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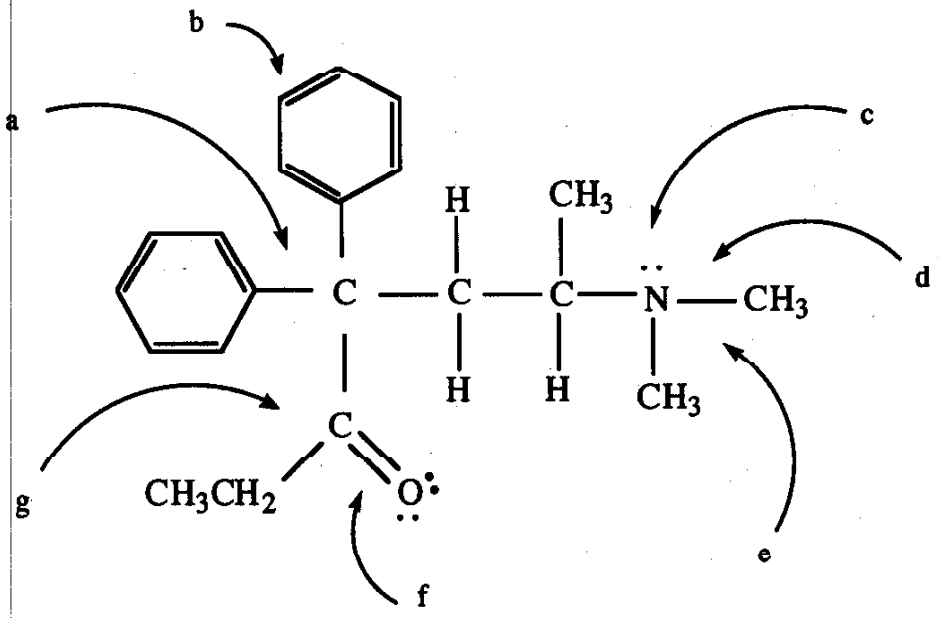
Chemistry 103-3-2006, third exam Name or initials _____

PART 1. STRUCTURE AND BONDING

1. (20 pts) The structure of methadone (given to drug addicts which reportedly lessens cravings for heroin) is shown below. Answer the questions below about this structure. The letters a -> g shown along with the figure identify the parts of the question.



a) What is the C-C-C bond angle? 109.5°

b) What is the bond order of the carbon-carbon bonds in this ring? 1.5

c) What orbital contain this lone pair of electrons? sp^3

d) What orbitals overlap to form this N-C bond? $C(sp^3) + N(sp^3)$

e) What is the molecular geometry of this nitrogen atom? trigonal pyramid

f) What orbitals overlap to form the pi bond between C and O? $C(p) + O(p)$

g) What is the hybridization of this carbon? sp^2

h) Do all non-hydrogen atoms in this structure obey the octet rule? (Yes) or No

i) Do any of the atoms in this structure bear a formal charge? Yes or (No)

j) Is the molecule diamagnetic (D) or paramagnetic (P)? (D) or P

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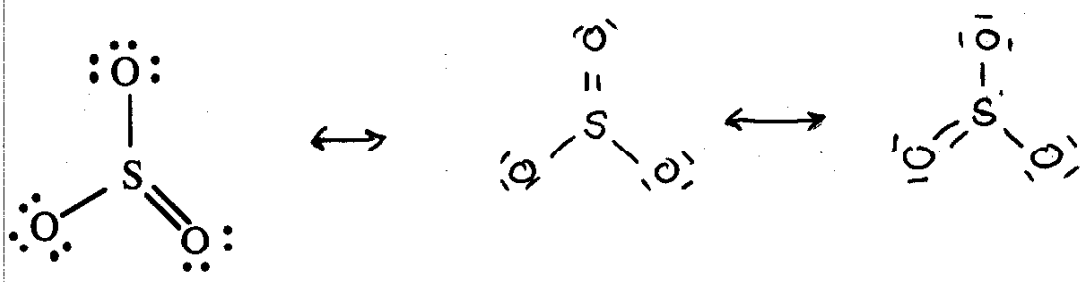
2. (14 pts). Let's look at the compound SO_3 in detail. Each question is valued at 1 point except when noted otherwise.

a) (2 pts) A Lewis structure for SO_3 is drawn below. Draw all other appropriate resonance structures for SO_3.



b) (2 pts) Why does a single Lewis structure for SO_3 not accurately represent the actual bonding in this compound? In the actual structure, the 3 S–O

Answer: bonds, and the 3 oxygens, are equivalent.

