Review

- Two opposing processes:
  - In evaporation, particles leave the surface of a liquid to form a gas (or vapor).
  - In condensation, vapor particles form a liquid.

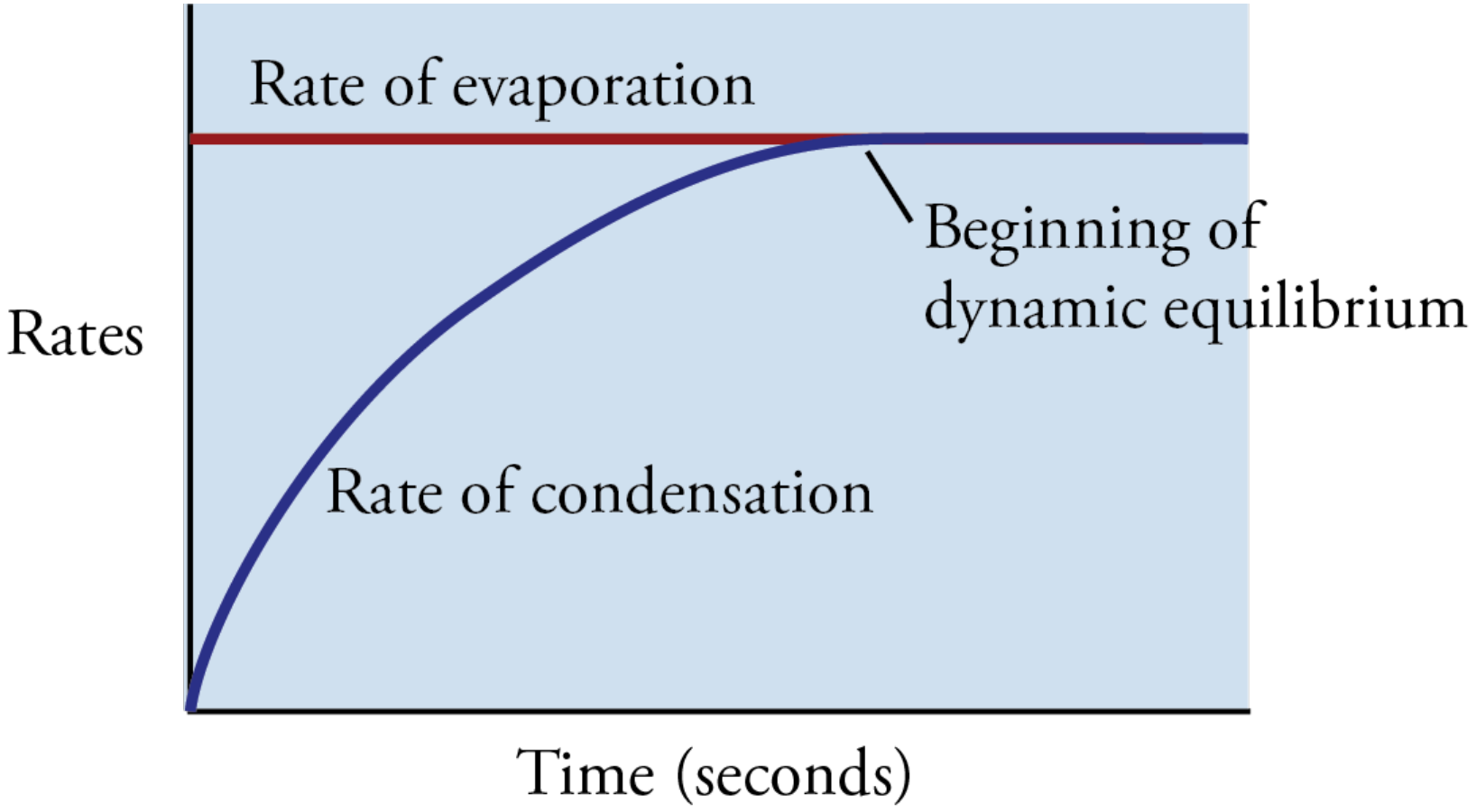
Rate of Evaporation

- The rate of evaporation (R_{evap}) is the number of particles moving from liquid to vapor per second.
  - Increased surface area → increased R_{evap}
  - Decreased strength of attractions → decreased R_{evap}
  - Increased temperature → increased R_{evap}

