Dec 4th, 2015 LB 273, Physics I Prof. Vashti Sawtelle
Prof. Leanne Doughty

Today:

- Heat and Thermal Motion

Irish Phrasebook

Dia dhuit *– Gaelic for hello (singular)*

(It's 'Dia dhaoibh' if you're saying hello to more than one person)

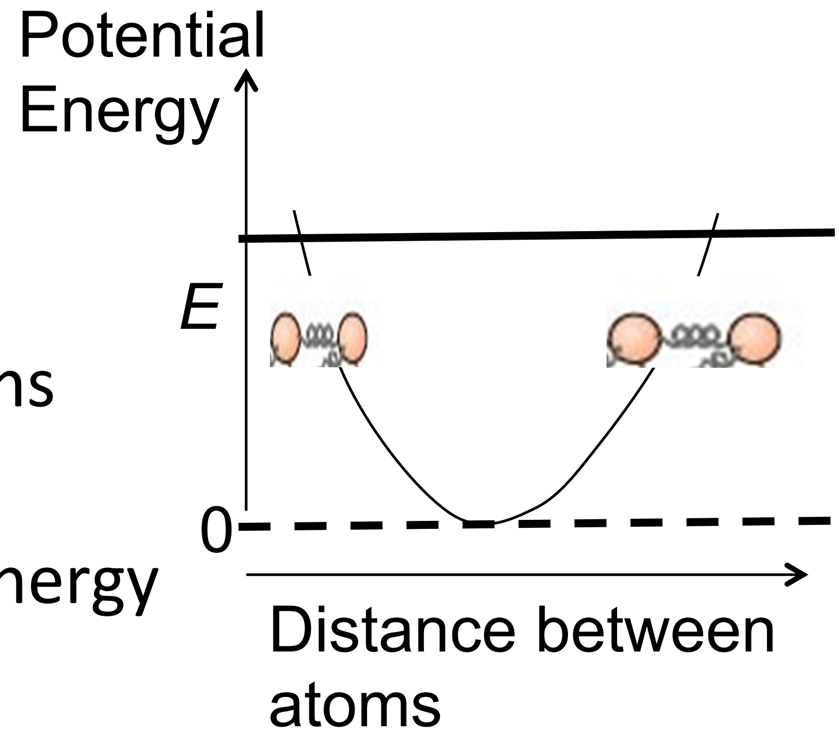
Final Exam Announcements

- Final exam dates and times are set:
  - Tuesday 15th, 3-5pm
  - Friday 18th, 10am-12pm
  - Please complete registration survey on LON-CAPA
- Review session:
  - Thursday 10th, 7pm, C106

Announcements

- Reading Questions for Ch15 due Sunday
- LON-CAPA Homework for Ch13 and Ch14 due Wednesday 9th
- Extra-credit survey will likely be in your emails on Monday
  - More details then

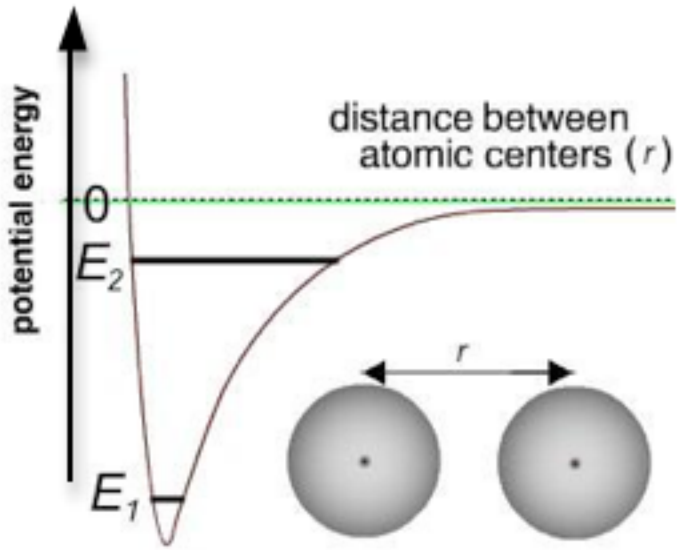
Energy in a 2-Atom Molecule



- For small displacements around the bond length, the PE of a pair of bound atoms can be modeled as a spring.
- Define the zero of potential energy as the minimum of the Potential Energy curve.
- With this definition, in a gas of these molecules, **ON AVERAGE** the energy is the same for both potential and kinetic energy

While wandering around their environment,
a molecule winds up being shifted to the state with a total energy E_2 as shown on the figure.
What could be responsible for this shift from E_1 to E_2?

A. The temperature of the system was increased.
B. The temperature of the system was decreased.
C. The molecule collided with another molecule and lost kinetic energy.
D. The molecule collided with another molecule and gained kinetic energy.
E. More than one is true.



