

CHEMISTRY 101  
Hour Exam III  
April 27, 2023  
McCarren

Name KEY

Signature \_\_\_\_\_

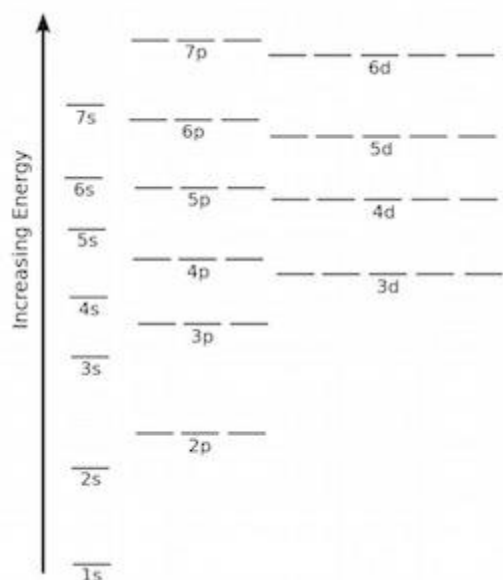
Section \_\_\_\_\_

***“The difference between ordinary and extraordinary is that little extra.” — Jimmy Johnson***

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	(15 pts.)	_____
17	(15 pts.)	_____
Total	(60 pts)	_____

Useful information:



**Part 1: Multiple Choice**

1. Which is **true** about an **exothermic** reaction?

+2 points  
each  
multiple  
choice

- a. Energy in the form of heat is added from the surroundings into the reaction system.
- b. The products of the reaction are less stable than the reactants.
- c. No activation energy is needed for this reaction to begin.
- d. The reaction must occur at a high temperature.
- e. **The products have less potential energy than the reactants.**

2. How many of the following phase changes are considered to be **endothermic** processes?  
The system is underlined in each case.

- **Dry ice** subliming to become carbon dioxide gas
- **Ice** melting to form water
- **Molten (liquid) iron** hardening to become solid iron
- **Water** boiling to form steam

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

3. You are studying with a friend and they are having trouble understanding what an atom looks like. You want to make a drawing of an atom to help them. How should you draw the atom?

*Your drawing of the atom should...*

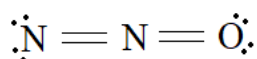
- a. look like a solid sphere.
- b. show electrons orbiting a nucleus on circular paths.
- c. include a large positively charged cloud for most of the atom.
- d. **include a lot of empty space where electrons might be.**
- e. include a large nucleus consisting of protons.

4. Recall the “flame test” demonstration from the lecture, in which we saw different elements burn with various flames. What is **true** about this demonstration and our understanding of the structure of the atom?
- Using the match to ignite the salts was an exothermic process.
  - The process of the salts burning was an endothermic process.
  - As the salts burned, electrons moved further from the nucleus of the atom.
  - At least one of the salts burned with a white flame due to having a continuous spectrum of energy.
  - The different colors for each individual element were a result of unique electron arrangements.**
5. Which is **true** about orbitals as they relate to our current understanding of atomic structure?

***Orbitals...***

- are solid shells positioned outside the center of the atom.
  - show the spaces where electrons must be present.
  - all have spherical shapes.
  - each hold an octet of electrons.
  - become more complex for higher energy levels.**
6. What is the ground state electron configuration for a neutral atom of palladium?
- [Kr]5s<sup>2</sup>4d<sup>8</sup>**
  - [Kr]5s<sup>2</sup>5d<sup>8</sup>
  - [Ar]5s<sup>2</sup>4d<sup>8</sup>
  - [Kr]5s<sup>1</sup>4d<sup>9</sup>
  - [Ar]4s<sup>2</sup>3d<sup>8</sup>
7. The following electron configuration is for a neutral atom in an excited state. Which atom does this electron configuration represent?
- [Ar]4s<sup>2</sup>3d<sup>5</sup>4p<sup>1</sup>**
- Fe**
  - Mn
  - Cr
  - Mo
  - Tc