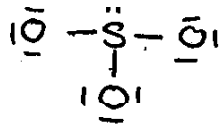
c) What is the molecular geometry of SO_3? trigonal planar

d) To describe the bonding in this compound, what hybridization should be assigned to sulfur? sp^2

e) (2 pts) What is the bond order for the sulfur-oxygen bonds in SO_3? 1.33

f) (2 pts) What are the formal charges on S and O in this compound? S + 2

O $-\frac{2}{3}$



g) (2 ptsa) Is SO_3 a polar molecule? Yes or (No)

h) (2 pts) SO_3 can be reduced by adding 2 electrons, forming the sulfite ion, SO_3^{2-}. What is the molecular geometry of this ion? trigonal pyramid

3. (6 pts) Ionic compounds

a) Define: Lattice energy: The energy for the process $A^{+?}(g) + B^{-?}(g) \rightarrow AB(s)$. (Energy for formation of 1 mol ionic solid from ions in the gaseous state.

b) Which has the more negative lattice energy, MgO or NaF? Explain why.

MgO – due to fact that Mg^{2+} and O^{2-} have +2 and –2 charges.

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PART 2. MULTIPLE CHOICE, 32 PTS

d 1. A flask contains 1.0 g each of N_2, O_2, CO_2, and He. Which gas exerts the greatest partial pressure?

a) N_2 b) O_2 c) CO_2 d) He

c 2. Consider the gases listed below, all at the same temperature. In which gas do the molecules have the lowest average velocity?

a) N_2 b) O_2 c) CO_2 d) He

d 3. What is the volume occupied by 1.0 mol of $N_2(g)$ at 0.50 atm and 546 K?

a) 22.4 L b) 44.8 L c) 11.2 L d) 89.6 L

b 4. The density of an unknown gas at STP is 1.4 g/L. Identify the gas as one of the following. (The molar mass (MM) of each gas is given in parentheses.)

64/22.4 32/22.4 4/22.4 2/22.4

a) SO_2 (MM = 64) b) O_2 (MM = 32) c) He (MM = 4) d) H_2 (MM = 2)

a 5. A flask contains 1 mole of $H_2(g)$ and 2 moles of $Cl_2(g)$. A reaction occurs: [$H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$] The temperature rises from 300 °C to 350 °C due to the heat of the reaction. How will the pressure in the flask change (constant volume is assumed)? (no. of moles remains the same, T increases.)

a) P increases b) P decreases c) P doesn't change d) not predictable

d 6. Which of the following is not correct?

a) Diffusion of gases occurs more rapidly at higher temperatures
b) Effusion of H_2 is faster that effusion of He (assumes similar conditions)
c) Diffusion will occur faster at low pressure than at high pressure
d) The rate of effusion of a gas is directly proportional to molar mass.

b 7. A sample of $N_2(g)$ is placed inside a cylinder with a movable piston. The initial pressure in the cylinder is 2.0 atm. The volume containing the gas is decreased from 4.0 L to 1.0 L and the temperature is reduced from 350 K to 175 K. What is the final pressure in the cylinder?

a) 2.0 atm b) 4.0 atm c) 1.0 atm. d) 0.50 atm

b 8. Under which conditions will calculations using PV = nRT for a sample of $CO_2(g)$ be least accurate?

a) 10 atm, 0 °C b) 10 atm, -20 °C c) 10 atm, 100 °C d) 1.0 atm, 0 °C

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a 9. Which of the following compounds has the most negative lattice energy?

a) NaF b) KCl c) KF d) NaCl

a 10. In which of the following do the iodine atom obey the octet rule?

a) ICl b) ICl_3 c) ICl_5 d) ICl_6^-

b 11. Which compound is the most polar?

a) H_2O b) HF c) H_2S d) HCl

d 12. Which element listed below is the least electronegative?

a) Cl b) S d) P d) Si

b 13. Three of the following species are isoelectronic. Which is not?

a) SiF_4 b) SF_4 c) PF_4^+ d) AlF_4^-

b 14. Which of the following molecules is polar?

a) CO_2 b) $COCl_2$ c) CCl_4 d) CS_2

d 15. Which of the following does not require drawing several resonance structures to accurately describe the bonding?

a) SO_2 b) SO_3 c) NO_3^- d) H_2S

c 16. When comparing carbon-carbon bonds in various compounds, which statement is correct?

a) both bond length and bond strength increase with increasing bond order
b) bond length increases, bond strength decreases, with increasing bond order
c) bond length decreases, bond strength increases, with increasing bond order
d) both bond length and bond strength decrease with increasing bond order

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PROBLEMS: 16 PTS, 8 PTS EACH. ANSWER 2 OUT OF 3 ONLY.

1. Jacques Charles (of Charles's law fame) experimented with balloons. As described in the text (page 547), early in his scientific career, he used the reaction of 450 kg of iron with (excess) sulfuric acid to produce the hydrogen he needed to fill a balloon [$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$.] What volume of hydrogen would be generated by this reaction, assuming the pressure is 0.973 atm and a temperature of 24 °C?