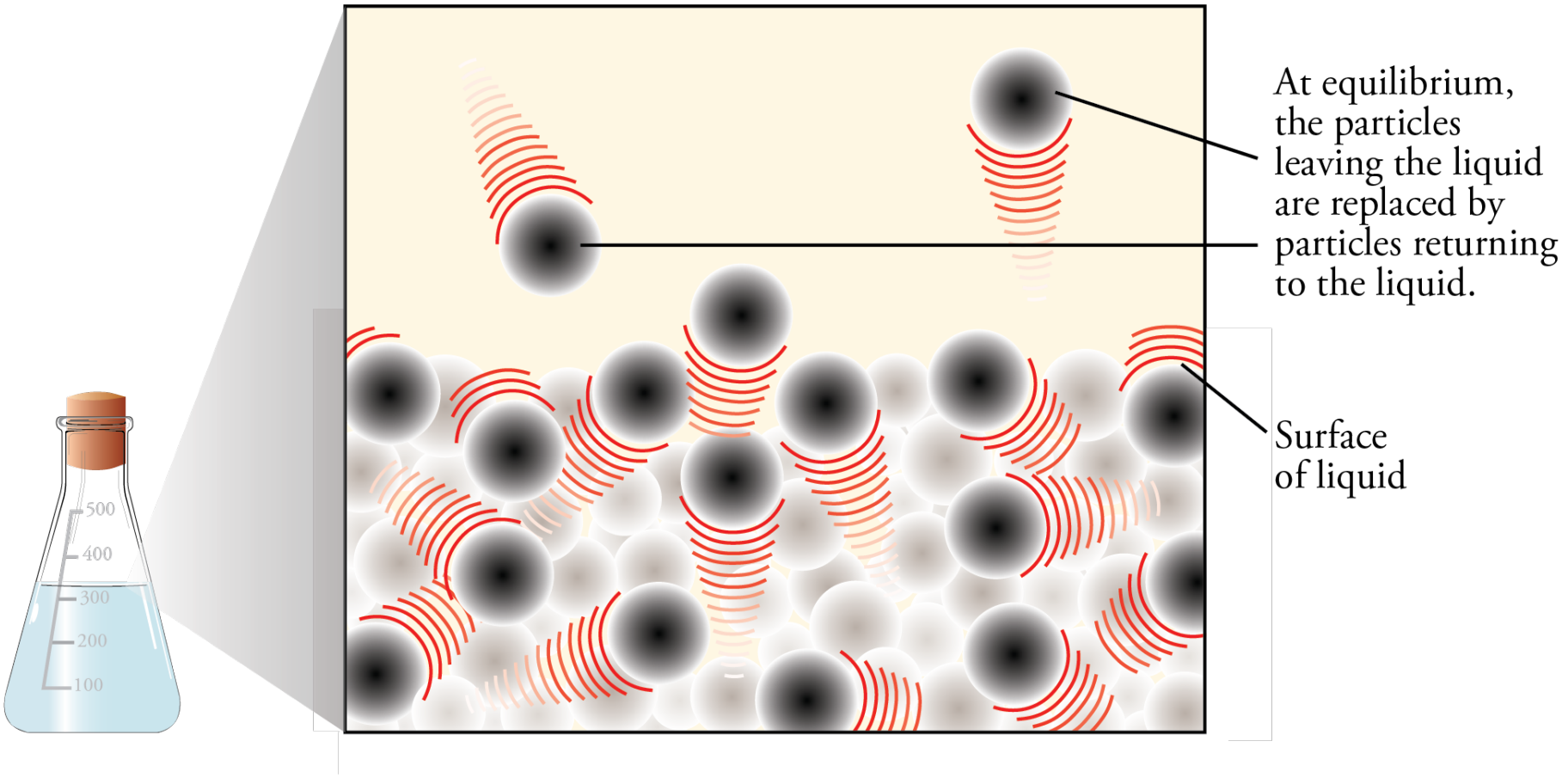
Rate of Condensation

- The rate of condensation (R_{cond}) is the number of particles moving from vapor to liquid per second.
  - Increased surface area → increased R_{cond}
  - Increased concentration of gas → increased R_{cond}

