CHEMISTRY 101
Hour Exam III
May 1, 2025
Dr. E. McCarren

Name _____KEY_____

Signature _____

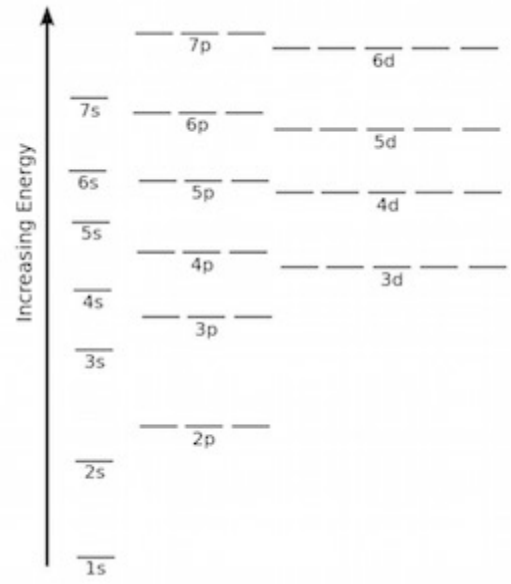
Section _____

"The big talent is persistence." – Octavia E. Butler, American author

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

+2 points each

1. Each of the following statements were all considered components of the structure of the atom. Which of these is still believed to be **true**?
    a. Atoms are solid spheres.
    b. **Atoms of each element have unique energy levels holding electrons.**
    c. All atoms of a given element are identical.
    d. The positive charge of the atom is organized like a cloud.
    e. Electrons orbit the nucleus of the atom on fixed paths.

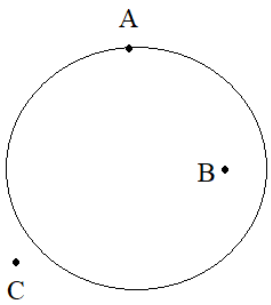
2. Which is **false** regarding endothermic processes?

    Endothermic processes…
    a. involve the transfer of heat energy into a system.
    b. may require activation energy to start.
    c. **result in products that are stabler than reactants.**
    d. require removing heat energy from surroundings.
    e. may involve a phase change, such as from solid to gas.

3. We have seen each of the following demonstrations during class related to heat transfer and chemical processes. How many of these are exothermic? The system is underlined in each case.
    - Colored salts release energy by burning flames of unique colors.
    - A racquetball hardens in liquid nitrogen.
    - A loud bang occurs when hydrogen and oxygen react to form water.
    - A heat pack makes your hands warmer.

    a. 0 (None are exothermic.)
    b. 1
    c. 2
    d. 3
    e. **4 (All are exothermic.)**

4. Consider the diagram below which represents an s shape orbital.



At which location(s) is it possible for an electron to be found?
   a. Point A only
   b. Point B only
   c. Point C only
   d. Either points A or B
   e. **Any of points A, B, or C**

5. Which of the following is **true** related to orbitals and electron configurations? The electron filling diagram on the front page may be helpful in answering this question.
   a. For a ground state atom, the 3d electrons are filled before the 4s electrons.
   b. **A ground state p orbital is full when it contains two electrons.**
   c. Electrons in the 1s orbitals are higher in energy than electrons in the 2s orbitals.
   d. There are six different types of p orbitals.
   e. The shapes of the s orbitals are more complex than the shapes of the p orbitals.

Consider the electron configuration shown below which represents the ground state electron configuration for a neutral atom. Use this electron configuration to answer the next two questions.

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

6. What element does this electron configuration represent?
   a. **Fe**
   b. Co
   c. Ru
   d. Mn
   e. Rh

7. Which of the following is a possible excited state electron configuration for this element?
   a. $[Ar]4s^2 3d^6$
   b. $[Ar]4s^1 3d^6$
   c. **$[Ar]4s^1 3d^5 4p^2$**
   d. $[Ar]4s^2 3d^5$
   e. $[Kr]5s^2 4d^6$

8. Consider the bond formed between an atom of nitrogen and an atom of oxygen as shown below.

N – O

Which of the following is **true** about this bond?

a. This bond is best considered to be ionic.
b. When this bond forms, oxygen loses an electron and donates it to nitrogen.
c. Based on electronegativity trends, electrons are likely to spend more time close to the nitrogen atom.
d. This bond was formed because the connected atoms are more stable than the unconnected atoms.
e. Any species containing an N-O bond must be polar overall. NO_3^- is an example.

9. Which of the following shows the neutral atoms below ranked from lowest to highest first ionization energy?

a. **Xe < Kr < Ar < He**
b. He < Ar < Kr < Xe
c. Xe < Ar < Kr < He
d. He < Kr < Ar < Xe
e. Kr < Ar < Xe < He

Each of the molecules below has a linear shape. Draw Lewis structures for these molecules. Then, use the structures you drew to answer the next two questions.

H_2 F_2 O_2 I_2 N_2

10. Which of the five Lewis structures for the molecules has a triple bond?

a. H_2
b. F_2
c. O_2
d. I_2
e. N_2

11. One of the substances represented by the Lewis structures shown here is a solid at room temperature. The remaining substances are gases. Which substance is the solid?

a. H_2
b. F_2
c. O_2
d. **I_2**
e. N_2

Each of the Lewis structures for the following molecules has a central atom with an expanded octet. Draw these Lewis structures and use them to answer the next four questions.

