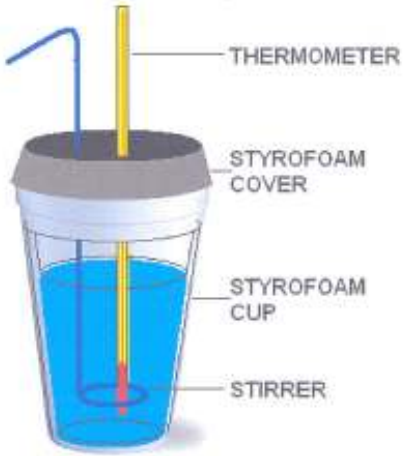
Name: Mrs Hanson

Thermochemistry



Practice Test A

General Chemistry
Honors Chemistry

Objective 1: Use the relationship between mass, specific heat, and temperature change to calculate the heat flow during a chemical or physical process.
Directions: Show all work, including units, to solve the following problems.

1. The specific heat of iron metal is 0.450 J/g-K. How many J of heat are necessary to raise the temperature of a 1.05 kg block of iron from 25°C to 88.5°C?

Kg must be converted to grams!

(endo) $q = (1050\,g)(.450\,J/g°C)(88.5 - 25)$

$= +\ 30003.75\,J$ or $30.0\,KJ$

2. How much heat energy, in Joules, is absorbed when 150 grams of water is warmed from 34.8°C to 96.3°C?

(endo) $q = (150\,g)(4.184\,J/g°C)(96.3 - 34.8)$

$= +\ 38597.4\,J$

3. A chunk of silver has a heat capacity of 42.8 J/°C. If the silver has a mass of 181 grams, calculate the specific heat of silver.

$42.8\,\frac{J}{°C}\left(\frac{1}{181\,g}\right) = .236\,J/g°C$

4. When a certain substance with a mass of 100 grams is heated from 25°C to 75°C, it absorbed 4500 Joules of heat energy. Calculate the specific heat of the substance, and identify it using the following table:

Water:	4.184 J/g-K
Ice:	2.1 J/g-K
Aluminum:	0.90 J/g-K
Silver:	0.24 J/g-K
Mercury:	0.14 J/g-K

$+4500\,J = (100\,g)(C_p)(75 - 25)$

$C_p = \frac{4500\,J}{(100 \times 50)} = .9\,J/g°C$ = Aluminum

5. A student mixed 75 mL of water containing 0.50 mol HCl at 22.5°C with 75 mL of water containing NaOH at the same temperature in a foam cup calorimeter. The temperature of the resulting solution increased to 26°C. How much heat in kilojoules was released by this reaction? Assume the density of the resulting solution was 1.0 g/mL.

75mL HCl + 75mL NaOH = 150 mL total volume $\times\ 1.0\,\frac{g}{mL} = 150g$

$q = (150\,g)(4.184\,J/g°C)(26 - 22.5°C)$

$= -\ 2196.6\,J$

(exo)

Score: _____ / 2

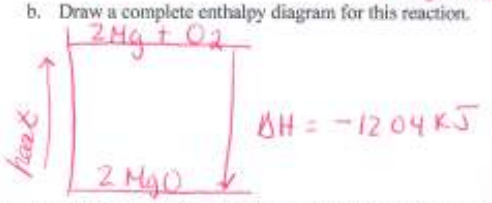
Objective 2: Construct thermochemical equations and enthalpy diagrams for any chemical reaction given thermochemical data. Indicate if the change is endothermic or exothermic.

1. Consider the following reaction:
   $2\ Mg(s) + O_2(g) \rightarrow 2MgO(s)$ $\Delta H = -1204kJ$

   a. Is this reaction exothermic or endothermic? Explain your choice.

   Exothermic. The enthalpy change is negative = heat releasing.

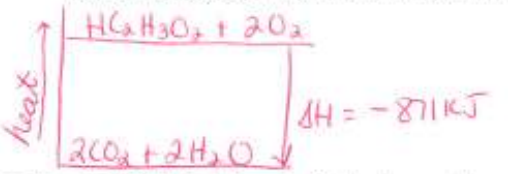
   b. Draw a complete enthalpy diagram for this reaction.



2. The complete combustion of acetic acid releases 871 kJ of heat per mole of the acid.
   a. Write a balanced thermochemical equation for the reaction.

   $HC_2H_3O_2 + 2\ O_2 \rightarrow 2\ CO_2 + 2\ H_2O$

   b. Draw a complete enthalpy diagram for the reaction. $\Delta H = -871\ KJ$



3. Exactly 3352 kJ of heat is required for the decomposition of aluminum oxide into its elements.
   a. Write a balanced thermochemical equation for the reaction.

