JOHN ABBOTT COLLEGE
CHEMISTRY DEPARTMENT

202-NYA-05
GENERAL CHEMISTRY
Winter 2020
FINAL EXAM

Please note the following unusual features of this exam (due to the unusual Winter 2020 semester- COVID-19 shutdown on March 13) :

- *It was designed to be written in two hours, instead of the usual three.*
- *There were no multiple choice questions*
- *It did not include material from the first 2 weeks of the term*

Some working spaces have been removed from this document for posting.

1. a. i. An unknown transition metal (X), forms an ion X^+ which has a half-filled 3*d* sublevel ($3d^5$). Which element (name or symbol) could X be? _____

[2]

ii. Support your answer with the electron configuration of the transition metal X and its corresponding ion X^+. (You may use the noble gas configuration to abbreviate the full configuration.)

[4]

X:	
X^+:	

b. i. Give the number of core electrons for Mg^{2+}. Support your answer with the orbital box diagram for the ground-state electron configuration of Mg^{2+} (no noble gas abbreviation) and briefly (<15 words) explain your reasoning.

[3]

ii. Is Mg^{2+} paramagnetic or diamagnetic? Briefly explain.

[2]

c. Why do Li, Na, and K have similar chemical properties?

[3]

2. a. What is the general relationship between the radius of an atom and its first ionization energy? Explain the factors that give rise to this relationship.

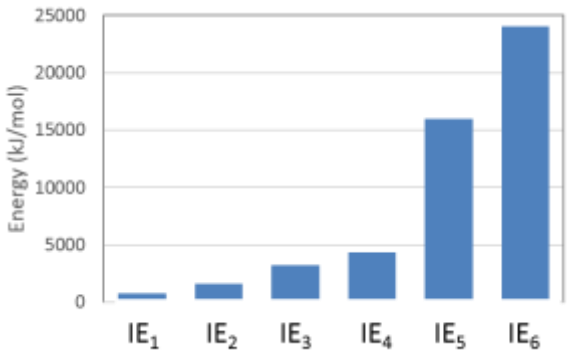
[5]

b. Arrange K, Ga, and Cl in order of increasing atomic radius.

Smallest Radius		Largest Radius

[2]

c. The figure below shows the successive ionization energies (IE) for an element in the third period of the periodic table.



Identify the element and justify your choice.

[3]

3. The table below contains the lattice energies (kJ/mol) of various sodium and magnesium compounds.

Cation/Anion	*Fluoride*	*Chloride*	*Bromide*
Sodium	-940	-780	-740
Magnesium	-2920	-2500	-2400

Why do the magnesium compounds have lattice energies that are so much larger in magnitude than those of the sodium compounds? Provide <u>two</u> factors that cause these differences, specifying in what ways they impact the lattice energies of these sets of compounds.

[7]

If you are writing below this line you are probably writing too much.

4. The S – O bond length in the sulfur trioxide (SO_3) molecule is measured experimentally as 142pm. The S – O bond length in the sulfite anion (SO_3^{2-}) is longer and is measured experimentally as 151 pm.

(Note: All atoms follow the Octet Rule here. None are hypervalent.)

Explain the difference between the experimentally observed bond lengths using Lewis structures. Draw all relevant structures and include any non-zero formal charges.

[11]

5. a. Rank the following species by expected F-N-F bond angle, from smallest to largest angle: NF_3, NF_4^+, NF_2^-

_____ _____ _____

smallest bond angle largest bond angle

Briefly justify your ranking (30 words or less). Support your explanation with 3-D structures.

[6]

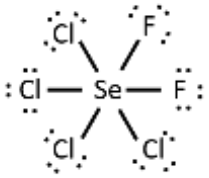
b. Complete this table by naming the molecular & electron group geometry of the species in a.

	NF_3	NF_2^-	NF_4^+
Electron group geometry			
Molecular geometry			

[6]

c. The Lewis structure of SeF_2Cl_4 is shown below. There are two possible (3-D) molecular geometries for this compound, only one of which is polar. Draw 3-D representations of both the geometries. Indicate which one is polar and show the net dipole on your drawing.

