General Chemistry

Lecture 2

Atomic Theory

Basic Definitions

- **Matter** is anything that has mass and occupies space
- An **Atom** is the smallest stable unit of matter

Basic Definitions

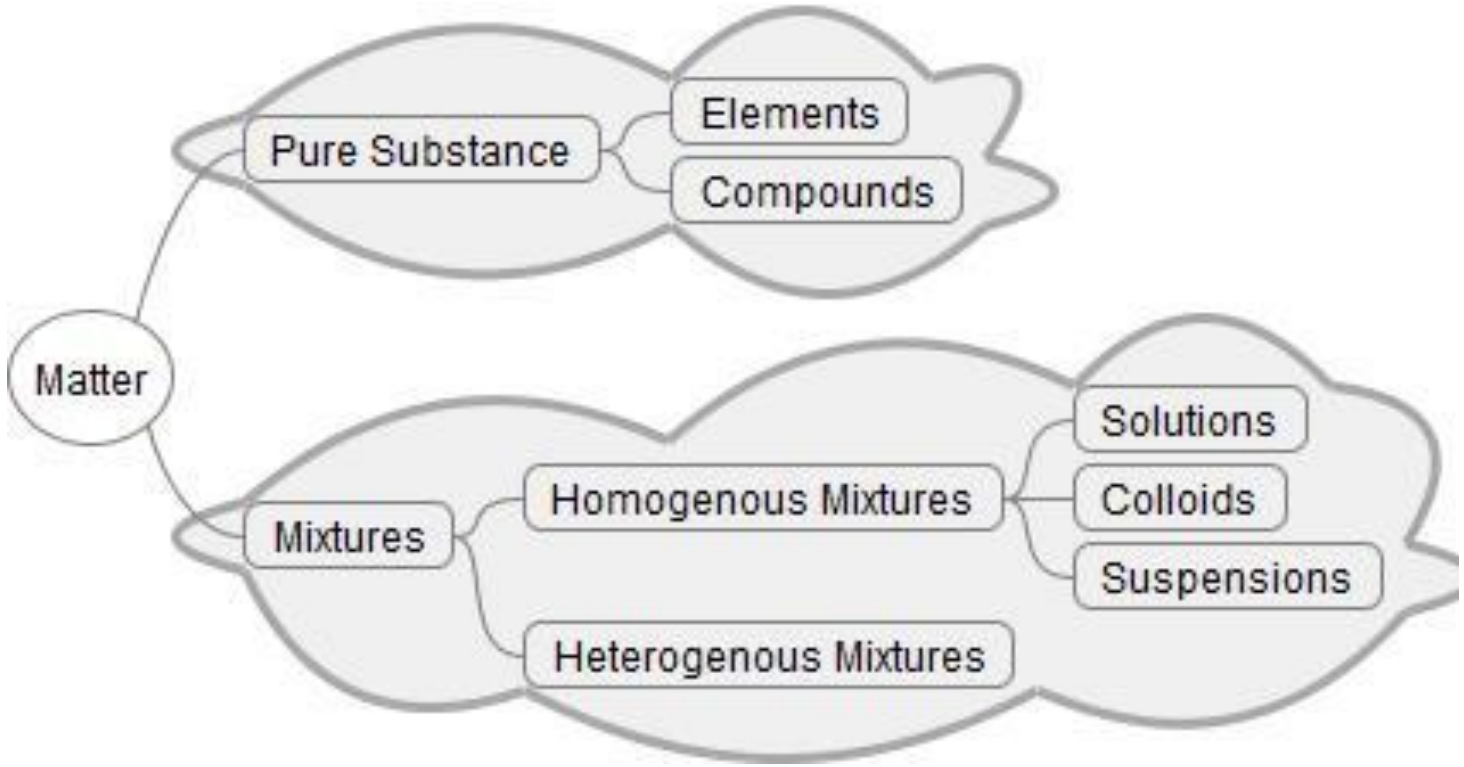
- A **Pure substance** is matter that has a fixed and definite composition. Two types exist
  - Elements – the simples type of a chemically pure substance. It is composed of atoms of only one type (silver, calcium, carbon, etc.). Elements can not be broken down by ordinary physical or chemical means.
  - Compounds – A pure substance that consists of atoms of two or more elements combine in a consistent proportion. These atoms are held together by bonds which form small groups of atoms called molecules (H_2O, CH_4, etc.). Compounds can be broken down by chemical processes
- **Mixtures** consist of two or more substances which are physically mixed, but not chemically combined (such as air which contains a mixture of O_2 and N) Mixtures can be either homogenous (uniform throughout) or heterogeneous (not uniform)

