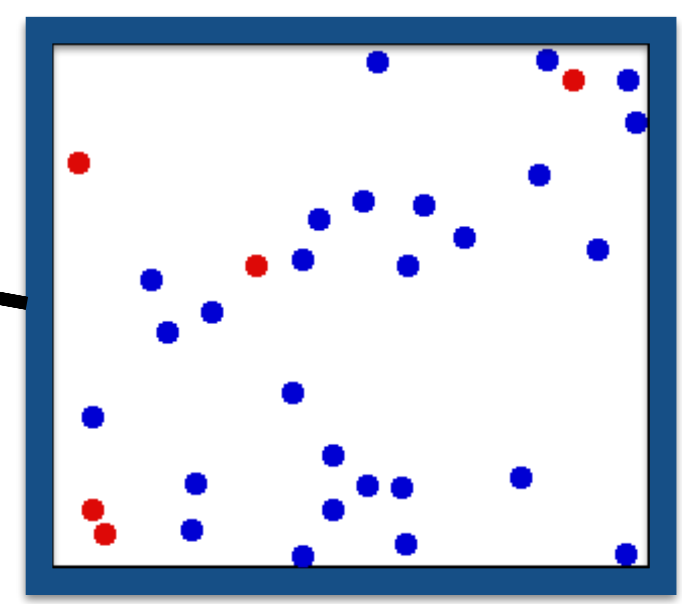
Microscopic Definition of Temperature

Consider a box of gas

The temperature of the gas is proportional to the translational kinetic energy of the gas in the box.

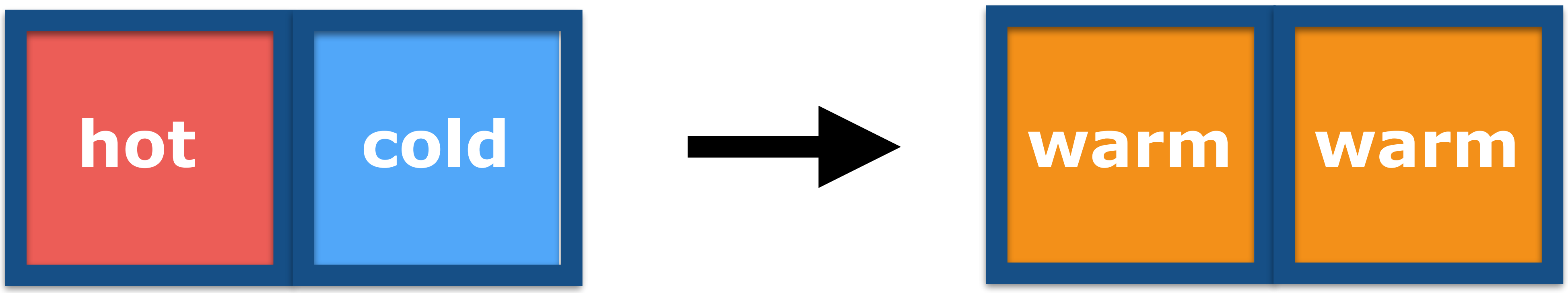
The gas can store other forms of energy, but they don't contribute to the temperature.

$$T = \frac{2}{3k_{\mathrm{B}}}\epsilon_{\mathrm{avg}}$$



translational kinetic energy

Macroscopic Definition of Temperature



cools heats

in thermal equilibrium (nothing changes)

