CHEM 112

Midyear Exam Review Session

WebStraw x QAKCSE

CHEM 112 Midyear Exam Review Session

Annotated

Please see pages 43 - 47 for solutions for in-class problems for M4 - M7.

Sincerely,
Gurdit Sood

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December 1, 2022

Acknowledgments

The core philosophy behind WebStraw is open-access. Education should be available to all, free of cost. We have spent months curating this content that has filtered out unnecessary information, and are providing you with a high-yield, open-access resource to help you study for the CHEM 112 midyear exam. We hope that this provides you the confidence to not only excel on the midyear exam, but also allow you to appreciate the material that is taught in general chemistry.

I would like to extend my sincere gratitude and thanks to our incredible **Education Team** for their hard work and dedication to providing open-access educational content. This would not have been possible without their hard work.

Additionally, this event would not have been possible with my fellow executive team members: Rose (Strategy Director) for organizing the collaboration and advertising, David (Executive Director) for setting out logistics and registration, and Dhruv (Research Director) who provided guidance for the education team.

On behalf of the entire WebStraw Team, we wish you all the best with the midyear exam!

Sincerely,

Gurdit Sood

Module 1: Introductory Material

Important concepts to know:

Stoichiometry: using relationships between reactants and products in a chemical reaction

- Allows to determine quantitative data

Oxidation states: hypothetical charge of an atom if all bonds are ionic

Significant figures/digits: for accuracy of measurements

Practice Problem

1. Balance the following reaction of silver oxide and sulfadiazine, and determine the mass of silver sulfadiazine produced if 28.6 g of silver oxide is used.

$$C_{10}H_{10}N_4SO_2 \quad + \quad Ag_2O \quad \rightarrow \quad AgC_{10}H_9N_4SO_2 \quad + \quad H_2O$$

Note: the molar mass of silver sulfadiazine is 357.182 g/mol

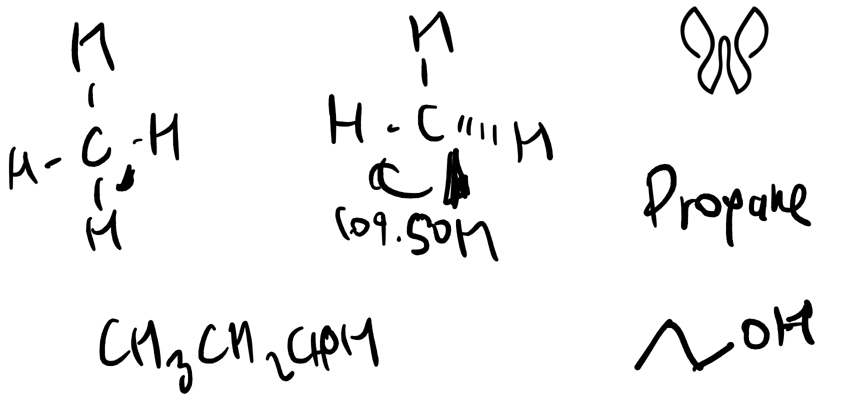
a) 44.1 g

b) 115 g

c) 88.1 g

d) 57.2 g

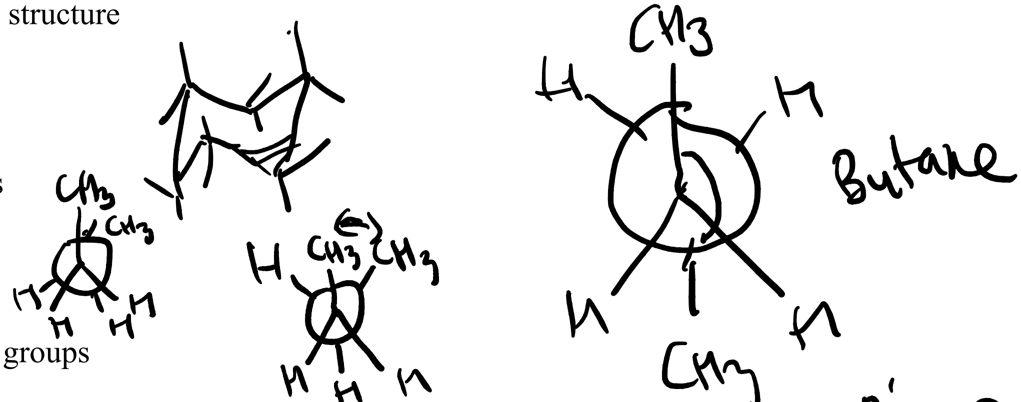
Module 2: Organic Chemistry



Important concepts to know:

Familiarity With Structures:

- ❖ Structural formula
- ❖ Dashed-wedged line structure
- ❖ Line diagram
- ❖ Condensed formula
- ❖ Cyclohexanes
- ❖ Newman projections

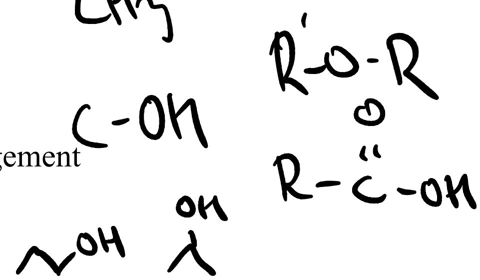


Naming:

- ❖ Alkanes
- ❖ Knowing functional groups

Isomers:

- ❖ Constitutional = same formula, different connectivity
- ❖ Stereoisomers = same formula, same connectivity, different arrangement
  - ➢ Enantiomers = non-superimposable mirror images
  - ➢ Diastereomers = not mirror images, or superimposable



Chiral: usually a tetrahedral atom 4 different substituents on an atom

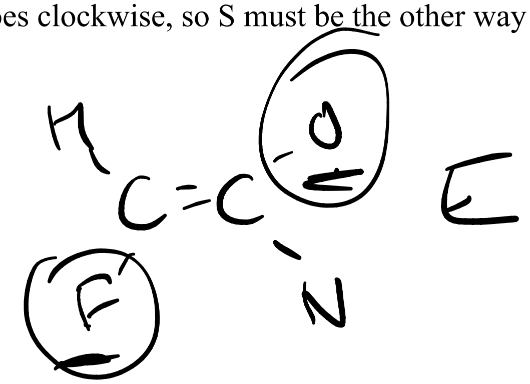
Tips:

To remember R/S:

- ❖ Start at the top of molecule, R = right, so it goes clockwise, so S must be the other way

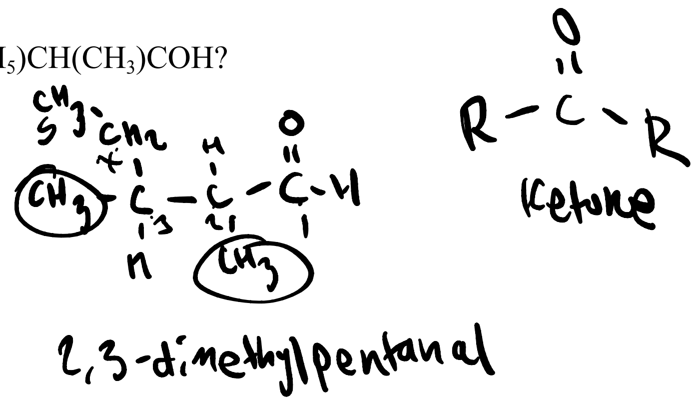
To remember E/Z:

- ❖ E = entgegen, German for "opposite"
- ❖ Z = zusammen, German for "together"



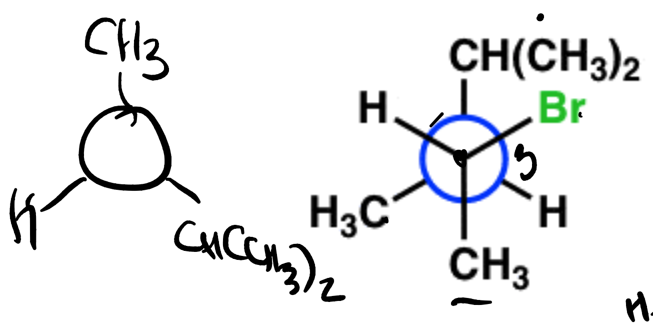
Practice Problems

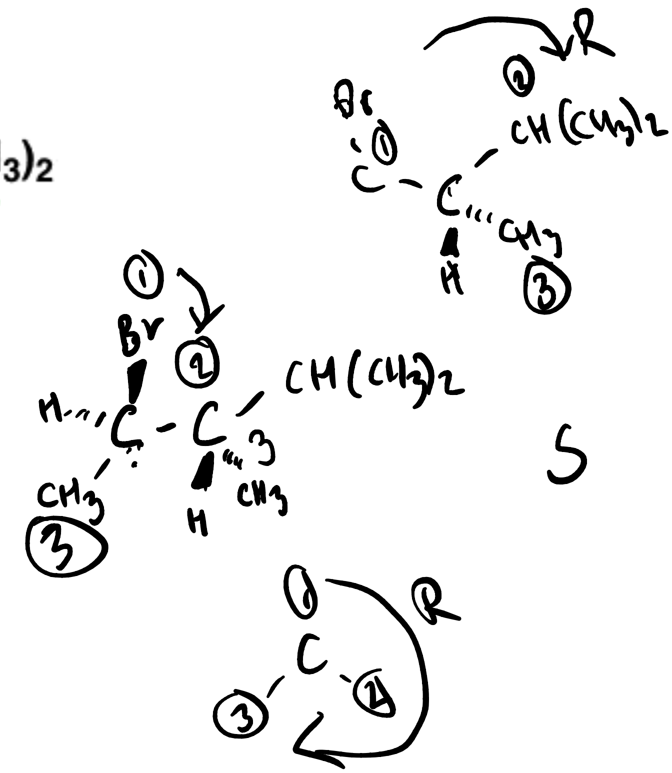
1. What is the IUPAC name of $CH_3CH(C_2H_5)CH(CH_3)COH$?



   a) 1-heptanol
   b) 2,3-dimethylpentanal
   c) 2-methylhexanal
   d) 2,3-dimethyl-1-pentanol

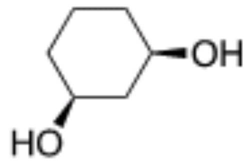
2. What is the IUPAC name of this molecule?



