Please print:

Last name: _____

First name:_____

Chem 1061 Exam 3

Fall 2004

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Tuesday, November 9, 2004

Instructions:

Time: You have 85 minutes to complete this exam.

Allowed items: This exam will require the use of a calculator. A calculator and your writing instrument are the only personal items allowed on your table while the exam is being administered. A #2 pencil is required to fill out the Scantron form for the multiple choice questions. Please use pen on the problems section of the exam if you would like the opportunity for regrades beyond simple score-addition errors.

Provided information: A periodic table and conversion chart are provided for you inside this exam booklet.

Contents:

I.	**Multiple choice**, 12 questions, 3 points each.	36 points
II.	**Problems.** 4 questions, 16 points each.	64 points
	Total:	**100 points**

I, _____ have read and understand the directions given above, and pledge that I will follow all regulations with regard to Academic Dishonesty as outlined by this college when taking this exam.

Signature _____ Date and Time _____

I. Multiple choice

Choose the best answer from the choices given, and mark your choice on the provided Scantron sheet with a #2 pencil. *(3 points each)*

1. Equal volumes of propane, C_3H_8 and carbon monoxide at the same temperature and pressure have the same

   I. density
   II. number of molecules
   III. number of atoms

   a. **I** only
   b. **II** only
   c. **III** only
   d. **I** and **II** only
   e. **I**, **II**, and **III**

2. In an ideal gas, which pairs of variables are inversely proportional to each other (if all other factors remain constant)?

   I. *P, T*
   II. *P, V*
   III. *V, T*
   IV. *n, V*

   a. **I** and **II** only
   b. **III** and **IV** only
   c. **II** only
   d. **I** and **III** only
   e. **I**, **III**, and **IV** only

3. The pressure of 4.0 L of nitrogen in a flexible container is decreased to one-half its original pressure, and its absolute temperature is increased to double the original temperature. The volume is now
   a. 2.0 L
   b. 4.0 L
   c. 8.0 L
   d. 16.0 L
   e. 32.0 L

4. An empty 2.0 L soda bottle is tightly capped at 22 °C and 650 mmHg. If the bottle is placed in water at 95 °C, what is the pressure in the bottle?
   a. 520 mmHg
   b. 780 mmHg
   c. 810 mmHg
   d. 930 mmHg
   e. 2800 mmHg

5. If 250 mL of methane, CH_4, effuses through a small hole in 48 s, the time required for the same volume of helium to pass through the hole will be
   a. 12 s
   b. 24 s
   c. 48 s
   d. 96 s
   e. 192 s

6. For the process of ice melting to form liquid water, which of the following is true?
   a. ΔH is positive, and the process is exothermic
   b. ΔH is positive, and the process is endothermic
   c. ΔH is negative, and the process is exothermic
   d. ΔH is negative, and the process is endothermic
   e. Not enough information given

7. Which of the following statements is (are) true?

   I. The reaction vessel becomes warmer when an endothermic reaction occurs.
   II. An exothermic reaction is characterized by a negative value of Δ*H*.
   III. Heat is evolved when an exothermic reaction occurs.

   a. **I** only
   b. **II** only
   c. **I** and **II** only
   d. **II** and **III** only
   e. **I**, **II**, and **III**

8. Consider the following specific heats of metals:

Metal	Specific heat
copper	0.385 J/(g • °C)
cobalt	0.418 J/(g • °C)
chromium	0.447 J/(g • °C)
gold	0.129 J/(g • °C)
silver	0.237 J/(g • °C)

   100-g samples of each of the metals at 95 °C are added to 100 mL of water at 25 °C. Which element will increase the temperature of the water the least?
   a. copper
   b. cobalt
   c. chromium
   d. gold
   e. silver

9. In a coffee-cup calorimeter, reactions are carried out
   a. At constant temperature
   b. At constant volume
   c. At constant pressure
   d. At standard temperature and pressure
   e. None of these

10. The ΔH_f° of $Cr_2O_3(s)$ is -1134.7 kJ/mol. Which of the following thermochemical equations is correct?
   a. $4Cr(s) + 3O_2(g) \rightarrow 2Cr_2O_3(s)$; ΔH = -1134.7 kJ
   b. $2Cr(s) + \frac{3}{2}O_2(g) \rightarrow Cr_2O_3(s)$; ΔH = -1134.7 kJ
   c. $Cr_2(s) + O_3(g) \rightarrow Cr_2O_3(s)$; ΔH = -1134.7 kJ
   d. $2Cr(s) + 3O(g) \rightarrow Cr_2O_3(s)$; ΔH = -1134.7 kJ
   e. None of the above are correct.

