

Chemistry Exam Review

Unit 1 – Organic Chemistry

- **BIG IDEAS:**
 - **Organic compounds have predictable chemical and physical properties determined by their respective structures.**
 - **Organic chemical reactions and their applications have significant implications for society, human health, and the environment.**
- Naming and drawing compounds
 - Alkanes / Alkenes / Alkynes
 - Single / Double / Triple bonds
 - Cyclic and aromatic hydrocarbons
 - Hydrocarbon derivatives

Halocarbon (g7 prefix)	Group7	Ether (-oxy)	O	Carboxylic Acid (-oic acid)	CO/OH
Alcohol (-ol)	OH	Aldehyde (-al)	CO	Ester (-oate)	CO/O
Amine (-amine)	N	Ketone (-one)	CO	Amide (-amide)	CO/N

- Organic reactions
 - Addition
 - Markovnikov's Rule: “The hydrogen atom of the small molecule will attach to the carbon atom of the double bond that is bonded to the most hydrogens”
 - Elimination
 - Double bond forms between the carbon atoms that had the atoms removed
 - The hydrogen atom is more likely to be removed from the carbon atom with the most C-C bonds.
 - Substitution
 - $C - Y + A - Z \rightarrow C - Z + A - Y$
 - Condensation
 - Water is often the smaller molecule formed
 - Esterification
 - A carboxylic acid and an alcohol react to produce an ester and water
 - Hydrolysis
 - A molecule is broken apart through the addition of a water molecule
 - The -OH is added to one side of a bond, and the H is added to the other side of the bond

- Reduction
 - Forming more bonds to hydrogen. Common reducing agents are [H], LiAlH₄, H₂/Pt
- Oxidation
 - Forming more bonds to oxygen. Common oxidizing agents are [O], KMnO₄, K₂Cr₂O₇
- Combustion
 - Complete Combustion: $C_xH_yO_z + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)} + \text{energy}$
 - Incomplete Combustion: $C_xH_yO_z + O_{2(g)} \rightarrow C_{(s)} + CO_{(g)} + CO_{2(g)} + H_2O_{(g)} + \text{energy}$
- Polymers and monomers
 - Molecules that repeat. ex DNA, protein, nylon, polyester
 - Addition Polymerization
 - Monomers with multiple bonds are added together by breaking down the bonds
 - Condensation Polymerization
 - Uses condensation to produce synthetic polymers of multiple functional groups

Unit 2 – Structures and Properties of Matter

- **BIG IDEAS:**
 - **The nature of the attractive forces that exist between particles in a substance determines the properties and limits the uses of that substance.**
 - **Technological devices that are based on the principles of atomic and molecular structures can have societal benefits and costs.**
- Properties of water
 - Polar, good solvent because it's polar, very abundant
- Properties of various bonding
 - Ionic

Property	Description
Melting and Boiling Points	High due to strong attractions between ions
Solubility	Soluble in water when the attractive forces between the ions and water molecules are stronger than the attractive forces among the ions themselves
Mechanical Properties	Hard and Brittle, so will break when struck
Conductivity	No conductivity in solid because ions can't move. However, compounds conduct when dissolved in water and ions can move

- Covalent

Property	Description
Melting and Boiling Points	Low due to weak intermolecular forces, being non-polar and having low electronegativity
Solubility	Low solubility due to being non-polar
Mechanical Properties	Soft and squishy due to being very flexible and molecules can slide around each other
Conductivity	Cannot conduct because there are no ions

- Metallic

Property	Description
Melting and Boiling Points	The stronger the bonding forces, the higher the melting and boiling points of pure metals
Electrical and Thermal Conductivity	Metals are good conductors because their electrons can freely move between atoms
Malleability and Durability	Based on the electron-sea model, metals can be shaped due to the electrons surrounding them
Hardness	Variations between metals is due to a difference in crystal size (smaller = harder)

- Influences of molecular forces

Dipole-Dipole	Dipole and polarity due to partial charges causing attraction
Induced Dipole	Between a polar molecule or an ion and a non-polar molecule due to the nearby polar molecule
London Dispersion	Attraction that occurs between all molecules
Ion-Dipole	Ionic charge and dipoles attraction

- Quantum numbers and symbols

Name	Symbol	Allowed Values	Property
Principal	n	n = 1 to n = ∞	Orbital Size and energy level
Second / Orbital	l	l = 0 to l = (n - 1)	Orbital shape
Magnetic	m_l	$m_l = -n$ to $m_l = +n$	Orbital orientation
Magnetic-Spin	m_s	$m_s = +\frac{1}{2}$ or $m_s = -\frac{1}{2}$	Spin orientation

