Heat

Enthalpy of Formation and Hess's Law

Part 1. Balance the following equations. Then use the heats of formation and Hess's Law to find the enthalpy of the reaction. Classify each reaction as endothermic or exothermic.

Balance first! → 1. $NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$ $\Delta H_r = -176.01$ kJ

$\Delta H_r = [-314.43] - [-46.11 + (-92.307)]$

$= -314.43 + 46.11 + 92.307$

$= -176.01$ kJ (exothermic rxn)

Balance first! → 2. $2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$ $\Delta H_r = -393.08$ kJ

$\Delta H_r = [2(-482.37) + 0] - [2(0) + 2(-285.83)]$

$= -964.74 - (-571.66)$

$= -393.08$ kJ (exothermic)

Balance first! → 3. $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $\Delta H_r = -114.14$ kJ

$\Delta H_r = [2(33.18)] - [2(90.25) + 0]$

$= 66.36 - 180.50$

$= -114.14$ kJ (exothermic)

Balance! → 4. $4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(g)$ $\Delta H_r = -1133.75$ kJ

$\Delta H_r = [4(33.18) + 6(-241.818)] - [4(-46.11) + 7(0)]$

$= [132.72 + (-1450.908)] - [-184.44]$

$= -1133.75$ kJ (exothermic)

Part 2. Solve the following problems using enthalpy of formation, Hess's Law and stoichiometry.

1. How much heat is released from the combustion of 1.00 gram of methane gas (CH_4)?

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ (all gases)

$\Delta H_r = [-393.509 + 2(-241.818)] - [-74.81 + 2(0)]$

$= [-877.145] - [-74.81]$

$= -802.34$ kJ

$$\frac{1.00\ g\ CH_4}{1} \times \frac{1\ mol\ CH_4}{16.05\ g\ CH_4} \times \frac{802.34\ kJ}{1\ mol\ CH_4} = 49.9\ kJ\ released$$

2. How much heat is evolved when 8.00 grams of oxygen reacts with an excess of C_2H_4?

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$ (all gases)

$\Delta H_r = [2(-393.509) + 2(-241.818)] - [52.26 + 3(0)]$

$= [-787.018 - 483.636] - [52.26]$

$= -1322.91$ kJ

If you wish to put (-) signs in front of kJ that is fine!

$$\frac{8.00\ g\ O_2}{1} \times \frac{1\ mol\ O_2}{32.00\ g\ O_2} \times \frac{1322.91\ kJ}{3\ mol\ O_2} = 110\ kJ\ released$$

3. Calculate the heat produced when 15.0 grams of solid calcium hydroxide forms from the reaction of solid calcium oxide and liquid water.

$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2\,(s)}$

$\Delta H_r = [-986.09] - [-635.09 + (-285.83)]$

$= -986.09 + 635.09 - 285.83$

$= \boxed{-65.17\ kJ}$

$\frac{15.0\ g\ Ca(OH)_2}{1} \times \frac{1\ mole\ Ca(OH)_2}{74.10\ g\ Ca(OH)_2} \times \frac{65.17\ kJ}{1\ mol\ Ca(OH)_2} = \boxed{13.2\ kJ\ produced}$

4. Carbon monoxide gas reacts with solid iron (III) oxide to produce solid iron and carbon dioxide. How much heat is involved when 56.0 grams of carbon monoxide react with excess iron (III) oxide? Is the reaction endothermic or exothermic?

$3CO_{(g)} + Fe_2O_{3\,(s)} \rightarrow 2Fe_{(s)} + 3CO_{2\,(g)}$

$\Delta H_r = [2(0) + 3(-393.509)] - [3(-110.595) + (-824.2)]$

$= [-1180.527] - [-331.785 - 824.2]$

$= \boxed{-24.5\ kJ}$ exothermic

$\frac{56.0\ g\ CO}{1} \times \frac{1\ mol\ CO}{28.01\ g\ CO} \times \frac{24.5\ kJ}{3\ mol\ CO} = \boxed{16.3\ kJ\ released}$

Part 3. Use the thermochemical reactions provided to find the enthalpy of the designated reaction. This is also an application of Hess' Law.

1. Calculate ΔH for the reaction: $C_2H_4\,(g) + H_2\,(g) \rightarrow C_2H_6\,(g)$, from the following thermochemical data.

