**Lesson Plan: Dancing Thermodynamics Through Gibbs Free Energy**
**Dancing Gibbs Free Energy: Thermodynamics Through Movement**

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Lesson Topic: This lesson teaches thermodynamics through dance, focusing on Gibbs free energy and the equation: **$\Delta G = \Delta H - T\Delta S$.** Students learn how temperature, enthalpy, entropy, and Gibbs free energy affect whether a reaction or process is favorable. Lesson Length: 45 minutes total

The full choreography to **"Kamasutra" by Mar Omin** is about **30 seconds**, but the full class includes concept teaching, brainstorming, section-by-section movement instruction, a full run with music, the example video, and discussion. This will be longer than what we were able to do in class in person due to in-class presentations' time constraints.

## Key Terms

- **Thermodynamics:** the study of energy, heat, work, and how systems change.
- **Gibbs free energy ($\Delta G$):** a quantity that tells us whether a process is favorable or spontaneous.
- **Enthalpy ($\Delta H$):** the heat absorbed or released by a system during a process.
- **Temperature (T):** a measure of the average kinetic energy of particles in a system; in this lesson, represented as speed and intensity.
- **Entropy ($\Delta S$):** a measure of disorder, freedom, or the number of possible arrangements in a system.
- **Spontaneous process:** a process that occurs without continuous outside energy input ($\Delta G < 0$).
- **Equilibrium:** a balanced state where there is no net change ($\Delta G = 0$).
- **Favorable / unfavorable:** whether a process is thermodynamically allowed to proceed on its own.
- **Locomotor / non-locomotor movement:** movement that travels through space vs. movement that stays in place.

## Abstract

This lesson uses dance to help students understand Gibbs free energy and reaction favorability. Students first learn the basic thermodynamic concepts of $\Delta G$, $\Delta H$, T, and $\Delta S$. Then they brainstorm how energy, heat, order, disorder, and spontaneity might look as movement. After this, the instructors demonstrate a 30-second choreography to "Kamasutra" by Mar Omin. The dance begins in a low, ordered line formation to represent a low-entropy system at equilibrium. As temperature increases, dancers rise and begin synchronized arm movements, showing added energy but still limited freedom. The dancers then gather and "entropically explode," dispersing across the room and freestyling to represent increased entropy and spontaneous reaction behavior. After learning each section separately, students put the full phrase together with music and compare their interpretation with the instructors' example video.

## Goals

Students should understand that Gibbs free energy helps explain whether a process is favorable or spontaneous.
Students should also understand that:

- Thermodynamics studies energy, heat, work, and change.

- $\Delta G$ depends on enthalpy, entropy, and temperature.
- A system can move from order to disorder when energy is added.
- Dance can represent scientific ideas through speed, spacing, formation, force, and movement quality.

**Learning Objectives**

By the end of the lesson, students should be able to:

1. Explain that Gibbs free energy describes whether a process is favorable.
2. Identify the parts of $\Delta G = \Delta H - T\Delta S$.
3. Explain that entropy is related to disorder, freedom, or possible arrangements. 4. Explain that temperature can be represented through increasing speed, energy, and intensity.
5. Distinguish between $\Delta G < 0$, $\Delta G > 0$, and $\Delta G = 0$.
6. Connect specific movement choices to thermodynamic ideas.
7. Perform a short choreographic phrase that represents a thermodynamic process.

**Assessment**

Understanding will be checked through discussion, observation, and short student explanations.

The instructor will look for whether students can:

● Explain why the beginning line formation represents order and low entropy. ● Describe why rising and increasing speed represents added temperature. ● Explain why dispersing across the room represents increasing entropy. ● Identify how the final freestyle section represents a more spontaneous reaction. ● Use thermodynamic vocabulary correctly when describing the dance. At the end, students answer one reflection question:

**How did one movement choice in the dance represent one thermodynamic concept?**

**Purpose/Rationale**

Thermodynamics is often taught through equations and diagrams, which can feel abstract. Students may memorize $\Delta G = \Delta H - T\Delta S$ without fully understanding how the parts of the equation work together.