Homogenous Mixtures

- There are 3 types of homogenous mixtures based on particle size
  - 1) Solutions
  - 2) Colloids
  - 3) Suspensions
- We will discuss solutions for now
- Solutions consists of
  - Solvent – the medium in which other atoms, ions, or molecules are disperse.
  - Solute – the dispersed substances
  - Solution – a uniform mixture of two or more substances
- Mixtures can be separated by various physical means such as filtration

Suspensions, Colloids, and Solutions

- Suspensions include particles that are greater than 7500nm, these particles are too large to stay evenly dispersed and if left alone, sedimentation will form
  - This is the case for blood, whole blood is a suspension of blood cells in plasma. If blood is removed from the body and clotting is prevented, blood cells will settle to the bottom of a container. This settling rate “sedimentation rate, sed rate, or eurythrocyte sedimentation rate (ESR)” can be measured for clinical reasons
- Solutions include solutes that are < 2nm
  - If the solutes are dissolved in an aqueous solution of water it is written as X(aq)
- Colloids are in between and include particles that are 2-500nm
  - Colloids are an essential component of the ECM of connective tissue
- *Molecule size is not necessary to remember, but colloids have interesting properties biologically*

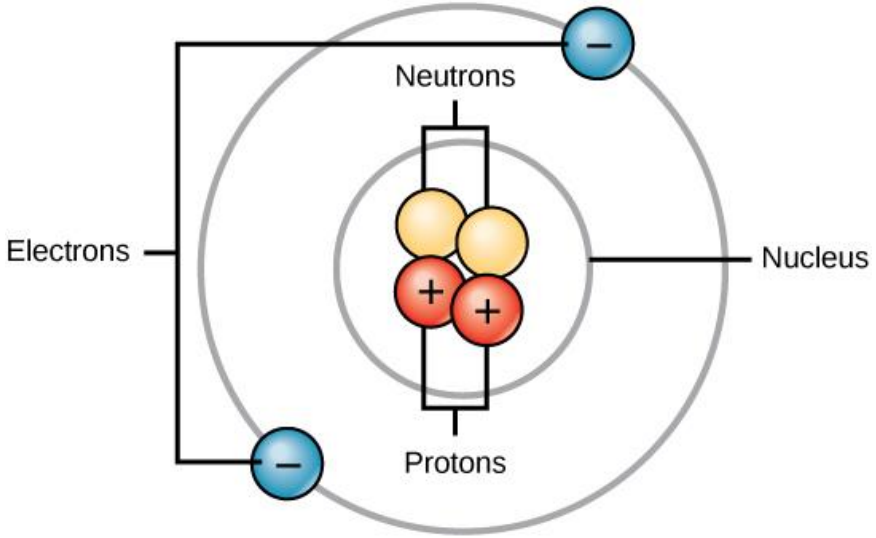

Matter
Pure Substance
Elements
Compounds
Mixtures
Homogenous Mixtures
Solutions
Colloids
Suspensions
Heterogenous Mixtures

Elements and Atoms

- Elements are a chemically pure substance that consist of atoms of only one type
- Atoms consist of many types of subatomic particles, we will discuss
  - Protons
  - Neutrons
  - Electrons

