

### Question:

A glass of ice water contains both ice and water.  
After a few minutes of settling, how do the temperatures of the ice and the water compare?

1. The ice is colder than the water
2. The water is colder than the ice
3. The ice and water are at the same temperature

### Phases of Matter

- Solid: fixed volume and fixed shape
  - Ice: a transparent, low-density solid
- Liquid: fixed volume but variable shape
  - Water: a transparent, mid-density liquid
- Gas: variable volume and variable shape
  - Steam: an invisible gas

### Ice and Water

- Melting temperature:
  - Below it, solid (ice) is stable phase
  - Above it, liquid (water) is stable phase
  - At it, liquid and solid phases can coexist
- Coexistence is a form of equilibrium
- Equilibrium is dynamic: molecules move
- Ice into water takes energy (latent heat)

### Melting/Freezing 1

- Any change that causes more water molecules to leave the solid than return to it causes the ice to melt
- Any change that causes more water molecules to return to the solid than leave it causes the water to freeze

### Melting/Freezing 2

- To melt ice:
  - Add heat
  - Squeeze the ice (unusual!)
- To freeze water:
  - Remove heat
  - Reduce the pressure on the water (unusual!)

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## Water and Steam

- Liquid and gas phases can coexist over a broad range of temperatures
  - Gas density increases with temperature
  - Liquid density remains constant
  - Equilibrium gas pressure is called vapor pressure
- Equilibrium is dynamic: molecules move
- Water into steam takes energy (latent heat)

## Evaporation/Condensation 1

- Any change that causes more water molecules to leave the liquid than return to it causes the water to evaporate
- Any change that causes more water molecules to return to the liquid than leave it causes the steam to condense

## Evaporation/Condensation 2

- To make water evaporate:
  - Add heat
  - Expand steam
  - Lower relative humidity
- To make steam condense:
  - Remove heat
  - Squeeze steam
  - Raise relative humidity

## Boiling

- Evaporation bubbles can form inside water
- Pressure inside bubble is vapor pressure
- If vapor pressure exceeds atmospheric pressure, bubble is stable and grows
- Boiling occurs when bubbles nucleate and grow easily
- Latent heat need stabilizes temperature

## Sublimation/Frost

- Solid and gas phases can coexist over a broad range of temperatures
- When ice becomes steam: sublimation
- When steam becomes ice: frost