   $2Al_2O_3 \rightarrow 4\ Al + 3O_2$ $\Delta H = +3352kJ$

   b. Draw a complete enthalpy diagram for the reaction.

Score: _____

Sorry ↑

Objective 3: Calculate enthalpy changes in chemical and physical processes from a thermochemical equation. Indicate if the change is endothermic or exothermic.

Directions: Show all work, including units, to solve the following problems.

1. Gasohol contains ethanol, C_2H_5OH, which completely combusts to produce 1235 kJ of heat energy.
   a. Write the balanced thermochemical equation:

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O \quad \Delta H = -1235\,kJ$$

   b. How much heat is released when 50 grams of ethanol completely combusts?

$$50\,g\,C_2H_5OH\left(\frac{1\,mol\,C_2H_5OH}{46\,g\,C_2H_5OH}\right)\left(\frac{-1235\,kJ}{1\,mol\,C_2H_5OH}\right) = -1342.4\,kJ$$

2. When magnesium metal combines with oxygen from the air, 1204 kJ of heat energy is released.
   a. Write the balanced thermochemical equation:

$$2Mg + O_2 \rightarrow 2MgO \quad \Delta H = -1204\,kJ$$

   b. Calculate the amount of heat transferred when 2.4 g of magnesium reacts:

$$2.4\,g\,Mg\left(\frac{1\,mol\,Mg}{24\,g\,Mg}\right)\left(\frac{-1204\,kJ}{2\,mol\,Mg}\right) = -60.2\,kJ$$

24.3

$-59.5\,kJ$

   c. How many grams of magnesium oxide are produced during an enthalpy change of -96 kJ?

$$-96\,kJ\left(\frac{2\,mol\,MgO}{-1204\,kJ}\right)\left(\frac{40.3\,g\,MgO}{1\,mol\,MgO}\right) = 6.43\,g\,MgO$$

   d. How many kilojoules of heat are absorbed when 7.5 grams of magnesium oxide are decomposed?

reverse the RXN

$2MgO \rightarrow 2Mg + O_2 \quad \Delta H = +1204\,kJ$

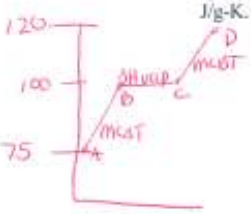
$$7.5\,g\,MgO\left(\frac{1\,mol\,MgO}{40.3\,g\,MgO}\right)\left(\frac{+1204\,kJ}{2\,mol\,MgO}\right) = +112.03\,kJ$$

Score: _____

Objective 4: Calculate enthalpy changes that occur using a warming or cooling curve; including phase changes such as melting, freezing, boiling, or condensing.

Directions: Show all work, including units, to solve the following problems.

1. How much heat (in kJ) is absorbed when 50 grams of liquid water at 75°C is converted to steam at 120°C? The molar heat of vaporization for water is 40.7 kJ/mole. The specific heat of water is 4.184 J/g-K. The specific heat of steam, gaseous water, is 1.84 J/g-K.



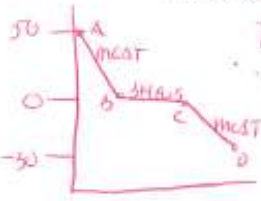
$\overline{AB} = (50g)(4.184\ J/g°C)(25°) \div 1000 = 5.23\ kJ$

$\overline{BC}\quad 50g\left(\frac{1\ mol\ H_2O}{18g\ H_2O}\right)\left(\frac{40.7\ kJ}{1\ mol}\right) = 113.1\ kJ$

$\overline{CD}\quad (50g)(1.84\ J/g°C)(20°C) \div 1000 = 1.84\ kJ$

120.17 kJ total

2. What is the enthalpy change during the process in which 100 grams of water at 50°C is cooled to ice at -30°C. The specific heat of liquid water is 4.184 J/g-K. The specific heat of ice is 2.09 J/g-K. The molar heat of fusion for water is 6.01 kJ/mol.



$\overline{AB} = (100g)(4.184\ J/g°C)(50°C) \div 1000 = 20.92\ kJ$

$\overline{BC} = \left(100g\left(\frac{1\ mol\ H_2O}{18g\ H_2O}\right)\right)\left(\frac{6.01\ kJ}{1\ mol}\right) = 33.39\ kJ$

$\overline{CD} = (100g)(2.09\ J/g°C)(30°C) \div 1000 = 6.27\ kJ$

total -60.58 kJ

Score: _____

Objective 5: Calculate the enthalpy change during a dissolving process given thermochemical data.

Directions: Show all work, including units, to solve the following problems.

