19.3   Gibbs Free Energy
Gibbs Free Energy and Temperature

Free Energy and Temperature
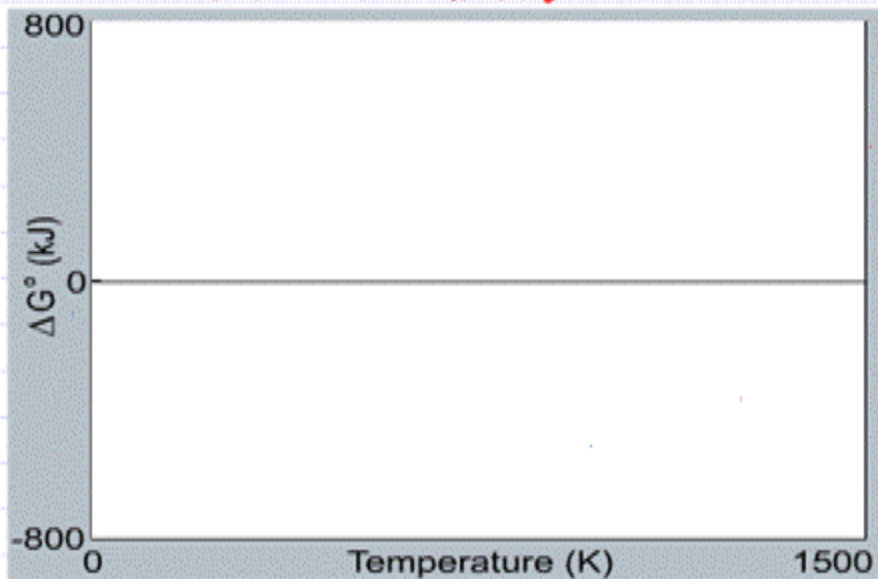
Temperature   0 K

◄ | | ►

[Calculate]

⦿ $2\ Fe_2O_3(s) + 3\ C(s) \longrightarrow$
           $3\ CO_2(g) + 4\ Fe(s)$

○ $C(s) + 2H_2(g) \longrightarrow CH_4(g)$

○ $N_2(g) + 2O_2(g) \longrightarrow 2\ NO_2(g)$

○ $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$

○ $2\ HCl(aq) + Na_2CO_3(s) \longrightarrow$
           $2\ NaCl(aq) + H_2O(\ell) + CO_2(g)$

$\Delta S° = 561.00\ J/K \cdot mol$

$\Delta H° = 468.00\ kJ/mol$

$\Delta G° = 468.00\ kJ/mol$

[Graph: y-axis $\Delta G°\ (kJ)$ from −800 to 800, x-axis Temperature (K) from 0 to 1500]

i) $\Delta G°_{RXN} = \Sigma \Delta G°_f\ (Products) - \Sigma \Delta G°_f\ (Reactants)$

OR

ii) $\Delta G°_{RXN} = \Delta H°_{RXN} - T\Delta S°_{RXN}$: This one often prefered as we can gleam
further insights into the reaction. ? What type of insights ?

1. $\Delta H° > 0,\ \Delta S° > 0$: likely $\Delta G°$ starts out + due to $\Delta H°$ being in kJ. But at what T does $-T\Delta S$ which is (−) make $\Delta G° < 0$?
2. $\Delta H° < 0,\ \Delta S° < 0$: likely $\Delta G°$ starts out − due to $\Delta H°$ being in kJ. But at what T does $-T\Delta S$ which is (+) make $\Delta G° > 0$?
3. $\Delta H° > 0,\ \Delta S° < 0$: $\Delta G° > 0$ at all T, since $\Delta H°$ is + and $-T\Delta S$ is +. Nonspontaneous at all Temperatures.
4. $\Delta H° < 0,\ \Delta S° > 0$: $\Delta G° < 0$ at all T, since $\Delta H°$ is − and $-T\Delta S$ is −. Spontaneous at all Temperatures.

19.3   Gibbs Free Energy

Gibbs Free Energy and Temperature

Without doing any calculations, match the following thermodynamic properties with their appropriate numerical sign for the following **endothermic reaction**.

$$2CO_2(g) + N_2(g) = 2CO(g) + 2NO(g)$$

a) ΔH_{rxn}

b) ΔS_{rxn}

c) ΔG_{rxn}

d) ΔS_{univ}

a. >0

b. <0

c. =0
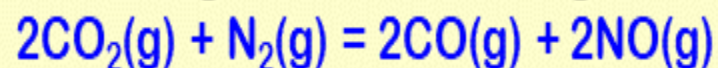
d. >0 low T, <0 high T

e. <0 low T, >0 high T

$$\Delta G_{RXN} = \Delta H_{RXN} + (-T\Delta S_{RXN})$$

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a) a) ✓ : We are told that the Reaction is Endothermic.