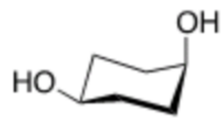


   a) (2R, 3S)-4-bromo-2,3-dimethylpentane
   b) (2S, 3R)-2-bromo-3,4-dimethylpentane
   c) (2S, 3R)-2-bromo-3,5-dimethylpentane
   d) (2R, 3S)-2-bromo-3,4-dimethylpentane

3. What is the IUPAC name of this molecule, and which of the options below is the most stable conformation?



II



III

a) Cis-1,3-cyclohexanediol, III

b) Trans-1,3-cyclohexanediol, III

c) Cis-1,3-cyclohexanediol, II

d) Trans-1,3-cyclohexanediol, II

Module 3: Gases

Ideal gas equation: $PV = nRT$

KEY equation, includes the known relationships:

- Boyle's law: $P \propto \frac{1}{V}$
- Charles' Law (at fixed n and P): $V \propto T$ $\quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$
- Gay-Lussac's Law (at fixed n and V): $P \propto T$ $\quad \frac{P_1}{T_2} = \frac{P_2}{T_2}$
- Avogadro's Law (at fixed T and P): $\frac{n_1}{V_1} = \frac{n_2}{V_2}$

Dalton's Law of partial pressures: $P_{tot} = P_1 + P_2 + P_3 \ldots$

Diffusion: movement from high concentration to low concentration using collisions

Effusion: escape of gas molecules from a container through a hole without collisions

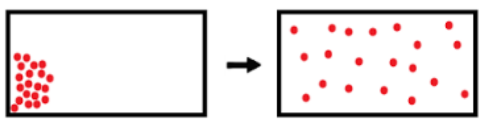


Figure 1: The diffusion of gas molecules inside a closed container.

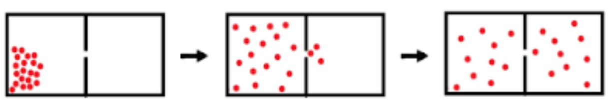


Figure 2: The effusion of gas molecules through a small gap.

Graham's Law and effusion:

$$\text{rate of effusion of A} = \frac{1}{\sqrt{M_A}} \qquad \frac{\text{rate of effusion of A}}{\text{rate of effusion of B}} = \frac{1/\sqrt{M_A}}{1/\sqrt{M_B}} = \sqrt{\frac{M_B}{M_A}}$$

Van der Waals equation: accounts for the properties of different real/non ideal gases

a = "attractive force" between real molecules, b = non-zero volume of real molecules

$$(P + \frac{n^2 a}{V^2})(V - nb) = nRT$$

Practice Problems

1. An unknown gas was added to an isolated 7.60 L flask, which was weighed to be 3.36 g. Identify the gas if the mass of the flask increases to 13.3 g at SATP.
    a) Oxygen gas
    b) Nitrogen gas
    c) Fluorine gas
    d) Hydrogen gas

$V = 7.6L$
$m = 13.3 - 3.36$
$m = 9.94$
$P = 101.325\ kPa$
$T = 298.15\ K$

$PV = nRT$
$PV = \frac{m}{M}RT$
$M = \frac{mRT}{PV}$
$M = 32$

$M = \frac{m}{n}$
$n = \frac{m}{M}$

2. Earth's atmosphere pressure is contributed by the pressures of multiple gases: 78.08% N_2, 20.95% O_2, 0.93% Ar, 0.04% of CO_2, and other gases. What is the partial pressure of argon and carbon dioxide?

$101.325\ kPa$
$0.0004 \times 101.325 = 0.04\ kPa$
$0.0093 \times 101.325 = 0.94\ kPa$

    a) P_{Ar} = 84.2 kPa, P_{CO2} = 3.00 kPa
    b) P_{Ar} = 0.84 kPa, P_{CO2} = 0.03 kPa
    c) P_{Ar} = 94.2 kPa, P_{CO2} = 4.00 kPa
    d) P_{Ar} = 0.94 kPa, P_{CO2} = 0.04 kPa

Module 4: Atoms and Electromagnetic Radiation

Quantum Mechanics

- ❖ Properties of waves
- ❖ Quantization of energy
- ❖ Wave-particle duality
  - ➢ Photoelectric effect
  - ➢ Heisenberg uncertainty principle
  - ➢ de Broglie's wavelength
- ❖ Atomic spectra
  - ➢ Rydberg formula

Electron Configuration

- ❖ Atomic orbitals
  - ➢ Aufbau principle
  - ➢ Hund's rule
  - ➢ Pauli exclusion principle

Periodic Table

- ❖ Atom and ion size
- ❖ Ionization energy
- ❖ Electron affinity

Practice Problem

1. Which of the following ions have the largest radius?

   a) F^-

   b) Na^+

   c) Mg^{2+}

   d) Al^{3+}

2. What is the de Broglie frequency of a 145g baseball travelling at 95.2 km/h?

   a) 4.80×10^{-35} Hz

b) 1.73×10^{-34} Hz

c) 1.73×10^{42} Hz

d) 6.25×10^{42} Hz

3. The electron of a one-electron species falls from n = 4 to n = 1. What is the one-electron species if the wavelength of the wave emitted is 10.8 nm?

   a) H

   b) He^{+}

   c) Li^{2+}

   d) Be^{3+}

4. An electron travels at 96% the speed of light. If its momentum is measured with 2% uncertainty, what is the uncertainty in its position?

   a) 2×10^{-13} pm

   b) 1×10^{-11} pm

   c) 0.2 pm

   d) 10 pm

5. What is the electron configuration of molybdenum?

   a) [Kr] $5s^2\ 4d^4$

   b) [Kr] $5s^2\ 5d^4$

   c) [Kr] $5s^1\ 4d^5$

   d) [Xe] $5s^2\ 4d^4$

6. A 710 nm light is shone onto a metal surface with a work function of $1.64*10^{-19}$ J. What is the speed of the ejected electrons? ($m_e = 9.1094 \times 10^{-31}$ kg, $h = 6.626 \times 10^{-34}$ J · s, $c = 2.9979 \times 10^8$ m/s)

see attached for solution

   a) 2.5×10^5 m/s
   b) 5.0×10^5 m/s
   c) 6.1×10^5 m/s
   d) 7.8×10^5 m/s

7. When a 560 nm light is shone onto an unknown metal surface, electrons are ejected at 7.29×10^5 m/s. What is the work function of the surface? ($m_e = 9.1094 \times 10^{-31}$ kg, $h = 6.626 \times 10^{-34}$ J · s, $c = 2.9979 \times 10^8$ m/s)

see attached

   a) 1.1×10^{-19} J
   b) 2.4×10^{-19} J
   c) 3.5×10^{-19} J
   d) 1.2×10^{-12} J

Module 5: Molecules

<u>Lewis Theory - Main Ideas</u>

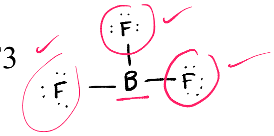
The Lewis Theory describes the general behavior of electrons during bonding. Components of the Lewis Theory include:	1. Valence electrons are the electrons in the outermost shell and play an important role in chemical bonding.
	2. Ionic bonds are the result of valence electrons being transferred from one atom to another (producing a cation and anion)
	3. Covalent bonds are the result of atoms sharing electrons in their own valence.
	4. Electrons are usually shared or transferred to ensure every atom has a stable configuration. This is usually the configuration of a noble gas — or having a full valence consisting of 8 electrons a. This is the octet rule. b. NOTE: one exception to the octet rule is the Hydrogen atom which has 2 atoms in its valence.

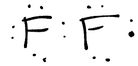
Covalent	**Polar-Covalent**	**Ionic**
• Covalent bond: both atoms contribute electrons to the bond. • A coordinate covalent bond: one single atom gives both the electrons to make a shared pair	• Covalent bonds that have electrons which are not shared equally between two atoms • Usually due to differences in electronegativity between two atms.	• One atom transfers an electron to another forming an anion and a cation — usually between a halogen and a metal.

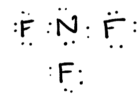
The electronegative difference between 2 atoms in a compound can tell if the compound is covalent, polar covalent, or ionic.