Dynamic Equilibrium and Rates of Evaporation and Condensation



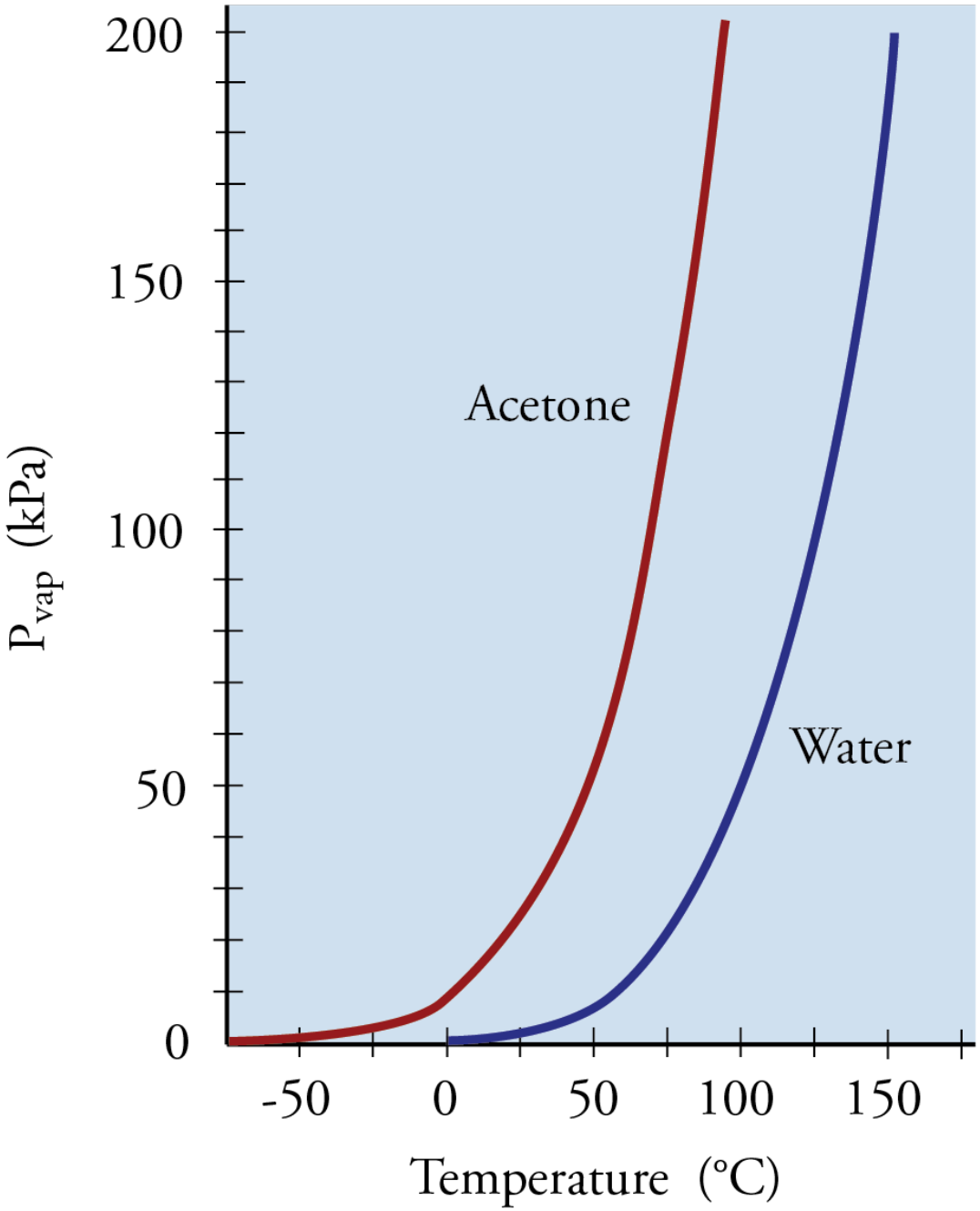
Liquid-Vapor Equilibrium



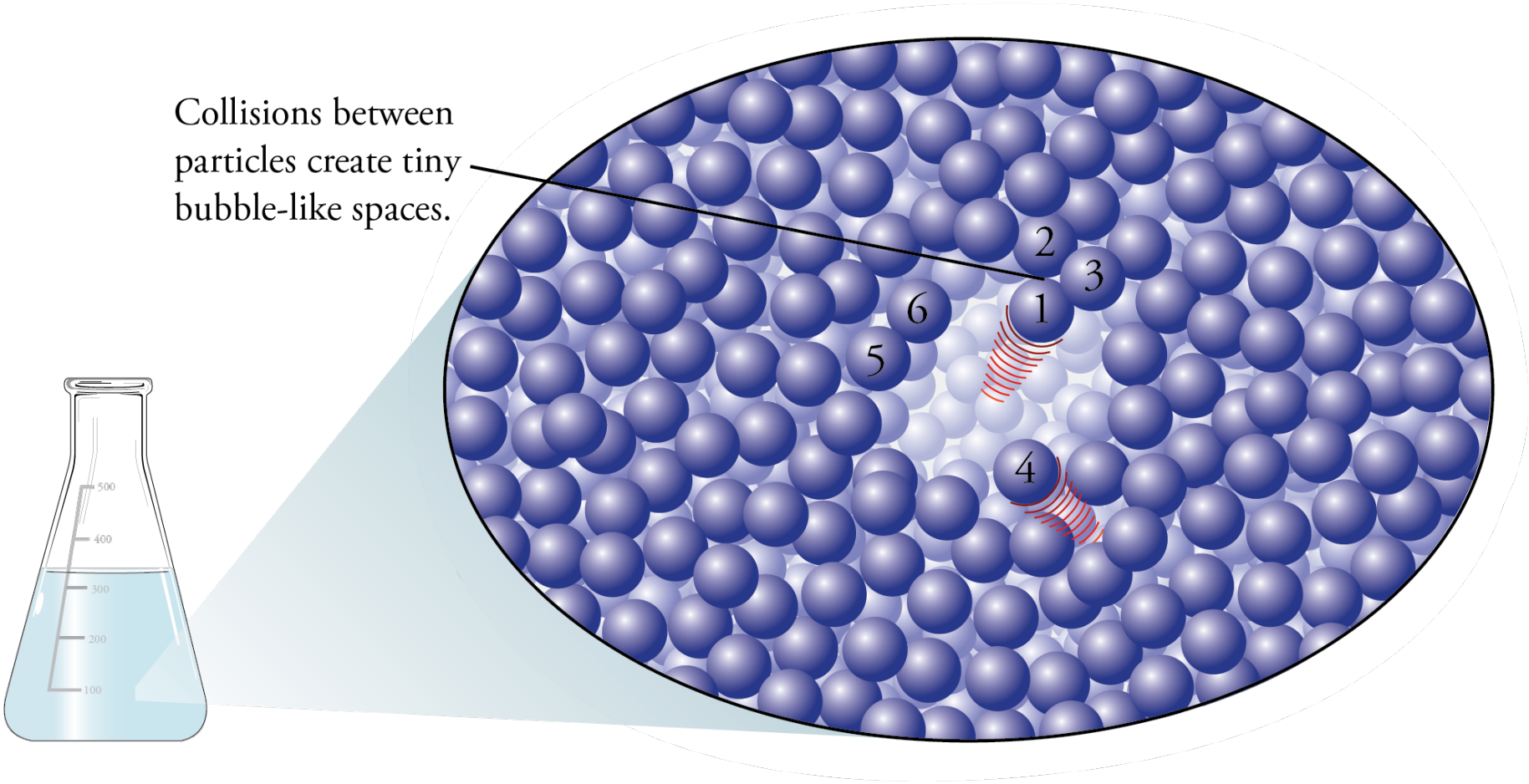
Equilibrium
Vapor Pressure

- **Equilibrium vapor pressure, P_{vap}** is the vapor pressure above a liquid when there is a dynamic equilibrium between the rates of evaporation and condensation.
  - Weaker the attractions → higher P_{vap}
  - Increased temperature → increased P_{vap}

