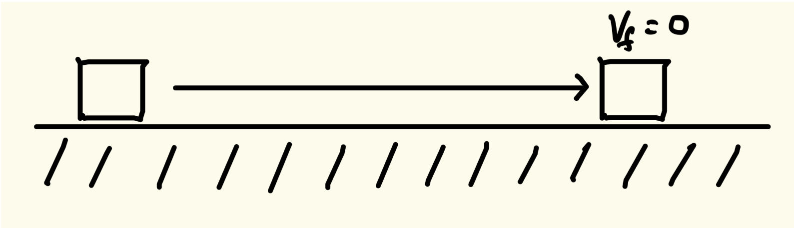
A block slides across a rough surface, eventually coming to a stop.



1) What happens to the block's internal thermal energy U and entropy S?

a. U and S both stay the same
b. U decreases, S increases
c. U stays the same, S increases
✓ d. U and S both increase
e. U increases, S stays the same

The next two questions pertain to the situation described below.

3.5 moles of helium gas is stored in a container that has two chambers. The container has a total length of 6 m and a constant cross-sectional area of 1 m^2. The two chambers of the container are separated by a moveable dividing wall, which prevents particles from flowing between the two sides but allows for the transfer of heat. Initially, the dividing wall is fixed in the middle of the container, with 1 mole of He atoms on the left side and 2.5 moles of He atoms on the right side. The temperature of the whole system is fixed at 300 K.

2) If the dividing wall were allowed to move, which of the following statements would ***not be true*** about its equilibrium position?

a. At equilibrium, the net force on the wall due to collisions from particles on the left side would be equal in magnitude to that from particles on the right side.
b. The equilibrium position would be independent of temperature.
✓ c. The equilibrium position would change if we replaced every helium atom on the right side with a hydrogen molecule (H_2).

3) With the temperature fixed at 300 K, the dividing wall is allowed to freely move and find an equilibrium position. What is the equilibrium position, as measured from the left end of the container?

a. 3 m
✓ b. 1.71 m
c. 2.4 m
d. 0.343 m
e. 4.07 m

Consider a system of a 1 kg block of copper in thermal contact with a 1 kg block of aluminum, ***in thermal equilibrium*** near room temperature.

4) Roughly 6.0 x 10^4 J of thermal energy is stored in the copper block and 1.3 x 10^5 J is stored in the aluminum block. We now transfer just a small amount of energy between the blocks, with 0.1 J of heat flowing from the copper to the aluminum. In this process, the entropy of the copper block decreases by 0.3 mJ/K. For this same process, which of the following answers best matches the change in entropy of the aluminum block?

a. 0 mJ/K
✓ b. +0.3 mJ/K
c. -0.3 mJ/K
d. -0.65 mJ/K
e. +0.65 mJ/K

An ideal gas of *N* atoms initially fills the left side (volume 1 L) of a container with a total volume of 3L. The right side, separated by a thin barrier, is initially empty.

5) If we suddenly remove the barrier, such that the gas freely expands to fill the entire container, by what factor will the total number of available states of the *N*-atom system increase? That is, find the ratio [(final # of states) / (initial # of states)] for the *N*-atom system.

a. N ln(3)
b. 3
✓ c. 3^N

A small block of copper with a mass of 0.0025 kg is heated to a uniform temperature of 558 K. It is then tossed into the Olympic swimming pool at the ARC, which has a temperature of 300 K and a total water volume of 2500 m^3, corresponding to 2.5 x 10^6 kg of water. The temperature of the water does not change very much.

Over the relevant temperature ranges, the specific heat of copper is 385 J/(kg-K) and the specific heat of water is 4186 J/(kg-K).

6) By how much does the ***entropy of the pool water*** change as the block/water system reaches thermal equilibrium?

a. 0 J/K
b. 0.597 J/K
✓ c. 0.828 J/K
d. -0.828 J/K
e. -0.597 J/K

Consider a 3 kg block of solid zinc (Zn has atomic weight 65.38 g/mol).

7) Compute the heat capacity, assuming that equipartition applies.

a. 191 J/K
b. 24.9 J/K
✓ c. 1140 J/K
d. 572 J/K
e. 381 J/K

The next two questions pertain to the situation described below.

At extremely low temperatures the molar heat capacity of copper is temperature-dependent, and is given by C(T) = A*T, where the constant A=0.0064 J/(K^2-mol).

Suppose that I have a sample of copper with mass 5 kg, initially at a temperature of 4 Kelvin.

8) Suppose that I cool this sample to 0.3 Kelvin using a refrigerator. How much thermal energy must the refrigerator extract from the sample?

a. 0.0237 Joules
b. 62.2 Joules
✓ c. 3.98 Joules
d. 0 Joules
e. 0.064 Joules

9) Assuming that this sample has zero entropy at absolute zero (S=0 at T=0), by what factor (S_{final} / $S_{initial}$) does the entropy of the sample change when I cool it from 4 Kelvin to 0.3 Kelvin?

a. 13.3
b. 1
✓ c. 0.075

The next two questions pertain to the situation described below.