[6]



6. Using the table provided below, determine the *ΔH* of reaction for the following reaction:

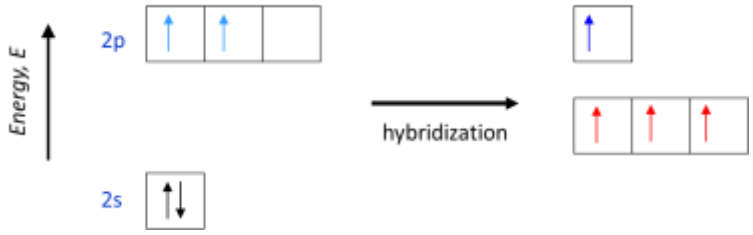
$$C_2H_2\,(g) + 2F_2\,(g) \rightarrow C_2H_2F_4\,(g)$$

Your work should show all Lewis structures.

[10]

Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)	Bond	Bond Energy (kJ/mol)
O-O	142	C≡C	839	C-Br	276
O=O	498	C≡N	891	C-I	240
H-O	464	C=O	745 (799 in CO_2)	F-F	154
H-H	436	C-H	413	Cl-Cl	243
C-C	347	C-F	453	Br-Br	218
C=C	614	C-Cl	339	I-I	149

7. Consider the following orbital box diagram for carbon.



a. What is the hybridization of the carbon atom?

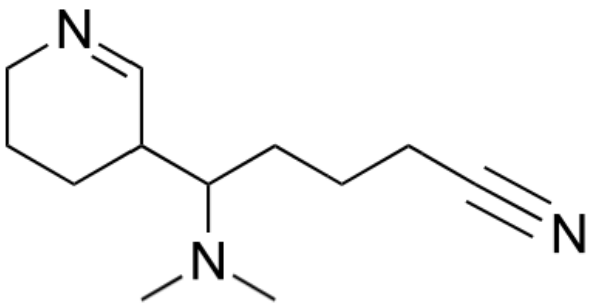
[1]

b. Justify your answer above in terms of the number of hybridized and unhybridized orbitals.

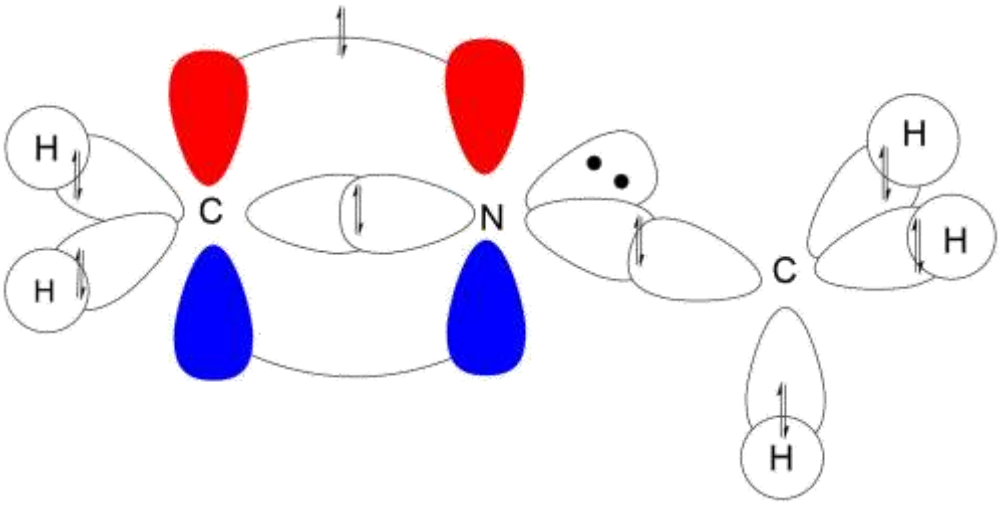
[3]

c. On the molecule shown below, indicate (e.g., with an arrow) *ONE* carbon atom which has the hybridization you chose in part a.

