Exam 3

# Part 1: Multiple Choice (2 points each)

## Directions: Please circle the *best* answer for each of the following questions.

1. A shell consists of all \_\_\_\_\_\_\_\_
	1. electrons with the same  quantum number.
	2. orbitals with the same quantum numbers.
	3. orbitals with the same principal quantum number.
	4. electrons with the same magnetic quantum number.
	5. orbitals with the same  and *ml* quantum numbers.
2. Which of the following is *not* an allowed value for the principal quantum number?
	1. 0
	2. 1
	3. 2
	4. 3
	5. 10
3. Atomic spectra are due to the changes in the energy of \_\_\_\_\_\_\_\_
	1. protons.
	2. neutrons.
	3. nuclei.
	4. electrons.
	5. electromagnetic radiation.
4. Which of the following electron configurations represents an excited state?
	1. [Ne]3*s*23*p*5
	2. [Kr]4*d*105*s*25*p*1
	3. [Ar]3*d*104*s*24*p*6
	4. [Ne]3*s*23*p*64*s*1
	5. [Kr]4*d*105*s*15*p*1
5. Which of the following oxoacids would you predict not to exist?
	1. HFO4
	2. HClO4
	3. HBrO4
	4. HIO4
	5. HClO
6. What are the hybridizations of the carbon atoms in CH3CH2(CO)H, in order from left to right? Note that the CO bond is a double bond.
	1. *sp*3, *sp*3, *sp*2
	2. *sp*3, *sp*3, *sp*3
	3. *sp*3, *sp*2, *sp*3
	4. *sp*2, *sp*2, *sp*3
	5. *sp*3, *sp*2, *sp*2
7. Which of the following substances is a solid at 25°C and 1 atm?
	1. 
	2. 
	3. 
	4. 
8. Which is the dominant interaction between oxygen and nitrogen molecules in air?
	1. ion–ion
	2. ion–dipole
	3. dipole–dipole
	4. hydrogen bonding
	5. dispersion or London forces
9. The vapor pressure of a liquid increases with increasing temperature because \_\_\_\_\_\_\_\_
	1. more molecules can escape from the liquid because their average kinetic energy is greater.
	2. the number of gas molecules above the liquid does not change but their average kinetic energy increases.
	3. the molecules in the liquid move faster and exert a greater pressure.
	4. the ideal gas law states that the pressure is proportional to the temperature.
	5. molecules interact less strongly at higher temperatures.
10. What are the F-Po-F bond angles in polonium(VI) fluoride?
11. 90°
12. 109.5°
13. 120°
14. 180°
15. 90° and 120°

# Part 2: Short Answer

## Directions: Answer each of the following questions. Be sure to use complete sentences where appropriate. For full credit be sure to show all of your work.

1. A light detector based on the photoelectric effect is made with cesium metal. Cesium metal has a work function of 3.40  10–19 J (6 points).
	1. What is the longest wavelength in nm of light that one could expect to detect with this device?
	2. What is the frequency of the light?
2. Astronomers have detected hydrogen atoms in interstellar space in the *n* = 732 energy level. Suppose an atom in this excited state emits a photon and undergoes a transition from *n* = 732 to *n* = 721 (8 points).
	1. How much energy does the atom lose as a result of this transition?
	2. What is the wavelength of the emitted photon, RH = 1.097 × 107 m-1?
	3. In which spectral region does this radiation lie?\_radio frequency region of the spectrum
3. Consider the radial distribution shown below for an electron in an *s* atomic orbital where *r* is the distance of the electron from the nucleus (4 points).

Identify: (1) where the atomic nucleus is located; (2) a radial node; (3) the most probable distance of the electron from the nucleus; and (4) the principle quantum number for this orbital.

(1) The nucleus is located at A; (2) radial nodes are at *r*/a = 2 and 7 (C); (3) the most probable distance is *r*/a = 13 (D); (4) and *n* = 3, because there are two radial nodes.

