Dr. Zellmer	Chemistry 1250	T, R
Time: 7 PM Sun.	Spring Semester 2022	March 6, 2022
40 min	Quiz VII	

Name ______KEY__________ Rec. TA/time ____________________

1. (3 pts) Which hybrid orbitals lead to a **bent** shape with bond angles of about 105°?

   a) sp   b) sp^2 c)* sp^3 d) sp^3d e) sp^2d

sp^3 hybrid orbitals give an electron-domain tetrahedral geometry with angles of 109.5°. When an atom has 4 things around it the atom generally is using **sp^3** hybrid orbitals for bonding. The **bent** shape arises when an atom is bonded to 2 other atoms and has 2 lpe^- on it (4 things total). An example is H_2O. The O atom is sp^3 hybridized and uses two of the hybrid orbitals to form the bonds to the H atoms and two sp^3 hybrid orbitals are used for the lpe^- on the O atom. The two lpe^- spread out and force the H atoms closer together. For a central atom from period 2, each lpe^- reduces the bond angle by about 2°.

The hybrid orbital give the electron-domain geometries and bond angles below:

sp linear, 180°

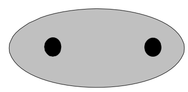
sp^2 trigonal planar, 120° (molecular shapes: trigonal planar, bent)

sp^3 tetrahedral, 109.5° (molecular shapes: tetrahedral, trigonal pyramidal, bent)

You don't have to invoke hybridizations of sp^3d and sp^3d^2 to get the trigonal pyramidal and octahedral geometries as pointed out in the textbook. Some books use these types of hybrid orbitals to explain these geometries but our book doesn't.

2. (3 pts) Describe what a sigma, σ, bond is and what a pi, π , bond is in terms of their electron density. Sketch what a pi bond between two atoms looks like (use two large dots to represent the nucleus of each atom).

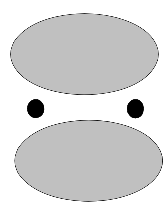
σ bond



Electron density concentrated along the internuclear axis, mostly between the two nuclei. Sigma bonds result from the following types of overlap,

s - s (like between H atoms in H_2)
s - p (end on)
p - p (end on)
s - hybrid (end on)
p - hybrid (end on)
hybrid - hybrid (end on)

π bond



Two lobes with electron density lying above and below the internuclear axis. Pi (π) bonds result from the sideways overlap of two p orbitals, one on each atom, which are perpendicular to the internuclear axis.

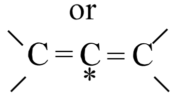
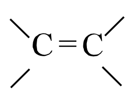
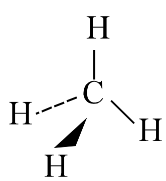
3. (3 pts) How many **sp** hybridized carbon atoms are contained in the following compound?

$$\begin{matrix} & sp & & sp & & sp^3 & & sp & & sp & & sp^3 & & sp & & sp & & sp^2 & & sp^2 & & sp^3 & & sp^2 & & sp^2 & & sp^3 \\ H & - & C & \equiv & C & - & CH_2 & - & C & \equiv & C & - & CH_2 & - & C & \equiv & C & - & CH & = & CH & - & CH_2 & - & CH & = & CH & - & CH_3 \end{matrix}$$

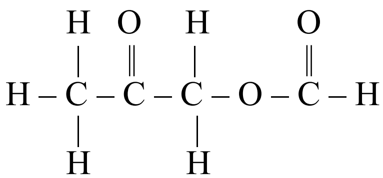
The carbon atoms in the triple bond form 2 ***sp*** hybrid orbitals each with two *p* orbitals remaining . The ***sp*** orbitals form a σ bond with hydrogen and/or with carbon atoms (total of 2 σ bonds). The other two bonds between the carbon atoms results from a side-by-side overlap of the two *p* orbitals of each carbon atom to form two pi (π) bonds. The molecule above has 4 ***sp³***, 4 ***sp²*** and 6 ***sp*** hybridized C atoms.

