Name: _____ Date: _____ Class Pd. _____

AP Chemistry: Hess's Law CW

1. The heat of combustion of C to CO_2 is -393.5 kJ/mol of CO_2, whereas that for combustion of CO to CO_2 is -283.0 kJ/mol of CO_2. Calculate the heat of combustion of C to CO. (-110.5 kJ)

keep $C \rightarrow CO_2$ $\Delta H = -393.5$ kJ

flip $CO \rightarrow CO_2$ $\Delta H = -283.0$ kJ

$C \rightarrow CO$ $\Delta H = -393.5 + (283.0\text{ kJ}) =$ **-110.5 kJ**

2. Ethanol, C_2H_5OH, is made industrially by the reaction of water with C_2H_4. Calculate $\Delta H°$ for:
$C_2H_4(g) + H_2O(l) \rightarrow C_2H_5OH(l)$ given:

keep $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ $\Delta H = -1411.1$ kJ and

flip $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$ $\Delta H = -1367.1$ kJ (-44 kJ)

$2CO_2 + 3H_2O \rightarrow C_2H_5OH + 3O_2$

$\Delta H = (-1411.1\text{ kJ}) + (1367.1\text{ kJ}) =$ **-44 kJ**

3. We can generate hydrogen chloride by heating a mixture of sulfuric acid and potassium chloride according to the following reaction: $2KCl(s) + H_2SO_4(l) \rightarrow 2HCl(g) + K_2SO_4(s)$ Calculate the change in enthalpy for this reaction from the following thermochemical equations. Give your answer in kJ. (64.8 kJ)

2x flip $HCl(g) + KOH(s) \rightarrow KCl(s) + H_2O(l)$ $\Delta H = -203.6$ kJ

flip $K_2SO_4(l) + 2KOH(s) \rightarrow K_2SO_4(s) + 2H_2O(l)$ $\Delta H = -342.4$ kJ

$2KCl + 2H_2O \rightarrow 2HCl + 2KOH$

$H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O$

$\Delta H = (2 \cdot -(-203.6)) + -342.4 =$ **64.8 kJ**

4. Calculate the change in enthalpy for the following reaction, which describes the preparation of an unstable, acid, HNO_2, nitrous acid: $HCl(g) + NaNO_2(s) \rightarrow HNO_2(l) + NaCl(s)$ Use the following thermochemical equation. Calculate the answer in kJ (-78.60 kJ)

1/2 flip $2NaCl(s) + H_2O(l) \rightarrow 2HCl(g) + Na_2O(s)$ $\Delta H = +507.31$ kJ → $-507.31/2$

1/2 flip $NO(g) + NO_2(g) + Na_2O(s) \rightarrow 2NaNO_2(s)$ $\Delta H = -427.14$ kJ → $427.14/2$

1/2 keep $NO(g) + NO_2(g) \rightarrow N_2O(g) + O_2(g)$ $\Delta H = -42.68$ kJ → $-42.68/2$

1/2 flip $2HNO_2(l) \rightarrow N_2O(g) + O_2(g) + H_2O(l)$ $\Delta H = +34.35$ kJ → $-34.35/2$ = **-78.60 kJ**

$2HCl + Na_2O \rightarrow 2NaCl + H_2O$

$2NaNO_2 \rightarrow NO + NO_2 + Na_2O$

$NO + NO_2 \rightarrow N_2O + O_2$

$N_2O + O_2 + H_2O \rightarrow 2HNO_2$

$\frac{1}{2}(2HCl + 2NaNO_2 \rightarrow 2NaCl + 2HNO_2)$

5. An aqueous solution of calcium hydroxide, $Ca(OH)_2$, is called limewater. It neutralizes hydrochloric acid, HCl(aq), as follows: $Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$
Calculate the change in enthalpy for this reaction. The following thermochemical equations can be used as needed. (-111.1 kJ)

$CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$ $\Delta H = -186$ kJ

flip $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$ $\Delta H = -62.3$ kJ

flip $Ca(OH)_2(s) \rightarrow Ca(OH)_2(aq)$ $\Delta H = -12.6$ kJ

~~$CaO(s)$~~ $+ 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l)$ $\Delta H = -186 + 62.3 + 12.6$

~~$Ca(OH)_2(s)$~~ $\rightarrow$ ~~$CaO(s)$~~ $+ H_2O(l)$ $\Delta H = -111.1$ kJ

$Ca(OH)_2(aq) \rightarrow$ ~~$Ca(OH)_2(s)$~~

$2HCl(aq) + Ca(OH)_2(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$

6. Given the heats of formation for the following:
$C_2H_2(l) = 226.7$ kJ/mol; $CO_2(g) = -393.5$ kJ/mol; $H_2O(l) = -285.9$ kJ/mol
Find the heat of combustion of C_2H_2. ~~(-110.5 kJ)~~

$2\,C_2H_2 + 5O_2 \rightarrow 4CO_2 + 2H_2O$

$\Delta H^\circ_{rxn} = \left((4 \times -393.5) + (2 \times -285.9)\right) - \left((2 \cdot 226.7)\right)$

$\Delta H^\circ_{rxn} = -2599$ kJ/mol

7. Calculate the change in enthalpy for each of the following reactions: (appendix four page A21 - A24 for ΔH°_f values)
a) $HCl(g) + NaOH(s) \rightarrow NaCl(s) + H_2O(l)$ (-178 kJ)

$\Delta H^\circ_{rxn} = (\Delta H^\circ_{f\,NaCl} + \Delta H^\circ_{f\,H_2O}) - (\Delta H^\circ_{f\,HCl} + \Delta H^\circ_{f\,NaOH})$

$(-411 + -286) - (-92 + -427)$

$\Delta H^\circ_{rxn} = -178$ kJ

b) $CH_4(g) + 2O2(g) \rightarrow CO2(g) + 2H2O(g)$ (-891 kJ)

$\Delta H^\circ_{rxn} = (\Delta H^\circ_{f\,CO_2} + \Delta H^\circ_{f\,2(H_2O)}) - (\Delta H^\circ_{f\,CH_4})$

$(-393.5 + 2(-285.9)) - (-75)$

$\Delta H^\circ_{rxn} = -890$ kJ