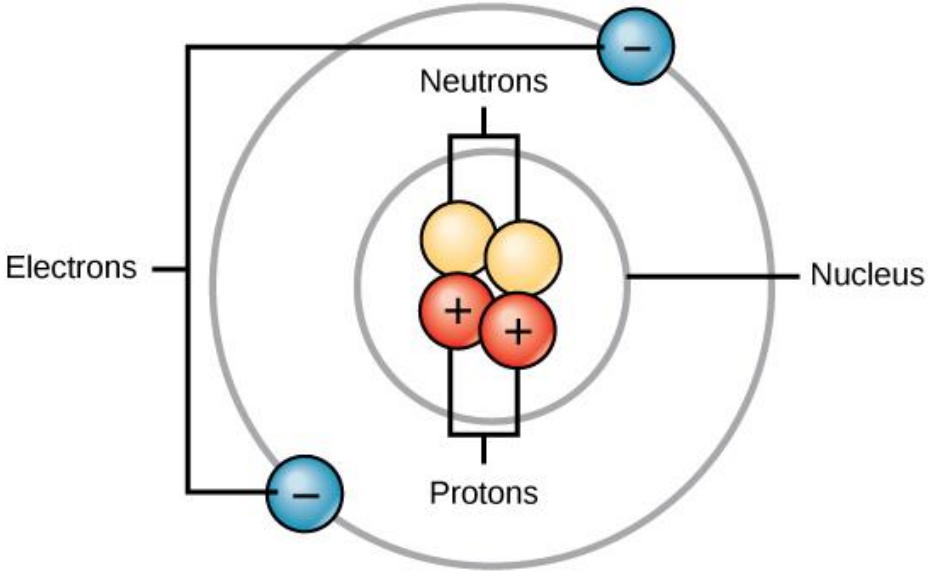
Elements and Atoms

- An atom contains a nucleus, this is in the center of an atom
  - The nucleus contains protons which are positively charged and 1 amu
  - The number of protons in the nucleus of an atom is unique for atoms of that element. This determines the atomic number
  - The atomic number = the number of protons in the nucleus of atoms of an particular element
  - The nucleus contains neutrons which have a neutral charge and 1 amu



Elements and Atoms

- Electrons orbit the nucleus in various energy levels
  - The number of electrons equals the number of protons in an atom
  - Electrons do not contribute significantly to the mass of an atom and do not effect the atomic mass number
  - However, they do contribute to the charge. They also contribute to the chemical characteristics of this element



Elements and the Periodic Table

- Elements are organized on the period table in vertical columns called groups and horizontal rows called periods.
  - These groups and columns indicate certain properties of the elements contained in them
  - Ex) Group IA is known as alkali metals (contains Li-Fr). These react rapidly with water to form products that are highly alkaline. Since they are highly reactive, they are never found in nature in the pure state, but only in combination with other elements
  - Group 8A contains inert gases. These have 8 electrons in their valence shell and therefore are inert, not reacting with other elements
  - Metals are on the left hand side of the period table, non-metals are on the right hand side and semi metals are in between

Periodic Table Organization – Groups and Periods

Groups

- Each vertical column is called a group
- The elements of the first 2 columns and the last six columns are called representative elements. They are designated with the number (from left to right) and A (1A, 2A, 3A, etc)
- The elements in the middle groups are called transitional elements. They are designated with a number (starting with 3) and the letter B (3B, 4B, etc.)
- A newer numbering system simply designates each column with a number from 1-18)
- Both systems are in use and indicated on the periodic table

Periods

- Each horizontal row is called a period
- Period 1 is on the top and period 7 is on the bottom
- Each period is organized based on the number of electron levels

