1. A weather balloon is filled with 0.295 m^3 of helium on the ground at 18 °C and 756 torr. What will the volume of the balloon be at an altitude of 10 km where the temperature is -48°C and the pressure is 0.14 atm. (760 torr = 1 atm)

$$756 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.995 \text{ atm}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{(0.995 \text{ atm})(0.295 \text{ m}^3)}{291.15 \text{ K}} = \frac{0.14 \text{ atm } (V_2)}{225.15 \text{ K}}$$

$$\boxed{V_2 = 1.6 \text{ m}^3}$$

2. The density of liquid nitrogen is 0.8080 g/mL at -196.0 °C. What volume of nitrogen gas at STP must be liquefied to make 10.00L of liquid nitrogen?

Calculate moles:

$$10 \text{ L } N_2 \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{0.8080 \text{ g } N_2}{1 \text{ mL}} \times \frac{1 \text{ mole}}{28.02 \text{ g } N_2} = 288.4 \text{ mol } N_2$$

$$PV = nRT$$

$$(1 \text{ atm}) V = (288.4 \text{ mol } N_2)\left(\frac{0.08206 \text{ L} \cdot \text{atm}}{\text{K} \cdot \text{mol}}\right)(273.15 \text{ K})$$

$$V = 6464 \text{ L}$$

3. An unknown gas has a density of 7.06 g/L at a pressure of 1.50 atm and 280 K. Calculate the molar mass of the gas.

$$d = \frac{PM}{RT}$$

$$\frac{7.06g}{L} = \frac{(1.5 atm) M}{\frac{0.08206 \; L \cdot atm}{K \cdot mol}(280 K)}$$

$$\boxed{\frac{108g}{mol} = M}$$

4. HCl(g) can be prepared by reaction of NaCl with H_2SO_4. What mass of NaCl is required to prepare enough HCl gas to fill a 340.0 mL cylinder to a pressure of 151 atm at 20.0 °C.

$$2NaCl(s) + H_2SO_4(l) \rightarrow 2HCl\ (g) + Na_2SO_4$$

Solve for moles of $HCl_{(g)}$ needed:

$$PV = nRT$$

$$(151 atm)(0.340L) = n\left(\frac{0.08206 \; L \cdot atm}{K \cdot mol}\right)(293.15 K)$$

$$n = 2.134 \; mol \; HCl$$

$$2.134 \; mol \; HCl \times \frac{2 \; mol \; NaCl}{2 \; mol \; HCl} = 2.134 \; mol \; NaCl$$

$$2.134 \; mol \; NaCl \times \frac{58.44 g \; NaCl}{1 \; mol \; NaCl} = \boxed{125 g \; NaCl}$$

5. Determine the mass of NaN_3 required for an air bag to produce 100.0L of N_2 gas at 85 °C and 1.00 atm according to the equation,

$$2NaN_3(s) \rightarrow 2\ Na(s) + 3\ N_2(g)$$

Calculate moles of N_2:

$$PV = nRT$$

$$(1\ atm)(100.0\ L) = n\left(\frac{0.08206\ L\cdot atm}{K\cdot mol}\right)(358.15\ K)$$

$$n = 3.403\ mol\ N_2$$

$$3.403\ mol\ N_2 \times \frac{2\ mol\ NaN_3}{3\ mol\ N_2} = 2.268\ mol\ NaN_3$$

$$2.268\ mol\ NaN_3 \times \frac{65.01g}{1\ mol} = 147.5g\ NaN_3$$

6. A compound has an empirical formula SF_4. At 20 °C, a 0.1013g of the gaseous compound occupies a volume of 22.1 mL and exerts a pressure of 1.02 atm. What is the molecular formula of the gas? What is its molecular geometry?

$$PV = nRT$$

$$(1.02\ atm)(0.0221\ L) = n\left(\frac{0.08206\ L\cdot atm}{K\ mol}\right)(293.15K)$$

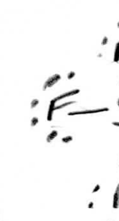
$$n = 0.000937\ mol$$

$$\text{molar mass} = \frac{0.1013g}{0.000937\ mol} = 108.1g/mol$$

Mass of Empirical Formula SF_4 $= \frac{32.07g}{mol} + 4\left(\frac{19.00g}{mol}\right) = 108.1g/mol$

