CHEMISTRY 101 Name _____KEY_____
Hour Exam III
November 30, 2023 Signature _____
McCarren

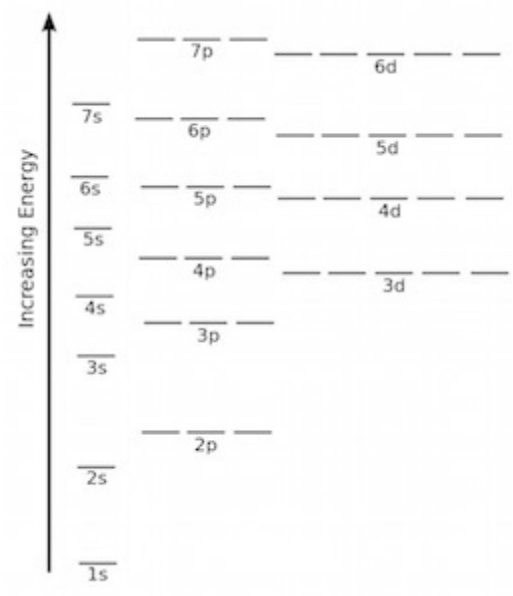
Section _____

"Celebrate your strength by stepping forward." - Anonymous

This exam contains 17 questions on 9 numbered pages. **Check now** to make sure you have a complete exam. You have one hour and thirty minutes to complete the exam. Determine the best answer to the first 15 questions and enter these on the special answer sheet. Also, circle your responses in this exam booklet. Show all of your work and provide complete answers to questions 16 and 17.

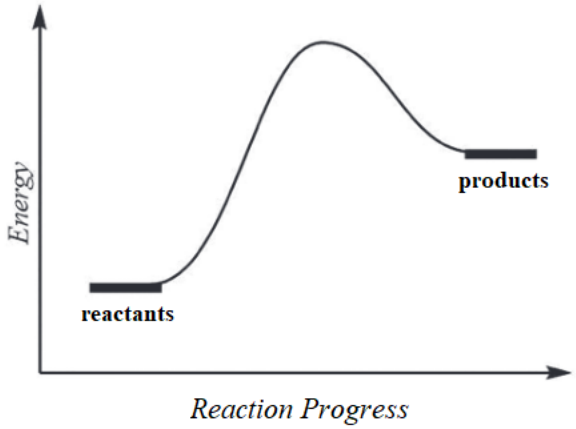
1-15	(30 pts.)	_____
16	(12 pts.)	_____
17	(18 pts.)	_____
Total	(60 pts)	_____

Useful information:



Part 1: Multiple Choice

1. Does the diagram below display an endothermic or exothermic process? Select the best answer and explanation.



   a. *Exothermic:* The energy is lost from reactants to products.
   b. *Exothermic:* The reactants are more energetically stable than the products.
   c. *Endothermic:* Energy is required to start the processes.
   d. *Endothermic:* The products are higher in energy than the reactants.
   e. *Neither endothermic nor exothermic*: Mass is conserved in the process, so energy is not added or released.

2. How many of the following processes are endothermic? The system is underlined in each case.
   - Liquid nitrogen becomes gaseous nitrogen.
   - A racquetball hardens in liquid nitrogen.
   - Hydrogen and oxygen burn in a balloon to make water.
   - Ice cream melts on a warm day.

   a. 0 (None of the processes are endothermic.)
   b. 1
   c. 2
   d. 3
   e. 4 (All four of the processes are endothermic.)

3. What is a limitation of our current understanding of the structure of the atom?
   a. We are unable to predict atomic size.
   b. We do not know whether a proton is negatively or positively charged.
   c. We do not know which particles make up an atom.
   d. We do not know exactly how electrons are moving.
   e. We cannot explain why compounds exist.

4. What is the ground state electron configuration for a neutral atom of molybdenum (#42)?
   a. $[Kr]4s^2 4d^4$
   b. $\underline{[Kr]5s^2 4d^4}$
   c. $[Kr]4s^2 3d^4$
   d. $[Kr]4d^7$
   e. $[Kr]5s^2 5d^4$

5. How many unpaired electrons are present in a ground state neutral atom of cobalt? (Hint: The energy diagram on the front cover may be helpful for this question.)
   a. 0 (All electrons are paired.)
   b. 2
   c. $\underline{3}$
   d. 5
   e. 7

6. What is the difference between the ground state electron configuration and an excited state electron configuration for a given element?

   The ground state electron configuration….

   a. has more electrons than the excited state electron configuration.
   b. <u>has electrons in lower energy levels than the excited state configuration.</u>
   c. is used when the element is in the ion form and the excited state configuration is for neutral elements.
   d. is used for elements which are metals and the excited state electron configuration is used for nonmetals.
   e. includes all electrons and the excited state configuration includes only valence electrons.

