Name: _____

Thermochemistry

Practice Test C

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 lead metal is 0.352 J/g-K. How many kJ of heat are necessary to raise the temperature of a 1kg block of lead from 53°C to 72°C?

$q = (1000g)(.352 \frac{J}{g\text{-}K})(72-53^\circ)$

$= 6688J = +6.69KJ$

2. How much heat energy, in Joules, is absorbed when 12.5 moles of water is warmed from 20°C to 89.3°C? $q = mc\Delta T$: change moles of H_2O to grams H_2O

$12.5 mol\ H_2O \left(\frac{18g\ H_2O}{1 mol}\right) = 225g\ H_2O$ ~sorry

$q = (225g H_2O)(4.184 \frac{J}{g°C})(89.3-20°C) =$ +65239.02 Joules

3. A chunk of copper has a heat capacity of 1246 J/°C. If the ice has a mass of 3.24 kg, calculate the specific heat of copper.

change to grams!

3.24 kg = 3240g

$\left(\frac{1246J}{°C}\right)\left(\frac{1}{3240g}\right) =$ .385 J/g°C

4. When a certain substance with a mass of 500 grams is heated from 15°C to 75°C, it absorbed 27 kJ 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

27KJ = 27000J

$27000J = (500g)(C_p)(75-15)$

$C_p = .90 \frac{J}{g°C}$ = Aluminum

5. A student mixed 155 mL of water containing 0.50 mol HCl at 22.5°C with 155 mL of water containing NaOH at the same temperature in a foam cup calorimeter. The temperature of the resulting solution increased to 49.5°C. How much heat in kilojoules was released by this reaction? Assume the density of the resulting solution was 1.0 g/mL. 155mL HCl + 155mL NaOH = 310mL total volume $\times$ $1.0 \frac{g}{mL}$ = 310g

$q = (310g)(4.184 \frac{J}{g°C})(49.5-22.5)$

$= -35020.08$ Joules $= -35.02$ KJ

Score: _____

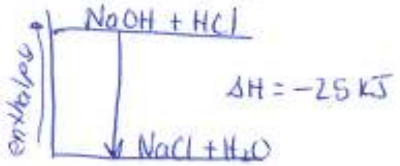
Objective 2: Construct thermochemical equations and enthalpy diagrams for any chemical reaction given thermochemical data. Indicate if the change is endothermic or exothermic.

1. Consider the following reaction:
   $NaOH + HCl \rightarrow NaCl + H_2O$ $\Delta H = -25$ kJ

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

   Exothermic. The value for enthalpy is negative. for exothermic,

   b. Draw a complete enthalpy diagram for this reaction.

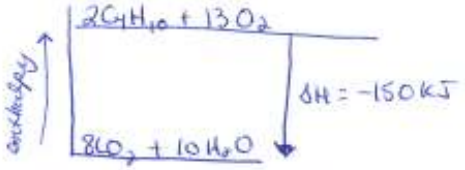


2. The complete combustion of butane, C_4H_{10}, releases 150 kJ of heat per mole of the reactant.

   a. Write a balanced thermochemical equation for the reaction.

   $2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$ $\Delta H = -150$ KJ

   b. Draw a complete enthalpy diagram for the reaction.

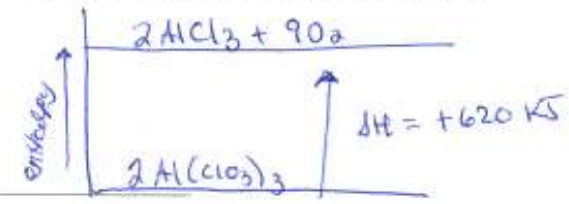


3. Exactly 620 kJ of heat is required for the decomposition of Aluminum Chlorate.

   a. Write a balanced thermochemical equation for the reaction.

   $2\ Al(ClO_3)_3 \longrightarrow 2\ AlCl_3 + 9\ O_2$ $\Delta H = +620$ KJ

   b. Draw a complete enthalpy diagram for the reaction.



