General Chemistry

Chemistry and the Branches of Chemistry

Chemistry

- Chemistry is the study of composition, structure, properties, and reactions of matter
- Matter is all the substances that make up our world
- Chemistry occurs all around you and involves chemical reactions that take place in a laboratory, but also reactions that occur in your body during metabolism, in plants, and in the environment around you

Chemicals

- A Chemical is a substance that always has the same composition and properties wherever it is found
- All the things around you are composed of one or more chemicals

Chemistry and the Branches of Chemistry

- Branches of Chemistry
  - General Chemistry
    - The study of the composition, properties, and reactions of matter
  - Organic Chemistry
    - The study of substances that contain the element carbon
  - Inorganic Chemistry
    - The study of all other substances except those that contain carbon

Scientific Notation and Significant Figures

Scientific Notation

- In chemistry, very large or very small numbers are often used
- These are often written in scientific notation
  - This contains 3 parts
    - 1) a coefficient
    - 2) a power of 10
    - 3) a measurement unit
  - Ex) 45,000 m would be written 4.5×10^4 m
    - 1) 4.5 is the coefficient (determined my moving the decimal point to the left or right to give a coefficient that is at least 1 but less than 10
    - 2) 4 is the power of 10 (because decimal point is moved 4 places, the power of 10 is 4). For any number greater than 1, the power of 10 is positive, for any number less than one, the power of 10 is negative
    - 3) m is the measurement unit of meters

Scientific Notation

- Ex) In Water (H_2O), a small percentage of H^+ dissociates.
  - $H_2O \leftrightarrow H^+ + OH^-$
  - One liter of pure water has 0.0000001 mol of hydrogen ions
  - This can be written as $[H^+] = 1 \times 10^{-7}$ mol/L
    - The brackets indicate the "concentration of"
    - pH is a shorthand to indicate this
    - The pH scale is logarithmic, meaning that each decrease in number is actually 10 times greater in H^+ concentration
      - pH 6 - $[H^+] = 1 \times 10^{-6}$mol/L or 0.000001 mol/L
      - ph 5 - $[H^+] = 1 \times 10^{-5}$mol/L or 0.00001 mol/L
      - ph 4 - $[H^+] = 1 \times 10^{-4}$mol/L or 0.0001 mol/L
      - ph 8 - $[H^+] = 1 \times 10^{-8}$mol/L or 0.00000001 mol/L
- Acids have a lower pH number (more hydrogen ions) and Bases have a higher pH (less hydrogen ions)

Significant Figures and Scientific Notation

- Significant figures are all the digits including the estimated digits
  - Ex) 5.082 has 4 significant figures
- Nonzero numbers are always counted as significant figures
- A zero may or may not be counted. It is counted if
  - It is between two nonzero numbers (205 m has 3 significant figures)
  - It is at the end of a decimal number (50. L and 5.0 L both have 2, 16.00 g has 3 significant figures)
  - It is the coefficient of a number written in scientific notation (5.70×10^{-3} g has 3 significant figures)
- A zero is not counted
  - If it is at the beginning of a decimal number (0.0003 m has 1 significant figure)
  - If it is used as a placeholder in a large number without a decimal point (850,000 m has 2 significant figure)

Significant Figures and Scientific Notation

- Significant figures are all the digits including the estimated digits
  - Ex) 5.082 has 4 significant figures
- Nonzero numbers are always counted as significant figures
- A zero may or may not be counted. It is counted if
  - It is between two nonzero numbers (205 m has 3 significant figures)
  - It is at the end of a decimal number (50. L and 5.0 L both have 2, 16.00 g has 3 significant figures)
  - It is the coefficient of a number written in scientific notation (5.70×10^{-3} g has 3 significant figures)
- A zero is not counted
  - If it is at the beginning of a decimal number (0.0003 m has 1 significant figure)
  - If it is used as a placeholder in a large number without a decimal point (850,000 m has 2 significant figure)
- When 1 or more zeros in a large number are significant digits, they are more clearly shown by writing in scientific notation
  - Ex) if the first zero in the measurement 500 m is significant, it is written as 5.0×10^{2} m

