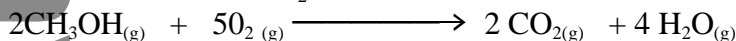


# Enthalpy: Review Questions

1. How much heat energy (in joules) is required to raise the temperature of 454 g of tin from room temperature (25.0 °C) to its melting point, 231.9 °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.

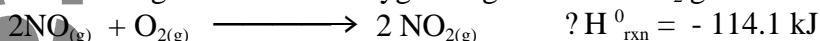
2. Ethanol, C<sub>2</sub>H<sub>5</sub>OH, boils at 78.29 °C. How much heat energy (in joules) is required to heat 1.00 kg of this liquid from 20.0 °C to the boiling point and then change the liquid completely to a vapor at that temperature? (The specific heat of liquid ethanol is 2.44 J/g K, and the enthalpy of vaporization is 38.56 kJ/mol.)

3. Methanol, CH<sub>3</sub>OH, is a possible automobile fuel. The alcohol produces energy in a combustion reaction with O<sub>2</sub>:



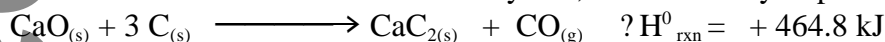
A 0.115 g sample of methanol evolves 1110 J when burned at constant pressure. What is the enthalpy change,  $\Delta H^\circ_{\text{rxn}}$ , for the reaction? What is the enthalpy change per mole of methanol (often called the molar heat of combustion)?

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 NO<sub>2</sub> gas:



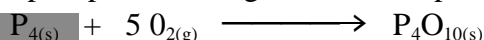
Is the reaction endothermic or exothermic? If 1.25 g of NO is converted completely to NO<sub>2</sub>, what quantity of heat is absorbed or evolved?

5. Calcium carbide, CaC<sub>2</sub>, is manufactured by reducing lime (CaO) with carbon at a high temperature. The carbide is used to make acetylene, an industrially important organic chemical:



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?

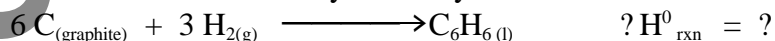
6. White phosphorus, P<sub>4</sub>, ignites in air to produce heat, light, and P<sub>4</sub>O<sub>10</sub>



If 3.56 g of P<sub>4</sub> 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<sub>4</sub>?

Use this information to calculate the enthalpy change for the formation of 1 mol of PCl<sub>3(l)</sub> from P<sub>4</sub> and Cl<sub>2(g)</sub>.

7. Suppose you wish to know the enthalpy change for the formation of benzene, C<sub>6</sub>H<sub>6</sub>, and that the value is not available directly from any data tables.



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.



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<sub>3</sub>OH(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  $-1260 \text{ kJ/mol}$

(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  $-1260 \text{ kJ}$ .

11. The molar enthalpy of formation of pyridine<sub>(l)</sub>,  $C_4H_5N_{(l)}$  is  $+100.2 \text{ kJ/mol}$ .

(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  $+100.2 \text{ kJ}$ .

(b) Write the balanced equation for which the enthalpy change is  $+200.4 \text{ kJ}$ .

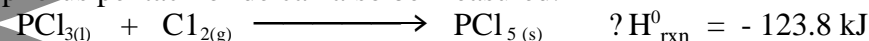
12. Suppose you wish to know the enthalpy change for the formation of liquid  $PCl_3$  from the elements:



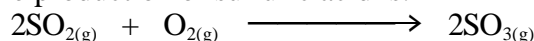
This reaction cannot be carried out directly. Instead, the enthalpy change for the reaction of phosphorus and chlorine to give phosphorus pentachloride can be determined:



The enthalpy change for the reaction of phosphorus trichloride with more chlorine to give phosphorus pentachloride can also be measured.

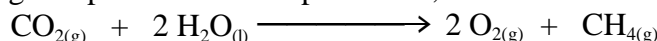


13. An important step in the production of sulfuric acid is:



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?

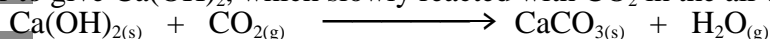
14. In photosynthesis, the sun's energy brings about the combination of  $CO_2$  and  $H_2O$  to form  $O_2$  and a carbon-containing compound. In its simplest form, the reaction is:



Using the enthalpies of formation in Data Book, (a) calculate the enthalpy of reaction and

(b) decide if the reaction is exothermic or endothermic.

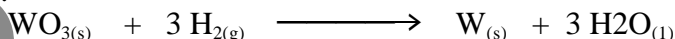
15. The Romans used calcium oxide,  $CaO$ , as mortar in stone structures. The  $CaO$  was mixed with water to give  $Ca(OH)_2$ , which slowly reacted with  $CO_2$  in the air to give limestone,  $CaCO_3$ .



(a) Calculate the enthalpy change for the reaction above.

(b) What quantity of heat is evolved or absorbed if  $1.00 \text{ kg}$  of  $Ca(OH)_2$  is allowed to react with a stoichiometric amount of  $CO_2$ ?

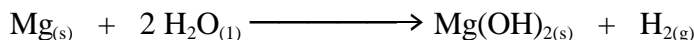
16. Pure metals can often be prepared by reducing the metal oxide with hydrogen gas. For example:



(a) Calculate the enthalpy change for this reaction.  $? H^0_{rxn}$  for  $WO_{3(s)}$  is  $-842.9 \text{ kJ/mol}$ .

(b) What quantity of heat is evolved or absorbed if  $1.00 \text{ g}$  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:



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  $25.0 \text{ mL}$  of water from  $25.0 \text{ }^\circ\text{C}$  to  $85.0 \text{ }^\circ\text{C}$ ? [ $d = 1.00 \text{ g/mL}$ ,  $? H^0_f (Mg(OH)_{2(s)}) = -924.7 \text{ kJ/mol}$ ]