Score: _____

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. When Aluminum Oxide absorbs 1490 kJ of heat energy, it decomposes.
   a. Write the balanced thermochemical equation:

$2\,Al_2O_3 \longrightarrow 4\,Al + 3\,O_2 \quad \Delta H = +1490\ kJ$

   b. How much heat is released when 10 grams of aluminum oxide completely decomposes?

$$10g\ Al_2O_3 \left(\frac{1mol\ Al_2O_3}{102g\ Al_2O_3}\right)\left(\frac{+1490\ kJ}{2mol\ Al_2O_3}\right) = \boxed{+73.04\ kJ}$$

2. When calcium metal reacts with hydrochloric acid, 450 kJ of heat is released.
   a. Write the balanced thermochemical equation:

$Ca + 2HCl \rightarrow H_2 + CaCl_2 \quad \Delta H = -450\ kJ$

   b. Calculate the amount of heat transferred when 100 grams of calcium metal reacts:

$$100g\ Ca \left(\frac{1mol\ Ca}{40g\ Ca}\right)\left(\frac{-450\ kJ}{1mol\ Ca}\right) = \boxed{-1125\ kJ}$$

   c. How many liters of hydrogen gas are produced during an enthalpy change of -2220 kJ, assuming STP conditions?

$$-2220kJ \left(\frac{1mol\ H_2}{-450\ kJ}\right)\left(\frac{22.4L\ H_2}{1mol\ H_2}\right) = \boxed{110.5\ L\ H_2}$$

   d. How many kilojoules of heat are released when 1.5×10^{23} formula units of calcium chloride form?

$$1.5\times10^{23}\ CaCl_2 \left(\frac{1mol\ CaCl_2}{6.02\times10^{23}\ CaCl_2}\right)\left(\frac{-450\ kJ}{1mol\ CaCl_2}\right) = \boxed{-112.12\ kJ}$$

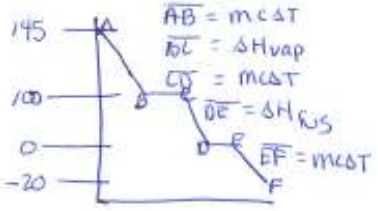
Score: _____

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

DRAW DIAGRAMS

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

1. How much heat (in kJ) is released (EXO) when 10 moles of steam, gaseous water, at 145°C is converted to ice at -20°C? The molar heat of vaporization for water is 40.7 kJ/mole. The molar heat of fusion for water is 6.01 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. The specific heat of ice is 2.09 J/g-K.



$\overline{AB} = (10\,mol\,H_2O \times \frac{18g}{1\,mol})(1.84\,J/g°C)(45°C) \div 1000 = 14.9\,kJ$ (= 180g)

$\overline{BC} = 10\,mol\,H_2O \times \frac{40.7\,kJ}{1\,mol} = -407\,kJ$

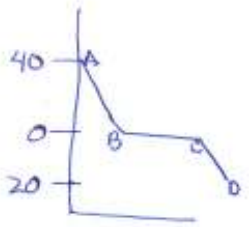
$\overline{CD} = (180g\,H_2O)(4.184\,J/g°C)(100°C) \div 1000 = -75.31\,kJ$

$\overline{DE} = 10\,mol\,H_2O \times \frac{6.01\,kJ}{1\,mol} = -60.1\,kJ$

$\overline{EF} = (180g\,H_2O)(2.09\,J/g°C)(20°) \div 1000 = -7.52\,kJ$

2. What is the enthalpy change during the process in which 75 grams of water at 40°C is cooled to ice at -20°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.

$= -564.83\,kJ$ total



$\overline{AB} = (75g\,H_2O)(4.184\,J/g°C)(40°) \div 1000 = -12.552\,kJ$

$\overline{BC} = 75g\,H_2O\left(\frac{1\,mol\,H_2O}{18g\,H_2O}\right)\left(\frac{6.01\,kJ}{1\,mol}\right) = -25.04\,kJ$

$\overline{CD} = (75g\,H_2O)(2.09\,J/g°C)(20°) \div 1000 = -3.135\,kJ$

total $= -40.727\,kJ$

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 aluminum chloride is dissolved into water, forming aqueous aluminum ions and chloride ions, 50 kJ/mol of heat energy is released.
   a. Write the balanced thermochemical equation for this physical process:

$$AlCl_{3\,(s)} \xrightarrow{H_2O} Al^{+3}_{(aq)} + 3Cl^{-}_{(aq)} \quad \Delta H = -50\,kJ$$

   b. How much heat, in kJ, is released when 150 grams aluminum chloride is dissolved in water?

