Enthalpy: Review Questions

1. How much heat energy (in joules) is required to raise the temperature of 454 g of tin from room temperature (25.0 ^{0}C) to its melting point, 231.9 ^{0}C, and then melt the tin at that temperature? The specific heat of tin is 0.227 J/g.K , and the metal requires 59.2 J/g to convert the solid to a liquid.

2. Ethanol, C_2H_5OH, boils at 78.29 ^{0}C. How much heat energy (in joules) is required to heat 1.00 kg of this liquid from 20.0 ^{0}C to the boiling point and then change the liquid completely to a vapor at that temperature? (The specific heat of liquid ethanol is 2.44 J/g K, and the enthalpy of vaporization is 38.56 kJ/mol.)

3. Methanol, CH_3OH, is a possible automobile fuel. The alcohol produces energy in a combustion reaction with O_2:

$$2CH_3OH_{(g)} + 50_{2\,(g)} \longrightarrow 2\,CO_{2(g)} + 4\,H_2O_{(g)}$$

A 0.115 g sample of methanol evolves 1110 J when burned at constant pressure. What is the enthalpy change, ? H^0_{rxn}, for the reaction? What is the enthalpy change per mole of methanol (often called the molar heat of combustion)?

4. Nitrogen monoxide has recently been found to be involved in a wide range of biological processes. The gas reacts with oxygen to give brown $N0_2$ gas:

$$2NO_{(g)} + O_{2(g)} \longrightarrow 2\,NO_{2(g)} \qquad ?\,H^0_{rxn} = -114.1\text{ kJ}$$

Is the reaction endothermic or exothermic? If 1.25 g of NO is converted completely to $N0_2$, what quantity of heat is absorbed or evolved?

5. Calcium carbide, CaC_2, is manufactured by reducing lime (CaO) with carbon at a high temperature. The carbide is used to make acetylene, an industrially important organic chemical:

$$CaO_{(s)} + 3\,C_{(s)} \longrightarrow CaC_{2(s)} + CO_{(g)} \qquad ?\,H^0_{rxn} = +464.8\text{ kJ}$$

Is the reaction endothermic or exothermic? If 10.0 g of CaO is allowed to react with an excess of carbon, what quantity of heat is absorbed or evolved by the reaction?

6. White phosphorus, P_4, ignites in air to produce heat, light, and P_40_{10}

$$P_{4(s)} + 5\,0_{2(g)} \longrightarrow P_4O_{10(s)}$$

If 3.56 g of P_4 is burned, 37.4 kJ of heat is evolved at constant pressure. What is the enthalpy change for the combustion of 1 mol of P_4?
Use this information to calculate the enthalpy change for the formation of 1 mol of $PCI_{3(l)}$ from P_4 and $Cl_{2\,(g)}$.

7. Suppose you wish to know the enthalpy change for the formation of benzene, C_6H_6 , and that the value is not available directly from any data tables.

$$6\,C_{(graphite)} + 3\,H_{2(g)} \longrightarrow C_6H_{6\,(l)} \qquad ?\,H^0_{rxn} = ?$$

Use information from the Data Book and the enthalpy change for the combustion of benzene, which was determined experimentally, to calculate the standard molar enthalpy of formation of benzene.

$$2\,C_6H_{6(l)} + 15\,O_{2(g)} \longrightarrow 12\,CO_{2(g)} + 6H_2O_{(1)} \qquad ?\,H^0_{rxn} = -6534.8\text{ kJ}$$

8. The standard molar enthalpy of formation of solid chromium(III) oxide is - 1139.7 kJ/mol. Write the balanced thermochemical equation for which the molar enthalpy of formation is -1139.7 kJ.

9. The molar enthalpy of formation of methanol, $CH_3OH_{(l)}$, is - 238.7 kJ/mol. Write the balanced thermochemical equation for which the enthalpy of reaction is - 238.7 kJ.

