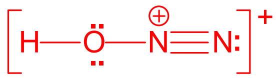
Chem 10113, Exam 3 **Answer Key**

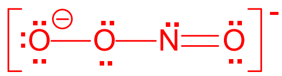
November 28, 2018

1. (8 points) Write ***complete Lewis electron dot formulas*** for each of the following ions.

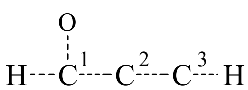
   (a) HON_2^+ (skeletal structure: H–O–N–N)

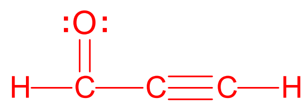


   (b) O_2NO^- (skeletal structure: O–O–N–O)



2. The simple organic compound, C_3H_2O, known as propynal, is very unstable but has been detected in interstellar space. Propynal has a skeletal framework as indicated in the figure below. The numbers on the figure are just labels to distinguish the carbon atoms in the following questions.





   (a) (1 point) The ***total*** number of ***valence*** electrons in this molecule is 20.

   (b) (2 points) In the space above, complete the Lewis electron dot formula for C_3H_2O.

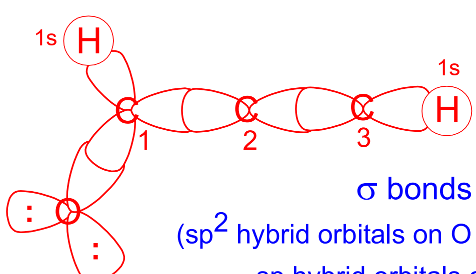
   (c) (2 points) What is the hybridization at each of the atoms?

   O sp^2 C^1 sp^2 C^2 sp C^3 sp

   (d) (1 point) The H—C^1— C^2 bond angle is 120 degrees.

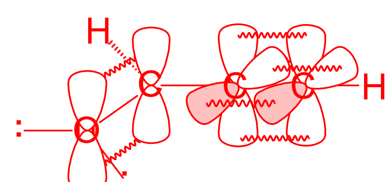
   (e) (1 point) The C^2— C^3—H bond angle is 180 degrees.

   (f) (7 points) **Describe the bonding** in propynal, C_3H_2O, using **Valence Bond Theory** (i.e., hybrid atomic orbitals, etc.). ***Draw and clearly label one or more pictures*** to show the ***types of orbitals*** that you are using to form the σ and/or π bonds. Also, clearly show the 3-D structure of the molecule, including the relative orientation of the C-H, C-C-C, and C-O linkages, etc.



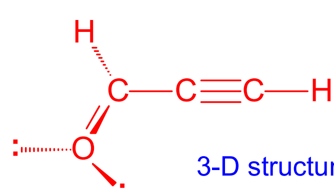
σ bonds

(sp^2 hybrid orbitals on O and C^1, sp hybrid orbitals on C^2, C^3)



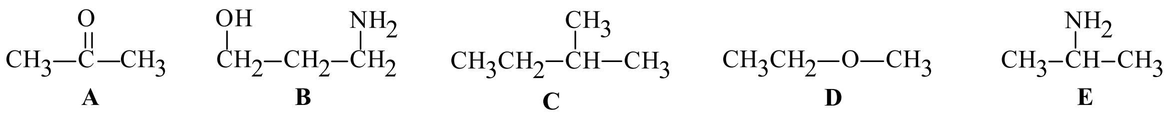
π bonds

(all unhybridized p orbitals on O and C's)



3-D structure

3. (6 points) Consider the following organic liquids. Use the letters, **A** - **E** to fill in the blanks in the statements below. (The same letter may be used more than once.)



(a) B has the greatest surface tension.

(b) C should be the least soluble in water.

(c) B has the lowest vapor pressure at room temperature.

(d) C has only London (dispersion) forces.