2. Fluorination of CCl_4 can give four possible products (CCl_3F, CCl_2F_2, $CClF_3$ or CF_4, all gases.) To identify one of these compounds you decide to find its molecular weight by the gas density method. You weigh a glass bulb that has been evacuated (wt. empty = 32.30 g), then fill it with the unknown and weigh it again (wt. filled = 33.75 g) . You also know the following: volume of bulb = 294 cm^3, temperature = 18 °C, pressure of gas in bulb = 740 mm Hg. Calculate the molecular weight and identify the compound.

3. Separation of uranium-235 and uranium-238 can be achieved by effusion, using the gaseous compound UF_6. Which effuses faster, $^{235}UF_6$ or $^{238}UF_6$ (uranium hexafluoride with the U-235 or U -238 isotope)? What is ratio of the rates of effusion of these two compounds (rate of $^{235}UF_6$ / rate of $^{238}UF_6$)?

1. $\text{moles } H_2 = \text{moles Fe} = 4.50\times10^5\,g\left(\frac{1\,mol}{55.85\,g}\right) = 8.06\times10^3$

$PV = nRT$

$V = \frac{(8.06\times10^3)(0.08206\ \frac{L\,atm}{mol\,K})(291\,K)}{0.973\,atm.}$

$= 2.02\times10^5\ L$

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2. mass of gas = 1.45 g.

$\frac{g}{V} = \frac{P\,MW}{RT}$; $MW = \frac{g\,RT}{PV}$

$= \frac{(1.45\,g)(0.08206\ \frac{L\,atm}{mol\,K})(291\,K)}{(740/760\,atm)(0.294\,L)}$

$= 121\ g/mol$

(CCl_2F_2 MW is 121 g/mol)

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3. MW $^{235}UF_6$ = 349 g/mol $^{235}UF_6$ effuses faster

$^{238}UF_6$ = 352 g/mol

$\frac{\text{rate } ^{235}UF_6}{\text{rate } ^{238}UF_6} = \sqrt{\frac{352}{349}} = 1.004$

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4. (12 pts) A constant volume calorimeter with a volume of 1.50 L contains $C_3H_8(g)$ and $O_2(g)$. The partial pressure of C_3H_8 is 0.10 atm and the partial pressure of O_2 is 5.0 atm. The temperature is 20 °C. A reaction occurs between the two compounds forming $CO_2(g)$ and $H_2O(l)$. Assume that heat from the reaction is transferred to the surroundings so that after the reaction the temperature is still 20 °C.

a) (For 2 pts) Balance the chemical equation for the reaction.

$$\underline{1}\ C_3H_8(g) + \underline{5}\ O_2(g) \rightarrow \underline{3}\ CO_2(g) + \underline{4}\ H_2O(l)$$

b) (4 pts) How many moles of $C_3H_8(g)$ are present in the flask?

$$n = \frac{PV}{RT} = \frac{(0.10\ atm)(1.5\ L)}{(0.08206\ \frac{L\,atm}{mol\,K})(293K)}$$

$$= 6.2 \times 10^{-3}\ moles$$

Moles C_3H_8 6.2×10^{-3} (mol)

(before doing part c and d, read the question given as part e)

c) (2 pts) How many moles of $O_2(g)$ are present in the flask?

n is directly proportional to P

$$6.2 \times 10^{-3}\ mol \left(\frac{5.0}{0.1}\right) = 0.31\ mol$$

Moles O_2 0.31 (mol)

d) (2 pts) After the reaction, the flask contains excess oxygen and the products of the reaction, that is, $CO_2(g)$ and $H_2O(l)$. What is the partial pressure exerted by the $CO_2(g)$ in this system? What is the partial pressure exerted by the oxygen that remains?

6.2×10^{-3} mol C_3H_8 → 18.6×10^{-3} mol CO_2

pressure from CO_2 is 3X original C_3H_8 pressure

moles O_2 remaining = $0.31 - 5(6.2 \times 10^{-3}) = 3.1 \times 10^{-2}$ mol

$P(O_2) = 5.0\left(\frac{0.28}{0.31}\right)$ atm

$= 0.88$ atm

Partial pressure CO_2 0.30 atm

Partial pressure O_2 4.5 atm

e) (For 2 pts) The calculations for part c and d will be **greatly simplified** if you recognized that the pressure in the system is **directly proportional** to which of the following (circle answer). NOTE: Pressure is related to each of these quantities **but only one will be useful** to simplify the calculations.)

a) (n (moles of gas)) b) 1/volume c) temperature d) R (the gas law constant)