Lecture 3

PHYC 161 Fall 2016

Phase changes

- The **phases** (or states) of matter are solid, liquid, and gas.
- A **phase change** is a transition from one phase to another.
- The temperature does not change during a phase change.
- The **latent heat**, L, is the heat per unit mass that is transferred in a phase change.

Heat transfer in a phase change

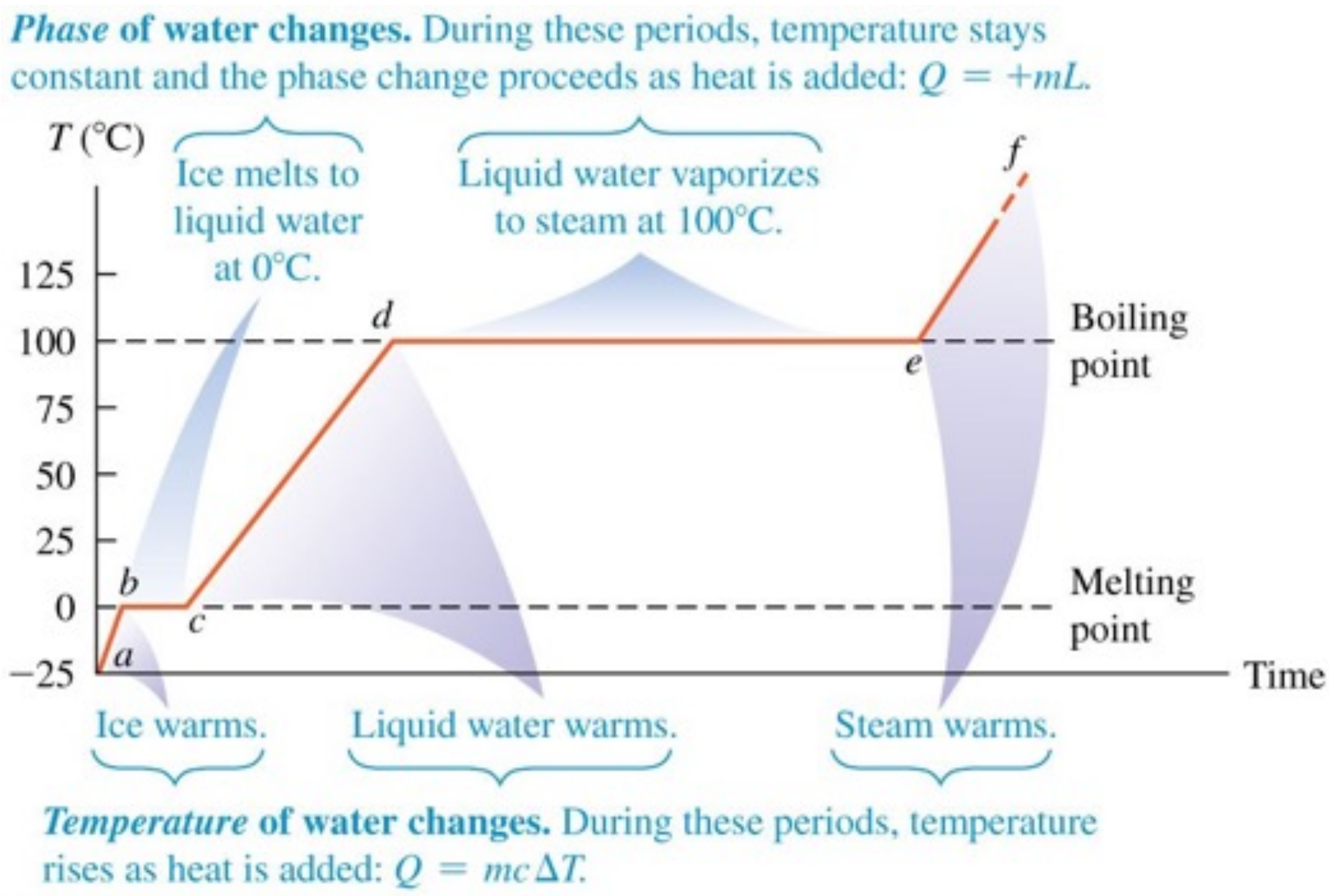
$$Q = \pm mL$$

Mass of material that changes phase

Latent heat for this phase change

+ if heat enters material, − if heat leaves

Heat added to ice at a constant rate



Heat of fusion

- The metal gallium, shown here melting in a person's hand, is one of the few elements that melts at room temperature.
- Its melting temperature is 29.8°C, and its **heat of fusion** is $L_f = 8.04 \times 10^4$ J/kg.

Heat of vaporization

- The water may be warm and it may be a hot day, but these children will feel cold when they first step out of the swimming pool.
- That's because as water evaporates from their skin, it removes the **heat of vaporization** from their bodies.
