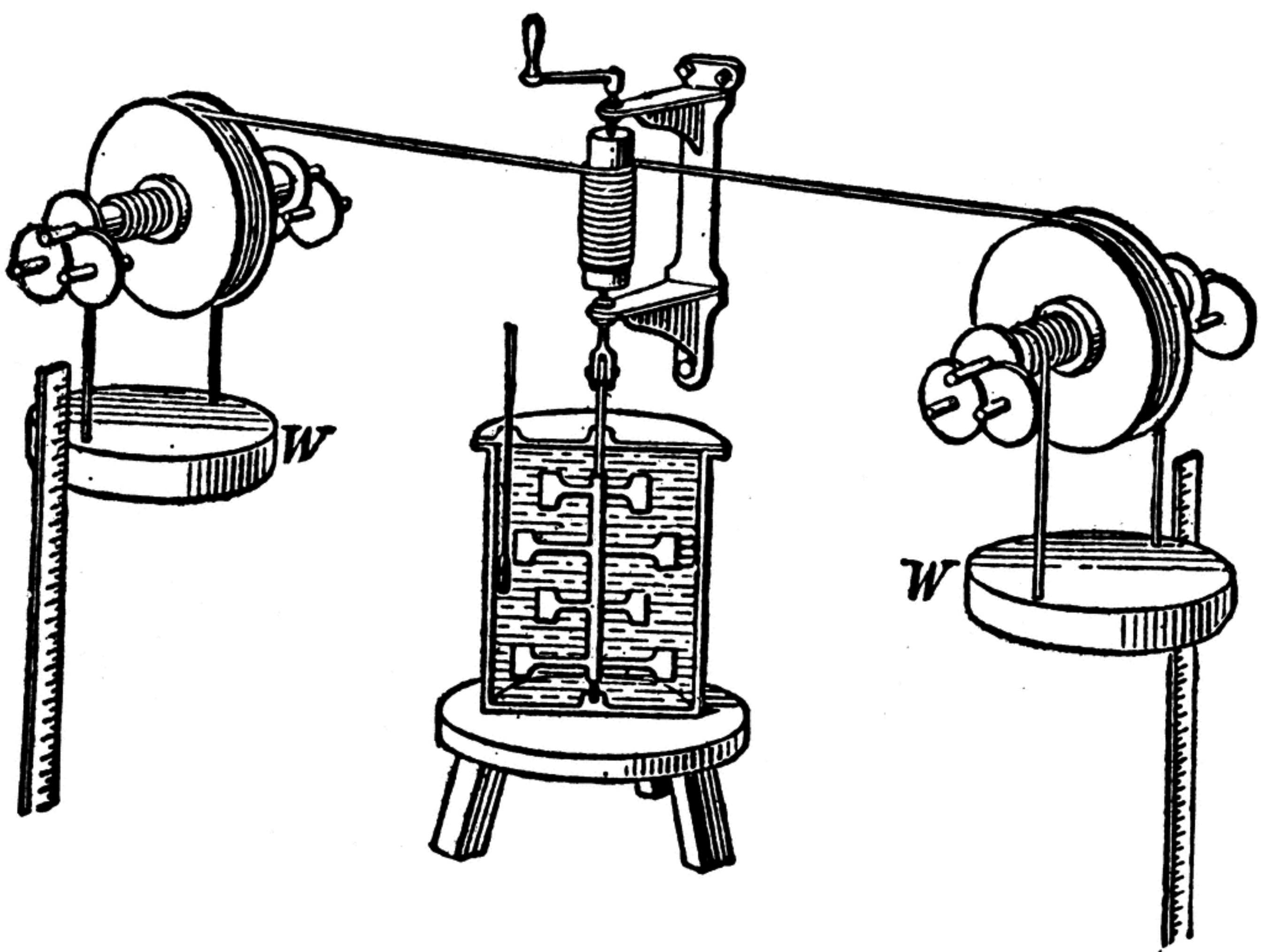
