This review is intended to help review the majority of topics we have discussed in class. It is not 100% inclusive of all material that may be on the exam. Questions may be asked about topics that are not listed on this review sheet.

Chapter 1 – Matter

Matter, properties of matter; physical vs. chemical changes, states: solids, liquids, gases
Pure substances and mixtures; types of mixtures – heterogeneous vs. homogeneous,
Types of pure substances: elements, compounds; Atoms and molecules
Chemical symbols of the elements: know symbols and names of selected elements on periodic table
Chemical formulas (with subscripts)

Chapter 2 – Measurements

Metric system: meter, liter, gram
Exact and inexact numbers, significant numbers, calculations involving significant figures
Scientific notation (only significant figures are written)
Dimensional analysis (unit factor method): include unit labels with numbers to help set up calculations
Know by memory: 454g = 1pound, 3.78 liters = 1 gallon, 2.54 cm = 1 inch
Density = mass/ volume (g/cm^3); be able to calculate density given mass and volume.
Temperature scales: °F, °C, K: convert from one to another, understand the relationships between scales
Heat energy content is measured in calories; 1 calorie is the amount of energy to raise 1 g H_2O by 1°C.

Chapter 3 – Atomic Structure

Structure of the atom: nucleus, subatomic particles, protons, neutrons, electrons
Atomic number and mass number; each atom has unique numbers that define it
Isotopes: atoms with the same number of protons and electrons, but different numbers of neutrons
Atomic mass: average atomic mass of an element, depends on the natural abundances of elements
Metals vs. Nonmetals: Metals are located to the left of the staircase line on the periodic table, nonmetals to the right. Metals conduct heat and electricity, exhibit luster, and are malleable.
Electrons are located on quantized energy levels around the nucleus called "orbitals" and have very little mass.
We will use the Bohr model of the atom:
- circular orbits having 8 electrons in the outermost orbital (except H, He that have only 2)
- we will not discuss electron "shells," "subshells," or "configurations" (such as $1s^2 2s^2 2p^6 3s^2$… etc)

Be able to draw Lewis dot structures with the appropriate numbers of valence electrons
Understand the relationships between valence electrons and the representative groups in the periodic table
Distinguish between groups and periods on the periodic table; identify the following elements on the table:
- noble gases, representative elements, transition elements, alkali metals and alkaline earth metals

Nuclear chemistry - fission: parent and daughter nuclei, general concept of $E=mc^2$
Nuclear stability and radioactivity: excessive neutrons contribute to instability
Radioactive emissions: alpha ($^4_2\alpha$), beta ($^{\ 0}_{-1}\beta$), gamma (γ)
- Describe each type of emission, its mass, velocity, penetration depth, damage to tissues, etc.
- Be able to balance nuclear equations (e.g., $^{32}_{15}\mathrm{P} \rightarrow {}^4_2\alpha$ + __?__)

Half life: Understand the concept of half life for radioisotopes
- Calculate how much of an isotope is remaining after a given number of half lives, or calculate the half life, given the amount remaining after a measured period of time.

Chapter 4 – Chemical Bonds

Understand the octet rule and the related role of valence electrons in determining bonding
Ionic compounds: charged attraction between metals and nonmetals, determine ionic formulas & names
Molecular compounds: covalent bonds between two or more nonmetal atoms, bonding & non-bonding pairs
Covalent bonds can be single, double or triple bonds; predict bonding using valence electrons and octet rule
Polarity of a covalent bond is determined by the electronegativity of the atoms involved in the bond.
Predict molecular geometry (shape) of molecules from bonding and non-bonding pairs around central atom.
Assign names to ionic and covalently-bonded compounds; e.g., NaCl (ionic) or CO_2 (covalent)
Memorize 7 polyatomic ions and their charges: OH^-, CN^-, CO_3^{2-}, SO_4^{2-}, NO_3^-, PO_4^{3-}, NH_4^+.
Be able to write compound formulas involving polyatomic ions, using correct parentheses and subscripts.

