General Chemistry 1 – Practice Exam (Adapted from in-person Midterm 2021)

Instructions :

This is a **CLOSED BOOK** exam. All answers must be written within the exam booklet. If you have any issues with an exam question, write them on top of page 1 (this page).

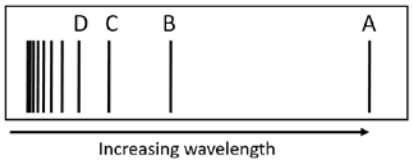
NO EXTRA BOOKLETS AND NO CRIB SHEETS are permitted.

Use of **translation-only** dictionaries, and only **non-programmable** calculators is permitted.

Use of Molecular Modeling kits is allowed. This booklet has **13 total pages** including the cover page.

- Please write legibly and dark enough for a scanner to read.
- **Answer ONLY on the sheets that have a QR code**.
- **Do not write on the QR codes** at the top of the page.
- **Do not write beyond the margins and the diagonal line in the top corners**.
- If you need extra paper to complete a question, use the extra workspace with the QR-code at the end of this booklet. Indicate in the appropriate question that the marker should look at Page # for the full answer.

1. **(8 points)**



The figure given represents a part of a calculated *emission* spectrum of a one-electron ion in the gas phase (Assume Bohr's model can apply). Each line represents the wavelength of a photon resulting from the transition from an initial state to a final state of n = 5. The four longest wavelengths (A, B, C, and D) are denoted in the figure.

a. What transition corresponds to line D? Give $n_{initial}$ and n_{final} **2 points (+1 each no partial points)**

(i) $n_{initial}$	9	(ii) n_{final}	5

b. Among the lines A, B, C, and D, circle the correct choice reflecting which corresponds to a photon of (i) lowest and (ii) highest frequency? If line C is at a wavelength of 415.5 nm, which ion does this calculated emission spectrum correspond to? Show your work **6 points**

(i) Lowest:	**A**	B	C	D	(ii) Highest:	A	B	C	**D**

C represents the transition from $n_{initial} = 8$ to $n_{final} = 5$

(Can use either Rydberg or Bohr's equation)

Using Rydberg equation:

$1/\lambda = 1.097 \times 10^7\ m^{-1} \times Z^2 ((1/n_1^2) - (1/n_2^2))$ where n2 = 8; n1 = 5

$1/(415.5 \times 10^{-9}) = 1.097 \times 10^7 \times Z^2 ((1/25) - (1/64))$

$Z^2 ((1/25) - (1/64)) = 1/(415.5 \times 10^{-9}) * (1.097 \times 10^7)$

$Z^2 (0.024375) = 0.21939$

$Z^2 = 9.00$; Z = 3; so the atom is Li and the ion is Li^{2+}

Using Bohr's equation:

$\Delta E = -2.18 \times 10^{-18} \times Z^2 ((1/n_{final}^2) - (1/n_{initial}^2))$ where $n_{initial} = 8$; $n_{final} = 5$

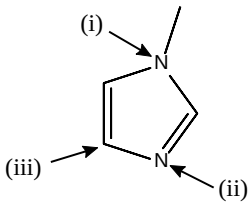
$\Delta E = hc/\lambda = 4.78 \times 10^{-19}$ J (since it is emission it should have a negative sign)

$-4.781 \times 10^{-19} = -2.18 \times 10^{-18} \times Z^2 ((1/25) - (1/64))$

$Z^2 (0.024375) = 0.2193$

$Z^2 \sim 9$; Z = 3; so the atom is Li and the ion is Li^{2+}

2. (12 points)



For the molecule and indicated atoms (denoted with an arrow, (i) to (iii)) answer the following questions. Consider the structure as given (no need to consider resonance structures). All atoms have formal charge of 0 (lone pairs are not shown). (Use valence bond theory and hybridization to describe the bonding.)

a. How many **total** sp^2-s sigma bonds are in the given molecule **(1 point)**

3 total **No partial points**

b. **1.** Describe the orbitals involved in all bonds formed by N (i). Designate sigma/pi bonds. **(2 points)**

N: 2 sp3-sp2 sigma bonds ; 1 sp3-sp3 sigma bond

2. What is the electron **and** molecular geometry at N (i)? **(2 points)**

Electron Geometry: Tetrahedral (+1) ; Molecular Geometry: Trigonal Pyramidal (+1)