Significant Figures in Calculation

- Many things are measured in the sciences and the numbers obtained are often used in calculations
- The number of significant figures in the measured numbers determines the number of significant figures in the reported or final answer
  - Ex) To buy carpet for a 5.52 m by 3.58 m room, you would determine the area by multiplying these 2 numbers (19.7616). Since both the original numbers have 3 significant figures, they are product is written 19.8 m^2
  - *Note: in multiplication and division, the final answer is written so that it has the same number of significant figures as the measurement with the fewest significant figures*
  - *In addition and subtraction, the final answer is written so it has the same number pf decimal places as the measurement with the fewest decimal places*

Questions

- How many significant figures does 85.00 have?
  - 4
- How many significant figures does 0.00304 have?
  - 3
- Write 500,000 m in scientific notation with three significant figures
  - 5.00×10^5 m
- Round 8.42334 to three significant figures
  - 8.42
- Round 14.780 to two significant figures
  - 15
- What is 8.00/2.00?
  - 4.00
- What is 2.045 + 34.1?
  - 36.1 (adjusted from 36.145)
- *Note: significant figures do not apply to exact number that are not measured. Ex) 3 people, 12 inches in a foot, etc.*

Prefixes and Equalities

Prefixes can be placed in front of any unit of measurement to increase or decrease its size by some factor of 10

Prefixes that Increase Size of the Unit

Prefix	Symbol	Numerical Value	Scientific Notation
tera	T	1,000,000,000,000	10^{12}
giga	G	1,000,000,000	10^{9}
mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}

Prefixes that Decrease Size of the Unit

Prefix	Symbol	Numerical Value	Scientific Notation
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	µ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}

Length, Volume and Mass Equalities

- Length
  - 1 m = 100 cm = 1 x 10^2 cm
  - 1 m = 1000mm = 1x 10^3 mm
- Volume
  - 1 L = 10 dL = 1 x 10^1 dL
  - *Note: lab results for blood are often reported in mass per deciliter*
  - Cubic centimeter (cc or cm^3) is the volume of a cube whose dimensions are 1 cm on each side. This has the same volume as a mL and can be used interchangeably (1 cc = 1 mL).
- Mass
  - Patient weight is often in kg, lab tests often in g, mg, µg
  - 1 kg = 1000 g = 1 x 10^3 g
  - 1 g = 1000 mg = 1 x 10^3 mg

Example of Blood Lab Ranges

Substances in Blood	Typical Range
Albumin	3.5-5.0 g/dL
Ammonia	20-150 µg/dL
Calcium	8.5-10.5 mg/dL
Cholesterol	105-250 mg/dL
Iron (male)	80-160 µg/dL
Protein (total)	6.0-8.0 g/dL

Density, Substances, and Compounds

- Density is the mass of a substance divided by its volume
- D = mass of substance/volume of substance
- Every substance has a unique density

- A substance is matter which has a specific composition and specific properties
- Every pure element and every pure compound is a substance
- A compound is formed when atoms of two or more different elements combine and create new materials
- A compound has a constant composition with constituent units which are identical
- Ex) Na and Cl react to form NaCl (table salt)
- Ex) two atoms of H combine with one atom of O to form H_20
- Such transformations are called chemical reactions
- Na, CL and NaCl are all substances

Matter and Energy

Classification of Matter

Classification of Matter

- Matter is anything that has mass and takes up space
  - A pure substance is matter that has a fixed and definite composition
    - Ex) C, H, NaCl, CH_4
  - There are two types of pure substances
    - Elements – composed of one type of material. Each element is composed of atoms which are listed in the periodic table.
      - Ex) Na, Cl, Ca, N, H, C, etc.
      - Elements can not be broken down further by ordinary chemical processes
    - Compound – Consists of atoms of two or more elements always combined in the same proportions
      - Ex) CH_4
      - Compounds can be broken into smaller substances

Compounds and Bonds

- Compounds are held together by attractions called bonds
- We will see several types of bonds including:
  - Ionic bonds
  - Covalent bonds
  - Hydrogen bonds

Mixtures

- Mixtures consist of two or more substances which are physically nixed but not chemically combined
  - Ex) blood is a mixture of blood cells, water, and other dissolved substances
- Mixtures can be homogenous (uniform throughout) or heterogenous (not uniform)
- There are 3 types of homogenous mixtures
  - 1) Solutions
  - 2) Colloids
  - 3) Suspensions
- Homogenous mixtures 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

