

Preview of Period 6: Entropy

6.1 Order, Disorder and Entropy

What defines an "orderly" pattern?

What is entropy? Why does it increase?

6.2 Equilibrium and the 2nd Law of Thermodynamics

Why do systems go toward equilibrium?

What is the 2nd Law of Thermodynamics?

6.3 Reversible Process and Perpetual Motion

What is an irreversible system?

Is perpetual motion possible?

Ordered and Disordered Systems

An orderly system matches a specific criteria.

- ◆ For activity 1, an orderly arrangement consists of 3 cards with the same picture.
- ◆ For activity 2, an orderly arrangement consists of checker colors that match the color of the checkerboard square on which they are placed.

Which are more common in nature - ordered systems or disordered systems? Why?

What is the probability of drawing an ordered arrangement of checkers?

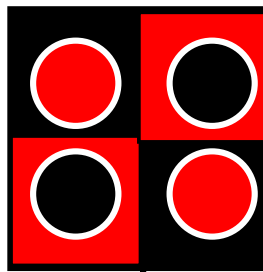
Four-Square Board

We use four squares from a checkerboard to find the probability of drawing an ordered arrangement of checkers.

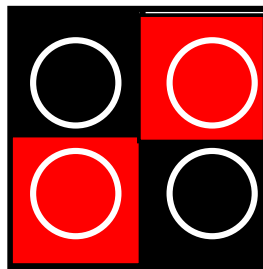
The arrangement is ordered if the color of the checker matches the color of the square on which it is placed.

Example:

Disorderly arrangement because checker colors do not match checkerboard colors.



Orderly arrangement because colors match.



R	R
R	R

R	R
R	B

R	B
R	B

B	B
B	R

B	B
B	B

R	R
R	R

R	R
R	B

R	B
R	R

B	R
R	R

R	R
B	R

R	B
R	B

B	R
R	B

R	R
B	B

B	B
R	R

R	B
B	R

B	R
B	R

B	B
B	R

B	R
B	B

R	B
B	B

B	B
R	B

B	B
B	B

Entropy (Disorder)

- ◆ Entropy is the measure of degree of order or disorder of a system.
- ◆ The greater the disorder, the greater the entropy
- ◆ Order and disorder are described in relation to a set of rules or properties.
- ◆ In most physical situations there are more disordered than ordered states.
- ◆ As systems change with time, they are more likely to become disordered than they are to become ordered.
- ◆ Therefore, the entropy (disorder) of the Universe always increases.
- ◆ To reduce the entropy of a system, work must be done on that system.

Entropy Calculations

If the temperature of a system is constant, the change in entropy is given by

$$\Delta S = \frac{\Delta Q}{T}$$

where

ΔS = change in entropy (joules/Kelvin or calories/Kelvin)

ΔQ = change in heat of the system (joules or calories)

T = temperature (Kelvin)

Equilibrium

- A system, when left undisturbed, progresses toward equilibrium with its surroundings.

For example, ice melts at room temperature. The melted water warms until it reaches room temperature - thermal equilibrium with the room.

- Entropy increases as a system moves toward equilibrium.
- A system is at maximum entropy when it is at equilibrium with its surroundings.
- The entropy of a system that is in equilibrium with its surroundings remains constant because the system has already reached its maximum entropy.
- As systems move toward equilibrium, they can give off energy or do work or do both.
- To change a system from its equilibrium state requires that work be done on the system or that energy be added to the system or both.

Equilibrium and Steady States

Not all unchanging systems are in equilibrium.

- ◆ A system in equilibrium does not change over time. No energy is required to keep the system in an unchanging state.
- ◆ Steady state systems also do not change over time, but this is only true because energy is added to keep the system in an unchanging state.
- ◆ A running faucet is an example of a steady state system.
- ◆ The open faucet provides a steady stream of water. However, this is not a system in equilibrium because energy is needed to pump water to the faucet.

The 2nd Law of Thermodynamics

The second law of thermodynamics can be stated in several ways:

- a) The entropy of a physical system left to itself will **increase** or, if the system is already at its maximum entropy, the entropy will remain the same.
- b) Any system, when left to itself, tends toward equilibrium with its surroundings.
- c) The entropy of a system that is in equilibrium with its surroundings remains constant.

Give examples from our class activities of these statements.

Reversible and Irreversible Systems

Work is required for moving a system at equilibrium to a non-equilibrium state.

- ◆ The work put in becomes stored energy.
- ◆ This stored energy can be used to do work as the system moves back to equilibrium.

Is it possible to get work out as a system goes to equilibrium and still have enough energy left to do work to return the system to its original non-equilibrium state? (To **reverse** the system?)

- ◆ Reversible processes are not possible.
- ◆ In every energy conversion, some energy is wasted as thermal energy.
- ◆ Therefore, the remaining energy could never be enough to return the system to its original non-equilibrium state.

All physical processes are irreversible

- ◆ Processes are irreversible if energy must be added or work be done or both to return the system to its original state.

Perpetual Motion

Perpetual motion is motion that continues forever with no input of energy.

Perpetual motion would represent a reversible process.

Is perpetual motion possible?

What conservation law would perpetual motion violate?

A perpetual motion machine could take energy out of a system and use this energy to do work. The machine would continue to run indefinitely with no input of energy.

Is a perpetual motion machine possible?

Period 6 Summary

6.1: An ordered system conforms to a predetermined set of rules.

In nature, disordered systems are more common than ordered systems because there are many more disorderly arrangements than orderly arrangements.

Entropy is a measure of the degree of disorder of a system. The greater the disorder, the greater the amount of entropy.

If the temperature is constant, the change in entropy is given by

$$\Delta S = \Delta Q / T$$

Entropy tends to increase with time. For example, ice melts at room temperature or metal rusts when exposed to moisture.

6.2: The entropy of a system increases until the system reaches a state of equilibrium with its surroundings.

Example: A hot object cools until it is at the same temperature as its surroundings.

Period 6 Summary, Continued

The 2nd law of thermodynamics can be stated in several ways:

- 1) The entropy of a physical system left to itself will increase or, if the system is already at its maximum entropy, the entropy will remain the same.
- 2) Any system, when left to itself, tends toward equilibrium with its surroundings.
- 3) The entropy of a system that is in equilibrium with its surroundings remains constant.

6.3: As systems move toward equilibrium, they can give off energy or do work or do both.

To change a system from its equilibrium state requires that work be done on the system or energy be added to the system.

Physical changes are **irreversible** if energy must be added or work be done or both to return the system to its original state.

All physical processes are irreversible.

Period 6 Review Questions

- R.1** You draw M & M candies from a bag and place them on a table. How do you decide if you have an ordered pattern of M & M's?
- R.2** Once your definition of an ordered pattern of M & M's has been decided upon, which are you more likely to draw at random – an ordered pattern or a disordered pattern of candy? Why?
- R.3** An ice cube is dropped into a hot cup of coffee. As the ice cube melts, the coffee cools down. What happens to the entropy of the ice cube, the entropy of the coffee, and the entropy of the system as a whole?
- R.4** Give examples of work done by systems at non-equilibrium as they move toward equilibrium. What is necessary to move a system at equilibrium to a non-equilibrium state?
- R.5** What are irreversible processes? Why are perpetual motion machines doomed to failure?