IF_3 $XeCl_2$ IBr_5 $XeCl_4$

12. Which two of the molecules have octahedral electron pair geometry?
    a. IF_3 and $XeCl_2$
    b. IBr_5 and IF_3
    c. **IBr_5 and $XeCl_4$**
    d. $XeCl_2$ and $XeCl_4$
    e. IF_3 and $XeCl_4$

13. Which of the molecules has a t-shape?
    a. **IF_3**
    b. $XeCl_2$
    c. IBr_5
    d. $XeCl_4$
    e. None of the molecules are t-shaped.

14. Which two of the molecules are polar?
    a. IF_3 and $XeCl_2$
    b. **IBr_5 and IF_3**
    c. IBr_5 and $XeCl_4$
    d. $XeCl_2$ and $XeCl_4$
    e. IF_3 and $XeCl_4$

15. How many of the molecules have at least one bond angle which is 90°?
    a. 0 (None of the molecules have at least one 90° bond angle.)
    b. 1
    c. 2
    d. **3**
    e. 4 (All four of the molecules have at least one 90° bond angle.)

Please go on to the next page.

Part 2: Free Response

16. Consider each of the three statements in parts a. – c. below related to atomic radius and the periodic table. For each of the three statements, explain why the statement is true. For each response, your answer should go beyond simply stating a trend on the periodic table.

+4 points total

a. A neutral atom of lithium has a larger radius than a neutral atom of hydrogen. Explain why, being sure to address the number of energy levels and electron configurations present for each species and how these relate to radius.

+2 energy levels comparison

+2 coherent explanation

A neutral atom of lithium has electrons in two energy levels ($1s^2 2s^1$) and a neutral atom of hydrogen has electrons in only one energy level ($1s^1$). The greater number of energy levels in the lithium atom means that outer electrons are positioned further from the nucleus of the atom, making lithium a larger atom overall.

b. A neutral atom of sulfur (S) has a smaller atomic radius than the most stable ion of sulfur (S^{2-}). Explain why, being sure to address the number of protons and electrons present in each species and how these relate to radius.

+4 points total

+1 protons

+1 electrons

+2 coherent explanation

Neutral sulfur has 16 protons and 16 electrons. The most stable ion of sulfur has 16 protons and 18 electrons. The additional electrons end up repelling each other and moving further from the nucleus of the atom. This means that the sulfur ion ends up being larger than the sulfur atom.

+4 points total

c. The most stable ion of fluorine (F^-) has a larger radius than the most stable ion of sodium (Na^+). Explain why, being sure to address the number of protons and electrons present in each species and how these relate to radius.

+1 protons

+1 electrons

+2 coherent explanation

The fluorine ion has 9 protons and 10 electrons, and the sodium ion has 11 protons and 10 electrons. Because the sodium ion has a greater number of protons for the same number of electrons, the nucleus is able to better attract the electrons. Therefore, the electrons are closer to the nucleus in the sodium ion versus the fluorine ion, making the sodium ion smaller.

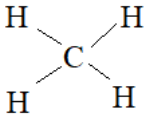
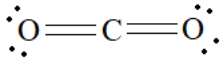
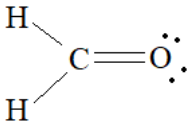
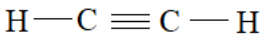
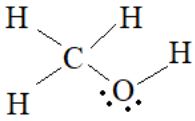
Please go on to the next page.

17. Consider the five molecules shown below. For part a., draw the Lewis structures and give the geometry and shape of each molecule. If there are multiple central atoms, give the shape and geometry around one of the carbon atoms. Then, state whether the molecule is polar or nonpolar. For parts b. and c., answer the questions using the five molecules from part a. You do not need to draw resonance structures.

+10 points total

a.

+0.5 points each blank, no partial credit

Molecule	Lewis Structure	Electron Pair Geometry	Molecular Shape	Polar or nonpolar?
CH_4		**Tetrahedral**	**Tetrahedral**	**Nonpolar**
CO_2		**Linear**	**Linear**	**Nonpolar**
CH_2O		**Trigonal planar**	**Trigonal planar**	**Polar**
HCCH		**Linear**	**Linear**	**Nonpolar**
CH_3OH		**Tetrahedral**	**tetrahedral**	**Polar**

Use the information regarding the molecules on the previous page to answer the next two questions. Justify your answer in both instances.

+3 points total

b. Which of the five molecules are likely to dissolve in water? State which molecule or molecules. Then, explain your answer in the space below.

CH_2O and CH_3OH will dissolve in water because they are both polar and water is polar. Polar substances should dissolve in other polar substances.

+1 CH_2O

+1 CH_3OH

+1 polarity explanation

+5 points total

c. Rank the five molecules from lowest to highest boiling point by filling in the blanks below. Then, explain your answer in words, being sure to give the strongest intermolecular forces displayed between molecules of each substance.

+1 ranking

CH_4 < HCCH < CO_2 < CH_2O < CH_3OH

+1 LDF molecules correct

+1 dipole-dipole molecule correct

+1 hydrogen bonding molecule correct

CH4, HCCH, and CO2 are all nonpolar so they only exhibit London dispersion forces. These become stronger with a greater number of overall electrons or a greater molar mass, so of these CH_4 has the lowest boiling point and they increase with HCCH and CO_2, respectively. CH2O has a greater boiling point than any of these three molecules because it is polar so it exhibits dipole-dipole forces. CH3OH exhibits hydrogen bonding which is the strongest type of intermolecular force present between any of these molecules. Therefore, it has the highest boiling point.

+1 general explanation

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