CHEMISTRY 101
Hour Exam III
December 2, 2021
Leveritt/McCarren

Name _____KEY_____

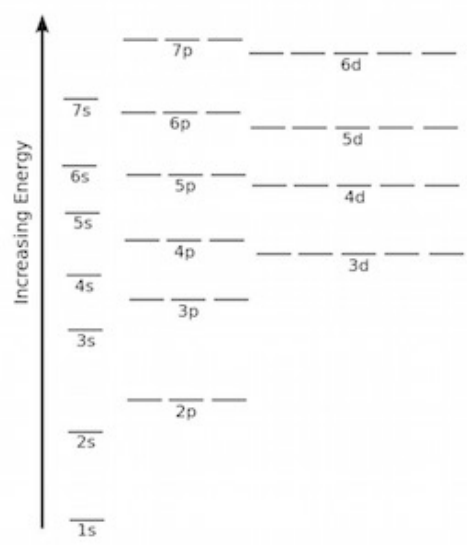
Signature _____

Section _____

"Start where you are. Use what you have. Do what you can." –Arthur Ashe

This exam contains 21 questions. The first 15 questions are multiple choice and the remaining questions may be a mix of multiple choice, checkboxes, and drop-down questions. Please be sure to answer all of the questions on the exam. You may use the periodic table and equation sheet provided.

Useful information:



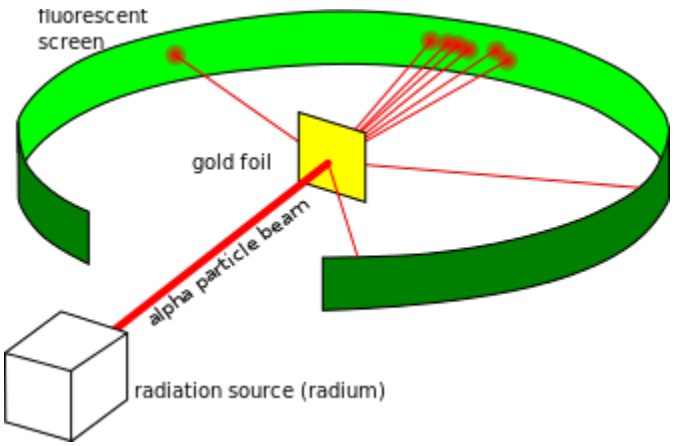
Part 1: Multiple Choice

1. What neutral element is represented by the following ground state electron configuration?

   $[Xe]6s^2 4f^{14} 5d^6$

   a. Ruthenium (Ru)
   b. Tungsten (W)
   c. Hassium (Hs)
   d. Rhenium (Re)
   e. **Osmium (Os)**

2. An image of the Rutherford Gold Foil experiment is shown below. In this experiment, it was observed that the majority of the alpha particles shot towards the gold atoms moved straight through the gold foil. However, a small percentage of particles were deflected back at wide angles.



   What was the key conclusion drawn from this particular experiment that is still used in our modern understanding of atomic structure?

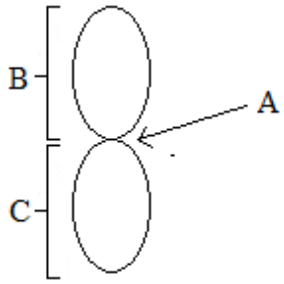
   a. Energy of electrons is quantized within the atom.
   b. Orbitals are a mathematical model used to determine an electron's probable location.
   c. The atom is mostly empty space but contains a small, dense, positive nucleus.
   d. Negatively charged electrons are dispersed evenly throughout the atom.
   e. Electrons move in circular orbits around the nucleus.

3. How many of the following electron configurations describe either the ground or potential excited states for the aluminum ion **(Al^{+3})**?
   - $1s^2 2s^2 2p^6 3s^1 3p^2$
   - $1s^2 2s^2 2p^6 3s^2 3p^1$
   - $[He] 2s^2 2p^6$
   - $[He] 2s^2 2p^6 3s^2 3p^3$

   a. 0 (none of them)
   b. <u>1</u>
   c. 2
   d. 3
   e. 4 (all of them are possible)

4. Carbon has four valence electrons. In a ground state electron configuration for carbon, how many of the valence electrons would you expect to be unpaired? (The orbital filling diagram is on the equation sheet.)
   a. 0 (All of the valence electrons are paired.)
   b. 1
   c. <u>2</u>
   d. 3
   e. 4 (All of the valence electrons are unpaired.)

