

Water, Steam, and Ice

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?
- The ice is colder than the water
- The water is colder than the ice
- They're at the same temperature

Observations About Water, Steam, and Ice

- Water has three forms or phases
- Ice is typically present below 32 °F or 0 °C
- Water is typically present above that
- Steam is typically present at high temps
- The three phases sometimes coexist

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 the stable phase
 - Above it, liquid (water) is the stable phase
 - At it, the liquid and solid phases can coexist
- Coexistence is a form of equilibrium
- Dynamic equilibrium – molecules swap
- Turning ice to water takes (latent) heat

Melting/Freezing Part 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 Part 2

- To melt ice,
 - add heat
 - or increase pressure (unique to water & ice!)
- To freeze water,
 - remove heat
 - or reduce pressure (unique to water & ice!)

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Water and Steam

- Liquid and gas can coexist over a broad range of temperatures. But at equilibrium,
 - liquid density remains nearly constant
 - gas density increases with temperature
- Equilibrium gas pressure: Vapor Pressure
- Dynamic equilibrium - molecules swap
- Turning water to steam takes (latent) heat

Evaporation/Condensation Part 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 Part 2

- To make water evaporate,
 - add heat
 - or expand the steam
 - or lower the relative humidity
- To make steam condense,
 - remove heat
 - or compress the steam
 - or raise the relative humidity

Boiling Part 1

- Evaporation bubbles can form inside water
 - Bubble pressure is the vapor pressure
 - When vapor pressure exceeds ambient pressure, the bubble survives and grows
- Boiling occurs when
 - bubbles can nucleate (seed bubbles form)
 - bubbles can grow
- Need for latent heat stabilizes temperature

Boiling Part 2

- Ambient pressure affects boiling temp
 - Elevated pressure raises boiling temp
 - Diminished pressure lowers boiling temp
- Cooking uses boiling to set temperature
 - Foods cook fast at high pressures (sea level)
 - Foods cook slow at low pressures (↑ height)

Sublimation/Frost

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

Impurities

- Dissolved impurities stabilize liquid phase
 - Melting temperature drops
 - Boiling temperature rises
- Proportional to density of dissolved items:
 - Salt ions
 - Sugar molecules

Summary About Water, Steam, and Ice

- Stable phases determined by equilibria
- Temperature & pressure affect phases
- Shifting between phases involves heat