Acetone/ Water P_{vap} vs. T



Spaces in Liquids

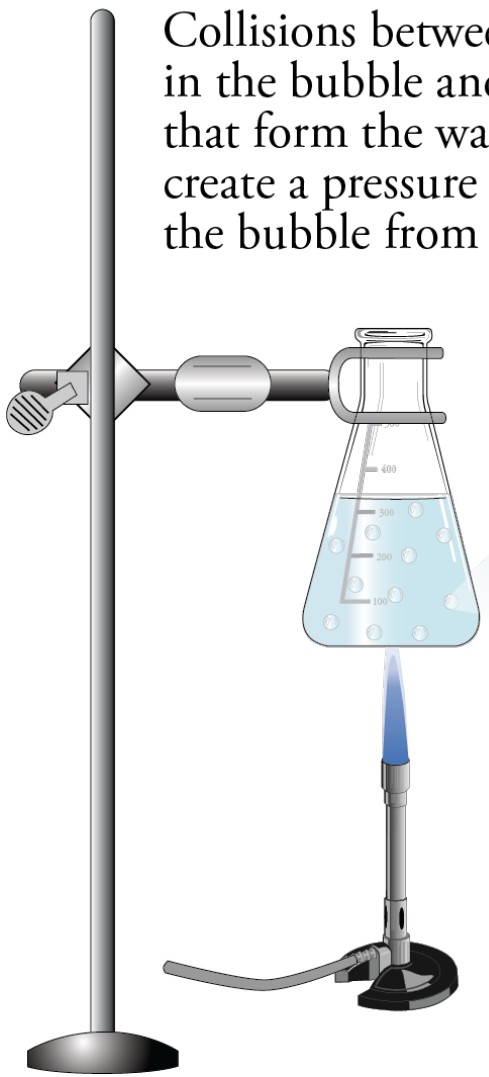


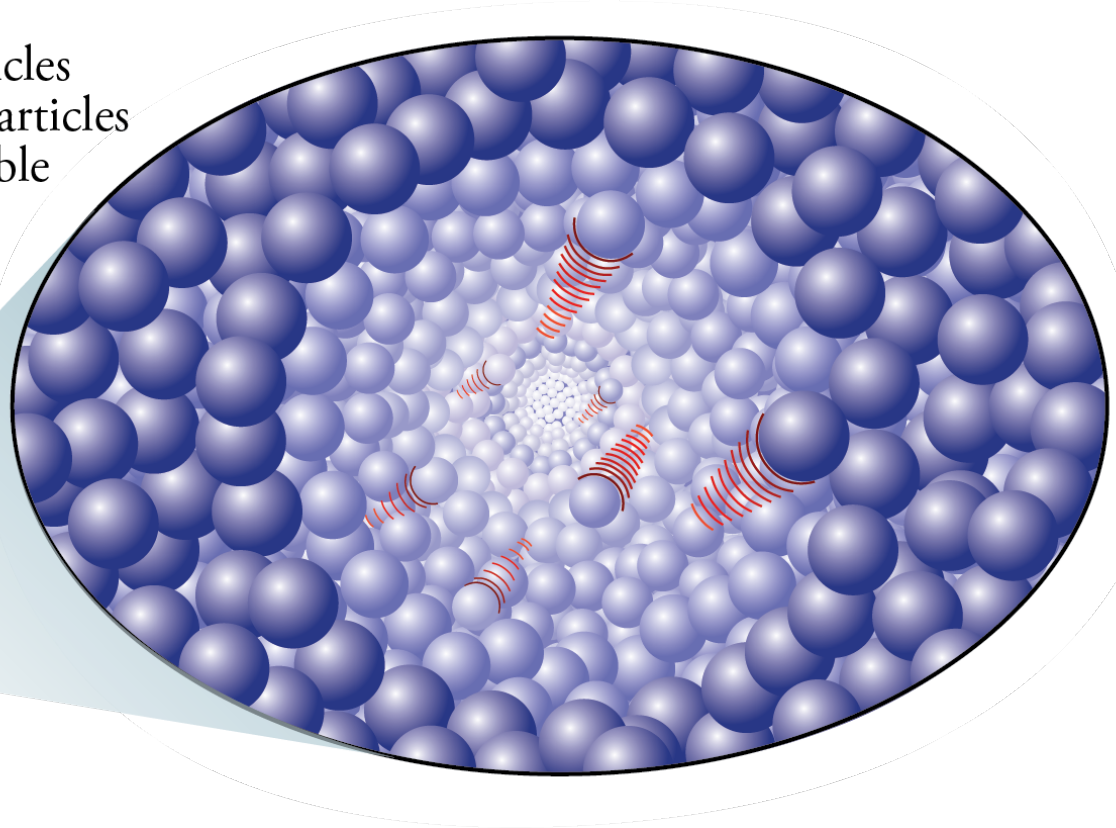
Forces Pushing in on Bubble

- Two sources of the force pushing in on a bubble.
  - External pressure acting on the surface of the liquid
  - Force due to the weight of the liquid above the bubble
- For a bubble to continue to exist, the force due to the collisions of the particles moving in the bubble with the walls of the bubble must be equal to or greater than the force pushing in on the bubble.