Students complete a short pre-reading before class so they enter with a basic understanding of Gibbs free energy, spontaneity, and the equation $\Delta G = \Delta H - T\Delta S$. This allows the in-class lesson to focus less on memorizing definitions and more on applying the concepts through movement. The dance activity then translates the equation into physical choices: temperature is represented by speed and intensity, entropy by spacing and freedom, enthalpy by force, and Gibbs free energy by the overall favorability or direction of the movement. By placing the reading before the dance, students first encounter the scientific framework and then use choreography to make the abstract thermodynamic relationships more concrete.

Dance makes the concept more physical. When students begin in a low, tight, synchronized formation, they can feel what it means for a system to be ordered and restricted. When they rise, move faster, and eventually spread out, they can feel the difference between low entropy and high entropy. The dance works like a moving diagram of a reaction by showing how added energy and increased freedom can shift a system toward a more favorable process.

Interleaving short explanations with movement practice also helps students connect each movement choice back to the scientific concept it represents, rather than treating the choreography as separate from the thermodynamics.

**Instructor Preparation**
The instructors should prepare:
- A short explanation of thermodynamics and Gibbs free energy.
- A slide or board with **$\Delta G = \Delta H - T\Delta S$**.
- A simple table connecting thermodynamics to dance:
    - **$\Delta G$:** direction/favorability of the movement
    - **$\Delta H$:** strength or force
    - **T:** speed and intensity
    - **$\Delta S$:** order versus disorder / formation versus chaos
- The 30-second choreography to **"Kamasutra" by Mar Omin**.
- The teaching example video.
- A classroom or studio space where students can safely move.

**Student Preparation**
Students do not need prior dance experience. They should wear clothing and shoes that allow comfortable movement.
Required pre-reading is approximately 15 min: Khan Academy Intro Article - Covers *Gibbs free energy and spontaneity:* students should arrive understanding the basic equation $\Delta G = \Delta H - T\Delta S$ and the meaning of negative, positive, and zero $\Delta G$.

**Materials and Resources**
Needed materials:
- Open classroom or studio space
- Speaker for music
- Projector or screen for the teaching example video
- Slides or whiteboard for the equation and definitions
- Optional floor markers to show line, cluster, and dispersed formations

45-Minute Lesson Procedure
Step 1: Introduction to Thermodynamics
**Time: 4 minutes -** The instructor asks review questions to prepare for the activity:

**"Why do some reactions or processes happen naturally, while others need energy added?"**
Explanation:
Thermodynamics is the study of energy, heat, work, and how systems change. It helps explain why processes happen or do not happen. In this lesson, movement will represent energy, disorder, and reaction favorability.

**"What are examples of these processes that occur seemingly on their own?"**
Example answers: ice melts in a warm room, iron rusts, a ball rolls downhill.

**"What are examples of processes that are unfavorable on their own?"** Example answers: water doesn't freeze at room temperature, and a ball won't roll uphill by itself.

**"What's the difference between a fast reaction and a spontaneous one?**

A *fast* reaction happens quickly and it's about **rate** (how much time it takes). A *spontaneous* reaction happens on its own without needing continuous energy input and it's about **direction** (whether it's thermodynamically favorable). The two are independent: a reaction can be spontaneous but slow, or fast but non-spontaneous.

Step 2: Teach Gibbs Free Energy
**Time: 6 minutes**
The instructor writes:
$$\Delta G = \Delta H - T\Delta S$$
Explain each part simply:
- **ΔG** tells us whether a process is favorable.
- **ΔH** is enthalpy, or energy/heat change. In dance, this can look like strength or force.
- **T** is temperature. In dance, this can look like speed and intensity.
- **ΔS** is entropy. In dance, this can look like order versus disorder.

Then explain the three cases:
- **$\Delta G < 0$:** favorable/spontaneous; movement looks smooth and natural.
- **$\Delta G > 0$:** not favorable on its own; movement looks forced or tense.
- **$\Delta G = 0$:** equilibrium; movement looks balanced or stable.