[2]



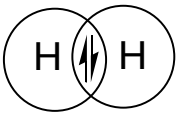
8. Observe the following orbital overlap diagram (hybridization and bonding scheme):



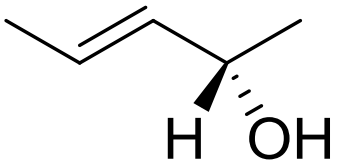
[8]

On the diagram, identify all unique bond types in this diagram and indicate what orbitals are overlapping to create that particular bond. You may use the formal notation shown below to denote the bonds. For example, for the molecule H_2, the covalent bond is a sigma bond created by the overlap of the s orbital from each H atom.

Example (notation used in *Tro*): σ: H(s)-H(s)

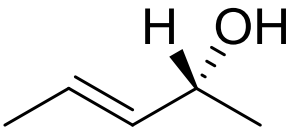
for the bond H-H 

9. Consider Structure A, below:

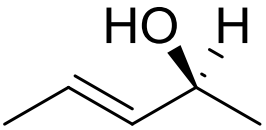


A

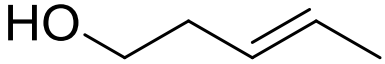
Compare it to the various other structures, B to F, below:



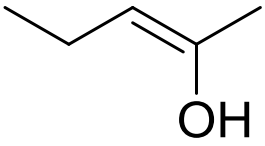
B



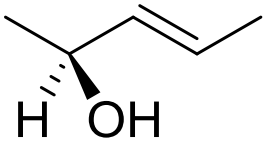
C



D



E



F

Answer the following questions by indicating option "B", "C", etc. or, if none of the above structures matches, write "none".

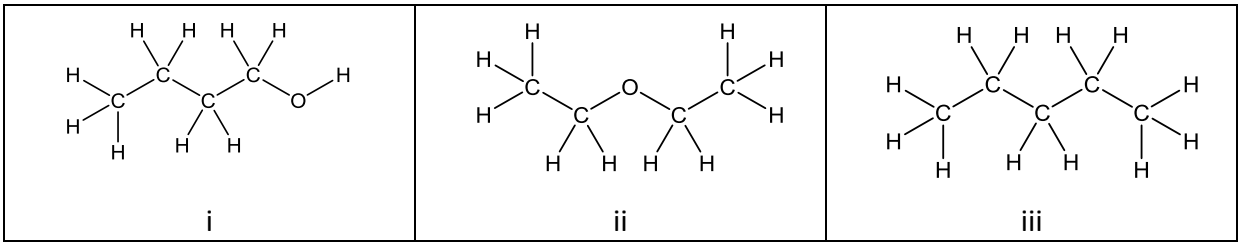
a. List all structures (among B to F) that are structural isomers of Structure A: _____
[3]

b. List all enantiomers of Structure A: _____
[3]

c. List all *cis-trans* diastereomers of Structure A: _____
[2]

d. Of the six structures shown in this question, how many are chiral? _____
[2]

10. For the following three molecules (i-iii):



a. Put these molecules in order from lowest to highest boiling point. Justify your ranking by including all relevant intermolecular forces.

[6]

b. One of these compounds is more soluble in water than the two others. Identify that compound and explain this observation with the help of the intermolecular forces between solute and solvent (water). Limit your answer to <20 words.

[4]

11. The strength of an acid depends upon the stability of its conjugate base.

a. Write the equation for the hydrolysis (dissociation reaction of acid in water) for the generic acid HA and water.

[1]

b. Explain how the numerical value of the K_a of an acid reflects the stability of that acid's conjugate base.

[3]

(Question 11 continues on the next page.)

c. This stability of the conjugate base in turn depends upon factors which include size, resonance, and inductive effects. Complete the table below to show which factor is most important in determining which of the two species is the stronger acid. Add a check mark under the most important factor.

[6]

	Size	Resonance	Inductive Effect
Sulfuric acid (H_2SO_4) vs Sulfurous acid (H_2SO_3)			
Hydrofluoric acid vs Hydrochloric acid			
Acetic acid (CH_3COOH) vs chloroacetic acid ($CH_2ClCOOH$)			

d. HCO_3^- can act as a weak acid. Draw the complete Lewis structure (including any resonance and any non-zero formal charges) of the conjugate base of HCO_3^- and specifically explain the factors that lead to its stability.

[6]