1. When solid sodium hydroxide is dissolved into water, forming aqueous sodium ions and hydroxide ions, 445 kJ/mol of heat energy is released.
   a. Write the balanced thermochemical equation for this physical process:

$NaOH_{(s)} \xrightarrow{H_2O} Na^+_{(aq)} + OH^-_{(aq)} \quad \Delta H = -445\ kJ$

   b. How much heat, in kJ, is released when 50 grams of sodium hydroxide is dissolved in water?

$50g\ NaOH\left(\frac{1\ mol\ NaOH}{40g\ NaOH}\right)\left(\frac{-445\ kJ}{1\ mol\ NaOH}\right) = -556.25\ kJ$

2. When ammonium nitrate is dissolved into water, ammonium and nitrate ions are released, absorbing 82.8 kJ of heat energy from the water.
   a. Write this balanced thermochemical equation.

$NH_4NO_{3(s)} \longrightarrow NH_4^+(aq) + NO_3^-(aq) \quad \Delta H = +82.8\,kJ$

   b. How many grams of ammonium nitrate must be dissolved in water so that 108 kJ of heat is released from the water?

$108\,kJ \left(\frac{1\,mol\,NH_4NO_3}{82.8\,kJ}\right)\left(\frac{80\,g\,NH_4NO_3}{1\,mol\,NH_4NO_3}\right) = +104.35\,g$

   c. Calculate the enthalpy change when 500 grams of ammonium nitrate dissolves into water.

$500\,g\,NH_4NO_3 \left(\frac{1\,mol\,NH_4NO_3}{80\,g\,NH_4NO_3}\right)\left(\frac{+82.8\,kJ}{1\,mol\,NH_4NO_3}\right) = 517.5\,kJ$

Score: _____

Objective 6: Apply Hess's law of heat summation to find enthalpy changes for chemical and physical processes.

Directions: Show all work, including units, to solve the following problems.

1. Calculate the heat change, ΔH, for the formation of nitrogen monoxide from its elements
   Write the target balanced equation here:

$N_2 + O_2 \rightarrow 2NO \qquad \Delta H = 180\,kJ$

   Use these thermochemical equations:

$\div 2 \leftarrow 4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g) \quad \Delta H = -1530\,kJ \rightarrow \div 2$

$2 \times 4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g) \quad \Delta H = -1170\,kJ \times 2$

$N_2 + 3H_2O \rightarrow 2NH_3 + \frac{3}{2}O_2 \quad \Delta H = +765$

$2NH_3 + \frac{5}{2}O_2 \rightarrow 2NO + 3H_2O \quad \Delta H = -585$

$(+765) + (-585) =$

Answer: 180 kJ

2. Calculate the enthalpy change for the reaction

$P_4O_6(s) + 2O_2(g) \rightarrow P_4O_{10}(s)$

   Given the following enthalpies of reaction:

$P_4(s) + 3O_2(g) \rightarrow P_4O_6(s)$ ← leave $\quad \Delta H = -1640.1\,kJ$

$P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$ leave $\quad \Delta H = -2940.1\,kJ$

② $P_4 + 5O_2 \rightarrow P_4O_{10} \quad \Delta H = -2940.1$

① $P_4O_6 \rightarrow P_4 + 3O_2 \quad \Delta H = +1640.1$

Score: _____

Answer: −1300 kJ

$+1640.1 + (-2940.1) = -1300$

Objective 7: (Honors Only): Calculate enthalpy changes using standard heats of formation.

Directions: Show all work, including units, to solve the following problems.

1. Using values from the standard table of heats of formation, calculate the value of ΔH for each of the following reactions:
   a. $N_2O_4(g) + 4H_2(g) \rightarrow N_2(g) + 4\,H_2O(g)$

$\Delta H_{RXN} = [(0) + (4 \cdot -241.82)] - [(9.66) + (0)]$
(N_2 + 4 H_2O ; N_2O_4 ; H_2)

$= -976.94$ KJ

   b. $2KOH(s) + CO_2(g) \rightarrow K_2CO_3(s) + H_2O(g)$

$\Delta H_{RXN} = [(-1150.18) + (-241.82)] - [(2 \cdot -924.7) + (-393.5)] = -149.1$ KJ
(K_2CO_3 ; H_2O ; KOH ; CO_2)

2. Complete combustion of 1 mole of acetone (C_3H_6O) liberates 1790 kJ.
   a. Write the balanced thermochemical equation.

$C_3H_6O(l) + 4O_2(g) \rightarrow 3CO_2(g) + 3H_2O(g)$ $\Delta H = -1790$ KJ

   b. Using this information together with data from the standard table of heats of formation, calculate the enthalpy of formation of acetone.