3. Circle the one value that best describes the C-N-C bond angle at N(i)). **(0.5 point)**

>90° to <109.5° 109.5° >109.5° to <120° 120° >120° to <180

c. **1.** Describe the orbitals involved in all bonds formed by N (ii). Designate sigma/pi bonds. **(2 points)**

N: 2 sp2-sp2 sigma bonds ; 1 p-p pi bond

2. What is the molecular geometry at N (ii). **(1 point)** Bent

3. Circle the one value that best describes the C-N-C bond angle at N (ii). **(0.5 point)**

>90° to <109.5° 109.5° >109.5° to <120° 120°

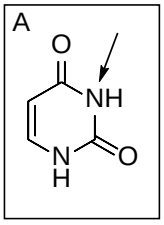
4. Consider x as the bond axis, how many p_x-p_x and p_y-p_y pi bonds does (ii) have? **(1 points)**

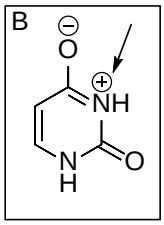
p_x-p_x pi bonds = 0 p_y-p_y pi bonds = 0 or 1 acceptable

d. What is the electron **and** molecular geometry at (iii) **(2 points)**

Electron Geometry: Trigonal Planar (+1) ; Molecular Geometry: Trigonal Planar (+1)

3. (8 points)





One of the research projects in Prof. McKeague's lab focuses on understanding how small molecules may bind to nucleic acids (DNA/RNA) and develop small molecules for therapeutic purposes. A and B represent the structures of a nucleotide (building block of nucleic acids). Note: Lone pairs of electrons are not shown.

i. What is the relationship between A and B? **(1 point)**

Resonance Structures (+1)

ii. What is the hybridization on the N (indicated with an arrow) in A? What is the hybridization of the N (indicated with an arrow) in structure B? **(2 points)**

Hybridization of indicated N in A: sp^3 (N also has a lone pair not)
Hybridization of indicated N in B: sp^2 (no lone pair on this nitrogen – has complete octet)

iii. What are the intermolecular forces present between different molecules of A? **(3 points)**

London Dispersion (or Dispersion) (+1.5)
Hydrogen Bonding (+1.5)

iv. Between structures A and B, how many electrons are delocalized? **(2 points)**

4 electrons are delocalized (one lone pair and one pi bond)

4. (12 points)

i. In increasing order of boiling point

1. 2-methylpentane 2. 2,2-dimethylbutane 3. Heptane

Increasing Order (lowest to highest): 2 1 3 (2,2-dimethylbutane, 2-methylpentane, heptane) +1 (no partial points)
Explanation:
(+2) All have only London dispersion forces. Larger size – larger LDF – so heptane is highest.
More branching results in lower surface area of contact between molecules, and hence lower IMF. So 2 is the lowest.
Higher IMF → Higher boiling point

ii. In increasing order of bond angles

1. H_2S 2. XeF_2 3. $[SbF_6]^-$

Increasing Order (smallest to largest): 3 1 2 (SbF6- , H2S, XeF2) +1 (no partial points)

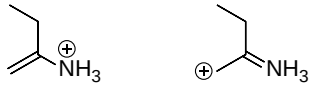
Explanation: (+2) SbF6- – octahedral : bond angle is 90 degree; H2S – bent; bond angle is <109.5; XeF2 is linear; bond angle is 180 degree

b. (6 points) Circle True or False in the space provided. Briefly explain your reasoning.

Pair 1 is a pair of resonance structures
True or False (+1)
Explain your choice (+2): The second structure is not a plausible Lewis structure because the nitrogen has five bonds (N cannot have an expanded octet)

Pair 2 is a pair of resonance structures
True or False (+1)
Explain your choice (+2): Only electrons are moving, no atoms are being moved. These are resonance structures. (Draw out carbons and hydrogens, if you are having trouble visualizing the movement of electrons. In resonance structures only electrons move and not atoms)