- Aufbau principle, Pauli Exclusion Principle, Hund's rule
 - Pauli Exclusion Principle: No two electrons have the same four quantum number values
 - Aufbau Principle: An energy sublevel must be filled before moving onto another sublevel
 - Hund's Rule: Electrons in an unfilled shell must be spread out as much as possible

- VSEPR theory (shape, angles)
 - **VSEPR** stands for **V**alence-**S**hell-**E**lectron-**P**air-**R**epulsion Theory
 - Chart will be provided on exam, memorize bonding angles.
 - Covalent bond formation involved atomic orbital overlap, creating molecular orbitals
 - Molecular orbitals have different energy levels and shapes than atomic orbitals
 - Electrons in molecular orbitals are delocalized
 - Hybridization
 - Depends on the shape and angle of the atom
- Electron Configuration
 - $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d$
 - Follow periodic table
- Exceptions
 - Resonance: Structures that show relative position of atoms but different positions of electron pairs due to bond lengths being different, such as in O_3
 - Co-ordinate Covalent Bond: Some atoms contribute multiple electrons, such as in NH_4
 - Incomplete octet: Central atom has fewer than a completed octet, such as in BF_3
 - Expanded octet: Central atom has more than an octet of electrons, shown in P3 elements, such as in SF_6
- Properties of solids

Crystal	Particles	Force/Bond	Properties
Ionic	Ions (+, -)	Ionic	Hard, brittle, high m.p/b.p, conducts as liquid/solution
Metallic	Cations	Metallic	Soft/hard, conducts in solid/liquid, ductile, malleable, lustrous
Molecular	Molecules	London, dipole-dipole, hydrogen	Soft, low m.p/b.p, no conductivity
Covalent Network	Atoms	Covalent	Very hard, very high m.p/b.p, non-conducting

Unit 3 – Energy Changes and Rates of Reaction

- **BIG IDEAS:**
 - Energy changes and rates of chemical reactions can be described quantitatively.
 - Efficiency of chemical reactions can be improved by applying optimal conditions.
 - Technologies that transform energy can have societal and environmental costs and benefits.
- Heat transfer (exothermic, endothermic)
 - **Exothermic** (releasing thermal energy as heat flows out of the system)
 - **Endothermic** (absorbing thermal energy as heat flows into the system)
- System types → Open, closed, isolated
 - Open System: Energy and matter can freely flow in and out of the system.
 - Closed System: Energy can freely flow in and out of the system, but not matter.
 - Isolated System: An ideal system where neither energy or matter can flow in or out.
- Specific heat capacity
 - Given in question
- Enthalpy changes (ΔH)
 - If heat enters a system, ΔH is positive and the process is endothermic.
 - If heat leaves a system, ΔH is negative and the process is exothermic.

Physical Changes
 $\Delta H = 10^0 - 10^2$ kJ/mol

Energy is used to overcome or allow intermolecular forces to act
Fundamental particles remain the same
ex. Changing states of matter or dissolving matter

Chemical Changes
 $\Delta H = 10^2 - 10^4$ kJ/mol

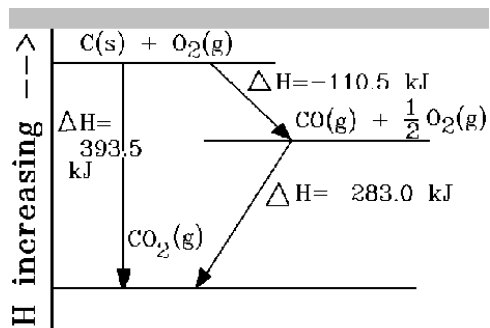
- Energy changes overcome the electronic structure and chemical bonds within particles
- ex. The composition of matter changes, a reaction occurs

Nuclear Changes
 $\Delta H = 10^{10} - 10^{12}$ kJ/mol

- Energy changes overcome the forces between protons and neutrons in nuclei
- ex. New atom with different number of protons and neutrons form, through a process such as nuclear decay

- Molar enthalpy
 - Molar enthalpy (ΔH_x) can be used to describe enthalpy change per mole.