SF_4 = Empirical and molecular Formula

SF_4

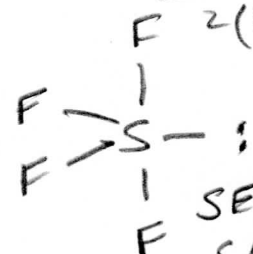


Valence e^- =
6 (S)
28 (F)

34
− 8 (Bonds)

26
− 24 (on F)

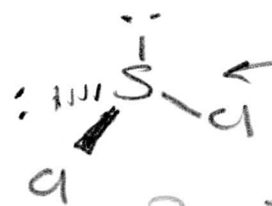
2 (lone pair)



SEE-SAW

7. Predict the molecular geometry of sulfur dichloride (SCl_2) and the hybridization of the sulfur atom.

Lewis dot:



4 electron domains

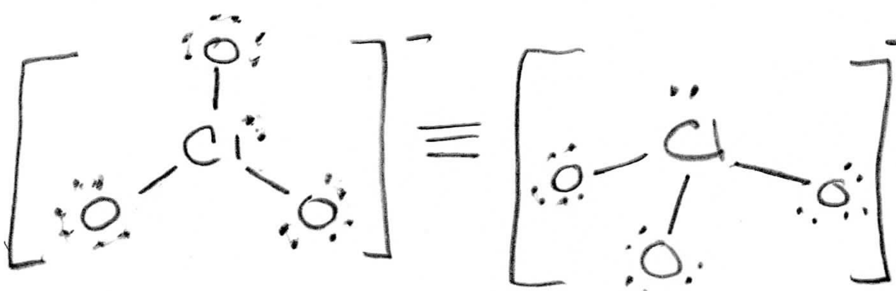
4 hybrid orbitals

sp^3

Bent

8. Draw Lewis structures and give the other information requested for the following molecules:

   a. ClO_3^- What's the molecular geometry?



trigonal pyramid

   b. OF_2 Is this polar or non-polar?

Polar.

Bent

   c. NO_2 (N is central atom) Estimate the ONO bond angle.

with only one e^- the repulsion is lower. $>120°$

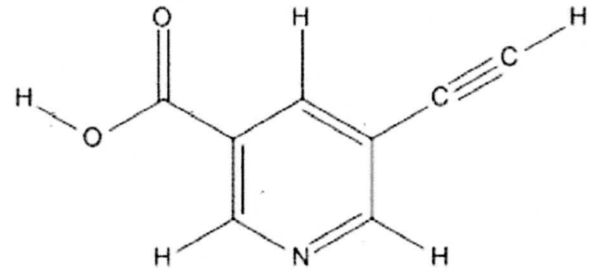
$> 120°C$

σ π

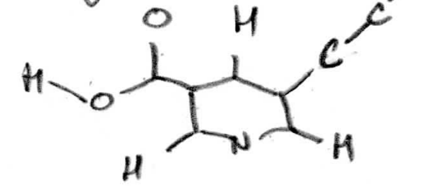
9. Determine the number of sigma and pi bonds in:

16 σ bonds

6 π bonds



Skeleton of σ Bonds:



Each single bond is one sigma bond

Each double bond is one sigma bond + one π bond.

Each triple bond is one sigma bond + two π bonds.

10. Use molecular orbital theory to determine which has a higher bond enthalpy: F_2 or F_2^-. Draw the molecular orbital diagram.

F_2 (14 e^- to fill in)

σ^*_{2px} ___

π^*_{2py}, π^*_{2pz} ↿⇂ ↿⇂

π_{2py}, π_{2pz} ↿⇂ ↿⇂

σ_{2px} ↿⇂

σ^*_{2s} ↿⇂

σ_{2s} ↿⇂

Bond order = 1

$\frac{8 \text{ Bonding} - 6 \text{ antibonding}}{2} = 1$

Greater Bond Enthalpy

F_2^-

σ^*_{2px} ↿

π^*_{2py}, π^*_{2pz} ↿⇂ ↿⇂

π_{2py}, π_{2pz} ↿⇂ ↿⇂

σ_{2px} ↿⇂

σ^*_{2s} ↿⇂

σ_{2s} ↿⇂

Bond order = 0.5

$\frac{8 \text{ Bonding} - 7 \text{ antibonding}}{2} = 0.5$

Lower Bond Enthalpy

The bond in F_2^- is weaker since the bond order is lower. Therefore, the Bond Enthalpy of F_2 is greater than F_2^-.