Step 3: Student Brainstorm
**Time: 4 minutes**
Before showing the choreography, students brainstorm how they would represent thermodynamics through movement.
Prompts:
- What would low entropy look like?
- What would high entropy look like?
- How could dancers show temperature increasing?
- What would a spontaneous reaction look like?
- What would equilibrium look like?

Students can answer verbally or try small gestures in place.

Step 4: Explain Choreography Structure
**Time: 2 minutes**
The instructors explain that the dance is a 30-second phrase to **"Kamasutra" by Mar Omin**. The dance has four sections:
1. Ordered system / equilibrium
2. Adding heat / increasing temperature
3. Entropic explosion
4. Freestyle / spontaneous reaction

The music was chosen because its fluidity and beat changes match the reaction stages.

Step 5: Teach Section 1: Ordered System / Equilibrium
**Time: 5 minutes**
Students begin in a straight line formation and squat down or fold forward. Movement:
- Very little movement
- Slow rising from the ground
- Synchronized timing
- Clean, controlled body shape

Scientific meaning:

- The line shows order.
- The low squat shows limited energy and freedom.
- The synchronized timing shows a controlled system.
- This represents low entropy and equilibrium.

Instructor cue:
**“Start as an ordered system. You have little freedom, little movement, and no major change yet.”**
Students move through Section 1 slowly.

Step 6: Teach Section 2: Adding Heat / Increasing Temperature
**Time: 5 minutes**
Students rise up and begin synchronized arm movements.
Movement:
- Arms move in the same pattern
- Tempo increases
- Energy increases
- Dancers remain mostly synchronized

Science meaning:
- Rising shows energy being added.
- Faster tempo shows increasing temperature.
- Synchronized movement shows that freedom is still limited.
- The reaction is beginning but is not fully chaotic yet.

Instructor cue:
**“As temperature increases, the system gains energy. Show that through rising, faster timing, and stronger movement.”**
Students practice Sections 1 and 2 together.

Step 7: Teach Section 3: Entropic Explosion
**Time: 6 minutes**
Students briefly gather together, then disperse outward across the room. Movement:
- Dancers move closer together first
- On the beat change, they explode outward
- They travel through space
- The formation breaks
- Movements become bigger and looser

Scientific meaning:
- Dispersing represents entropy increasing.
- Breaking formation shows the system becoming less ordered.
- Traveling through space shows more freedom and more possible arrangements.

Instructor cue:
**“Entropy increases when the system has more possible arrangements. Break the formation and spread across the room.”**
Students practice the transition from Section 2 into Section 3 several times.

Step 8: Teach Section 4: Freestyle / Spontaneous Reaction
**Time: 4 minutes**
Students freestyle in different parts of the room.
Movement:
- Each dancer chooses their own movement

- Dancers use different directions, levels, and speeds
- The movement is freer and less restricted
- The ending feels smooth, open, or resolved

Scienctific meaning:

- Freestyle represents increased freedom.
- Different movement choices represent higher entropy.
- A smooth ending represents a favorable or spontaneous process, or **$\Delta G < 0$**.

Instructor cue:
**“Now the reaction has more freedom. Let the movement feel spontaneous and resolved.”**

Step 9: Combine All Sections Without Music
**Time: 4 minutes**
The class runs the full choreography slowly without music.
Sequence:

1. Low ordered line
2. Rise and add heat
3. Synchronized arm phrase
4. Gather
5. Entropic explosion
6. Disperse and freestyle

After the run, the instructor asks:

- Which section showed low entropy?
- Which section showed increasing temperature?
- Which section showed increasing entropy?
- Which section showed spontaneity?

Step 10: Dance With Music
**Time: 3 minutes**
Students (better in groups) perform the full 30-second choreography with **“Kamasutra” by Mar Omin**.
Reminder cues:

- Start controlled.
- Rise as temperature increases.
- Keep early movement synchronized.
- Explode outward when entropy increases.
- Freestyle with more freedom at the end.

