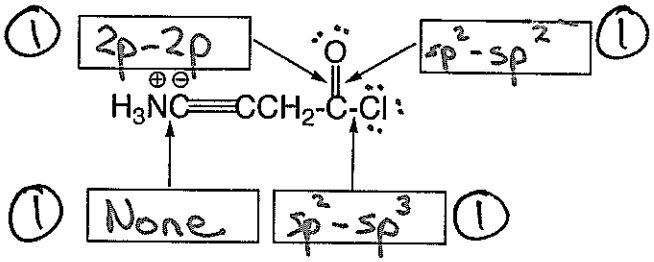
CHEMISTRY 121 MIDTERM 3

Nov. 21, 2007

Unless otherwise stated, show all your reasoning/work/sig figs for full marks.

(4) 1) If possible, describe the AO (atomic orbital) overlap for each arrow.



2) Consider the BS molecule (ahem, that's boron and sulfur).

(4) a) Could it exist? You may add another logical level to your MO Aufbau diagram.

$21\ e^{\ominus}$

$\sigma_{1s}^2\ \sigma_{1s}^{*2}\ \sigma_{2s}^2\ \sigma_{2s}^{*2}\ \sigma_{2p}^2\ \pi_{2p}^2\ \pi_{2p}^2\ \pi_{2p}^{*2}\ \pi_{2p}^{*2}\ \sigma_{2p}^{*2}\ \sigma_{3s}^1\ \sigma_{3s}^{*}$

$B.O. = \frac{11-10}{2} = \frac{1}{2}$

Could exist!

(1) b) Use a term to predict the BS molecule's behaviour towards a magnet. No explanation required.

Paramagnetic

(3) 3) An arctic sea drilling ship hits a methane pocket deep under the sea at 74 °C and 7.49 atm. All the methane is collected in the ship and found to occupy 20,000 L at -40 °C. Find the original volume of the methane under the sea.

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

$$\frac{(7.49\ atm)(V_1)}{273.15+74} = \frac{(1\ atm)(20{,}000\ L)}{273.15-40}$$

$$V_1 = 3.9758 \times 10^3\ L$$

$3.98 \times 10^3\ L$

4) In a 2 L flask, ethane gas (C_2H_6, 5 moles) is burned with O_2 gas (4 moles) to form CO_2 and H_2O gases. It leaves one of the reactant gases partially unreacted. After the reaction, the 3 gases combine for a pressure in the flask of 2.1 atm.

(3) a) Calculate the number of moles of reactant gas which remains. Show your calculations/reasoning. Equation...

$2C_2H_6 + 7O_2 \longrightarrow 4CO_2 + 6H_2O$ (1)

5 mol ÷2 → 2.5 ; 4 mol ÷7 → .57 = L.R. (1)

$4\text{ mol } O_2 \times \frac{2C_2H_6}{7O_2} = 1.14\text{ mol } C_2H_6$ needed (1). We have 5 mol

∴ 3.86 mol left unreacted (1)

(3) b) Find the partial pressure of water which contributes to the total pressure of 2.1 atm.

$P_T \chi_{H_2O} = P_{H_2O}$ (1)

$4\text{ mol } O_2 \times \frac{6H_2O}{7O_2} = 3.43\text{ mol } H_2O$

$4\text{ mol } O_2 \times \frac{4CO_2}{7O_2} = 2.29\text{ mol } CO_2$

Add 3.86 mol C_2H_6

$\Sigma = 9.57$ mol (1)

$\therefore (2.1\text{ atm})\left(\frac{3.43}{9.57}\right) = 0.75\text{ atm} = P_{H_2O}$ (1)

(2) c) Calculate Graham's effusion velocity ratio of $C_2H_6 : O_2$.

$\frac{v_{C_2H_6}}{v_{O_2}} = \left(\frac{m_{O_2}}{m_{C_2H_6}}\right)^{1/2} = \left(\frac{32\text{ g/mol}}{30\text{ g/mol}}\right)^{1/2} = 1.03$ (1) (1)

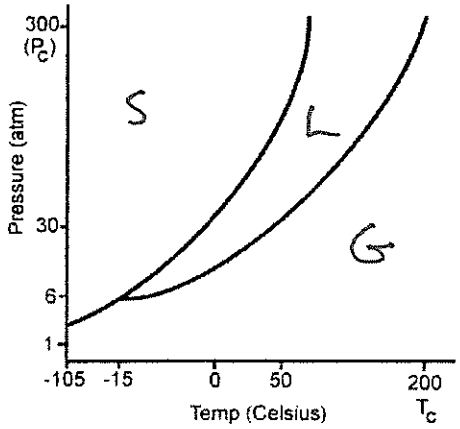
(2) d) Would you expect the root mean square velocity ratio of C_2H_6: O_2 to have the identical value as c) above. Explain without a calculation.

Sure. (1) Both velocities are based on MW. (1)

(3) **5)** Mixing 3 moles of H_2O (l) with 3 moles of CH_3OH (l) makes 6 moles in total. True! So it follows that at constant temperature and pressure that mixing 3 L of water and 3 L of methanol must make 6 L in total. Comment.

Untrue. (1) Water & methanol H bond (1) ∴ decreasing (1) volume to less than 6L

6) Answer the questions below based upon this phase diagram.



(1) **a)** Identify the phase present at STP.

Gas (1)

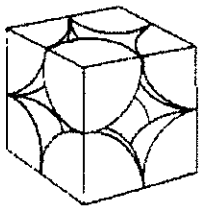
(1) **b)** Define T_c. (don't say critical temperature)

Temp past which no gas can be made to liquify. (1)

(1) **c)** Moving isopiestically from 30 atm and -15 °C will encounter what new phase?

Liquid (1)

(3) **7)** Diagram look familiar? Atomic radius is still 1.2×10^{-8} cm. Calculate the **% volume** in the simple cubic unit cell which is **free space**. Volume of a sphere = $4/3\pi r^3$, mL = cm^3



Edge length = $2r = 2.4 \times 10^{-8}$ cm

$V = (2.4 \times 10^{-8}\ cm)^3 = 1.38 \times 10^{-23}\ cm^3$ (1)

1 atom in unit cell = $\frac{4}{3}\pi r^3$

$= \frac{4}{3}\pi (1.2 \times 10^{-8}\ cm)^3$

$= 7.24 \times 10^{-24}\ cm^3$ (1)

$$\%\ Volume_{free} = \frac{1.38 \times 10^{-23} - 7.24 \times 10^{-24}}{1.38 \times 10^{-23}} \times 100$$

$= 48.\%$ (1)

(1) **Bonus**. Circle the meaning of "postulate".

a) a late letter b) experiment (c) theoretical proposal d) fact-based statement e) incorrect statement