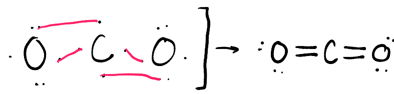
Practice Problems:

1. Determine which of the following structure(s) has a ~~complete~~ incomplete octet
   a. BF_3
   b. F_2
   c. NF_3
   d. CO_2
   e. O_2



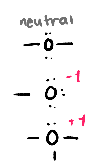






2. Determine the type of bonds between these structures
   a. NaCl ionic
   b. F_2 cov
   c. CO_2 cov
   d. NH_4 cov

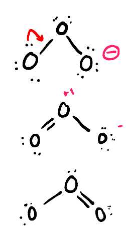
3. Draw a lewis structure for the following structures
   a. NOCl
   b. H_2Te
   c. SO_4^{2-}
   d. HOClO

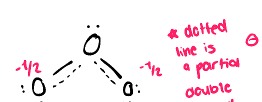


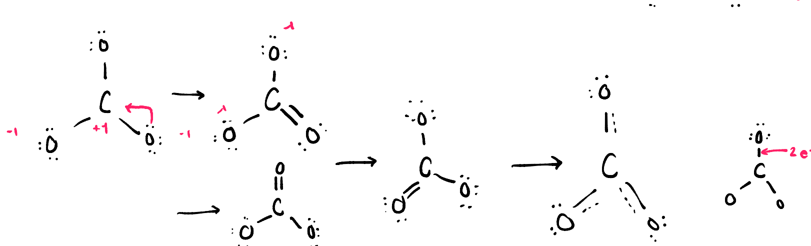
<u>Resonance</u>

- ❖ Occurs when there is a lone pair next to a double bond or a single bond
- ❖ Create multiple Lewis Structures with the true one being a hybrid of the two

1. Draw the Lewis structure(s) for the following
   a. O_3
   b. CO_3^{2-}







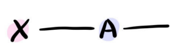
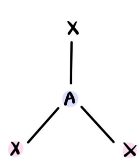
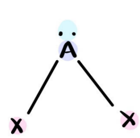
c. ~~H3COO~~ CH_3COO

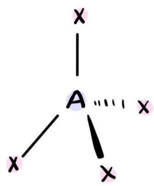
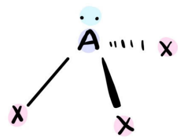
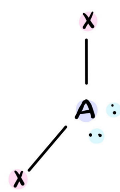
d. NO3

<u>VSEPR Theory</u>

1. Draw the best Lewis Structure
2. Figure out the number of electron groups on the central atom. Bond pairs = letter “X”, and lone pairs = “E”. “A” is designated for the central atom.
3. Determine the electron group geometry by considering both X and E
4. Determine the molecular geometry by considering only X

VSEPR CHART

Total Domain	Generic Formula	Diagram	Atoms bonded to main	Lone pairs	Molecular Shape	Electron Geometry	Hybridization	Bond Angles
1	AX		1	0	Linear	Liner	s	180°
2	AX_2		2	0	Linear	Linear	sp	180°
	AXE		1	1				
3	AX_3		3	0	Trigonal Planar	Trigonal Planar	sp^2	120°
	AX_2E		2	1	Bent			
	AXE_2		1	2	Linear			

4	AX_4		4	0	Tetrahedral	Tetrahedral	sp^3	109.5°
	AX_3E		3	1	Trigonal Pyramidal			
	AX_2E_2		2	2	Bent			
	AXE_3		1	3	Linear			

1. What are the molecular geometric shapes of the following?
   a. HCN   H··C··N· → H–C≡N: AX_2
   b. NSF
   c. PF_6^-
   d. NH_3

2. Which one has a trigonal-planar molecular shape out of the following list:
   a. $BeCl_2$ AX_2
   b. BF_4^- AX_4
   c. SO_3^{2-} AX_3
   d. CO_3^{2-} ? AX_3

see attached for lewis structures

both are trigonal planar

Length ∝ 1/strength

Bond Order and Length

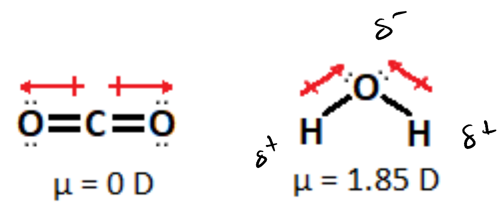
Bond length: the distance between the centers of two atoms in a covalent bond.	
Single bond, bond order	= 1
Double bond, bond order	= 2
Triple bond, bond order	= 3
Bond orders are split between atoms during resonance structures	

Bond Dissociation Energy

- Amount of energy required to break a covalent bond of a molecule in its gas phase
- $\Delta H = \Sigma_r H(bonds\ broken) - \Sigma_r H(bonds\ formed)$
- $\Delta H \approx \Sigma BE(reactants) - \Sigma BE(products)$

Dipole-Dipole Moments

- A molecule with multiple, symmetrical dipole moments will be neutral overall.
- The dipole moment (μ) measures the charge displacement in a covalent bond. This is based on the electronegativity differences between the structures
  - μ is measured in Debyes (D). A high dipole moment indicates a highly polar covalent bond.



Practice Problems

1. Determine the enthalpy of this reaction:
   $YO_2\ (g) + ZO_2\ (g) \rightarrow YO_3\ (g) + ZO\ (g)$

   $2\ YO_2\ (g) + O_2(g) \rightarrow 2\ YO_3(g)$ $\Delta_r H = -198.8$ kJ/mol

   flip! $2\ ZO\ (g) + O_2(g) \rightarrow 2\ ZO_2(g)$ $\Delta_r H = -113.14$ kJ/mol $\Delta_r H = 173.14$ kj/mol

   $\frac{-85.66\ kj/mol}{2}$

2. Determine which of the molecules has the most dipole moments
   a. BF_3
   b. Cl_2
   c. CH_4

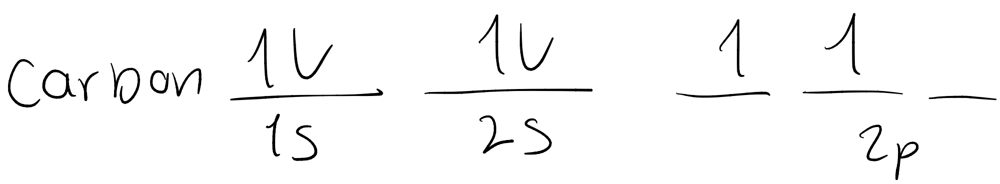
see attached for lewis structure

d. H_2O

Valence Bond Theory

- Valence Bond (VB) Theory describes a covalent bond as a result of an overlap between two half-filled atomic orbitals, or between a filled atomic orbital with an empty one.
- This theory explains how atomic orbitals combine to form a bond between atoms. However, it fails to explain organic molecules such as CH_4. Specifically, it does not explain how a carbon atom can form 4 bonds with a tetrahedral shape when it has only 2 unpaired electrons.

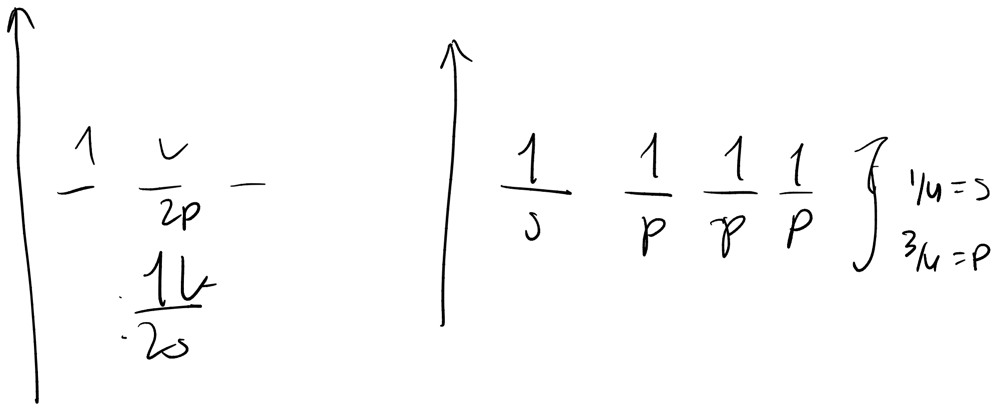
Orbital diagram of carbon



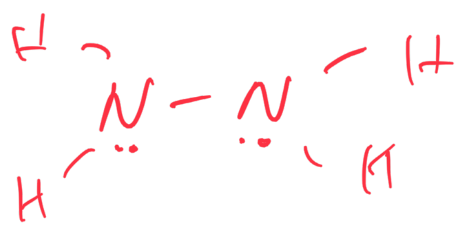
Hybridization

- Hybridization of orbitals is a rationalization of observed molecular shapes (e.g., tetrahedral CH_4).
- Orbitals similar in energy are combined to produce equivalent orbitals that have the characteristics of the initial orbitals.
- For example, one s orbital and three p orbitals hybridize to produce 4 equivalent sp^3 orbitals
  - 25% s characteristic and 75% p characteristic (due to the 1:3 ratio)
  - Because these sp^3 orbitals are identical, they repel each other identically and form a tetrahedral shape.

Sp^3 hybridization. Note that each of the sp^3 has higher energy than the s orbital, but lower energy than p orbitals.



