Name BETH "KEY"

Calorimetry & Enthalpy

1. For each of the following, define the system and the surroundings, and indicate the direction of heat transfer.
   a) Natural gas is burned in a gas furnace in your home.
   THE COMBUSTION RXN OF THE GAS IS THE SYSTEM.
   THE FURNACE AND HOME ARE THE SURROUNDINGS.
   HEAT IS GOING TO THE SURROUNDINGS.
   b) Water drops, sitting on your skin after a dip in the pool, evaporate.
   H_2O System
   SKIN SURROUNDINGS
   HEAT TRANSFERRED FROM SKIN TO SURROUNDINGS.
2. If you pour hot tea over a cup of ice, what are all the factors that will affect the final temperature of the mixture?
   QUANTITY OF TEA
   QUANTITY OF ICE
   T_{TEA}
   T_{ICE} (ASSUME 0°C, BUT COULD BE COLDER)
3. Does a negative ΔH_{rxn} mean that the heat of reaction can be thought of as a reactant or a product?

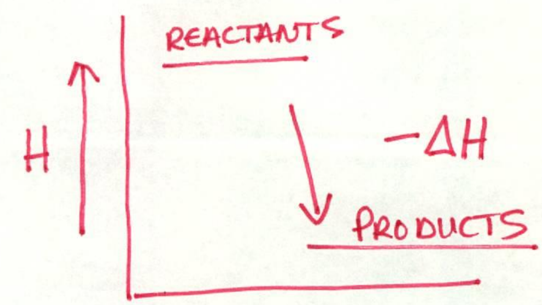
   PRODUCT

4. a) What is the difference between an *endothermic* and an *exothermic* reaction or process? How does this relate to the sign of the enthalpy change for each process?

   ENDOTHERMIC - HEAT GOES FROM SURROUNDINGS TO SYSTEM $+\Delta H$

   EXOTHERMIC - HEAT GOES FROM SYSTEM TO SURROUNDINGS $-\Delta H$

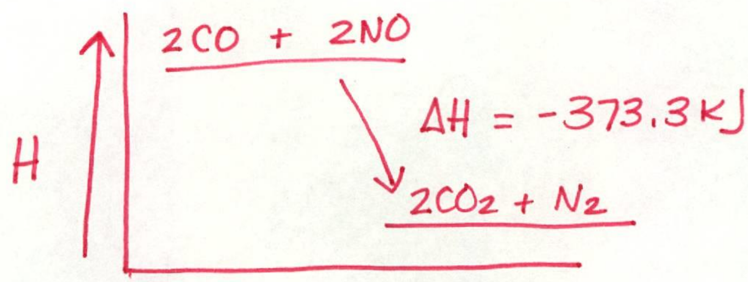
   b) Would the products or reactants of an exothermic reaction have higher thermal energy on an enthalpy diagram? Draw such a diagram to represent a generic exothermic reaction, making sure to label all keys features.



5. For the reaction

$2CO\ (g) + 2NO\ (g) \longrightarrow 2CO_2\ (g) + N_2\ (g)$ $\Delta H = -373.3\ kJ$

a) Which should go at higher energy on an enthalpy diagram, the products or the reactants? **Draw** an enthalpy diagram that illustrates this reaction.



6. If equal amounts of heat are added to equal masses of aluminum and copper, both at the same initial temperature, which will reach the higher final temperature? Explain your answer.

Cu will reach the higher final temperature because it has a smaller specific heat.

$Cu = 0.387\ J/g \cdot °C$

$Al = 0.900\ J/g \cdot °C$

7. The nutritional calorie (Calorie) is equivalent to 1kcal. One pound of body fat is equivalent to about 4.1×10^{10} Calories. Express this energy equivalence in joules and kilojoules.

$$4.1 \times 10^{10}\ Cal \times \frac{1000\ cal}{1\ Cal} \times \frac{4.184\ J}{1\ cal} = 1.7 \times 10^{14}\ J$$

$$1.7 \times 10^{14}\ J \times \frac{1\ kJ}{1000\ J} = 1.7 \times 10^{11}\ kJ$$

8. A 30.5g sample of an alloy at 93.0°C is placed into 50.0g of water at 22.0°C in an insulated coffee cup. If the final temperature of the system is 26.2°C, what is the specific heat of the alloy? Assume all heat transferred is done so between alloy and water only.

26.2
− 22.0

$\Delta t_{H_2O} = 4.2°C$

$c = 4.184\ J/g \cdot °C$

Heat gained by H_2O = heat lost by alloy.

$q_{H_2O} = 50.0g \times 4.184 J/g \cdot °C \times 4.2°C$

$q_{H_2O} = 878.64 J$

$93 - 26.2 = 66.8°C$

$\frac{878.64 J}{(66.8°C) \cdot (30.5g\ alloy)} = c = 0.43\ J/g \cdot °C$

9. Translate the following word statements into complete, balanced thermochemical equations.

a) The complete combustion of acetylene (C_2H_2), the fuel used in acetylene welding torches, produces carbon dioxide gas and water vapor and releases 1256 kJ of heat energy per mole of acetylene.

$2C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O \quad \Delta H = -2512\ kJ$

b) The net reaction involved in the destruction of ozone by chlorofluorocarbons is the reaction of monatomic chlorine gas (Cl) with ozone (O_3) to produce chlorine monoxide gas and oxygen gas. This requires the input of 54 kJ of heat per mole of ozone.

