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

25% 1. $11 \times 10 = 110$
 25% 2. $10 \times 22 = 220$
 25% 3. $13 \times 11 = 143$
 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 \rightarrow entropy change
- Spontaneity of phase transitions: water \rightleftharpoons steam

Next lecture: ΔS picture colligative properties: Freezing point depression. Absolute entropy. Entropy change of reaction. System-only measure of total entropy change: ΔG . Using temperature to change spontaneity: ΔG versus T . The three faces of ΔG . 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**

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

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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 $(q, m) \rightarrow (q+1, m)$ has **larger** ΔS ...

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

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

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

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

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

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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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Response Counter

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Heat (energy) flow → entropy change

Which change $(q, m) \rightarrow (q + 1, m)$ has **larger ΔS** ,

adding 1 to 5: $(4, m) \rightarrow (5, m)$ or ...
 adding 1 to 9: $(9, m) \rightarrow (10, m)$?

$(4, m) \rightarrow (5, m)$ has **larger ΔS** than $(9, m) \rightarrow (10, m)$

This result illustrates that ...

ΔS 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 $(q, m) \rightarrow (q + 1, m)$ or $(q + 2, m)$ has **larger ΔS** ,

adding 1 to 4: $(4, m) \rightarrow (5, m)$ or ...
 adding 2 to 4: $(4, m) \rightarrow (6, m)$?

$(4, m) \rightarrow (6, m)$ has **larger ΔS** than $(4, m) \rightarrow (5, m)$

This result illustrates that ...

ΔS larger, the greater ΔH

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Heat (energy) flow → entropy change

Which changes have **larger ΔS** ?

(4, m) → (5, m) has **larger ΔS** than (9, m) → (10, m)

(4, m) → (6, m) has **larger ΔS** than (4, m) → (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 ...

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

Spontaneity **does not** require that ...

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

A neat illustration of the **separate roles** of ΔS_{sys} and ΔS_{surr} is understanding why **steam condenses** and **water boils**

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