CHEMISTRY 110 –Midterm Exam

Thursday November 7, 2024, 6:30 – 8:30 pm

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This booklet has 8 questions on 10 pages (The last page can be used as a scrap page).

The staple must NOT be removed from the question booklet. Your intact question booklet must be returned at the end of the exam.

A separate booklet contains a periodic table, and datasheet.

Write your answers directly under the questions in the space provided. Do not write on the QR codes or near the top edges (as it may be cut off).

Please write **legibly and dark enough** for the scan to be readable. For students who use English as a second language, dictionaries are permitted. Calculators are allowed.

DO NOT ASK QUESTIONS OF THE INVIGILATORS about interpretations of the exam questions. If you have a concern about a question, please summarize it at the top of this page. All concerns will be evaluated after the exam. GOOD LUCK!

Question 1 **8 points** *(Assume all transitions are possible)*

a. 6 points Calculate the **energy (in kJ/mol)** required to ionize (completely remove) the electron from the **n=3** level of **He^+ ion** (He: Helium). Show your work including equations. (3 sig. figs.)

He+ Z = 2 $n_{initial} = 3$ $n_{final} = \infty$

$\Delta E = E_{final} - E_{initial} = -B(2^2/\infty^2) - (-B(2^2/3^2)) = 0 + 2.18 \times 10^{-18}$ J $(4/9) = 0.9688.. \times 10^{-18}$ J

$\Delta E = 0.9688.. \times 10^{-18}$ J * $(6.022.. \times 10^{23})$ mol^{-1}

$\Delta E = 5.84 \times 10^5$ $Jmol^{-1} = 5.84 \times 10^2$ $kJmol^{-1}$ (584 kJ/mol)

b. 2 points **(NO PART MARKS)**

(I) Select the **largest (longest)** wavelength from the three choices below:

i. Wavelength of photon to *completely remove* an electron from *1s orbital of Hydrogen atom*
ii. Wavelength of photon to *completely remove* an electron from *1s orbital of Boron atom* (B)
iii. Wavelength of photon to *completely remove* an electron from *1s orbital of Boron cation* (B^+)

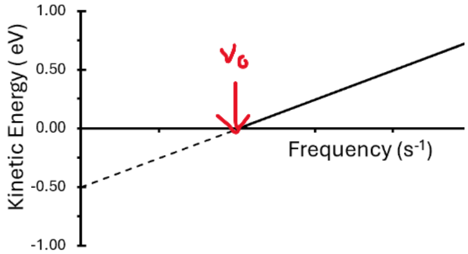
i **or** **ii** **or** **iii**

(II) Select the **smallest (shortest)** wavelength from the three choices below (*for H atom*):

i. Wavelength of photon *emitted* for an electron transitioning from *2p to 1s* orbital
ii. Wavelength of photon *absorbed* for an electron transitioning from *2s to 4p* orbital
iii. Wavelength of photon *absorbed* for an electron transitioning from *1s to 3p* orbital

i **or** **ii** **or** **iii**

Question 2 8 points



A Chem110 student plots the graph shown on the left, from data obtained for the kinetic energy (eV) of the ejected electron versus frequency (s^{-1}) of the incident light, for an unknown metal. (1eV = 1.6022×10^{-19} J)

Based on the plot, answer the questions **a to c** below:

a. 1 point *On the plot above*, label the **threshold frequency**. (NO PART MARKS)

b. 2 points What is the value of the work potential (in J) of the unknown metal?

(-ve of the value when x = 0)

Work potential = +0.50 eV = $0.50 \times 1.6022 \times 10^{-19}$ J = 0.8011×10^{-19} or 8.011×10^{-20} J

+1 for identifying +0.50 eV correctly; +1 for converting to J (no points if work potential given as a negative value)

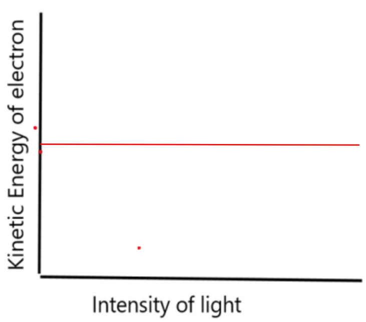
c. 3 points What is the *longest* wavelength (in nm) required to eject an electron from this metal's surface? Show your work including equation(s) used. (3 sig figs)

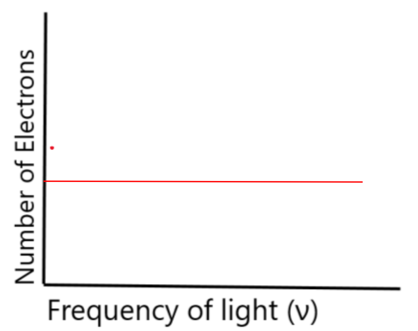
E = hc/lambda; E = 8.011×10^{-20} = hc/lambda; solve for lambda = 2.48×10^{-6} m = 2480 nm

d. 2 points In the space provided below, plot the following NO PART MARKS

(Assume frequency is *above* threshold frequency):

i. *Kinetic energy* of an ejected electron versus the *intensity* of the incident light (left)
ii. *Number of electrons* ejected versus the *frequency* of the incident light (right)
(Both should be straight lines – there is no relationship)





Question 3 6 points

a. 2 points

In the ground state of Ge (Germanium; Z = 32) atom, **name** the following orbitals:

i. Orbital containing the electron that requires the maximum energy to be removed.

1s

ii. Orbital containing the electron that experiences the minimum effective nuclear charge.

4p

b. 2 points

An unknown anion (A^-) has the following *excited* electronic configuration: [Ar] $4s^2 3d^3 4p^1$

(Ar: Argon; Z =18)

Give the **condensed ground state electronic configuration** of the atom, **A** and the cation, $\mathbf{A^{2+}}$. Show your work. (Assume all electronic transitions are possible)

Electronic Configuration of A: [Ar]$4s^2 3d^3$

Electronic Configuration of A^{2+}: [Ar]$3d^3$

c. 2 points

In a single atom, determine how many electrons can have the following set of quantum numbers?

(i) n = 5; l = 3 14 electrons

In a single atom, determine how many electrons can have the following set of quantum numbers?

(i) n =3; l = 2; m_s = +1/2 5 electrons

Question 4 8 points

Rank the following from 1 to 4 in ***increasing*** order. Provide the ranking in the boxes provided.

-0.5 for each incorrect rank (-2 max per part)

Note: Atomic number (Z) are provided for relevant atoms

a) Increasing (lowest to highest) order of *ionization energy*: **(1= lowest; 4 = highest)**

Mg	Rb	Cs	K
4	2	1	3

b) Increasing (lowest to highest) order of *bond angle*: **(1= lowest; 4 = highest)**

H_2O	CCl_4	XeF_4	HCN
2	3	1	4

c) Increasing (smallest to largest) order of *ionic size* **(1= smallest; 4 = largest)**

S^{2-}	O^{2-}	Be^{2+}	Na^+
4	3	1	2
S: Z = 16	O: Z = 8	Be: Z = 4	Na: Z = 11

d) Increasing (lowest to highest) order of *bond energy* **(1= lowest; 4 = highest)**

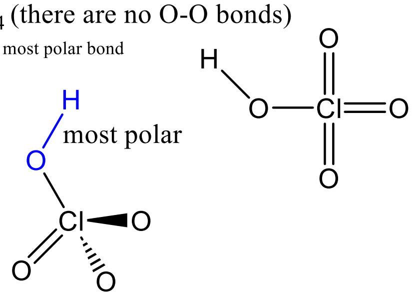
P-F	P-Cl	P-I	P-Br
4	3	1	2

Question 5 **12 points**

a. 9 points For the molecules $HClO_4$ and TeF_6, draw the most stable *Lewis structure* showing appropriate shape and *dashed/wedged bonds*, based on VSEPR. Determine the ***molecular geometry*** around the central atom. For $HClO_4$, label the *most polar bond*.

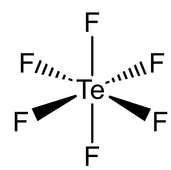
$HClO_4$ (there are no O-O bonds)

Label the most polar bond



Molecular Geometry around Cl: TETRAHEDRAL

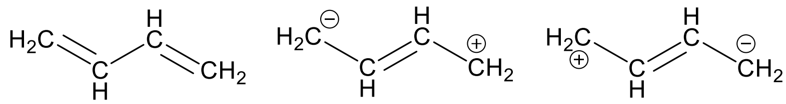
TeF_6



Molecular Geometry around Te: OCTAHEDRAL

b. 3 points (Note: Lone pairs are not shown in structures below)

(i) For the three *resonance* structures (1, 2 and 3) shown below, answer the following question*:*

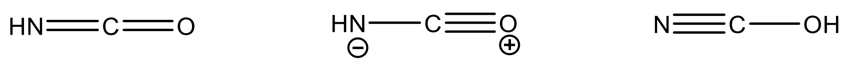


Structure 1   Structure 2   Structure 3

(I) Circle the *most contributing* resonance structure.

Structure 1   Structure 2   Structure 3

(ii) For the three structures given (4, 5, and 6) below, answer the following questions:



Structure 4   Structure 5   Structure 6

(I) Circle all the structures that represent *resonance structures* of each other:

Structure 4   Structure 5   Structure 6

(II) Among the resonance structures, circle the *most contributing* resonance structure.

Structure 4   Structure 5   Structure 6

Question 6 **6 points**

Using the data given below, calculate the **lattice energy** for SrO(s).

	$\Delta H°$ (kJ/mol)
$Sr(s) \longrightarrow Sr(g)$	+180
$Sr(g) \longrightarrow Sr^{2+}(g) + 2e^{-}$	+1468
$O_2(g) \longrightarrow 2O(g)$	+500
$O(g) + 2e^{-} \longrightarrow O^{2-}(g)$	+600
$Sr(s) + \frac{1}{2} O_2(g) \longrightarrow SrO(s)$	-550

Lattice Energy:

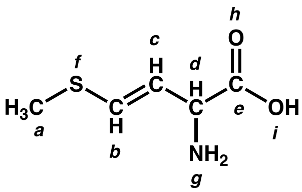
$SrO (s) \rightarrow Sr^{2+} (g) + O^{2-} (g)$

Rearrange given equations to obtain the final equation:

Equation 1 + Equation 2 + ½ Equation 3 + Equation 4 – Equation 5 = Lattice energy equation

180 + 1468 +1/2 (500) + 600 +550 = 3048 kJ/mol

Question 7 10 points



Consider the molecule given on the left, and answer questions (i) to (vi) using chemical bonding theories that we have learnt in class (valence bond theory, hybridization).