$Cl + O_3 \rightarrow ClO + O_2 \quad \Delta H = +54\ kJ$

c) The production of sulfuric acid rain can be broken down into three key steps. First is the combination of solid sulfur with oxygen gas to produce sulfur dioxide gas. This produces 297 kJ of heat per mole of sulfur. The next step is the combination of sulfur dioxide gas with oxygen gas to produce sulfur trioxide gas. This reaction produces 98 kJ of heat per mole of sulfur dioxide gas reacting. Finally the sulfur trioxide gas combines with water vapor in the air to produce sulfuric acid. This produces 227 kJ of heat per mole of sulfuric acid produced.

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)} \quad \Delta H = -297\ kJ$

$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)} \quad \Delta H = -196\ kJ \quad (2 \times -98kJ)$

$SO_{3(g)} + H_2O_{(g)} \rightarrow H_2SO_4 \quad \Delta H = -227\ kJ$

10. Pure liquid octane (C_8H_{18}, d= 0.702g/mL) is used as the fuel in a test of a new automobile drive train.

a) How much energy is produced (in kJ) when a tank full (20.4gal) is combusted? ΔH_{comb}= -5.45x10^3 kJ/mol)? (Start with a balanced equation for the combustion of one mole of octane to make carbon dioxide and water.)

3.785412L = 1gal

$20.4\,gal \times \frac{3.785412\,L}{1\,gal} = 77.2\,L \times \frac{1000\,mL}{L} = 77{,}200\,mL$

$77{,}200\,mL \times 0.702\,g/mL = \frac{54210\,g}{114.26\,g/mol\ C_8H_{18}} = 474.4\,mol$

$474.4\,mol\ C_8H_{18} \times \frac{5.45 \times 10^3\,kJ}{mol} = 2.59 \times 10^6\,kJ$ **$q = -2.59 \times 10^6\,kJ$**

b) The energy delivered at the wheels at 65mph is 5.5x 10^4 kJ/h. Assuming that all the energy is transferred to the wheels, what is the cruising range of the car (in km) on a full tank?

$2.59 \times 10^6\,kJ \times \frac{1\,h}{5.5 \times 10^4\,kJ} \times \frac{65\,mi}{1\,h} \times \frac{1609\,m}{1\,mi} \times \frac{1\,Km}{1000\,m}$

$= \boxed{4.9 \times 10^3\,Km}$

11. Consider the following reaction:

$2\,Mg(s) + O_2(g) \rightarrow 2\,MgO(s)$; ΔH = -1204 kJ

(a) Is this reaction endothermic of exothermic?

EXOTHERMIC

(b) Calculate the amount of heat produced when 2.4 g of magnesium reacts at constant pressure.

$2.4\,g\,Mg \times \frac{1\,mol\,Mg}{24.3\,g\,Mg} \times \frac{-1204\,kJ}{2\,mol\,Mg} = \boxed{-59\,kJ}$

(c) How many grams of MgO are produced during an enthalpy change of 96.0 kJ?

$96.0\,kJ \times \frac{2\,mol\,MgO}{-1204\,kJ} \times \frac{40.3\,g\,MgO}{1\,mol\,MgO} = \boxed{6.43\,g\,MgO}$

(d) How many kilojoules of heat are absorbed when 7.50 g of MgO are decomposed into magnesium and oxygen at constant pressure?

$\frac{7.50\,g\,MgO}{40.3\,g/mol} = 0.186\,mol\,MgO \times \frac{-1204\,kJ}{2\,mol\,MgO} = \boxed{112\,kJ}$

12. Lightweight camp stoves often make use of a mixture of C_5 and C_6 liquid hydrocarbons (a fuel called "white gas.") How much heat is produced by the complete combustion of 3.00 L of C_5H_{12} (l) given that the enthalpy of combustion is approximately -3540 kJ per mole of C_5H_{12} (l)? (Given: density of C_5H_{12} (l) = 0.625 g/mL)

$$3.00\,L = 3000\,mL \times 0.625\,g/mL = \frac{1875\,g\,C_5H_{12}}{72.17\,g/mol} = 25.98\,mol\,C_5H_{12}$$

$$25.98\,mol\,C_5H_{12} \times \frac{-3540\,kJ}{1\,mol} = \boxed{-9.20 \times 10^4\,kJ}$$

13. Some cold packs used to treat athletic injuries have a small pouch of ammonium nitrate, that when squeezed, dissolves in the surrounding water. This dissolving pulls in heat from its surroundings, to lower the temperature of the pack, according to the following thermochemical equation:

$$NH_4NO_3\,(s) \rightarrow NH_4NO_3\,(aq) \qquad \Delta H_{rxn} = +25.7\,kJ$$

What is the final temperature in °C in a squeezed cold pack that contains 25.0 g of NH_4NO_3 (s), dissolved in 125 mL of H_2O (l), at an initial temperature of 25.0°C? Assume no heat is lost to the environment, all heat transfer is between the system and surrounding water, and that the density of water is 1.00 g/mL. Also assume that the specific heat capacity of the dissolved ammonium nitrate in water is the same as that of water.

$$\frac{25.0\,g\,NH_4NO_3}{80\,g\,NH_4NO_3/mol} = 0.3125\,mol \times \frac{+25.7\,kJ}{mol} = +8.031\,kJ$$

$$8.03 \times 10^3\,J = m \cdot c \cdot \Delta T$$

$$8.03 \times 10^3\,J = 150\,g \cdot (4.184\,J/g \cdot °C) \cdot \Delta T$$

$$\boxed{12.2°C = T_F}$$