[TP] What do we need to know to sketch

$\ln(K) = -\Delta H°/R(1/T) + \Delta S°/R$?

17% 1. How K changes with T

17% 2. The sign of $\Delta H°$

17% 3. The sign of $\Delta S°$

17% 4. All of the above

17% 5. Either (1), or (2) and (3)

17% 6. Some other factor(s)

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Lecture 33 CH102 A1 (MWF 9:05 am)

Wednesday, April 24, 2019

- $\Delta G, E, \Delta H, \Delta S, Q, K$, and T

Next lecture: Begin ch18: Definition of "rate"; rate versus [...] from experiment; making sense of rate versus [...]: Reaction mechanisms

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Using temperature to change equilibrium: K versus T

$\Delta G, E, \Delta H, \Delta S, Q, K$, and T

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ΔG, ΔH, ΔS, E, Q, K, and T

Rearranging

$$\Delta G = -n_e F E_{cell} = RT\ln(Q/K) = \Delta H - T\Delta S$$

we see that this means

$$E_{cell} = -\left(\frac{RT}{n_e F}\right)\ln(Q/K) = -\left(\frac{RT}{n_e F}\right)2.303\log\left(\frac{Q}{K}\right)$$

using $x = 10^{\log(x)}$,

and so that $\ln(x) = \ln(10)\log(x) = 2.303\log(x)$

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ΔG, ΔH, ΔS, E, Q, K, and T

$$E_{\text{cell}} = -\left(\frac{RT}{n_e F}\right)\ln(Q/K) = -\left(\frac{RT}{n_e F}\right)2.303\log\left(\frac{Q}{K}\right)$$

At 25 °C

$$\left(\frac{R\,T}{n_e F}\right) = \left(\frac{R\ 298.15K}{n_e F}\right)2.303 = \frac{0.05912}{n_e}\text{V} \approx \frac{0.06}{n_e}\text{V}$$

and so at 25 °C

$$E_{\text{cell}} \approx -\frac{0.06}{n_e}\text{V}\log\left(\frac{Q}{K}\right) \text{ and } E°_{\text{cell}} \approx \frac{0.06}{n_e}\text{V}\log(K)$$

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ΔG, ΔH, ΔS, E, Q, K, and T

$$\Delta G = -nFE_{\text{cell}} = RT\ln(Q/K) = \Delta H - T\Delta S$$

How about for standard states?

$$\Delta G° = -nFE°_{\text{cell}} = RT\ln(1/K) = \Delta H° - T\Delta S°$$

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Connection between T and K

$$RT\ln(1/K) = \Delta H° - T\Delta S°$$

For values of T near 298 K, $\Delta H°$ and $\Delta S°$ are nearly constant.

What does this tell us about the graph of $\ln(K)$ versus $1/T$?

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Connection between T and K

Rearrange $RT\ln(1/K) = \Delta H° - T\Delta S°$ into the equation

$y = mx + b$ with

$y = \ln(K)$

$x = 1/T$ ...

$$\ln(K) = -\Delta H°/R(1/T) + \Delta S°/R$$

$$y \quad = \quad m \quad x \quad + \quad b$$

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[TP] What do we need to know to sketch
$\ln(K) = -\Delta H°/R(1/T) + \Delta S°/R$?

0% 1. How K changes with T
0% 2. The sign of $\Delta H°$
0% 3. The sign of $\Delta S°$
0% 4. All of the above
0% 5. Either (1), or (2) and (3)
0% 6. Some other factor(s)

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Connection between *T* and *K*

What do we need to make a sketch of $y = \ln(K) = -\Delta H°/R(1/T) + \Delta S°/R$ versus $x = 1/T$ for the process steam → water?

Can we get what we need to make the sketch?

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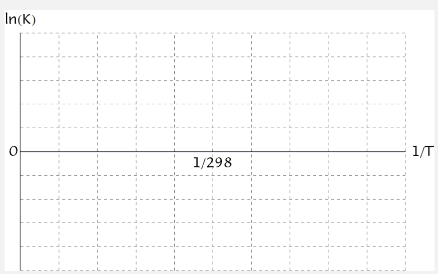
Connection between *T* and *K*

Make a sketch of $y = \ln(K) = -\Delta H°/R(1/T) + \Delta S°/R$ versus $x = 1/T$ for the process steam → water. If it crosses the $1/T$ axis, specify where relative to $1/(298\ \text{K})$.



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[TP] For the reaction $H_2O(g) \rightarrow H_2O(l)$, at what temperature range will result in the greatest amount of products (largest K)?

25% 1. Very low T (large $1/T$)
25% 2. Very high T (small $1/T$)
25% 3. The amount will be the same at all T
25% 4. More information needed

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[TP] For the reaction 2 $H_2O(g) \rightarrow 2\ H_2(g) + O_2(g)$, what temperature range will result in the greatest amount of products (largest K)?

25% 1. Very low T (large $1/T$)
25% 2. Very high T (small $1/T$)
25% 3. The amount will be the same at all T
25% 4. More information needed

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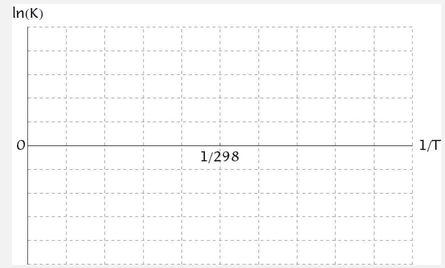
Connection between T and K

$\ln(K) = -\Delta H°/R(1/T) + \Delta S°/R$

Sketch $\ln(K)$ versus $1/T$ for 2 $H_2O(g) \rightarrow 2\ H_2(g) + O_2(g)$. If it crosses the $1/T$ axis, specify where relative to 1/(298 K).



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[TP] For the reaction 2 $NO_2(g) \rightarrow N_2O_4(g)$, what temperature range will result in the greatest amount of products (largest K)?

25% 1. Very low T (large $1/T$)
25% 2. Very high T (small $1/T$)
25% 3. The amount will be the same at all T
25% 4. More information needed

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[TP] The reaction 2 $NO_2(g) \rightarrow N_2O_4(g)$ is exothermic. What temperature range will result in the greatest amount of products (largest K)?

25% 1. Very high T (small $1/T$)
25% 2. Very low T (large $1/T$)
25% 3. The amount will be the same at all T
25% 4. More information needed

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[TP] The exothermic reaction $2\ NO_2(g) \rightarrow N_2O_4(g)$ has the greatest amount of products (largest K) at very low T. The reason for this is that …

17% 1. $\Delta_r H° < 0$ and so K increases as T is decreased.
17% 2. heat is a "product" so removing heat (decreasing T) shifts equilibrium to products
17% 3. $\Delta_r S° < 0$
17% 4. 1, 2 and 3
17% 5. 1 and 3
17% 6. Something else

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[TP] A certain chemical reaction is not spontaneous when $Q = 1$ at 300 K. The entropy change for the reaction is $+130$ J/K. The reaction must be …

25% 1. endothermic
25% 2. exothermic
25% 3. neither ($\Delta H = 0$)
25% 4. More information needed

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[TP] A chemical reaction is endothermic and has $\Delta S_{sys} < 0$. This means the reaction will be spontaneous when $Q = 1$ …

0% 1. only at low temperature
0% 2. only at high temperature
0% 3. always
0% 4. never
0% 5. Further information required

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[Quiz] At 300 K, when $Q = 1$ hydrogen burns vigorously in oxygen to form water. At very high temperature, water will …

33% 1. will not decompose into H_2 and O_2
33% 2. decompose into H_2 and O_2
33% 3. More information needed

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