$C_2H_4\,(g) + 3O_2\,(g) \rightarrow 2CO_2\,(g) + 2H_2O\,(l)$ ΔH = -1411. kJ

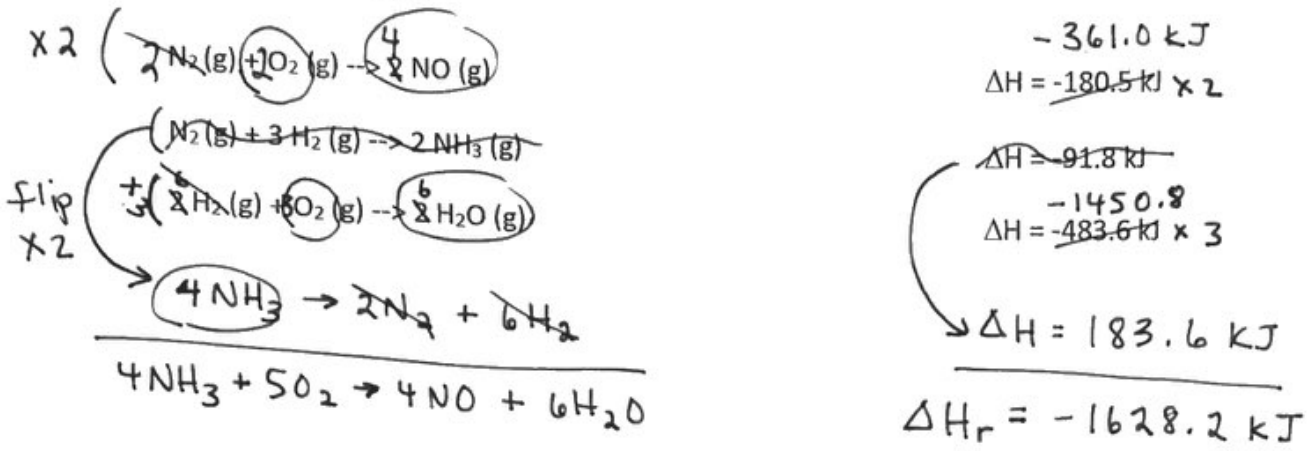
~~$C_2H_6\,(g) + 3\frac{1}{2}O_2\,(g) \rightarrow 2CO_2\,(g) + 3H_2O\,(l)$~~ ~~ΔH = -1560. kJ~~

flip $H_2\,(g) + \frac{1}{2}O_2\,(g) \rightarrow H_2O\,(l)$ ΔH = -285.8 kJ

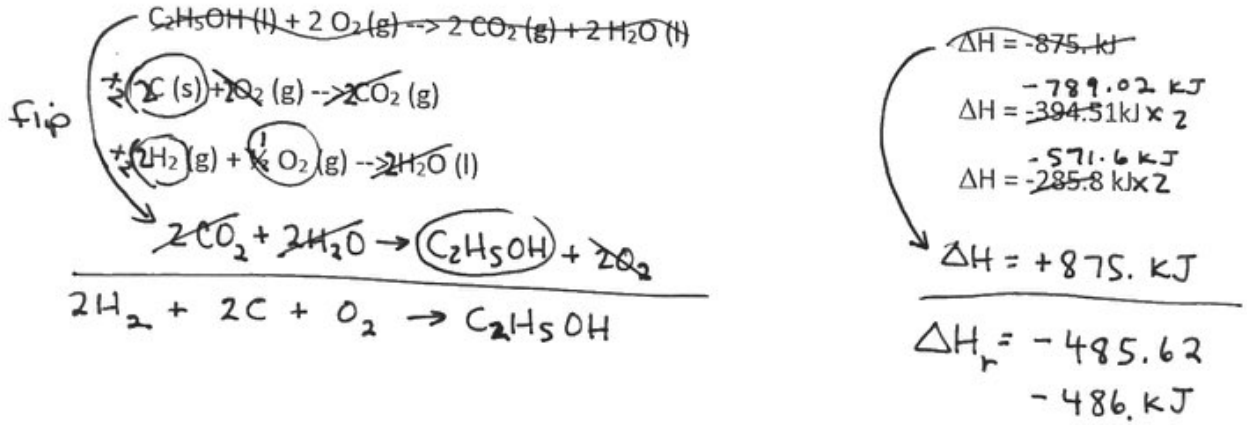
$2CO_2 + 3H_2O \rightarrow C_2H_6 + 3\frac{1}{2}O_2$ ΔH = +1560 kJ