b) a) ✓ : $\Delta S_{RXN} = S(products) - S(Reactants)$
        4 gas molecules − 3 gas molecules

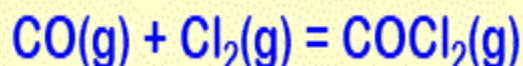   ∴ $\Delta S_{RXN} > 0$

c) d) ✓ : With ΔH_{RXN} being >0 expect ΔG_{RXN} to be >0; however with $(-T\Delta S) < 0$ expect that at some high value of T that this will overcome ΔH and make $\Delta G < 0$.

d) e) ✓ : Tutor Mode ☺. It is easier to understand and predict ΔG_{RXN}. So focus on that and ΔS_{UNIV} is the Reverse of ΔG_{RXN}. ☺

19.3 Gibbs Free Energy
Gibbs Free Energy and Temperature

Without doing any calculations, match the following thermodynamic properties with their appropriate numerical sign for the following **exothermic reaction**.

$$CO(g) + Cl_2(g) = COCl_2(g)$$

a) ΔH_{rxn}

b) ΔS_{rxn}

c) ΔG_{rxn}

d) ΔS_{univ}

a. >0

b. <0

c. =0

d. >0 low T, <0 high T

e. <0 low T, >0 high T

$\Delta G_{RXN} = \Delta H_{RXN} + (-T\Delta S_{RXN})$

---

a) b) ✓ : Reaction is Exothermic.

b) b) ✓ : ΔS_{RXN} = S(Products) − S(Reactants)

　　　　　　　1 gas molecule − 2 gas molecules

　　　　　　　∴ ΔS_{RXN} < 0

c) e) ✓ : Since ΔH_{RXN} < 0 expect ΔG_{RXN} to start < 0.
　　　　　　　However since (−TΔS_{RXN}) > 0 expect that at
　　　　　　　some high value of T that this will surpass
　　　　　　　ΔH_{RXN}, thereby making ΔG_{RXN} > 0.

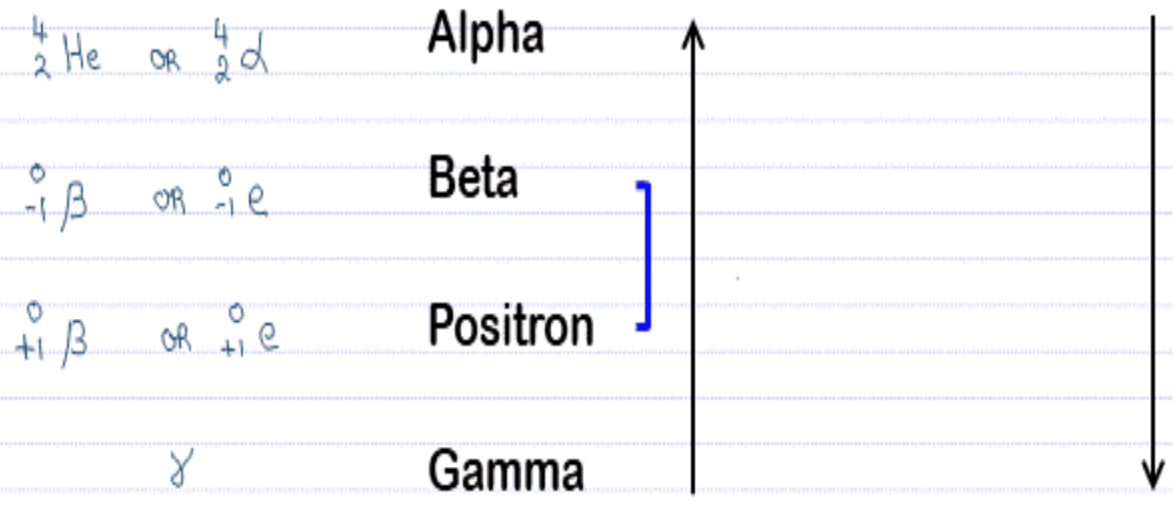d) d) ✓ : See previous slide for simple trick
　　　　　　　to predict ΔS_{UNIV}.