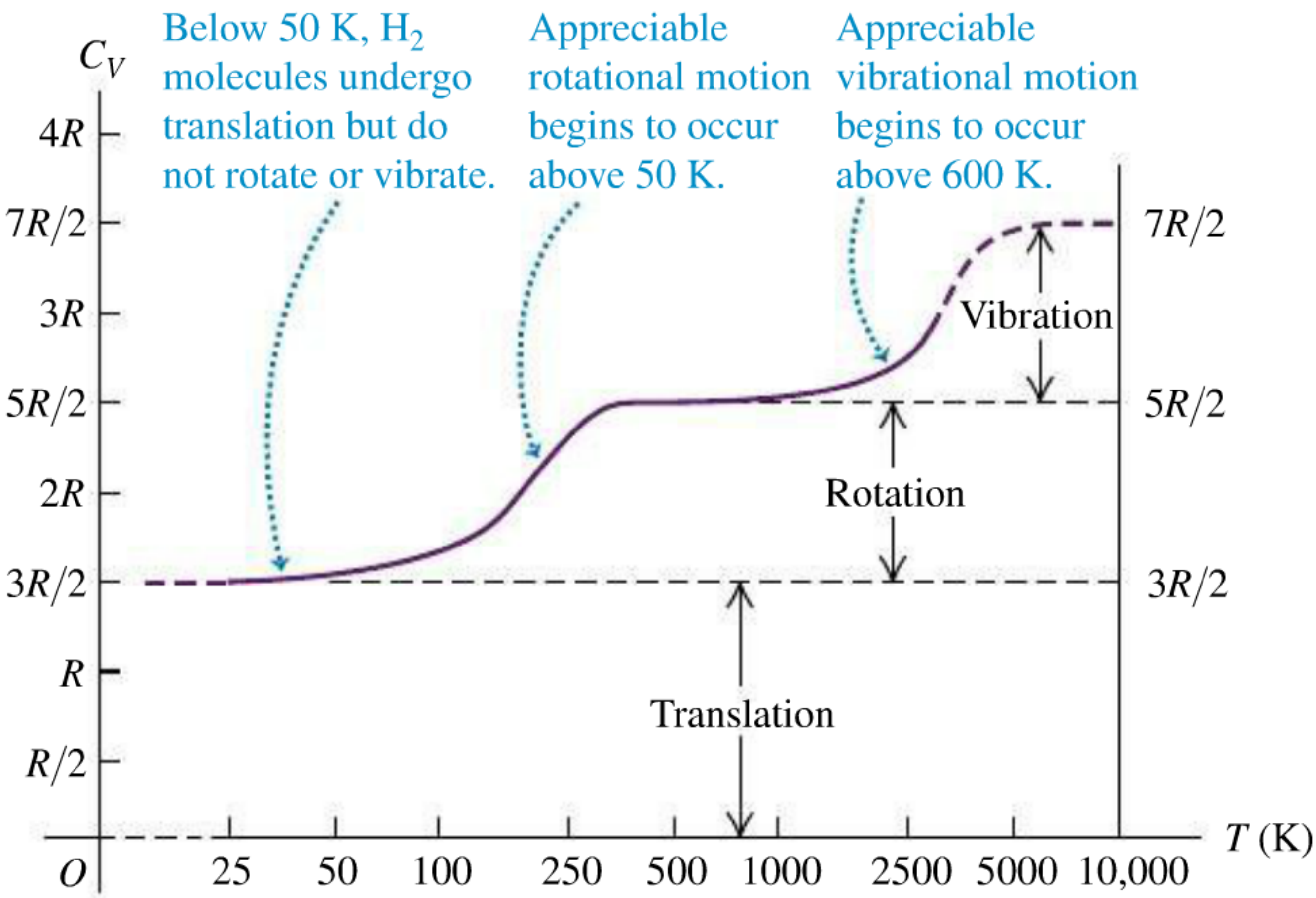
Work and Heat



