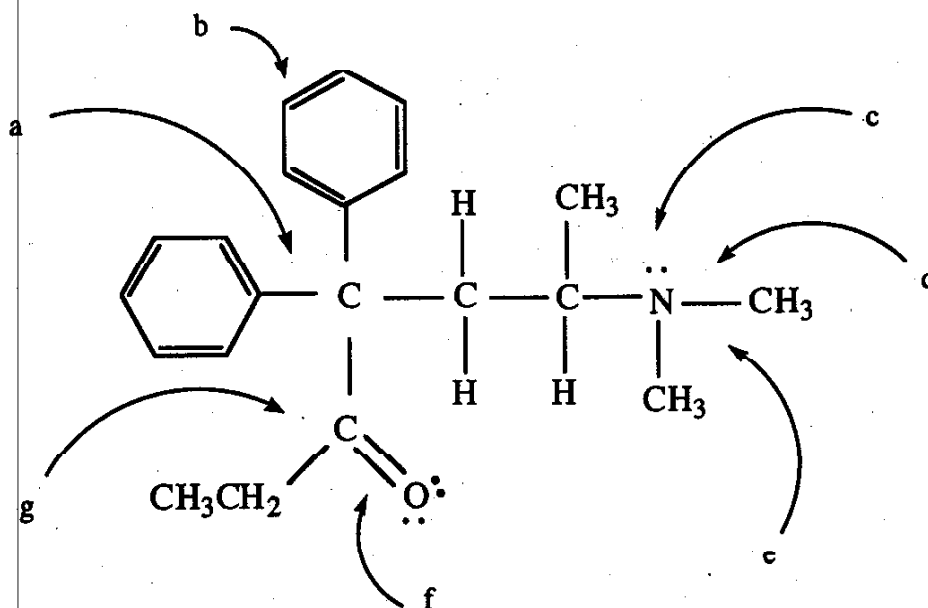


**PART 1. STRUCTURE AND BONDING**

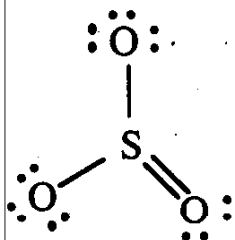
1. (20 pts) The structure of methadone (given to drug addicts which reportedly lessens cravings for heroin) is shown below. Answer the questions below about this structure. The letters a -> g shown along with the figure identify the parts of the question.



- a) What is the C-C-C bond angle? \_\_\_\_\_
- b) What is the bond order of the carbon-carbon bonds in this ring? \_\_\_\_\_
- c) What orbital contain this lone pair of electrons? \_\_\_\_\_
- d) What orbitals overlap to form this N-C bond? \_\_\_\_\_
- e) What is the molecular geometry of this nitrogen atom? \_\_\_\_\_
- f) What orbitals overlap to form the pi bond between C and O? \_\_\_\_\_
- g) What is the hybridization of this carbon? \_\_\_\_\_
- 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

2. (14 pts). Let's look at the compound  $\text{SO}_3$  in detail. Each question is valued at 1 point except when noted otherwise.

a) (2 pts) A Lewis structure for  $\text{SO}_3$  is drawn below. Draw all other appropriate resonance structures for  $\text{SO}_3$ .



b) (2 pts) Why does a single Lewis structure for  $\text{SO}_3$  not accurately represent the actual bonding in this compound?

Answer: \_\_\_\_\_

c) What is the molecular geometry of  $\text{SO}_3$ ? \_\_\_\_\_

d) To describe the bonding in this compound, what hybridization should be assigned to sulfur? \_\_\_\_\_

e) (2 pts) What is the bond order for the sulfur-oxygen bonds in  $\text{SO}_3$ ? \_\_\_\_\_

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

O \_\_\_\_\_

g) (2 pts) Is  $\text{SO}_3$  a polar molecule? Yes or No

h) (2 pts)  $\text{SO}_3$  can be reduced by adding 2 electrons, forming the sulfite ion,  $\text{SO}_3^{2-}$ . What is the molecular geometry of this ion? \_\_\_\_\_

3. (6 pts) Ionic compounds

a) Define: Lattice energy:

b) Which has the more negative lattice energy,  $\text{MgO}$  or  $\text{NaF}$ ? Explain why.

**PART 2. MULTIPLE CHOICE, 32 PTS**

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

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

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

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.)

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

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)?

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

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 than 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.

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 °C to 175 °C. What is the final pressure in the cylinder?

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

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

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

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

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

- a) ICl      ICl<sub>3</sub>      c) ICl<sub>5</sub>      d) ICl<sub>6</sub><sup>-</sup>

11. Which compound is the most polar?

- a) H<sub>2</sub>O      b) HF      c) H<sub>2</sub>S      d) HCl

12. Which element listed below is the least electronegative?

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

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

- a) SiF<sub>4</sub>      b) SF<sub>4</sub>      c) PF<sub>4</sub><sup>+</sup>      d) AlF<sub>4</sub><sup>-</sup>

14. Which of the following molecules is polar?

- a) CO<sub>2</sub>      b) COCl<sub>2</sub>      c) CCl<sub>4</sub>      d) CS<sub>2</sub>

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

- a) SO<sub>2</sub>      b) SO<sub>3</sub>      c) NO<sub>3</sub><sup>-</sup>      d) H<sub>2</sub>S

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

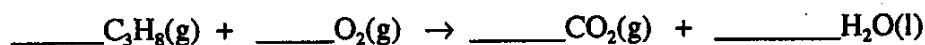
- a) both bond length and bond strength increase with increasing bond order  
b) bond length increases, bond strength decreases, with increasing bond order  
c) bond length decreases, bond strength increases, with increasing bond order  
d) both bond length and bond strength decrease with increasing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

**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 [  $\text{Fe(s)} + \text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{FeSO}_4(\text{aq}) + \text{H}_2(\text{g})$  ]. 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  $\text{CCl}_4$  can give four possible products ( $\text{CCl}_3\text{F}$ ,  $\text{CCl}_2\text{F}_2$ ,  $\text{CClF}_3$  or  $\text{CF}_4$ , 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  $\text{cm}^3$ , 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  $\text{UF}_6$ . Which effuses faster,  $^{235}\text{UF}_6$  or  $^{238}\text{UF}_6$  (uranium hexafluoride with the U-235 or U-238 isotope)? What is ratio of the rates of effusion of these two compounds (rate of  $^{235}\text{UF}_6$  / rate of  $^{238}\text{UF}_6$ )?


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  $20^\circ C$ . 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  $20^\circ C$ .

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



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

Moles  $C_3H_8$  \_\_\_\_\_

(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?

Moles  $O_2$  \_\_\_\_\_

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?

Partial pressure  $CO_2$  \_\_\_\_\_

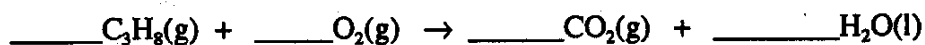
Partial pressure  $O_2$  \_\_\_\_\_

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)

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.



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

Moles  $C_3H_8$  \_\_\_\_\_

(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?

Moles  $O_2$  \_\_\_\_\_

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?

Partial pressure  $CO_2$  \_\_\_\_\_

Partial pressure  $O_2$  \_\_\_\_\_

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