The molecule above has 3 triple bonds. Since each triple bond has two sp hybridized carbon atoms, there are a total of **6 sp** hybridized carbon atoms. (Remember, each triple bond has 2 ***sp*** hybridized orbitals and two p orbitals). The double-bonded C atoms each have only 1 double bond to them so there are 4 ***sp²*** hybridized carbon atoms (Remember, each "normal" double bond has 2 ***sp²*** hybridized carbon atoms; see exception below). Normally carbon atoms with double bonds are ***sp²*** hybridized. However, there is an exception when a carbon atom has 2 double bonds to it (the 2nd carbon from the right). In this case the carbon atom is ***sp*** hybridized (see below).

– C ≡ C –	sp hybrid carbon atoms
\\ * / C = C = C / \\	sp hybrid carbon atom (= C* = in middle, = C(/ \\) is *sp²*)
\\ / C = C / \\	*sp²* hybridized carbon (2 single bonds and double bond to carbon)
| – C – |	*sp³* (4 single bonds)

–C≡C– or 	2 things attached to a central atom	sp hybridization linear, 180°
	3 things attached to a central atom	sp^2 hybridization trigonal planar, 120°
	4 things attached to a central atom	sp^3 hybridization tetrahedral, 109.5°

4. (7 pts) For the following molecule (draw in any lone-pair electrons not shown), what are the total number of σ and π bonds in the molecule? **Explain your answers.**



Single bonds are σ bonds.

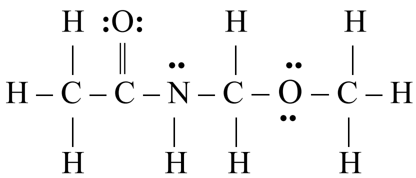
Also, σ bonds appear in double and triple bonds.

A double bond consists of 1 σ bond and 1 π bond.

A triple bond consists of 1 σ bond and 2 π bonds.

12 σ bonds & 2 π bonds

5. (6 pts) For the following molecule (draw in any lone-pair electrons not shown) answer the questions below. **Explain your answers.**



CH_3-C(=O)-NH-CH_2-O-CH_3 (Condensed formula)

a) What are the hybridizations of all the central atoms left to right?

CH_3 carbon atom on the far left: **sp^3**, the C is bonded to 4 other atoms, tetrahedral and has to be sp^3 hybridized. (4 single bonds, which are σ bonds).

C = O carbon atom: **sp^2**, the C is bonded to 3 other atoms so it's trigonal planar so has to be sp^2 hybridized. (3 σ bonds and 1 π bond to the C).

C – **N** – C nitrogen atom: **sp^3**, the N has 4 things around it (2 C atoms, 1 lone-pair and 1 H atom), it has to have a tetrahedral electron domain and thus has to be sp^3 hybridized.

N – **C** – O carbon atom: **sp^3**, the C is bonded to 4 other atoms, tetrahedral and has to be sp^3 hybridized. (4 single bonds, which are σ bonds)

C – **O** – C oxygen atom: **sp^3**, the O has 4 things around it (2 C atoms and 2 lone-pairs), it has to have a tetrahedral electron domain and thus has to be sp^3 hybridized.

CH_3 carbon atom on the far right: **sp^3**, the C is bonded to 4 other atoms, tetrahedral and has to be sp^3 hybridized. (4 single bonds, which are σ bonds).

b) What are the bond angles around all the central atoms from left to right?

H – **C** – C (1st C atom on the left): The C atom is bonded to 4 atoms so its ED geometry and molecular geom are both tetrahedral with a bond angle of ~ **109.5º**.

C – **C** – N (2nd C atom from left): This C atom is bonded to 3 atoms (no lpe^-) and is has a trigonal planar geometry so the bonds around it are ~ **120º**.

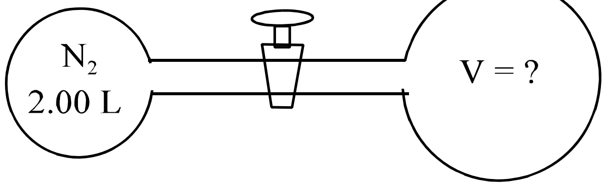
C – **N** – C (the N atom): The N atom is bonded to 3 atoms and has 1 lpe^- so its ED geometry is tetrahedral with a molecular geometry of trigonal pyramidal (like NH_3) and a bond angle of ~ **109.5º**.

