McGill

December 2022

Final Examination

General Chemistry 1

Chem110/001-002

Final Exam Fall 2022

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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 **12 total pages (6 double-sided – PRINTED ON BOTH SIDES)** 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.

THE COMPLETE EXAMINATION BOOKLET MUST BE RETURNED

HAPPY HOLIDAYS AND GOOD LUCK!

Q1 12 points

Arrange the following in increasing (lowest to highest) order. Explain your answer, briefly.

a) Increasing order of boiling point

(i) Carbon tetrabromide (CBr_4) (ii) Carbon tetraiodide (CI_4) (iii) Methane (CH_4)

b) Increasing order of intermolecular forces

(i) $CH_3CH_2CH_2OH$ (ii) $CH_3CH_2CH_2F$ (iii) $CH_3CH_2CH_3$

c) Increasing order of C-N bond length:

(i) $CH_3CH_2CH_2NH_2$ (ii) CH_3CH_2CN (iii) CH_3CH_2CHNH

d) Increasing order of *frequency* of a photon for the following transitions in a H atom (assume all given transitions are possible):

(i) 1s to 3d (ii) 5p to 1s (iii) 7p to 2s

Q2 10 points

a) The research group of Prof. Brad Siwick (McGill) works on understanding materials with unique optoelectronic properties. Their lab uses ultrafast laser pulse (wavelength = 400 nm) to study these materials. **(5 points)**

(i) Which one of the following metals (A, B, or C) will emit the slowest (lowest velocity) electron when excited with a photon of the ultrafast laser pulse (400 nm)? Explain your choice and show your work. **(4 points)**

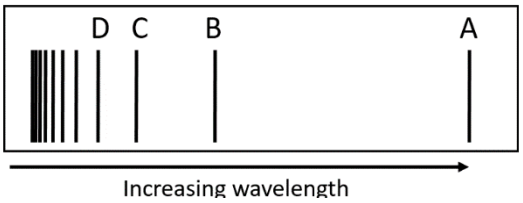
A: Work function = $6.63 * 10^{-19}$ J; B: Work function = $3.06* 10^{-19}$ J; C: Work function = $3.98 * 10^{-19}$ J

(ii) At a frequency above the threshold frequency for a metal, what will be the effect of *decreasing* the wavelength, on the kinetic energy of the ejected electron. Kinetic energy will _____ (fill in the blank)

Circle one of the following: Decrease Increase Remain unchanged

b) 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 (line A, line B, line C, line D etc.) represents the wavelength of a photon resulting from the transition from an initial state to a final state of n = 6.

The four longest wavelengths (A, B, C, and D) are denoted in the figure. **(5 points)**



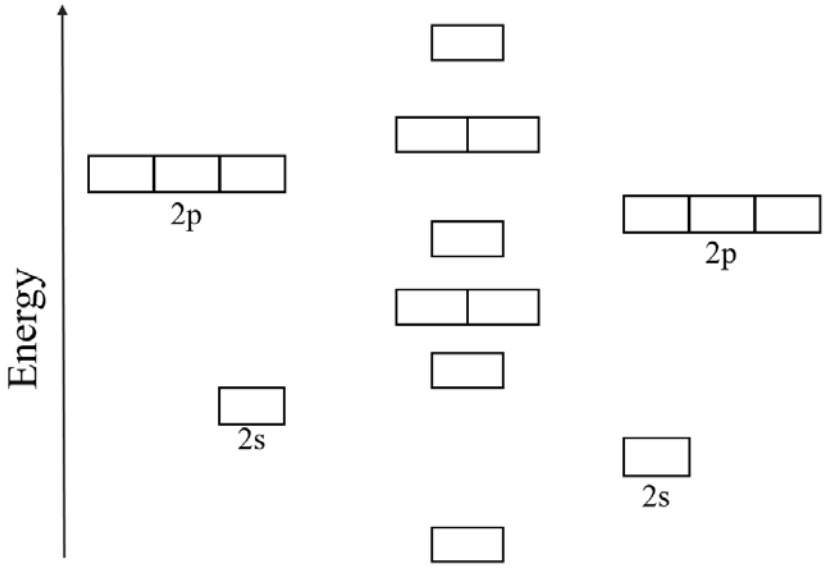
(i) What transition corresponds to line C? **(1 point)**

$n_{initial}$ = _____ ; n_{final} = _____

(ii) If line B is at a wavelength of 300 nm, which ion does this calculated emission spectrum correspond to? Show your calculations, including equations used. **(4 points)**