$$150g\ AlCl_3 \left(\frac{1mol\ AlCl_3}{133.5g\ AlCl_3}\right)\left(\frac{-50kJ}{1mol\ AlCl_3}\right) = \boxed{-56.18\,kJ}$$

2. When aluminum sulfate is dissolved into water, aluminum and sulfate ions are released, absorbing 245 kJ of heat energy from the water.
   a. Write this balanced thermochemical equation.

$$Al_2(SO_4)_{3\,(s)} \xrightarrow{H_2O} 2Al^{+3}_{(aq)} + 3SO_4^{-2}{}_{(aq)} \quad \boxed{\Delta H = +245\,kJ}$$

   b. How many grams of aluminum sulfate must be dissolved in water so that 1250 kJ of heat is released from the water?

$$1250kJ \left(\frac{1mol\ Al_2(SO_4)_3}{+245kJ}\right)\left(\frac{342g\ Al_2(SO_4)_3}{1mol\ Al_2(SO_4)_3}\right) = \boxed{1744.90g\ Al_2(SO_4)_3}$$

   c. Calculate the enthalpy change when 25 moles of sulfate ions are released into water.

$$25moles\ SO_4^{-2} \left(\frac{+245\,kJ}{3mol\ SO_4^{-2}}\right) = \boxed{+2041.7\,kJ}$$

♡

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 enthalpy change for the reaction

   $2N_2O(g) \rightarrow 2NO(g) + N_2(g)$

   Given the following enthalpies of reaction

   $N_2(g) + O_2(g) \rightarrow 2NO(g)$ Leave $\Delta H = +180.7$ kJ Leave
   $2N_2O(g) \rightarrow O_2(g) + 2N_2(g)$ Leave $\Delta H = -163.2$ kJ Leave

   $N_2 + O_2 \rightarrow 2NO$
   $2N_2O \rightarrow O_2 + 2N_2$
   $2N_2O \rightarrow 2NO + N_2$

   Answer: +17.5 kJ total

2. Calculate the enthalpy change for the reaction

   $3Fe_2O_3(s) + CO(g) \rightarrow CO_2(g) + 2Fe_3O_4(s)$

   Given the following reactions:

   3× $Fe_2O_3(s) + 3CO(s) \rightarrow 2Fe(s) + 3CO_2(g)$ $\Delta H = -28.0$ kJ ×3 = −84 kJ
   2× $3Fe(s) + 4CO_2(s) \rightarrow 4CO(g) + Fe_3O_4(s)$ $\Delta H = -393.5$ kJ ×2 = −787 kJ

   $3Fe_2O_3 + 9CO \rightarrow 6Fe + 9CO_2$
   $6Fe + 8CO_2 \rightarrow 8CO + 2Fe_3O_4$
   $3Fe_2O_3 + CO \rightarrow CO_2 + 2Fe_3O_4$

   −871 kJ total

   Score: _____ Answer: _____

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. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

   $\Delta H_{RXN} = \sum \text{products} - \sum \text{reactants}$

   $\Delta H_{RXN} = [2 \times -393.5\text{kJ}] - [2 \times -110.5\ \text{kJ}]$

   $= -566$ kJ

b. $HC_2H_3O_2$ (l) + $2O_2$(g) → $2CO_2$ (g) + $2H_2O$ (l)

$\Delta H_{RXN} = [2x\ -393.5\,kJ + 2x\ -285.83\,kJ] - [-487.0 + 0]$

$\Delta H_{RXN} = -871.66\,kJ$

2. When Octane, C_8H_{18}, completely combusts, 1250 kJ of heat are released. at 25°C

Write the complete balanced thermochemical equation:

$2\,C_8H_{18}(g) + 25\,O_2(g) \rightarrow 16\,CO_2(g) + 18\,H_2O(g) \quad \Delta H = -1250\,kJ$

Solve for the standard heat of formation for octane, using your table of values. Report your answer in terms of kJ/mole of octane.