5. One of the p-orbitals derived from the modern understanding of atomic structure is shown below. Which of the following statements is **true** regarding the location of the electron(s) that can occupy this orbital?



   a. <u>The orbital shape provides the likely, but not certain, location of the electrons.</u>
   b. The electrons move only around the outer surface of the orbital.
   c. Electrons are most often near the center of the orbital (marked by point A).
   d. This one p orbital can contain up to six electrons.
   e. A single electron can only move in the top or bottom half of the orbital (sections B or C).

6. Which of the following answers correctly ranks the atoms in order of **lowest to highest** first ionization energy?
   a. <u>K < Na < S < Cl</u>
   b. Cl < S < Na < K
   c. K < Na < Cl < S
   d. S < Cl < Na < K
   e. Cl < S < K < Na

7. Consider the neutral hydrogen and lithium atoms. Which has the larger atomic radius, and how do the sizes of the 1s orbitals compare?

	Larger atomic radius	**1s orbital sizes**
a.	H	Li > H
b.	H	H < Li
c.	Li	Li > H
<u>d.</u>	**<u>Li</u>**	**<u>H > Li</u>**
e.	Li	H = Li

8. In one of the lab activities, 3D glasses were used to see the different colors of visible fluorescent light. You also looked at the visible light spectrum of the element hydrogen. If you are studying a particular excited state of a specific element, which color would be **<u>impossible</u>** to observe?
   a. purple
   b. <u>white</u>
   c. orange
   d. red
   e. green

The next four questions refer to the four molecules shown below.

XeF_2 CH_3OCH_3 H_2O CH_4

9. For which molecule does the central atom not obey the octet rule?
   a. **XeF_2**
   b. CH_3OCH_3
   c. H_2O
   d. CH_4
   e. The octet rule is obeyed for all central atoms.

10. How many of the molecules above are polar?
   a. 0 (None are polar).
   b. 1
   c. 2
   d. 3
   e. 4 (All four are polar.)

11. How many of the molecules above contain at least one bond angle of 180°?
   a. 0 (None of them have bond angles of 180°.)
   b. 1
   c. 2
   d. 3
   e. 4 (All of them have bond angles of 180°.)

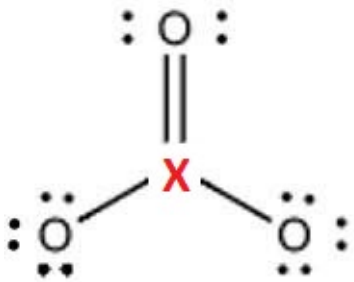
12. Which of the substances is expected to have the highest boiling point? Choose the correct answer *and* reason.
   a. **CH_3OCH_3:** CH_3OCH_3 has the greatest number of hydrogen atoms so it can form the strongest hydrogen bonds with other molecules.
   b. **H_2O: Hydrogen bonding forces can form between water molecules which are stronger than the forces between the other molecules.**
   c. **XeF_4:** XeF_4 has the highest molar mass and therefore strongest intermolecular forces of all of the molecules.
   d. **CH_4**: C_2H_4 only displays London dispersion forces which are weaker than those of the other molecules.
   e. All are expected to have the same boiling point.

13. The following hydrocarbons are ranked in increasing boiling points. Which intermolecular forces exist between these molecules which can be used to describe the phenomena?

$$CH_4 < CH_3CH_3 < CH_3CH_2CH_3 < CH_3CH_2CH_2CH_3$$

a. Hydrogen bonding forces only
b. London dispersion forces, hydrogen bonding
c. London dispersion forces, and dipole-dipole forces
d. London dispersion forces, dipole-dipole forces, hydrogen bonding
e. <u>London dispersion forces only</u>

14. What is **<u>true</u>** regarding central atom X in the species below? Consider the Lewis structure provided.



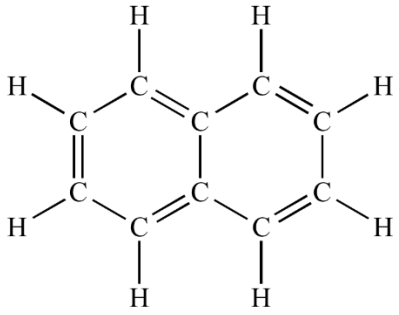
a. Central atom X may have four valence electrons if the molecule is neutral.
b. Central atom X may have four valence electrons if the overall charge of the molecule is -1.
c. Central atom X may have five valence electrons if the molecule is neutral.
d. <u>Central atom X may have five valence electrons if the molecule has an overall charge of -1.</u>
e. No matter the number of valence electrons, this molecule has a tetrahedral shape.