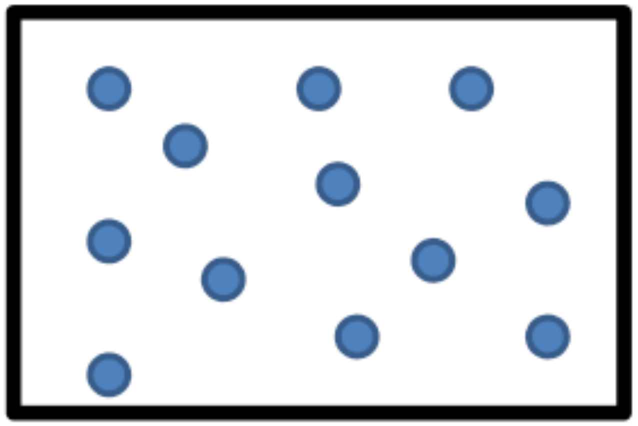
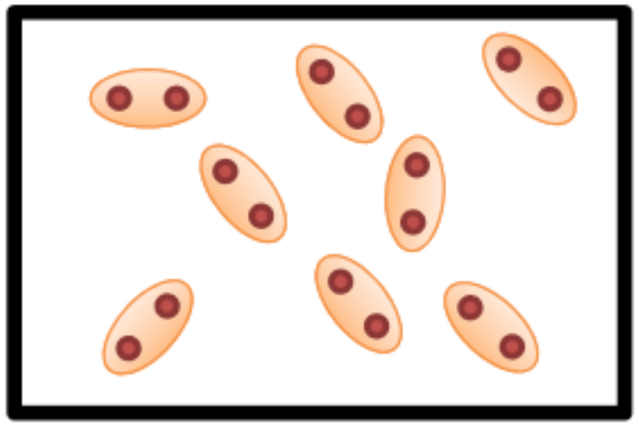
Consider three boxes A, B, and C.

If A and B are in thermal equilibrium and B and C are in thermal equilibrium, then A and C are in thermal equilibrium.

- Zeroth Law of Thermodynamics

We can define temperature to be *the same* for any two systems in thermal equilibrium.
The zeroth law allows us to build thermometers in a consistent way.

What other ways can energy be stored in a gas?

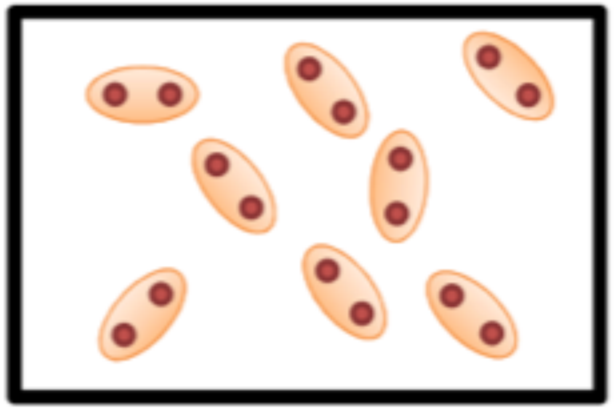
 

1 mole of helium and 1 mole of molecular hydrogen in identical containers are each heated from 300K to 400K. Compared to the amount of energy required to heat the helium, the amount of energy required to heat the hydrogen is

A) significantly larger
B) significantly smaller
C) approximately the same

In one case the energy all goes into translational kinetic energy, but for hydrogen the energy gets split between all the different types of energy.

Because the temperature increase is the same, the kinetic energy increase is the same, which means that