Bubble in Liquid

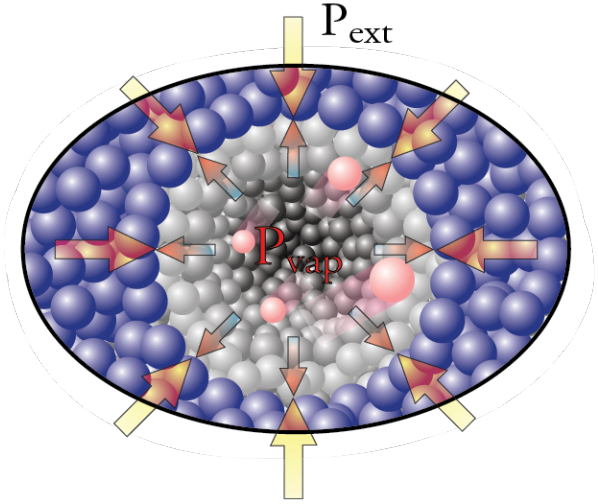
Collisions between vapor particles in the bubble and the liquid particles that form the walls of the bubble create a pressure that can keep the bubble from collapsing.



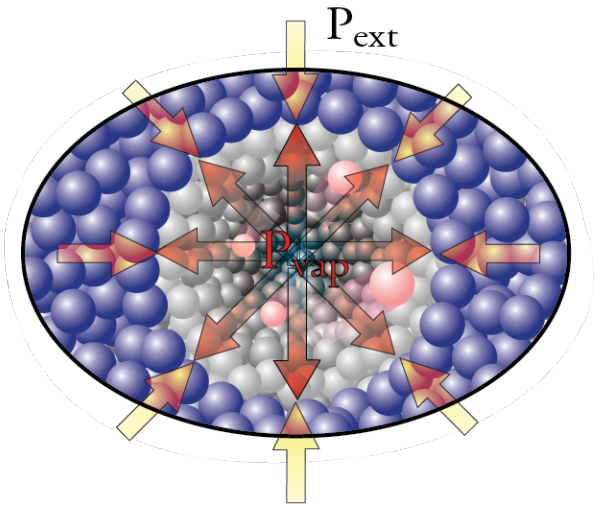


Bubble Formation

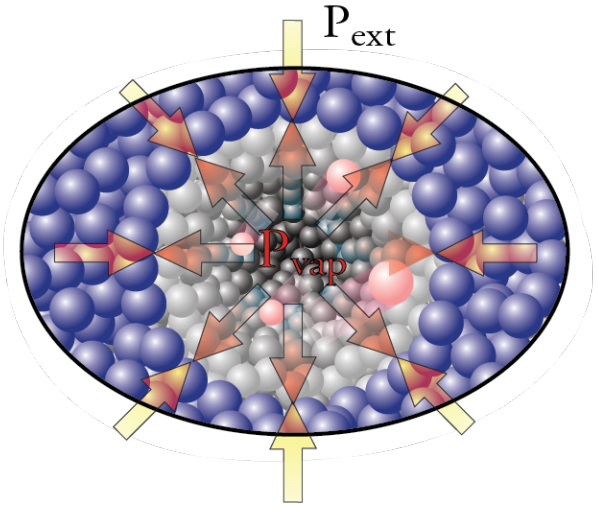
$P_{vap} < P_{ext}$
Bubble collapses



$P_{vap} > P_{ext}$
Bubble expands



$P_{vap} = P_{ext}$
Bubble maintains its volume



Boiling Point Temperature

- **Boiling point temperature** (or more commonly just **boiling point**) is the temperature at which a liquid boils.
- It is dependent on the external pressure acting on the liquid.
  - Water boils at about 72 ºC at the top of Mt. Everest where the pressure is about 34 kPa.
  - It boils at about 120 ºC in a pressure cooker at about 200 kPa.

Normal and Standard Boiling Points

- **Normal boiling point** (or **atmospheric boiling point**) is the temperature at which a liquid boils when the external pressure is 1 atm, which is the approximate pressure at sea level on the earth.
- **Standard boiling point** is the temperature at which a liquid boils when the external pressure is 1 bar.
- An atmosphere is 1.01325 bar. Because a bar is so close to an atmosphere, the normal boiling point and the standard boiling point for a substance are very close to the same.