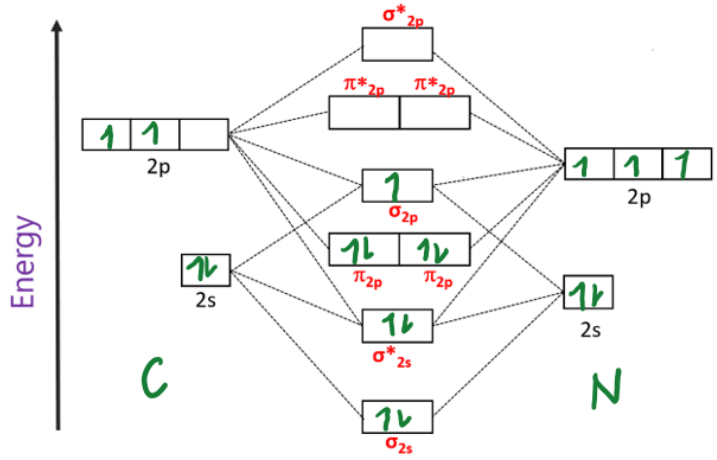
Pair 1



Pair 2

5 (7 points)

Draw the complete MO diagram (valence orbitals only) for the molecule CN. Make sure to label atomic and molecular orbitals. Label the energy axis. What is the bond order?

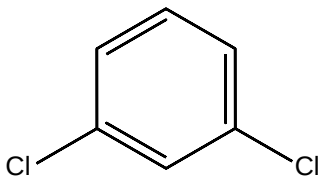
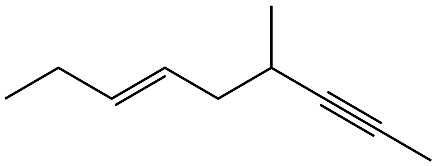
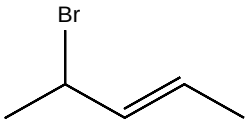
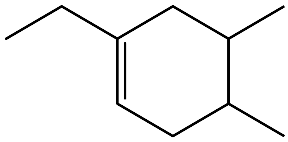


Bond order = (7-2)/2 = 2.5

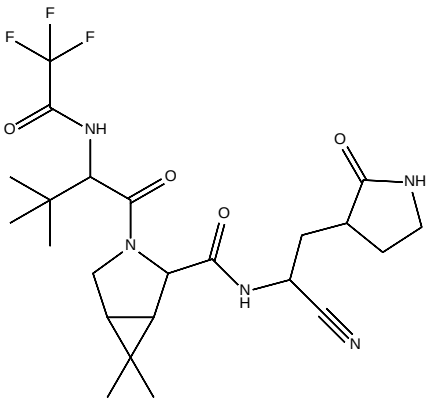
6 (10 points)

a. Draw the following molecules as skeletal structures. **(8 points)**

+2 for each

meta-dichlorobenzene 	4-methylnon-6-en-2-yne 
4-bromopent-2-ene 	1-ethyl-4,5-dimethylcyclohex-1-ene 

b. How many units of unsaturation are there in Paxlovid, the new Pfizer drug for COVID-19 shown below? **(2 points)**



3 rings (3); 4 double bonds (4); 1 triple bond

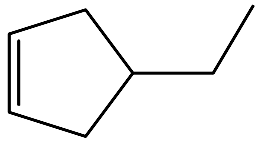
(2) = 9 degrees of unsaturation

Question 7 (10 points)

For the following hydrocarbons, determine the degree of unsaturation and draw one possible structure using skeletal structures **(6 points)**.

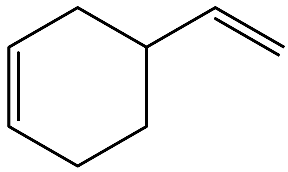
i. C_7H_{12}

2 unsaturations (can show any molecule with 7 carbons and 2 degrees of unsaturation; so 1 triple bond; or 2 double bonds or 2 rings; or 1 ring and one double bond

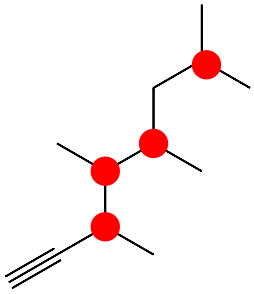


ii. C_8H_{12}

3 unsaturations (can show any molecule with 8 carbons and 3 degrees of unsaturation)



a. Consider the following molecule.



