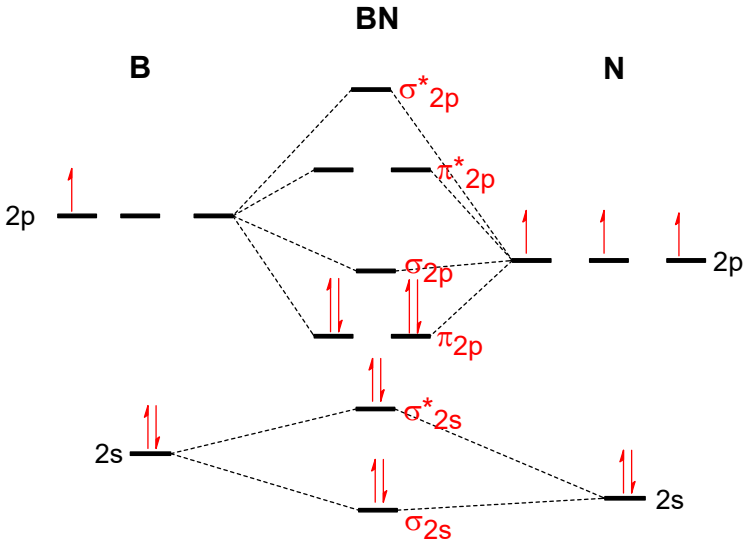
Chem 10113, Exam 3 **Answer Key**
December 4, 2019

1. The molecular orbital diagram for the diatomic molecule **BN** is shown below.

   (a) (2 points) Complete the labels (σ_{2s}, σ^*_{2s}, etc.) of the MO energy levels on the diagram.

   (b) (3 points) Fill in the diagram with the correct number of valence electrons for the individual atoms and for the BN molecule.

   (c) (3 points) What is the bond order in each of the following species?



   BN^+ 1.5 BN^- 2.5 BN 2

   (d) (2 points) Which of the above has the *shortest* B-N bond distance? BN^-

2. (3 points) Using Lewis dot symbols, illustrate the reaction of phosphorus and potassium atoms to form an ***ionic*** compound.

3. (3 points) (Fill in these blanks with the relevant chemical symbols, e.g., T, ΔE°, lnK, 1/R, etc.)
   A graphical representation of the Clausius-Clapeyron equation should be a straight line when lnP is plotted on the vertical axis versus 1/T on the horizontal axis.
   The slope of this line is equal to -ΔH/R.

4. (4 points) Circle any of the following molecules that are ***polar***.
   AsH_3 IF_5 SeF_4 BF_3 XeO_3 $SeCl_2$ GeH_4

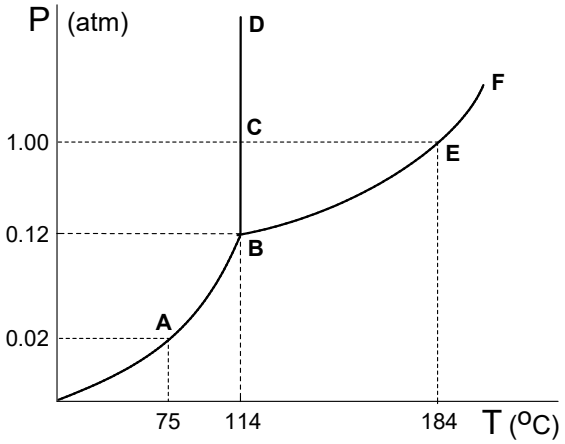
5. (4 points) The following questions refer to the phase diagram of elemental iodine (I_2) as shown below (not drawn to scale).

   (a) The triple-point temperature of I_2 is 114 °C.

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

   (c) At 150 °C and 1.00 atm, is I_2 a solid, liquid, or a gas? liquid

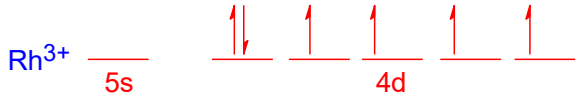
   (d) Which letter on the diagram indicates the critical point of I_2? F



6. (3 points) Write the ***short-hand electron configuration*** for polonium (Po).

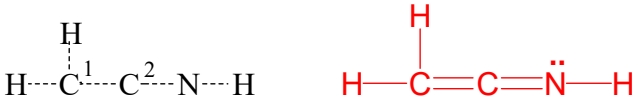
$[Xe]^{54}\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^4$

7. (4 points) Give the ***orbital diagram*** for the ***valence shell*** configuration of Rh^{3+}.



8. (2 points) If you needed to find $\Delta H°$ for the reaction: $2\ Fe^{3+}_{(g)} + 3\ O^{2-}_{(g)} \longrightarrow Fe_2O_{3(s)}$, you would look in your general chemistry textbook for a table of lattice energies.

9. A simple organic compound known as ketenimine, C_2H_3N, is isoelectronic with CO_2 and has a skeletal framework as indicated by dotted lines 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 16

(b) (2 points) In the space above, complete the Lewis electron dot formula for C_2H_3N.