Q3 10 points

a) Given below is an incomplete MO diagram for the molecule CO (carbon monoxide). Complete the MO diagram. Make sure to include the label for each atom (atomic orbitals are labeled but the atoms are not), label the molecular orbitals, show the electrons in the atomic orbitals and molecular orbitals. **(4 points)**



b) Using MO theory, predict which of the following will have the shortest bond length. **(2 points)**

CO CO^- CO^+

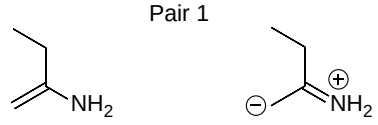
Justify your choice briefly:

c) Molecule A has a molecular formula of C_3H_6O. The molecule does not contain any sp^2-s sigma bonds. Draw the most stable Lewis structure showing appropriate shape and dashed/wedged bond where appropriate, based on VSEPR. Show lone pairs. Is the molecule *polar*? Denote the *largest* bond angle in the Lewis structure. (If there are multiple bond angles of the same value, denote any one). **(4 points)**

Q4 10 points

a) Circle True or False in the space provided for each statement for Pair 1 and 2, below. Briefly explain your reasoning. **(6 points)**

Pair 1



Pair 2

Statement:
Pair 1 is a pair of resonance structures.
Circle One: True or False
Explain your choice:

Statement:
There are 4 delocalized electrons in the given resonance structures in pair 2.
Circle One: True or False
Explain your choice:

b) In Pair 2 shown above, how many total pi molecular orbitals are in the resonance hybrid structure? **(1 point)**

c) Based on band theory, draw the energy level diagram (valence band, conduction band, acceptor/donor level) for a Silicon (Z = 14) semiconductor doped with Gallium (Z = 31). Show the energy axis. **(3 points)**

Question 5 (12 points)

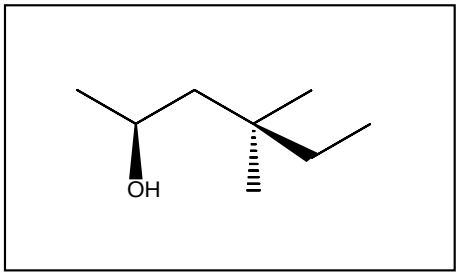
a) Draw the following molecules using skeletal structures. Be sure to use dash/wedged lines if necessary. **(8 points)**

7,7-diethyl-2,2-dimethylnonane	(*Z*)-1,1-dibromohept-2-ene
1-fluorocyclopentene	*(R)*-6-chloro-6-methyloct-2-yne

b) Draw two molecules with the molecular formula C_3H_8O that are functional isomers of each other. Circle and specify the exact type of functional groups in these molecules. Use skeletal structures. **(4 points)**

Question 6 (9 points)

a) For the molecule shown below, circle all chiral centers. Assign *R* vs S (show your work). **(3 points)**

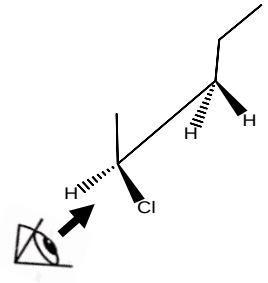


b) For the molecule from part a above, draw an example of the indicated isomer (use skeletal structures). **(3 points)**

Functional isomer	**Positional isomer**	**Enantiomer**

c) For the molecule below, indicated in the sawhorse diagram **(3 points)**:

i. Draw the correct Newman projection from the perspective indicated.



ii. Is the conformation shown above stable? Why or why not?

iii. Provide the IUPAC name for the molecule, indicating *R* and *S* if appropriate.

Question 7 (12 points)

a) Provide the detailed mechanism of the S_N1 reaction of sodium hydroxide with 2-chloro-2-methylpropane. Include all transition states and intermediates. Use arrows to indicate the flow of electrons and indicate any charge/lone pairs that are important. **(4 points)**

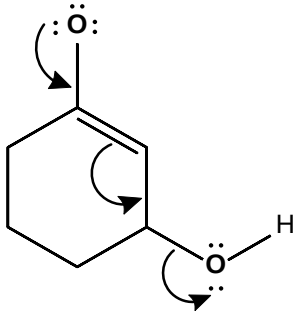
b) In the reaction above, draw or name the following. **(2 points)**

i. Nucleophile

ii. Electrophile

c) Assume that the S_N1 reaction above is endothermic, draw the associated reaction energy diagram for this reaction. Include all the necessary labels. **(3 points)**

d) The following molecule is missing appropriate charges. Calculate and indicate the formal charge on the two oxygens. Finally, draw the product(s) of this arrow pushing using skeletal structures. **(3 points)**