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*

Information Regarding Colloids and Connective Tissue

- Colloids in biological systems
  - Many large and complex organic molecules such as proteins or protein complexes (proteoglycans in the ECM) are held in a solution because of intermolecular forces
  - These can form thick viscous colloid dispersions with interesting properties
    - Remember the ingredients of connective tissue
      - Specialized cells
      - ECM
        - Fibers
        - Ground substance (colloids composed of proteoglycans and)

- Colloids can go back and forth from a gel to a sol state
- Colloids respond to the following
  - Heat
  - Cold
  - pH
  - Movement
- Colloids will go towards their gel state under the following situations
  - Cold, immobilization, inflammation, infection, acidic pH
- Colloids will go towards their sol state under the following conditions
  - Heat, less acidic pH, mobilization

Matter and Energy

2.2

States and Properties of Matter

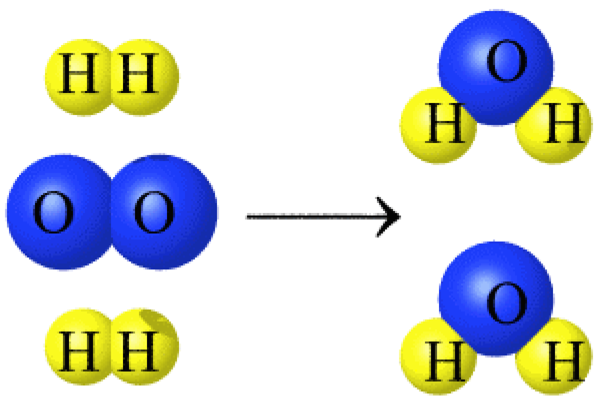
- Matter exists in 3 forms
  - Solid – has a definite shape and volume. Strong attractive forces hold particles (atoms and molecules) together.
  - Liquid – has a definite volume, but not shape. Particles move in random directions, but have sufficient attraction to maintain definite volume.
  - Gas – does not have definite shape or volume. Particles have little attraction and move at high speeds, taking the shape and volume of their container

Physical Properties and Physical Changes

- A substance has physical properties which can be observed and measured such as
  - State at a certain temperature
  - Color, odor
  - Melting point, boiling point
  - Heat and electrical conductivity
- Substances can undergo physical change which will change its state and appearance but not composition.
  - Ex) water changing state from solid – liquid – gas

Chemical Properties and Chemical Change

- Chemical properties describe the ability of a substance to change in a new substance
- When a chemical change occurs, the original substance is converted to one or more new substances.
  - Ex) $O_2 + 2\ H_2 \rightarrow 2H_2O$



- These chemical changes are called chemical reactions and are written in a standard format called a chemical equation which lists the starting substances (reactants) on the left and the final substances (products) on the right. The number and kinds of atoms are the same on both sides of the arrow
- A compound is written by giving its chemical formula. This formula lists the symbols of the elements that make it up and indicates the number of atoms of each element with a subscript
- If no subscript is given, it is understood to be 1
- $C_{12}H_{22}O_{11}$, H_20, NaCl

Energy and Heat

- Energy is defined as the ability to do work
- Energy can be classified as:
  - Potential energy – energy is stored. Something has potential energy based on position (ball on a hill) or based on chemical composition (bonds store energy, breaking bonds releases energy)
  - Kinetic energy – energy in motion
- Heat is know as thermal energy
  - The hotter substances contain particles that move at a faster rate
  - Colder substances contain particles the move at a slower rate

Units of Energy

- The SI unit of energy and work is the joule (J), scientists often use kJ to record this, as a J is a very small amount of energy
- To heat one cup of water you would need about 75,000 J or 75 kJ
- A calorie (cal) is the amount of energy needed to raise the temperature of 1 g of water by 1 degree C
  - 1 cal = 4.184 J

Specific Heat and Energy Values of Food

Specific Heat

- Every substance can absorb heat and every substance has its own characteristic ability to absorb heat
- The energy requirements for different substances are described in terms of a physical property called specific heat
- Specific heat is the amount of heat needed to raise the temperature of exactly 1 g of a substance by exactly 1 degree C

Energy Values of Food

- The energy (caloric) value of food are the kilocalories (or kilojoules) obtained by burning 1 g of this substance (carbohydrate, fat, protein)

