Hess's Law Worksheet

1. Calculate ΔH^o for the reaction C_2H_4 (g) + H_2 (g) → C_2H_6 (g), from the following data.

C_2H_4 (g) + 3 O_2 (g) → 2 CO_2 (g) + 2 H_2O (l)	ΔH^o = -1411. kJ
C_2H_6 (g) + 7/2 O_2 (g) → 2 CO_2 (g) + 3 H_2O (l)	ΔH^o = -1560. kJ
H_2 (g) + 1/2 O_2 (g) → H_2O (l)	ΔH^o = -285.8 kJ

2. Calculate ΔH^o for the reaction 4 NH_3 (g) + 5 O_2 (g) → 4 NO (g) + 6 H_2O (g), from the following data.

N_2 (g) + O_2 (g) → 2 NO (g)	ΔH^o = +180.5 kJ
N_2 (g) + 3 H_2 (g) → 2 NH_3 (g)	ΔH^o = -91.8 kJ
2 H_2 (g) + O_2 (g) → 2 H_2O (g)	ΔH^o = -483.6 kJ

3. Find ΔH_f^o for acetic acid, $HC_2H_3O_2$, using the following thermochemical data.

$HC_2H_3O_2$ (l) + 2 O_2 (g) → 2 CO_2 (g) + 2 H_2O (l)	ΔH^o = -875. kJ
C (s, graphite) + O_2 (g) → CO_2 (g)	ΔH^o = -394.51 kJ
H_2 (g) + 1/2 O_2 (g) → H_2O (l)	ΔH^o = -285.8 kJ

4. Calculate ΔH^o for the reaction CH_4 (g) + NH_3 (g) → HCN (g) + 3 H_2 (g), from the reactions.

N_2 (g) + 3 H_2 (g) → 2 NH_3 (g)	ΔH^o = -91.8 kJ
C (s, graphite) + 2 H_2 (g) → CH_4 (g)	ΔH^o = -74.9 kJ
H_2 (g) + 2 C (s, graphite) + N_2 (g) → 2 HCN (g)	ΔH^o = +270.3 kJ

5. Calculate ΔH^o for the reaction 2 Al (s) + 3 Cl_2 (g) → 2 $AlCl_3$ (s) from the following data.

2 Al (s) + 6 HCl (aq) → 2 $AlCl_3$ (aq) + 3 H_2 (g)	ΔH = -1049. kJ
HCl (g) → HCl (aq)	ΔH = -74.8 kJ
H_2 (g) + Cl_2 (g) → 2 HCl (g)	ΔH = -1845. kJ
$AlCl_3$ (s) → $AlCl_3$ (aq)	ΔH = -323. kJ

6. Calculate ΔH^o in kilojoules for the following reactions using a table of standard heats of formation.

a) 2 NO(g) + O_2(g) ---> 2 NO_2(g)
b) NaOH(s) + HCl(g) ----> NaCl(s) + H_2O(g)

7. Use a standard enthalpies of formation table to determine the change in enthalpy for each of these reactions.
a) 2 CO(g) + O_2(g) ---> 2 CO_2(g)
b) CH_4(g) + 2 O_2(g) ---> CO_2(g) + 2 H_2O(l)
c) 2 H_2S(g) + 3 O_2(g) ---> 2 H_2O(l) + 2 SO_2(g)

8. Calculate ΔH^o for these reactions. In each case, state whether the reaction is exothermic or endothermic, rewrite the equation as a thermochemical equation to include the heat term, and indicate whether the products have a greater or smaller enthalpy than the reactants. ΔH_f^o of NH_4Cl = 314.4 kJ/mol.
a) SO_2(g) + ½ O_2(g) ---> SO_3(g)
b) CaO(s) + H_2O(l) ---> $Ca(OH)_2$(s)
c) N_2(g) + 3 H_2(g) ---> 2 NH_3(g)
d) C_6H_6(l) + 1½ O_2(g) ---> 6 C(s) + 3 H_2O(l)

e) $NH_3(g) + HCl(g) \text{ ---> } NH_4Cl(s)$

Solutions

Reactions that were reversed or multiplied by a constant are shown in italics.

1. **ΔH = -137. kJ**

$C_2H_4\,(g) + 3\,O_2\,(g) \rightarrow 2\,CO_2\,(g) + 2\,H_2O\,(l)$ ΔH = -1411. kJ
$2\,CO_2\,(g) + 3\,H_2O\,(l) \rightarrow C_2H_6\,(g) + 7/2\,O_2\,(g)$ ΔH = +1560. kJ
$H_2\,(g) + 1/2\,O_2\,(g) \rightarrow H_2O\,(l)$ ΔH = -285.8 kJ

2. **ΔH = -906. kJ**

$2\,N_2\,(g) + 2\,O_2\,(g) \rightarrow 4\,NO\,(g)$ ΔH = 2 x (+180.5 kJ)
$4\,NH_3\,(g) \rightarrow 2\,N_2\,(g) + 6\,H_2\,(g)$ ΔH = 2 x (+91.8 kJ)
$6\,H_2\,(g) + 3\,O_2\,(g) \rightarrow 6\,H_2O\,(g)$ ΔH = 3 x (-483.6 kJ)

3. **ΔH_f = -486. kJ**

Reaction defining ΔH_f ($HC_2H_3O_2$) is: $2\,C(s, \text{graphite}) + 2\,H_2\,(g) + O_2\,(g) \rightarrow HC_2H_3O_2\,(l)$.
$2\,CO_2\,(g) + 2\,H_2O\,(l) \rightarrow HC_2H_3O_2\,(l) + 2\,O_2\,(g)$ ΔH = +875. kJ
$2\,C\,(s, \text{graphite}) + 2\,O_2\,(g) \rightarrow 2\,CO_2\,(g)$ ΔH = 2 x (-394.51 kJ)
$2\,H_2\,(g) + O_2\,(g) \rightarrow 2\,H_2O\,(l)$ ΔH = 2 x (-285.8 kJ)

4. **ΔH = +256.0 kJ**

$NH_3\,(g) \rightarrow 1/2\,N_2\,(g) + 3/2\,H_2\,(g)$ ΔH = 1/2 x (+91.8 kJ)
$CH_4\,(g) \rightarrow C\,(s, \text{graphite}) + 2\,H_2\,(g)$ ΔH = +74.9 kJ
$1/2\,H_2\,(g) + C\,(s, \text{graphite}) + 1/2\,N_2\,(g) \rightarrow HCN\,(g)$ ΔH = 1/2 x (+270.3 kJ)

5. **ΔH = -6387. kJ**

$2\,Al\,(s) + 6\,HCl\,(aq) \rightarrow 2\,AlCl_3\,(aq) + 3\,H_2\,(g)$ ΔH = -1049. kJ
$6\,HCl\,(g) \rightarrow 6\,HCl\,(aq)$ ΔH = 6 x (-74.8 kJ)
$3\,H_2\,(g) + 3\,Cl_2\,(g) \rightarrow 6\,HCl\,(g)$ ΔH = 3 x (-1845. kJ)
$2\,AlCl_3\,(aq) \rightarrow 2\,AlCl_3\,(s)$ ΔH = 2 x (+323. kJ)