Exercise 05.6
Hess' Law

Name: ______________________

Date:________________ Per:________

Germain Henri Hess, in 1840, discovered a very useful principle which is named for him:

The enthalpy of a given chemical reaction is constant, regardless of the reaction happening in one step or many steps.

Hess' Law is usually presented like this: $\Delta H°_{rxn} = \Sigma\ \Delta H°_f$ (products) - $\Sigma\ \Delta H°_f$ (reactants)

Or this: $\Delta H°_{rxn} = \Sigma\ \Delta H°_{f,\ products} - \Sigma\ \Delta H°_{f,\ reactants}$

Hess' Law states that the heat evolved in a given process can be expressed as the sum of the heats of several processes that, when added, yield the process of interest. Because enthalpy is a state function, if the reactants and products remain the same, it doesn't matter how the reaction is carried out.
Some general rules relating to Hess' Law:

- The standard enthalpy of formation for an element in its standard state is zero.
- When a reaction is reversed, the sign of ΔH is changed.
- If you modify the coefficients of a reaction, multiply ΔH by the same factor.

DIRECTIONS: Answer the following in the space provided:

1. Carefully and precisely describe the difference between H, ΔH, ΔH^o, and ΔH^o_f

2. Write a formation equation that goes with ΔH_f for:

   a. H_2O(l)

   b. C_3H_8(g)

   c. CO_2(g)

3. Given the following data:

   $S(s) + \frac{3}{2} O_2(g) \rightarrow SO_3(g)$ $\Delta H° = -395.2$ kJ

   $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ $\Delta H° = -198.2$ kJ

   Calculate $\Delta H°$ for the reaction: $S(s) + O_2(g) \rightarrow SO_2(g)$

4. Given the following data:

   $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ $\Delta H° = 67.7$ kJ

   $N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$ $\Delta H° = 9.7$ kJ

   Calculate $\Delta H°$ for the dimerization of NO_2: $2NO_2(g) \rightarrow N_2O_4(g)$

5. Given the following data:

   $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H° = -285.8$ kJ

   $N_2O_5(g) + H_2O(l) \rightarrow 2HNO_3(l)$ $\Delta H° = -76.6$ kJ

   $\frac{1}{2} N_2(g) + \frac{3}{2} O_2(g) + \frac{1}{2} H_2(g) \rightarrow HNO_3(l)$ $\Delta H° = -174.1$ kJ

   Calculate the $\Delta H°$ for the reaction: $2N_2(g) + 5O_2(g) \rightarrow 2\ N_2O_5(g)$

Answers: 3) -296.1 kJ 4) -58.0 kJ 5) 28.4 kJ 6) 226 kJ 7) -233 kJ 8) -202.6 kJ 9) -426 kJ 10) 15.3 kJ 11) 1268 kJ 12) −712.8 kJ 13) 16.8 kJ

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6. Given the following data:

   $C_2H_2(g) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$ $\Delta H° = -1300.$ kJ

   $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H° = -394$ kJ

   $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H° = -286$ kJ

   Calculate the $\Delta H°$ for the reaction: $2C(s) + H_2(g) \rightarrow C_2H_2(g)$

7. Given the following data:

   $2O_3(g) \rightarrow 3O_2(g)$ $\Delta H° = -427$ kJ

   $O_2(g) \rightarrow 2O(g)$ $\Delta H° = +495$ kJ

   $NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$ $\Delta H° = -199$ kJ

   Calculate $\Delta H°$ for the reaction: $NO(g) + O(g) \rightarrow NO_2(g)$

8. The bombardier beetle uses an explosive discharge as a defensive measure. The chemical reaction involved is the oxidation of hydroquinone by hydrogen peroxide to produce quinone and water;

   $C_6H_4(OH)_2(aq) + H_2O_2(aq) \rightarrow C_6H_4O_2(aq) + 2H_2O(l)$

   Calculate $\Delta H°$ for the reaction from the following data:

   $C_6H_4(OH)_2(aq) \rightarrow C_6H_4O_2(aq) + H_2(g)$ $\Delta H° = +177.4$ kJ

   $H_2(g) + O_2(g) \rightarrow H_2O_2(aq)$ $\Delta H° = -191.2$ kJ

   $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ $\Delta H° = -241.8$ kJ

   $H_2O(g) \rightarrow H_2O(l)$ $\Delta H° = -43.8$ kJ

9. Given the following data:

   $O_2(g) + H_2(g) \rightarrow 2OH(g)$ $\Delta H° = +77.9$ kJ

   $O_2(g) \rightarrow 2O(g)$ $\Delta H° = +495$ kJ

   $H_2(g) \rightarrow 2H(g)$ $\Delta H° = +435.9$ kJ

   Calculate $\Delta H°$ for the reaction: $O(g) + H(g) \rightarrow OH(g)$

10. 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 producing coal gas is:

    $2C(s) + 2H_2O(g) \rightarrow CH_4(g) + CO_2(g)$

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

    $C(s) + H_2O(g) \rightarrow CO(g) +\_ H_2(g)$ $\Delta H^o = 131.3$ kJ

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

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

Answers: 3) -296.1 kJ 4) -58.0 kJ 5) 28.4 kJ 6) 226 kJ 7) -233 kJ 8) -202.6 kJ 9) -426 kJ 10) 15.3 kJ 11) 1268 kJ 12) −712.8 kJ 13) 16.8 kJ

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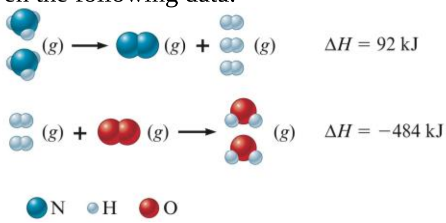
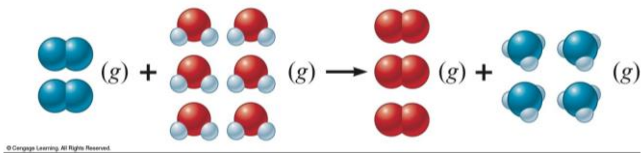
11. Given the following data:



Calculate ΔH for the reaction:



12. Given the following data:

$Ca(s) + 2C_{(graphite)} \rightarrow CaC_2(s)$	$\Delta H = -62.8$ kJ
$Ca(s) + {}^{1}/_{2}O_2(g) \rightarrow CaO(s)$	$\Delta H = -635.5$ kJ
$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$	$\Delta H = -653.1$ kJ
$C_2H_2(g) + {}^{5}/_{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$	$\Delta H = -1300.$ kJ
$C_{(graphite)} + O_2(g) \rightarrow CO_2(g)$	$\Delta H = -393.5$ kJ

Calculate ΔH for the following reaction:

$CaC_2(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + C_2H_2(g)$

13. Using the following data, calculate the standard heat of formation of ICl(g) in kJ/mol:

$Cl_2(g) \rightarrow 2Cl(g)$	$\Delta H° = 242.3$ kJ
$I_2(g) \rightarrow 2I(g)$	$\Delta H° = 151.0$ kJ
$ICl(g) \rightarrow I(g) + Cl(g)$	$\Delta H° = 211.3$ kJ
$I_2(s) \rightarrow I_2(g)$	$\Delta H° = 62.8$ kJ

Answers: 3) -296.1 kJ 4) -58.0 kJ 5) 28.4 kJ 6) 226 kJ 7) -233 kJ 8) -202.6 kJ 9) -426 kJ 10) 15.3 kJ 11) 1268 kJ 12) −712.8 kJ 13) 16.8 kJ