Chapter 5 – Chemical Calculations

Calculate formula masses and molecular weights using the periodic table.
Understand the concept of the mole; know Avagadro's number and what it means (6.023×10^{23})
Using the mass of a mole, calculate the number of molecules or individual atoms in a given mass.
Write and understand chemical formulas with subscripts and parentheses.
Write and balance chemical equations.
Calculate the grams and/or moles of reactants and products in chemical equations. (g → mole→ mole → g)

Chapter 6 – Gases. Liquids, and Solids
Matter is in motion; motion of molecules increases with heat.
Absolute zero is the temperature at which all atomic and molecular motion ceases. (0K, or -273°C).
Combined gas law, $P_1V_1/T_1 = P_2V_2/T_2$, with calculation (Terms cancel from both sides when they are constant.)
Ideal Gas Law: PV=nRT P=pressure(atm), V=volume(liters), n=moles, R=0.082 (L·atm/K·mole), T (Kelvins).
Dalton's Law of Partial Pressures: $P_t = p_1 + p_2 + p_3$…
Vapor pressure: evaporation, boiling, explain why boiling point of water changes with altitude
Intermolecular forces help determine boiling points: Define hydrogen bonding.

Chapter 7 – Solutions
Solute, solvent, alloys, liquids, solids, gasses as solutes. Explain the phrase, "Like dissolves Like."
Solution formation: dissolution of ionic compounds to form solvated ions.
Solubility rules for ionic compounds: e.g., which is more soluble, $CaCO_3$ or Na_2CO_3?
Solute concentration units: %(w/w), %(w/v), %(v/v), molarity (M=moles/L), normality (N=equivalents/L)
Dilution calculations: $C_1V_1=C_2V_2$ ← *Use this equation… given 3 values, calculate the 4th.*
Colligative Properties: freezing (melting) point depression (e.g. antifreeze).
Osmosis and Osmotic Pressure: solvent (water) passes through a membrane into liquids with less water.
Osmotic pressure draws water into plants, through the digestive tract, etc.
Osmotic pressure is determined by TOTAL dissolved particles: 1mole NaCl yields 2 total moles of ions (both Na^+ & Cl^-)
Define and know the meanings of the terms: Isotonic, hypertonic and hypotonic solutions.
Dialysis

Chapter 8 – Chemical Reactions
Combination reactions X+Y → XY; Decomposition reactions XY → X+Y; Single & Double displacement reactions
Oxidation and reduction reactions ("Redox" reactions): Oxidation = loss of elections; Reduction = gain of electrons
(Definition on page #205 is not correct!); Examples: Oxidation: $Cu \rightarrow Cu^{2+} + 2e^-$ Reduction: $Ag^+ + 1e^- \rightarrow Ag$
Formation of positively-charged metal ions from their elements is oxidation.
Reactants must collide with each other to react. Reaction rates depend on frequency, orientation, & energy of collisions.
Rates of chemical reactions depend on reactant concentrations, temperatures, and presence of catalysts.
Chemical Equlibrium: LeChatelier's principle: equilibrium shifts to relieve stress… temperature, reactants, pressure.

Chapter 9 – Acids, Bases, and Salts
Definition of acids and bases: acids donate H^+, bases increase OH^- ions in water
Names (formal & common) and formulas of common acids: HCl, HNO_3, H_2CO_3, H_2SO_4, H_3PO_4.
Identify the economically important acids and bases and their uses.
Names and formulas of common bases: NaOH, KOH, $Ca(OH)_2$, $Mg(OH)_2$, NH_4OH
Reactions of acids with metals (e.g., copper); know their reaction products (metal salt plus H_2 gas)
Identify elements oxidized and reduced during a reaction with acid and metals
Neutralization reactions between acids and bases: acid + base → salt + water; give examples, write eqns.
Self-ionization of water: $H_20 \leftrightarrow H^+ + OH^-$
pH definition: -log[hydrogen ion concentration in moles per liter]; calculate pH using calculator
Convert pH to H^+ concentration
Understand the pH scale: powers of 10, acid vs. basic pH
Buffers resist pH changes when acids or bases are added to the solution
Bicarbonate buffer system: $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow H^+ + CO_3^{2-}$

