

Exercise 6.4

Enthalpy of Formation

Name: _____

Date: _____ Per: _____

Hess' Law can be used to determine the enthalpy of reaction for chemical reactions by using the enthalpies of formation for the component reactants and products, using the formula:

$$\Delta H^{\circ}_{\text{rxn}} = \sum \Delta H^{\circ}_{\text{f, products}} - \sum \Delta H^{\circ}_{\text{f, reactants}}$$

Some general rules relating to Hess' Law when calculating ΔH° for a reaction from enthalpies of formation:

- The standard enthalpy of formation for an element in its standard state is zero.
 - Standard states for most elements are their solid, monatomic state.
 - Standard states for noble gases and H_2 , O_2 , N_2 , F_2 , Cl_2 are gaseous.
 - Standard state for $\text{C}(\text{s})$ is graphite.
 - Standard states for Hg and Br_2 are liquid.
 - Standard state for iodine is diatomic solid (I_2).
- If you modify the coefficients of a reaction, multiply ΔH by the same factor.

1. Give the definition of the standard enthalpy of formation for a substance.

Compound	ΔH_f (kJ/mol)	Compound	ΔH_f (kJ/mol)
$\text{AlCl}_3(\text{s})$	-704.2	$\text{MnO}_2(\text{s})$	-519.7
$\text{Al}_2\text{O}_3(\text{s})$	-1675.7	$\text{NaCl}(\text{s})$	-411.0
$\text{Ca}_3(\text{PO}_4)_2(\text{s})$	-4120.8	$\text{NaF}(\text{s})$	-569.0
$\text{CaSO}_4(\text{s})$	-1434.5	$\text{Na}_2\text{O}(\text{s})$	-414.2
$\text{CH}_4(\text{g})$	-74.8	$\text{NaOH}(\text{s})$	-426.7
$\text{ClF}_3(\text{g})$	-163.2	$\text{NH}_3(\text{g})$	-46.2
$\text{CO}(\text{g})$	-110.5	$\text{N}_2\text{H}_3\text{CH}_3(\text{l})$	54
$\text{CO}_2(\text{g})$	-393.5	$\text{NH}_4\text{Cl}(\text{s})$	-315.4
$\text{HCl}(\text{g})$	-92.3	$\text{NH}_4\text{ClO}_4(\text{s})$	-295
$\text{HCN}(\text{g})$	130.5	$\text{NO}(\text{g})$	+90.4
$\text{HF}(\text{g})$	-268.6	$\text{NO}_2(\text{g})$	+33.9
$\text{HNO}_3(\text{aq})$	-207.4	$\text{N}_2\text{O}_4(\text{l})$	-20.
$\text{H}_2\text{O}(\text{g})$	-241.8	$\text{SnCl}_4(\text{l})$	-545.2
$\text{H}_2\text{O}(\text{l})$	-285.8	$\text{SnO}(\text{s})$	-286.2
$\text{H}_3\text{PO}_4(\text{l})$	-1271.7	$\text{SnO}_2(\text{s})$	-580.7
$\text{H}_2\text{S}(\text{g})$	-20.1	$\text{SO}_2(\text{g})$	-296.1
$\text{H}_2\text{SO}_4(\text{l})$	-811.3	$\text{SO}_3(\text{g})$	-395.2
$\text{MgSO}_4(\text{s})$	-1278.2	$\text{ZnO}(\text{s})$	-348.0
$\text{MnO}(\text{s})$	-384.9	$\text{ZnS}(\text{s})$	-202.9

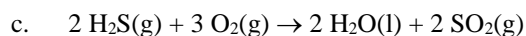
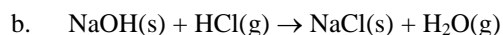
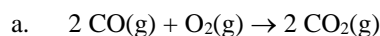
2. Write separate reactions for the formation of NaCl , $\text{C}_6\text{H}_{12}\text{O}_6$, and PbSO_4 that have ΔH° values equal to ΔH°_f for each compound.

a. NaCl : _____

b. $\text{C}_6\text{H}_{12}\text{O}_6$: _____

c. PbSO_4 : _____

3. Determine the ΔH° for each of these reactions. State whether each reaction is endothermic or exothermic.



4. The standard enthalpy of combustion for xylene, $\text{C}_8\text{H}_{10}(\text{l})$, is $-3908 \text{ kJ mol}^{-1}$. Calculate the standard enthalpy of formation of $\text{C}_8\text{H}_{10}(\text{l})$, in kJ mol^{-1} . (Hint: Write chemical equations for combustion of Xylene.)

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5. Use the values of ΔH_f° in the reference table to calculate ΔH° for the following reactions:
- $2\text{NH}_3(\text{g}) + 3\text{O}_2(\text{g}) + 2\text{CH}_4(\text{g}) \rightarrow 2\text{HCN}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$
 - $\text{Ca}_3(\text{PO}_4)_2(\text{s}) + 3\text{H}_2\text{SO}_4(\text{l}) \rightarrow 3\text{CaSO}_4(\text{s}) + 2\text{H}_3\text{PO}_4(\text{l})$
 - $\text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \rightarrow \text{NH}_4\text{Cl}(\text{s})$
6. The reusable booster rockets of the space shuttle use a mixture of aluminum and ammonium perchlorate as fuel. A possible reaction is: $3\text{Al}(\text{s}) + 3\text{NH}_4\text{ClO}_4(\text{s}) \rightarrow \text{Al}_2\text{O}_3(\text{s}) + \text{AlCl}_3(\text{s}) + 3\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$. Calculate ΔH° for this reaction.
7. The space shuttle orbiter utilizes the oxidation of methyl hydrazine by dinitrogen tetroxide for propulsion: $5\text{N}_2\text{O}_4(\text{l}) + 4\text{N}_2\text{H}_3\text{CH}_3(\text{l}) \rightarrow 12\text{H}_2\text{O}(\text{g}) + 9\text{N}_2(\text{g}) + 4\text{CO}_2(\text{g})$. Calculate ΔH° for this reaction.
8. Consider the reaction: $2\text{ClF}_3(\text{g}) + 2\text{NH}_3(\text{g}) \rightarrow \text{N}_2(\text{g}) + 6\text{HF}(\text{g}) + \text{Cl}_2(\text{g})$; $\Delta H^\circ = -1196 \text{ kJ}$. Calculate ΔH_f° for $\text{ClF}_3(\text{g})$.
9. The enthalpy of combustion of ethane gas, $\text{C}_2\text{H}_4(\text{g})$, is -1411.1 kJ/mol at 298 K. Calculate ΔH_f° for $\text{C}_2\text{H}_4(\text{g})$.
10. The Ostwald process for the commercial production of nitric acid from ammonia and oxygen involves the following steps. Use the values of ΔH_f° in the reference table to calculate the value of ΔH° for each of the reactions.
- $4\text{NH}_3(\text{g}) + 5\text{O}_2(\text{g}) \rightarrow 4\text{NO}(\text{g}) + 6\text{H}_2\text{O}(\text{g})$
 - $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$
 - $3\text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow 2\text{HNO}_3(\text{aq}) + \text{NO}(\text{g})$