Name ________KEY__________________________

Last 5 digits of Student Number: XXX – X ___ – ___ ___ ___ ___
(may be the same as your social security number)

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# Chem 103
## Sample Examination #3

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This exam consists of ten (10) pages, including this cover page. Be sure your copy is complete before beginning your work. If this test packet is defective, ask for another one.

A copy of the Periodic Table is attached at the back of the exam. You may remove it and use the back side of the Periodic Table as scratch paper. No work on scratch paper will be graded or collected.

The following information may be useful:

Constants of nature
Speed of light, $c = 2.998 \times 10^{8}$ m/s
Planck's constant, $h = 6.626 \times 10^{-34}$ J·s
$Rhc = 2.179 \times 10^{-18}$ J/atom = 1312 kJ/mol

Conversions/Metric Prefixes
1 nm = $10^{-9}$ m
1 Hz = 1 $s^{-1}$

Equations
$c = \lambda \nu$
$E = h\nu$

$$E_n = -\frac{Rhc}{n^2}$$

from which can be derived that

$$\Delta E = -Rhc\left(\frac{1}{n^2_{final}} - \frac{1}{n^2_{initial}}\right)$$

DO NOT WRITE BELOW THIS LINE

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Part 1 – Short response (out of 60):

Part 2 – Problems
  Problem 1 (out of 10):

  Problem 2 (out of 10):

  Problem 3 (out of 10):

Disclaimer:
This is a copy of a typical Exam 3 given in Chem 103 during the academic year. Your test will be different. This test is being posted to give you a sense of the format, style, scope and level of a typical test on this material. This test may have questions on topics that may not be covered on your exam. Moreover, your test may have questions on topics not covered in this practice exam. Posting this test in no way limits the format, style, scope and level of the test that you will take. Do not limit your preparation to the material in this practice exam.

Part 3 – Laboratory (out of 10):

TOTAL (out of 100):

## Part I. Multiple-Choice or Short Response

Point values of questions are indicated in curly brackets {…}.

1. {3 pts} Red light has wavelength 690 nm. What is the frequency of the red light?

   A) $2.1 \times 10^{11}$ Hz

   B) $4.2 \times 10^{5}$ Hz

   C) $2.3 \times 10^{-15}$ Hz

   [✓ D)] $4.3 \times 10^{14}$ Hz

2. {3 pts} Which <u>one</u> answer has the electromagnetic radiation correctly ordered from lowest energy to highest energy?

   A) ultraviolet, red, infrared, green

   [✓ B)] radio waves, infrared, orange, violet

   C) X-rays, microwaves, yellow, blue

   D) green, red, X-rays, ultraviolet

3. {3 pts} Which <u>one</u> of the following sets of quantum numbers for an electron is impossible?

|  | $n$ | $l$ | $m_l$ | $m_s$ |
|---|---|---|---|---|
| [✓ A)] | 3 | 3 | +2 | +½ |
| B) | 2 | 1 | 0 | –½ |
| C) | 1 | 0 | 0 | +½ |
| D) | 4 | 2 | –2 | +½ |

4. {3 pts} Which <u>one</u> of the following electron configurations is paramagnetic?

   A) $1s^2\ 2s^2\ 2p^6$

   B) $1s^2\ 2s^2\ 2p^6\ 3s^2$

   [✓ C)] $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

   D) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}$

5. {3 pts} Which <u>one</u> of the following molecules or ions has a central atom that does not have an octet of valence electrons around it?

   A) $H_2O$

   B) $PCl_3$

   C) $NO_3^-$

   [✓ D)] $Br_3^-$

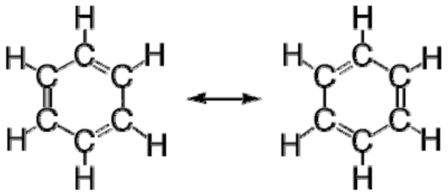
6. {3 pts} Which one of the following structures is <u>not</u> isoelectronic with the others in the list?

A) $CO_2$
[✓ B)] $O_3$
C) $N_2O$
D) $NO_2^+$

7. {3 pts} Which one of the following molecules is <u>not</u> a polar molecule?

A) $NH_3$
B) $BrF_3$
C) $H_2O$
[✓ D)] $CO_2$

8. {3 pts} Given the following resonance structures of benzene, what is the C-C bond order?