$-1790 = -2037.99 - x$

$-1790\text{ KJ} = [(3 \cdot -393.5) + (3 \cdot -285.83)] - [(x) + (0)]$

$247.99 = -x$

$-247.99 = x$ KJ

$X =$

Objective 8: Distributed Practice 1: Determine the limiting reagent and maximum yield of product formed given appropriate data.

Directions: Show all work, including units, to solve the following problems.

1. Hydrazine (N_2H_4) is used as rocket fuel. It reacts with oxygen to form nitrogen gas and water vapor.
   a. Write the balanced equation:

$N_2H_4 + O_2 \rightarrow N_2 + 2H_2O$

   b. How many liters of nitrogen gas (at STP) form if 100 grams of hydrazine reacts with 100 grams of oxygen gas?

$100\text{g } N_2H_4 \left(\frac{1\text{ mol } N_2H_4}{32\text{g } N_2H_4}\right) = 3.125\text{ mol } N_2H_4 \left(\frac{1\text{ mol } N_2}{1\text{ mol } N_2H_4}\right)\left(\frac{22.4\text{L } N_2}{1\text{ mol } N_2}\right) = 70\text{L } N_2$

$100\text{g } O_2 \left(\frac{1\text{ mol } O_2}{32\text{g } O_2}\right) = 3.125\text{ mol } O_2$

Perfect ratio, so no L.R.

2. Calcium carbonate reacts with phosphoric acid to produce calcium phosphate, carbon dioxide, and water.
   a. Write the balanced equation:

$3\,CaCO_3 + 2\,H_3PO_4 \rightarrow Ca_3(PO_4)_2 + 3CO_2 + 3H_2O$

   b. How many molecules of carbon dioxide form when 50 grams of calcium carbonate reacts with 70 grams of phosphoric acid?

L.R. $50g\,CaCO_3\left(\frac{1mol\,CaCO_3}{100g\,CaCO_3}\right)\left(\frac{3mol\,CO_2}{3mol\,CaCO_3}\right)\left(\frac{6.02\times10^{23}\,mlc\,CO_2}{1mol\,CO_2}\right) = 3.01\times10^{23}\,mlc\,CO_2$

X.S. $70g\,H_3PO_4\left(\frac{1mol\,H_3PO_4}{98g\,H_3PO_4}\right)\left(\frac{3mol\,CO_2}{2mol\,H_3PO_4}\right)\left(\frac{6.02\times10^{23}\,mlc\,CO_2}{1mol\,CO_2}\right) = 6.45\times10^{23}\,mlc\,CO_2$

Score: _____

Objective 9: (Honors Only): Distributed Practice 2: Calculate the Percent Yield of a reaction given appropriate data.

Directions: Show all work, including units, to solve the following problems.

1. Heating an ore of antimony (Sb_2S_3) in the presence of iron given the element antimony and iron (II) sulfide.
   a. Write the balanced equation.

$Sb_2S_3 + 3\,Fe \rightarrow 2\,Sb + 3\,FeS$

$\%\,yield = \frac{actual}{theor} \times 100$

   b. When 15 grams of the ore reacts with an excess of iron, 9.84 grams of Sb is produced. What is the percent yield of this reaction? (actual)

$15g\,Sb_2S_3\left(\frac{1mol\,Sb_2S_3}{339.68g\,Sb_2S_3}\right)\left(\frac{2mol\,Sb}{1mol\,Sb_2S_3}\right)\left(\frac{121.8g\,Sb}{1mol\,Sb}\right) = 10.76\,g\,Sb$ (theor.)

$\%\,yield = \frac{9.84g}{10.76g} \times 100 = 91.4\%$

2. When 50 grams of silicon dioxide is heated with an excess of carbon, 32.2 grams of silicon carbide (SiC) is produced. (actual)

$\_\_1\_\_\,SiO_2(s) + \_\_3\_\_\,C(s) \rightarrow \_\_1\_\_\,SiC(s) + \_\_2\_\_\,CO(g)$

   a. What is the percent yield of this reaction?

$50g\,SiO_2\left(\frac{1mol\,SiO_2}{60g\,SiO_2}\right)\left(\frac{1mol\,SiC}{1mol\,SiO_2}\right)\left(\frac{40g\,SiC}{1mol\,SiC}\right) = 33.33\,g\,SiC$ (theor.)

$\%\,yield = \frac{32.2g}{33.33g} \times 100 = 96.6\%$

   b. How many grams of CO gas are made?

$50g\,SiO_2\left(\frac{1mol\,SiO_2}{60g\,SiO_2}\right)\left(\frac{2mol\,CO}{1mol\,SiO_2}\right)\left(\frac{28g\,CO}{1mol\,CO}\right) = 46.67\,g\,CO$

$\times .966$ (% yield)

actual yield $45.08g\,CO$

Score: _____