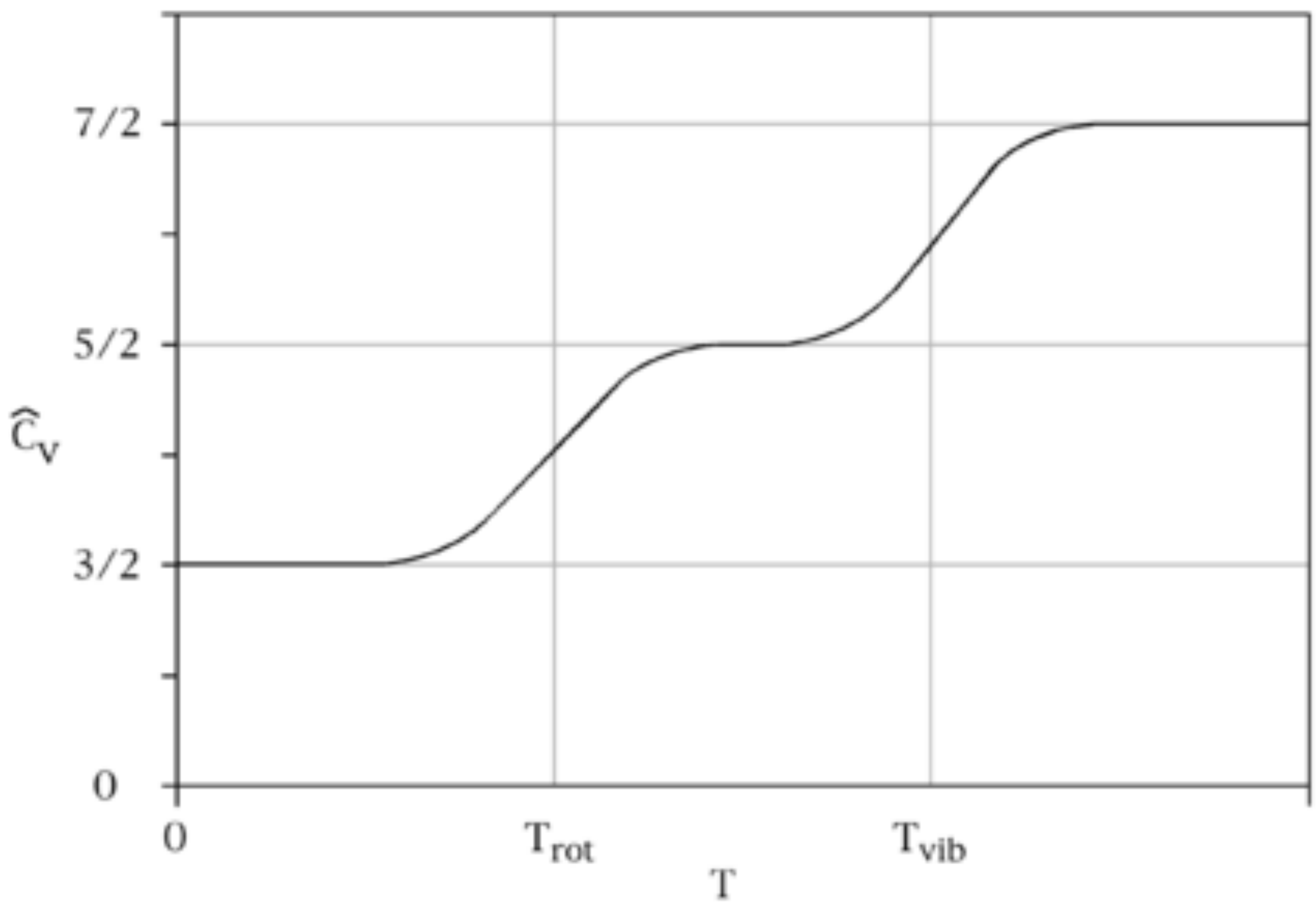


What is the C_V of a diatomic gas?

A) 3/2R
B) 2R
C) 5/2R
D) 3R
E) 7/2R

But we have 7 degrees of freedom - 3 translational, 2 vibrational, 2 rotational! Why isn't that what we measure? It turns out that these degrees of freedom aren't always "active".

Equipartition Theorem



Some degrees of freedom are “frozen out” due to quantum effects. The spacing between the energy levels is too high to be excited at low temperatures.

Simple Thermodynamic Processes

$$PV = nRT \qquad \Delta E = Q + W$$

Simplest processes involve holding one of the above variables constant.

1) Isochoric - constant V

2) Isobaric - constant P

3) Isothermal - constant T

4) Adiabatic - ?

Extra

A candle heats a box of gas. Which is true about the gas?

A) T constant
B) V constant
C) P constant
D) More than one is constant
E) Can’t decide