7. Which is <u>true</u> about the sizes of atoms and ions of elements on the periodic table?
   a. A cation of a given element has a larger radius than the neutral atom of that element.
   b. The average atomic radius for all elements in a given row of the periodic table is the same.
   c. If two different ions have the same number of electrons but a different number of protons, the one with the greater number of protons has a larger radius.
   d. <u>If two elements are in the same family (vertical column) on the periodic table, the one with the greater number of protons has a larger radius.</u>
   e. If two elements are in the same period (horizontal row) on the periodic table, the one with the greater number of protons is larger.

Consider the four pairs of atoms and ions given below and use those to answer the next two questions.

Pair 1: Ne and F^-

Pair 2: Sr and Mg

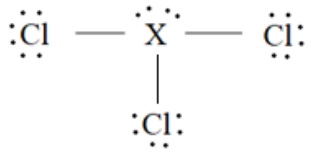
Pair 3: P and Ge

Pair 4: Ca and Ca^{+2}

8. In which two pairs does the first atom listed have the highest **ionization energy**?
   a. Pairs 2 and 3
   b. Pairs 1 and 4
   c. <u>Pairs 1 and 3</u>
   d. Pairs 3 and 4
   e. Pairs 1 and 2

9. In which pair are the two species isoelectronic?
   a. <u>Pair 1</u>
   b. Pair 2
   c. Pair 3
   d. Pair 4
   e. Two of the pairs (1-4) above have species which are isoelectronic.

10. The molecule represented by the Lewis structure below consists of a central atom X surrounded by three atoms of chlorine. Which of the following could be the central atom?



   a. Xe
   b. P
   c. C
   d. S
   e. <u>Br</u>

11. For molecules of similar sizes, how do the strength of London dispersion forces, hydrogen bonding forces, and dipole-dipole forces compare? Select the option which ranks the forces from weakest to strongest.
   a. <u>London dispersion forces < dipole-dipole forces < hydrogen bonding forces</u>
   b. London dispersion forces < hydrogen bonding forces < dipole-dipole forces
   c. hydrogen bonding forces < dipole-dipole forces < London dispersion forces
   d. hydrogen bonding forces < London dispersion forces < dipole-dipole forces
   e. dipole-dipole forces < London dispersion forces < hydrogen bonding forces

Draw the Lewis structures for the three compounds below and use those Lewis structures to answer the next four questions.

CO_2 SO_2 NH_3

12. Rank the compounds from least to greatest number of valence electrons.
    a. $NH_3 < SO_2 < CO_2$
    b. $\underline{NH_3 < CO_2 < SO_2}$
    c. $SO_2 < CO_2 < NH_3$
    d. $SO_2 < NH_3 < CO_2$
    e. $CO_2 < SO_2 < NH_3$

13. Rank the compounds from least to greatest number of effective pairs of electrons around the central atom.
    a. $NH_3 < SO_2 < CO_2$
    b. $NH_3 < CO_2 < SO_2$
    c. $SO_2 < CO_2 < NH_3$
    d. $SO_2 < NH_3 < CO_2$
    e. $\underline{CO_2 < SO_2 < NH_3}$

14. Rank the compounds from smallest to largest bond angle around the central atom.
    a. $\underline{NH_3 < SO_2 < CO_2}$
    b. $NH_3 < CO_2 < SO_2$
    c. $SO_2 < CO_2 < NH_3$
    d. $SO_2 < NH_3 < CO_2$
    e. $CO_2 < SO_2 < NH_3$

15. Rank the compounds from lowest to highest boiling point.
    a. $NH_3 < SO_2 < CO_2$
    b. $NH_3 < CO_2 < SO_2$
    c. $SO_2 < CO_2 < NH_3$
    d. $SO_2 < NH_3 < CO_2$
    e. $\underline{CO_2 < SO_2 < NH_3}$

Please go on to the free response section on the next page.

Part 2: Free Response

16. Show what you know! Please select the best answer to each of parts a, b, and c, and explain your answer in the space below. Read the questions carefully, being sure to answer all parts.

+4 points total

a. Moving from the left to the right across a horizontal row of the periodic table, does the size of the atomic radius for each element increase, decrease, or stay the same? Select the best option below and explain your answer. Your explanation should include the reasoning behind the trend at an atomic level (addressing protons, electrons, and energy levels) in addition to selecting the appropriate pattern.

+1

- ☐ increase
- ■ **decrease**
- ☐ remain the same

+1 **The size of the atomic radius decreases for each element. The reason for this is that there are more protons in the nucleus moving from the left to right across the periodic table. There are also more electrons, but the additional electrons are being added to the same energy level. The additional protons exert greater attraction on the electrons, which pull them closer to the nucleus of the atom, making the atoms further to the right smaller overall.**

+2

b. Liquid nitrogen (N_2) includes both non-polar covalent bonds as well as London dispersion forces. Based on your understanding of the difference between chemical bonds and intermolecular forces, would you expect London dispersion forces to be stronger or weaker than covalent bonds? Select the best answer below and then explain, including explaining the difference between a bond and an intermolecular force.

+4 points total

London dispersion forces are expected to be _____ than covalent bonds.