- To stay warm, they will need to dry off immediately.

Q17.6

A pitcher contains 0.50 kg of liquid water at 0°C and 0.50 kg of ice at 0°C. You let heat flow into the pitcher until there is 0.75 kg of liquid water and 0.25 kg of ice. During this process, the temperature of the ice-water mixture

A. increases slightly.

B. decreases slightly.

C. first increases slightly, then decreases slightly.

D. remains the same.

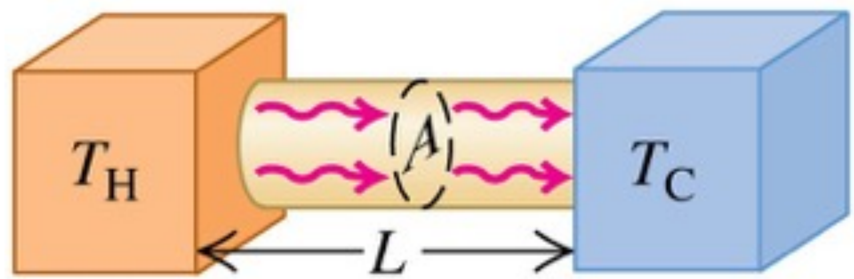
E. The answer depends on the rate at which heat flows.

Mechanisms of heat transfer

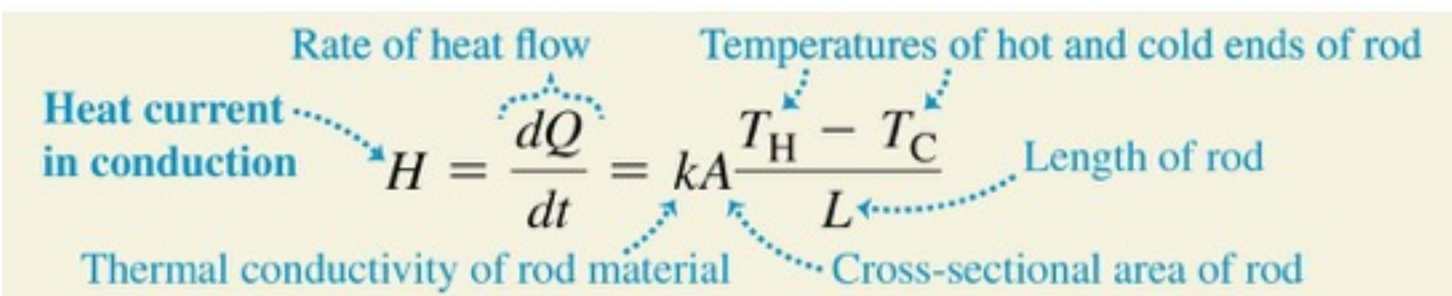
- In nature, energy naturally flows from higher temperature objects to lower temperature objects; this is called **heat transfer**.
- The three mechanisms of heat transfer are **conduction**, **convection**, and **radiation**.
- *Conduction* occurs within a body or between two bodies in contact.
- *Convection* depends on motion of mass from one region of space to another.
- *Radiation* is heat transfer by electromagnetic radiation, such as sunshine, with no need for matter to be present in the space between bodies.