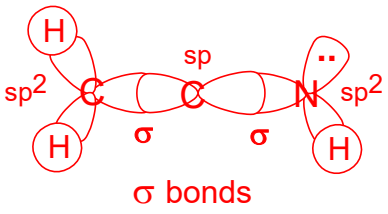
(c) (3 points) What is the hybridization at each of the atoms?

N sp^2 C^1 sp^2 C^2 sp

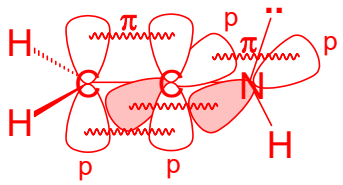
(d) (1 point) The H—C^1— H bond angle is *about* 120 degrees.

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

(f) (7 points) **Describe the bonding** in C_2H_3N 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 various 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-N, and N-H linkages, etc.

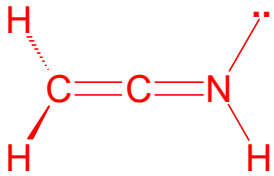


σ bonds



π bonds

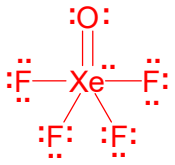
3-D structure:



(the H-C-H plane is perpendicular to the N-H bond)

10. Consider the Xe-centered molecule $OXeF_4$ from the viewpoint of bonding and structure concepts.

(a) (4 points) Write a complete Lewis electron dot formula for $OXeF_4$. The expected hybridization at Xe is sp^3d^2.



(b) (4 points) Draw two ***different*** but ***reasonable*** 3-D structures for the molecule $OXeF_4$. Indicate whether each one is polar or non-polar.

both are polar

11. (9 points) **SHOW ALL WORK.** Suppose that 2.50 g of acetone, $(CH_3)_2CO$ (molar mass = 58.08), evaporates from a 105-g block of aluminum. If the Al block is initially at 24.5 °C (and assuming that any heat transfer occurs only between the acetone and the Al block), determine the final temperature of the Al after the evaporation of the acetone is complete. (***Note***: The specific heat of Al is 0.903 J/g·°C. The heat of vaporization of acetone is 31.3 kJ/mole.)

heat required to vaporize alcohol = heat lost by Al

(2.50 g) (1 mole / 58.08 g) (31,300 J/mole) = 1347 J

1347 J = (105 g) (0.903 J/g·°C) (ΔT)

$\Delta T = 14.2\ °C = 24.5\ °C - T_f$ $\qquad T_f = 10.3\ °C$

12. (9 points) **SHOW ALL WORK.** Write a ***balanced chemical equation*** for the formation reaction of glycine (structure below), and then estimate the ***standard heat of formation*** ($\Delta H°_f$) of glycine by using 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

$1/2\ N_2 + 2\ C + O_2 + 5/2\ H_2 \longrightarrow H_2N{-}CH_2{-}C(=O){-}OH$

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

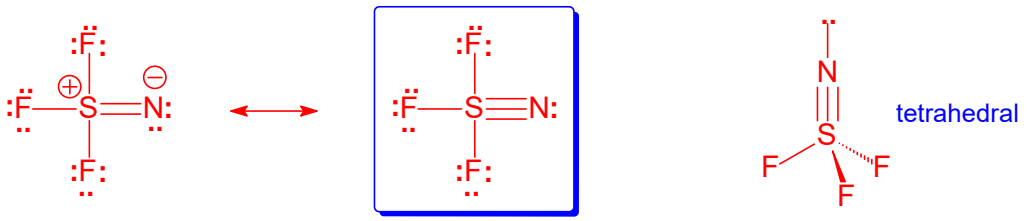
= 1/2 (946) + 498 + 5/2 (436) = 2061

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

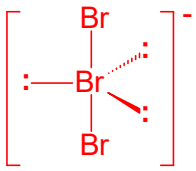
$\Delta H°_f$ = 2061 - 3818 = **- 1757** kJ/mole

13. (6 points) The F_3SN molecule has the *shortest* known S-N bond. Write ***two reasonable resonance forms*** for its Lewis dot formula, including any formal charges. Circle the one which is most consistent with the known bond distance. Also, clearly draw the ***3-D structure*** of F_3SN.



14. (8 points) Apply **VSEPR** concepts to the following anions. In each case, ***draw 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!)***

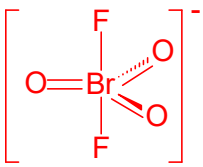
Br_3^-



linear

sp^3d

$F_2BrO_3^-$



trigonal bipyramid

sp^3d

15. (4 points) What is the *strongest* type of intermolecular force in each of the following?
    (a) liquid BF_3 dispersion (London) forces
    (b) solid HF H-bonding
    (c) liquid PCl_3 dipole-dipole forces
    (d) $Na_2CO_{3(aq)}$ ion-dipole forces

16. (8 points) Write ***complete Lewis electron dot formulas*** for each of the following anions.
    (a) $H_3BNO_2^-$ (b) $OONO^-$ (skeletal structure: O–O–N–O)