8. Select the option which ranks the atoms below in order from smallest to largest radius.
- a.  $\text{Cr} < \text{Fe} < \text{P} < \text{F}$
  - b.  $\text{F} < \text{P} < \text{Cr} < \text{Fe}$
  - c.  **$\text{F} < \text{P} < \text{Fe} < \text{Cr}$**
  - d.  $\text{F} < \text{Fe} < \text{P} < \text{Cr}$
  - e.  $\text{Cr} < \text{P} < \text{Fe} < \text{F}$
9. Consider the Lewis structure below, which shows the most stable structure for a molecule of  $\text{N}_2\text{O}$ . Complete the statement below which best describes the character of the bond between the two nitrogen atoms and the polarity of the molecule overall.



*The bond between N and N is best considered to be \_\_\_\_\_, and the entire  $\text{N}_2\text{O}$  molecule overall is \_\_\_\_\_.*

- a. nonpolar covalent; nonpolar
  - b. polar covalent; polar
  - c. polar covalent; nonpolar
  - d. **nonpolar covalent; polar**
  - e. ionic; polar
10. What is one of the limitations of this Lewis structure for  $\text{N}_2\text{O}$ ?

*The Lewis structure does not show....*

- a. the number and type of each of the atoms in the molecule.
- b. which atoms are connected to which.
- c. **the uncertainty of electron location.**
- d. whether the bonds are single, double, or triple bonds.
- e. how many valence electrons are in the molecule.

11. Which is **true** about intermolecular forces?
- a. Stronger intermolecular forces mean that a substance is more likely to be in the gas phase.
  - b. Molecules with stronger intermolecular forces boil at higher temperatures.**
  - c. London dispersion forces get weaker with increased molecule size.
  - d. For molecules of similar sizes, London dispersion forces are stronger than hydrogen bonds.
  - e. For molecules of similar size, polar molecules have weaker intermolecular forces than nonpolar molecules.

Draw the Lewis structures for the five molecules below and use these to answer the next four questions.



12. Which of the molecules contains a triple bond in its Lewis structure?
- a. H<sub>2</sub>
  - b. SO<sub>2</sub>
  - c. HCN**
  - d. HF
  - e. Br<sub>2</sub>
13. For which of the molecules is it possible to draw resonance structures?
- a. H<sub>2</sub>
  - b. SO<sub>2</sub>**
  - c. HCN
  - d. HF
  - e. Br<sub>2</sub>
14. How many of the substances would be expected to dissolve in water?
- a. 1
  - b. 2
  - c. 3**
  - d. 4
  - e. 5 (All five of the substances are polar.)
15. Which of the substances is expected to have the highest boiling point?
- a. H<sub>2</sub>
  - b. SO<sub>2</sub>
  - c. HCN
  - d. HF**
  - e. Br<sub>2</sub>

**Part 2: Free Response**

16. Parts a – c each include pairs of substances. Answer the questions below, appropriately addressing the differences in the characteristics of the two substances in each pair.

+5 points  
total

- a. It is easier to remove an electron from neutral magnesium (**Mg**) than to remove an electron from the most stable magnesium ion (**Mg<sup>+2</sup>**). Explain why it is easier to remove an electron from neutral magnesium. In your answer, include:

- How the number of electrons in each species compare
- How the sizes of each compare
- How these differences in electrons and size relate to difficulty to remove an electron.

+2

**Mg has 12 electrons and Mg<sup>+2</sup> has only ten electrons. They both have the**

+1

**same number of protons. Mg<sup>+2</sup> is smaller than Mg. It is easier to take an**

+2

**electron from Mg because Mg is larger and as a result its outer electrons are further away from the nucleus and easier to remove.**

- b. The neutral helium atom (**He**) has a smaller radius than the neon atom (**Ne**). Explain why helium is smaller than neon. Your answer should go beyond simply stating a trend and should explain why these two atoms have different sizes based on their atomic structures.