A) C-C bond order is 1
[✓ B)] C-C bond order is $^{3}/_{2}$
C) C-C bond order is 2
D) C-C bond order is $^{5}/_{2}$

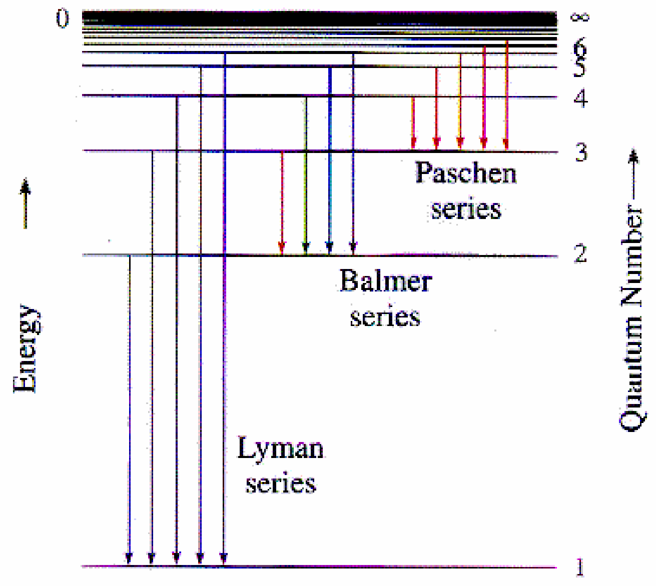
9. {3 pts} Which of the following bonds is <u>most</u> polar?

A) the N-O bond in $NO_2$
B) the C-N bond in $H_3CNH_2$
C) the S-O bond in $SO_3$
[✓ D)] the P-F bond in $PF_3$

10. {3 pts} Light sometimes behaves as particles and sometimes behaves as waves. Why can diffraction not be described by the particle behavior of light?

Particle behavior would predict that a single point of light would appear if you shine a beam of light through a diffraction grating. In fact, what appears is areas of brightness and no light, which can only be described by constructive and destructive interference patterns of waves.

Use the following diagram to assist in answering both questions 11 and 12.



11. {3 pts} The Balmer series in the hydrogen emission spectrum is in the visible range and has four distinct lines: red, green, blue and violet. According to the Rydberg equation, the red line in the Balmer series is predicted to have a transition energy of

[✓ A) 182 kJ/mol]
B) 219 kJ/mol
C) 292 kJ/mol
D) 1312 kJ/mol

red is $n = 3 \rightarrow n = 2$

$$\Delta E = -1312 \text{ kJ/mol} \left( \frac{1}{2^2} - \frac{1}{3^2} \right) = 182 \text{ kJ/mol}$$

12. {3 pts} When a high voltage is placed across a sample of hydrogen gas, electrical energy is added to the hydrogen. Explain why the resulting emission spectrum of hydrogen contains distinct wavelengths of light instead of a broad continuous spectrum with all wavelengths of light?

When energy is added to the atoms, electrons move up to excited state energy levels. When the electrons eventually relax down to lower states, they must transition from one distinct energy level to another (a specific change in energy). Energy is conserved, and the energy lost by the atom when the electron relaxes is released as a photon of light with a specific distinct energy

13. {6 pts} Complete the blanks or circle the correct words to complete the logical argument for the following question (the argument begins at the bottom of the graphic):

*Why does oxygen (O) have a larger ionization energy than sulfur (S)?*

To remove a valence electron from O requires a larger ionization energy than to remove a valence electron from S

↑

A valence electron in O experiences greater attraction to its core than a valence electron in S does

↑

The attraction between valence and core in O is (circle one)

[✓ **Larger**] OR **Smaller**

than that in S

↑

The difference in attraction between the valence and core in O and in S depends on (circle one)

[✓ **The distance separating valence and core**] OR **The product of valence and core charges**

↑

(complete blanks)

O has core charge of <u>+6</u> and valence charge of <u>+6</u>

S has core charge of <u>+6</u> and valence charge of <u>+6</u>

(complete blanks)

Oxygen is in period <u>2</u>

Sulfur is in period <u>3</u>

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14. {6 pts} Provide a logical explanation for the following:

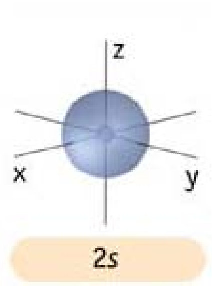
*Why does calcium sulfide (CaS) have lattice energy approximately four times greater than the lattice energy of potassium chloride (KCl)?*

Ca and K have the same number of shells, so their atomic radii are approximately the same. S and Cl have the same number of shells, so their atomic radii are approximately the same. However CaS is made of $Ca^{2+}$ and $S^{2-}$, while KCl is made of $K^+$ and $Cl^-$. Since the force of attraction between two ions is Force ~ $\frac{Q_+Q_-}{r^2}$, since $Q_+Q_-$ for CaS is $(+2)(-2)$ while $Q_+Q_-$ for KCl is $(+1)(-1)$, and r is same for both then 4x the energy is required to break CaS than KCl.