Pressure and Boiling Points

Decreased external pressure above liquid water

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Decreased vapor pressure necessary to allow bubbles to form

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Decreased temperature necessary to reach this lower vapor pressure

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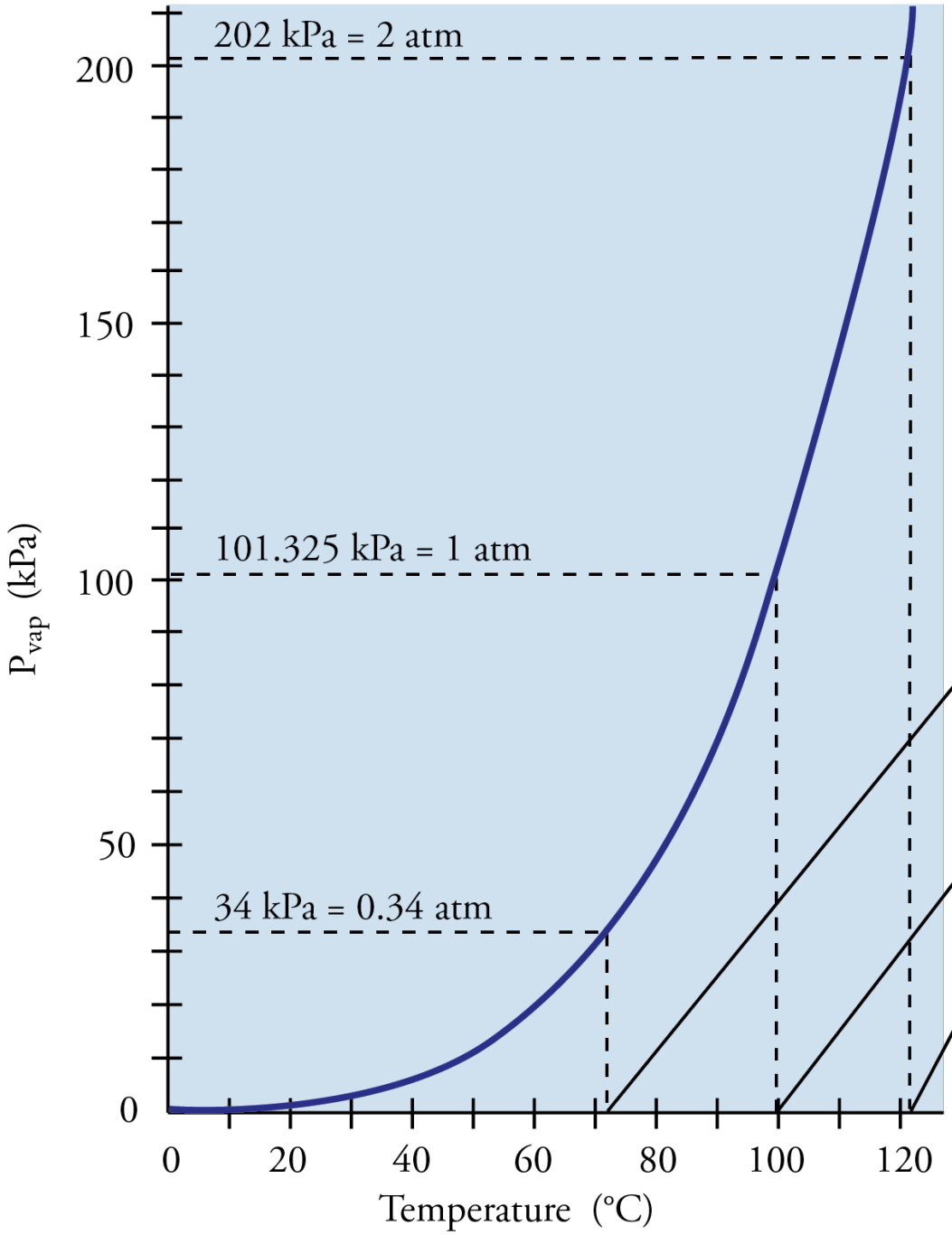
Decreased boiling-point temperature

Pressure and Boiling Point for Water



The boiling point of water at the top of Mount Everest with an external pressure of 34 kPa is 72 °C.