+1

- ■ **weaker**
- ☐ stronger

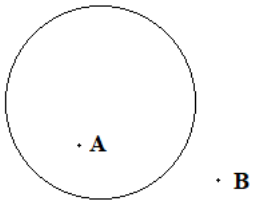
+1 **London dispersion forces are weaker than covalent bonding forces because covalent bonds (along with other bonds) actually hold the molecules together; i.e. in N_2 they keep the two different nitrogen atoms attached to each other.**

+1 **Intermolecular forces keep separate molecules attached to each other. These are much weaker and are sensitive to changes in temperature; for example, nitrogen as a gas does not display London dispersion forces though liquid nitrogen does.**

+1 general coherence to answer

c. Our current model of the atom uses orbitals to describe electron organization outside the nucleus of an atom. Consider the s orbital below with locations (A) and (B) labeled.

+4 points total



Could an electron be located at point A, point B, either location, or neither? Select the best option below and explain your answer. Be sure to include the definition of an orbital in your answer.

+2

- ☐ point (A) only
- ☐ point (B) only
- ■ **either point (A) or point (B)**
- ☐ neither point (A) nor point (B)

+1 orbital definition

+1 connections to points A and B

An electron could be at either point A or point B because an orbital is just a region of space where an electron is likely to be 90% of the time; the electron doesn't HAVE to be within the region designated by the orbital. So, is more often within the space designated by the orbital (point A), but it can be outside it also (point B).

Please go on to the next page.

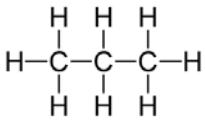
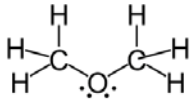
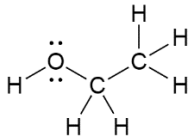
17. This question is divided into two parts. Each part consists of a set of molecules which have similar formulas but slightly different structures. Fill out the charts for each of the sets of molecules and use these to answer the questions related to the molecules.

Part 1

+6 points total (2 points per line)

a. Consider the three organic molecules below. Draw the Lewis structures for each of these molecules and then fill in the molecular geometry, and shape around the indicated atom, and give the overall molecule polarity.

+0.5 points each blank

Formula	Lewis Structure	Electron pair geometry	Molecular Shape	Polar or nonpolar overall?
$CH_3CH_2CH_3$		around the second carbon atom: **tetrahedral**	around the second carbon atom: **tetrahedral**	**non-polar**
CH_3OCH_3		around the oxygen atom: **tetrahedral**	around the oxygen atom: **bent/v-shape**	**polar**
CH_3CH_2OH		around the oxygen atom: **tetrahedral**	around the oxygen atom: **bent/v-shape**	**polar**

+3 points total

b. Rank the molecules above from lowest to highest boiling point in the boxes below. Then, justify your ranking, including giving the strongest intermolecular forces present between molecules of each of the three types.

+1 ranking

$CH_3CH_2CH_3$ < CH_3OCH_3 < CH_3CH_2OH

+1 IMFs

+1 explanation

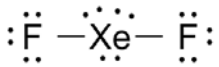
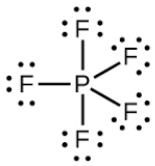
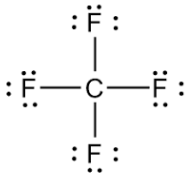
$CH_3CH_2CH_3$ is nonpolar and has London dispersion forces which are weaker than the dipole-dipole forces that CH_3OCH_3 has. These are both weaker than the hydrogen bonding forces present between molecules of CH_3CH_2OH. This means that CH_3CH_2OH has the highest boiling point and $CH_3H_2CH_3$ has the lowest.

Part 2

c. Each of the molecules below includes a central atom surrounded by atoms of fluorine. Draw the Lewis structures for each of these molecules and then fill in the molecular geometry and shape around the central atom. Then give the overall molecule polarity.

+6 points total

(2 points per line)

Formula	Lewis Structure	Electron pair geometry	Molecular Shape	Polar or nonpolar?
XeF_2 MW = 169.3 g/mol		**trigonal bipyramid**	**linear**	**nonpolar**
PF_5 MW = 126.0 g/mol		**trigonal bipyramid**	**trigonal bipyramid**	**nonpolar**
CF_4 MW = 88.0 g/mol		**tetrahedral**	**tetrahedral**	**nonpolar**

+0.5 points each blank

+3 points total

d. Rank the molecules above from lowest to highest boiling point in the boxes below. Then, justify your ranking, including giving the strongest intermolecular forces present between molecules of each of the three types. Note that molar masses are provided which may assist in answering this question.

+1 ranking

CF_4 < PF_5 < XeF_2

+1 LDFS

+1 explanation

All three of the compounds are nonpolar, so their only intermolecular forces are London dispersion forces. This means that the molecules with the greater number of electrons (or the greater molar mass overall) will have the strongest London dispersion forces and therefore the highest boiling point. Therefore CF_4 has the lowest boiling point, PF_5 is in the middle, and XeF_2 has the highest.

STOP. You have reached the end of the exam. Nothing written after this page will be graded.