Quantum Numbers:

- The ***principal quantum number (n)*** designates the *size* of the orbital. The larger n is, the greater the average distance of an electron in the orbital from the nucleus and therefore the larger the orbital.

$$n = 1, 2, 3, \ldots$$

- The ***angular momentum quantum number*** (***l***) describes the *shape* of the atomic orbital. For a given value of *n,* the possible values of l range from 0 to $n - 1$.

  Example: if n = 3, the possible values of l range from 0 to 2 (3-1). Therefore, when n=3 , the possible values of l are 0, 1, and 2.

ℓ	0	1	2	3
Orbital designation	*s*	*p*	*d*	*f*

The 3 shell has 3s, 3p, and 3d subshells.

- The ***magnetic quantum number*** (***m_l***) describes the *orientation* of the orbital in space. Within a subshell, the value of m_l depends on the value of l. For a certain value of l, there are $(2l + 1)$ integral values of m_l centered around zero as follows:

$$-l, \ldots, 0, \ldots, +l$$

- To specify the electron's spin, we use the ***electron spin quantum number*** (***m_s***).

  Because there are two possible directions of spin, opposite each other, m_s has *two* possible values: +1/2 and −1/2.

11. How many orbitals are there in a subshell designated by the quantum numbers n = 3, l = 2?

$n=3$ and $l=2$ designate the 3d subshell.
there are $2l+1$ integral values of m_l.
$2(2)+1=5$ $-2, -1, 0, +1, +2$
(5 d orbitals)

12. List the values of *n*, *l*, and m_l for each of the orbitals in a 4 subshell.

$n=4$
$l=1$ (Because p subshell)
$m_l = -1, 0, +1$ $(2l+1 = 2(1)+1 = 3$ possibilities$)$

13. Write out the electron configuration for Ca.

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

14. Arrange the following isoelectronic species in order of increasing ionization energy: O^{2-}, F^-, Na^+, Mg^{2+}.

$O^{2-} < F^- < Na^+ < Mg^{2+}$

In general, as effective nuclear charge increases, ionization energy increases.

15. Write out equations representing the following processes:

a. The electron affinity of S^-

$$S^- + e^- \longrightarrow S^{2-}$$

b. The third ionization energy of titanium

$$Ti^{2+} \longrightarrow Ti^{3+} + e^-$$

c. The electron affinity of Mg^{2+}

$$Mg^{2+} + e^- \longrightarrow Mg^+$$

d. The ionization energy of O^{2-}.

$$O^{2-} \longrightarrow O^- + e^-$$

16. Arrange the following atoms in order of increasing atomic radius: Na, Al, P, Cl, Mg .

$$Cl < P < Al < Mg < Na$$

$$\xrightarrow[\text{increasing radius}]{}$$

STUDENT Request

SAMPLE PROBLEM 8.6

Using data from Table 8.5, calculate the percent ionic character of the bond in HI.

Setup

$$\mu = Q \times r$$

$$\text{percent ionic character} = \frac{\mu\text{ (observed)}}{\mu\text{ (calculated assuming discrete charges)}} \times 100\%$$

From Table 8.5, the bond length in HI is 1.61Å (1.61×10^{-10} m) and the measured dipole moment of HI is 0.44 D.

SAMPLE PROBLEM 8.6

Solution

The dipole moment we would expect if the magnitude of charges were 1.6022×10^{-19} C is

$$\mu = Q \times r = (1.6022 \times 10^{-19}\ \mathrm{C}) \times (1.61 \times 10^{-10}\ \mathrm{m})$$

$$= 2.58 \times 10^{-29}\ \mathrm{C \cdot m}$$

$$2.58 \times 10^{-29}\ \cancel{\mathrm{C \cdot m}} \times \frac{1\ \mathrm{D}}{3.336 \times 10^{-30}\ \cancel{\mathrm{C \cdot m}}} = 7.73\ \mathrm{D}$$

$$\frac{0.44\ \mathrm{D}}{7.73\ \mathrm{D}} \times 100\% = 5.7\%$$

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