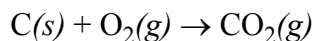
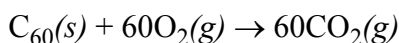


## Chapter 7 Wrap-Up Problems – Answer Key

1. Carbon is found in several forms. Graphite and diamond are common forms that have been known for millennia; other forms, such as buckyballs, have been known for only decades. Combustion of graphite in the presence of oxygen, forms carbon dioxide



releasing 394 kJ of energy per mole of C atoms. Combustion of buckyballs,  $\text{C}_{60}$

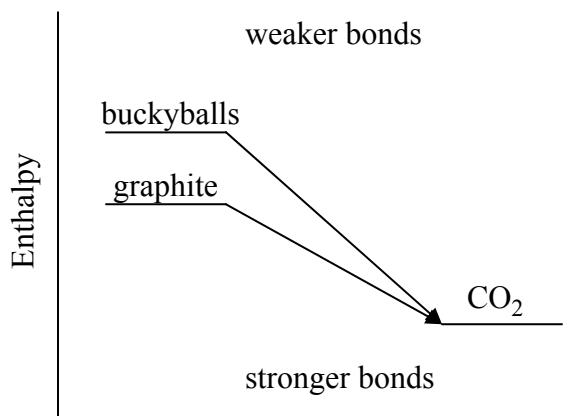


releases approximately 26100 kJ of energy is released per mole of  $\text{C}_{60}$ . Which of these two forms of carbon has the stronger average carbon-carbon bond? Assume that for graphite and buckyballs, the number of bonds per carbon atom is the same. Clearly explain your reasoning.

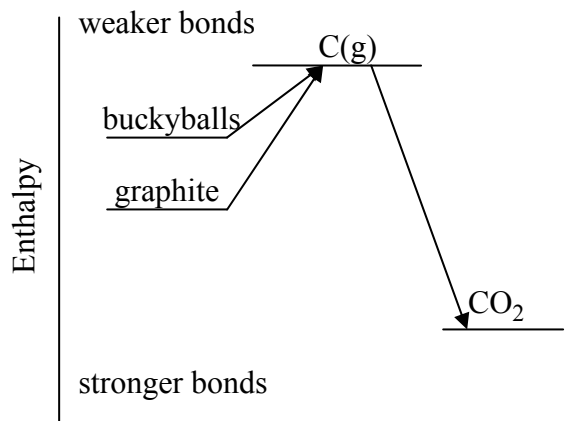
*Answer.* To make a comparison we first convert the energy released during the combustion of buckyballs from kJ/mol  $\text{C}_{60}$  to kJ/mol C; thus

$$\frac{26100 \text{ kJ}}{\text{mol C}_{60}} \times \frac{1 \text{ mol C}_{60}}{60 \text{ mol C}} = \frac{435 \text{ kJ}}{\text{mol C}}$$

Converting a mole of buckyballs to  $\text{CO}_2$  releases more energy per mole of carbon than converting a mole of graphite to  $\text{CO}_2$ . We know that a reaction is exothermic (energy released) when moving from reactants that have weaker bonds to products with stronger bonds. Because both reactions end at the same final state ( $\text{CO}_2$ ) and buckyballs release more energy per mole of C this form of carbon must have the weaker bonds (see figure below). Graphite, therefore, has the stronger bonds.

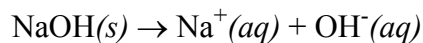


An alternative way to view this is to imagine that the reaction occurs by first converting the graphite and buckyballs to gas-phase carbon atoms and then allowing the atoms to react with O<sub>2</sub> to form CO<sub>2</sub>; the energy diagram now looks like this:



The energy needed to convert the buckyballs to C(g) is less than the energy needed to convert the graphite to C(g); thus, the carbon-carbon bonds in buckyballs must be weaker than those in graphite.

2. In an experiment to determine the enthalpy of dissolution for solid NaOH



a student dissolves 2.0 g of solid NaOH in 100.0 mL of water in a calorimeter and observes a temperature increase. In a second experiment she uses 4.0 g of NaOH and 200.0 mL of water. Will the change in temperature in the second experiment be:

- (a) the same
- (b) approximately twice that of the first experiment
- (c) approximately four times that of the first experiment
- (d) approximately one-half of that for the first experiment
- (e) approximately one-fourth of that for the first experiment?