11. For which substance is $\Delta H_f^\circ = 0$?
   a. $C_2H_6(g)$
   b. $C_2H_6(l)$
   c. $Br_2(s)$
   d. $Br_2(l)$
   e. $Br_2(g)$

12. The standard enthalpies of formation for various iodine species are given below:

   $I(g)$ ΔH_f° = 107 kJ/mol
   $I_2(g)$ ΔH_f° = 21 kJ/mol
   $HI(g)$ ΔH_f° = 26 kJ/mol

   What other additional information is needed to calculate the enthalpy of the following reaction?

   $H_2(g) + I_2(g) \rightarrow 2HI(g)$; ΔH = ?

   a. none, because the answer is 2 times 26 kJ/mol
   b. none, because the enthalpy of formation of an element in its stablest form is zero
   c. the enthalpy of formation of gaseous iodine
   d. the enthalpy of formation of gaseous hydrogen
   e. the enthalpy of formation of solid iodine

II. Problems

For all problems, show your work and round the final answer to the correct number of significant figures for full credit. Place a box around your final answer. (*16 points each*)

13. Given the following thermochemical equations, use Hess's law to calculate the ΔH_f of C_2H_6.

$C(\text{graphite}) + O_2(g) \rightarrow CO_2(g)$ ΔH = -393.5 kJ (**A**)
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ ΔH = -285.8 kJ (**B**)
$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$ ΔH = -3119.6 kJ (**C**)

$2C(\text{graphite}) + 3H_2(g) \rightarrow C_2H_6(g)$ ΔH = ?

The final equation contains 2 C(graphite) so multiply the first equation by 2.
$2C(\text{graphite}) + 2O_2(g) \rightarrow 2CO_2(g)$ $\Delta H = 2\mathbf{A}$

It also requires 3 $H_2(g)$ so multiply the second equation by 3.
$3H_2(g) + \frac{3}{2}O_2(g) \rightarrow 3H_2O(g)$ $\Delta H = 3\mathbf{B}$

Finally, it requires 1 C_2H_6 so invert the third equation and multiply it by ½.
$2CO_2(g) + 3H_2O(g) \rightarrow C_2H_6(g) + \frac{7}{2}O_2(g)$ $\Delta H = -\mathbf{C}/2$

When added together, the unwanted compounds cancel.
$2C(\text{graphite}) + \cancel{2O_2(g)} \rightarrow \cancel{2CO_2(g)}$ $\Delta H = 2\mathbf{A}$
$3H_2(g) + \cancel{\frac{3}{2}O_2(g)} \rightarrow \cancel{3H_2O(g)}$ $\Delta H = 3\mathbf{B}$
$\cancel{2CO_2(g)} + \cancel{3H_2O(g)} \rightarrow C_2H_6(g) + \cancel{\frac{7}{2}O_2(g)}$ $\Delta H = -\mathbf{C}/2$

$2C(\text{graphite}) + 3H_2(g) \rightarrow C_2H_6(g)$ $\Delta H = 2\mathbf{A} + 3\mathbf{B} - \mathbf{C}/2$

ΔH = 2(-393.5 kJ) + 3(-285.8 kJ) – (–3119.6kJ)/2

$\boxed{= -84.6 \text{ kJ}}$

14. A piece of potassium metal undergoes complete reaction with water as follows:

$$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$$

The hydrogen gas is collected over water at 25 °C. The volume of gas is 752 mL measured at 0.950 atm. Calculate the number of grams of potassium used in this reaction, assuming excess water. (The vapor pressure of water at 25 °C is 0.0313 atm)

First use the vapor pressure of water and the total pressure to find the partial pressure of the hydrogen gas collected.

$$P_{H_2} = P - P_{H_2O} = 0.950 \text{ atm} - 0.0313 \text{ atm} = 0.9187 \text{ atm}$$

Then, use the ideal gas law to solve for the number of moles of H_2.