Chapter 10 – Saturated Hydrocarbons
Carbon atoms bond to other carbons and hydrogen atoms to form hydrocarbons; valence of carbon, 4 bonds
Alkanes are hydrocarbons with single bonds between carbon atoms; non-cyclic: C_nH_{2n+2}, cyclic alkanes: C_nH_{2n}
Structural formulas and structural isomerism; different conformations are due to rotation of single bonds
Names of alkanes: C_1-C_{10}; methane, ethane, propane,…, decane
Cyclic alkanes can exhibit *cis*- and *trans*- isomerism
Assign proper IUPAC names of branched and/or cyclic alkanes
Hydrocarbons come from petroleum; distillation, cracking and reformation give us a wide variety of products
Physical properties of hydrocarbons: gases, liquids, solubilities
Chemical reactions of alkanes: combustion, halogenations (substitution of F, Cl, Br, or I for H)
Key reactions: Alkane + $O_2 \rightarrow CO_2 + H_2O$, and $R\text{-}H + X_2 \rightarrow R\text{-}X + H\text{-}X$ (R=alkane, X=halogen such as Cl, Br)

Chapter 11 – Unsaturated Hydrocarbons

Unsatuated hydrocarbons contain one or more C=C or C≡C bonds
General formula for non-cyclic alkenes: C_nH_{2n}, alkynes: C_nH_{2n-2}
Names of alkenes: C_2-C_{10}; ethene, propene,…, decene
Alkenes can exhibit *cis*- and *trans*- isomers
Names of alkynes: C_2-C_{10}; ethyne, propyne,…, decyne
Assign IUPAC names for branched and/or cyclic alkenes and alkynes
Chemical reactions of alkenes:

Addition reactions: H_2, Cl_2, Br_2, HCl, HBr, H_20 all add to double bonds; (Markovnkov's rule)
Polymerization of alkenes: small alkenes combine to form long chains of polymers
Know polymerization reactions and recognize names of important polymers in Table 11.2

Aromatic hydrocarbons: Rings with delocalized multiple double bonds; most common is benzene, C_6H_6
Name substituted benzene rings with proper numbering systems; also *ortho*-, *meta*-, and *para*- prefixs
Know the structures of toluene, xylenes, naphthalene, anthracene
Phenyl groups are benzene rings attached to carbon atoms as substituents on longer chains.
Reactions of benzene: alkylation and halogenation
Know reactions of alkenes and alkynes (pp. 304-305)

Chapter 12 – Single-bond Derivatives

Halogenated hydrocarbons: R-X (where X is F, Cl, Br, I)

Names start with number- and fluoro-, chloro-, bromo-, or iodo-: e.g., 2-chlorobutane
Common names for some solvents: e.g., carbon tetrachloride: CCl_4 or ethyl bromide

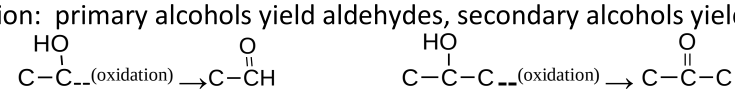
Alcohols & Phenols: R-OH

IUPAC (one-word) names: change alkane name by dropping "-e" and adding "-ol.": ethanol, methanol
Common names for common solvents: ethyl alcohol, methyl alcohol, isopropyl alcohol. (pg312)
Ethanol concentrations are often expressed using the "proof" scale, where 100% = "200 Proof"
Polyhydroxy alcohols: 1,2-ethanediol (ethylene glycol): HO-C-C-OH, propylene glycol, glycerin (p313)
Phenols names: IUPAC: phenol, 4-methylphenol; common name: phenyl alcohol
Properties of alcohols: boiling points go up with number of carbons and alcohol groups (p316-7)
Alcohols form strong hydrogen bonds to themselves and water
Reactions of alcohols:

dehydration yields alkenes (reversal of hydration)

C-C-OH $\xrightarrow{(H+)}$ C=C + H_2O

oxidation: primary alcohols yield aldehydes, secondary alcohols yield ketones



Ethers: R-O-R

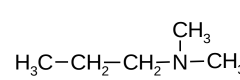
Names: ethyl methyl ether: C-O-C-C, dimethyl ether: C-O-C (p322)
Properties: flammable, anesthetic activities

Thiols: R-SH *(sulfhydryl group)*

Recognize thiol functional group(s)
Thiols have strong, disagreeable odors; e.g., skunk odor, added to natural gas for safety
Oxidation of thiols yields disulfide bonds: C-C-SH + HS-C-C → C-C-S-S-C-C decreases odor;
(dilute H_2O_2 is an excellent oxidizing agent)