Explain your reasoning.

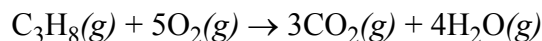
*Answer.* If the amount of heat released when 2.0 g of NaOH dissolves is X, then  $q_{\text{rxn1}} = X$ . The amount of heat released when dissolving 4.0 g of NaOH must be twice as great, or 2X, and  $q_{\text{rxn2}} = 2X$ . In each case the amount of heat absorbed by the solution,  $q_{\text{soln}}$ , is equal in magnitude but opposite in sign from  $q_{\text{rxn}}$ ; thus, assuming a density of 1.00 g/mL, we find that

$$q_{\text{soln1}} = (100.0 \text{ g}) \times (4.184 \text{ J/g}\cdot\text{C}) \times \Delta T_1 = -X$$

$$q_{\text{soln2}} = (200.0 \text{ g}) \times (4.184 \text{ J/g}\cdot\text{C}) \times \Delta T_2 = -2X$$

Solving each equation for  $\Delta T$  shows that  $\Delta T_1$  and  $\Delta T_2$  must be the same.

3. Propane,  $\text{C}_3\text{H}_8$ , is a gas at room temperature. To transport propane over a long distance, however, it is stored in liquid form. In the spring of 1996 five tank cars containing propane derailed in Weyauwega, WI forcing evacuation of the town for over a week due to the risk of a potential explosion. Residents within a square mile of the accident site were unable to return to their homes for over two weeks. Assuming that each tank car had a capacity of 126,800 L, knowing that the density of liquid propane at its boiling point ( $-44.5^\circ\text{C}$ ) is 0.5853 g/mL and assuming that the propane vaporized and warmed to  $25^\circ\text{C}$ , how many kJ of heat would have evolved if the propane in all five tanks reacted explosively with oxygen in the air according to the following reaction?



The standard state enthalpy of formation for  $\text{C}_3\text{H}_8(\text{g})$ , which is not listed in Appendix B.16 of your textbook, is  $-104 \text{ kJ/mol}$ .

*Answer.* First, we need to calculate the reaction's enthalpy change. Using heats of formation, this is

$$\Delta H^\circ_{\text{rxn}} = [(3)(-393.5) + (4)(-241.8)] - [(1)(-104) + (5)(0)] = -2043.7 \text{ kJ/mol}_{\text{rxn}}$$

Next, we need to convert this to the energy released when the entire contents of all five tank cars react; thus

$$\begin{aligned} & \frac{-2043.7 \text{ kJ}}{\text{mol}_{\text{rxn}}} \times \frac{1 \text{ mol}_{\text{rxn}}}{1 \text{ mol C}_3\text{H}_8} \times \frac{1 \text{ mol C}_3\text{H}_8}{44.094 \text{ g C}_3\text{H}_8} \times \frac{0.5853 \text{ g C}_3\text{H}_8}{\text{mL}} \\ & \times \frac{1000 \text{ mL}}{\text{L}} \times \frac{126,800 \text{ L}}{\text{car}} \times 5 \text{ cars} = -1.720 \times 10^{10} \text{ kJ} \end{aligned}$$

The explosive decomposition of TNT ( $\text{C}_7\text{H}_5\text{N}_3\text{O}_6$ ) has an enthalpy change of  $-1066.1 \text{ kJ}$  per mole of TNT. How many kg of TNT are needed to provide an energy equivalent to that produced by the combustion of five tank cars of propane?

*Answer.* This is just a simple conversion, as shown here.

$$-1.720 \times 10^{10} \text{ kJ} \times \frac{1 \text{ mol TNT}}{-1066.1 \text{ kJ}} \times \frac{227.14 \text{ g TNT}}{\text{mol TNT}} \times \frac{1 \text{ kg TNT}}{1000 \text{ g TNT}} = 3.664 \times 10^6 \text{ kg TNT}$$

By the way, this is equivalent to  $8.078 \times 10^6$  pounds or 4039 tons of TNT.