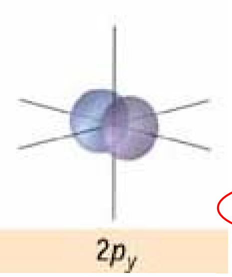
15. {8 pts} Answer the following questions about the 2*s*, 2$p_x$, 2$p_y$, and 2$p_z$ orbitals whose electron density graphs are pictured below.

a) In the boxes next to each orbital below, provide the correct set of quantum numbers (values of *n*, *l* and $m_l$) for each of the four orbitals pictured. (Note: it doesn't matter which value of $m_l$ you assign to which p-orbital, as long as you use allowed values of $m_l$.) {6 pts}

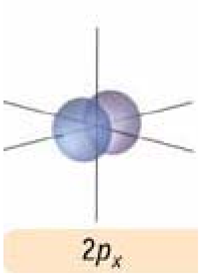
b) {2 pts} To which row in the periodic table do these orbitals correspond? ____



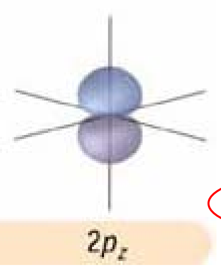
$n$ = **2**
$l$ = **0**
$m_l$ = **0**



$n$ = **2**
$l$ = **1**
$m_l$ = **0**



$n$ = **2**
$l$ = **1**
$m_l$ = **-1**



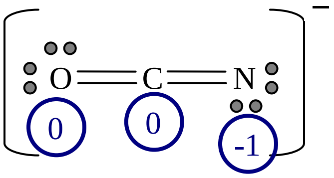
$n$ = **2**
$l$ = **1**
$m_l$ = **+1**

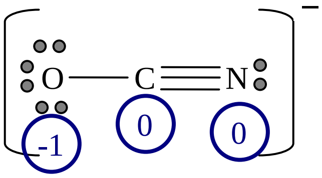
Note: $m_l$ values for the 2p orbitals could be any of +1, 0, -1, as long as you indicated different $m_l$ values for the different 2p orbitals

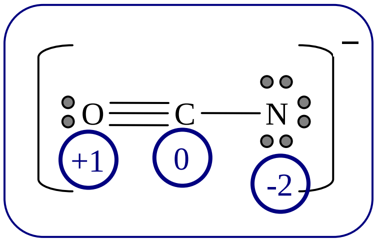
16. {6 pts} The following Lewis structures are the principal resonance forms of $OCN^-$.

a) Indicate the formal charges on all atoms, including when the formal charge is zero.

b) Circle the structure that probably contributes the *least* to the actual bonding state, and briefly explain why it contributes the least.







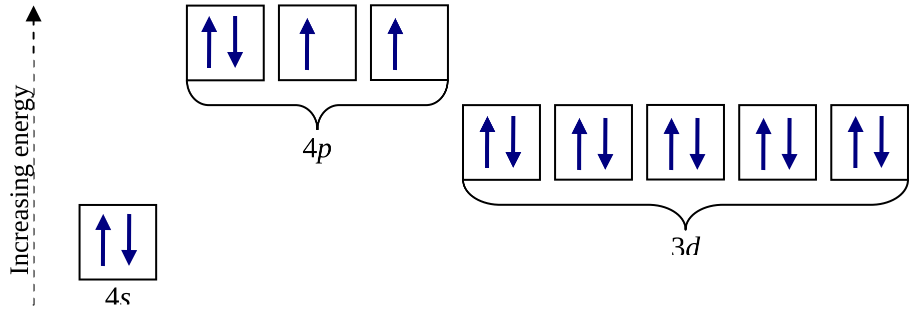
contributes least
because largest magnitude
formal charge (−2), and
it is not on most electronegative
element in ion (which
is O)

## Part II. Problems

Each problem is worth 10 points. Point values of parts of questions are indicated in curly brackets {…}.

