

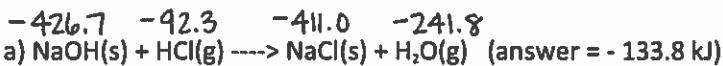
Thermochemistry Review

~ KEY ~

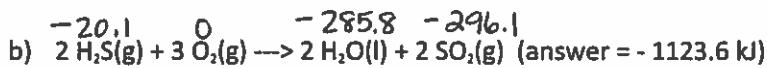
1. Which of these changes are endothermic? Which are exothermic? (You must know the names for each of the phase changes.)

- a) Melting of ice endo.
 b) $\text{CH}_4(\text{g}) + 2 \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2 \text{H}_2\text{O}(\text{g}) + 882 \text{ kJ}$ exo.
 c) Deposition of iodine exo. (deposition is gas \rightarrow solid)
 d) $\text{NH}_4\text{Cl}(\text{s}) \rightarrow \text{NH}_4\text{Cl}(\text{aq}) \quad \Delta H^\circ = +14.7 \text{ kJ/mol}$ endo
 e) Calcium oxide solid dissolving in water causes a temperature increase exo

2. Use the standard enthalpies of formation table to determine the ΔH_{rxn} for each of these reactions. (You must know the enthalpy of formation for all elements = 0.)



$$\begin{aligned} \Delta H_{rxn} &= \text{H products} - \text{H reactants} \\ &= [-411.0 + (-241.8)] - [-426.7 + (-92.3)] = -133.8 \text{ kJ} \end{aligned}$$



$$\begin{aligned} \Delta H_{rxn} &= \text{H products} - \text{H reactants} \\ &= [2(-285.8) + 2(-296.1)] - [2(-20.1) + 3(0)] \\ &= -1163.8 - (-40.2) = -1123.6 \text{ kJ} \end{aligned}$$



$$\begin{aligned} \Delta H_{rxn} &= \text{H products} - \text{H reactants} \\ &= [2(33.9)] - [2(90.4)] = -113.0 \text{ kJ} \end{aligned}$$

| Compound | ΔH_f (kJ/mol) | Compound | ΔH_f (kJ/mol) |
|-----------------------------------|-----------------------|----------------------------------|-----------------------|
| $\text{CH}_4(\text{g})$ | -74.8 | $\text{HCl}(\text{g})$ | -92.3 |
| $\text{CO}_2(\text{g})$ | -393.5 | $\text{H}_2\text{O}(\text{g})$ | -241.8 |
| $\text{CO}(\text{g})$ | -110.5 | $\text{SO}_2(\text{g})$ | -296.1 |
| $\text{H}_2\text{O}(\text{l})$ | -285.8 | $\text{NH}_4\text{Cl}(\text{s})$ | -315.4 |
| $\text{H}_2\text{S}(\text{g})$ | -20.1 | $\text{NO}(\text{g})$ | +90.4 |
| $\text{H}_2\text{SO}_4(\text{l})$ | -811.3 | $\text{NO}_2(\text{g})$ | +33.9 |
| $\text{MgSO}_4(\text{s})$ | -1278.2 | $\text{SnCl}_4(\text{l})$ | -545.2 |
| $\text{MnO}(\text{s})$ | -384.9 | $\text{SnO}(\text{s})$ | -286.2 |
| $\text{MnO}_2(\text{s})$ | -519.7 | $\text{SnO}_2(\text{s})$ | -580.7 |
| $\text{NaCl}(\text{s})$ | -411.0 | $\text{SO}_3(\text{g})$ | -296.1 |
| $\text{NaF}(\text{s})$ | -569.0 | $\text{SO}_3(\text{g})$ | -395.2 |
| $\text{NaOH}(\text{s})$ | -426.7 | $\text{ZnO}(\text{s})$ | -348.0 |
| $\text{NH}_3(\text{g})$ | -46.2 | $\text{ZnS}(\text{s})$ | -202.9 |



REVIEW: So far you've learned about how to calculate:

- Heat associated with a phase change
- Heat associated with a temperature change
- Heat of reaction using standard heat of formation (ΔH_f)

Determine which method applies and calculate the enthalpy for each of the problems below.