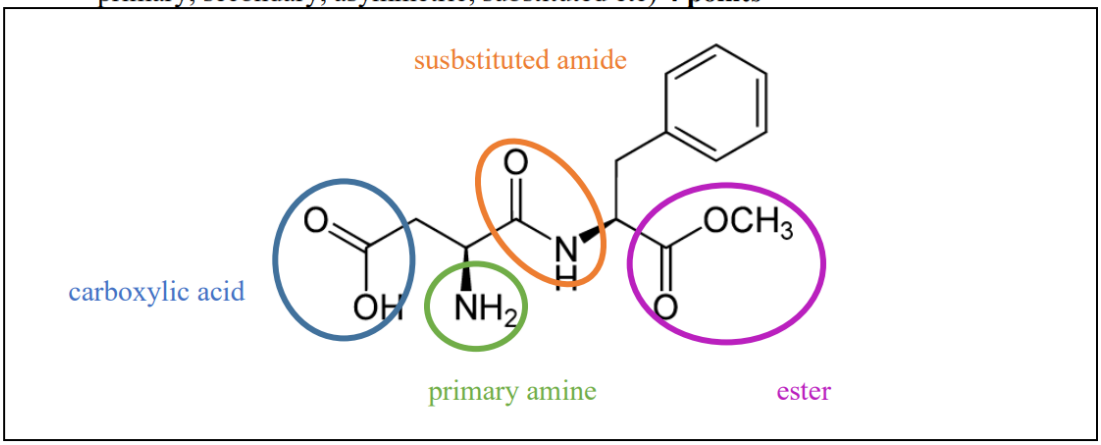
i. Circle all the tertiary carbons in the structure provided. **(1 point)**

ii. Provide the molecular formula of this molecule. **(1 point)** **$C_{12}H_{22}$**

iii. Provide the systematic (IUPAC) name **(2 point)** **3,4,5,7-tetramethyloct-1-yne**

Question 8 (7 points)

a) Regarding the molecule aspartame below, circle and identify all the functional groups present (what we learned in class). Be sure to provide the details about the functional groups (e.g., primary, secondary, asymmetric, substituted etc) **4 points**

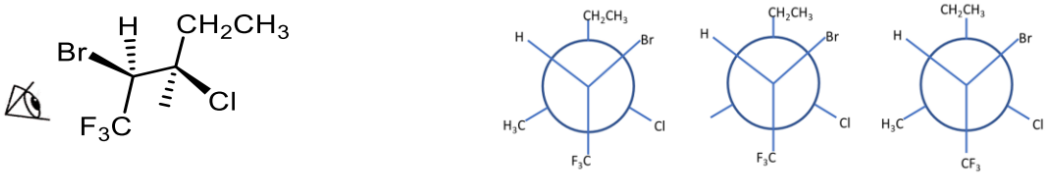


b) How many units of unsaturation are there in the aspartame molecular above? **1 point**

Answer: 7

(because there are 6 double bonds + 1 ring)

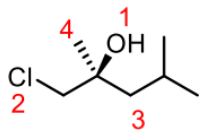
c) Draw the Newman projection of the following molecule from the perspective indicated **2 points**



Question 9. 10 points

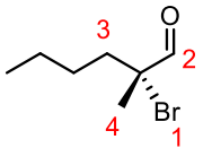
a) Give each molecule the appropriate stereochemical assignment (R vs S). Show the priority. **3 points**

i.



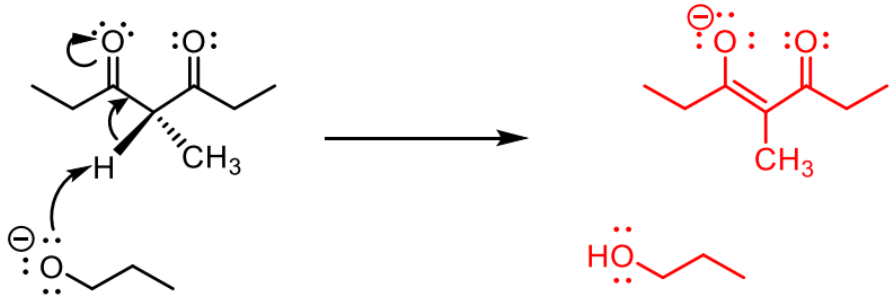
S

ii.