Food Type	kJ/g	Kcal/g
Carbohydrate	17	4
Lipid	38	9
Protein	17	4

Questions

- What three forms can matter exist in?
  - Solid, liquid, gas
- Does physical change of a substance change its composition?
  - No
- Does chemical change of a substance change its composition
  - Yes
- How many molecules of water are present in the following - H_20?
  - 1
- How many atoms are H are present in this molecule?
  - 2
- How many molecules of of water are present in the following - 2 H_20?
  - 2
- How many atoms of H are present in each molecule?
  - 2

Questions

- What is the SI unit of energy?
  - J
- What unit is often used for to express the amount of energy it takes to heat 1 g of a substance 1 degree C?
  - cal
- How many cal does 1 g of fat have?
  - 9 cal/g
- What is specific heat?
  - The amount of energy required to raise the temperature of 1 g of a substance 1 degree C
- What is the specific heat of water?
  - 1 cal/g or 4.184 J/g

Atomic Theory

Basic Definitions

- Atom
  - Smallest stable unit of matter
  - Smallest particle of an element that retains the characteristics of that element
- Element
  - Chemically pure substance that cannot be broken down by ordinary physical or chemical means
  - 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 symbols
    - 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])

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

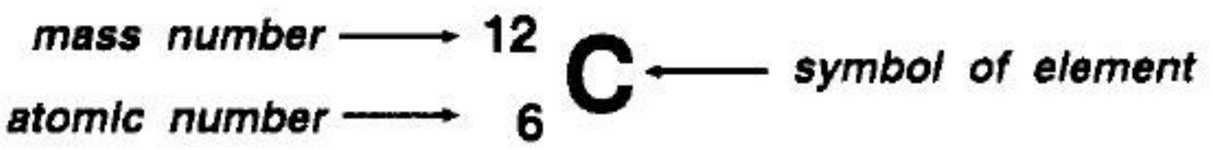
Periodic Table

- 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

Particles	Relative Charge	Relative Mass
Protons	+1	1
Neutrons	0	1
Electrons	-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 is the number of neutrons plus the number of protons
- The atomic weight in the is an average of all the isotopes of this element, taking into account frequency of occurrence.

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

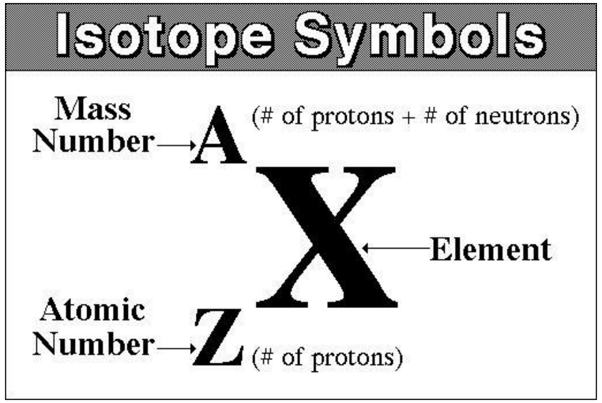
- All atoms of a given element have the same atomic number
  - This indicates the number of protons in the nucleus
  - The number of electrons will equal the number of protons
  - Protons have a positive charge and electrons have a negative charge, so the atom will have a neutral charge
- Atoms of a 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 weight 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



Review Elements

- Each element is identified by one or two letter symbols (if two, the second letter is lowercase)
- Each element has an atomic number which indicates the number of protons contained in the nucleus of atoms of this element. This number is constant for this element and distinguishes it from other elements
- 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
  - *New info: This is just an example, you are not required to know this for the test*
    - 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
- Elements have a mass number which is the number of protons in the nucleus of atoms of this element plus the average number of neutrons in the nucleus.
- The number of electrons equals the number of protons in an atom
- Electrons do not contribute to significantly to the mass 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

Review Isotopes and Ions

- Protons have a positive charge, electrons have a negative charge and neutrons have a neutral charge
- Only protons and neutrons contribute to the atomic mass
- Isotopes
  - Atoms of the same element (same number of protons and electrons), but with a different number of neutrons are referred to as isotopes (example, carbon-12 and carbon-13)
- Ions
  - Atoms without 2 electrons in its first electron shell if it only has one, or 8 electrons in its valence shell will react with other atoms by either gaining, losing or sharing and electron
  - If it gains an electron, it is a negative ion called a anion
  - If it loses an electron, it is a positive electron called a cation