- Enthalpy diagram



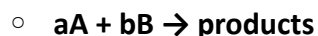
- Calorimetry
 - Calorimetry is the process of measuring energy changes in a chemical system.
 - $Q = mc\Delta T$
- Enthalpy of a Reaction
 - $H^\circ_r = n\Delta H^\circ$
 - Standard molar enthalpy change
- Hess' law
 - $\Delta H_{\text{target}} = \Delta H_1 + \Delta H_2 + \Delta H_3 + \dots$ or $\Delta H_{\text{target}} = \sum \Delta H_{\text{known}}$
- Enthalpy of Formations
 - $\Delta H^\circ_f = \sum (n\Delta H^\circ_f \text{ products}) - \sum (n\Delta H^\circ_f \text{ reactants})$
- Efficiency
 - $Eff = \frac{E_{out}}{E_{in}}$
- Chemical Kinetics
 - $r = \Delta[A]/\Delta t$
- Collision Theory
 - The orientation of the reactants (the collision geometry) must be favorable
 - The collision must occur with sufficient energy (Also called the activation energy, E_a)
- Reaction Mechanisms
 - Rate-Determining Step: The slowest elementary step, highest E_a

- Factors affecting rates of reaction

Chemical Nature of the substance	<ul style="list-style-type: none"> • The chemical properties of a compound • ex. Gold and silver reacts slowly, while potassium and sodium are very reactive.
Concentration	<ul style="list-style-type: none"> • The concentration of a substance • ex. Stomach acid (diluted) reacts slowly while pure acetic acid (concentrated) reacts much faster.
Temperature	<ul style="list-style-type: none"> • The temperature of the substance • ex. The higher temperature of the substance, the faster it reacts. Generally, every increase of 10°C results in the reaction occurring 2-3x faster.
Presence of a catalyst	<ul style="list-style-type: none"> • A catalyst is an external element that is usually not consumed during the reaction • The presence of a catalyst can speed the reaction up • ex. Enzymes in the body can help break down sugars and other nutrients.
Surface Area	<ul style="list-style-type: none"> • The amount of surface area of a substance • ex. The difference between wood grains and a wood log. Wood grains burn very fast and can be lethal due to how fast combustion will occur, while a wood log burns relatively slowly.

- Rate law

- $r = \frac{\Delta[A]}{\Delta t}$



- **$r = k[A]^x[B]^y$**

- Rate constant (k)

- Order of reaction

	Order of Reaction			
Concentration Change	0	1	2	3
x1	$1^0 = 1$	$1^1 = 1$	$1^2 = 1$	$1^3 = 1$
x2 (doubling)	$2^0 = 1$	$2^1 = 2$	$2^2 = 4$	$2^3 = 8$
x3 (tripling)	$3^0 = 1$	$3^1 = 3$	$3^2 = 9$	$3^3 = 27$

Unit 4 – Chemical Systems and Equilibrium

- **BIG IDEAS:**
 - **Chemical systems are dynamic and respond to changing conditions in predictable ways.**
 - **Applications of chemical systems at equilibrium have significant implications for nature and industry.**
- Le Chatelier principle → graphing

Change	System Shift	Explanation
Concentration Changes		
[Reactant] ↑ / [Product] ↓	Favors product	Increases rate of forward reaction, shifting equilibrium towards the right
[Reactant] ↓ / [Product] ↑	Favors reactant	Increases rate of reverse reaction, shifting equilibrium towards the left
Volume and Pressure Changes		
Volume ↑ / Pressure ↓	Favors side with more gas	Less molecule collision, counteracts by increasing number of molecules
Volume ↓ / Pressure ↑	Favors side with less gas	More molecule collision, counteracts by decreasing number of molecules
Pressure ↑ (adding inert gas)	No shift occurs	Increases pressure and concentration equally
Temperature Changes		
Temperature / E _{th} ↑	Favors side absorbing E _{th} , K _{eq} decreases	Thermal energy is converted to chemical energy to counteract temperature increase
Temperature / E _{th} ↓	Favors side releasing E _{th} , K _{eq} increases	Chemical energy is converted to thermal energy to counteract temperature decrease
Addition of a Catalyst		
Catalyst ↑	No shift occurs	Increases rates of forward and reverse reactions equally

- Factors necessary for equilibrium
 - System must be closed
 - Visible properties of a system are unchanging
 - System must remain at a constant pressure and temperatures
 - Even at equilibrium, forward and reverse reactions still occur, but at an equal rate
- Equilibrium constant (K_{eq})

$$K_{eq} = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

- Approximation method

- $[reactant] - x \simeq [reactant]$
- $\frac{[reactant]}{K_{eq}}$
- Assumption rule
 - If answer ≥ 1000 , expression is simplified
 - If answer < 1000 , expression cannot be simplified