Practice Problems

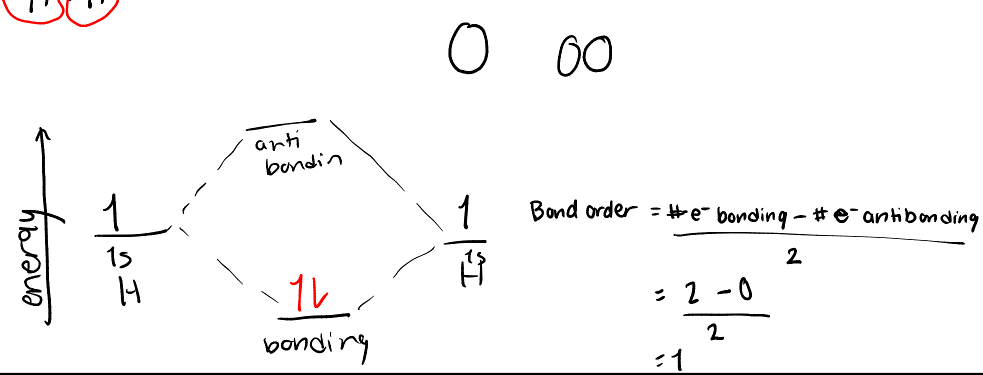
1. Draw the Lewis structure of hydrazine, N_2H_4.	
2. Identify the hybridization of the nitrogen atoms of hydrazine.	AX_3E

3. What is the molecular geometry of hydrazine at each nitrogen atom?	Trigonal pyramidal

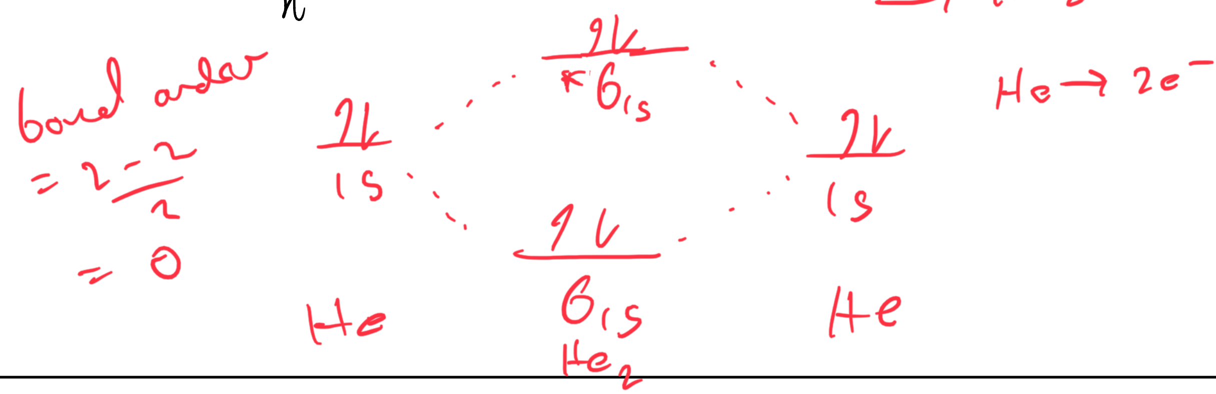
<u>Molecular Orbital Theory</u>

- ❖ This method essentially takes the concept of atomic orbitals (AOs) to form molecular orbitals (MOs) which are found when bonding occurs in molecules.
- ❖ In other words, we are looking at the set of molecular orbitals that are specific to a molecule.
- ❖ General Rules of Molecular Orbital Theory
    1. Every MO can be mathematically represented as a linear combination of AOs
    2. Total number of MOs must equate to number of AOs
    3. Every MOs can be classified as either bonding, antibonding, or nonbonding
    4. Electron configuration of molecule is determined by placing all available electrons into the MOs from low to high energy
    5. In order for a molecule to be stable, there must be more electrons in bonding MOs than antibonding MOs

Molecular Orbital Theory of Hydrogen Gas



Molecular Orbital Theory of Helium Gas



Delocalized Electrons

- The idea of delocalized electrons essentially describes electrons that are not directly associated with a single covalent bond or atom.
- Instead, these electrons are shared among multiple atoms in a molecule.
- This situation is specifically applicable when we look at molecules with pi bonds.
  - Electrons move around multiple atoms — namely occurs with resonance structures

Practice Problem

1. Which of the following molecules have delocalized electrons?
   a. H_3O^+
   b. O_3
   c. CH_3OH
   d. O_2
   e. H_2O
2. What is the bond order of Li_2?

Refer to solutions afterward

Module 6: Introduction to Thermochemistry

<u>Enthalpy of a reaction</u>

- Exothermic and endothermic reactions
- Calculations
  - Calorimetry
  - $\Delta_r H° = \Sigma\Delta_f H°_{products} - \Sigma\Delta_f H°_{reactants}$
  - Bond enthalpy
  - Hess's law

<u>Energy</u>

- Heat
- First law of thermodynamics

Practice Problem

1. When a sample of benzene is combusted in a calorimeter, the temperature rises from 21.65°C to 38.14°C. The heat of combustion of benzene is -3267 kJ/mol, and the heat capacity of the calorimeter is 16.4 kJ/°C. How much benzene is present at the beginning of the reaction? (M = 78.11 g/mol)

   see attached

   a) 0.392 g
   b) 6.47 g
   c) 8.49 g
   d) 15.0 g

2. Using the average bond energies, what is the standard enthalpy of combustion of n-heptane? Given that D(C–C) = 347 kJ/mol, D(O=O) = 498 kJ/mol, D(C–H) = 414 kJ/mol, D(O–H) = 464 kJ/mol, and D(C=O) = 799 kJ/mol.

   $\Delta H^\circ = \sum D(\text{broken}) - \sum D(\text{formed})$

   see attached

   a) – 4879 kJ/mol
   b) – 4426 kJ/mol
   c) 4426 kJ/mol
   d) 4879 kJ/mol

3. What is the change in internal energy of a 4.13 L sample of acetaldehyde if it is compressed to 2.45 L against an external pressure of 1.80 atm?

   $\Delta U = w = -P\Delta V$

   see attached

   a) -306 J
   b) -3.02 J
   c) 3.02 J

d) 306 J

4. In the preparation of a large Earl Grey milk tea half sugar, less ice, 35 g of ice at -10°C is added to 400 mL of cool (30°C) milk tea. What is the equilibrium temperature of the system if the cup is effectively isolated from the environment? Assume that for both milk tea and ice, the specific heat capacity, density, and ΔH^{o}_{fusion} are 4.184 $\frac{J}{g*C}$, 1.0 g/mL, and 6.01 kJ/mol, respectively.

a) 16°C

b) 20°C

c) 24°C

d) 27°C

q_1 = heat absorbed to increase ice T from -10°C to 0°C

q_{fus} =

Module 7: Intermolecular Forces

<u>Intermolecular Forces</u>

- London dispersion forces
- Dipole-dipole
- Hydrogen bonding
- Viscosity of Liquids
  - When there are strong IMFs like hydrogen bonds acting between molecules, the liquid is more viscous (notable in Figure 2). This is because these IMFs prevent molecules from moving around freely, making them hold in place.
- Surface tension
  - This suggests that strong IMFs can lead to high surface tension.

Practice Problems

1. Classify each of the following as polar or nonpolar
   a. HCl polar
   b. H_2O polar
   c. CO_2 nonpolar
   d. NH_3 polar
2. What is/are the intermolecular forces present in the following molecules?
   a. Octane LDF
   b. CH_3OH LDF, D.D., H-bonding
   c. HSO_4 ← as well
   d. HBr ↓ LDF, D.D -

Vaporization and Vapour Pressure

<u>Vaporization and Vapour Pressure</u>	
There are **three** factors that affect vaporization	❖ Increased temperature (molecules gain more kinetic energy) ❖ Increased surface area (more molecules are at the surface) ❖ Decreased strength of intermolecular forces (less kinetic energy needed)

The enthalpy of vaporization ($\Delta_{vap}H$)	The enthalpy of condensation ($\Delta_{cond}H$)
❖ The amount of heat needed to vaporize one mole of liquid at a constant temperature and pressure. ➢ $\Delta_{vap}H$ is always positive, because vaporization is an endothermic process	❖ The amount of heat that needs to be released to condense one mole of gas at a constant temperature and pressure. ➢ Always negative, because condensation is an exothermic process

Vapor Pressure	Characteristics of Vapor Pressure
Definition = The pressure exerted by a liquid on its container when the liquid is in its vapor state.	❖ These vapor pressures are dictated by the strength of the intermolecular forces within the liquid; volatile liquids will have weaker intermolecular forces than nonvolatile ones. ➢ When liquids can exert a lot of pressure in their vapor at room temperature, they are **volatile**
	❖ The vapor pressure of a liquid **increases** with temperature.

The vapor pressure of a liquid is determined by the Clausius-Clapeyron Equation:

$$ln\left(\frac{pressure_1}{pressure_2}\right) = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Practice Problems

1. Explain why vapor pressure increases with temperature.	• Kinetic energy
2. A liquid at standard conditions is heated to 37 degrees celsius, if the enthalpy of vaporization is 49.0 kJ/mol, what is the vapor pressure at the new temperature?	2.15 atm see attached for solution

<u>Boiling and Critical Point</u>

- *Boiling point* = change in phase of water in an open container as it absorbs enough heat to enter the gas phase.
- *Critical point* = phase between liquid and gas, when a liquid reaches the boiling temperature in a closed container. The liquid enters an equilibrium with its gas form.
  - The density of the liquid will decrease while the density of the vapor will increase until they become even and the surface tension eventually disappears, blending the line between liquid and vapor.