Suppose that I begin with a container containing a mixture of 2 mol of helium gas and 10^{-9} mole of radon gas. Both helium and radon are monatomic and well-approximated as ideal gases. Radon is radioactive, and each atom releases a total of 3.8×10^{-12} J of energy when it decays. The container is perfectly insulating (no heat exchange with the outside world), begins at 1 atm pressure and 300 Kelvin, and maintains constant volume.

10) Suppose that I wait long enough for all of the radon to decay, and all of the decay energy goes into heating the helium (neglect decay products). How much will the temperature of the contents of the container change after the decay is complete?

a. 2290 Kelvin
b. 9.18×10^{10} Kelvin
c. The temperature does not change
d. 55.1 Kelvin
✓ e. 91.8 Kelvin

11) Now suppose that we repeat the experiment, this time replacing the 2 mol of helium with 2 mol of nitrogen gas. Assume that the nitrogen is an ideal diatomic gas, with rotational and translational degrees of freedom at this temperature. How will the temperature change here compare to that in the previous question?

The change in temperature ΔT with nitrogen is:

✓ a. Less than with helium
b. The same as with helium
c. Greater than with helium

The next two questions pertain to the situation described below.

A 2 kg block of aluminum initially at 80° Celsius is placed in contact with a 4 kg block of copper initially at 10° Celsius. The molar heat capacities of aluminum and copper are 24.2 J/(K-mol) and 24.5 J/(K-mol), respectively.

12) When the two blocks come into thermal equilibrium, what temperature will they reach?

a. 364 Celsius
b. 30.8 Celsius
✓ c. 47.8 Celsius
d. 45 Celsius
e. 33.3 Celsius

13) How does the entropy of the *aluminum* change during this process?

a. Increases
b. Stays the same
✓ c. Decreases

The next two questions pertain to the situation described below.

Suppose that we have a balloon at atmospheric pressure (1.01×10^5 Pa), initial volume 1.6 m^3, and temperature 300 K. It is filled with monatomic He gas. (3 degrees of freedom)

14) How many atoms of He are in the balloon?

a. 6.02×10^{23}
✓ b. 3.9×10^{25}
c. 1.17×10^{28}

15) Suppose we now compress the balloon to 1.1 m^3 while keeping the temperature constant. How much pressure (including the pressure exerted by the atmosphere) must we apply to keep it at that smaller volume?

✓ a. 1.47×10^5 Pa
b. 69400 Pa
c. 1.11×10^5 Pa
d. 1.01×10^5 Pa
e. 1.61×10^5 Pa

The next two questions pertain to the situation described below.

Let's model your lungs as a container that can hold volume 0.007 m^3 of air, at atmospheric pressure 10^5 Pa and 300 K. Air is made up mostly of O_2 and N_2, which have 5 degrees of freedom at this temperature.

When you breathe in the air and hold it, it equilibrates to your body temperature of roughly 310 K. The pressure and volume may change a little when this happens.

16) How much heat does your body supply to raise the temperature of the air?

a. 0.191 J
b. 35 J
✓ c. 58.3 J

17) How much does the entropy change when the air is heated in this way?

✓ a. 0.191 J/K
b. 35 J/K
c. 58.3 J/K

The next two questions pertain to the situation described below.

Suppose we have a two-state system with two states separated by an energy $\Delta = 1.7 \times 10^{-21}$ J in contact with a large thermal reservoir at temperature T.

18) At which temperature are the two energy states *closest* to being equally probable?

a. 0.1 K
b. 100 K
c. 1000 K
d. 1 K
✓ e. 10000 K

19) At which temperature is the probability of finding the lower energy state twice as large as the probability to find the higher energy state?

a. 0.00812 K
b. 123 K
c. 246 K
✓ d. 178 K
e. 0.00563 K

The next two questions pertain to the situation described below.

Consider 3 quantum simple harmonic oscillators.

20) How many ways can we distribute 3 quanta among these oscillators?

✓ a. 10
b. 4
c. 6

21) There are 36 ways to distribute 7 quanta among the oscillators. What is the entropy of this new configuration of oscillators?

✓ a. 4.95×10^{-23} J/K
b. 3.58×10^{-20} J/K
c. 4.97×10^{-22} J/K

The next three questions pertain to the situation described below.

Suppose we have a proton placed in a magnetic field B = 10 Tesla. Like electrons, protons have two possible states of their magnetic moments, either aligned or anti-aligned with the magnetic field, and we can model it as a two-state system. The energy of a proton with its magnetic moment aligned with the magnetic field is $E_{align}=-\mu_P B$ where $\mu_P= 1.4 \times 10^{-26}$ J/Tesla is the magnetic moment of the proton. The energy of the anti-aligned state is $E_{anti}=+\mu_P B$. The proton is in contact with a thermal reservoir at temperature T=0.1 K.

22) At this temperature what is the probability that the proton has its magnetic moment anti-aligned with the magnetic field, i.e., is in the state with *higher* energy?

a. 0.5
b. 0
c. 0.551
✓ d. 0.449
e. 0.475

23) At this temperature the entropy S of the system is

✓ a. Less than k ln(2)
b. Greater than k ln(2)
c. Equal to k ln(2)

24) If we increase the magnetic field to B=15 Tesla does the entropy of the proton system at this temperature

a. Increase
✓ b. Decrease
c. Stay the same