1. Answer the following questions about the element selenium (Se).

a) {4 pts} Draw the orbital box notation of only the electrons after the noble gas below Se. Use the boxes shown below to fill in the arrows.



b) {2 pts} Write the full *spdf* notation for Se, beginning with $1s^2$.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^4$

c) {4 pts} Write the full *spdf* notation for the ion $Se^{2-}$. Also explain why it is a stable ion.

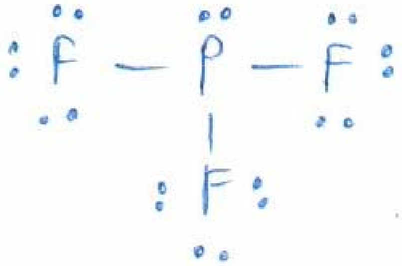
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6$

It is stable because it has all full sublevels (or, a noble gas configuration).

2. Draw the Lewis structures for the molecules or ions, showing all valence electrons. Make sure to clearly indicate how you determined the total number of valence electrons on the structure. {5 pts each}

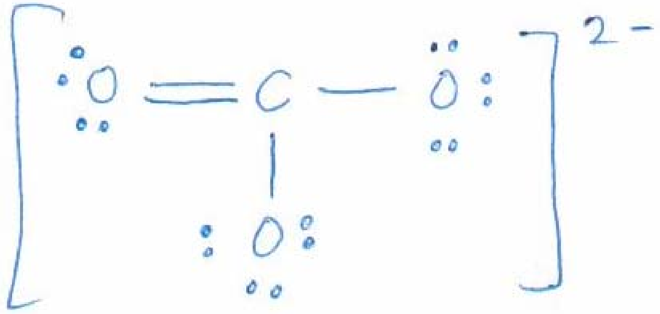
a) $PF_3$

5
$+ (3 \times 7)$
26

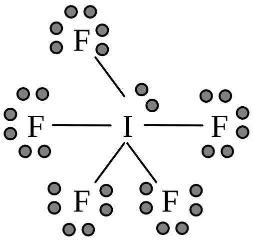


b) $CO_3^{2-}$

4
$(3 \times 6)$
$+ 2$
24



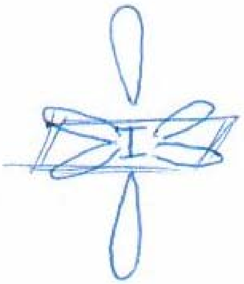
3. The molecule $IF_5$ has a Lewis structure as shown below. Based on this structure, answer the questions that follow.



a) {3 pts} What is the *geometry of the electron pairs* around the central atom? (You can either give the name of the arrangement or draw a picture. If you choose to draw a picture, make sure it's clear from your picture what the 3-dimensional geometry is.)

electron pairs
have
octahedral
geometry

or



b) {4 pts} Valence shell electron pair repulsion (VSEPR) theory can be used to make some predictions about F-I-F bond angles in this molecule. Which two answers below are correct about these angles? (circle two answers)

A) two F-I-F bond angles are slightly less than 60°
B) two F-I-F bond angles are slightly greater than 60°
[✓ C)] all F-I-F bond angles are slightly less than 90°
D) all F-I-F bond angles are slightly greater than 90°
E) all F-I-F bond angles are 90°
F) all F-I-F bond angles are 60°

Note: this question contained an error. There was only one correct answer among the choices.