Conduction of heat

- In conduction, heat flows from a higher to a lower temperature.
- Consider a solid rod of conducting material with cross-sectional area *A* and length *L*.
- The left end of the rod is kept at a temperature T_H and the right end at a lower temperature T_C.



- The rate that heat is transferred is:



$$H = \frac{dQ}{dt} = kA\frac{T_H - T_C}{L}$$

Q17.7

A chair has a wooden seat but metal legs. The chair legs feel colder to the touch than does the seat. Why is this?

A. The metal is at a lower temperature than the wood.

B. The metal has a higher specific heat than the wood.

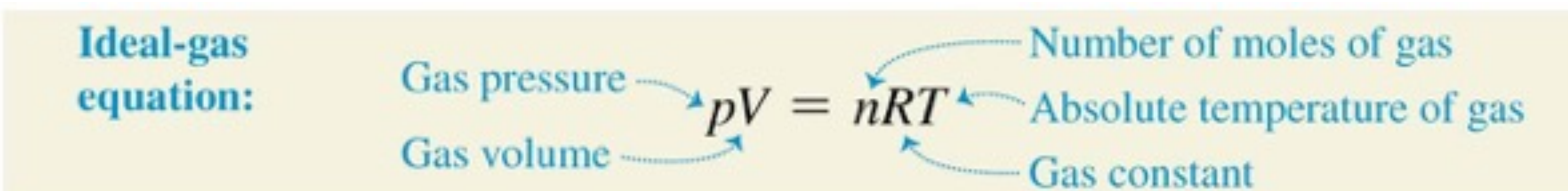
C. The metal has a lower specific heat than the wood.

D. The metal has a higher thermal conductivity than the wood.

E. The metal has a lower thermal conductivity than the wood.

Equations of state and the ideal-gas law

- Quantities such as pressure, volume, temperature, and the amount of a substance are **state variables** because they describe the state of the substance.
- The **equation of state** relates the state variables.
- The ideal-gas equation is an equation of state for an ideal gas:



- The **molar mass** ***M*** (*molecular weight*) is the mass per mole. The total mass of n moles is $m_{\text{total}} = nM$.

Introduction

- The ideal-gas equation $pV = nRT$ gives a good description of the air inside an inflated vehicle tire, where the pressure is about 3 atmospheres and the temperature is much too high for nitrogen or oxygen to liquefy.
- As the tire warms (T increases), the volume V changes only slightly but the pressure p increases.

Q18.1

A quantity of an ideal gas is contained in a balloon. Initially the gas temperature is 27°C. You double the pressure on the balloon and change the temperature so that the balloon shrinks to one-quarter of its original volume. What is the new temperature of the gas?