Practice Problem

1. The point at which liquid and gas phases become indistinguishable is called:
   a. Triple point
   b. Critical point
   c. Boiling point
   d. Absolute point

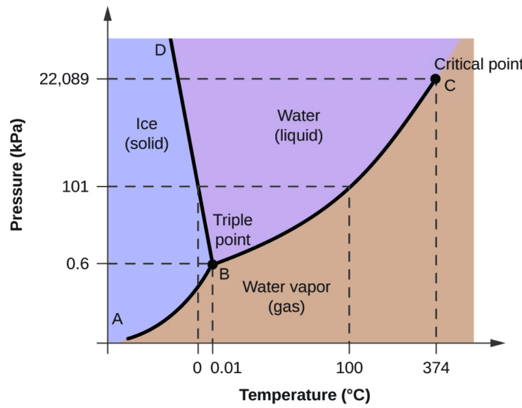
Properties of Solids

- The required energy to melt a solid is called *the enthalpy of fusion, ΔfusH*. Each substance has its own enthalpy of fusion.
- *Enthalpy of sublimation, ΔsubH*, is the amount of energy required to convert a substance in its solid state to its vapor state.

$$\Delta_{sub}H = \Delta_{fus}H + \Delta_{vap}H$$

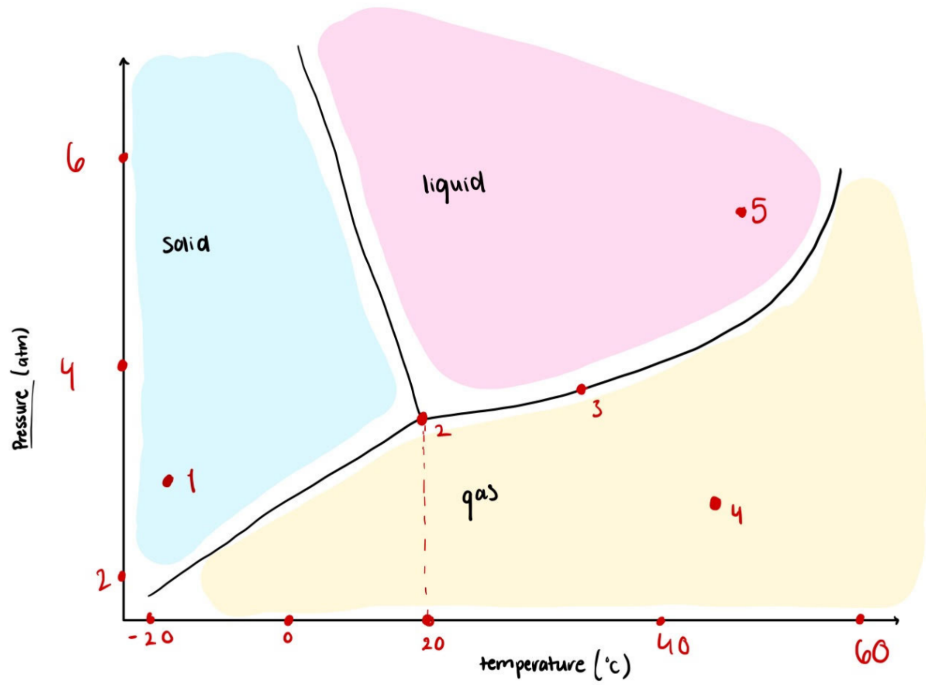
Phase Diagrams

- A phase diagram is a pressure-temperature graph which shows the phase of a substance at different pressures and temperatures.



Practice Problem

1. According to the diagram below, which statements are correct? Note: there may be more than one correct statement.



   a. At point 1, the substance A exists as a one-phase solid system
   b. At point 2, the substance A exists as a three-phase equilibrium system
   c. If the liquid substance A is continuously under the pressure at point 3 and the temperature is decreased to -10℃, substance A will vaporize
   d. If the liquid substance A is continuously under the pressure at point 5 and the temperature is decreased to 30℃, substance A will vaporize
   e. If the liquid substance A is continuously under the pressure at point 5 and the temperature is decreased to -10℃, substance A will solidify

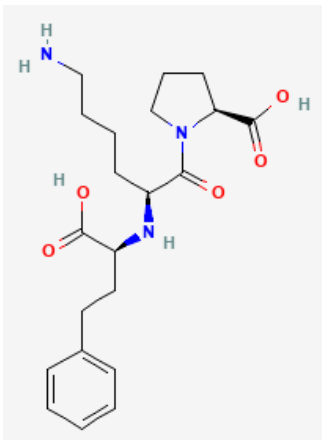
Additional Practice Problems

Module 1

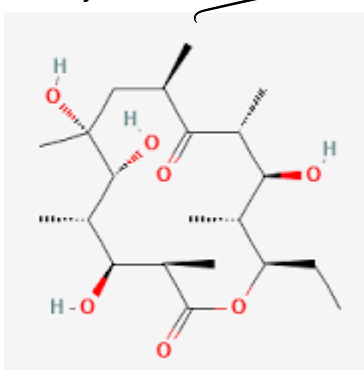
❖ No high-yield practice problems, don't spend much time on module 1!

Module 2

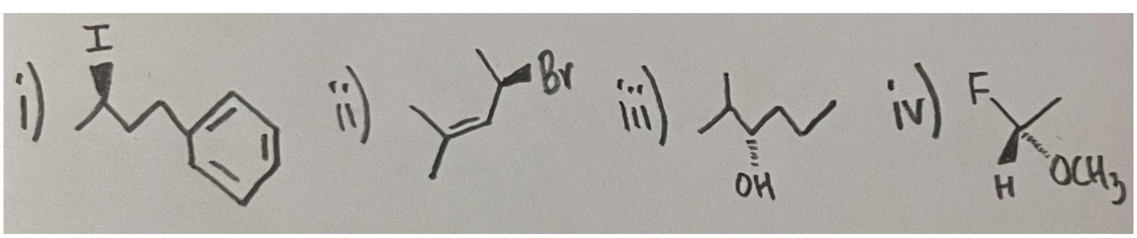
1. Identify the functional groups in lisinopril:



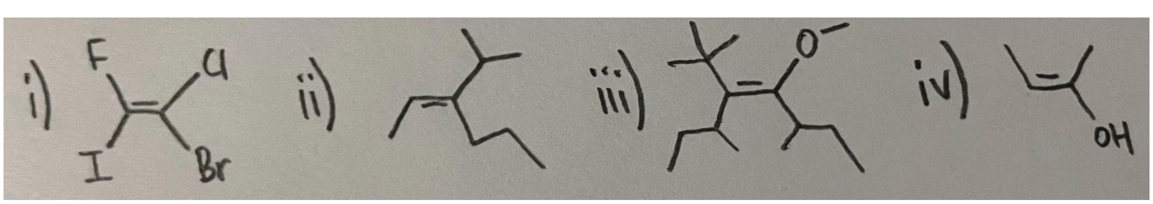
2. Identify all the chiral centers in erythronolide b.



3. Write the molecular formula and line formula for 5-ethyl-4,6-dimethyloctane.
4. Assign (S/R) configurations for each of the following compounds:



5. Assign (E/Z) configurations for the following compounds:



Module 3

6. Calculate the pressure (in kPa) caused by 1.00 x 10^20 molecules of a particular gas at 175°C and in a 305 mL container.
7. What is the final pressure of a particular gas when its moles remain constant, and the initial pressure is 1 bar, the initial temperature is 273 K, and the final temperature is 373 K?
8. A 3.5 L closed beaker containing He at 250 torr is connected by a valve to a 1.5 L light bulb containing Ar at 150 torr. The valve between the 2 containers opens, allowing the gases to mix together. What is the mole fraction of Ar once the gases fully mix?
9. (challenge question) Dmitri finds a pressure tank containing a mysterious gas when cleaning his basement. With his Bachelors of Science in Chemistry, he wants to identify this gas by determining its molar mass. He decides to blow up two identical balloons to 5.00 L, one with the unknown gas, and the other with carbon dioxide. These balloons are placed in a 300. K and 0.81 atm chamber. Overnight, the volume of the carbon dioxide balloon reduces to 3.80 L, while the unknown gas balloon reduces to 4.12 L. He knows that the unknown gas is a hydrogen halide with a form of HX, where X is a halogen. What is the chemical formula of the mystery gas?
10. (challenge question) Unable to continue with his outdoor research due to COVID-19 lockdown, out of boredom, Dr. Brzęczyszczykiewicz decides to inject 109.145 g of gaseous carbon dioxide into an empty 5.92 L pressure tank at 300.0 K.
    a. He wants to try using the van der Waals equation that he learned years ago. Given a = 3.658 bar*L^2*mol^{-2} and b = 0.0429 L*mol^{-1}, what is the pressure inside the pressure tank, in bar? Use R = 0.08314 bar*L*mol^{-1}*K^{-1}.
    b. The pressure gauge indicates that the pressure inside the tank is 11.4 bar. This pressure gauge was manufactured by his NASA engineer friends and is very accurate. What is the percent error of the calculated pressure?
    c. Which of the following may cause the calculated pressure to be *lower than the actual pressure?*

        A. The valve of the pressure tank is faulty. The pressure inside the tank increases as the pressurized air rushes outside.
        B. There is air remaining in the tank before carbon dioxide is added. The extra air exerts additional pressure inside the tank.
        C. He assumes that the gas carbon dioxide behaves ideally and intermolecular attractions are negligible.
        D. More than one of the above options

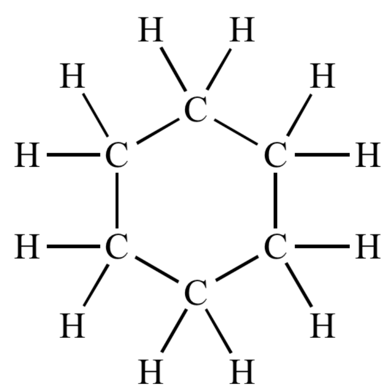
Module 4

11. What is the energy of an X-ray with a wavelength of 1.0 nm per quantum?

12. What is the de Broglie wavelength of a soccer ball with a mass of 412 g and velocity of 83.2 km/h?
13. Determine the angular and radial nodes in a 3p orbital
14. Determine the element with the following electron configuration: [Kr] $4d^{10}5s^{2}5p^{2}$
15. List the following elements from least to greatest first ionization energy: Mg, O, Sr, F

Module 5

16. Create a Lewis structure for NOCl
17. Create a Lewis Structure for HOClO
18. What are the molecular geometric shapes of the following?
    a. HCN
    b. NSF
    c. PF_6^-
    d. NH_3
    e. PCl_5
    f. ClF_3
19. Which one has a trigonal-planar molecular shape out of the following list: $BeCl_2$, BF_4^-, SO_3^{2-}, CO_3^{2-} ?
20. Using D(C=O) = 799 kJ/mol, D(O=O) = 499 kJ/mol, and the bond energies provided in Figure 1, what is the enthalpy of combustion of 0.314 mol of cyclohexane?



cyclohexane

21.
    a. Draw the Lewis structure of hydrazine, N_2H_4.
    a. Identify the hybridization of the nitrogen atoms of hydrazine.
    b. What is the <u>molecular</u> geometry of hydrazine at each nitrogen atom?
22. Draw the MO energy level diagram for F_2

Module 6

23. (challenge question) A student heats up 200.0 g of water in a 140.0g beaker as part of his high school lab experiment. He records the temperature of water every minute in the following table:

Time (min)	Temperature (°C)
0	20.0
1	24.1
2	29.6
3	35.0
4	40.8

Water and the beaker have a specific heat capacity of 4.184 and 0.84 $\frac{J}{g°C}$, respectively. Assume that the heat released or absorbed by air is negligible.

a. Calculate the amount of heat absorbed by the water 0 to 4 minutes.