N – **C** – O (C atom between N & O atoms): The C atom is bonded to 4 atoms so its ED geometry and molecular geom are both tetrahedral with a bond angle of ~ **109.5º**.

C – **O** – C (O atom between the two C atoms on the right): The **O** atom is bonded to 2atoms and has 2 lpe^- so its ED geometry is tetrahedral with a molecular geometry of trigonal pyramidal (like NH_3) and a bond angle of ~ **109.5º**.

O – **C** – H (C atom on the far right): The C atom is bonded to 4 atoms so its ED geometry and molecular geom are both tetrahedral with a bond angle of ~ **109.5º**.

6. (5 pts) Two flasks are connected by a stopcock. Both flasks are held at the same temperature. The 2.00 L flask is filled with N_2 at a pressure of 1456 mm Hg. The flask with an unknown volume, V, was evacuated (contains no gas). The stopcock is opened and the N_2 fills both flasks. The resulting pressure after the N_2 fills both flasks is 416 mm Hg? What is the volume, V, of the flask on the right (in liters, L)?



There's a flask with unknown volume, V, connected to the 2.0 L flask with N_2 at a pressure of 1456 mm Hg. The stopcock is opened and the N_2 expands to fill both flasks. The final pressure is 416 mm Hg. What is the volume of the flask on the right? Use Boyle's Law to calculate the TOTAL volume of both flasks and then the volume of the flask on the right.

P &V change at constant T - Use **Boyle's** Law

$$P_2V_2 = P_1V_1 \qquad \text{or} \qquad P_fV_f = P_iV_i$$

$P_1 = 1456$ mm Hg $\qquad$ $P_2 = 416$ mm Hg

$V_1 = 2.00$ L $\qquad$ $V_2 = ?$ L

$$V_2 = \frac{P_1V_1}{P_2} = \left(\frac{P_1}{P_2}\right) V_1 = \left(\frac{1456 \text{ mm Hg}}{416 \text{ mm Hg}}\right) 2.00 \text{ L} = 7.00 \text{ L}$$

Check: If P dec, V inc and it did. Hopefully this makes sense, the gas fills the whole thing.

Determine the volume of the container,

$V_2 = V_1 + V \qquad V = V_2 - V_1 = 7.00 - 2.00 =$ **5.00 L**

7. (4 pts) Consider three one-liter flasks labeled A, B, and C filled with the gases NO, NO_2, and N_2O, respectively, each at STP. What can be said about the number of molecules of each gas? (atomic weights: N = 14.01, O = 16.00)

a) flask A b) flask B c) flask C d) none e)* all are the same

We can calculate the moles for each of the gases given using the P, V and T data given, (STP means 1 atm and 0 °C (273.15 K)) and a volume of 1 L:

$$n = \frac{PV}{RT}$$

However, you do NOT have to do this calculation. Since all have the same P, V and T they have the **same number of moles** (**same # of molecules**).

8. (5 pts) What volume (L) of NO at 500°C and 0.5 atm will be produced in the following reaction if 10.0 L of oxygen reacts with excess NH_3 and the volume of NO is measured under the same conditions of temperature and pressure? (atomic weights: N = 14.01, H = 1.008, O = 16.00)

$$4\,NH_3(g) + 5\,O_2(g) \longrightarrow 4\,NO(g) + 6\,H_2O(g)$$

Can calculate the volume of desired from volume of given by using the volume ratio which is the same as the mole ratio from the balanced equation. You can see this from **Avogadro's Law**:

$$\frac{V_2}{n_2} = \frac{V_1}{n_1} \quad \text{or} \quad \frac{n_2}{n_1} = \frac{V_2}{V_1} \qquad \text{vol ratio = mole ratio}$$

$$?\text{ L NO} = 10.0\text{ L } O_2 \times \frac{4\text{ L NO}}{5\text{ L } O_2} = 8.00\text{ L}$$

numbers in this ratio are
coefficients in bal. eqn.