A. 54°C

B. 27°C

C. 13.5°C

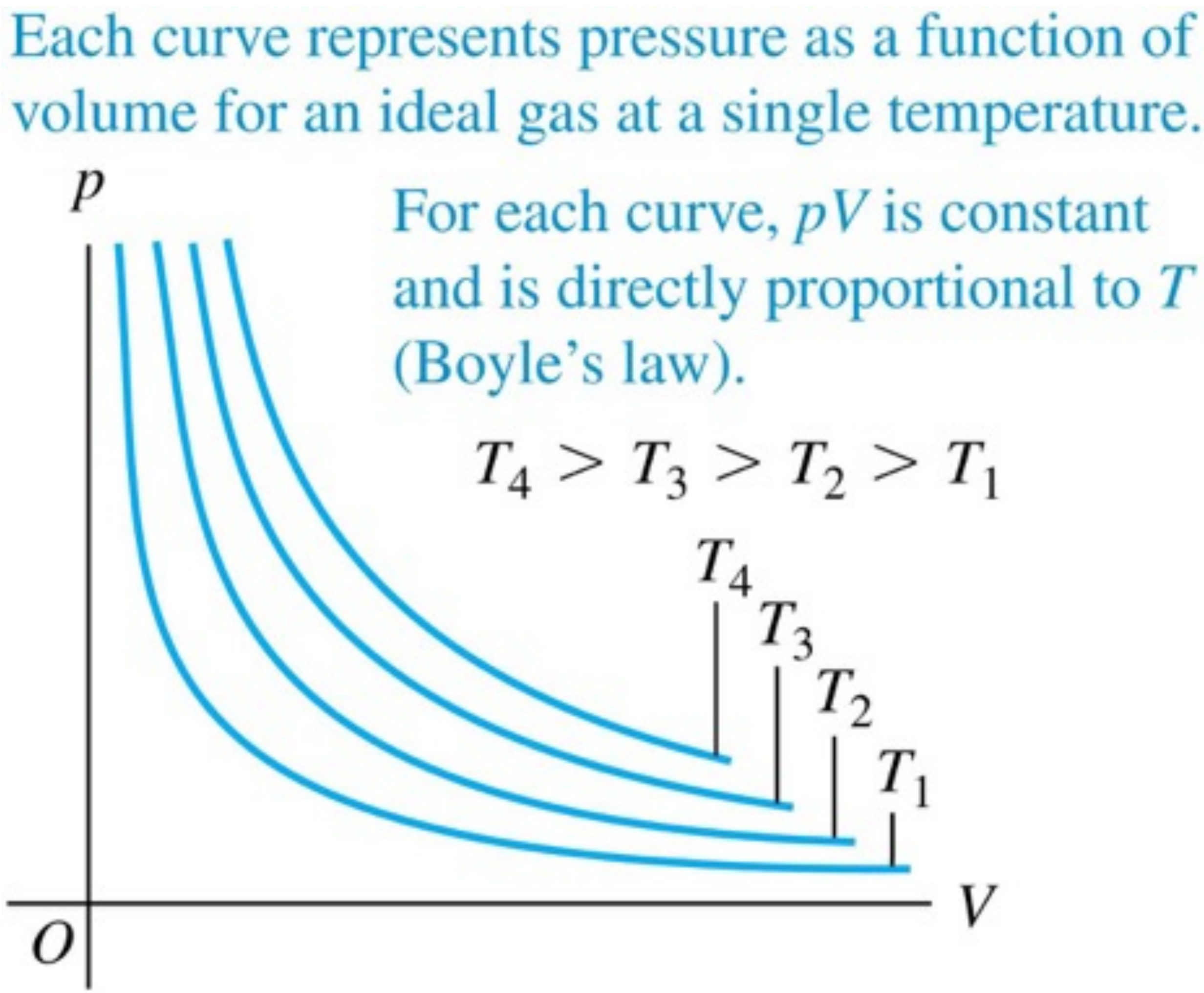
D. –123°C

E. –198°C

- $pV = nRT$

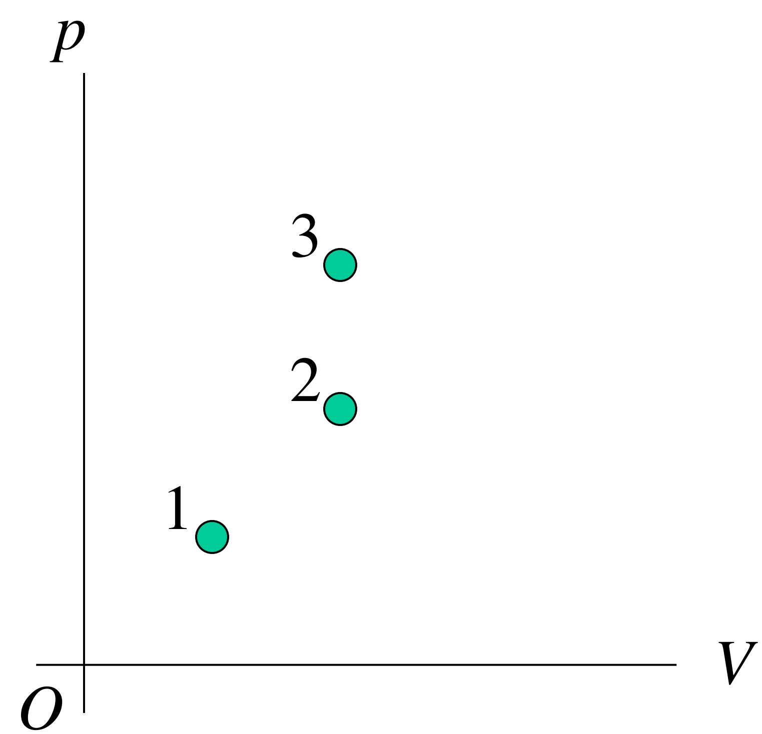
pV-diagrams

- These show isotherms, or constant-temperature curves, for a constant amount of an ideal gas.



Q18.2

This *p*-*V* diagram shows three possible states of a certain amount of an ideal gas. Which state is at the *highest* temperature?