$-1250\,kJ = [(16x\ -393.5) + (18x\ -285.83)] - [2(x)]$

$-6296 + -5144.94 = -11440.94$

$-1250 = -11440.94 - 2x$

$10190.94 = -2x$

$-5095.47 = x$

$= -5095.47\,kJ/mol$

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. When calcium nitrate reacts with potassium phosphate, a white precipitate forms.
   a. Write the balanced equation, circle the precipitate:

$3\,Ca(NO_3)_2 + 2\,K_3PO_4 \rightarrow \underline{\quad}\,Ca_3(PO_4)_2 + 6\,KNO_3$

   b. How many grams of the precipitate form if 100 grams of calcium nitrate reacts with 125 grams potassium phosphate?

LR $100g\ Ca(NO_3)_2 \left(\frac{1mol\ Ca(NO_3)_2}{164g\ Ca(NO_3)_2}\right)\left(\frac{1mol\ Ca_3(PO_4)_2}{3mol\ Ca(NO_3)_2}\right)\left(\frac{310g\ Ca_3(PO_4)_2}{1mol}\right) = 63.01g\ Ca_3(PO_4)_2$

XS $125g\ K_3PO_4 \left(\frac{1mol\ K_3PO_4}{212g\ K_3PO_4}\right)\left(\frac{1mol\ Ca_3(PO_4)_2}{2mol\ K_3PO_4}\right)\left(\frac{310g\ Ca_3(PO_4)_2}{1mol\ Ca_3(PO_4)_2}\right) = 91.39g\ Ca_3(PO_4)_2$

2. Lithium Hydroxide is neutralized by sulfuric acid.
   a. Write the balanced equation:

$2\,LiOH + H_2SO_4 \rightarrow Li_2SO_4 + 2\,H(OH)$

   b. How many molecules of water form when 125 grams of the base reacts with 150 grams of the acid?

XS $125g\ LiOH \left(\frac{1mol\ LiOH}{24g\ LiOH}\right)\left(\frac{2mol\ H_2O}{2mol\ LiOH}\right)\left(\frac{6.02\times10^{23}\ mlc\ H_2O}{1mol\ H_2O}\right) = 3.13\times10^{24}\ mlc\ H_2O$

LR $150g\ H_2SO_4 \left(\frac{1mol\ H_2SO_4}{98g\ H_2SO_4}\right)\left(\frac{2mol\ H_2O}{1mol\ H_2SO_4}\right)\left(\frac{6.02\times10^{23}\ mlc\ H_2O}{1mol\ H_2O}\right) = 1.84\times10^{24}\ mlc\ H_2O$

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. Beryllium and nitrogen react to produce beryllium nitride.
   a. Write the balanced equation.

$$3\,Be + N_2 \rightarrow Be_3N_2$$

   b. If 50 grams of each reactant undergoes a reaction with an 88.5% yield, how many grams of product are obtained from the reaction?

XS $50\,g\,Be\left(\frac{1\,mol\,Be}{9\,g\,Be}\right) = 5.55\,mol\,Be$

LR $50\,g\,N_2\left(\frac{1\,mol\,N_2}{28\,g\,N_2}\right) = 1.79\,mol\,N_2\left(\frac{1\,mol\,Be_3N_2}{1\,mol\,N_2}\right)\left(\frac{55\,g\,Be_3N_2}{1\,mol\,Be_3N_2}\right) = 98.45\,g\,Be_3N_2$

$\times .885$

$87.13\,g\,Be_3N_2$

2. When hydrogen sulfide gas is bubbled into a solution of sodium hydroxide, the reaction forms sodium sulfide and water. How many grams of sodium sulfide are formed if 40 grams of hydrogen sulfide is bubbled into a solution containing 62.00 grams of sodium hydroxide, assuming that the sodium sulfide is made in 75% yield?

Write the balanced equation:

$$\underset{40g}{H_2S_{(g)}} + \underset{62g}{2NaOH} \rightarrow \underset{?g}{Na_2S} + 2H(OH)$$

$40\,g\,H_2S\left(\frac{1\,mol\,H_2S}{34\,g\,H_2S}\right) = 1.18\,mol\,H_2S$ (XS)

Score: $62\,g\,NaOH\left(\frac{1\,mol\,NaOH}{40\,g\,NaOH}\right) = 1.55\,mol\,NaOH\left(\frac{1\,mol\,Na_2S}{2\,mol\,NaOH}\right)\left(\frac{78\,g\,Na_2S}{1\,mol\,Na_2S}\right) = 60.45\,g\,Na_2S$ (LR)

$\times .75$

$45.34\,g\,Na_2S$