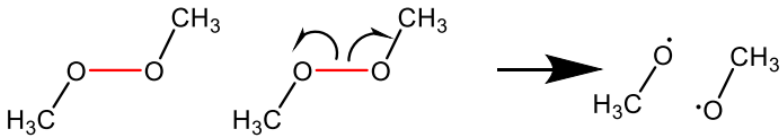
R

b) Draw the **product(s)** of this arrow pushing. Use skeletal structures. Be sure to include any charges and lone pairs in the product(s). **4 points**

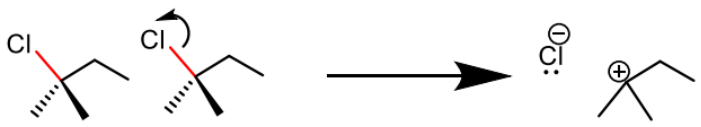


c) Break the red bond of the following molecules as indicated, showing the correct arrows to represent the movement of electrons. Show the cleaved products with the appropriate electrons or charge. **3 points**

i. homolytic

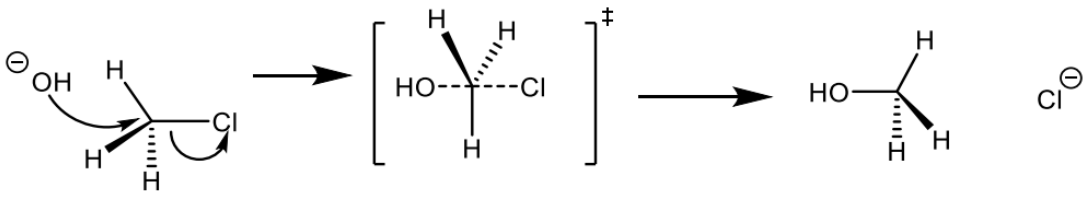


ii. heterolytic

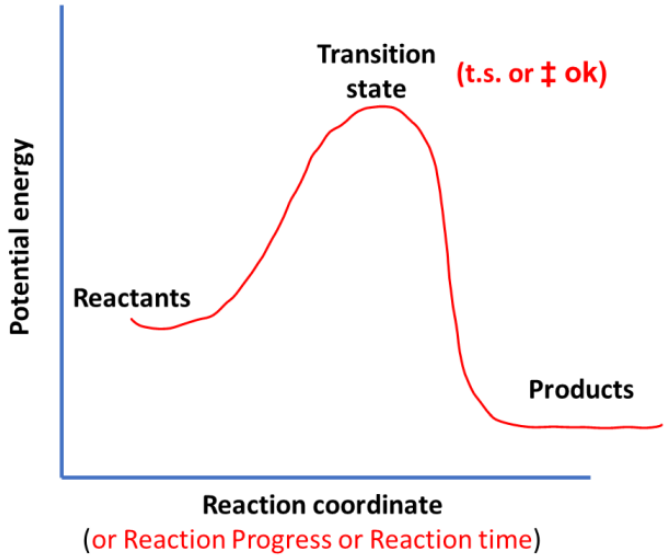


Question10 (7 points)

a) Provide the detailed mechanism of the SN2 reaction. Include any transition states or intermediates of the reaction of methylchloride with the hydroxyl shown below. Use arrows to indicate the flow of electrons and indicate any charge/long pairs that are important. **4 points**

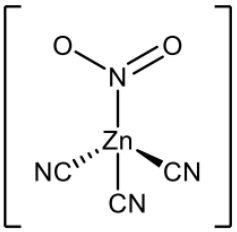
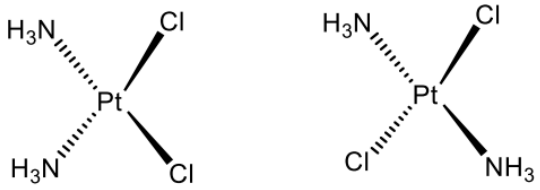
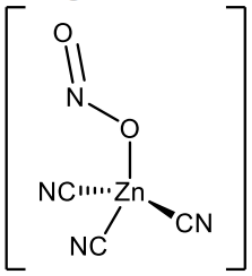


b) Assume that the SN2 reaction above is exothermic, draw the associated reaction energy diagram for this reaction. Include all the necessary labels. **(3 points)**



Question 11 (9 points)

Fill out the table by providing the following information for the two coordination complexes. **8 points**

	diamminedichloroplatinum(II)	Na_2 
Oxidation state	+2	+2
Coordination number	4	4
Shape	Square planar	tetrahedral
Draw isomers indicated	The pair of geometric isomers 	Linkage isomer Na_2 

b) Provide the IUPAC name for this coordination complex: $[Cr(en)_2Cl_2]Cl$ **(1 points).**

Dichlorobis(ethylenediamine)chromium(III) chloride