2. For the reaction



the $\Delta H^\circ_{\text{comb}}$ is -2877.4 kJ .

a) What is the $\Delta H^\circ_{\text{comb}}$ for the combustion of 1 mole of C_4H_{10} ? (answer = -1438.7 kJ)

$$\begin{array}{c|c} 1 \text{ mole } \text{C}_4\text{H}_{10} & -2877.4 \text{ kJ} \\ \hline & 2 \text{ moles } \text{C}_4\text{H}_{10} \end{array} = -1438.7 \text{ kJ}$$

b) What is the $\Delta H^\circ_{\text{comb}}$ for the production of 5 moles of H_2O ? (answer = -575.5 kJ)

$$\begin{array}{c|c} 5 \text{ moles } \text{H}_2\text{O} & -2877.4 \text{ kJ} \\ \hline & 10 \text{ moles } \text{H}_2\text{O} \end{array} = -1438.7 \text{ kJ}$$

c) What is the $\Delta H^\circ_{\text{rxn}}$ for the production of 1 mole of C_4H_{10} ? (answer = $+1438.7 \text{ kJ}$) sign switches (C_4H_{10} now a product)

$$\begin{array}{c|c} 1 \text{ mole } \text{C}_4\text{H}_{10} & +2877.4 \text{ kJ} \\ \hline & 2 \text{ moles } \text{C}_4\text{H}_{10} \end{array} = +1438.7 \text{ kJ}$$

3. Calculate the mass of a sample of lead ($C_p = 0.160 \text{ J/g}\cdot\text{°C}$) when it loses 200. J cooling from 75.0°C to 42.0°C . (answer = 37.9 g)

$$q = m C \Delta T, \text{ so } m = \frac{q}{C \Delta T}$$

$$m = \frac{-200. \text{ J}}{(0.160 \text{ J/g}\cdot\text{°C} \cdot (42.0 - 75.0^\circ\text{C}))}$$

$$m = 37.9 \text{ g}$$

4. Calculate the energy required to take 450.0 g of water from 27.5°C to 102.0°C . ($C_{\text{H}_2\text{O}} = 4.184 \text{ J/g}\cdot\text{°C}$, $C_{\text{steam}} = 2.006 \text{ J/g}\cdot\text{°C}$, $H_{\text{vap}} = 2260 \text{ J/g}$) (answer = $1.16 \times 10^6 \text{ J}$) 3-step problem

a) H_2O @ 27.5°C to 100.0°C

$$q = m C \Delta T$$

$$= 450.0 \cdot 4.184 \cdot (100.0 - 27.5^\circ\text{C})$$

$$= 136503 \text{ J}$$

b) boil $450.0 \text{ g H}_2\text{O}$

$$q = m H_{\text{vap}}$$

$$= 450.0 \cdot 2260 \text{ J/g}$$

$$= 1017000 \text{ J}$$

c) $\text{H}_2\text{O(g)}$ @ 100°C to 102.0°C

$$q = m C_g \Delta T$$

$$= 450.0 \cdot 2.006 \cdot 2.0^\circ\text{C}$$

$$= 1805.4 \text{ J}$$

$$\text{total} = 1155308.4 \text{ J} = 1.16 \times 10^6 \text{ J}$$

5. A 28.4 g sample of aluminum is heated to 39.4°C , and placed in a calorimeter containing 50.0 g of water. The temperature of water increases from 21.00°C to 23.00°C . What is the specific heat capacity, C , of aluminum? (for $\text{H}_2\text{O(l)}$, $C = 4.184 \text{ J/g}\cdot\text{°C}$) (answer = $0.898 \text{ J/g}\cdot\text{°C}$) $C_{\text{Al}} = ?$



$$-q_{\text{Al}} = q_{\text{H}_2\text{O}}$$

$$-(m_{\text{Al}} \cdot C_{\text{Al}} \cdot \Delta T_{\text{Al}}) = (m_{\text{H}_2\text{O}} \cdot C_{\text{H}_2\text{O}} \cdot \Delta T_{\text{H}_2\text{O}})$$

$$C_{\text{Al}} = \frac{m_{\text{H}_2\text{O}} \cdot C_{\text{H}_2\text{O}} \cdot \Delta T_{\text{H}_2\text{O}}}{-(m_{\text{Al}} \cdot \Delta T_{\text{Al}})} = \frac{50.0 \cdot 4.184 \cdot (23.00 - 21.00)}{-(28.4 \cdot (23.00 - 39.4))} = 0.898 \text{ J/g}\cdot\text{°C}$$

6. Calculate the heat of formation of ethane, $\text{C}_2\text{H}_6(\text{g})$, if its heat of combustion, $\Delta H^\circ_{\text{comb}}$, is -3120 kJ

The equation is $2 \text{C}_2\text{H}_6(\text{g}) + 7 \text{O}_2(\text{g}) \rightarrow 6 \text{H}_2\text{O(l)} + 4 \text{CO}_2(\text{g})$. (answer = -285.8 kJ/mol)

$x =$
heat of
formation

$$\Delta H_{\text{rxn}} = \Delta H_{\text{comb}} = -3120 = H_{\text{products}} - H_{\text{reactants}}$$

$$-3120 = [6(-285.8) + 4(-393.5)] - [2x + 7(0)]$$

$$-3120 = -3288.8 - 2x$$

$$\frac{(-3120 + 3288.8) \text{ kJ}}{-2 \text{ moles}} = x = 84.4 \text{ kJ/mole}$$