Thermodynamics Worksheet

Fill the blanks in the following sentences with the correct thermodynamics term:

1) The thing we measure when we want to determine the average kinetic energy of random motion in the particles of a substance is temperature.

2) The specific heat is the energy needed to raise the temperature of one gram of a substance one degree Celsius.

3) A(n) exothermic reaction is one where the products have lower energy than the reactants.

4) Endothermic reactions require energy in order to take place.

5) Spontaneous changes take place by themselves, without any help.

6) The enthalpy change (ΔH) is used to describe how much energy is produced or used during a chemical change.

7) Potential energy is energy that is stored chemical energy.

8) Kinetic energy is energy associated with the movement of an object.

9) Heat is a form of energy transfer to or from a system. which occurs from hot to cold.

10) Sign Convention: Heat gained (absorbed) is considered +; heat lost by system to surroundings is − .

11) A calorimeter is a device used to measure heat transfer.

12) The standard enthalpy of formation is the enthalpy change in the formation of one mole of a compound when formed in the standard state (T = 298 K; P = 1 atm) from its elements.

13) Hess's Law states that enthalpies of individual reactions can be added to calculate enthalpy of overall reaction.

14) The joule is a metric unit of energy equal to 1 $kg \cdot m^2/sec^2$.

Thermodynamics Worksheet

Fill the blanks in the following sentences with the correct thermodynamics term:

1) The thing we measure when we want to determine the average kinetic energy of random motion in the particles of a substance is _____.

2) The _____ is the energy needed to raise the temperature of one gram of a substance one degree Celsius.

3) A(n) _____ reaction is one where the products have lower energy than the reactants.

4) _____ reactions require energy in order to take place.

5) _____ changes take place by themselves, without any help.

6) The _____ is used to describe how much energy is produced or used during a chemical change.

7) _____ is energy that is stored chemical energy.

8) _____ is energy associated with the movement of an object.

9) _____ is a form of energy transfer to or from a system. which occurs from hot to cold.

10) Sign Convention: Heat gained (absorbed) is considered _____; heat lost by system to surroundings is _____.

11) A _____ is a device used to measure heat transfer.

12) The _____ is the enthalpy change in the formation of one mole of a compound when formed in the standard state (T = 298 K; P = 1 atm) from its elements.

13) _____ states that enthalpies of individual reactions can be added to calculate enthalpy of overall reaction.

14) The _____ is a metric unit of energy equal to 1 $kg \cdot m^2/sec^2$.

Practice Problems:

1) A 12 oz. can of soda weighs about 450. grams. How many joules are released when a can of soda is cooled from 25.0 degrees Celsius (room temperature) to 4.0 degrees Celsius (the temperature of a refrigerator). The heat capacity of liquid water is 4.18 J / g · °C.

$q = m \cdot C \cdot \Delta T$

$q = (450.g)(4.18\ J/g \cdot °C)(25.0-4.0)$

$q = -39,501\ J$

(-39.5 kJ)

2) How many joules are required to heat 250.grams of liquid water from 0.0˚C to 100.0˚ C ?

$q = m \cdot C \cdot \Delta T$

$q = (250.g)(4.184\,J/g\cdot{}^\circ C)(100.0^\circ C)$

$q = +105{,}000\,J$

(105. kJ)

3) By how many degrees Celsius would the temperature of 3 kg of a substance change if the substance absorbed 4.328 kJ of energy? Assume that the specific heat of the substance equals 0.630 J/g˚C.

$q = m \cdot C \cdot \Delta T$

$\Delta T = \frac{q}{m \cdot C}$

$\Delta T = \frac{4328\,kJ}{3000g \cdot 0.630J/g\cdot{}^\circ C} = 2^\circ C$

(2˚C)

4) What amount of heat is released when the temperature of 450.0 g of a substance drops by 7.050˚C? Assume that the specific heat equals 1.264 J/g˚C.

$q = m \cdot C \cdot \Delta T$

$q = (450.0g)(1.264J/g\cdot{}^\circ C)(7.050^\circ C)$

$q = -4010\,J$

(-4010 J)

5) If 2.508 kg of a substance increases in temperature by 4.051˚C when it absorbs 3.42 kJ of energy, what is the specific heat of the substance, in J/g˚C?

$q = m \cdot C \cdot \Delta T$

$C = \frac{q}{m \cdot \Delta T}$ $\quad C = \frac{3420\,J}{2508g \cdot 4.051^\circ C} = .337J/g\cdot{}^\circ C$

(0.337 J/g.˚C)

2 sig. figs.