10. The molar enthalpy of formation of glucose, $C_6H_{12}O_{6(s)}$, is - 1260 kJ/mol
(a) Is the formation of glucose from its elements exothermic or endothermic?
(b) Write a balanced thermochemical equation depicting the formation of glucose from its elements and for which the enthalpy of reaction is - 1260 kJ.

11. The molar enthalpy of formation of pyridine$_{(l)}$, $C_4H_5N_{(l)}$ is + 100.2 kJ/mol.
(a) Write the balanced thermochemical equation for the formation of pyridine from its elements, that is, for the reaction for which the enthalpy of reaction is +100.2 kJ.
(b) Write the balanced equation for which the enthalpy change is +200.4 kJ.

12. Suppose you wish to know the enthalpy change for the formation of liquid PCI_3 from the elements: $P_{4(s)} + 6\ C1_{2(g)} \longrightarrow 4\ PCl_{3(l)}$ $?H^0_{rxn} = ?$
This reaction cannot be carried out directly. Instead, the enthalpy change for the reaction of phosphorus and chlorine to give phosphorus pentachloride can be determined:
$P_{4(s)} + 10\ C1_{2(g)} \longrightarrow 4\ PCl_{5\ (s)}$ $?H^0_{rxn} = -1774.0$ kJ
The enthalpy change for the reaction of phosphorus trichloride with more chlorine to give phosphorus pentachloride can also be measured.
$PCl_{3(l)} + C1_{2(g)} \longrightarrow PCl_{5\ (s)}$ $?H^0_{rxn} = -123.8$ kJ

13. An important step in the production of sulfuric acid is:
$2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$
It is also a key reaction in the formation of acid rain, beginning with the air pollutant SO_2. Using the Data Book, calculate the enthalpy change for the reaction. Is the reaction exothermic or endothermic?

14. In photosynthesis, the sun's energy brings about the combination of CO_2 and H_2O to form O_2 and a carbon-containing compound. In its simplest form, the reaction is:
$CO_{2(g)} + 2\ H_2O_{(l)} \longrightarrow 2\ O_{2(g)} + CH_{4(g)}$
Using the enthalpies of formation in Data Book, (a) calculate the enthalpy of reaction and (b) decide if the reaction is exothermic or endothermic.

15. The Romans used calcium oxide, CaO, as mortar in stone structures. The CaO was mixed with water to give $Ca(OH)_2$, which slowly reacted with CO_2 in the air to give limestone, $CaCO_3$.
$Ca(OH)_{2(s)} + CO_{2(g)} \longrightarrow CaCO_{3(s)} + H_2O_{(g)}$
(a) Calculate the enthalpy change for the reaction above.
(b) What quantity of heat is evolved or absorbed if 1.00 kg of $Ca(OH)_2$ is allowed to react with a stoichiometric amount of CO_2?

16. Pure metals can often be prepared by reducing the metal oxide with hydrogen gas. For example:
$WO_{3(s)} + 3\ H_{2(g)} \longrightarrow W_{(s)} + 3\ H2O_{(1)}$
(a) Calculate the enthalpy change for this reaction. $?H^0_{rxn}$ for $WO_{3(s)}$ is - 842.9 kJ/mol.
(b) What quantity of heat is evolved or absorbed if 1.00 g of WO_3 is allowed to react with an excess of hydrogen gas?

17. The meals-ready-to-eat (MRE) in the military can be heated on a flame-less heater). Assume the reaction in the heater is:
$Mg_{(s)} + 2\ H_2O_{(1)} \longrightarrow Mg(OH)_{2(s)} + H_{2(g)}$
Calculate the enthalpy change under standard conditions (in joules) for this reaction. What quantity of magnesium is needed to supply the heat required to warm 25.0 mL of water from 25.0 ^OC to 85.0 ^OC ? [d = 1.00 g/mL, $?H^0_f$ ($Mg(OH)_{2(s)}$) = - 924.7 kJ/mol]