$C_2H_4 + H_2 \rightarrow C_2H_6$ $\Delta H_r = -136.8\ kJ$

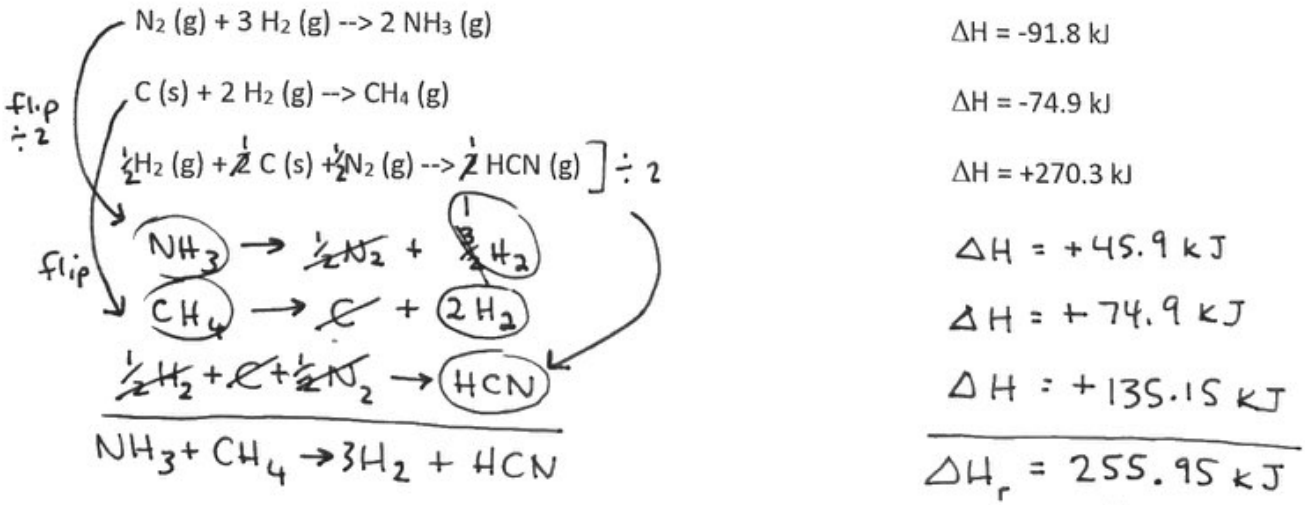
2. Calculate ΔH for the reaction $4\ NH_3\ (g) + 5\ O_2\ (g) \rightarrow 4\ NO\ (g) + 6\ H_2O\ (g)$, from the following thermochemical data.



3. Find ΔH for the reaction $2H_2(g) + 2C(s) + O_2(g) \rightarrow C_2H_5OH(l)$, using the following thermochemical data.



4. Calculate ΔH for the reaction $CH_4\ (g) + NH_3\ (g) \rightarrow HCN\ (g) + 3\ H_2\ (g)$, given: (Hint: You can multiply by a fraction like ½)



5. Calculate ΔH for the reaction 2 Al (s) + 3 Cl_2 (g) --> 2 $AlCl_3$ (s) from the data. (Hint: pay attention to states of matter)

2 Al (s) + 6 HCl (aq) --> 2 $AlCl_3$ (aq) + 3 H_2 (g)

x 6 (HCl (g) --> HCl (aq))

x 3 (3 H_2 (g) + 3 Cl_2 (g) --> 6 HCl (g))

x 2 ($AlCl_3$ (s) --> $AlCl_3$ (aq))

2 $AlCl_3$ (aq) → 2 $AlCl_3$ (s)

2 Al (s) + 3 Cl_2 (g) → 2 $AlCl_3$ (s)

ΔH = -1049. kJ

-448.8 kJ

ΔH = -74.8 kJ

-5535 kJ

ΔH = -1845. kJ

ΔH = -323. kJ

ΔH = +646 kJ

ΔH = -6386.8

= -6387 kJ

More Hess's Law Practice (if you need it!)

(1) Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:
$PCl_5(g) \rightarrow PCl_3(g) + Cl_2(g)$

$P_4(s) + 6Cl_2(g) \rightarrow 4PCl_3(g)$ ΔH = -2439 kJ
$PCl_5(g) \rightarrow P_4(s) + 10Cl_2(g)$ ΔH = 3438 kJ
answer = 249.8 kJ

(2) Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:
$2CO_2(g) + H_2O(g) \rightarrow C_2H_2(g) + 5/2O_2(g)$ $\Delta H_r = ?$

$C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$ ΔH = -94.5 kJ
$H_2O(g) \rightarrow H_2(g) + 1/2O_2(g)$ ΔH = 71.2 kJ
$C_2H_6(g) + 7/2O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ ΔH = -283 kJ
answer = 235 kJ

(3) Find the ΔH for the reaction below, given the following reactions and subsequent ΔH values:
$N_2H_4(l) + H_2(g) \rightarrow 2NH_3(g)$

$N_2H_4(l) + CH_4O(l) \rightarrow CH_2O(g) + N_2(g) + 3H_2(g)$ ΔH = -37 kJ
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ ΔH = -46 kJ
$CH_4O(l) \rightarrow CH_2O(g) + H_2(g)$ ΔH = 65 kJ
answer = -18 kJ