

Summary

- Hess's law states that the enthalpy change of a process is the same whether the process takes place in one step or in a series of steps.
- By applying Hess's law, we can manipulate and combine different chemical equations to determine the enthalpy change of a reaction of interest.

Questions

1. (a) State Hess's law in your own words.

(b) In a correct equation for a reverse reaction,

what happens to the sign and magnitude of ΔH° ?

(c) When you multiply the coefficients of a balanced equation by a constant, what changes must you

make to the sign and magnitude of ΔH° ?

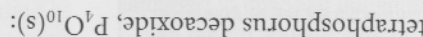
2. Explain how Hess's law is consistent with the law of

conservation of energy.

3. What characteristic of enthalpy change is the basis

of Hess's law?

4. Phosphorus burns spontaneously in air to produce



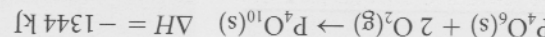
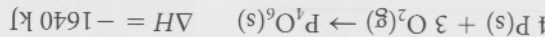
Using the following thermochemical equations,

determine:

(a) the enthalpy of combustion for phosphorus

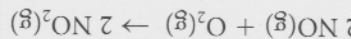
(b) the molar enthalpy of combustion for

phosphorus, expressed in kJ/mol



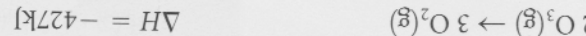
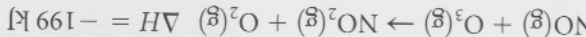
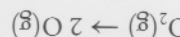
5. Nitric oxide gas, NO(g) , can be oxidized in air to

produce nitrogen dioxide gas, $\text{NO}_2\text{(g)}$:



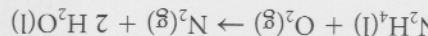
Determine the enthalpy change for this reaction

using any of these thermochemical equations:



6. Liquid hydrazine, $\text{N}_2\text{H}_4\text{(l)}$, is a rocket fuel. It combusts

in oxygen gas to form nitrogen gas and liquid water:



Use the following thermochemical equations to

calculate the enthalpy change for the combustion of

liquid hydrazine:

- $$2\text{NH}_3\text{(g)} + 3\text{N}_2\text{O(g)} \rightarrow 4\text{N}_2\text{(g)} + 3\text{H}_2\text{O(l)} \quad \Delta H = -1010 \text{ kJ}$$

$$\text{N}_2\text{O(g)} + 3\text{H}_2\text{(g)} \rightarrow \text{N}_2\text{H}_4\text{(l)} + \text{H}_2\text{O(l)} \quad \Delta H = -317 \text{ kJ}$$

$$2\text{NH}_3\text{(g)} + \frac{7}{2}\text{O}_2\text{(g)} \rightarrow \text{N}_2\text{H}_4\text{(l)} + \text{H}_2\text{O(l)} \quad \Delta H = -143 \text{ kJ}$$

$$\text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{H}_2\text{O(l)} \quad \Delta H = -286 \text{ kJ}$$
7. Solid calcium carbide, $\text{CaC}_2\text{(s)}$, reacts with liquid water to produce ethyne, $\text{C}_2\text{H}_2\text{(g)}$ (acetylene):

$$\text{CaC}_2\text{(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Ca(OH)}_2\text{(aq)} + \text{C}_2\text{H}_2\text{(g)}$$

Using the following thermochemical equations, calculate the enthalpy change for this reaction:

$$\text{Ca(s)} + 2\text{C}^{\text{graphite}}\text{(s)} \rightarrow \text{CaC}_2\text{(s)} \quad \Delta H = -62.8 \text{ kJ}$$

$$\text{Ca(s)} + \frac{7}{2}\text{O}_2\text{(g)} \rightarrow \text{CaO(s)} \quad \Delta H = -635.5 \text{ kJ}$$

$$\text{CaO(s)} + \text{H}_2\text{O(l)} \rightarrow \text{Ca(OH)}_2\text{(aq)} \quad \Delta H = -653.1 \text{ kJ}$$

$$\text{C}_2\text{H}_2\text{(g)} + \frac{5}{2}\text{O}_2\text{(g)} \rightarrow 2\text{CO}_2\text{(g)} + \text{H}_2\text{O(l)} \quad \Delta H = -1300. \text{ kJ}$$

$$\text{C}^{\text{graphite}}\text{(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} \quad \Delta H = -393.5 \text{ kJ}$$
8. The neutralization reaction between lithium hydroxide solution, LiOH(aq) , and hydrochloric acid, HCl(aq) , will produce water and aqueous lithium chloride, LiCl(aq) . Using the following thermochemical equations, determine the enthalpy of neutralization for 1 mol of aqueous lithium hydroxide:

$$\frac{1}{2}\text{H}_2\text{(g)} + \frac{1}{2}\text{Cl}_2\text{(g)} \rightarrow \text{HCl(g)} \quad \Delta H = -92.3 \text{ kJ}$$