Note that the lone pairs are not shown in the structure:

i. Consider the carbon atoms marked in as ***a***, ***b***, ***c***, ***d,* and *e*** in the molecule, and determine **hybridization** at each of the carbon centers. (2.5 points)

Atom	**Hybridization**
Carbon (***a***)	sp3
Carbon (***b***)	sp2
Carbon (***c***)	sp2
Carbon (***d***)	sp3
Carbon (**e**)	sp2

ii. Now, consider the sulfur atom (S) marked as ***f*,** nitrogen (N) atom (***g***), and oxygen(O) atoms (**h and *i***), and determine their **hybridization**. (2 points)

Atom	**Hybridization**
Sulfur (***f***)	sp3
Nitrogen (***g***)	sp3
Oxygen (***h***)	sp2
Oxygen (***i***)	Sp3

iii. **Describe** all the bonds formed by the carbon atoms ***a*** and ***b***, using sigma and pi designation as appropriate. (2 points)

Atom	**Bonds formed (use sigma and pi as appropriate)**
Carbon (***a***)	sp^3-s σ bonds, sp^3-sp^3 σ (0.5 for the orbitals; 0.5 for sigma)
Carbon (***b***)	sp^2-s σ bonds, sp^2-sp^3 σ bonds; sp^2-sp^2 σ bonds; p-p pi bond (0.25 for orbitals; 0.25 for identifying sigma or pi)

iv. How many total sp^3-s sigma bonds are in the molecule? (1 point) 7

v. Determine **electronic** and **molecular geometry** at carbon (C) labeled ***e*** and sulfur (S) labeled ***f*** centres. (2 points)

Atom	**Electronic Geometry**	**Molecular Geometry**
Carbon (***e***)	Trigonal Planar	Trigonal Planar
Sulfur (***f***)	Tetrahedral	Bent (or V-shaped)

vi. Circle the value from the choices given below, that describes the **C-S-C bond angle at sulfur** (S) marked ***f***: (0.5 points)

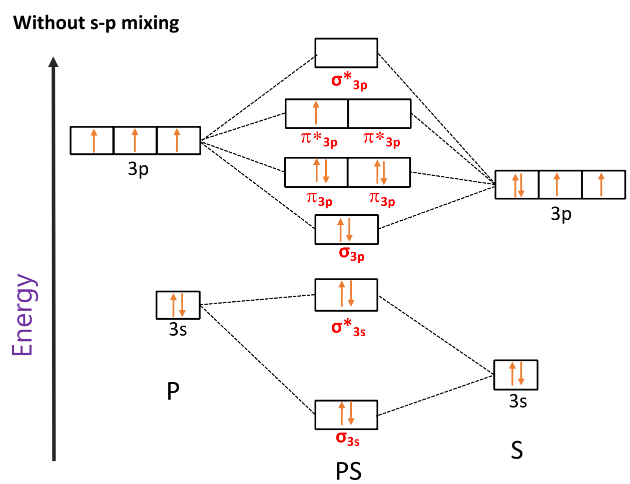
>90° to <109.5° 109.5° >109.5 to <120° 120° >120° to <180°

Question 8   12 points

Using the **valence shell orbitals only** draw a **complete** molecular orbital (MO) diagram (with no s-p mixing) for the molecule **PS**, in the space provided below. **(6 points)**

Assume that 3s and 3p atomic orbitals will form molecular orbitals like those formed by the combination of 2s and 2p atomic orbitals that we learnt in class, and there is no s-p mixing.

Show **energy arrow**, **atomic orbitals** involved, **atom labels**, the **molecular orbitals** that are formed, **filled electrons** in the MO diagram etc. Make sure to **label all the atomic and molecular orbitals**.



Using the MO diagram above, answer the following questions:

(i) Which one of the following will have the *highest bond order*? Circle the correct choice

A) PS^{1-} B) PS   C) PS^{1+}

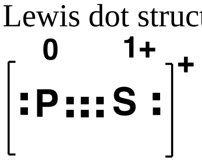
(ii) Which one of the following will have the *longest bond length*? Circle the correct choice

A) PS^{1-} B) PS   C) PS^{1+}

(iii) Which of the following will be *diamagnetic*? Circle the correct choice.

A) PS^{1-} B) PS   C) PS^{1+}

(iv) Draw Lewis dot structure of the molecule with the shortest bond length (based on the MO diagram) from among the three (PS^{1-}, PS, PS^{1+}), and indicate the bond order calculated from the Lewis dot structure. **(3 points)**



Bond Order
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