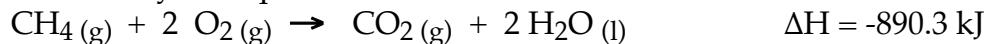


## Thermochemistry Practice Problems

1. Brass has a density of  $8.40 \text{ g/cm}^3$  and a specific heat of  $0.385 \text{ J/g}\bullet\text{°C}$ . A  $14.5 \text{ cm}^3$  piece of brass at an initial temperature of  $152 \text{ °C}$  is dropped into an insulated container with  $138 \text{ g}$  water initially at  $23.7 \text{ °C}$ . 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:

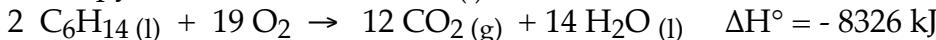


- What mass of methane, in kg, must be burned to liberate  $1.00 \times 10^6 \text{ kJ}$  of heat?
  - What quantity of heat, in kJ, is liberated in the complete combustion of  $1.03 \times 10^3 \text{ L}$  of  $\text{CH}_4(\text{g})$ , measured at  $21.8 \text{ °C}$  and  $748 \text{ mmHg}$ ?
  - If 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  $60.8 \text{ °C}$  as a result?
3. The enthalpy change in the combustion of the hydrocarbon octane is  $\Delta H = -5.48 \times 10^3 \text{ kJ/mol C}_8\text{H}_{18}(\text{l})$ . 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  $\text{NaOH}$  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.)

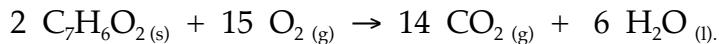
mass of o-phthalic acid burned:	1.078 g
initial calorimeter temperature	$24.96 \text{ }^\circ\text{C}$
final calorimeter temperature	$30.76 \text{ }^\circ\text{C}$

6. Use data from the Appendix and  $\Delta H^\circ$  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  $1 \text{ atm}$ .



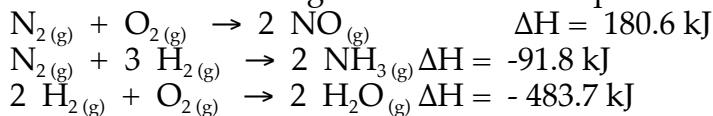
7.  $5.93 \text{ g}$  of  $\text{CH}_3\text{CHO}$  is combusted in  $9.29 \text{ L}$  of  $\text{O}_2(\text{g})$  measured at  $25 \text{ }^\circ\text{C}$  and  $1.00 \text{ atm}$ . How much heat is produced? (Assume that water is produced as a liquid.)  $\Delta H_f^\circ \text{ CH}_3\text{CHO} = -166 \text{ kJ/mol}$ .

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>.  
 $(\Delta H^\circ_f \text{ values: } \text{NaOH}_{(\text{aq})} = -470.114 \text{ kJ/mol}, \text{H}_2\text{SO}_4_{(\text{aq})} = -909.27 \text{ kJ/mol},$   
 $\text{Na}_2\text{SO}_4_{(\text{aq})} = -1390 \text{ kJ/mol}, \text{H}_2\text{O}_{(\text{l})} = -285.83 \text{ kJ/mol})$
- 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

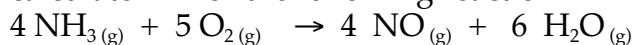


Calculate ΔE and ΔH for the above reaction as written. Assume the reaction occurs at 31.69°C.

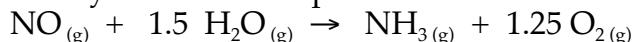
13. a. Given the following thermochemical equations:



calculate ΔH for the following reaction:



b. Use your answer to part a to determine ΔH for:



**Answers:**

- |  |                                       |
|--|---------------------------------------|
| 1. 33.3°C  | 9. $8.4 \times 10^2$ kJ               |
| 2. a. 18.0 kg  | 10. 52.8 g                            |
| b. $-3.73 \times 10^4$ kJ                                  | 11. $-3.09 \times 10^3$ kJ/mol        |
| c. 234 L   | 12. $\Delta E = -6.18 \times 10^3$ kJ |
| 3. $-1.28 \times 10^5$ kJ                                  | $w = +2.534$ kJ                       |
| 4. 91 °C   | $\Delta H = -6.18 \times 10^3$ kJ     |
| 5. 3.61 kJ/°C  | 13. a. -906.3 kJ                      |
| 6. -1.99 kJ/mol  | b. +226.6 kJ                          |
| 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> |                                       |