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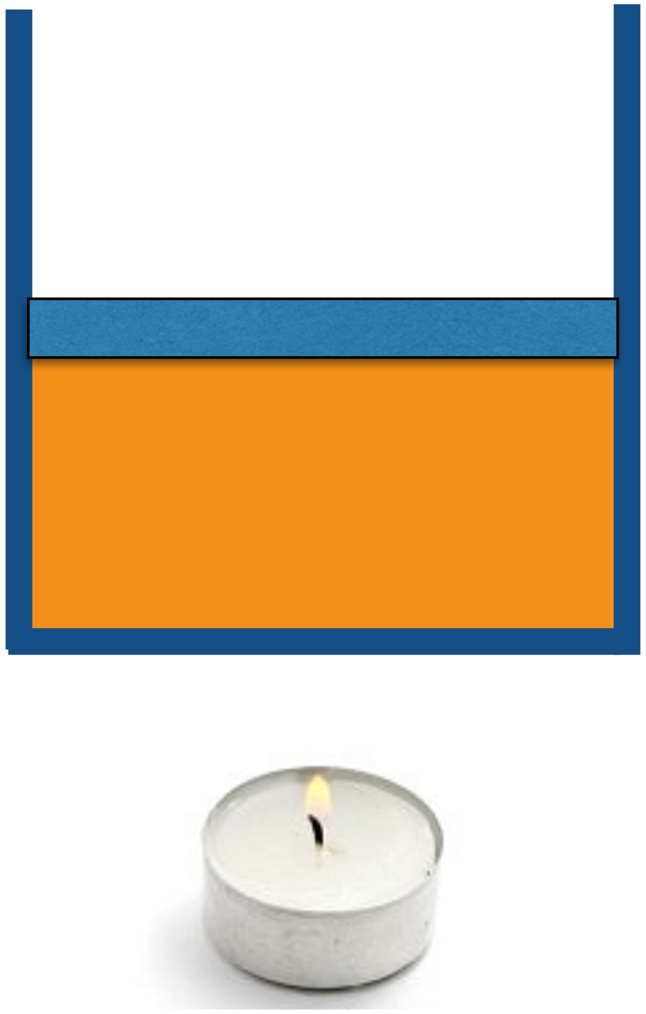

A candle heats a piston with some gas in it. The piston can move up and down and has some mass *m*. Which is true about the gas?

A) T constant
B) V constant
C) P constant
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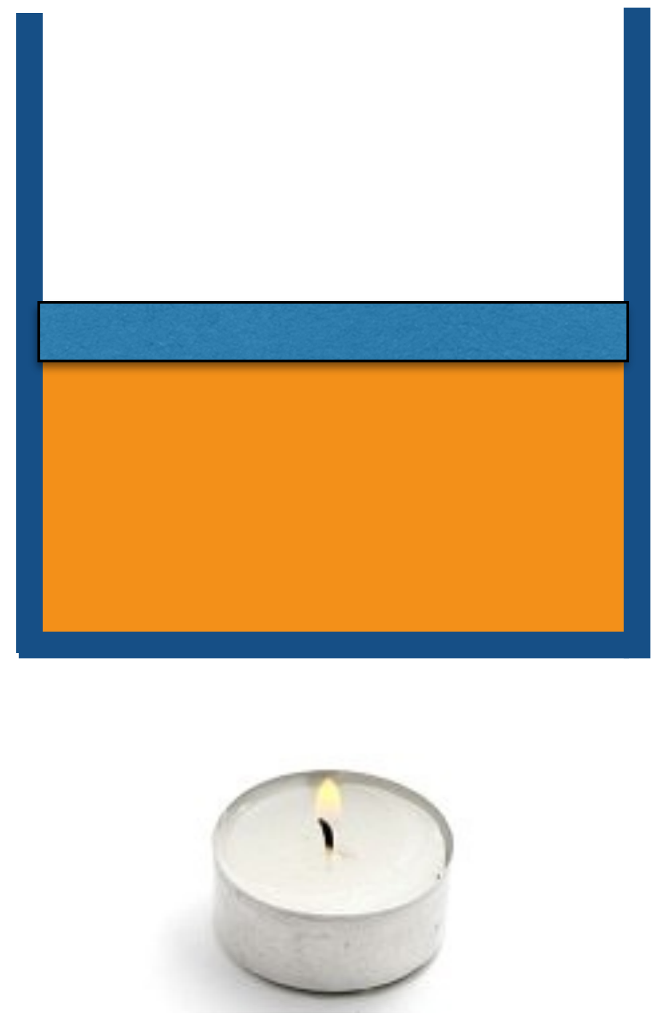