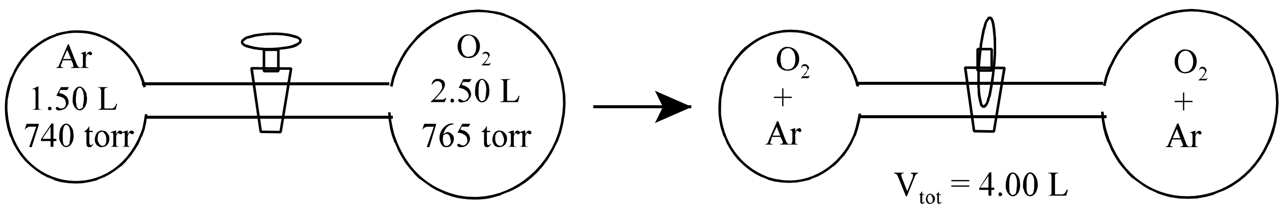
Could use the P, T, V data given to first calculate the moles of O_2 that reacts. Then do a mole-to-mole stoichiometry problem to determine the moles of NO produced from the moles of O_2. Then you could use the moles of NO with the P and T data given to calculate the volume of NO. This is not complicated but certainly more complicated and much more work than above.

9. (6 pts) A 1.50 L container of Ar at 740.0 torr and 25.0 °C is connected to a 2.50 L container of O_2 at 765.0 torr and 25.0 °C. What is the **total pressure** (torr) after the gases have mixed if the temperature remains at 25.0 °C? (Atomic weights: O = 16.00, Ar = 39.95)

Use Dalton's Law of Partial Pressures,

$$P_{Total} = P_1 + P_2 + P_3 + \cdots$$

Each gas acts independently of the other gases and each follows the IGL as does P_{Tot}.



Open the valve and allow the gases to mix.

Now each gas occupies the **ENTIRE volume** of both flasks, 4.0 L.

Need to find new Pressure of each gas in "new" 4.0 L container - Use Boyle's Law

Ar $\quad P_{Ar,2} = \dfrac{P_{Ar,1}\,V_1}{V_2} = \dfrac{(740\text{ torr})(1.5\text{ L})}{4.0\text{ L}} = 27\underline{7}.5\text{ torr}$

O_2 $\quad P_{O2,2} = \dfrac{P_{O2,1}\,V_1}{V_2} = \dfrac{(765\text{ torr})(2.5\text{ L})}{4.0\text{ L}} = 47\underline{\mathbf{8}}.125\text{ torr}$

$P_T = 27\underline{7}.5 + 47\underline{\mathbf{8}}.125 = 75\underline{\mathbf{5}}.625\text{ torr} = 756\text{ torr}$ (using DLPP)

10. (3 pts) Which of the following is the ordering of **average kinetic energies** of 1 mole each of the following gases; H_2S at 900 K, Ne at 750 K and O_2 at 400 K? (Assuming ideal gas behavior.) (atomic weights: H = 1.008, O = 16.00, Ne = 20.18, S = 32.07)

a)* $O_2 < Ne < H_2S$ b) $Ne < H_2S < O_2$ c) $H_2S < O_2 < Ne$

d) $O_2 < H_2S < Ne$ e) $Ne = O_2 = H_2S$

The root-mean-square speed (average speed) is proportional to the square root of the temperature ($T^{1/2}$) and inversely prop. to the absolute temperature. However, the **average kinetic energy** is **<u>directly</u>** proportional to the **absolute temperature**.

$$u = \left(\frac{3\,R\mathbf{T}}{\mathcal{M}}\right)^{1/2} \qquad KE_{\text{avg per mol}} = 3/2\ RT$$

Have 1 mole of: H_2S at 900 K, Ne at 750 K, O_2 at 400 K

The gas with the **highest T** will have the **greatest avg**. total **KE** per mole

$O_2 < Ne < H_2S$

Also, remember that if several gases have the **<u>same</u> temperature** they have the **<u>same</u>** avg. **KE**.