Hess' Law

Name_____ Section_____

1. Predict the product for the following reactions

   a) $NaOH(aq) + HCl(aq) \rightarrow$ **$NaCl(aq) + H_2O(l)$**

   b) $NaOH(s) + HCl(aq) \rightarrow$ **$NaCl(aq) + H_2O(l)$**

2. Predict the product for the following reactions

   a)

$$\mathbf{Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)}$$

$$\mathbf{H^+(aq) + OH^-(aq) \rightarrow H_2O(l)}$$

   b)

$$\mathbf{NaOH(s) + H^+(aq) + Cl^-(aq) \rightarrow H_2O(l) + Na^+(aq) + Cl^-(aq)}$$

$$\mathbf{NaOH(s) + H^+(aq) \rightarrow H_2O(l) + Na^+(aq)}$$

3. For each of the following chemical equations predict whether the reaction is exothermic or endothermic.

   a) $2C_6H_6O(l) + 17O_2(g) \rightarrow 12CO_2(g) + 12H_2O(l)$ **exothermic**

   b) $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$ **exothermic**

   c) $H_2O(s) \rightarrow H_2O(l)$ **endothermic**

   d) $H_2O(g) \rightarrow H_2O(l)$ **exothermic**

4. Calculate Δn (the change in the moles of gaseous substances) for each of the following balanced chemical equations.

   a) $2C_6H_6O(l) + 17O_2(g) \rightarrow 12CO_2(g) + 12H_2O(l)$ **$\Delta n = -5$**

   b) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ **$\Delta n = -1$**

   c) $N_2(g) + O_2(g) \rightarrow 2NO(g)$ **$\Delta n = 0$**

   d) $2Na(s) + Br_2(l) \rightarrow 2NaBr(s)$ **$\Delta n = 0$**

5. When 8.50 g of NH_3 are formed, according to the following balanced chemical equation,

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

23.1 kJ of heat are released.

a) How many kJ of heat are released when 1 mol of N_2 reacts with excess H_2?

$$\mathbf{8.50\ g\ NH_3\left(\frac{1\ mol\ NH_3}{17.0\ g\ NH_3}\right) = 0.500\ mol\ NH_3}$$

$$\mathbf{\frac{23.1\ kJ}{0.5\ mol\ NH_3} = \frac{46.2\ kJ}{1\ mol\ NH_3}}$$

b) How many kJ of heat are released when 2 mol of NH_3 are formed?

$$\mathbf{2\ mol\ NH_3\left(\frac{46.2\ kJ}{1\ mol\ NH_3}\right) = +\ 92.4\ kJ}$$

c) How many kJ of heat are released when 4 mol of N_2 reacts with 4 mol H_2?

$(moles\ N_2)_o$	$(moles\ H_2)_{required}$	$(moles\ H_2)_o$	Conclusion
4 mol	**12 mol**	**4 mol**	**H_2 limiting**

$$\mathbf{4\ mol\ N_2\left(\frac{3\ mol\ H_2}{1\ mol\ N_2}\right) = 12\ mol\ H_2}$$

$$\mathbf{4\ mol\ H_2\left(\frac{92.4\ kJ}{3\ mol\ H_2}\right) = 123.2\ kJ\ released}$$

6. Use Hess' Law and the following chemical equations

Chemical Equation	ΔH (kJ mol^{-1})
$\frac{1}{2}\ N_{2(g)} + \frac{1}{2}\ O_{2(g)} \rightarrow NO_{(g)}$	30.0
$\frac{1}{2}\ N_{2(g)} + O_{2(g)} \rightarrow NO_{2(g)}$	46.0

Calculate the ΔH_{rxn} for the equation.

$$2N_{2(g)} + 3O_{2(g)} \rightarrow 2NO_{(g)} + 2NO_{2(g)}$$

Chemical Equation	**ΔH (kJ mol^{-1})**
$\mathbf{2 \cdot (\frac{1}{2}\ N_{2(g)} + \frac{1}{2}\ O_{2(g)} \rightarrow NO_{(g)})}$	**$2 \cdot (30.0)$**
$\mathbf{2 \cdot (\frac{1}{2}\ N_{2(g)} + O_{2(g)} \rightarrow NO_{2(g)})}$	**$2 \cdot (46.0)$**

$$\mathbf{\Delta H = 60\ kJ\ mol^{-1} + 92\ kJ\ mol^{-1} = 152\ kJ\ mol^{-1}}$$

7. Calculate ΔH_{rxn} for the following reactions

a) $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

$\mathbf{\Delta H^\circ_f}$ **-296.8 kJ mol^{-1}** **0** **-395.7 kJ mol^{-1}**

$$\mathbf{\Delta H^\circ_{rxn} = \Sigma m \Delta H^\circ_f\ (products) - \Sigma n \Delta H^\circ_f\ (reactants)}$$

$$\mathbf{\Delta H^\circ_{rxn} = 2\Delta H^\circ_f\ (SO_3) - [2\Delta H^\circ_f\ (SO_2) - \Delta H^\circ_f\ (O_2)]}$$

ΔH°_{rxn} **= 2(-395.7 kJ mol^{-1}) - [2(-296.8 kJ mol^{-1})- (0)]**

ΔH°_{rxn} **= –197.8 kJ mol reaction^{-1}**

b) $2C_6H_{6(l)} + 15O_{2(g)} \rightarrow 12CO_{2(g)} + 6H_2O_{(l)}$

ΔH°_f	**49.0 kJ mol^{-1}**	**0**	**-393.5 kJ mol^{-1}**	**-285.85 kJ mol^{-1}**

ΔH°_{rxn} **= $\Sigma m\Delta H^\circ_f$ (products) - $\Sigma n\Delta H^\circ_f$ (reactants)**

ΔH°_{rxn} **= 12ΔH°_f (CO_2) + 6ΔH°_f (H_2O) - [2ΔH°_f (C_6H_6) + 15ΔH°_f (O_2)**

ΔH°_{rxn} **= 12(-393.5 kJ mol^{-1}) + 6(-285.85 kJ mol^{-1}) - [2(49.0 kJ mol^{-1}) + 15(0)]**

ΔH°_{rxn} **= -6535 kJ mol^{-1}**