Thermochemistry Problem Set

1. White phosphorous, $P_4(s)$, burns in air to produce heat, light and $P_4O_{10(s)}$. The reaction can be written:

   $P_{4(s)}$ + 5 $O_{2(g)}$ → $P_4O_{10(s)}$

   If you burn 8.90 g of $P_4(s)$, you find that 216.3 kJ of heat is released. Calculate the molar heat of combustion of $P_4(s)$.

2. Suppose you place 0.7500 g of Mg in a coffee cup calorimeter and then add 150g of 1.0 M $HCl_{(aq)}$. 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.

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   a. Write a balanced equation for the complete combustion of propane gas, which yields $CO_2(g)$ and $H_2O(l)$.
   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 ΔH^o_f of $H_2O(l)$ = –285.3 kJ/mol and ΔH^o_f of $CO_2(g)$ = –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 J/g° C)
H_2O (g)	2.01
H_2O (l)	4.18
H_2O (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.
    a. What equipment would be needed?
    b. What measurements should be taken?
    c. Without performing calculations, describe how the resulting data should be used to obtain the standard molar enthalpy of neutralization.
    d. 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.