$$P_{H_2}V = nRT$$

$$n = \frac{P_{H_2}V}{RT}$$

$$P_{H_2} = 0.9187 \text{ atm}$$

$$V = 0.752 \text{ L}$$

$$R = 0.08206 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol}$$

$$T = 25 \text{ °C} + 273.15 \text{ K} = 298.15 \text{ K}$$

$$n = \frac{(0.9187 \text{ atm})(0.752 \text{ L})}{(0.08206 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol})(298.15 \text{ K})}$$

$$= 0.02823 \text{ mol } H_2$$

Finally, use the balanced chemical equation to convert moles H_2 into grams K.

$$.02823 \text{ mol } H_2 \times \frac{2 \text{ mol K}}{1 \text{ mol } H_2} \times \frac{39.10 \text{ g K}}{1 \text{ mol K}} = \boxed{2.21 \text{ g K}}$$

15. An ideal gas with a density of 0.626 g/L is placed in a 1.5 L flask at 25 °C. If the pressure of the gas is 0.899 atm, what is the molecular weight, in amu, of this gas?

You are given enough information in the question to solve for number of moles of this gas, using the ideal gas law.

$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$P = 0.899 \text{ atm}$$

$$V = 1.5 \text{ L}$$

$$R = 0.08206 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol}$$

$$T = 25 \text{ °C} + 273.15 \text{ K} = 298.15 \text{ K}$$

$$n = \frac{(0.899 \text{ atm})(1.5 \text{ L})}{(0.08206 \text{ L} \cdot \text{atm} / \text{K} \cdot \text{mol})(298.15 \text{ K})}$$

$$= 0.055\underline{1} \text{ mol}$$

Since molecular weight in amu is the same value as molar mass in g/mol, use the density to find the number of grams in the sample, and then find the molar mass.

$$1.5 \text{ L} \times \frac{0.626 \text{ g}}{\text{L}} = 0.939 \text{ g in } 1.5 \text{ L}$$

$$M_m = \frac{0.939 \text{ g}}{0.055\underline{1} \text{ mol}} = 17 \text{ g/mol} = \boxed{17 \text{ amu}}$$

16. 0.20 moles of HCl were neutralized by NaOH. The concentrations of base and acid were equal. If the temperature of the water in the calorimeter increased from 19.9 °C to 24.6 °C, what was the original concentration of HCl? The molar enthalpy of neutralization is -80 kJ/mole acid, signified by the below thermochemical equation.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l);\ \Delta H = -80\ kJ$$

Assume the density of water is 1.00 g/mL, and that all the heat of the neutralization reaction is absorbed by the surrounding water only. The specific heat of water is 4.184 J/g°C.

Since 0.20 moles of HCl were used, we can use the thermochemical equation to figure out the exact amount of heat given off by this reaction.

$$0.20\ \text{mol HCl} \times \frac{-80\ \text{kJ}}{1\ \text{mol HCl}} \times \frac{10^3\ \text{J}}{1\ \text{kJ}} = -16{,}000\ \text{J}$$

The heat given off by the reaction is heat absorbed by the surrounding water in the calorimeter.

$$q_{system} = -q_{surroundings}$$

And we can use the specific heat equation to figure out the mass of water present.

$$q_{surroundings} = sm\Delta t$$

$$m = \frac{q_{surroundings}}{s\Delta t} = \frac{16{,}000\ \text{J}}{(4.184\ \text{J/g°C})(4.7\ °\text{C})} = 813.6\ \text{g}$$

Since we assume the density of water is 1.00 g/mL, this gives us the volume of water, and since equal amounts of equal-concentration HCl and NaOH were added, the volume of the HCl solution must be half of the total volume.

$$813.\underline{6}4\ \text{g} \times \frac{1\ \text{mL}}{1.00\ \text{g}} = 813.\underline{6}4\ \text{mL solution}$$

$$V_{HCl} = \frac{813.\underline{6}4\ \text{mL}}{2} = 406.\underline{8}2\ \text{mL HCl solution}$$

Concentration is given in units of molarity, or moles per liter.

$$\text{molarity} = \frac{n}{V} = \frac{0.20\ \text{mol}}{0.40682\ \text{L}} = \boxed{0.49\ \text{M}}$$

--END OF EXAM QUESTIONS--