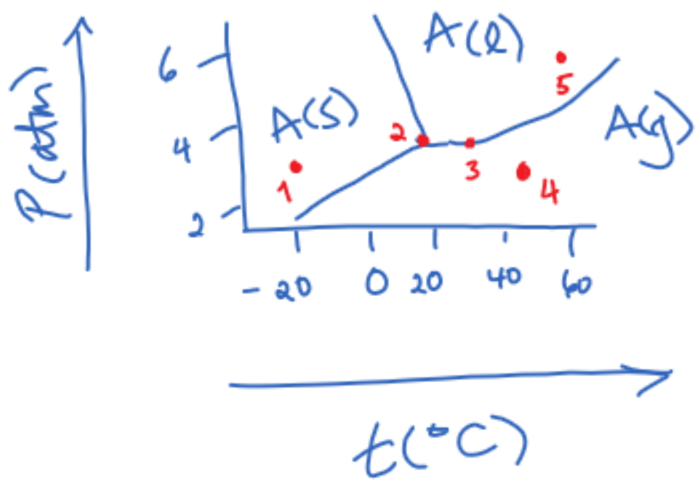
24. (challenge question) The combustion of liquid benzene (C_6H_6) with oxygen produces carbon dioxide and water. When a sample of benzene is combusted in a calorimeter, the temperature rises from 25.16°C to 34.33°C. The heat of combustion of benzene is -3267 kJ/mol, and the heat capacity of the calorimeter is 11.2 kJ/°C.
    a. How much benzene, in grams, is present at the beginning of the reaction?
    b. In a different experiment, 1500. g of water is added to the same calorimeter. How much n-heptane (C_7H_{16}), in grams, needs to be combusted in the calorimeter to produce the same temperature change as part (a)? The specific heat capacity of water is 4.184 $\frac{J}{g°C}$, and the heat of combustion of n-heptane is -4817 kJ/mol.
25. What is the change in a system's internal energy if the system does 123J of work and absorbs 234J of heat?
26. What is $\Delta_r H$ of $2NO_2 \rightarrow N_2 + 2O_2$. If the $\Delta_r H^0$ of ½ $N_2 + O_2 \rightarrow NO_2$ is 33.18 kJ/mol
27. What is the internal energy of the following reaction: Gas 8A + Gas B → 2Gas C
    a. ΔU = -990 kJ
    b. T = 298K
    c. Constant Volume

Module 7

28. Classify each of the following as polar or nonpolar
    a. HCl
    b. H_2O

c. CO_2
d. NH_3

29. What is/are the intermolecular forces present in the following molecules?
    a. Octane
    b. CH_3OH
    c. HSO_4
    d. HBr
30. A liquid at standard conditions is heated to 37 degrees celsius, if the enthalpy of vaporization is 49.0 kJ/mol, what is the vapor pressure at the new temperature?
31. According to the diagram below, which statements are correct? Note: there may be more than one correct statement.



    a. At point 1, the substance A exists as a one-phase solid system
    b. At point 2, the substance A exists as a three-phase equilibrium system
    c. If the liquid substance A is continuously under the pressure at point 3 and the temperature is decreased to -10℃, substance A will vaporize
    d. If the liquid substance A is continuously under the pressure at point 5 and the temperature is decreased to 30℃, substance A will vaporize
    e. If the liquid substance A is continuously under the pressure at point 5 and the temperature is decreased to -10℃, substance A will solidify
    f. If the liquid substance A is continuously exposed to the temperature at point 5 and the pressure is reduced to 2 atm, A will vaporize
    g. If the liquid substance A is continuously exposed to the temperature at point 4 and the pressure is increased to 6 atm, A will liquify
32. Explain how simple cubic cell contains 1 atom in a cell
33. In a stack of 5 face-centered cubic cell, what is the volume occupied by the atoms?
34. What is the coordination number in a face-centered cubic cell?

Solutions

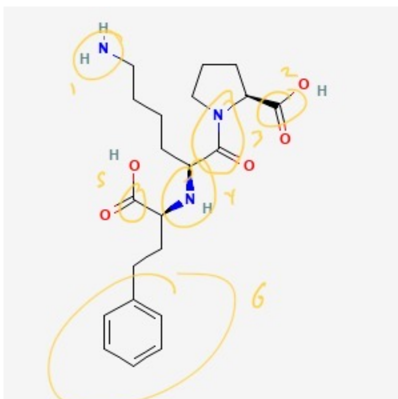
Module 1

N/A

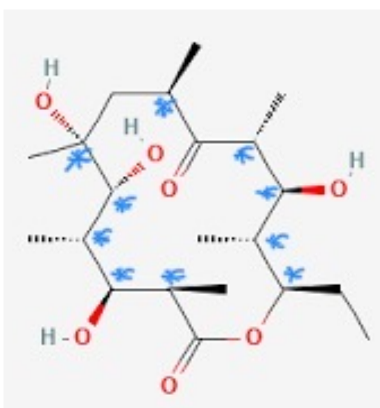
Module 2

Typo: 2 carboxylic acids

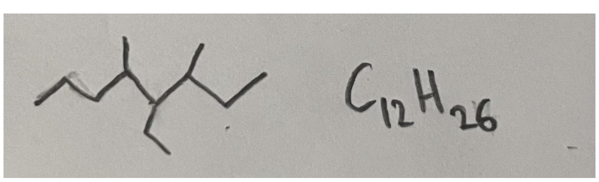
1. There are 6 functional groups in total: two amines, ~~two esters~~, one amide, and one arene.



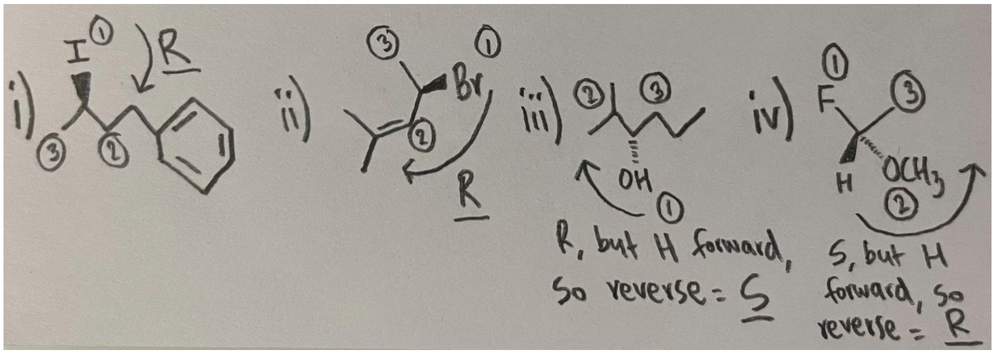
2. There are 10 chiral centers.



3. Answer:

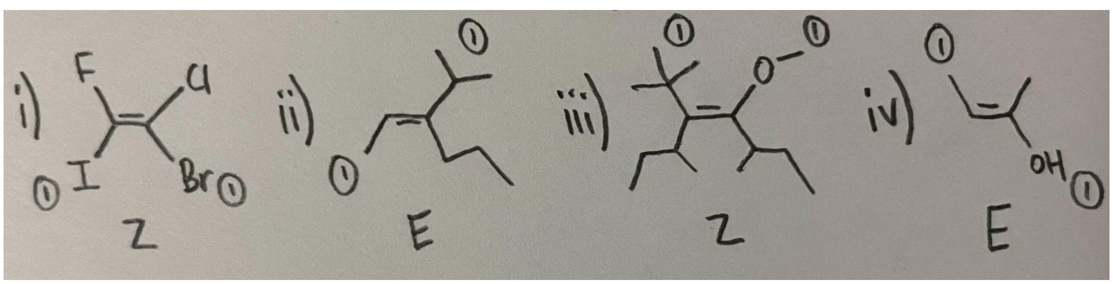


4. i) R ii) R iii) S iv) R



Note: when it says “H forward, so reverse” it means that the lowest priority group is facing forward, so instead of rewriting the whole molecule, you can simply assign the configuration, and then “reverse” it to get the actual configuration. The “reversing” is the forward facing group becoming a back facing group, which is why the “configuration switch” works. This method ONLY works if the lowest priority group is forward. Please use a model kit to consolidate this concept, as this is a crucial time-saving trick.