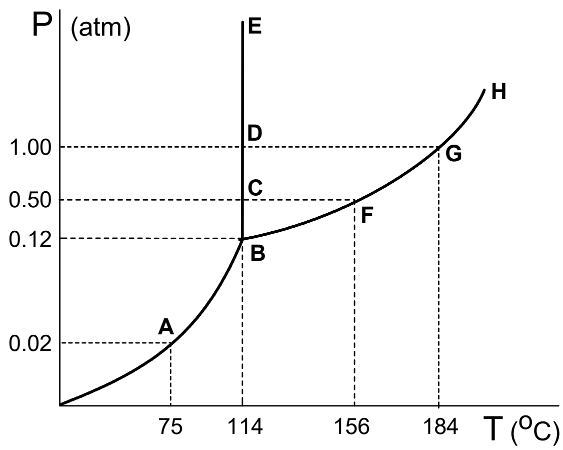
(e) In compounds A and D, the ***predominant*** (i.e., strongest) intermolecular interactions are ***dipole-dipole forces***.

4. (3 points) Arrange the following in order of decreasing atomic radius.

Te^{2-} Xe Ba^{2+} Cs^{+} I^{-} Te^{2-} > I^{-} > Xe > Cs^{+} > Ba^{2+}

(largest) (smallest)

5. (6 points) The following questions refer to the phase diagram of elemental iodine (I_2) as shown below (not drawn to scale).



(a) At 200 °C and 0.20 atm is I_2 a solid, liquid, or a gas? gas

(b) The triple point of I_2 is at P = 0.12 atm and T = 114 °C.

(c) Which letter on the diagram indicates the critical point of I_2? H

(d) At 380 torr, I_2 boils at 156 °C.

(e) Which letter on the diagram best represents a sublimation point? A

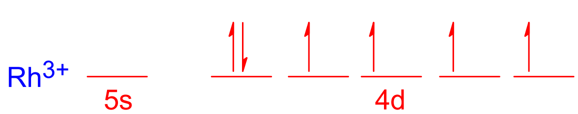
6. (2 points) For a certain substance, a plot of ln P (natural log of vapor pressure, in atm) *vs* 1/T (1 over temperature, in K) affords a straight line with slope = -3675 K.

For this substance, $\Delta H_{vaporization}$ = 30.6 kJ/mole.

7. (2 points) Write the ***short-hand*** electron configuration for rhodium (Rh).

$[Kr]^{36}\ 5s^2\ 4d^7$

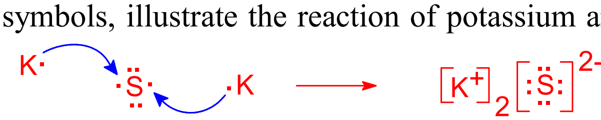
8. (3 points) Give the ***orbital diagram*** for the ***valence shell*** electron configuration of Rh^{3+}.



9. (3 points) Circle any of the following molecules that are ***non-polar***.

PF_3 XeF_4 BrF_5 BF_3 SF_2 AsF_5

10. (3 points) Using Lewis dot symbols, illustrate the reaction of potassium and sulfur atoms to form a stable ***ionic*** compound.



11. (11 points) Use ***Molecular Orbital Theory*** as it applies to simple diatomic molecules and ions to answer the following questions.

(a) Circle any of the following molecules that are paramagnetic.

Li_2 B_2 C_2 N_2 O_2 F_2

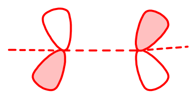
(b) The molecule NO has one unpaired electron(s) in the π^*_{2p} energy level.

(c) The bond order of the anion NO^- is 2 .

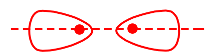
(d) Which has the shortest bond distance? (circle one) O_2 O_2^+ O_2^- O_2^{2-}

(e) Sketch the ***shapes*** of each of the following molecular orbitals.

π^*_{2p}



σ^*_{2s}



12. (9 points) **SHOW ALL WORK.** The heat of combustion of propane, C_3H_8 (molar mass = 44.1), is -2220 kJ/mole. Determine the mass (in grams) of propane that is required to provide enough energy to convert 2.50 kg of ice at 273 K to water vapor at 373 K.

