Answer Key
Hess' Law Worksheet

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

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 = -1628. 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)*

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

3. **ΔH_f^0 = -486. kJ**

Reaction defining ΔH_f^0 ($HC_2H_3O_2$) is: $2\ C(s, graphite) + 2\ H_2\ (g) + O_2\ (g) \rightarrow HC_2H_3O_2\ (l)$. $\Delta H = -485.62\ kJ$

$2\ CO_2\ (g) + 2\ H_2O\ (l) \rightarrow HC_2H_3O_2\ (l) + 2\ O_2\ (g)$	*ΔH = +875. kJ*
$2\ C\ (s, graphite) + 2\ O_2\ (g) \rightarrow 2\ CO_2\ (g)$	*ΔH = 2 x (-394.51 kJ) = -789.02*
$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (l)$	*ΔH = 2 x (-285.8 kJ) = -571.6*

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) = + 45.9*
$CH_4\ (g) \rightarrow C\ (s, graphite) + 2\ H_2\ (g)$	*ΔH = +74.9 kJ*
$1/2\ H_2\ (g) + C\ (s, graphite) + 1/2\ N_2\ (g) \rightarrow HCN\ (g)$	ΔH = 1/2 x (+270.3 kJ) = + 135.15

$CH_4 + NH_3 \rightarrow HCN + 3H_2 \quad \Delta H = +255.95\ kJ$

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) = -448.8*
$3\ H_2\ (g) + 3\ Cl_2\ (g) \rightarrow 6\ HCl\ (g)$	*ΔH = 3 x (-1845. kJ) = -5535*
$2\ AlCl_3\ (aq) \rightarrow 2\ AlCl_3\ (s)$	*ΔH = 2 x (+323. kJ) = + 646*

$2Al + 3Cl_2 \rightarrow 2AlCl_3 \quad \Delta H = -6386.8\ kJ$

Here are some additional Hess' Law problems:

Ref. Moore, J.W., Stanitski, C.L., and Jurs, P. C., Chemistry: The Molecular Science, 2nd ed., Thomson, 2005.

ΔHf

1. Calculate the standard enthalpy change, ΔH°, for the formation of 1 mol of strontium carbonate (the material that gives the red color in fireworks) from its elements.

$Sr(s) + C(\text{graphite}) + \frac{3}{2}O_2(g) \rightarrow SrCO_3(s)$ why is this a formation rxn?

The information available is

(1) $Sr(s) + \frac{1}{2}O_2(g) \rightarrow SrO(s)$ $\Delta H^\circ = -592$ kJ

(2) $SrO(s) + CO_2(g) \rightarrow SrCO_3(s)$ $\Delta H^\circ = -234$ kJ

(3) $C(\text{graphite}) + O_2(g) \rightarrow CO_2(g)$ $\Delta H^\circ = -394$ kJ

nothing to do! everything cancels as is!

$\Delta H_f = -1220$ kJ

2. The combination of coke and steam produces a mixture called coal gas, which can be used as a fuel or as a starting material for other reactions. If we assume coke can be represented by graphite, the equation for the production of coal gas is

$2C(s) + 2H_2O(g) \rightarrow CH_4(g) + CO_2(g)$ $\Delta H_{rxn} = ?$

Determine the standard enthalpy change for this reaction from the following standard enthalpies of reaction :

(1) $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$ $2(\Delta H^\circ = 131.3\text{ kJ}) = 262.6$

(2) $CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$ $\Delta H^\circ = -41.2$ kJ

(3) $CH_4(g) + H_2O(g) \rightarrow 3H_2(g) + CO(g)$ $\Delta H^\circ = 206.1$ kJ

$3H_2 + CO \rightarrow CH_4 + H_2O$ -206.1

The next one is challenging!

3. One reaction involved in the conversion of iron ore to the metal is

$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$ $\Delta H = ?$ -15.3 kJ ? know this!

Calculate the standard enthalpy change for this reaction from these reactions of iron oxides with CO :

$\frac{1}{6}$ (1) $3Fe_2O_3(s) + CO(g) \rightarrow 2Fe_3O_4(s) + CO_2(g)$ $\frac{1}{6}\Delta H^\circ = -47.0$ kJ $= -7.8$

$\frac{1}{2}$ (2) $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$ $\frac{1}{2}\Delta H^\circ = -25.0$ kJ $= -12.5$

(3) $Fe_3O_4(s) + CO(g) \rightarrow 3FeO(s) + CO_2(g)$ $\Delta H^\circ = 19.0$ kJ

$\frac{1}{3}(3FeO + CO_2 \rightarrow Fe_3O_4 + CO)$ $\frac{1}{3}(-19.0) = -6.3$

Answers: 1. – 1220 kJ
2. + 15.3 kJ
3. – 11.0 kJ

$FeO + \frac{1}{3}CO_2 \rightarrow \frac{1}{3}Fe_3O_4 + \frac{1}{3}CO$ -6.3

$\frac{1}{2}Fe_2O_3 + \frac{3}{2}CO \rightarrow Fe + \frac{3}{2}CO_2$ -12.5

$\frac{1}{3}Fe_3O_4 + \frac{1}{6}CO_2 \rightarrow \frac{1}{2}Fe_2O_3 + \frac{1}{6}CO$ $+7.8$

-11 kJ