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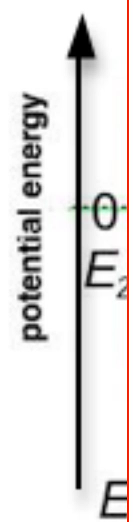
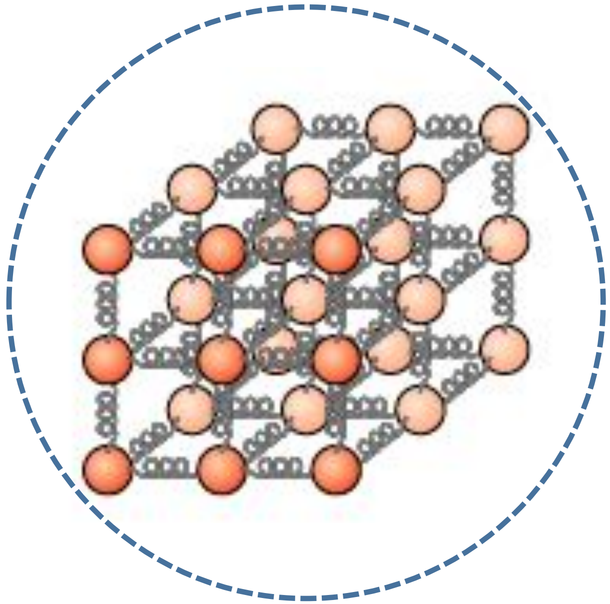


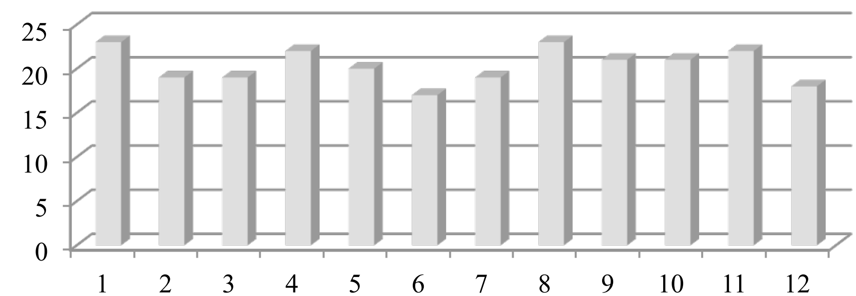
Either A or C is possible. Moving from total energy, E_1 to total energy, E_2 means that the maximum kinetic energy has increased (which we can see if we stand at the bottom of the potential well). Increasing the kinetic energy of the system could also correspond to increasing the temperature.

Temperature in any object

Object contains MANY atoms (kinetic energy) *and* interactions (potential energy)

Object A

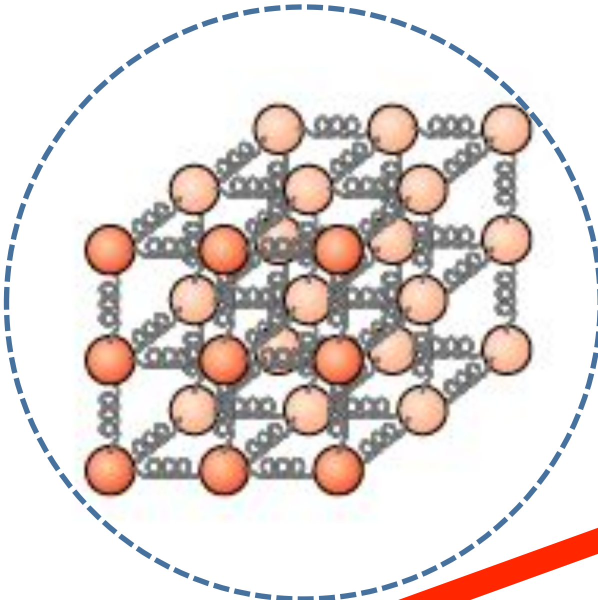


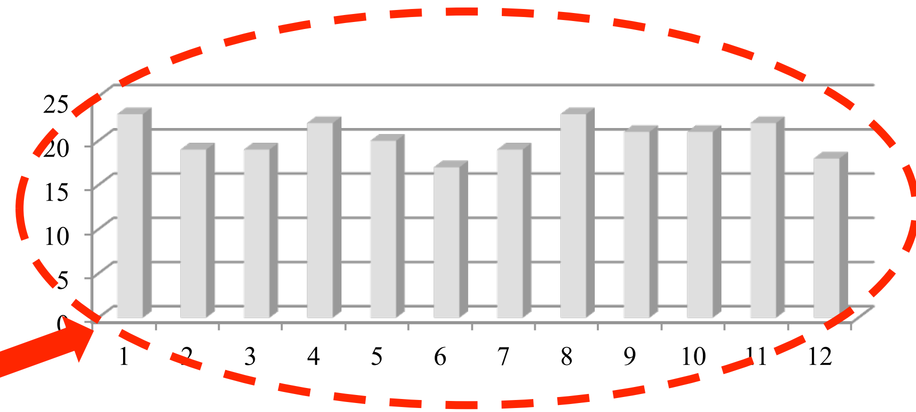


- **Temperature:** Measures the amount of energy in each atom or interaction – thermal energy is **on average** equally distributed among all these possible "bins" in which energy could reside.
- **Note: Potential energy of each bin is here defined relative to each minimum of the Potential Energy Curve.**

Thermal Energy in an object

Object A





- **Thermal energy of object A :** Measures the TOTAL energy in the whole object. Depends on temperature and the number of “bins” where energy could reside.
- Energy in each bin: $3/2\, k_B T$

Foothold ideas: Thermal Equilibrium & Equipartition

- Degrees of freedom – where energy can reside in a system.
- Thermodynamic equilibrium is dynamic. Changes keep happening, but equal amounts in both directions.
- Equipartition – At equilibrium, the same energy density in all space and in all DoFs.

