# 15-5 Reaction Spontaneity

* there is a natural tendancy towards disaster!

Spontaneous Rxns = physical or chemical change that, once begun, continues w/out outside intervention.
- sometimes they are endothermic and need energy to get going ex) lighting a bunsen burner

Rusting Iron = spontaneous $4Fe + 3O_2 \rightarrow 2Fe_2O_3$ $\Delta H = -1625$ Exo
* reverse rxn is NOT spontaneous $2Fe_2O_3 \rightarrow 4Fe + 3O_2$ $\Delta H = 1625$ endo

$\Delta H$ does **Not** indicate if rxn is spontaneous

Entropy (S) - is a measure of the possible ways that energy of a system can be distributed - based on freedom of particles.
- the # of possible arrangements of atoms in a system ↑ when: volume ↑, Energy ↑, # of particles ↑, or when freedom to move ↑.

2nd Law of thermodynamics - states that spontaneous processes always proceed in such a way the entropy ↑
- measure of disorder or randomness
- particles that spread out have more entropy than close ones.

$$\boxed{\Delta S_{system} = S_{products} - S_{reactants}}$$

If $S_{prod.} > S_{react}$, $\Delta S_{sys} = \oplus$
$S_{prod.} < S_{react}$, $\Delta S_{sys} = \ominus$

Rules

1. Entropy ↑ when states go up ($s \rightarrow L \rightarrow g$) $\Delta S = \oplus$
2. Dissolving gas into solution ↓ entropy $\Delta S = \ominus$
3. Entropy ↑ when # of gaseous products > # of gaseous reactants $\Delta S = \oplus$
4. Mostly Entropy ↑ when Liq. or Sol. dissolve in Solution $\Delta S = \oplus$
5. When temp ↑, $\Delta S = \oplus$

Since the universe ↑ in disorder, $\Delta S_{univ} > 0$ ⊕ when:

1. Rxn or process is exothermic ($\Delta H = -$)
2. Entropy of system ↑, so $\Delta S_{sys} = \oplus$

* Exothermic chem. rxns followed by ↑ in Entropy are spontaneous

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Free energy = energy available to do work = Gibbs Free Energy or $G_{system}$.

Free energy change ($\Delta G_{sys}$) = diff. between systems change in Enthalpy ($\Delta H_{sys}$) and product of Kelvin temp. & change in entropy ($T\Delta S_{sys}$)

$$\boxed{\Delta G_{sys} = \Delta H_{sys} - T\Delta S}$$

* Convert all units to kJ when solving

$-\Delta G_{sys}$ = <u>spontaneous</u> $+\Delta G_{sys}$ = <u>non-spontaneous</u>

remember
$\Delta^{\circ}$ = known standard value

ex) $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

$\Delta H^{\circ}_{sys} = -91.8\,kJ$ $\Delta S^{\circ}_{sys} = -197\,J/K$

* Entropy ↓ because gaseous products (moles) < reactants
2 moles < 4 moles $\Delta S = \ominus$ & Exothermic

- convert $\Delta S^{\circ}_{sys}$ to kJ $\frac{-197\,J}{1\,K} \cdot \frac{1\,kJ}{1{,}000\,J} = -.197\,\frac{kJ}{K}$

$$\Delta G = \Delta H - T\Delta S$$
$$= -91.8\,kJ - (298\,K)(-.197\,kJ/K)$$
$$= -91.8\,kJ - -58.7\,kJ = -33.1\,kJ$$

$\Delta G_{sys} = \ominus$

- rxn is <u>spontaneous</u>

<u>Table 15.6</u> pg 547

| $\Delta H_{sys}$ | $\Delta S_{sys}$ | $\Delta G_{sys}$ | Reaction Spontaneity |
|---|---|---|---|
| − | + | always − | always spontaneous |
| − | − | − / + | spon. @ low temps |
| + | + | − / + | spon. @ high temps. |
| + | − | always + | never spontaneous |

* <u>Determine if the following are Spontaneous</u>

ex) In a reaction, $\Delta H_{sys} = -75.9$ kJ
$T = 535$ K
$\Delta S_{sys} = 138$ J/K

ex) $\Delta H_{sys} = -27.6$ kJ
$T = 535$ K
$\Delta S_{sys} = -55.2$ J/K