Reaction product(s):

Question 8 (14 points)

a) Consider the complexes $[CoF_6]^{3-}$ and $[Co(NH_3)_6]Cl_3$ **(9 points).**

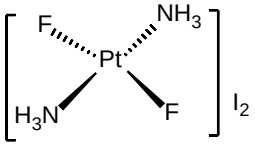
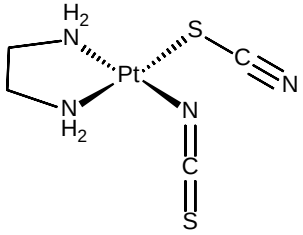
i. Fill in the table.

	$[CoF_6]^{3-}$	$[Co(NH_3)_6]Cl_3$
Oxidation state		
Coordination Number		
IUPAC name		
Paramagnetic **or** diamagnetic?		

ii. Draw d-orbital energy diagrams to compare the energy splitting of these complexes.

iii. Which complex is more likely to absorb blue light? Why?

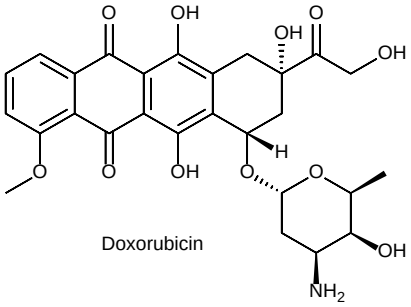
b) Draw an example of the isomer listed for each of the complexes indicated. **(4 points)**

Isomer type	Complex	Isomer
Coordination isomer		
Linkage isomer		

c) What is lanthanide contraction? **1 point.**

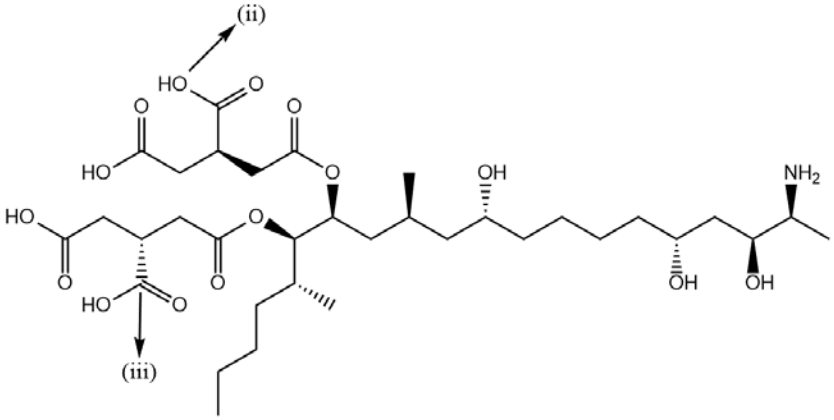
d) Question 9 (11 points)

a) To help improve the safe and effective delivery of the drug doxorubicin to cancer cells, Prof. Janine Mauzeroll developed liposomes to "carry" this drug. How many units of unsaturation are present in doxorubicin (shown below)? Explain your answer. **(2 points)**



Doxorubicin

b) At Carleton University, I (Prof. McKeague) developed a "biosensor" to screen food for the presence of fumonisin B1. Fumonisin B1 (shown below) is a toxin often occurring in corn. **(9 points)**



(i) Circle and identify all the functional groups in the molecule. Be sure to specify if they are primary, secondary, tertiary, asymmetric, symmetric, substituted, or unsubstituted if appropriate. Indicate directly on the diagram. **(4 points)**

(ii) Describe all bonds (include sigma and pi, where necessary) formed by the indicated oxygen atom (ii). What is the expected H-O-C bond angle? **(2.5 points)**

(iii) Describe all bonds (include sigma and pi, where necessary) formed by the indicated carbon atom (iii). What is the molecular geometry at the carbon atom? **(2.5 points)**

EXTRA SPACE: (THE ENTIRE BOOKLET INCLUDING THIS PAGE MUST BE RETURNED AT THE END OF THE EXAM)

If you need extra paper to complete a question, use this extra workspace. Indicate in the appropriate question that the marker should look at Page # 11 for the full answer.

EXTRA SPACE: (THE ENTIRE BOOKLET INCLUDING THIS PAGE MUST BE RETURNED AT THE END OF THE EXAM)

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