Step 11: Show Teaching Example Video
**Time: 3 minutes**
The instructors show their example video after students have tried the phrase. Students watch for:

- Low line formation
- Squatting and rising
- Synchronized arm movement
- Gathering before the explosion
- Dispersal across the room
- Freestyle/spontaneous reaction at the end

Step 12: Final Discussion and Reflection
**Time: 3 minutes**

The instructor asks:

1. How did the dance help show entropy?
2. What movement represented temperature most clearly?
3. Why did the final freestyle section feel more spontaneous?

Students answer the final reflection question:
**How did one movement choice in the dance represent one thermodynamic concept?**
Instructor closes with:
**“In this dance, $\Delta G$ is the overall favorability of the reaction. $\Delta H$ appears as strength and force. T appears as speed and intensity. $\Delta S$ appears as formation, spacing, and freedom. By moving from a low, ordered line into a dispersed freestyle, we modeled how a system can gain energy, increase entropy, and move toward a more favorable reaction.”**

**Supplemental discussion if time remains:**

**“If you had to add a fifth section to the dance to represent $\Delta G > 0$ (a non-spontaneous reaction), what would it look like?”**

45-Minute Timeline

| Lesson Part | Time |
|---|---|
| Introduction to thermodynamics | 4 min |
| Gibbs free energy equation | 6 min |
| Student brainstorm | 4 min |
| Explain choreography structure | 2 min |
| Teach Section 1 | 5 min |
| Teach Section 2 | 5 min |
| Teach Section 3 | 6 min |
| Teach Section 4 | 4 min |
| Combine without music | 4 min |
| Dance with music | 3 min |
| Show example video | 3 min |
| Final discussion and reflection | 3 min |
| **Total** | **45 min** |

**Movement Design Requirements**
*Two Formations*
The choreography begins in a line, moves into a gathered cluster, and ends in a dispersed formation.
*Transitions Between Formations*

Students travel from the line into a gathered shape, then explode outward into different parts of the room.
*Locomotor Movement*
The entropic explosion includes traveling steps as dancers disperse across the space.
*Non-Locomotor Movement*
The synchronized arm movements in Section 2 happen mostly in place. *Movement Modifier*
Speed, size, level, and energy increase as temperature increases.
*Intentional Body Shape*
The beginning low squat represents a contained, low-energy, ordered system. The middle arm movement represents increasing temperature and energy. The ending freestyle shape represents increased freedom and a spontaneous reaction.

**Accessibility and Adaptations**
Students who cannot or do not want to do full-body movement can still participate. Adaptations:

- Perform seated using arms, torso, head, and hand gestures.
- Show dispersal by pointing in different directions instead of traveling.
- Use small hand motions for low entropy and larger gestures for high entropy.
- Participate as a director by arranging classmates into formations and explaining the thermodynamic meaning.
- Use objects on a desk to model the formations.

**Possible Challenges and Solutions**

- Challenge: Students feel awkward moving.
  Solution: Start with simple gestures and remind them that this is a science model, not a dance audition.
- Challenge: Students confuse entropy with temperature.
  Solution: Repeat: temperature is speed/intensity; entropy is freedom/disorder/spacing.
- Challenge: Students think spontaneous means fast.
  Solution: Clarify that spontaneous means favorable, not necessarily quick.
- Challenge: The room is small.
  Solution: Use smaller groups, or show dispersal with arms and facing direction instead of large travel.
- Challenge: Students copy the movement without understanding it.
  Solution: After each section, ask what concept the movement represents before moving on.

**Final Lesson Takeaway**
This 45-minute lesson uses a short dance phrase to make Gibbs free energy easier to understand. Students begin in an ordered, low-energy formation, rise as temperature increases, move through synchronized reaction-like gestures, break formation during an entropic explosion, and end in freer movement that represents spontaneity. By learning the choreography section by section and then dancing it with music, students connect $\Delta G = \Delta H - T\Delta S$ to physical experiences of order, energy, freedom, and reaction favorability.

**Bibliography and Future Readings**

Khan Academy. “Gibbs free energy and spontaneity.” Used as the required pre-reading to introduce Gibbs free energy, spontaneity, and the equation $\Delta G = \Delta H - T\Delta S$. Khan Academy Intro Article

Khan Academy Further Reading on Entropy: Introduction to entropy (video)