Thermochemistry Practice Problems

1. Brass has a density of 8.40 g/cm^3 and a specific heat of 0.385 J/g•°C. A 14.5 cm^3 piece of brass at an initial temperature of 152 °C is dropped into an insulated container with 138 g water initially at 23.7 °C. What will be the final temperature of the brass-water mixture?

2. The combustion of methane gas, the principal constituent of natural gas, is represented by the equation:

   $CH_{4\,(g)} + 2\ O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2\ H_2O_{(l)}$ $\Delta H = -890.3$ kJ

   a. What mass of methane, in kg, must be burned to liberate 1.00×10^6 kJ of heat?

   b. What quantity of heat, in kJ, is liberated in the complete combustion of 1.03×10^3 L of $CH_{4\,(g)}$, measured at 21.8 °C and 748 mmHg?

   c. If the quantity of heat calculated in (b) could be transferred with 100 % efficiency to water, what volume of water, in L, could be heated from 22.7 to 60.8 °C as a result?

3. The enthalpy change in the combustion of the hydrocarbon octane is $\Delta H = -5.48 \times 10^3$ kJ/mol $C_8H_{18\,(l)}$. How much heat, in kJ, is liberated per gallon of octane? (Density of octane = 0.703 g/mL; 1 gal = 3.785 L)

4. Care must be taken in preparing solutions of solutes that liberate heat on dissolving. The heat of solution of NaOH is - 42 kJ/mol NaOH. To what approximate temperature will a sample of water, originally at 21°C, be raised in the preparation of 500 mL of 7.0 M NaOH? Assume that no effort is made to remove heat from the solution.

5. o-phthalic acid, $C_8H_6O_4$, is sometimes used as a calorimetric standard. Its heat of combustion is -3.224×10^3 kJ/mol $C_8H_6O_4$. From the following data determine the heat capacity of a bomb calorimeter assembly (i.e., of the bomb, water, stirrer, thermometer, wires, etc.)

mass of o-phthalic acid burned:	1.078 g
initial calorimeter temperature	24.96 °C
final calorimeter temperature	30.76 °C

6. Use data from the Appendix and ΔH° for the following reaction to determine the enthalpy of formation of $C_6H_{14\,(l)}$ at 25°C and 1 atm.

   $2\ C_6H_{14\,(l)} + 19\ O_2 \rightarrow 12\ CO_{2\,(g)} + 14\ H_2O_{(l)}$ $\Delta H° = -8326$ kJ

7. 5.93 g of CH_3CHO is combusted in 9.29 L of $O_{2\,(g)}$ measured at 25 °C and 1.00 atm. How much heat is produced? (Assume that water is produced as a liquid.) $\Delta H°_f$ CH_3CHO = - 166 kJ/mol.

8. a. Calculate the amount of energy involved when 300. mL of 2.00 M NaOH is mixed with 400. mL of 1.00 M H_2SO_4.
($\Delta H°_f$ values: $NaOH_{(aq)}$ = -470.114 kJ/mol, $H_2SO_{4\,(aq)}$ = - 909.27 kJ/mol, $Na_2SO_{4\,(aq)}$ = - 1390 kJ/mol, $H_2O_{\,(l)}$ = - 285.83 kJ/mol)
b. If both of the original solutions start at 25°C, what is the final temperature of the solutions after the reaction? Assume no heat is lost to the surroundings, and assume the heat capacity of the final solution is 4.2 J/g°C and that it has a density of 1.05 g/mL.
c. How many moles of NaOH and H_2SO_4 would be needed to give off 100. kJ of energy?

9. Calculate the amount of energy needed to convert 250. g of ice at - 25 °C to steam at 250.°C. Heat capacities may be found on p. 254 of the text.

10. If 136 kJ of energy is added to water, what mass of water can be heated from 25 °C to 100°C <u>and</u> vaporized at 100°C?

11. Benzoic acid, $C_7H_6O_2$, occurs naturally in many berries. Suppose you burn 1.500 g of the compound in a combustion calorimeter and find that the temperature of the calorimeter increases from 22.50 °C to 31.69 °C. The calorimeter contains 775 g of water, and the bomb has a heat capacity of 893 J/K. How much heat is evolved per mole of benzoic acid?

12. Refer to problem 11 above. The balanced equation for the combustion of benzoic acid is

$$2\ C_7H_6O_{2\,(s)} + 15\ O_{2\,(g)} \rightarrow 14\ CO_{2\,(g)} + 6\ H_2O_{\,(l)}.$$

Calculate ΔE and ΔH for the above reaction as written. Assume the reaction occurs at 31.69°C.

13. a. Given the following thermochemical equations:

$N_{2\,(g)} + O_{2\,(g)} \rightarrow 2\ NO_{(g)}$ ΔH = 180.6 kJ
$N_{2\,(g)} + 3\ H_{2\,(g)} \rightarrow 2\ NH_{3\,(g)}$ ΔH = -91.8 kJ
$2\ H_{2\,(g)} + O_{2\,(g)} \rightarrow 2\ H_2O_{(g)}$ ΔH = - 483.7 kJ

calculate ΔH for the following reaction:
$4\ NH_{3\,(g)} + 5\ O_{2\,(g)} \rightarrow 4\ NO_{(g)} + 6\ H_2O_{(g)}$

b. Use your answer to part a to determine ΔH for:
$NO_{(g)} + 1.5\ H_2O_{(g)} \rightarrow NH_{3\,(g)} + 1.25\ O_{2\,(g)}$

Answers:

1. $33.3°C$
2. a. 18.0 kg
   b. $- 3.73 \times 10^4$ kJ
   c. 234 L
3. $- 1.28 \times 10^5$ kJ
4. 91 °C
5. 3.61 kJ/°C
6. - 1.99 kJ/mol
7. - 161 kJ
8. a. - 33.6 kJ
   b. 36 °C
   c. 1.79 mol NaOH, 0.893 mol H_2SO_4
9. 8.4×10^2 kJ
10. 52.8 g
11. $- 3.09 \times 10^3$ kJ/mol
12. $\Delta E = - 6.18 \times 10^3$ kJ
    $w = + 2.534$ kJ
    $\Delta H = - 6.18 \times 10^3$ kJ
13. a. – 906.3 kJ
    b. + 226.6 kJ