[TP] Evaluate $W_e$(9 quanta, 4 molecules).

25% 1. 11 x 10 = 110
25% 2. 10 x 22 = 220
25% 3. 13 x 11 = 143
25% 4. None of the above

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# Lecture 32 CH102 A1 (MWF 9:05 am)

Friday, April 14, 2017

- Heat (energy) flow → entropy change
- Spontaneity of phase transitions: water ⇌ steam

Next lecture: $\Delta S$ picture colligative properties: Freezing point depression. Absolute entropy. Entropy change of reaction. System-only measure of total entropy change: $\Delta G$. Using temperature to change spontaneity: $\Delta G$ versus $T$. The three faces of $\Delta G$. Using temperature to change equilibrium: $K$ versus $T$.

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## Counting energy dispersal

Unique (distinguishable) arrangements of
q identical quanta among
m identical molecules

$$W_{energy}(q, m) = \frac{(q + m - 1)!}{q!\,(m - 1)!}$$

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[TP] Evaluate $W_e$(9 quanta, 4 molecules).

25% 1. 11 x 10 = 110
25% 2. 10 x 22 = 220
25% 3. 13 x 11 = 143
25% 4. None of the above

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## Particles versus Energy

$$W_{\text{particles}}(j,k) = \frac{(j+k)!}{j!k!}$$

$$W_{\text{energy}}(q,m) = \frac{(q+m-1)!}{q!(m-1)!}$$

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## Heat (energy) flow → entropy change

Which energy change $(q, m) \to (q + 1, m)$ has larger $\Delta S$ ...

adding 1 quantum to 4: $(4, m) \to (5, m)$ or ...

adding 1 quantum to 9: $(9, m) \to (10, m)$?

We can answer theses questions using by analyzing energy dispersal and the corresponding entropy change.

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[TP] The change $W_e(9, 4) \to W_e(10, 4)$ is 286 – 220 = 66, and the change $W_e(4, 4) \to W_e(5, 4)$ is 56 – 35 = 21.
For which change do you expect the entropy increase to be greater?

50% 1. $W_e(9, 4) \to W_e(10, 4)$
50% 2. $W_e(4, 4) \to W_e(5, 4)$

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[TP] The general expression for the entropy change of a 4 molecule system with $q$ quanta gaining 1 quantum is ...

25% 1. $W_e(q + 1, 4) - W_e(q, 4)$
25% 2. $\ln[W_e(q + 1, 4)] - \ln[W_e(q, 4)]$
25% 3. $\ln[W_e(q + 1, 4) / W_e(q, 4)]$
25% 4. Both 2 and 3

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[Quiz] Which is larger? (Simplifying ratios speeds the evaluations.)

25% 1. $W_e(10, 4) / W_e(9, 4)$
25% 2. $W_e(5, 4) / W_e(4, 4)$
25% 3. They are equal
25% 4. More information is needed

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# Heat (energy) flow → entropy change

Which change $(q, m) \to (q + 1, m)$ has larger $\Delta S$,

adding 1 to 5: $(4, m) \to (5, m)$ or ...

adding 1 to 9: $(9, m) \to (10, m)$?

$(4, m) \to (5, m)$ has larger $\Delta S$ than $(9, \text{m}) \to (10, \text{m})$

This result illustrates that ...

$\Delta S$ is larger, the lower $T$

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[TP] Which is larger? (Simplifying ratios speeds the evaluations.)

25% 1. $W_e(6, 4) / W_e(4 ,4)$
25% 2. $W_e(5, 4) / W_e(4, 4)$
25% 3. They are equal
25% 4. More information is needed

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# Heat (energy) flow → entropy change

Which change $(q, m) \to (q + 1, m)$ or $(q + 2, m)$ has larger $\Delta S$,

adding 1 to 4: $(4, m) \to (5, m)$ or ...

adding 2 to 4: $(4, m) \to (6, m)$?

$(4, m) \to (6, m)$ has larger ΔS than $(4, \text{m}) \to (5, \text{m})$

This result illustrates that ...

$\Delta S$ larger, the greater $\Delta H$

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## Heat (energy) flow → entropy change

Which changes have larger $\Delta S$?

$(4, m) \rightarrow (5, m)$ has larger $\Delta S$ than $(9, m) \rightarrow (10, m)$

$(4, m) \rightarrow (6, m)$ has larger $\Delta S$ than $(4, m) \rightarrow (5, m)$

Taken together, these results illustrate that ...

$\Delta S = \Delta H / T$

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Spontaneity of phase transitions

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## Taking stock

Spontaneity means that ...

$\Delta S_{tot} = \Delta S_{sys} + \Delta S_{sur} > 0$

Spontaneity does not require that ...

$\Delta S_{sys} > 0$ or $\Delta S_{surr} > 0$

A neat illustration of the separate roles of $\Delta S_{sys}$ and $\Delta S_{surr}$ is understanding why steam condenses and water boils

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