Free Response Questions

I. These questions are based on the gas phase reaction:

 S(g) + O2(g) ➞ SO2(g) ΔH° = -576 kJ

 The following information is available:

 ΔH°f, the enthalpy of formation of SO2(g) = -297 kJ/mol

 Bond energies: O=O in O2, 495 kJ

 A. Why is the enthalpy change for the given reaction NOT equal to the

 enthalpy of formation of SO2(g) ?

 B. Calculate the enthalpy of formation of S(g)

 C. Calculate the average bond energy of the Sulfur-oxygen bonds in SO2(g)

D. There is some disagreement about what the best way is to represent an SO2 molecule. One possible Lewis structure results in octets, 8 valence electrons, around all three atoms.

 i. Draw the Lewis dot structure of SO2 that is described above.

 ii. Explain why the sulfur - oxygen bonds are all of equal length

iii. Find the formal charge of the sulfur atom on the structure you have drawn

 E. In another possible Lewis structure, the sulfur has an extended octet, and

 all of the atoms have formal charges of zero. Draw this Lewis structure.

 F. The bond energy of an S-O single bond is 423 kJ/mol, while the bond energy of an S=O double bond is 525 kJ/mol. Based on these bond energies, which of the two Lewis structures appears to best represent an SO2 molecule? Explain your choice.

II. A student performs two calorimetry experiments using a coffee cup “calorimeter.” The purpose of the first experiment is to determine the molar heat of solution of ammonium nitrate. The student adds 100.0 mL of water to the coffee cup. The directions call for the addition of sufficient ammonium nitrate to produce a 1.00 molar solution.

A. How many grams of ammonium nitrate must be added to produce the desired solution?

B. The addition of the ammonium nitrate causes the temperature of the solution

to decrease from 24.0̊C to 19.5̊C. The density of the water is 0.997g/mL, and the specific heat of the resulting solution is 3.90J/mol̊ .

 i. What is the total mass of the solution?

 ii. What is the calculated heat of solution in kJ/mol of ammonium nitrate?

C. The procedure ignores any heat that was transferred to or from the coffee cup and to or from the thermometer. This omission produces an inaccuracy in the calculated heat of solution. Does it cause the value to be greater than the correct value, or less than the correct value? Explain your choice.

D. Why is this experiment conducted in a coffee cup, rather than in a glass beaker?

E. A second experiment is performed to find the specific heat of copper, in

j/g̊. A 20.0 gram sample of Cu is placed in a test tube in a water bath at 100̊C.

 After 20 minutes, the copper sample is poured into a coffee cup that contains

 50.0 grams of water, initially at 20.0̊C. The final temperature of the mixture

 is 22.8̊ C. The specific heat of water is 4.18 J/g̊

i. How much heat was transferred to the water?

ii. Assuming that the same amount of heat was lost by the copper, calculate the specific heat of copper.

III. Magnesium reacts with dilute acids to produce hydrogen. If HCl is used, the reaction is Mg(s) + 2 HCl(aq) ➞ H2(g) + MgCl2(aq)

 0.0400 grams of Mg are placed in a jar to whichis added 50.0 mL of 2.00 molar HCl

 A. Calculate the volume of hydrogen gas produced at a temperature of 25.0̊C and a

 pressure of 760.0 torr.

 B. The hydrogen gas is often collected over water (by water displacement). In such

 a case, how would the volume of gas collected in this experiment be affected? Jusify your prediction.

 C. Calculate

 i. The moles of HCl consumed by the reaction, and

 ii. the molarity of the remaining HCl after the reaction has gone to completion,

 assuming that the volume of the solution does not change.

 D. ΔH for the reaction is -466 kJ/mol.

 (Mg(s) + 2 HCl(aq) ➞ H2(g) + MgCl2(aq))

i. How much heat is produced when 0.0400 grams of Mg are reacted as shown?

ii. If 50.0 mL of 2.00 molar hydroiodic acid, HI, is used instead of the HCl, the same amount of heat is produced. Why do the two different acids produce the same amount of heat in this reaction?

iii. If acetic acid is used instead of HCl, the amount of heat produced is

 **different.** Explain why the reaction of Mg with acetic acid produces less

 heat per mole than the reaction with hydrochloric acid.

IV. Formic acid, HCOOH, is the simplest organic acid.

 A. Draw a Lewis structure of HCOOH.

 B. Indicate the hybridization on the carbon atom

 C. When HCOOH reacts with bases, it forms the formate ion, HCOO− .

Compare the bond lengths of the carbon-oxygen bonds in the formate ion

with those in formic acid. Explain any differences.

V. SO2 gas is added to a 10.0 liter inflexible container at 400. K.

 The initial pressure of SO2 is 14.0 atm, and then enough oxygen is added to increase the total gas pressure to 20.0 atm. The reaction 2 SO2(g) + O2(g) ➞ 2 SO3(g) occurs

 at constant temperature.

 A. Calculate the number of moles of O2 gas in the vessel before any reaction occurs.

 B. Assuming that the reaction goes to completion, calculate the pressure of the SO2

 remaining in the flask at 400. K

C. In fact, the reaction does not go to completion. After a certain amount of time, it is found that the total pressure in the flask, still at 400 K, has dropped to 18.0 atm.

 Determine the partial pressure of EACH of the three gases now in the mixture.