+4 points  
total

**The helium atom is smaller than the neon atom because helium has fewer**

+2

**energy levels overall. Neon has two energy levels (n = 1 and n = 2), and**

**helium has only one (n = 1). This greater number of energy levels results in**

+2

**the outer electrons being further from the nucleus, which results in greater size for neon.**

- c. The sulfur ion ( $\text{S}^{2-}$ ) has a larger radius than the potassium ion ( $\text{K}^+$ ). Explain why the sulfur ion is larger than the potassium ion. Your explanation should include:

+6 points  
total

- The number of protons in each species
- The number of electrons in each species
- How the number of protons and electrons relate to size.

+2

The sulfur ion has 16 protons and the potassium ion has 19 protons. Both ions have 18 electrons. Because electrons (and thus both the number of

+2

energy levels and the amount of electron-electron repulsions) are the same for both species, we need to compare the number of protons to see which

+2

is larger. The species with the greater number of protons (potassium) will be smaller because the protons better attract the electrons to the nucleus.

The species with the nucleus with less positive charge (sulfur) will be larger because the attraction between the nucleus and the electrons is not as strong.

*Please go on to the next page.*

17. The compounds in each of the three sets below all have similar formulas. However, within each of the three sets, each compound has a different electron pair geometry. Draw Lewis structures for each of the three compounds on scratch paper and use those Lewis structures to fill in the table. Answer the follow up questions about each set at the end.

**Set 1:**

- a. Fill in the table for set 1 below. Each molecule consists of a central atom which is connected to four fluorine atoms.

Formula	Electron pair geometry	Molecular Shape	Polar or nonpolar?	Strongest Intermolecular Forces
SF <sub>4</sub>	Trigonal bipyramid	See-saw	Polar	Dipole-dipole
CF <sub>4</sub>	Tetrahedral	Tetrahedral	Nonpolar	London dispersion forces
XeF <sub>4</sub>	Octahedral	Square planar	Nonpolar	London dispersion forces

**Set 2:**

- b. Fill in the table for set 2 below. Each molecule consists of a central atom which is connected to two oxygen atoms.

Formula	Electron pair geometry	Molecular Shape	Polar or nonpolar?	Strongest Intermolecular Forces
CO <sub>2</sub>	Linear	Linear	Nonpolar	London dispersion forces
XeO <sub>2</sub>	Tetrahedral	Bent	Polar	Dipole-dipole
SeO <sub>2</sub>	Trigonal planar	Bent	Polar	Dipole-dipole



**Set 3:**

+3  
points  
total

- c. Fill in the table for set 3 below. Each molecule consists of a central atom which is connected to three chlorine atoms.

Formula	Electron pair geometry	Molecular Shape	Polar or nonpolar?	Strongest Intermolecular Forces
PCl <sub>3</sub>	Tetrahedral	Trigonal pyramid	Polar	Dipole-dipole
BCl <sub>3</sub>	Trigonal planar	Trigonal planar	Nonpolar	London dispersion
BrCl <sub>3</sub>	Trigonal bipyramid	T-shape	Polar	Dipole-dipole

+0.25  
each  
box

+3 points  
total

- d. Which compound each set is expected to have the **lowest** boiling point? List three compounds, selecting one of the three compounds from each of set 1, set 2, and set 3.

- Compound from set 1 with lowest boiling point: CF<sub>4</sub>
- Compound from set 2 with lowest boiling point: CO<sub>2</sub>
- Compound from set 3 with lowest boiling point: BCl<sub>3</sub>

+1 each  
blank

- e. Of the three compounds from part d., one of them is a liquid at room temperature and the other two are gases. Which of the compounds is a liquid? Briefly explain your answer, including giving the strongest intermolecular forces between molecules of each of the three compounds.

+3 points  
total

**BCl<sub>3</sub> is a liquid.**

+1

**All three of these compounds have the same intermolecular forces (London dispersion forces).**

+1

**However, the compound which has the strongest intermolecular forces is BCl<sub>3</sub> because it has the greatest molar mass and greatest number of electrons.** This means that it has stronger London dispersion forces and therefore boils at the highest temperature of the three compounds listed here.

+1