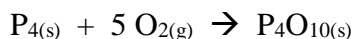


## Thermochemistry Problem Set

1. White phosphorous,  $\text{P}_4(\text{s})$ , burns in air to produce heat, light and  $\text{P}_4\text{O}_{10}(\text{s})$ . The reaction can be written:



If you burn 8.90 g of  $\text{P}_4(\text{s})$ , you find that 216.3 kJ of heat is released. Calculate the molar heat of combustion of  $\text{P}_4(\text{s})$ .

2. Suppose you place 0.7500 g of Mg in a coffee cup calorimeter and then add 150g of 1.0 M  $\text{HCl}_{(\text{aq})}$ . The reaction is single replacement and hydrogen gas is produced. Calculate the enthalpy change per mole of Mg reacted if the temperature of the solution increases from 22.2 °C to 44.8 °C. The heat capacity of the solution is 4.184 J/g °C and the calorimeter has a heat capacity of 2.90 J/°C.
3. In liquid fuel rockets, such as the lunar module of the Apollo moon missions, the fuel is liquid hydrazine,  $\text{N}_2\text{H}_4$ , and the oxidant is dinitrogen tetroxide,  $\text{N}_2\text{O}_4$ .
- Write a balanced equation for the reaction of these two substances to form liquid water and  $\text{N}_2$  gas.
  - Using a table of heats of formation, calculate the heat of reaction per mole of hydrazine.
  - Would more, or less, heat be released if the oxidant were  $\text{O}_2$  instead of  $\text{N}_2\text{O}_4$ ? (not a thorough calculation here – just a rough idea)
  - Ok – now tell me how much more or less? (this should be a calculation to confirm your answer to c)
4. Propane,  $\text{C}_3\text{H}_8$ , is a hydrocarbon that is commonly used as fuel for cooking.
- Write a balanced equation for the complete combustion of propane gas, which yields  $\text{CO}_2(\text{g})$  and  $\text{H}_2\text{O}(\text{l})$ .
  - Calculate the volume of air at 30°C and 1.00 atm. that is needed to burn completely 10.0 grams of propane. Assume that air is 21.0 percent  $\text{O}_2$  by volume.
  - The heat of combustion of propane is  $-2,220.1$  kJ/mol. Calculate the heat of formation, of propane given that  $\Delta\text{H}^\circ_{\text{f}}$  of  $\text{H}_2\text{O}(\text{l}) = -285.3$  kJ/mol and  $\Delta\text{H}^\circ_{\text{f}}$  of  $\text{CO}_2(\text{g}) = -393.5$  kJ/mol.
  - Assuming that all of the heat evolved in burning 30.0 grams of propane is transferred to 8.00 kilograms of water (specific heat = 4.18 J/g·K), calculate the increase in temperature of water.

5. Determine the energy change that occurs as 25 grams of water is heated from  $-5^{\circ}\text{C}$  to  $120^{\circ}\text{C}$ . Relevant values are included in the tables below.

Substance	Specific Heat (in $\text{J/g}^{\circ}\text{C}$ )
$\text{H}_2\text{O (g)}$	2.01
$\text{H}_2\text{O (l)}$	4.18
$\text{H}_2\text{O (s)}$	2.01

Enthalpy of Fusion of Water ( $\text{kJ/mol}$ )	6.01
Enthalpy of Vaporization of Water ( $\text{kJ/mol}$ )	44.0

6. An experiment is to be performed to determine the standard molar enthalpy of neutralization of a strong acid by a strong base. Standard school laboratory equipment and a supply of standardized 1.00 molar  $\text{HCl}$  and standardized 1.00 molar  $\text{NaOH}$  are available.
- What equipment would be needed?
  - What measurements should be taken?
  - Without performing calculations, describe how the resulting data should be used to obtain the standard molar enthalpy of neutralization.
  - When a class of students performed this experiment, the average of the results was  $-55.0$  kilojoules per mole. The accepted value for the standard molar enthalpy of neutralization of a strong acid by a strong base is  $-57.7$  kilojoules per mole. Propose two likely sources of experimental error that could account for the result obtained by the class.