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Chapter 8 Practice Worksheet:
Thermochemistry: Chemical Energy

1) Describe the difference between potential energy and kinetic energy.

PE: stored energy; KE: energy of motion/vibration/reaction

2) What is the difference between heat and temperature?

Temperature is a measure of the kinetic energy of molecules in a substance. Heat is a measurement of the total **energy** in a substance (potential and kinetic).

3) Describe what we mean by conservation of energy. Give an example.

Conservation of energy means that energy cannot be created or destroyed, only converted from one form to another. For example, in a chemical reaction, potential energy stored in chemical bonds may be converted to heat, light, or sound energy as a result of a chemical reaction.

4) Draw a picture showing the direction of heat flow in an endothermic reaction versus an exothermic reaction. Define the system and the surroundings in each case.

(See figure 8.2 on page 301)

5) Explain why boiling water is an endothermic process. (Hint: Think about what is happening to the attractive forces between water molecules.)

Boiling water is endothermic because heat must be absorbed (go into) the system in order to break the intermolecular forces that hold molecules together.

6) Hydrogen gas and oxygen gas release 482.6 kJ of heat when they combine to form steam. Is this reaction endothermic or exothermic? In which direction does heat transfer (between system and the surroundings) for this reaction? Is ΔH for this reaction positive or negative?

Exothermic (release is the key word). Heat transfers from the system to the surroundings. ΔH is negative.

7) _2__ H_2 (g) + ___ O_2 (g) → _2__ H_2O (g) $\Delta H = -482.6$ kJ

a. Interpret this thermochemical equation (i.e., how much heat is given off per amount of each substance?).

For every 2 moles of H_2, 482.6 kJ of energy are given off (482.6 kJ/2 mol H_2). We can also write this in terms of oxygen or steam: 482.6 kJ/1 mol O_2; 482.6 kJ/2 mol H_2O

b. How much heat is released if we begin with 2.0087 g of O_2 gas?

2.0087 g O_2 → mol O_2 → heat released: 30.29 kJ of heat given off

c. How much heat is released if we begin with 1.5021 g of H_2 gas?

1.5021 g H_2 → mol H_2 → heat released: 179.8 kJ of heat given off

8) Which substance in each pair below has a higher specific heat? Circle your answer.

a)	aluminum foil	water
b)	wood	metal
c)	ethanol (C = 2460 J/kg·°C)	gold (C = 129 J/kg·°C)
d)	mercury	copper

9) How much heat is lost when a 640 g piece of copper cools from 375°C to 26°C? (The specific heat of copper is 0.385 J/g·°C)

86 kJ of heat lost

10) The specific heat of iron is 0.4494 J/g·°C. How much heat is transferred when a 24.7 kg iron bar is cooled from 880°C to 13°C?

9.6×10^3 kJ of heat are transferred from the iron to air or water (or whatever cooler substance it was placed in)

11) 8750 J of heat are applied to a 170 g sample of metal, causing a 56°C increase in its temperature. What is the specific heat of the metal? Which metal is it?

q = m*sp.ht.*ΔT; sp.ht. = 0.919 J/g°C; metal is aluminum

12) Use the following enthalpies of reaction to determine the enthalpy for the reaction of ethylene with fluorine.

C_2H_4 (g) + $6F_2$ (g) → $2CF_4$ (g) + 4HF (g) ΔH = ?

H_2 (g) + F_2 (g) → 2HF (g) ΔH = -537 kJ (multiply x 2)

C (s) + $2F_2$ (g) → CF_4 (g) ΔH = -680 kJ (multiply x 2)

2C (s) + $2H_2$ (g) → C_2H_4 (g) ΔH = 52.3 kJ (reverse)

-2486.3 kJ

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13) Using the thermochemical equations below, what combination of the following numbered ΔH's (1-4) will determine the ΔH_{rxn}? If a reaction needs to be reversed, write it as –ΔH. If a reaction needs to be multiplied by a factor (x), write it as xΔH.