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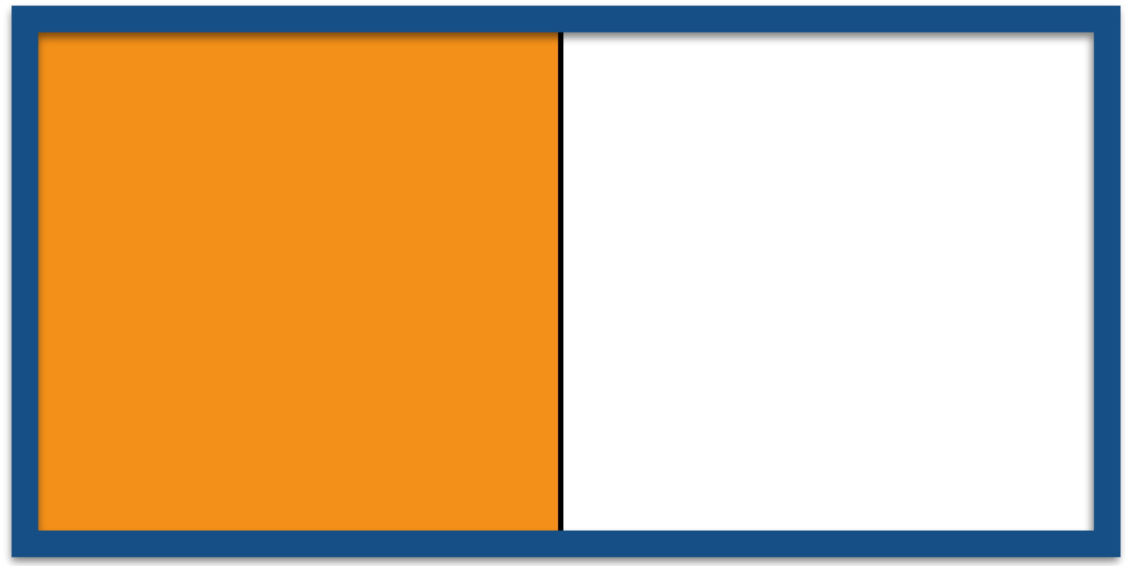
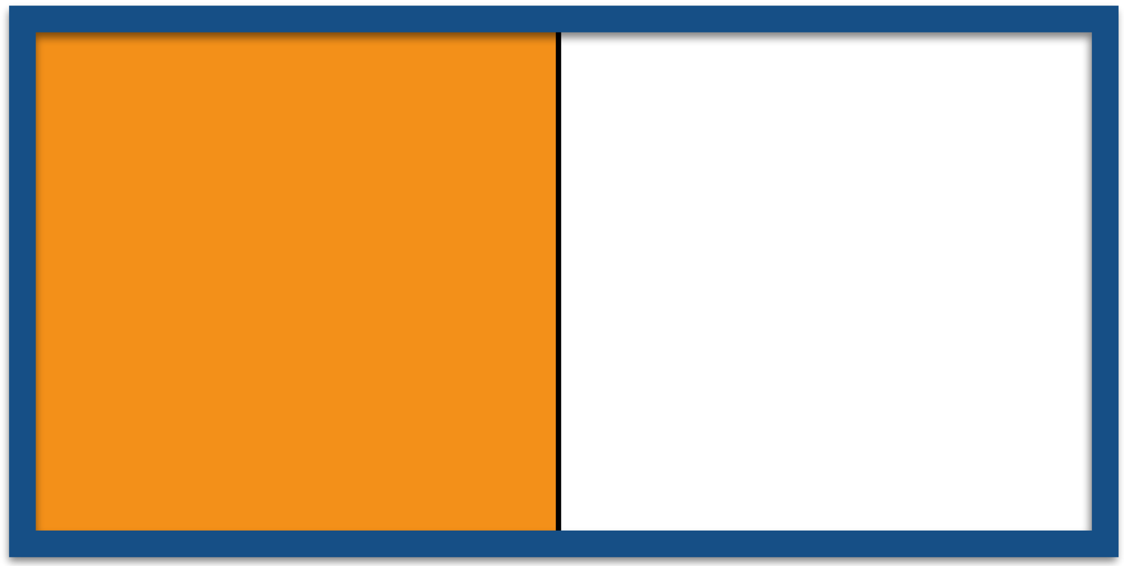


A container with a partition in the middle is filled with gas on one side. The partition is quickly removed. Which is true about the gas?

