We defined the entropy (S) of a system as kB ln W, where W is the number of possible arrangements of the system.  But why?  Why not just say that entropy **is** the number of arrangements?  Let's think through why it has to be defined this way.

We want to define entropy as an **extensive property**, i.e. if I have two systems A and B, the total entropy should be the entropy of A plus the entropy of B.  This is like mass (2 kg + 2 kg = 4 kg), and not an **intensive property**like temperature (if you combine two systems that are each at 300 K, you have a system at 300 K, **not** at 600 K!).

What happens to the number of possible arrangements when you combine two systems?  If system A can be in 3 different arrangements and system B can be in 5 different arrangements, then there are 3\*5 = 15 possible combinations.  They multiply!  This '80s [music video](http://www.youtube.com/watch?v=w0i_ZFlGTVY) explains why.

So we can't just define entropy as the number of possible arrangements, because we need the entropy to **add**, not **multiply**, when we combine two systems.

How do you turn multiplication into addition?  Just take the logarithm.  3 \* 5 = 15, but ln 3 + ln 5 = ln 15.

So that's why entropy is defined as a constant times ln W.  W (the number of arrangements) is a dimensionless number, so ln W is too.

The constant out in front could be any constant, but we use Boltzmann's constant, 1.38 x 10-23 J/K.  When we get to Gibbs free energy, we'll see that this constant has the right units, since we need entropy to be in units of energy/temperature.

Ben Dreyfus 1/9/2012