Periodic Table Organization – Classifications of Groups

- Several groups contain special names
- Group 1A
  - Contains a family of elements know as alkali metals
  - These are good conductors of heat and have a relatively low melting point
  - These react vigorously with water and form white products when combined with oxygen
  - *Note: Hydrogen contains different properties and is not an alkali metal, despite being in this group*
- Group 2A
  - Contains the alkaline earth metals
  - These are not as reactive as those in 1A
- Group 7A
  - Contains the halogens
  - These are highly reactive
- Group 8A
  - Contains the noble gases
  - These are unreactive and are seldom in combination with other elements

Periodic Table Organization – Classifications of Periods

- Period 1
  - Contains H and He
  - Atoms of these elements only have electrons in the first energy level
  - These electrons can be written as 1 or 2 respectively
- Period 2
  - Contains Li to Ne
  - Atoms of these elements contain two electrons in the first level and the remaining electrons are in the second electron level
  - These electrons can be written as 2,1 (for Li), 2,4 (C), etc.
- Period 3
  - Contains atoms of elements which have 2 electrons in the first level, 8 in the second, and the remaining electrons are in the third level
  - These electrons can be written as 2,8,1 (Na), 2,8,6 (S), etc.
- Periods 4 and higher follow this general trend, but atoms of the transition elements start to fill up the levels below the valence level

Common Elements

- Element
  - There are 92 naturally occurring elements
  - From these 6 make up almost 99% of the body (oxygen, carbon, hydrogen, nitrogen, calcium, and phosphorus); 25 are important for biochemical processes in the body, and others are possibly necessary in very small amounts
  - Elements are organized on the periodic table and are listed by abbreviated chemical symbols
    - This is a 1 or 2 letter symbol. The first letter is capitalized and the second (if there is a second) is lower case
    - Many of the symbols are relatively obvious (H – Hydrogen, Ca –Calcium)
    - Others are derived from their Latin or Greek names (Na – sodium [originally Natrium], K – Potassium [originally Kalium])

Metals, Nonmetals, and Metalloids

- The heavy zigzag feature of the periodic table separates the metals from the nonmetals
- Metals
  - Shiny solids (such as Cu - Copper, Au - Gold, Ag - Silver)
  - They are ductile, malleable, good conductors of heat
  - They usually melt at a higher temperature than nonmetals
  - All are solid at room temperature (except Hg – mercury)
- Nonmetals
  - Not especially shiny, ductile, or malleable
  - They are often poor conductors of heat
  - They usually have a low melting point
  - Include H – hydrogen, O – oxygen, Ch – chlorine)

Metals, Nonmetals, and Metalloids

- Metalloids are along the heavy line
- Exhibit some properties of each
- For example, they are better conductors of heat and electricity than nonmetals but not as good as metals

Elements and Their Symbols

Actinium - Ac
Aluminum - Al
Americium - Am
Antimony - Sb
Argon - Ar
Arsenic - As
Astatine - At
Barium - Ba
Berkelium - Bk
Beryllium - Be
Bismuth - Bi
Boron - B
Bromine - Br
Cadmium - Cd
Caesium - Cs
Calcium - Ca
Californium - Cf
Carbon - C
Cerium - Ce
Chlorine - Cl
Chromium - Cr
Cobalt - Co
Copper - Cu
Curium - Cm
Dysprosium - Dy
Einsteinium - Es
Erbium - Er
Europium - Eu
Fermium - Fm
Fluorine - F
Francium - Fr
Gadolinium - Gd
Gallium - Ga
Germanium - Ge
Gold - Au
Hafnium - Hf
Helium - He
Holmium - Ho
Hydrogen - H
Indium - In
Iodine - I
Iridium - Ir
Iron - Fe
Krypton - Kr
Lanthanum - La
Lawrencium - Lr
Lead - Pb
Lithium - Li
Lutetium - Lu
Magnesium - Mg
Manganese - Mn
Meitnerium - Mt
Mendelevium - Md
Mercury - Hg
Molybdenum - Mo
Neodymium - Nd
Neon - Ne
Neptunium - Np
Nickel - Ni
Niobium - Nb
Nitrogen - N
Nobelium - No
Osmium - Os
Oxygen - O
Palladium - Pd
Phosphorus - P
Platinum - Pt
Plutonium - Pu
Polonium - Po
Potassium - K
Praseodymium - Pr
Promethium - Pm
Protactinium - Pa
Radium - Ra
Radon - Rn
Rhenium - Re
Rhodium - Rh
Rubidium - Rb
Ruthenium - Ru
Samarium - Sm
Scandium - Sc
Selenium - Se
Silicon - Si
Silver - Ag
Sodium - Na
Strontium - Sr
Sulphur - S
Tantalum - Ta
Technetium - Tc
Tellurium - Te
Terbium - Tb
Thallium - Tl
Thorium - Th
Thulium - Tm
Tin - Sn
Titanium - Ti
Tungsten - W
Unnilhexium - Unh
Unniloctium - Uno
Unnilpentium - Unp
Unnilquadium - Unq
Unnilseptium - Uns
Uranium - U
Vanadium - V
Xenon - Xe
Ytterbium - Yb
Yttrium - Y
Zinc - Zn
Zirconium - Zr