1. Cyanogen is a gas which contains 46.2% C and 53.8% N by mass. At a temperature of 25 °C and a pressure of 750 mm Hg, 1.50 g of cyanogen occupies 0.714 L (18 points).
	1. What is the molecular formula of cyanogen?

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| --- | --- |
| **Bond** | **Bond Energy****(kJ/mol)** |
| N–N | 163 |
| N=N | 418 |
| NN | 941 |
| N–H | 388 |
| O–O | 146 |
| O=O | 495 |
| O–H | 463 |

* 1. Draw the best Lewis structure for cyanogen, and label the orbital geometry, molecular geometry, bond angle, and hybridization of the central atom(s).



each carbon has a orbital geometry = linear

molecular geometry = linear

bond angle = 180°

hybridization = sp

1. Hydrazine (N2H4) is used as a rocket fuel. The combustion products are nitrogen (N2) and water (H2O) (12 points).
	1. Write the balanced chemical equation and then draw the Lewis structures of the reactants and products.

N2H4 (l) + O2 (g) → N2 (g) + 2 H2O (g)



* 1. Use the above information about bond energies to estimate the change in enthalpy associated with the combustion of 1 mol of hydrazine.
1. Describe the valence bond picture of bonding in ethylene, C2H2, which is shown below. Identify the number of valence electrons, the number of pi bonds, the number of sigma bonds, and the hybridization of the carbon atomic orbitals (4 points).



Ethylene has 12 valence electrons, 1 pi bond, 5 sigma bonds, and the carbon hybridization is *sp*2.

1. Use the 1*s* orbital of hydrogen to form atomic orbitals for H2 and draw the molecular orbital energy-level diagram. Label the energy levels with the MO symbols. Which of the following species of hydrogen would you predict to be stable based on your energy-level diagram? Explain (6 points).

H22+, H2+, H2, H2–, H22–

*σ*\*\_\_\_\_\_\_\_\_

*σ*\_\_\_\_\_\_\_\_

Bond orders are 0 for H22+; 0.5 for H2+; 1 for H2; 0.5 for H2–; 0 for H22–. Expect those species with bond orders greater than 0 to be stable.

1. Would water rise to the same height in a capillary tube made of polyethylene plastic as it does in a glass capillary tube of the same diameter? Polyethylene is a hydrocarbon, and glass is mostly silicon dioxide. Explain (3 points).

Water will not interact as strongly with the hydrocarbon walls of a plastic capillary tube as it does with the silicon dioxide walls of a glass capillary tube where oxygen is available for hydrogen bonding with water. Consequently, water will rise higher in the glass capillary tube.

1. CH2F2 has a dipole moment of 1.93 D and a boiling point of –52°C. CH2Cl2 has a dipole moment of 1.60 D and a boiling point of 40°C. Why is the boiling point of dichloromethane so much higher than that of difluoromethane (4 points)?

Both molecules have dipole–dipole and dispersion interactions. Difluoromethane has the larger dipole–dipole interactions because it has the larger dipole moment, but dichloromethane has the larger dispersion interactions because it has more electrons. Evidently, the larger dispersion interactions are more important in producing a higher boiling point for dichloromethane.

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| **Temperature (K)** | **Pressure (torr)** |
| 65 | 130.5 |
| 70 | 289.5 |
| 75 | 570.8 |
| 80 | 1028 |
| 85 | 1718 |

1. The vapor pressure of nitrogen at several different temperatures is shown: (15 points)
	1. Make a linear graph.

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| **Temperature (K)** | **Pressure (torr)** | **1/T (1/K)** | **Ln(P)** |
| 65 | 130.5 | 0.015 | 4.8714 |
| 70 | 289.5 | 0.014 | 5.6682 |
| 75 | 570.8 | 0.013 | 6.3470 |
| 80 | 1028 | 0.013 | 6.9354 |
| 85 | 1718 | 0.012 | 7.4489 |

The graph of pressure vs. temperature is exponential. But, the graph of ln(P) vs. 1/T is linear:

* 1. Using points off your graph determine the equation of the best fit straight line.
	2. Determine the heat of vaporization of nitrogen.
	3. Determine the normal boiling point of nitrogen.