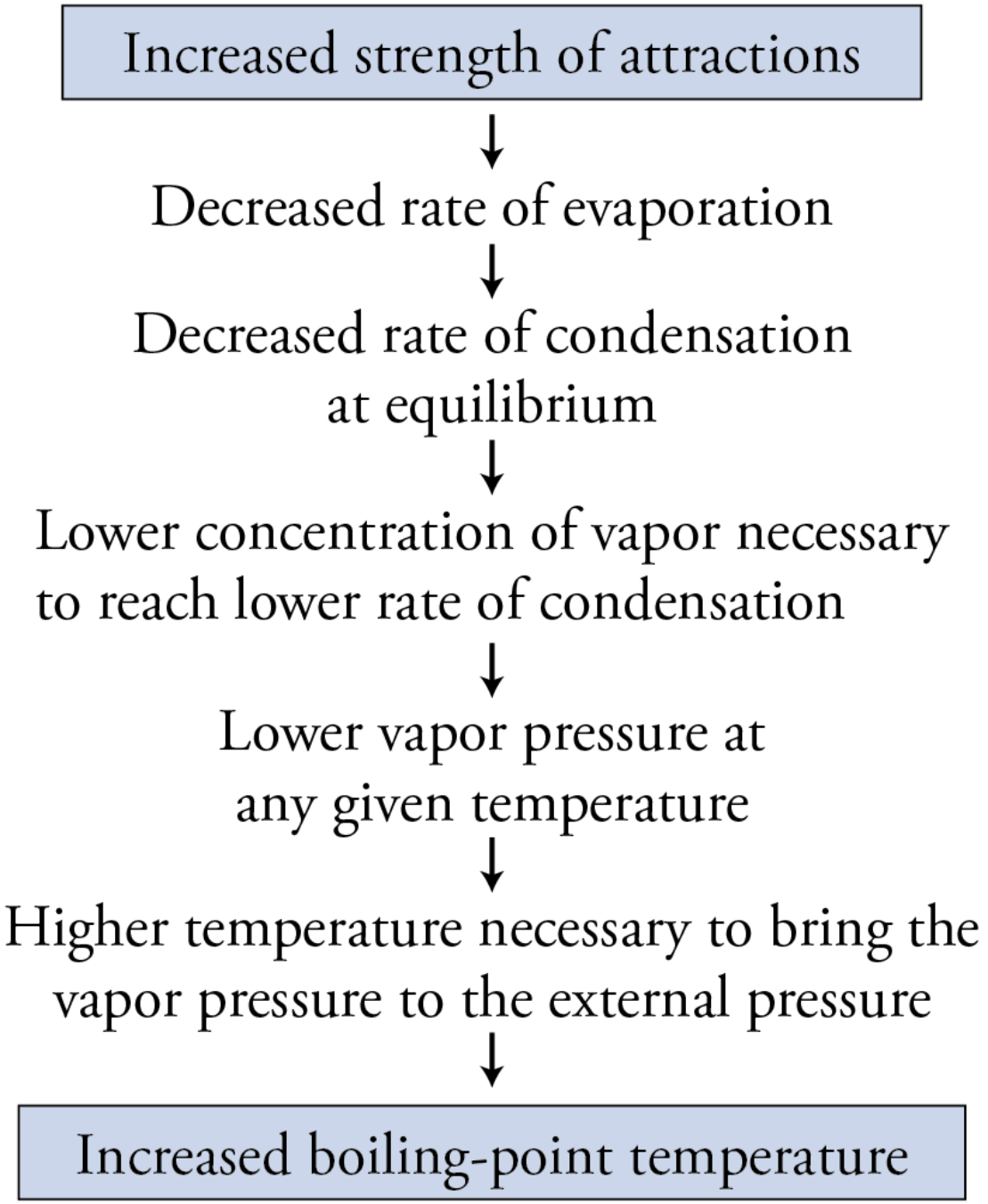
The normal boiling point of water is 100 °C.

The boiling point of water with an external pressure of 202 kPa is about 120 °C.

Boiling Point Temperature

- Each liquid has a unique normal boiling point that is determined by the strengths of attractions between the particles.
  - Acetone has weaker attractions between its particles than the attractions between water molecules, so its normal boiling point (56.5 ºC) is lower than that of water.
  - Acetic acid has stronger attractions between its particles than the attractions between water molecules, so its normal boiling point (139 ºC) is higher than that of water.

Strengths of Attractions and Boiling Point



Normal Boiling Points