6) A calorimeter that contains 2.5 kg of water is used to measure the heat associated with the reaction of 520 g of a reactant added to the water. Calculate the energy, in joules per gram of reactant, associated with the reaction if the temperature of the water changes from 27.40˚C to 20.28˚C. Assume that the specific heat of water is 4.184 J/g˚C. Is the reaction exothermic or endothermic?

$m = 2500\,g + 520\,g = 3020\,g$

$q = 3020\,g \cdot 4.184\,J/g\cdot{}^\circ C \cdot (27.40^\circ C - 20.28^\circ C)$

$q = 89966\,J$

$\frac{89966\,J}{520\,g\ \text{reactant}} = 170\,J/g$

(170 J/g; endothermic)

7) A calorimeter that contains 6.050 kg of surrounding water is used to measure the heat associated with the dissolving of 0.50 mole of NaOH. If the initial temperature of the water is 15.0˚C and the final temperature is 19.5˚C, how much heat, in joules per mole of reactant, is associated with the reaction? .Assume the specific heat of the solution is the same as that of water. Is the reaction exothermic or endothermic?

$q = 6050\,g \cdot 4.184\,J/g\cdot{}^\circ C \cdot 4.5^\circ C = 113909\,J$

$\frac{0.50\,mol\ NaOH}{113909\,J} = \frac{1\,mol}{x\,J}$ $\quad x = 227818 \rightarrow 2.3\times10^5\,J/mol$

(2.3 x 10^5 J/mol; exothermic)

8) If you burn 0.315 moles of hexane (C_6H_{14}) in a bomb calorimeter (the combustion material is separated from the water so its mass should not be included in your energy calculation) containing 5.65 liters of water, what's the molar heat of combustion of hexane if the water temperature rises 55.4˚ C? The heat capacity of water is 4.184 J/g˚C.

$q = 5650\,g \cdot 4.184\,J/g\cdot{}^\circ C \cdot 55.4^\circ C = 1309634\,J$

$\frac{0.315\,mol}{1309.634\,KJ} = \frac{1\,mol}{x\,KJ}$ $\quad x = 4157.567\,KJ$

4160 or $4.16\times10^3\,KJ/mol$

(4160 kJ/mol)

9) If you burn 22.0 grams of propane (C_3H_8) in a bomb calorimeter containing 3.25 liters of water, what's the molar heat of combustion of propane if the water temperature rises 29.5˚ C?

$q = 3250\,g \cdot 4.184\,J/g\cdot{}^\circ C \cdot 29.5^\circ C$

$mm_{C_3H_8} = 44.11\,g/mol$ $\quad q = 401141\,J$

$\frac{22.0\,g}{44.11\,g/mol} = 0.4988\,mol$ $\quad \frac{0.4988\,mol}{401.141\,KJ} = \frac{1\,mol}{x\,KJ}$ $\quad x = 804\,KJ/mol$

(804 kJ/mol)

10) As it turns out, the data from the two experiments described above would not give the correct molar heats of combustion for the compounds stated. Explain why this is, based on your knowledge of how calorimetry works.

Heat is lost to calorimeter and air!

11) What is the enthalpy change for the following reaction?

N_2 (g) + 2 H_2 (g) --- > N_2H_4 (l)

Use the following:

H_2 (g) + ½ 0_2 (g) ---> H_20 (g) ----------ΔH = -242 kJ

N_2 (g) + 2 H_20 (g) --- > N_2H_4 (1) + 0_2 (g) ---------ΔH = +534 kJ *(ΔH=50.kJ)*

$2(H_2 + \frac{1}{2}O_2 \rightarrow H_2O)$ $\Delta H = 2(-242\ kJ)$

$N_2 + 2H_2O \rightarrow N_2H_4 + O_2$ $\Delta H = +534\ kJ$

$N_2 + 2H_2O + 2H_2 + O_2 \rightarrow 2H_2O + N_2H_4 + O_2$ $\Delta H = +50.\ kJ$

12) What is the enthalpy change for the following reaction?

CH_4 (g) + 2 0_2 (g) --- > $C0_2$ (g) + 2 H_20 (l)

Use the following:

C (s) + 2 H_2 (g) ---> CH_4 (g) ----------ΔH =-74.8 kJ

C (s) + O_2 (g) ----> CO_2(g)----------ΔH = -393.5 kJ

H_2 (g) + ½ O_2 (g) ----> H_2O (l) ----------ΔH = -235.8 kJ *(ΔH=-790.3kJ)*

$CH_4 \rightarrow 2H_2 + C$ $\Delta H = 74.8\ kJ$

$C + O_2 \rightarrow CO_2$ $\Delta H = -393.5\ kJ$

$2(H_2 + \frac{1}{2}O_2 \rightarrow H_2O)$ $\Delta H = 2(-235.8\ kJ)$

$CH_4 + C + O_2 + 2H_2 + O_2 \rightarrow 2H_2O + CO_2 + 2H_2 + C$

13) Calculate the enthalpy of change for:

2 C_2H_6(g) + 7 0_2(g) ---- > 4 $C0_2$(g) + 6 H_20(g)

Use the following:

2 C(s) + 3 H_2(g) ---- > C_2H_6(g) ----------ΔH = -84.7 kJ

C(s) + 0_2(g) ---- > $C0_2$(g) ----------ΔH = -393.5 kJ

H_2(g) + ½ 0_2(g) ---- > H_20(g) ----------ΔH = -241.8 kJ *(ΔH=-2855.4kJ)*

$2(C_2H_6 \rightarrow 3H_2 + 2C)$ $\Delta H = 2(84.7\ kJ)$

$4(C + O_2 \rightarrow CO_2)$ $\Delta H = 4(-393.5\ kJ)$

$6(H_2 + \frac{1}{2}O_2 \rightarrow H_2O)$ $\Delta H = 6(-241.8\ kJ)$

$2C_2H_6 + 4C + 4O_2 + 6H_2 + 3O_2 \rightarrow 6H_2 + 4C + 4CO_2 + 6H_2O$

$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

14) The standard heat of formation, ΔH of, for sulfur dioxide (SO_2) is -297 kJ/mol. How many kJ of energy are given off when 25.0 g of SO_2 (g) is produced from its elements?

$S + O_2 \rightarrow SO_2 \quad \Delta H = -297 kJ$

$$\frac{25.0 g\ SO_2}{64.07 g/mol} = 0.3902 mol\ SO_2$$

$$\frac{1 mol\ SO_2}{-297 kJ} = \frac{0.3902 mol\ SO_2}{x\ kJ} \quad x = -116 kJ$$

(-116kJ)

15) The heat of reaction for the combustion of 1 mol of ethyl alcohol is -9.50×10^2 kJ:

$$C_2H_5OH\ (l) + 3\ O_2\ (g) \rightarrow 2\ CO_2\ (g) + 3\ H_2O\ (l) + 9.5 \times 10^2\ kJ$$

How much heat is produced when 11.5 g of alcohol is burned?

$$\frac{11.5 g\ C_2H_5OH}{46.08 g/mol} = 0.2496 mol\ C_2H_5OH$$

$$\frac{1 mol\ C_2H_5OH}{9.5 \times 10^2 kJ} = \frac{0.2496 mol}{x\ kJ}$$

$x = 238 kJ$ *(2.38×10^2 kJ)*

16) ΔH for the complete combustion of 1 mol of propane is -2.22×10^3 kJ:

$$C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4\ H_2O\ (l)$$

Calculate the heat of reaction for the combustion of 33.0 g of propane.

$$\frac{33.0 g\ C_3H_8}{44.11 g/mol} = 0.7481 mol\ C_3H_8$$

$$\frac{1 mol}{2.22 \times 10^3 kJ} = \frac{0.7481 mol}{x\ kJ}$$

$x = 1660 kJ$

(1.67×10^3 kJ)

17) Calcium carbonate decomposes at high temperature to form carbon dioxide and calcium oxide:

$$CaCO_3 \rightarrow CO_2 + CaO$$

Given that the heat of formation of calcium carbonate is –1207 kJ/mol, the heat of formation of carbon dioxide is –394 kJ/mol, and the heat of formation of calcium oxide is –635 kJ/mol, determine the heat of reaction.

$\Delta H_{RXN} = [1(-394\,kJ) + 1\cdot(-635K)] - [1\cdot(-1207KJ)]$

$= +178\ KJ$

(ΔH_{rxn} =+178 kJ)

18) Carbon tetrachloride can be formed by reacting chlorine with methane:

$$CH_4 + 2\ Cl_2 \rightarrow CCl_4 + 2\ H_2$$

$\Delta H=0$ $\Delta H>0$

Given that the heat of formation of methane is –75 kJ/mol and the heat of formation of carbon tetrachloride is –135 kJ/mol, determine the heat of reaction.

$\Delta H_{RXN} = (-135) - (-75) = -60,K$

(ΔH_{rxn} = -60. kJ)

19) When potassium chloride reacts with oxygen under the right conditions, potassium chlorate is formed:

$$2\ KCl + 3\ O_2 \rightarrow 2KClO_3$$

$\Delta H=0$

Given that the heat of formation of potassium chloride is –436 kJ/mol and the heat of formation of potassium chlorate is –391 kJ/mol, determine the heat of reaction.

$\Delta H = [2\cdot(-391\,KJ)] - [2\cdot(-436KJ)] = 90K$

(ΔH_{rxn} = 90. kJ)