5. i) Z ii) E iii) Z iv) E



Module 3

6. 2.03 kPa
7. 1.37 bar
8. Using Boyle’s Law, we can calculate the partial pressure of each gas in the new container, which has a combined volume of 5 L. $P_1V_1 = P_2V_2 \rightarrow P_2 = P_1V_1/V_2$. For He, P_2 = (250)(3.5)/(5) = 175 torr. For Ar, P_2 = (150)(1.5)/(5) = 45 torr. By Dalton’s Law, the total pressure is the sum of the partial pressures, or 220 torr. By comparing the ratio of the pressure of Ar to the total pressure, we can obtain the mole fraction of Ar: 45/220 = 0.205.
9. The unknown gas is HBr.

a. Using equation (3): $\frac{Rate\ of\ effusion\ of\ unknown}{Rate\ of\ effusion\ of\ CO_2} = \frac{\Delta V_{unknown}}{\Delta V_{CO_2}} = \sqrt{\frac{M_{CO_2}}{M_{unknown}}}$

$$M_{unknown} = M_{CO_2} * (\frac{\Delta V_{CO_2}}{\Delta V_{unknown}})^2 = 44.01\frac{g}{mol} * (\frac{5.00L-3.80L}{5.00L-4.11L}) = 80.0\frac{g}{mol} = M_{HX}$$

$$M_X = 80.0\frac{g}{mol} - 1.0\frac{g}{mol} = 79.0\frac{g}{mol} \approx M_{Br}$$

10. a. P = 10.0 bar
    b. $\%_{error}$ = 12.3%
    c. The answer is **B**.

Module 4

11. $E = h\nu = \frac{hc}{\lambda}\ (Equation\ 2) = \frac{hc}{1.0*10^{-9} m} = 2.0 * 10^{-16} J$
12. $\lambda = \frac{h}{mu} = \frac{6.626*10^{-34} J\ s}{(0.412\ kg)(83.2\ \frac{km}{h} * \frac{1\ h}{3600\ s} * \frac{1000\ m}{1\ km})} = 6.96 * 10^{-35}\ m$
13. Angular node = ℓ
    Angular node = 1

    The angular node is 1 because the p orbital results in ℓ = 1

    Radial node = n - ℓ - 1
    Radial node = 3 - 1 - 1
    Radial node = 1
14. Tin
15. Sr, Mg, O, F

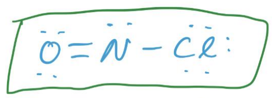
Module 5

16. Answer:

1. NOCl

valence electrons $= 5 + 6 + 7$

$= 18$



$FC_N = 5 - 2 - \frac{1}{2}(6)$

$= 3 - 3$

$= 0$

$FC_O = 6 - 4 - \frac{1}{2}(4)$

$= 2 - 2$

$= 0$

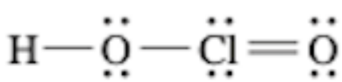
$FC_{Cl} = 7 - 6 - \frac{1}{2}(2)$

$= 1 - 1$

$= 0$

∴ Best Lewis structure for NOCl

17. Answer:



18. Answers
    a. Linear
    b. Bent
    c. Octahedral
    d. Trigonal pyramidal
    e. Trigonal bipyramidal
    f. T-shaped
19. CO_3^{2-} has a trigonal-planar shape
20. Answer:

$$C_6H_{12} + 9O_2 \rightarrow 6CO_2 + 6H_2O$$

Bonds broken: 6 C—C, 12 C—H, 9 O=O

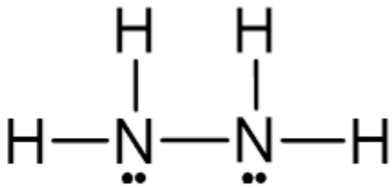
Bonds formed: 12 C=O, 12 H—O

$$\Delta H^o = \Sigma BE^o(reactants) - \Sigma BE^o(products)$$

$$= (6 * 345 + 12 * 415 + 9 * 499) - (12 * 799 + 12 * 460) = -3567 \frac{kJ}{mol}$$

$$\Delta H = n\Delta H^o = 0.314\, mol * (-3567 \frac{kJ}{mol}) = -1120\, kJ$$

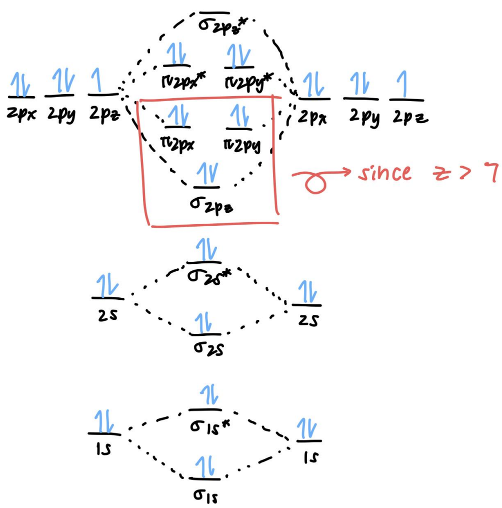
21.

a. 

b. Each nitrogen atom has the form AX_2E. Therefore, each N is sp^3 hybridized.

c. Hydrazine has a trigonal pyramidal geometry at each N.

22. Answer:



Module 6

23. Answer:

First, notice that the question asks for the heat absorbed from 0 to 4 minutes. Therefore, only the temperatures at 0 and 4 minutes (T_0 and T_4) are relevant for the purpose of this question. The temperature change ΔT is:

$$\Delta T = T_4 - T_0 = 20.8°C.$$

The heat capacity of the system is:

$$m * c_p = 200.0\, g * 4.184 \frac{J}{g°C} = 836.8 \frac{J}{°C}.$$

And the heat absorbed to heat the water by 20.8°C is:

$$q = mc_p \Delta T = (836.8 \frac{J}{°C})(20.8°C) = 17410\, J = 17.41\, kJ$$

Similarly, equation 3 can be rearranged to calculate the heat capacity of a system if the temperature change and the amount of heat absorbed (or released) are known.

24. Answer:

(a) We are given the temperature change and the heat capacity of the calorimeter. Therefore, we can start by calculating the amount of heat absorbed by the calorimeter:

$$q_{absorbed} = C\Delta T = 11.2 * (34.33 - 25.16) = 102.7\ kJ$$

Important: When performing calculations, ensure that the units are consistent. For example, in this case, make sure that the unit of q is the same as the unit of C times ΔT.

Recall the law of conservation of energy: $q_{released} = -q_{absorbed}$, Therefore:

$$q_{released} = -102.7\ kJ$$

We know that the combustion of 1 mol of benzene releases 3267 kJ of heat. Thus, the mass of benzene is:

$$m_{C_6H_6} = \frac{-102.7\ kJ}{-3267\ kJ/mol} * 78.11 \frac{g}{mol} = 2.46\ g$$

(b) This problem is similar to (a), except water has been added to the calorimeter. First, we calculate the overall heat capacity of the water-filled calorimeter:

$$C = C_{cal} + C_{water} = C_{cal} + mc_{water}$$

$$= 11.2\ \frac{kJ}{°C} + 1500\ g * 4.184 \frac{J}{g°C} * \frac{0.001\ kJ}{1\ J} = 17.476 \frac{kJ}{°C}$$

Repeat the steps in part (a) with the heat of combustion and molar mass of n-heptane to calculate the mass of n-heptane needed, and we get m = 3.33 g.

25. Use the equation: $\Delta U = q + w$, where $\Delta U = 234J + (-123J) = 111$. The system does work, meaning the work is done by the system, thus the value for work must be negative. Please refer to the section “Using the Equation: $\Delta U = q + w$”.
26. $\Delta_r H = -(2 \times 33.18$ kJ/mol$) = -66.36$ kJ/mol
27. -990kJ

Module 7

28. Answers:
    a. Polar
    b. Polar
    c. Nonpolar
    d. Polar

29. Answers:
    a. LDF
    b. LDF, H-bonds, DD
    c. LDF, H-bonds, DD
    d. LDF, DD
30. 2.15 Pa
31. Statements a, b, e, f, g are correct.
32. There are 8 1/8th of an atom therefore, 1 atom in total
33. 74% of volume occupied
34. 12

Presentation's Module 04 - Q4 Revised:

An electron travels at 96% the speed of light. If its momentum is measured with 2% uncertainty, what is the uncertainty in its position?

a) 2×10^{-13} pm

b) 1×10^{-11} pm

c) 0.2 pm

d) 10 pm

Answer key for the presentation MCs:
Module 4:

1. **A) F^-**
2. **C) 1.73×10^{42} Hz**
3. **C) Li^{2+}**
4. **D) 10 pm**
5. Half-filled and filled subshells are more stable due to symmetry. Using the Aufbau principle, the electron configuration would be [Kr] $5s^2\ 4d^4$. However, an electron from the 5s subshell can be moved into the 4d subshell to create two half-filled subshells to increase stability.
   The correct answer is **C) [Kr] $5s^1\ 4d^5$.**
6.

$$E_{photon} = \frac{hc}{\lambda} = \Phi + \frac{1}{2}m_e u^2$$

$$u = \sqrt{2\frac{\frac{hc}{\lambda}-\Phi}{m_e}} = \sqrt{2\frac{\frac{(6.626*10^{-34} J\ s)*(299792458\ m/s)}{710*10^{-9} m}-1.64*10^{-19} J}{9.11*10^{-31}\ kg}} = 5.0 * 10^5\ m/s$$

   The correct answer is **B) 5.0×10^5 m/s**.
7.

$$E_{photon} = \frac{hc}{\lambda} = \Phi + \frac{1}{2}m_e u^2$$

$$\Phi = \frac{hc}{\lambda} - \frac{1}{2}m_e u^2$$

$$= \frac{(6.626*10^{-34} J\ s)*(299792458\ m/s)}{560*10^{-9} m} - \frac{1}{2}(9.11 * 10^{-31} kg)(7.29 * 10^5\ m/s)^2$$

$$= 1.13 * 10^{-19} J$$

   The correct answer is **A) 1.1×10^{-19} J**.