15. For the molecule ClF_5, draw the Lewis structure and determine the molecular shape. Is this molecule polar or non-polar? Select the answer that states whether it is polar or nonpolar and why.
a. **Nonpolar**: The central atom contains one lone pair of electrons.
b. **Nonpolar**: The Cl-F bonds evenly distribute themselves throughout the molecule.
c. **It depends:** There are multiple resonance structures possible for ClF_5 and some are polar and others are nonpolar.
d. **Polar**: The molecule consists of polar Cl-F bonds, making the molecule polar overall.
e. **<u>Polar: There is a lone pair of electrons on the central Cl that is not balanced by another lone pair.</u>**

Part 2: Free Response

Section A and Section B below refer to compounds that are found as a solid white power. Though these compounds may look similar, they may behave differently due to their molecular properties. Please select the correct responses in the spaces below.

Section A



Naphthalene is a **non-polar molecule with formula $C_{10}H_8$** which is used as a common pesticide and deodorant. The molecular structure of naphthalene is shown in the image above. It is found as a white solid (right), though it can easily be melted into the liquid form by heating. Use this information to answer the questions below.

16. Which of the following solvents would you expect Naphthalene to dissolve with? Select "yes" or "no" for each option.

+2.5 points (0.5 each)

- ★ $CH_3CH_2CH_2CH_2CH_2CH_3$
- ☐ H_2O
- ☐ CH_3CH_2OH
- ☐ NH_3
- ☐ $CHCl_3$

17. When kept at room temperature, naphthalene ($C_{10}H_8$) gradually sublimes under normal conditions and passes directly into the gas phase. Is this an endothermic or exothermic process? Assume naphthalene is the system. **Endothermic**

+1 point

18. When solid, naphthalene ($C_{10}H_8$) is heated on a stove, it melts and becomes a liquid. Is this an endothermic or exothermic process? Assume naphthalene is the system. **Endothermic**

+1 point

Section B

Solid potassium sulfide solution and solid calcium chloride salts are dissolved in water to produce aqueous solutions of potassium sulfide and calcium chloride. Then, these are mixed to produce solid calcium sulfide, a white powder frequent found in rock salt. This takes place according to the balanced equation below. Use this information and your knowledge of particles to answer the following questions.

$$K_2S(aq) + CaCl_2(aq) \rightarrow 2KCl(aq) + CaS(s)$$

There are four different ions present in solution **before** mixing occurs.

$$K^+, S^{2-}, Ca^{+2}, Cl^-$$

19. Give the number of protons and electrons in each of the ions:

+2 points (0.25 each)

Ion	Protons	Electrons
K^+	**19**	**18**
S^{2-}	**16**	**18**
Ca^{+2}	**20**	**18**
Cl^-	**17**	**18**

+2 points (0.5 each)