Amines: R-NH_2 (R-NH-R, or R-N-R_2)

Names: ethyl amine: C-C-NH_2, ethylmethylamine: C-C-NH-C, *N,N*-dimethylpropanamine:



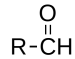
Dopamine, epinephrine, and ephedrine are all biologically active amines (p330)
Low molecular weight amines have a "fishy" smell
Amines can be protonated with acid to form amine salts:

R-NH_2 + H^+ → R-NH_4^+ (non-volatile; increases solubility of amines: e.g, "hydrochloride"salts)

Heterocyclic amines have ring systems where N has been substituted for at least one C in the ring.
Caffeine, nicotine morphine, codeine, heroin are all examples of heterocyclic amines (p334)
Review key reactions and equations on pg 336

Chapter 13 – Carbon-oxygen Double Bonds

Carbonyl group: C=O

Aldehydes: -CHO; names end in "-al": 

methanal (formaldehyde), ethanol (acetaldehyde), propanal, benzaldehyde, etc.

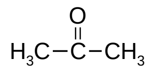
usually have peculiar odors (almonds, cinnamon, vanilla)

reactions: reduction to alcohols: C=O + H_2 -> CH-OH

oxidation to acids: C=O -> -COOH

during oxidation, aldehydes can reduce metal ions: Cu^{2+} to Cu^{1+} (Benedict's test)

or Ag^{1+} to Ag^{o} (Tollen's test - mirror forms)

Ketones: names end in "-one": 

2-propanone (acetone), 2-butanone (ethylmethylketone), 3-pentanone (diethylketone), etc.

Reactions: reduction to alcohols C=O + H_2 -> CH-OH

oxidation does not occur!

Excellent solvents used industrially e.g., finger-nail polish remover, varnish remover, etc.

Carboxylic acids: -COOH, names end in "-ic acid":

Formic acid (from ants), acetic acid (vinegar), propanoic acid, butanoic acid, benzoic acid, etc.

Acids release protons in aqueous solutions: -COOH -> $-COO^-$ + H^+

Some acids have more than one –COOH group: succinic acid(2), glutaric acid(2), citric acid(3)

Three common OTC pain relievers are carboxylic acids: Ibuprofen and Naproxen and aspirin

Carboxylate salts form when acids are neutralized with base: -COOH + NaOH -> $-COO^-$ Na^+ + H_2O

Carboxylate salts are principle ingredient in soaps

Small molecular weight carboxylic acids are preservatives: benzoic acid, sorbic acid, propionic acid

Carboxylic acid reactions (condensations):

with alcohols to form esters: R-COOH + HO-R' -> R-COO-R' + H_2O

with amines to form amides: R-COOH + H_2H-R' -> R-CONH-R' + H_2O

Esters: -COOR, names end in "-ate."

Methylformate, methylacetate, propylbutanonate, ethylbenzoate, etc.

Recognize the acid and alcohol building blocks for esters

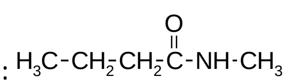
Esters have characteristic flavors and odors ("fruit-like" smells)

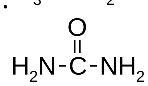
Aspirin is an ester of acetic acid and the alcohol group on salilcylic acid, "acetylsalicylic acid"

Esters are easily hydrolyzed, yielding the original acids and alcohols.

Amides: - CONH-R, names end in "-amide."

Formamide, acetamide, benzamide, etc.

IUPAC names include "*N*-": N-methylpropanamide: 

Urea, diamide, is an important amide biologically: 

The pain reliever, acetaminophen, is an amide of acetic acid (pg371)

Reactions of amides: hydrolysis yields carboxylic acids and amines

Condensation Polymers: polyesters and polyamides

Polyesters are synthesized from diacids and dialcohols: PET: Dacron, Mylar, soft-drink bottles, etc.

Polyamides are synthesized from diacids and diamines: nylons, Kevlar, etc.

