COMBINATION PROBLEMS
SCH 4U – THERMODYNAMICS

5 1. 30 L of water in a bomb calorimeter is warmed from 20.00 °C to 23.94 °C when 10 g of butane (C_4H_{10}) is reacted with sufficient oxygen to allow complete combustion. Use this information plus appropriate heats of formation (i.e. values for carbon dioxide, water and oxygen) to derive the heat of formation for the compound butane. Check this answer with the heat of formation value for butane found in the table to see if the information in the question is correct.

2 2. Determine the change in temperature in 50.00 L of water when warmed by the combustion of 25.00 g of butane, $C_4H_{10}(g)$.

1 3. Determine the heat of formation of hexane given that the combustion of 15.0 g of hexane (C_6H_{14}) can warm 25.000 l of water from 25.000 °C to 31.925 °C. DO NOT USE THE TABLES IN THE BOOK FOR THIS QUESTION (except to check your answer)!!! Note that this is a multi-step problem – use appropriate format.

4. From the following information, calculate $\Delta H_{H_3PO_4(aq)}$ in kJ

a) $\Delta H_{H_2O(l)}$ = -285.77 kJ

7 b) $\Delta H_{P_4O_{10}(s)}$ = -3012.48 kJ

c) The natural form of phosphorus is P(s).

d) 13.5 g of $P_4O_{10}(s)$ is placed in exactly 1 L of water and an exothermic reaction proceeds inwhich $H_3PO_4(aq)$ is the only product. The temperature is observed to increase from 15.03 °C to 19.93°C

e) The specific heat capacity of water is 4.184 J/g°C.

f) The answer is $\Delta H_{H_3PO_4(aq)}$ = -308.2 kcal

3 5. Calculate the mass of benzene liquid ($C_6H_6(l)$) that can provide 100 kJ of heat through a combustion reaction. Use the table in your text. No need to use Hess' Law.

9 6. Determine the mass of propane that must be combusted to warm 160 L of water from 15 °C to 52 °C. You may use any heats of formation from the textbook that you like.

9 7. If 50 L of water is warmed by 11.469 °C by the combustion of 50 g of decane ($C_{10}H_{22}(l)$), determine the heat of formation of decane. This is not a Hess' Law problem. You may use any heats of formation that you wish from the textbook.

8 8. The combustion of 21.9 g of ethanol C_2H_5OH is able to warm 8.000 L of water from 20 °C to 40 °C, determine the heat of formation of ethanol. Do not use Hess' Law in your solution.

9. Determine the volume of water in L that can be warmed from
12 15 °C to 70 °C, by the combustion of 500 g of cyclopropane.

10. When 10 g of butane (C_4H_{10}) is reacted with sufficient oxygen to allow complete combustion 30 L of water in a bomb calorimeter is warmed from 20.00 °C to 23.94 °C. Use this information plus appropriate heats of formation (i.e. values for carbon dioxide, water and oxygen) to derive the heat of
10 formation for the compound butane. Check this answer with the heat of formation value for butane found in the table in your text to see if the information in this question is correct. Please perform your calculation in kJ. Do not use Hess' Law.

11. Determine the mass of water at 25 °C that can be converted to water at 100 °C by the combustion of 800 g of propane.
11 At no point use Hess' Law in this determination. (For a bonus, determine what the mass of water would be if it were converted to steam at 100 °C instead of water at 100 °C)

12. From the following data and the eventual use of Hess' Law, determine the heat of formation of calcium oxide (CaO). Note, both reactions were performed in 100 mL of 1.0 M HCl,
11 which can be considered to be the same as water (i.e. specific heat capacity is 4.184 J /g°C Hummm! This looks a lot like one of your lab calculations!

Equation	Initial Temp. °C	Final Temp. °C	Masses etc.
$Ca(s) + 2HCl(aq) \Rightarrow CaCl_2(aq) + H_2(g)$	21.0	58.9	1.500 g Ca
$CaO(s) + 2HCl(aq) \Rightarrow CaCl_2(aq) + H_2O(g)$	21.0	30.2	2.000 g CaO
$H_2(g) + ½O_2(g) \Rightarrow H_2O(l)\ \Delta H = -285.8$ kJ			

13. 30 L of water in a bomb calorimeter is warmed from 20.00 °C to 23.94 °C when 10 g of butane (C_4H_{10}) is reacted with sufficient oxygen to allow complete combustion. Use this information plus appropriate heats of formation (i.e. values
7 for carbon dioxide, water and oxygen) to derive the heat of formation for the compound butane. Check this answer with the heat of formation value for butane found in the table to see if the information in the question is correct.

14. From the following information determine the percent by mass of a 20 kg block of ice at –30°C that can be converted to water through the combustion of 130 g of octane (C_8H_{18}).

$\Delta H_{C_8H_{18}(l)}$ = -250.1 kJ

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$\Delta H_{H_2 0(l)}$ = -285.8 kJ

$\Delta H_{CO_2(g)}$ = -393.5 kJ

specific heat capacity of water = 4.184 J/g °C

specific heat capacity of ice = 2.010 J/g °C

latent heat of fusion for water = 6.03 kJ/mol

Note: do not use Hess' Law in your solution
Hint: start this problem using the heat summation method to determine the $\Delta H_{combustion}$ for octane.

15. From the following information and <u>Hess' Law</u>, calculate the heat of formation of CaO in kJ

a) $CaO(s) + 2HCl(aq) \rightarrow CaCl_2(s) + H_2O(l)$

15.00 g of CaO was reacted in 5 L of an HCl solution.* A change in temperature of 19.6 C was noted

5 b) $Ca(s) + 2HCl(aq) \rightarrow CaCl_2(s) + H_2(g)$

12.00 g of Ca was reacted in 5 L of an HCl solution.* A change in temperature of 8.7 C was noted.

c) $H_2(g) + O_2(g) \rightarrow H_2O(l)$ $\Delta H° = -285.6$ kJ/mol

* consider these solution to have the same heat capacity as water (4.184 J/g°C) and ignore any mass contributions from the addition of CaO and Ca