A) T constant
B) V constant
C) P constant
D) More than one is constant
E) Can’t decide



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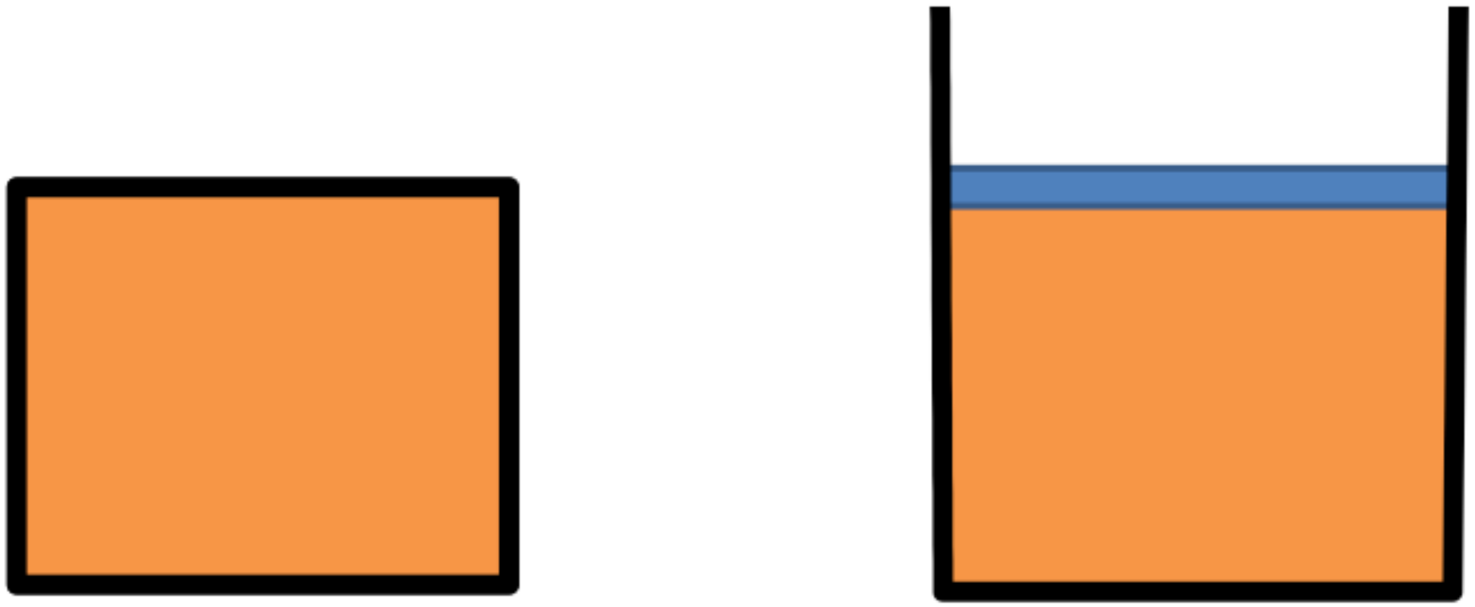
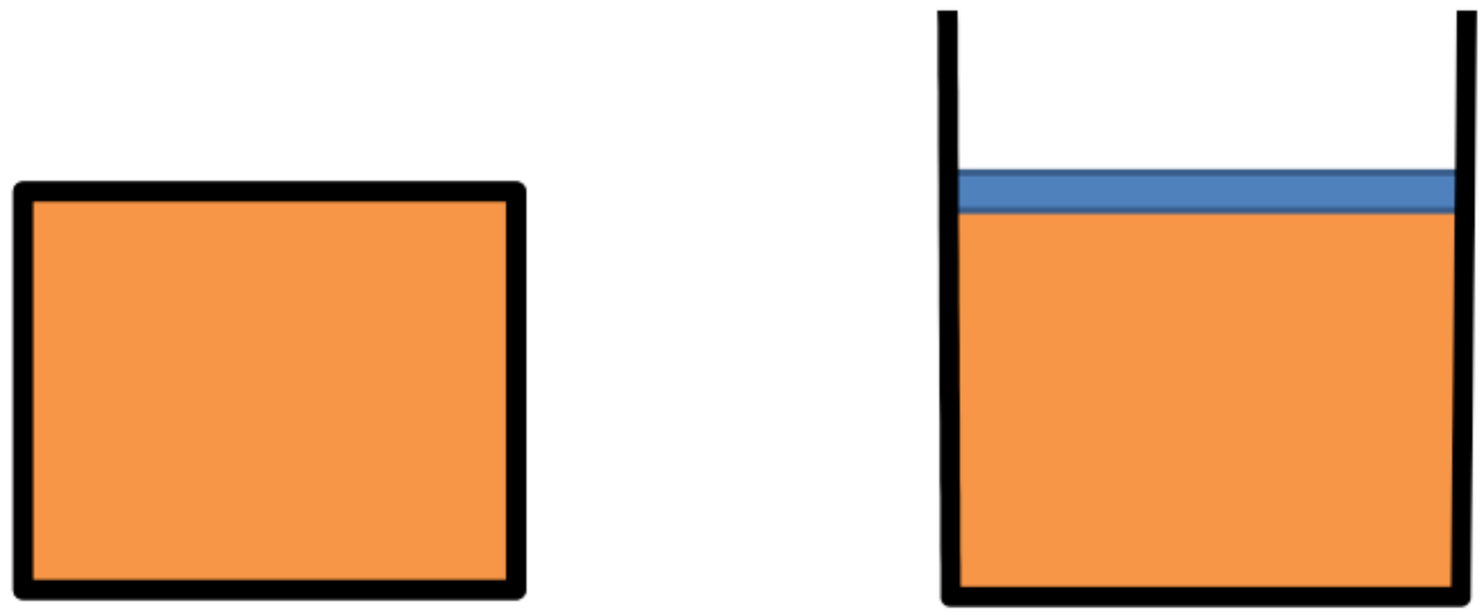