- Reaction Quotient

$$Q_{eq} = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

- $Q_{eq} < K_{eq}$...system needs to shift right (reactants are favored)
- $Q_{eq} = K_{eq}$...system is at equilibrium
- $Q_{eq} > K_{eq}$...system needs to shift left (products favored)
- Common ion effect
 - Equilibrium shifts due to two compounds that share a common ion being in the same solution (ex. HCL and NaCl) and causing precipitation
- Polyprotic acids
 - Monoprotic / Diprotic / Triprotic
 - ex. HNO_3 / H_2SO_4 / H_3PO_4
- K_a/K_b
 - $K_a K_b = K_w = 1.0 \times 10^{-14}$
- Finding pH/pOH – Has the same formulas
 - $pH = -\log[H]$
 - $[H] = 10^{-pH}$
- Percent dissociation / ionization
 - $p = \frac{\text{concentration of acid ionized}}{\text{concentration of acid solute}}$
- Acid-base theories
 - Arrhenius (1884)
 - Acids contain H^+
 - Bases contain OH^-

- Bronsted-Lowry (1932)
 - Acids are proton donators (conjugate base)
 - Bases are proton acceptors (conjugate acid)
- Strong/weak acid/bases

Strong Acids	Weak Acids
Hydrochloric Acid	Acetic Acid
Sulfuric Acid	Carbonic Acid
Nitric Acid	Hydrosulfuric Acid

Unit 5 – Electrochemistry

- **BIG IDEAS:**
 - **Oxidation and reduction are paired chemical reactions in which electrons are transferred from one substance to another in a predictable way.**
 - **The control and applications of oxidation and reduction reactions have significant implications for industry, health and safety, and the environment.**
- Redox
 - LEO says GER
 - Reduction: A process in which electrons are gained. (Oxidation number increases)
 - Oxidation: A process in which electrons are lost. (Oxidation number decreases)
- Oxidation Numbers
 - Used to determine the oxidizing and reducing agents. Oxidation numbers in an atom should equal zero or its designated charge
- Electric Cells
 - Cathode (negative terminal): The electrode where reduction occurs. The strongest oxidizing agent always undergoes a reduction at the cathode. Receives positive ions to balance gaining electrons (reduction)
 - Anode (positive terminal) : The electrode where oxidation occurs The strongest reducing agent always undergoes an oxidation at the anode. Receives negative ions to balance losing electrons (oxidation)
 - Electrode: A solid electrical conductor
 - Electrolyte: An aqueous electrical conductor

- Primary Cell: An electric cell that cannot be recharged.
 - ex. dry cell, alkaline dry cell, mercury cell
 - Commonly used in consumer items such as flashlights, radios, hearing aids and watches.
- Secondary Cell: An electric cell that can be recharged.
 - ex. Ni-Cad cell, lead-acid cell
 - Commonly used in long-term technology such as power tools, portable computers, and vehicles.
- Fuel Cell: An electric cell that produces electricity by a continually supplied fuel.
 - ex. aluminum-air cell, hydrogen-oxygen cell
 - Used in high-level technology such as electric cars, vehicles and space shuttles.
- Standard Cell Voltage
 - $\Delta E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}}$
 - If the value is positive, the reaction is spontaneous
 - If the value is negative, the reverse reaction is spontaneous and the electrodes are reversed.
- Corrosion
 - Spontaneous redox altering the strength of a metal
 - Metals are readily oxidized by atmospheric oxygen

Painting	Uses a protective coat to prevent exposure to water and air. Susceptible to corrosion if the paint is chipped or wears off.
Enamel	Nonreactive glass that is melted onto a metal surface. It is effective but is not durable, so it is used in jewelry, pots and pans.
Alloys	Uses different metal combinations to prevent rust by changing physical and chemical properties. For example, stainless steel, which is an alloy of iron and chromium and is more resistant to corrosion. However, it is extremely expensive, so it is not likely to be used in large projects.
Galvanizing / Sacrificial Protection	Uses a metal that is more reactive and less resistant to oxidation in order to cause oxygen to prioritize it. This way, the material is corroded in place of the structure. Effective, but requires constant replacement.
Cathodic Protection	Supplies an electron flow to the metal to force it to become a cathode, preventing corrosion because it is no longer an anode and cannot be oxidized