Chapter 14 - Carbohydrates

General: $C{\cdot}H_2O$; Subclasses: pentoses(C_5), hexoses(C_6); aldoses (aldehydes) and ketoses (ketones)

Handedness ("D" & "L") forms of monosaccharides; rotation of plane-polarized light right or left

Important monosaccharides:

Glucose (dextrose, blood sugar) is a hexose (C_6) and an aldose, (an aldohexose), is a reducing sugar, and rotates light to the *right* in aqueous solution; it is an important nutrient in the blood stream.

Fructose (levulose) is a ketohexose (hexose and ketose); it is the sweetest tasting sugar; it rotates light to the left, and is an important sweetener for soft drinks and other foods;

Ribose is an aldopentose (aldose and pentose); 5-carbon sugar, important building block in DNA and RNA.

Monosaccharides exist primarily as cyclic forms in solution

Most monosaccharides are reducing sugars; that is, they oxidize easily and concomitantly reduce other chemicals such as Cu^{2+} ions (Benedict's test).

Disaccharides:

- Maltose: glucose-glucose — reducing sugar; common in foods (malt flavoring, beer)
- Lactose: galactose-glucose — reducing sugar; "milk sugar"
- Sucrose: glucose-fructose — non-reducing sugar; "table sugar," "cane and beet sugar"

Polysaccharides:

- Cellulose: polyglucose, linked with β(1→4) bonds, not digestible, structural component of plants
- Starch: polyglucose, linked with α(1→4) bonds, complex carbohydrate, good glucose source
- Glycogen: branched polyglucose, linked with α(1→4) bonds; very soluble, "animal starch"
- Chitin: linear polymer with β(1→4) bonds, contains acetylamino groups on each glucose monomer

Chapter 15 – Lipids

Lipids are fats and oils that are extractable into non-polar organic solvents such as hexane
Fatty acids are the principle components of fats and oils; fatty acids have 12-20 carbon reduced atoms (contain mostly hydrogen atoms);
Saturated and unsaturated fatty acids: (*cis*- double bonds in fatty acid chains)
Essential fatty acids: linoleic and linolenic acid, omega-3 family of fatty acids,
Triacylglycerols are tri-esters of 3 fatty acids and glycerol
Unsaturated nature of fatty acids lowers the melting point and as such, "oils" are liquids at room temp.

Reactions: hydrolysis / saponification: yields free fatty acids and glycerol; components of soaps
Hydrogenation: adding hydrogen across C=C double bonds to create more saturated FAs
Oxidation: oxygen reacts with C=C double bonds to create small aldehydes and acids.

Phospholipids: Tri-esters of glycerol with 2 fatty acids and one phosphoric acid group. ("lecithin")
Principle components of biological membranes

Sphingolipids: fatty-acid liked to sphingosine via an amide linkage; present in nerve tissues.

Steroids: Lipids that contain a characteristic fused 4-ring system (pg 423)
Cholesterol – the most abundant human steroid; alcohol; building block for hormones
Bile salts: emulsifying agents to help solubilize dietary lipids; stored in the gall bladder
Steroid hormones: estrogens (estradiol), androgens (testosterone), progestins

Cell Membranes are composed of lipids; phospholipids are most common lipids; membranes also contain significant amounts of protein and some carbohydrates and cholesterol.

Chapter 16 – Proteins

Amino acids are the building blocks for proteins
AA properties are determined by their side-chains: e.g., polar, non-polar, aromatic, acids, bases, etc.
Two AAs contain sulfur; cystine, forms disulfide linkages that are easily oxidized and reduced.
AAs are classified as either "essential" or "non-essential"
Phenylalanine can cause developmental problems for PKU babies
Tryptophan is a precursor for serotonin
AAs are linked together with amide (peptide) bonds to form long polymers called proteins
Peptide bonds may be hydrolyzed in acid, yielding free amino acids and smaller peptide chains
There are four levels of protein structure:

- Primary: linear sequence of AAs
- Secondary: alpha-helix and beta-sheet
- Tertiary: Overall 3-D shape of protein
- Quaternary: Interactions between separate subunits of proteins

Enzymes are proteins that act as catalysts
Enzymes are unique catalysts that are highly specific and are regulated by conditions in the cells
Enzymes react with "substrates" and help speed up their conversion to "products"
Enzyme turnover numbers describe how fast substrates can be converted to products.

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