Two containers each contain one mole of neon at 350K. The containers are heated by a flame to 400K, one at constant volume and the other at constant pressure. Compared to the amount of heat required to heat the gas at constant volume, the amount of heat to heat the gas at constant pressure is

A) Larger
B) Smaller
C) The same



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B) Smaller
C) The same

The ideal gas law implies that at constant pressure, the volume increases proportional to temperature. So when we add heat to the gas, some of the energy goes into changing the energy of the case and some goes into doing work on the piston. Thus we need to add more heat than the constant volume case to achieve the same increase in gas energy (which is implied by an equal increase in temperature).

Helium gas in a cylinder is compressed horizontally while the cylinder is held at constant temperature. In the ideal gas approximation, we can say that

A) The total energy of the gas remains the same
B) The total energy of the gas increases
C) The total energy of the gas decreases

Extra: what would the answer be for real helium?

Helium gas in a cylinder is compressed horizontally while the cylinder is held at constant temperature. We can say that

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Constant temperature means that the average kinetic energy per atom stays the same. The number of atoms stays the same, so the total kinetic energy stays the same.

The gravitational potential energy of the atoms doesn't change.

For an ideal gas, there is no potential energy associated with interactions between the atoms.

So the total energy is just the kinetic energy, which stays constant.

Helium gas is placed in a well-insulated cylinder and compressed. We can say that

A) The temperature of the gas remains the same
B) The temperature of the gas increases
C) The temperature of the gas decreases

Extra: For the quantities ΔT, ΔP, ΔV, ΔE, W, and Q, which ones are positive, which are negative, and which are zero?

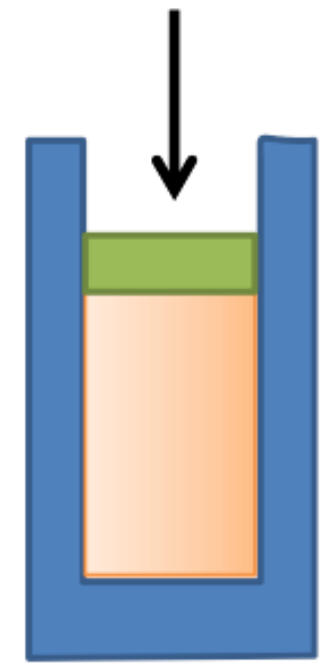
Helium gas is placed in a well-insulated cylinder and compressed. We can say that

A) The temperature of the gas remains the same
B) The temperature of the gas increases
C) The temperature of the gas decreases

Here, $Q=0$, so we have $\Delta E = W$, which is positive for compression.

Also, $\Delta E = n\, c\, \Delta T$, so temperature will increase.

Gas at temperature **T** and pressure **p** is placed in a well-insulated cylinder of cross-sectional area **A** and height **h**. Someone presses down on a piston with a constant force **F**, compressing the gas a distance d before the piston stops. If the molar specific heat of the gas is $C_V = 3R$ find the change in temperature of the gas.



Answer in terms of T, P, F, A, and h.

Extra: by how much could we heat up air by having a person press on the piston in the cylinder at the front of the room?