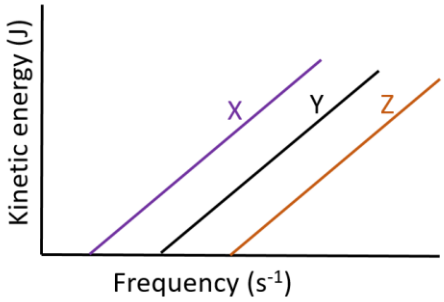
1. **10 points**

   The absorption of energy results in the excitation of an electron in an **ion.**
   The excited electronic configuration of the ion is $5p^1$ i.e. the electron in the ion is excited to the 5p orbital.

   In the ***emission*** spectrum of the ion, the ***longest*** wavelength observed is 112.54 nm. Using Bohr's or Rydberg's equation, determine which ion does this spectrum correspond to?
   Show your work and calculations, including formulae used.
   (Assume all transitions are possible for the ion)

Question 2:

1. 10 points



The plot of kinetic energy of the ejected electron versus frequency, for three unknown metals (X, Y, and Z) is shown above (not drawn to scale).
1 eV = 1.6022 * 10^{-19} J

a. 8 points

The three possible values corresponding to work functions for the metals shown, are 4.14 eV, 2.26 eV, and 2.07 eV (in no order).
Which one of the following metals (X, Y, or Z) will emit the slowest (lowest velocity) electron when excited with a photon of an ultrafast laser pulse (400 nm)?
What is the velocity (ms^{-1}) of the ejected electron (3 significant figures)? Show your work and calculations.

b. 2 points

Assume the plot shown represents the ejection of *easiest* to remove electron in metals Mg/Sr/Ca.

Which of the plots (X, Y, or Z) corresponds to Ca? Explain your reasoning.

QUESTION 3:

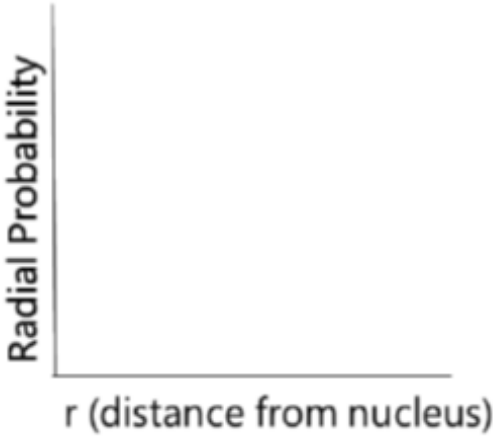
1. 12 points

a. 6 points

Name the orbital and *draw* the radial probability distribution for the following orbitals **on one plot**, for Cl (chlorine) atom (Assume ground state electronic configuration)

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

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



b. 4 points

An unknown cation (A^{2+}) has the following *excited* electronic configuration:

[Ar] $4s^2\ 3d^{10}\ 5s^1$

Give the ground state electronic configuration of the atom, A and the anion, A^{2-}. Show your work.

(Assume all electronic transitions are possible)

c. 2 points

In a single atom:

How many electrons can have the following two quantum numbers?

$n = 5$; $m_l = +1$

Explain your choice, briefly.

4. 10 points

Based on what you have learned in Chem110 so far, arrange the following in increasing order, and *briefly* explain your reasoning:

A) In increasing (smallest to largest) order of size:

I^- Sb^{3-} Ca^{2+} Mg^{2+}

B) In increasing (smallest to largest) order of bond angle for the central atom

CH_2Cl_2 SCl_2 ICl_2^-

C) In increasing order (shortest to longest) of C-N bond length:

$ClCH_2CH_2NH_2$ CH_3CHNH $ClCH_2CH_2CN$

D) In increasing order (smallest to largest) of ionization energy:

IE_5 of Si IE_2 of Na IE_4 of Al

5. 10 points

a. 8 points

For each molecule below, draw the most stable Lewis structure showing appropriate shape and dashed/wedged bond where appropriate based on VSEPR. Show lone pairs.

(i) $HOCH_2CH_2CCH$

For (i) denote the most polar bond(s) in the Lewis structure. Is the molecule polar?

(ii) H_3AsO_4 (there are no O-O bonds)

For (ii) denote the *largest* bond angle in the Lewis structure. (If there are multiple bond angles of the same value, denote any one).

b. 2 points

You have discovered a new ionic compound Y_2X (Y forms 1+ cation and X forms 2- anion).

The lattice energy of Y_2X is the energy change for which process (use a chemical equation, showing reactants and products and their states, to describe the process)?

6. 6 points

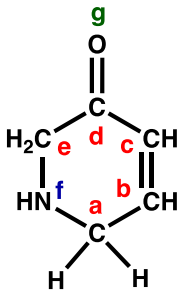
Below are the subsequent ionization energies (kJ/mol) of Chromium (Cr, atomic number 24)

	IE1	IE2	IE3	IE4	IE5	IE6
Cr	652.9	1590.6	2987	4743	6702	8744

Using the ionization energy data for Chromium (Cr) given above, determine the **longest wavelength (in nm; 3 significant figures)** of a photon required to remove the first electron from the 3d orbital of the appropriate Cr cation. Show your calculations.

7. 15 points

Consider the molecule given below and note that the lone pairs are not shown in the structure.



Using chemical bonding theories that we have learnt in class (valence bond theory, hybridization), answer the following questions:

i) **(5 points)** Consider the carbon atoms marked in red (**a**, **b**, **c**, **d, and e**) in the molecule, one at a time, and determine hybridization at each of the carbon centers.

ii) **(2 points)** Now consider the nitrogen atom marked in blue (**f**), and oxygen marked in green (g) and determine each of their hybridization.

iii) **(4 points)** Describe all the bonds formed by the carbon atoms marked in red as **a** and **b**. Indicate sigma/pi bonds.

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

v) **(2 points)** Determine electronic and molecular geometry at carbon **d** and nitrogen **f** centres.

vi) **(1 point)** Indicate the value from the choices provided below that best describes the C-N-C bond angle at nitrogen marked **f**:

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

8. 12 points

Using the valence shell orbitals only:

(i) **(6 points)** Draw a **complete** molecular orbital diagram for SiP^{1-}, and then use it to answer the questions (ii to v) given below. Assume that 3s and 3p atomic orbitals will form molecular orbitals similar to those formed by the combination of 2s and 2p atomic orbitals that we learnt in class. Your molecular orbital diagram should clearly show energy arrow, atomic orbitals involved, the molecular orbitals that are formed etc. Make sure to label all the atomic and molecular orbitals.

(ii) **(1 point)** Which one of the following will have the highest bond order:

A) SiP^{1-} B) SiP C) SiP^{2+}

(iii) **(1 point)** Which one of the following will have the longest bond length:

A) SiP^{1-} B) SiP C) SiP^{2+}

(iv) **(1 point)** Which one of the following will be diamagnetic:

A) SiP^{1-} B) SiP C) SiP^{2+}

(v) **(3 points)** Draw Lewis dot structure of SiP^{1-}. Does the bond order from the Lewis dot structure agree with the bond order that you calculated from your molecular orbital diagram?