$$\text{H}_2\text{(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{H}_2\text{O(l)} \quad \Delta H = -285.8 \text{ kJ}$$

$$\text{Li(s)} + \frac{1}{2}\text{Cl}_2\text{(g)} \rightarrow \text{LiCl(s)} \quad \Delta H = -815.0 \text{ kJ}$$

$$\text{Li(s)} + \frac{1}{2}\text{O}_2\text{(g)} + \frac{1}{2}\text{H}_2\text{(g)} \rightarrow \text{LiOH(s)} \quad \Delta H = -487.0 \text{ kJ}$$

$$\text{LiOH(s)} \rightarrow \text{LiOH(aq)} \quad \Delta H = -19.2 \text{ kJ}$$

$$\text{HCl(g)} \rightarrow \text{HCl(aq)} \quad \Delta H = -77.0 \text{ kJ}$$

$$\text{LiCl(s)} \rightarrow \text{LiCl(aq)} \quad \Delta H = -36.0 \text{ kJ}$$

Summary

- Hess's law states that the enthalpy change of a process is the same whether the process takes place in one step or in a series of steps.
- By applying Hess's law, we can manipulate and combine different chemical equations to determine the enthalpy change of a reaction of interest.

Questions

1. (a) State Hess's law in your own words.

(b) In a correct equation for a reverse reaction,

what happens to the sign and magnitude of ΔH° ?

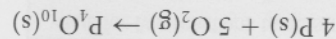
(c) When you multiply the coefficients of a balanced equation by a constant, what changes must you

make to the sign and magnitude of ΔH° ?

2. Explain how Hess's law is consistent with the law of conservation of energy.

3. What characteristic of enthalpy change is the basis of Hess's law?

4. Phosphorus burns spontaneously in air to produce tetraphosphorus decaoxide, $P_4O_{10}(s)$:

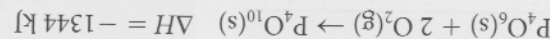
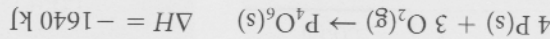


Using the following thermochemical equations, determine:

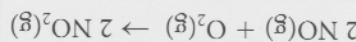
(a) the enthalpy of combustion for phosphorus

(b) the molar enthalpy of combustion for phosphorus

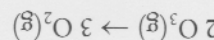
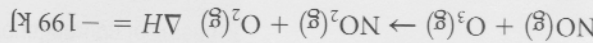
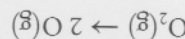
phosphorus, expressed in kJ/mol



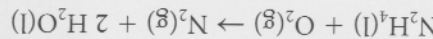
5. Nitric oxide gas, $NO(g)$, can be oxidized in air to produce nitrogen dioxide gas, $NO_2(g)$:



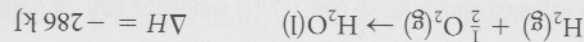
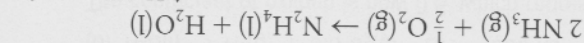
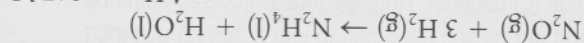
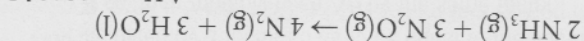
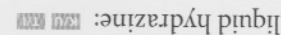
Determine the enthalpy change for this reaction using any of these thermochemical equations:



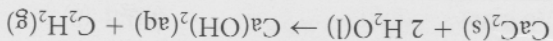
6. Liquid hydrazine, $N_2H_4(l)$, is a rocket fuel. It combusts in oxygen gas to form nitrogen gas and liquid water:



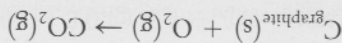
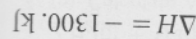
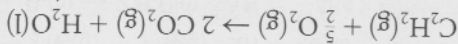
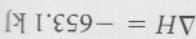
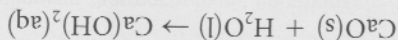
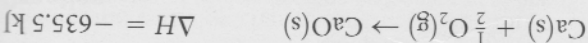
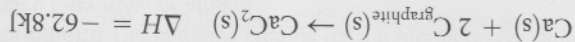
Use the following thermochemical equations to calculate the enthalpy change for the combustion of liquid hydrazine:



7. Solid calcium carbide, $CaC_2(s)$, reacts with liquid water to produce ethyne, $C_2H_2(g)$ (acetylene):



Using the following thermochemical equations, calculate the enthalpy change for this reaction:



8. The neutralization reaction between lithium hydroxide solution, $LiOH(aq)$, and hydrochloric acid, $HCl(aq)$, will produce water and aqueous lithium chloride, $LiCl(aq)$. Using the following thermochemical equations, determine the enthalpy of neutralization for 1 mol of aqueous lithium hydroxide:

