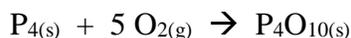


Thermochemistry Problem Set

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, N_2H_4 , and the oxidant is dinitrogen tetroxide, N_2O_4 .
 - a. Write a balanced equation for the reaction of these two substances to form liquid water and N_2 gas.
 - b. Using a table of heats of formation, calculate the heat of reaction per mole of hydrazine.
 - c. Would more, or less, heat be released if the oxidant were O_2 instead of N_2O_4 ? (not a thorough calculation here – just a rough idea)
 - d. Ok – now tell me how much more or less? (this should be a calculation to confirm your answer to c)
 4. Propane, C_3H_8 , is a hydrocarbon that is commonly used as fuel for cooking.
 - a. Write a balanced equation for the complete combustion of propane gas, which yields $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O}(\text{l})$.
 - b. 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 O_2 by volume.
 - c. 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.
 - d. 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°C to 120°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 (kJ/mol)	6.01
Enthalpy of Vaporization of Water (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 HCl and standardized 1.00 molar 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.