(***Note***: For H_2O, $\Delta H°_{fusion}$ = 6.02 kJ/mole and $\Delta H°_{vaporization}$ = 40.7 kJ/mole)

moles H_2O = (2500 g) (1 mole / 18.0 g) = 138.9 mole

heat to melt ice = (138.9 mole) (6.02 kJ/mole) = 836.1 kJ

heat to warm up water = (2500 g) (4.184 J/g·°C) (100 °C) = 1046000 J = 1046 kJ

heat to evaporate water = (138.9 mole) (40.7 kJ/mole) = 5653.2 kJ

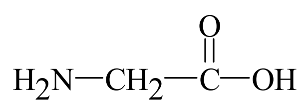
total heat = 836 kJ + 1046 kJ + 5653 kJ = 7535 kJ

mass propane = (7535 kJ) (1 mole / 2220 kJ) (44.1 g/mole) = 150 g

13. (8 points) **SHOW ALL WORK.** Write a ***balanced chemical equation*** for the ***formation reaction*** of glycine (an amino acid, structure below), and then determine the ***standard heat of formation*** ($\Delta H°_f$) of glycine from the bond energy data given below.

Bond Energy (kJ/mole)	
H–H	436
N–H	389
O–H	464
C–H	414
C–C	347
C–N	305
C–O	360
C=O	736
N≡N	946
O=O	498

$1/2\ N_2 + 2\ C + O_2 + 5/2\ H_2 \longrightarrow$



bonds broken = 1/2 N≡N + O=O + 5/2 H-H

= 1/2 (946) + 498 + 5/2 (436) = 2061

bonds formed = 2 N-H + 2 C-H + 1 C-N + 1 C-C + 1 C=O + 1 C-O + 1 O-H

= 2 (389) + 2 (414) + 305 + 347 + 736 + 360 + 464 = 3818

$\Delta H°_f$ = 2061 - 3818 = **- 1757** kJ/mole

14. (9 points) **SHOW ALL WORK.** The vapor pressure of CCl_3F (molar mass = 137.4) at 300 K is 856 torr. If a 12.0 g quantity of CCl_3F is enclosed in a 1.25 L container, determine the mass of CCl_3F that is in the ***liquid phase*** after the liquid-gas equilibrium is established.

n = moles CCl_3F in gas phase = PV/RT

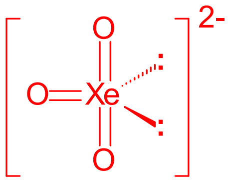
= (856/760) atm (1.25 L) / (0.0821 L·atm/mole·K) (300 K) = 0.0572 mole

(0.0572 mole) (137.4 g/mole) = 7.85 g CCl_3F gas

moles CCl_3F liquid = 12.0 g total - 7.85 g CCl_3F gas = 4.15 g

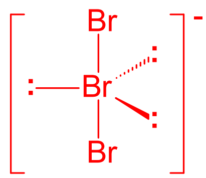
15. (9 points) Apply **VSEPR** concepts to the following anions. In each case, ***<u>draw</u> a clear 3-D structure*** and give a ***description*** of the shape (i.e., tetrahedral, trigonal planer, etc.). Also, ***state*** the ***hybridization*** of the central atom in each case. (***Do NOT draw orbital pictures!)***

XeO_3^{2-}



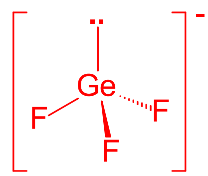
T-shaped
sp^3d

Br_3^-



linear
sp^3d

GeF_3^-



pyramidal
sp^3

16. (4 points) The rather unusual anion BrF_6^- contains six Br-F bonds but its 3-D shape is ***not*** octahedral. Apply the VSEPR concept to this anion (***extend*** the basic premise of the theory as needed) and predict the most likely 3-dimensional structure for it. Clearly draw your proposed 3-D structure and indicate the expected bond angle(s) in degrees.

This anion has a steric number of 7 at the central Br atom. The electron geometry is a "pentagonal bipyramid" with one axial fluorine (labeled F^a), an axial lone pair, and five "equatorial" fluorines arranged in a pentagon perpendicular to the axial direction. The axial-equatorial angle is 90° and the equatorial-equatorial angle is 72° (i.e., 360°/5). This can be viewed as an "extension" of the SN 5 and 6 cases that have 3 and 4 positions in the horizontal plane, respectively. This structure has 5. (Incidentally, the hybridization at bromine is sp^3d^3.)