
9. polysaccharides
10. starch
11. glycogen
12. cellulose
13. Lipids
14. glycerol
15. fatty acids
16. Proteins
17. Building blocks of all proteins
18. Construction of a protein
19. primary structure
20. secondary structure
21. tertiary structure

D. Nucleic acids

E. Energy of the Cell --- ATP study

1. ATP
2. Summary of energy

F. Enzyme Study

1. chemical nature of Enzymes
2. characteristics of Enzymes
3. Lock and Key Theory
4. Catalysis