Thermodynamics
6.9 Hess's Law
Worksheet Key

1) Determine the value of the enthalpy change, ΔH_{rxn}, for the following reaction using the information below. $2\ Fe_2O_3(s) + 3\ C_{(graphite)} \rightarrow 4\ Fe(s) + 3\ CO_2(g)$

$C_{(graphite)} + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ/mol

$8\ Fe(s) + 6\ O_2(g) \rightarrow 4\ Fe_2O_3(s)$ $\Delta H = -3296.8$ kJ/mol

Reaction	Enthalpy(ΔH)
$3\ C_{(graphite)} + 3\ O_2(g) \rightarrow 3\ CO_2(g)$	$3\times(-393.5\ \text{kJ/mol})$
$2\ Fe_2O_3(g) \rightarrow 4\ Fe(s) + 3\ O_2(g)$	$-0.5\times(-3296.8\ \text{kJ/mol})$
$3\ C_{(graphite)} + 2\ Fe_2O_3(s) \rightarrow 4\ Fe(s) + 3\ CO_2(g)$	$\Delta H_{rxn} = 467.9$ kJ/mol

2) Determine the value of the enthalpy change, ΔH_{vap}, for the evaporation of one mole of water using the information below. $H_2O(l) \rightarrow H_2O(g)$

$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$ $\Delta H = -890.5$ kJ/mol

$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g)$ $\Delta H = -802.3$ kJ/mol

Reaction	Enthalpy (ΔH)
$1/2\ CO_2(g) + H_2O(l) \rightarrow 1/2\ CH_4(g) + O_2(g)$	$-0.5\times(-890.5\ \text{kJ/mol})$
$1/2\ CH_4(g) + O_2(g) \rightarrow 1/2\ CO_2(g) + H_2O(g)$	$0.5\times(-802.3\ \text{kJ/mol})$
$H_2O(l) \rightarrow H_2O(g)$	$\Delta H_{vap} = 44.1$ kJ/mol

3) Determine the value of the enthalpy change, ΔH_{rxn}, for the following reaction using the information below.

$N_2O(g) + NO_2(g) \rightarrow 3\ NO(g)$

$2\ NO(g) \rightarrow N_2(g) + O_2(g)$ $\Delta H = -181$ kJ/mol

$2\ N_2O(g) \rightarrow 2\ N_2(g) + O_2(g)$ $\Delta H = -163$ kJ/mol

$NO(g) + ½\ O_2(g) \rightarrow NO_2(g)$ $\Delta H = -57$ kJ/mol

Reaction	Enthalpy(ΔH)
$N_2O_{(g)} \rightarrow N_{2(g)} + 1/2\ O_{2(g)}$	$(-163\ \text{kJ/mol})\div 2$
$NO_{2(g)} \rightarrow NO_{(g)} + 1/2\ O_{2(g)}$	$(-1)(-57\ \text{kJ/mol})$
$N_{2(g)} + O_{2(g)} \rightarrow 2\ NO_{(g)}$	$(-1)(-181\ \text{kJ/mol})$
$N_2O_{(g)} + NO_{2(g)} \rightarrow 3\ NO_{(g)}$	$\Delta H_{rxn} = 157$ kJ/mol

4) Determine the value of the enthalpy change, ΔH_{rxn}, for the following reaction using the information below.

$$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(l)$$

$C_{(graphite)} + O_2(g) \rightarrow CO_2(g)$	ΔH = -393.5 kJ/mol
$H_2O(l) \rightarrow H_2(g) + \frac{1}{2}\ O_2(g)$	ΔH = 286 kJ/mol
$C_3H_8(g) \rightarrow 3\ C_{(graphite)} + 4\ H_2(g)$	ΔH = 105 kJ/mol

Reaction	Enthalpy(ΔH)
$C_3H_{8(g)} \rightarrow 3\ C_{(graphite)} + 4\ H_{2(g)}$	105 kJ/mol
$4\ H_{2(g)} + 2\ O_{2(g)} \rightarrow 4H_2O_{(l)}$	$-4\times$(286 kJ/mol)
$3\ C_{(graphite)} + 3\ O_2 \rightarrow 3\ CO_2$	$3\times$(–393.5 kJ/mol)
$C_3H_{8(g)} + 5\ O_{2(g)} \rightarrow 3\ CO_{2(g)} + 4\ H_2O_{(l)}$	$\Delta H_{rxn} = -2220$ kJ/mol

5) Determine the value of the enthalpy change, ΔH_{rxn}, for the following reaction using the information below.

$$C_2H_4(g) + 6\ F_2(g) \rightarrow 2\ CF_4(g) + 4\ HF(g)$$

$2\ C_2H_4(g) \rightarrow 4\ H_2(g) + 4\ C(s)$	ΔH = -104.6 kJ
$CF_4(g) \rightarrow C(s) + 2\ F_2(g)$	ΔH = +680.0 kJ
$H_2(g) + F_2(g) \rightarrow 2\ HF(g)$	ΔH = -537 kJ

Reaction	Enthalpy(ΔH)
$C_2H_2(g) \rightarrow 2H_2(g) + 2C(s)$	-104.6kJ/mol ÷ 2
$2C(s) + 4F_2(g) \rightarrow 2CF_4(g)$	$-2\times$(680.0 kJ/mol)
$2H_2(g) + 2F_2(g) \rightarrow 4HF(g)$	$2\times$(–537 kJ/mol)
$C_2H_2(g) + 6F_2(g) \rightarrow 2CF_4(g) + 4HF(g)$	$\Delta H_{rxn} = -2486$ kJ/mol

6) Determine the value of the enthalpy change, ΔH^o_{rxn}, for the following reaction using the information below.

$$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(l)$$

$CH_4(g) + O_2(g) \rightarrow CH_2O(g) + H_2O(g)$	ΔH^o = -284 kJ
$2\ CH_2O(g) + 2\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(g)$	ΔH^o = -1036 kJ
$H_2O(g) \rightarrow H_2O(l)$	ΔH^o = -44 kJ

Reaction	Enthalpy(ΔH)
$CH_{4(g)} + O_{2(g)} \rightarrow CH_2O_{(g)} + H_2O_{(g)}$	-284 kJ/mol
$CH_2O_{(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$	$0.5\times$(–1036 kJ/mol)
$2\ H_2O_{(g)} \rightarrow 2\ H_2O_{(l)}$	`$2\times$(–44 kJ/mol)
$CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(l)}$	$\Delta H_{rxn} = -8.90\times10^2$ kJ/mol

7) Determine the value of the enthalpy change, ΔH^{o}_{rxn}, for the following reaction using the information below.

$$C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$$

$C(s) + O_2(g) \rightarrow CO_2(g)$	$\Delta H^{o} = -394$ kJ
$2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$	$\Delta H^{o} = -566$ kJ
$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$	$\Delta H^{o} = -484$ kJ

Reaction	Enthalpy(ΔH)
$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$	-394 kJ/mol
$CO_{2(g)} \rightarrow CO_{(g)} + 1/2\ O_{2(g)}$	$-0.5 \times (-566$ kJ/mol)
$H_2O_{(g)} \rightarrow H_{2\,(g)} + 1/2\ O_{2(g)}$	$-0.5 \times (-484$ kJ/mol)
$C_{(s)} + H_2O_{(g)} \rightarrow CO_{(g)} + H_{2\,(g)}$	$\Delta H_{rxn} = 131$ kJ/mol