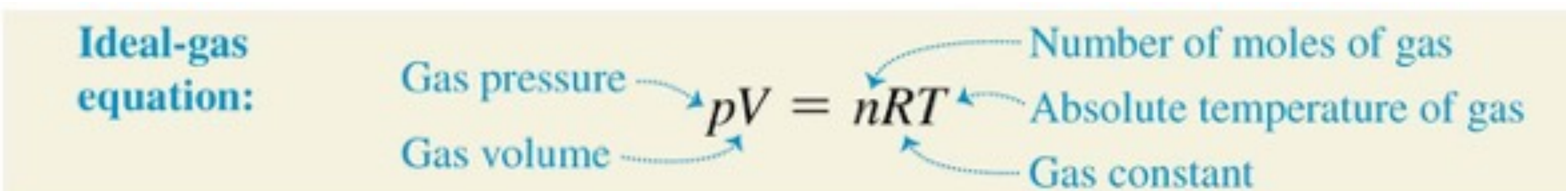
Lecture 4

PHYC 161 Fall 2016

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 $m_{\text{total}} = nM$.

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** $\boldsymbol{M}$ is the mass of one mole.

$$M = N_A m$$

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

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

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

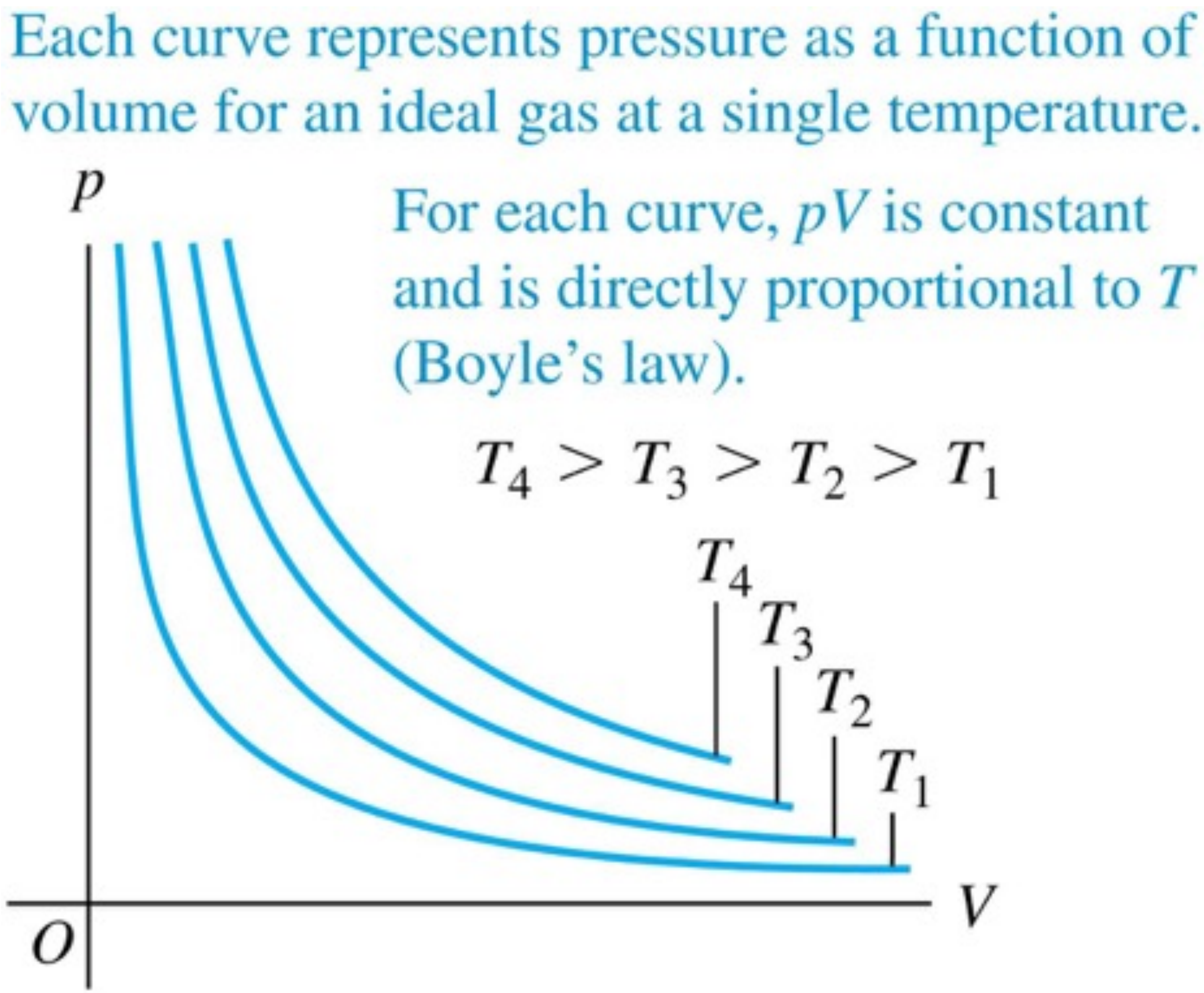
D. –123°C

E. –198°C

- $pV = nRT$

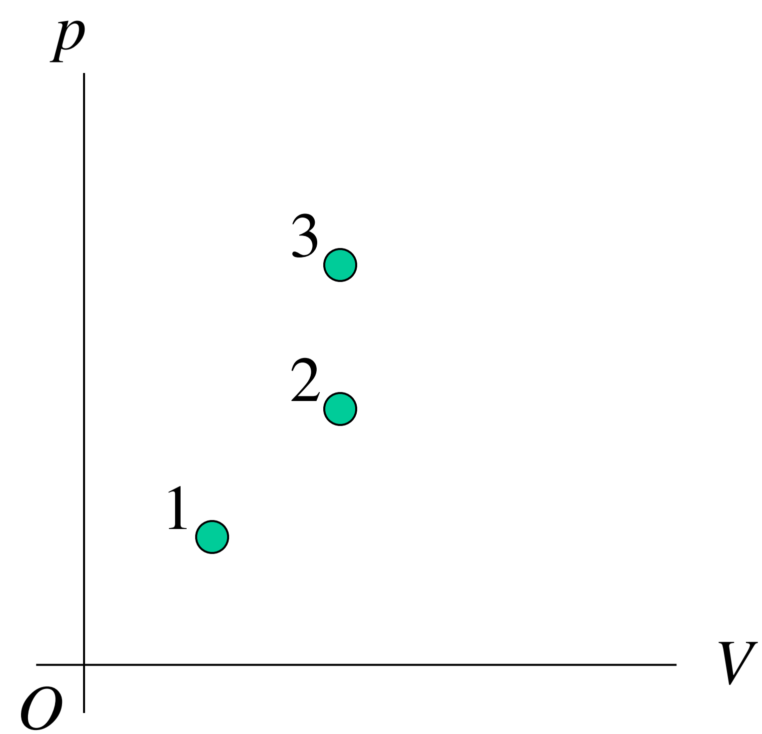
pV-diagrams

- 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

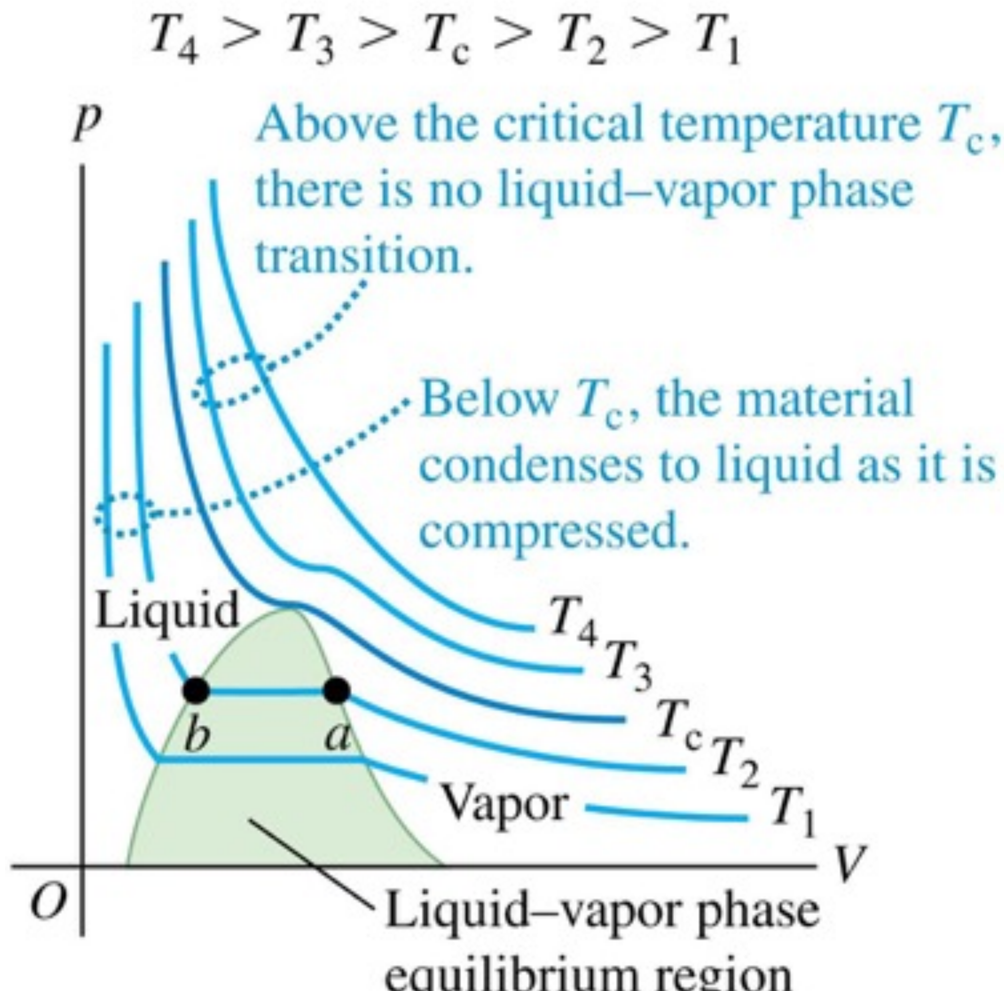
C. state #3

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.



Phases of matter

- For an ideal gas we ignore the interactions between molecules.
- But those interactions are what makes matter condense into the liquid and solid phases under some conditions.
- Each phase is stable in only certain ranges of temperature and pressure.
- A transition from one phase to another ordinarily requires **phase equilibrium** between the two phases, and for a given pressure this occurs at only one specific temperature.
- We can represent these conditions on a graph with axes p and T, called a **phase diagram**. (See next slide.)
- Each point on the diagram represents a pair of values of p and T.

A typical *pT* phase diagram