Elements and Their Symbols
Know for Test 1

Calcium - Ca
Carbon - C
Chlorine - Cl

Fluorine - F
Hydrogen - H
Iodine - I
Iron - Fe
Magnesium - Mg
Manganese - Mn

Nitrogen - N
Oxygen - O
Phosphorus - P
Potassium - K

Sodium - Na
Sulphur - S

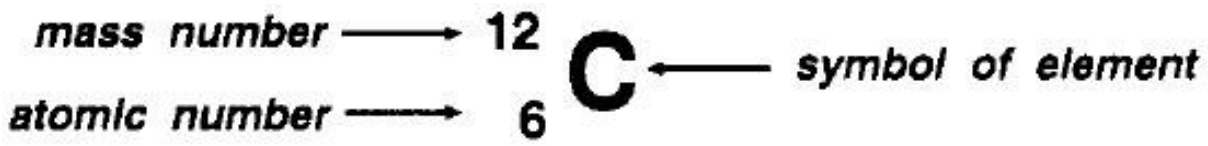
Atomic Number and Mass Number

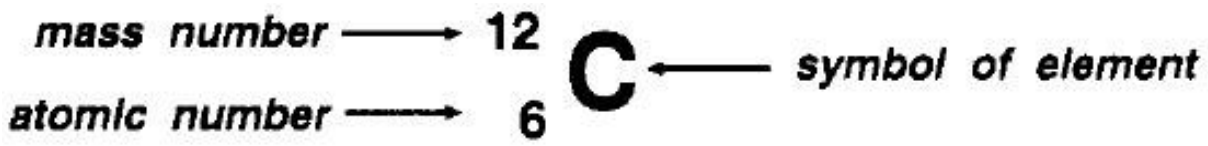
- The atomic number is unique for each element
- This indicates the number of protons in the nucleus of atoms of this element
- Atomic number = number of protons in an atom
- The mass number of an atom is the sum of the protons and neutrons of an atom
  - This is always a whole number
- The atomic mass (or weight) of an element is the average weight of atoms of an element taking into account frequency of isotope occurrence
  - This number is not a whole number and it appears on the period table

Particles	Relative Charge	Relative Mass
Protons (p or p^+)	+1	1 amu (atomic mass unit)
Neutrons (n or n^0)	0	1 amu
Electrons (e or e^-)	-1	Negligible*

**1/1840 the mass of a proton or neutron*

- Protons and neutrons are found in the nucleus of atoms
- An atom and the contents of its nucleus can be represented with the symbol, its atomic number as a subscript and its mass as a superscript





- This is often written as ^{12}C (called carbon-12). There are actually three varieties of carbon atoms: ^{12}C (called carbon-12) ^{13}C (called carbon-13) and ^{14}C (called carbon-14). This depends on how many neutrons each variety has.
- Each variant of an atom with a different amounts of neutrons is called an isotope
- Certain isotopes of a given element occur at a higher frequency
- The atomic mass of an atom is the number of neutrons plus the number of protons
- The atomic weight or mass of an element is the average of all the isotopes of this element, taking into account frequency of occurrence.
- For example, the atomic weight of C is 12.011. ^{12}C is by far the most frequently occurring isotope of C, with ^{13}C and ^{14}C very seldom occurring.