Demo – Transfer Thermal Energy

A. Hot – Front
B. Hot – Back
C. Not Hot

Demo – Transfer Thermal Energy
When I say “interact” play rock-paper-scissors with 6 people in the class. If you win in a game with someone who has a card – you win their card.

A. Hot – Front
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Demo – Transfer Thermal Energy

How can random movement at a cellular level cause a unified motion on a larger scale?

- Through random interactions we see thermal energy transfer
- At the same time we see the energy distribution begin to equilibrate
- What would happen if we did this 10,000 times?

Can we get back to the original state?

Foothold ideas: Microstate and macrostates

- A *microstate* is a specific distribution of energy telling how much is in each DoF.
- A *macrostate* is a statement about some average properties of a state (pressure, temperature, density,...).
  - A given macrostate corresponds to many microstates.
- If the system is sufficiently random, each microstate is equally probable. As a result, the probability of seeing a given macrostate depends on how many microstates it corresponds to.

If we release a set of gas atoms all on one side of the room, they will spread out until they are approximately uniformly spread throughout the room. Why does this always happen?

A. The force of entropy pushes them into doing this
B. They repel one another
C. Internal pressure makes them fly apart
D. There are more ways to split them up evenly than to keep them all on one side
E. Any given atom has a 50/50 chance of being on one side of the room, so it evens out.

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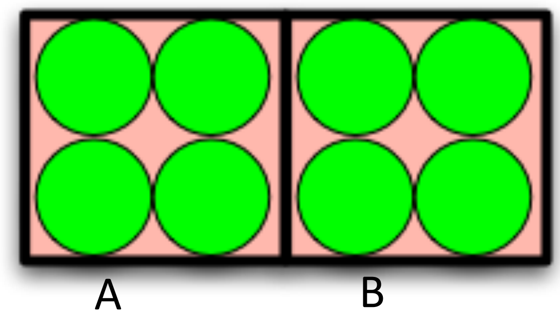
Suppose I have two blocks of matter A and B touching each other. Suppose each block has 4 “Degrees of Freedom” (bins in which to place energy)



I have 4 packets of thermal energy.

Which of the two scenarios are more likely:

A. Four packets in A
B. Two packets in A and two packets in B
C. Need more information

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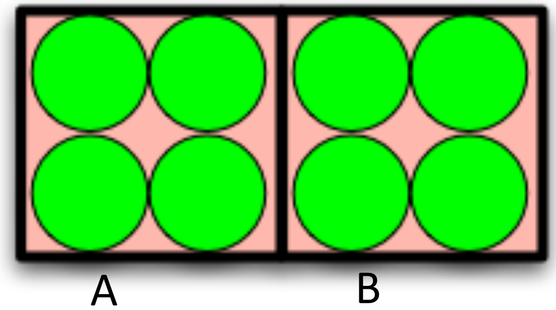

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Consider a “joint” system with 6 gas atoms and 6 water molecules.

We put in 8 packets of thermal energy

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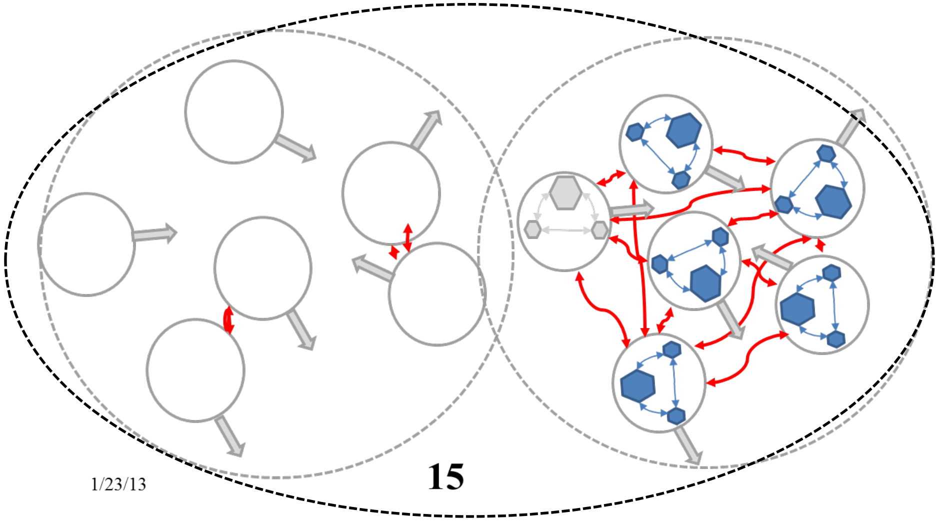
B. They are more likely to be in water
C. They are equally likely to be in any atom/molecule



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There are more places for the packets of energy to go in the water.