

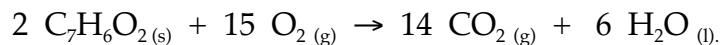
## Thermochemistry Practice Problems

1. Brass has a density of  $8.40 \text{ g/cm}^3$  and a specific heat of  $0.385 \text{ J/g}\cdot^\circ\text{C}$ . A  $14.5 \text{ cm}^3$  piece of brass at an initial temperature of  $152^\circ\text{C}$  is dropped into an insulated container with  $138 \text{ g}$  water initially at  $23.7^\circ\text{C}$ . 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:  
$$\text{CH}_4(\text{g}) + 2 \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{l}) \quad \Delta\text{H} = -890.3 \text{ kJ}$$
  - a. What mass of methane, in kg, must be burned to liberate  $1.00 \times 10^6 \text{ kJ}$  of heat?
  - b. What quantity of heat, in kJ, is liberated in the complete combustion of  $1.03 \times 10^3 \text{ L}$  of  $\text{CH}_4(\text{g})$ , measured at  $21.8^\circ\text{C}$  and  $748 \text{ mmHg}$ ?
  - 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  $60.8^\circ\text{C}$  as a result?
3. The enthalpy change in the combustion of the hydrocarbon octane is  $\Delta\text{H} = -5.48 \times 10^3 \text{ kJ/mol C}_8\text{H}_{18}(\text{l})$ . How much heat, in kJ, is liberated per gallon of octane? (Density of octane =  $0.703 \text{ g/mL}$ ;  $1 \text{ gal} = 3.785 \text{ L}$ )
4. Care must be taken in preparing solutions of solutes that liberate heat on dissolving. The heat of solution of NaOH is  $-42 \text{ kJ/mol NaOH}$ . To what approximate temperature will a sample of water, originally at  $21^\circ\text{C}$ , be raised in the preparation of  $500 \text{ mL}$  of  $7.0 \text{ M NaOH}$ ? Assume that no effort is made to remove heat from the solution.
5. o-phthalic acid,  $\text{C}_8\text{H}_6\text{O}_4$ , is sometimes used as a calorimetric standard. Its heat of combustion is  $-3.224 \times 10^3 \text{ kJ/mol C}_8\text{H}_6\text{O}_4$ . 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	$24.96^\circ\text{C}$
final calorimeter temperature	$30.76^\circ\text{C}$
6. Use data from the Appendix and  $\Delta\text{H}^\circ$  for the following reaction to determine the enthalpy of formation of  $\text{C}_6\text{H}_{14}(\text{l})$  at  $25^\circ\text{C}$  and  $1 \text{ atm}$ .  
$$2 \text{C}_6\text{H}_{14}(\text{l}) + 19 \text{O}_2 \rightarrow 12 \text{CO}_2(\text{g}) + 14 \text{H}_2\text{O}(\text{l}) \quad \Delta\text{H}^\circ = -8326 \text{ kJ}$$
7.  $5.93 \text{ g}$  of  $\text{CH}_3\text{CHO}$  is combusted in  $9.29 \text{ L}$  of  $\text{O}_2(\text{g})$  measured at  $25^\circ\text{C}$  and  $1.00 \text{ atm}$ . How much heat is produced? (Assume that water is produced as a liquid.)  
 $\Delta\text{H}^\circ_{\text{f}} \text{ CH}_3\text{CHO} = -166 \text{ kJ/mol}$ .

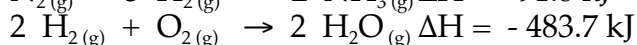
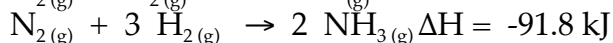
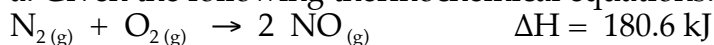
8. a. Calculate the amount of energy involved when 300. mL of 2.00 M NaOH is mixed with 400. mL of 1.00 M H<sub>2</sub>SO<sub>4</sub>.  
 ( $\Delta H^\circ_f$  values: NaOH<sub>(aq)</sub> = -470.114 kJ/mol, H<sub>2</sub>SO<sub>4(aq)</sub> = -909.27 kJ/mol, Na<sub>2</sub>SO<sub>4(aq)</sub> = -1390 kJ/mol, H<sub>2</sub>O<sub>(l)</sub> = -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<sub>2</sub>SO<sub>4</sub> 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 and vaporized at 100°C?
11. Benzoic acid, C<sub>7</sub>H<sub>6</sub>O<sub>2</sub>, 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

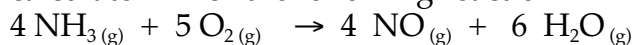


Calculate  $\Delta E$  and  $\Delta H$  for the above reaction as written. Assume the reaction occurs at 31.69°C.

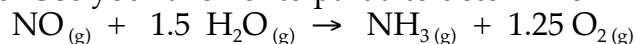
13. a. Given the following thermochemical equations:



calculate  $\Delta H$  for the following reaction:



- b. Use your answer to part a to determine  $\Delta H$  for:



**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<sub>2</sub>SO<sub>4</sub>
9.  $8.4 \times 10^2$  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