# Free Energy
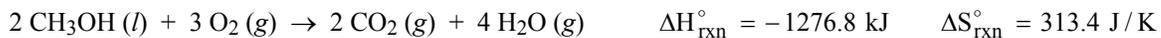
1.  Methanol is a high-octane fuel used in high-performance racing engines. Is the combustion of methanol spontaneous at 25°C?

    $$2\ CH_3OH\ (l)\ +\ 3\ O_2\ (g)\ \rightarrow\ 2\ CO_2\ (g)\ +\ 4\ H_2O\ (g) \qquad \Delta H^\circ_{rxn} = -1276.8\ kJ \qquad \Delta S^\circ_{rxn} = 313.4\ J/K$$

    a) Calculate $\Delta G^\circ_{rxn}$ from $\Delta G^\circ_f$ values.

    $\Delta G^\circ_{rxn} = \Sigma n \Delta G^\circ_f (products) - \Sigma n G^\circ_f (reactants)$
    $\Delta G_{rxn} = (2\ mol)(-394.4\ kJ/mol) + (4\ mol)(-228.6\ kJ/mol) - [(2\ mol)(-166.3\ kJ/mol) + (3\ mol)(0)]$
    **$\Delta G_{rxn} = -1370.6\ kJ$**

    b) Calculate $\Delta G^\circ_{rxn}$ from $\Delta H$ and $\Delta S$.

    $\Delta G = \Delta H - T\Delta S$
    $\Delta G = -1276.8 \times 10^3\ J - (298\ K)(313.4\ J/K)$
    **$\Delta G = -1.37 \times 10^6\ J = -1.37 \times 10^3\ kJ$**

2.  Given the following $\Delta H_{rxn}$ and $\Delta S_{rxn}$ values, predict whether the following change will be spontaneous, nonspontaneous, or if you need additional information.

    a.  $\Delta H = -152\ kJ$, $\Delta S = 100\ J/K$

    **Spontaneous**

    b.  $\Delta H = 25\ kJ$, $\Delta S = -40\ J/K$

    **Nonspontaneous**

    c.  $\Delta H = -60\ kJ$, $\Delta S = -100\ J/K$

    **Need additional information (temperature)**

    d.  $\Delta H = 88\ kJ$, $\Delta S = 40\ J/K$

    **Need additional information (temperature)**

**3.** At what temperature will the following reaction become spontaneous under standard conditions?

$$CaCO_3\ (s) \rightarrow CaO\ (s)\ +\ CO_2\ (g) \qquad \Delta H^{\circ}_{rxn} = 177.8\ kJ \qquad \Delta S^{\circ}_{rxn} = 160.5\ J\,/\,K$$

Set $\Delta G = 0$

$$T = \frac{\Delta H}{\Delta S}$$

$$T = \frac{177.8 \times 10^3\ J\,/\,mol}{160.5\ J\,/\,K \cdot mol} = \textbf{1108 K}$$