$Mg_3N_2 + 3H_2O \rightarrow 3MgO + 2NH_3$ $\quad \Delta H_{rxn} = ?$

$3Mg + N_2 \rightarrow Mg_3N_2$ $\quad \Delta H_1$

$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ $\quad \Delta H_2$

$Mg + \frac{1}{2} O_2 \rightarrow MgO$ $\quad \Delta H_3$

$\frac{1}{2} N_2 + 3/2\, H_2 \rightarrow NH_3$ $\quad \Delta H_4$

$\Delta H_{rxn} = -\Delta H_1 + -3\,\Delta H_2 + 3\,\Delta H_3 + 2\,\Delta H_4$

14) Which of the following substances do **NOT** have $\Delta H^o_f = 0$?

Cl_2 (g) Na (l) K (s) O (g) S_8 (s) Br_2 (l)

15) Calculate the standard enthalpy of formation of solid $Mg(OH)_2$ given the data shown below. (Hint: Write the equation for the standard enthalpy of formation of $Mg(OH)_2$ (starting from elements and forming 1 mol of product) first.)

$2Mg (s) + O_2 (g) \rightarrow 2 MgO (s)$	$\Delta H^o = -1203.6$ kJ	(multiply x ½)
$Mg(OH)_2 (s) \rightarrow MgO (s) + H_2O (l)$	$\Delta H^o = +37.1$ kJ	(reverse)
$2H_2 (g) + O_2 (g) \rightarrow 2H_2O (l)$	$\Delta H^o = -571.7$ kJ	(multiply x ½)

$Mg (s) + O_2 (g) + H_2 (g) \rightarrow Mg(OH)_2 (s)$ $\quad \Delta H^o = -924.8$ KJ

16) Write the equation that represents the standard enthalpy of formation of:

a) MgO (s): $Mg (s) + \frac{1}{2} O_2 (g) \rightarrow MgO (s)$

b) H_2O (l): $H_2 (g) + \frac{1}{2} O_2 (g) \rightarrow H_2O (l)$

c) $BaCl_2$ (s): $Ba (s) + Cl_2 (g) \rightarrow BaCl_2 (s)$

17) Calculate the ΔH^o of reaction for:

$BaO (s) + SO_3 (g) \rightarrow BaSO_4 (s)$

The values of ΔH^o_f are as follows: BaO (s) = -548 kJ/mol; SO_3 (g) = -395.7 kJ/mol; $BaSO_4$ (s) = -1473 kJ/mol.

$[BaSO_4] – [BaO + SO_3]$ = [-1473 kJ/mol] – [-548 kJ/mol + -395.7 kJ/mol] = -529.3 kJ

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18) Calculate the ΔH^o of reaction for:

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

The values of ΔH^o_f are as follows: C_3H_8 (g) = -103.95 kJ/mol; CO_2 (g) = -393.5 kJ/mol; H_2O (l) = -285.8 kJ/mol

[3(CO_2) + 4(H_2O)] – [C_3H_8 + 5(O_2)]
= [3(-393.5 kJ/mol) + 4(-285.8 kJ/mol)] – [(-103.95 kJ/mol + 0)]
= -2219.8 kJ

19) Determine the enthalpies of the following reactions using average bond enthalpies (from Table 7.1).

a. CH_4 (g) + Cl_2 (g) → CH_3Cl (g) + HCl (g) **($BE_{C\text{-}Cl}$ = 328 kJ/mol)**

ΔH^o = 4(C-H) + 1(Cl-Cl) + -3(C-H) + -1(C-Cl) + -1(H-Cl) = **-109 kJ/mol**

b. N_2H_4 (g) → N_2 (g) + $2H_2$ (g) **(N_2H_4 = H_2N – NH_2)**

ΔH^o = 1(N-N) + 4(N-H) + -1(N≡N) + 2(H-H) = **-17 kJ/mol**

c. $4NH_3$ (g) + $5O_2$ (g) → 4NO (g) + $6H_2O$ (g) **($BE_{N=O}$ = 631 kJ/mol)**

ΔH^o = 12(N-H) + 5(O=O) + -4(N=O) + -12(H-O) = **-874 kJ/mol**