20. Rank the ions from smallest to largest.

$Ca^{+2} < K^+ < Cl^- < S^{2-}$

+2 points

21. Do this set of ions make an isoelectronic series? **Yes**/No

22. Rank the Ca-Cl, K-Cl, and Ca-S bonds formed by these ions from least polar to most polar.

CaS < CaCl < KCl

+1.5 point

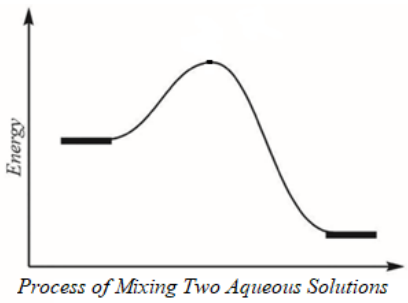
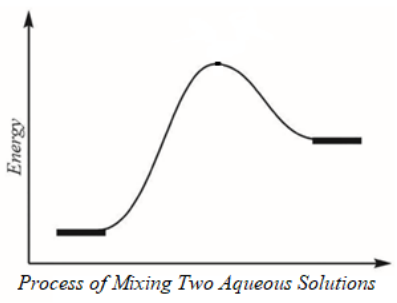
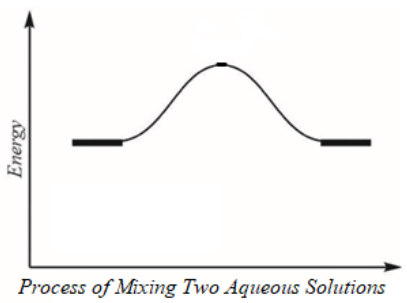
The potassium sulfide and calcium chloride solutions are mixed to produce a white solid calcium sulfide precipitate as shown below.

+1 point

23. Consider the system to be the calcium sulfide solid and the surroundings to be the aqueous solution that the calcium sulfide is present in. After the two solutions were mixed, this was an exothermic process with respect to the system. Did the temperature of the aqueous solution increase, decrease, or remain constant? **increase**

24. Choose the correct reaction coordinate diagram for this process from the three shown below.

+1 point

Diagram 1	Diagram 2	Diagram 3
		

The following list pairs of molecules, each of which have similar formulas or structures. Draw Lewis structures for each molecule in the pairs and use those Lewis structures to give the electron pair geometry, molecular shape, and polarity around each central atom. Then, for each Lewis structure, answer the related questions below.

25. **Set 1**:

At least one molecule in the following set of compounds has an expanded octet, consisting of more than eight electrons around the central atom. Fill in the table below, giving the geometry, shape, polarity, and indicating whether or not each molecule displays an expanded octet.

+4 points (0.33 each)

Molecule	Electron Pair Geometry	Molecular Shape	Polar or Nonpolar?	Expanded Octet?
NF_3	**tetrahedral**	**trigonal pyramid**	**polar**	**no**
ClF_3	**trigonal bipyramid**	**t-shape**	**polar**	**yes**
HF	**tetrahedral**	**linear**	**polar**	**no**

26. Set 2:

Carbonate (CO_3^{2-}), and nitrate (NO_3^-), and nitrite (NO_2^-) are common polyatomic ions that are found in both fertilizers and food preservatives. It is possible to draw resonance structures for at least one of these ions. Fill in the table below, giving the geometry, shape, type of bonds, and indicating whether or not it is possible to draw resonance structures for each compound.

+4 points (0.33 each)

Molecule	Electron Pair Geometry	Molecular Shape	Lewis structure contains at least one double bond?	Resonance Structures Possible?
CO_3^{2-}	**trigonal planar**	**trigonal planar**	**yes**	**yes**
NO_3^-	**trigonal planar**	**trigonal planar**	**yes**	**yes**
NO_2^-	**trigonal planar**	**bent**	**yes**	**yes**

27. Set 3:

CH_2Cl_2, NH_3, and H_2 are all molecules containing hydrogen atoms. At least one of these molecules displays hydrogen bonding forces when combining with similar molecules. Fill in the table below, giving the geometry, shape, polarity, and indicating the strongest intermolecular force displayed by each substance.

+4 points (0.36 each)

Molecule	Electron Pair Geometry	Molecular Shape	Polar?	Strongest Intermolecular Force
CH_2Cl_2	**tetrahedral**	**tetrahedral**	**polar**	**Dipole-dipole**
NH_3	**tetrahedral**	**trigonal pyramid**	**polar**	**Hydrogen bonds**
H_2	**linear**	**linear**	**nonpolar**	**London-dispersion**

28. **Set 4:**

CO, N_2, and O_2 all colorless, odorless gases. At least one of these gases has a Lewis structure containing a double or triple bond between the two atoms. Fill in the table below, giving the shape, polarity, and indicating whether a single, double, or triple bond is present. Then, give the strongest intermolecular forces between the molecules.

+4 points (0.33 each)

Molecule	Molecular Shape	Polar?	Single, double, or triple bond?	Strongest intermolecular force?
CO	**linear**	**polar**	**triple**	**Dipole-dipole**
N_2	**linear**	**nonpolar**	**triple**	**London dispersion**
O_2	**linear**	**nonpolar**	**double**	**London dispersion**

STOP. You have reached the end of the test. Please be sure to submit it. You are almost done with the semester!