Module 6:

1.

$$q_{absorbed} = -q_{released}$$

$$C\Delta T = -n\Delta H°_{combustion}$$

$$n = \frac{m}{M} \Rightarrow m = -\frac{MC\Delta T}{\Delta H°_{combustion}}$$

$$\Rightarrow m = -\frac{78.11\frac{g}{mol} * 16.4\frac{kJ}{°C} * (38.14 - 21.65)°C}{-3267\frac{kJ}{mol}} = 6.47\ g$$

The correct answer is **B) 6.47 g**.

2.

$$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$$

Number of bonds in the reactant side:

- C–C = 6
- C–H = 16
- O=O = 11

Number of bonds in the product side:

- C=O = 14
- O–H = 16

$$\Delta H^o_{combustion} = \Sigma(bonds\ broken) - \Sigma(bonds\ formed)$$

$$= (-6 * 347 + 16 * 414 + 11 * 498) - (14 * 799 + 16 * 464) = -4426\frac{kJ}{mol}$$

The correct answer is **B) -4426 kJ/mol**.

3.

$$\Delta U = w = -P\Delta V = -(1.80\ atm) * \frac{101.325\ kPa}{1\ atm} * (2.45 - 4.13)L = 306.4\ J$$

Notice that pressure must be converted into kPa first. This is because 1 kPa * 1 L = 1 J. The proof of this is left as an exercise to the reader. (1 kPa = 1000 N/m^2, 1 L = 0.001 m^3, 1 J = 1 Nm).

The correct answer is **D) 306 J**.

4. **Ice question. Answer:**

As a gentle reminder, exam questions will never be this long. If a question really is this long, save it for later since it is worth 1 point like every other one anyway.

First, we are dealing with a heat exchange type of problem. Mass is more relevant than volume here, so we will first convert milk tea volume into mass:

$$m_{MT} = 400\,mL * \frac{1.0g}{mL} = 400\,g$$

Then we identify the two systems involved in this heat exchange. The first system is 400g of milk tea at 30°C, and the second is 35g of ice at -10°C.

Let T be our equilibrium temperature, and c be our specific heat capacity (which is given).

Because energy is conserved, whatever energy is released by the milk tea must be absorbed by the ice (since the cup is isolated from the environment).

Now, we have 400g of 30°C water versus only 35g of -10°C ice, so it is safe to assume that our final temperature, T, will be above 0°C (although we could guess this based on the options). Therefore, the change in energy of the milk tea is

$$q_{MT} = m_{MT}c\Delta T = 400g * 4.184\frac{J}{g°C} * (T - 30)°C$$
$$= 1673.6\frac{J}{°C} * (T - 30)°C$$

Note that T is lower than 30, so q_{MT} will be negative. This makes sense because the milk tea is losing energy as heat. This heat will be absorbed by the ice.

However, recall that melting requires energy as well. The ice will increase its temperature from -10°C to 0°C, undergo a phase change at 0°C, and increase its temperature from 0°C to T. Because $\Delta H°_{fusion}$ describes the amount of energy required to melt 1 mole of ice, we multiply it by n to find the energy absorbed to melt n moles. Therefore, the energy the ice absorbs is

$$q_{-10\ to\ 0} + q_{melting} + q_{0\ to\ T}$$
$$= m_{ice}c[0 - (-10)] + n * \Delta H°_{fusion} + m_{ice}c(T - 0)$$
$$= m_{ice}c(10 + T) + n * \Delta H°_{fusion}$$

The sum of these 3 q values will be positive because the ice is absorbing energy. A negative sign is added to show that the change in energy of the ice is opposite of that of the milk tea.

$$q_{-10\ to\ 0} + q_{melting} + q_{0\ to\ T} = -q_{MT}$$
$$m_{ice}c(10 + T)°C + \frac{m_{ice}}{M} * \Delta H°_{fusion} = -1673.6\frac{J}{°C} * (T - 30)°C$$
$$(35\,g)(4.184\frac{J}{g°C})(10 + T)°C + \frac{35\,g}{18.02\,g/mol} * 6.01\frac{kJ}{mol} * \frac{1000\,J}{1\,kJ} = -1673.6\frac{J}{°C} * (T - 30)°C$$

Important: Notice how the enthalpy of fusion is converted into J/mol. This is because the rest of the equation uses J instead of kJ, and the units must agree with each other.

$$146.44\frac{J}{°C}(10 + T)°C + 11673\,J = -1673.6\frac{J}{°C} * (T - 30)°C \quad \textbf{(Eq. 1)}$$

The rest is basic algebra (albeit an annoying one). The units are not shown to save some space, but remember that they are still there.

$$1464.4 + 146.44T + 11673 = -1673.6T + 50208$$

$$1820.04T = 37070.6$$
$$T = 20.37°C \approx 20°C$$

Therefore, **B) 20°C** is our final answer.

Pro tip: A way to skip most of the algebra is by putting **Eq. 1** into a calculator with SOLVE function:

146.44 * (10 + X) + 11673 = -1673.6 * (X - 30)

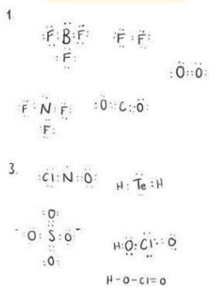
For fx-991 ES PLUS C and a few other CASIO calculators, we press SHIFT +) to type X, and ALPHA + CALC for the equal sign. After inputting the equation, press SHIFT + CALC then press = to get our X. However, this is not the best method when there are multiple solutions for X (which fortunately does not apply in this case).

Module 5 and Module 7 Solutions:

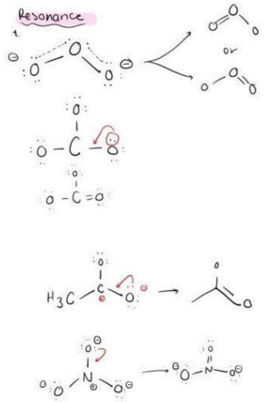
Mod 5

1.

3.



Resonance

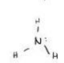


VESPR

1. a) H−C≡N: AX_2 Linear

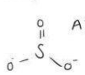
b) S=N̈−F AX_2E bent * choose the least Electroneg atom as centre

c)  AX_6 octahedral

d)  AX_3E trigonal pyramidal

2. a) AX_2

b) AX_4

c)  AX_3

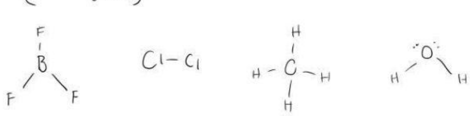
d) AX_3

Bond Order/enthalpy

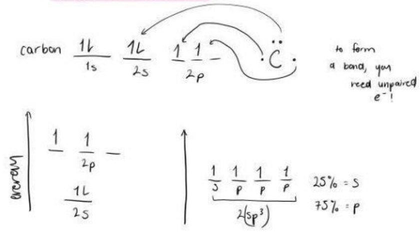
1) $4O_2 + 2O_2 \longrightarrow 4O_3 + 2O$

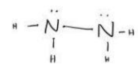
−198.8 kJ/mol + (+113.14 kJ/mol)

= (−85.66 kJ/mol)

2) 

valance of carbon



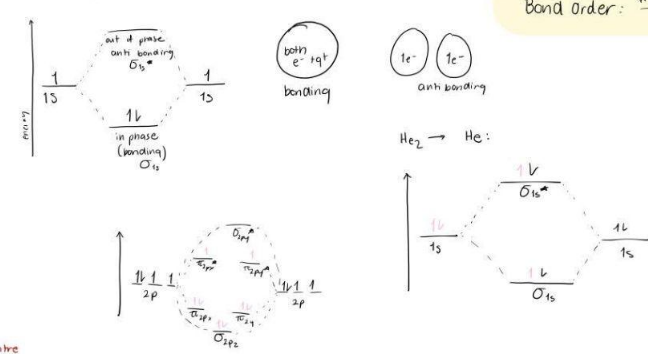
1. 

b) AX_3E

c) trigonal pyramidal

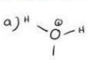
Molecular Orbital

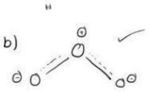
1. $H_2(g) \longrightarrow H:H$

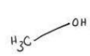


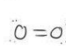
Bond order: $\frac{\#\text{ of bonding } e^- - \#\text{ of anti bonding } e^-}{2}$

Delocalized e⁻

1. a) 

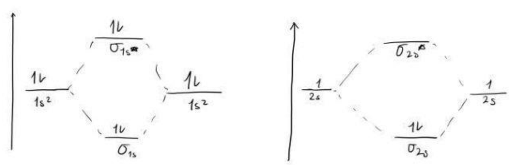
b) 

c) 

d) 

e) 

2) Li = $1s^2\ 2s^1$



Bond order = $\frac{(e^-) \text{ in bonding} - (e^-) \text{ in anti bonding}}{2}$

$= \frac{4-2}{2}$

$= 1$

Mod 7

* vap ↑ b/c kinetic energy

2) 2.15 pa

(1 atm 298.15 K)

310.15 K

$\ln\left(\frac{P_1}{P_2}\right) = \frac{-\Delta H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$

$\frac{P_1}{P_2} = e^{\left(\frac{-\Delta H}{R}\right)\left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$

$P_2 = \frac{P_1}{e^{\left(\frac{-\Delta H}{R}\right)\cdot\left(\frac{1}{T_1} - \frac{1}{T_2}\right)}}$

$P_2 = 2.15$ atm

Thank you!

Good luck on your CHEM 112 exam!

Recordings: The recording will be sent out after via the email you registered with. We'd also greatly appreciate it if you could take a second to fill out our feedback form below!

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