A. state #1

B. state #2

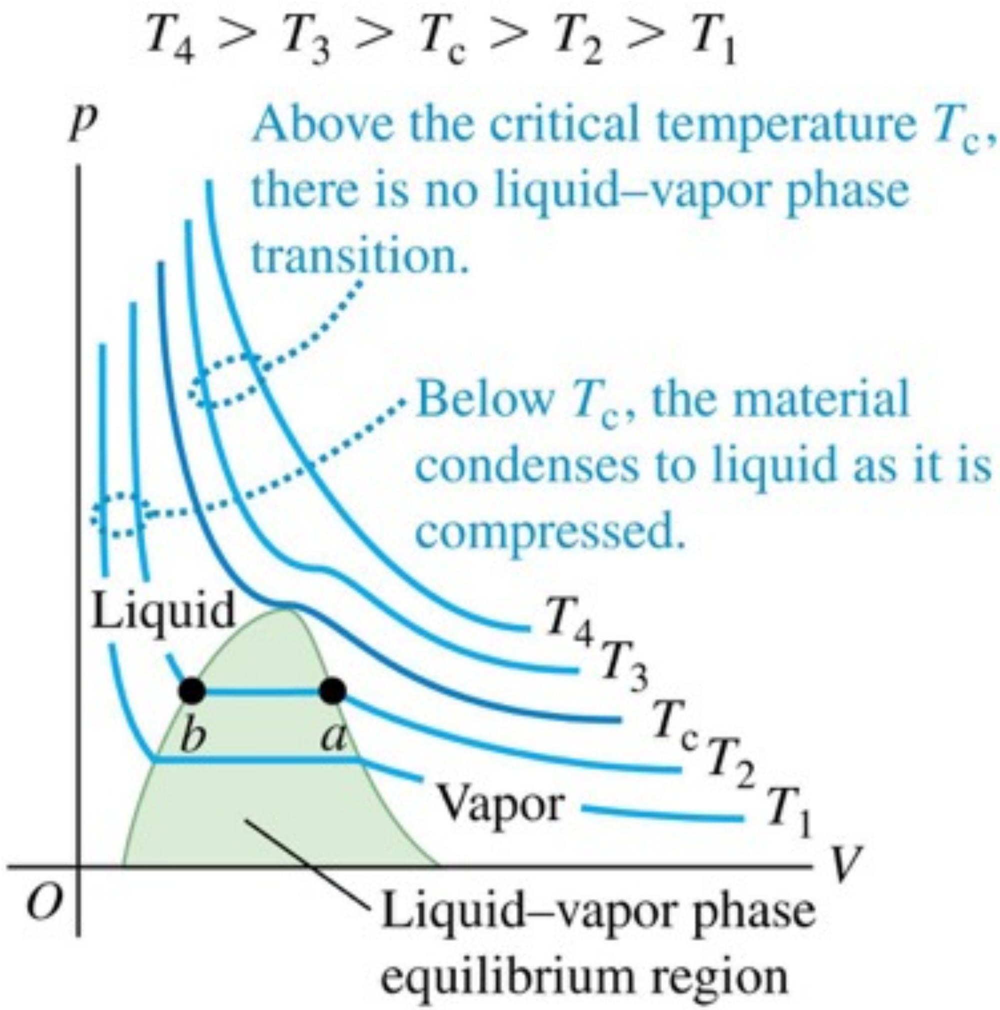
C. state #3

D. Two of these are tied for highest temperature.

E. All three of these are at the same temperature.

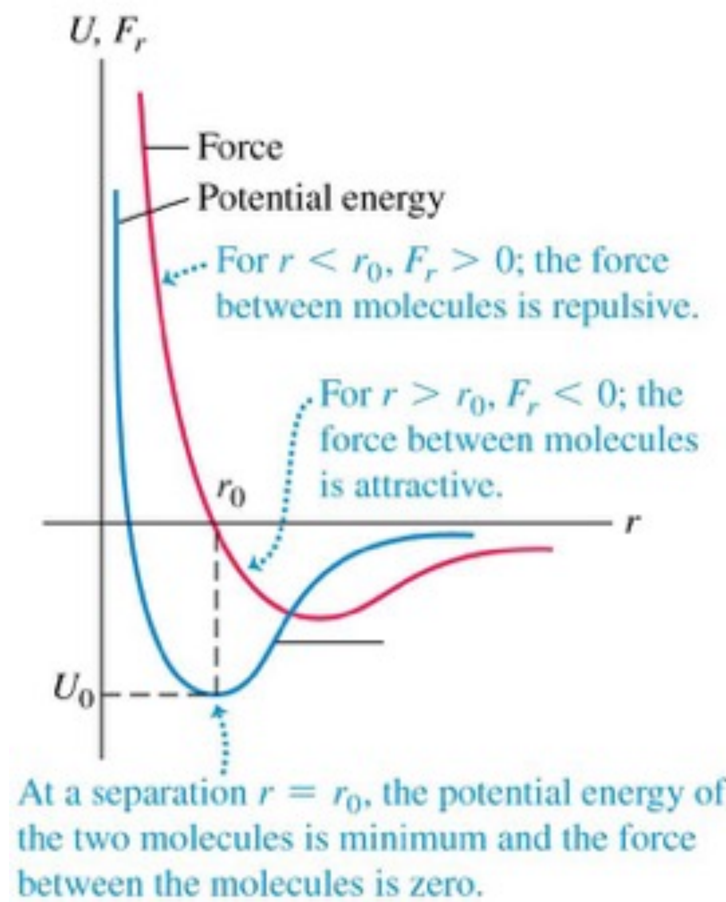
pV-diagrams

- A *pV*-diagram for a nonideal gas shows isotherms for temperatures above and below the critical temperature T_c.
- At still lower temperatures the material might undergo phase transitions from liquid to solid or from gas to solid.



Molecular properties of matter

- Figure 18.8 at the right shows how the force between molecules and their interaction potential energy depend on their separation *r*.
- Molecules in solids are essentially fixed in place, while those in liquids and gases have much more freedom to move.



Moles and Avogadro's number

- One *mole* of a substance contains as many elementary entities (atoms or molecules) as there are atoms in 0.012 kg of carbon-12.
- One mole of a substance contains *Avogadro's number* N_A of molecules.
- $N_A = 6.022 \times 10^{23}$ molecules/mol
- The **molar mass** ***M*** is the mass of one mole.

Molar mass of a substance → $M = N_A m$ ← Avogadro's number (N_A); Mass of a molecule of substance (m)

$$M = N_A m$$

- When the molecule consists of a single atom, the term **atomic mass** is often used instead of molar mass.