24.1   Nuclear Reactions
The Penetrating Power of Radiation
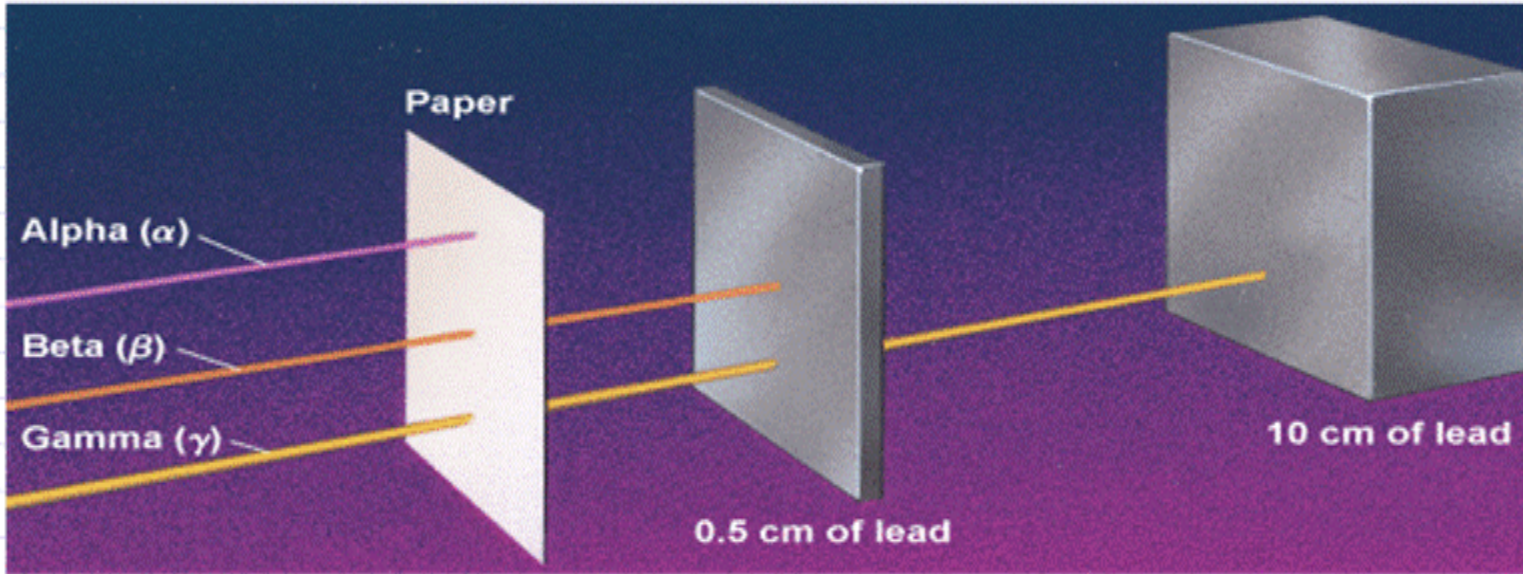
Particles: Energy   Vs   Penetration Power

$^{4}_{2}He$ OR $^{4}_{2}\alpha$ Alpha

$^{0}_{-1}\beta$ OR $^{0}_{-1}e$ Beta

$^{0}_{+1}\beta$ OR $^{0}_{+1}e$ Positron

γ Gamma

24.2 Nuclear Stability
Band of Stability

Black dots represent stable isotopes that do not undergo radioactive decay.

$\dfrac{\# \text{ NUTRONS}}{\# \text{ PROTONS}}$:- too large

$\dfrac{\# \text{ NEUTRONS}}{\# \text{ PROTONS}}$:- too small

$\# \text{ NEUTRONS} = \# \text{ PROTONS}$

↳ What is their primary role in the nucleus? Simple terms they are the buffer zone that keeps the nucleus together.

$\dfrac{\# \text{ Neutron}}{\# \text{ Proton}}$ } STABILITY

Number of Neutrons (y-axis: 20, 40, 60, 80, 100, 120, 140)

Number of Protons (x-axis: 0, 20, 40, 60, 80)

24.2 Nuclear Stability
Natural Radioactive Decay

1. Alpha Emission: Nucleus kicks out an Alpha particle, $_2He^4$ OR $_2^4He$ OR $_2^4\alpha$

2. Beta Emission: Nucleus kicks out a Beta particle, ONL: $_{-1}e^0$ $_{-1}^0e$ OR $_{-1}^0\beta$

3. Positron Emission: Nucleus kicks out a Positron, ONL: $_{+1}e^0$ $_{+1}^0e$ OR $_{+1}^0\beta$

4. Electron Capture: The nucleus captures one of its own electrons.

All of the above processes also result in emitting γ Rays.

Very Important Note: The most common mistake in balancing Nuclear Reaction is with 4. In 1, 2 and 3 the particle is on the Product side. In 4, the captured electron is on the Reactant side.

The driving force for all of these is to stabilize the Neutron to Proton Ratio. Let's have a look at what each one does.