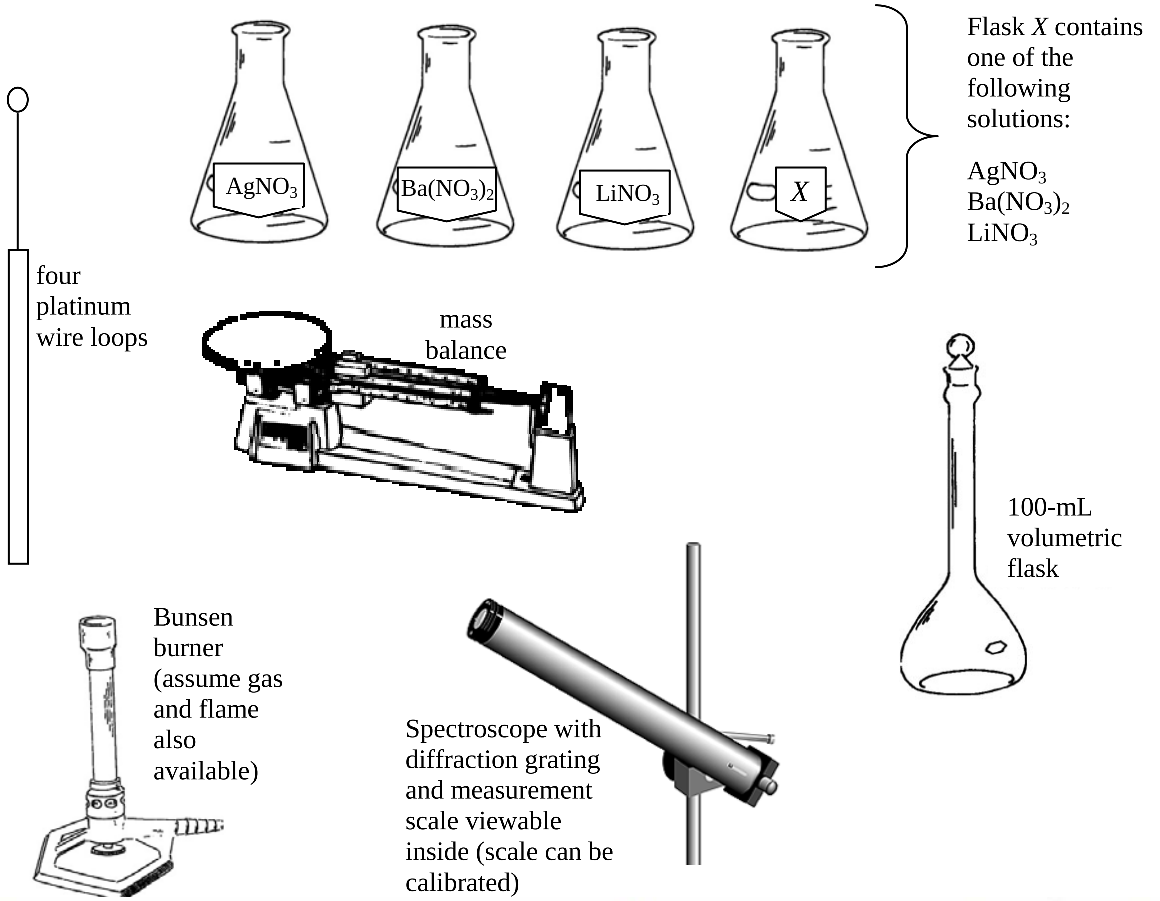
c) {3 pts} Circle which one of the following molecules has the *same molecular geometry* as the structure above?

$PF_5$ [✓ $ClF_5$] $SBr_4$ $SeF_6$

## Part III. Laboratory

This problem is worth 10 points. Point values of parts of the question are indicated in curly brackets {…}.

a) {6 pts} Given the following laboratory equipment and materials, briefly describe a procedure that involves emission spectroscopy for determining the identity of the unknown *X* shown below. (It is not necessary to use every piece of equipment, but clearly indicate in your procedure which pieces of equipment you will use.)

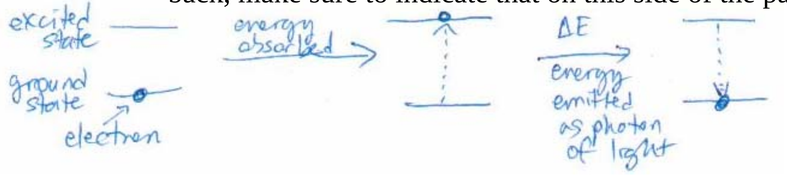


Light flame, adjust to form strong flame
Dip platinum wire in a solution, then hold platinum wire in flame.
Observe colors produced through spectroscope to separate colors.
Record results.
Do same for all solutions, using different platinum wires for each.
Compare. Whichever one X is like is likely the identity of X.

b) {4 pts}Explain why this procedure works. In other words, why are emission spectra different?

Emission spectra of different elements differ because they have different electron configurations, resulting in different possible energy transitions.

Extra credit {3 pts} Explain how atoms produce emission spectra. (If you continue your answer on the back, make sure to indicate that on this side of the paper so we will look for it when grading the exam.)



Energy is absorbed when an electron moves from the ground state to an excited state. When the electron relaxes down to a lower state, energy is released as a photon of light with the transition energy.