Common Isotopes Relevant to Biological Systems

Element	Isotope	# Protons	# Neutrons	Mass #
Hydrogen	^{1}H*	1	0	1
	^{2}H (deuterium)	1	1	2
	^{3}H (tritium)	1	2	3
Carbon	^{12}C*	6	6	12
	^{13}C	6	7	13
	^{14}C	6	8	14
Oxygen	^{15}O	8	7	15
	^{16}O*	8	8	16
	^{17}O	8	9	17
	^{18}O	8	10	18

**most abundant*

To Sum Up

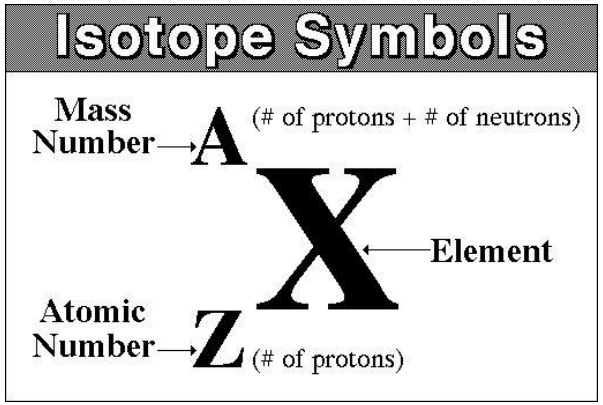
- All atoms of a given element have the same atomic number
  - This indicates the number of protons in the nucleus
  - The number of electrons will equal the number of protons
  - Protons have a positive charge and electrons have a negative charge, so the atom will have a neutral charge
- Atoms of a given elements have varying proportions of isotopes (atoms of the same element with different amounts of neutrons)
  - Isotopes are atoms of the same element with a different amount of neutrons in the nucleus
  - Neutrons have a neutral charge and do not contribute to the charge of an atom
  - Neutrons have a mass equal to that of a proton
  - Certain isotopes show up with a higher frequency (^{12}C is by far the most frequent)
  - The atomic mass is an average of all the isotopes, taking into account frequency of occurrence.
    - Example: ^{12}C is the most frequently occurring isotope of the element Carbon. ^{13}C and ^{14}C occur much less frequently. The atomic mass of C is 12.011.

Questions

- What two subatomic particles would be found in the nucleus?
  - Protons and neutrons
- What does the atomic number indicate?
  - The number of protons in an atoms nucleus
- What does the atomic weight indicate
  - The average weight of all the isotopes of an element, taking into account proportions of each
- What is an isotope?
  - Atoms of the same element, but with different amounts of neutrons in the nucleus
- How many neutrons would be found in the nucleus of ^{13}C?
  - 7 neutrons
- How many protons would be found in the nucleus of ^{13}C?
  - 6 protons
- What subatomic particle has a negative charge?
  - Electrons

Know and Recognize

- Know the three subatomic particles discussed, which are in the nucleus, what their charges are, and what their atomic masses are
- From the periodic chart, recognize which number is the atomic number and which is the atomic mass
- Know the symbols for the elements of biological significance. These are circled and boxed on the periodic chart on slide 4, and are bolded on slide 5
- Be able to fill in the chart on slide 9
- Be able to recognize the parts and significance or an isotope symbol



Group Number and Valence Electron

- Electrons orbit the nucleus in various energy levels
- Electrons are extremely important in determining the chemically characteristics of atoms of an element
- In particular, the valence electrons are important
  - The valence electrons are the electrons in the outer energy level