Molar Heat Capacity of a Diatomic Gas



A fixed amount of gas is compressed. What happens to the temperature?

1. The gas gets hotter
2. The gas gets colder
3. The temperature stays the same
4. More information is needed

ANS: **4**—More information is needed

You know that work is done on the gas, or equivalently that the gas does negative work. However, you have no idea how the gas is compressed. For example, you don't know how much heat is added to or taken from the gas. Without this information, there is no way to know what happens to the thermal energy, U, and therefore the temperature of the gas. If the gas is compressed adiabatically, the temperature will increase. If the gas is compressed isothermally, the temperature will not change. If the gas is compressed isobarically, the temperature will decrease.

You enclose an ideal gas in a container made of thermally conducting walls with a movable piston at the top. The container rests in a large swimming pool. You slowly push down on the piston, decreasing the volume in the container, and finally hold the piston in place.

Describe what happens to the temperature of the gas.

1. It increases.
2. It stays the same.
3. It decreases.
4. Not enough information.

ANS: **2**—The temperature stays the same.

In this case, the process is isothermal. Because the gas is compressed slowly, i.e. work is done more slowly than it takes for heat transfer through the walls of the container, the gas will stay in thermal equilibrium with the pool throughout the process.

It is also worth pointing out that the thermal energy of the gas, U, is constant in an isothermal process. Therefore, as you add energy to the gas in the form of work, you must lose energy from the gas in the form of heat being added to the surroundings. This means that you will actually heat up the pool by a very small amount. However, a pool is very large and acts as a *thermal reservoir*. The temperature will not increase by a measurable amount, so we really can say that the process is isothermal.

You enclose an ideal gas in a container made of thermally conducting walls with a movable piston at the top. The container rests in a large swimming pool. You slowly push down on the piston, decreasing the volume in the container, and finally hold the piston in place.

Describe what happens to the pressure of the gas.

1. It increases.
2. It stays the same.
3. It decreases.
4. Not enough information.

ANS: **1**—The pressure increases

In an isothermal process the pressure is inversely proportional to the volume: $P = (nRT)/V$ (Boyle's law). Therefore, as the volume decreases the pressure will increase in proportion.

You enclose an ideal gas in a container made of thermally conducting walls with a movable piston at the top. The container sits on stand over a Bunsen burner. The piston is free to move up and down. You slowly heat the container.

Describe what happens to the pressure of the gas.

1. It increases.
2. It stays the same.
3. It decreases.
4. Not enough information.

ANS: **2**—The pressure stays the same.
The pressure of the gas is fixed by the weight of the piston and air pressure. Regardless of how heat is added to the gas, the pressure will be constant as long as the weight of the piston and air pressure is constant.

You enclose an ideal gas in a container made of thermally conducting walls with a moveable piston at the top. The container sits on stand over a Bunsen burner. The piston is free to move up and down. You slowly heat the container.

Describe what happens to the volume of the gas.

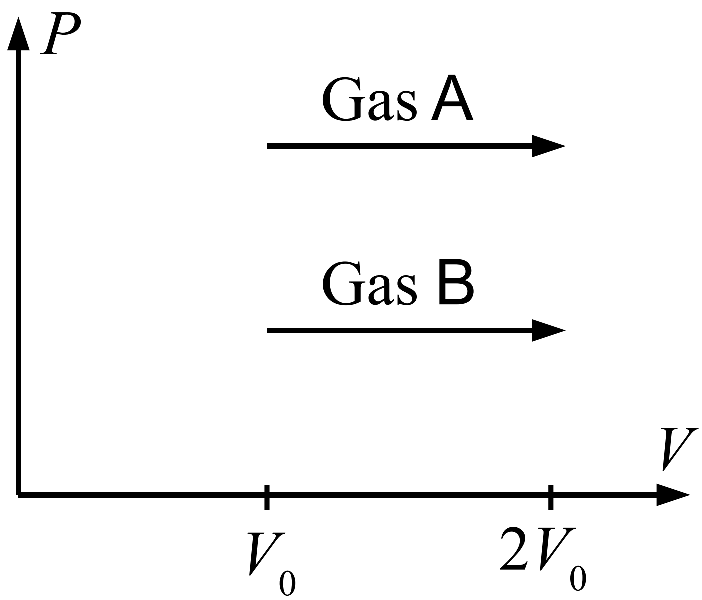
1. It increases.
2. It stays the same.
3. It decreases.
4. Not enough information.

ANS: **1**—The volume increases

In an isobaric process the volume of the gas is proportional to the temperature: $V = (nR/P)T$. As the Bunsen burner adds heat to the gas its temperature will increase and therefore its volume will increase.

Of course, as the temperature increases, the thermal energy of the gas will increase, as well. That means, while you are adding energy to the gas in the form of heat, and taking energy from the gas in the form of work done on its surroundings, you can conclude that the heat added is greater than the work done by the gas.

Two gases are confined in containers of identical volume, although gas A has a higher pressure than gas B. They are heated and allowed to expand until both volumes have doubled, while the pressures are kept constant. Which gas does more work?



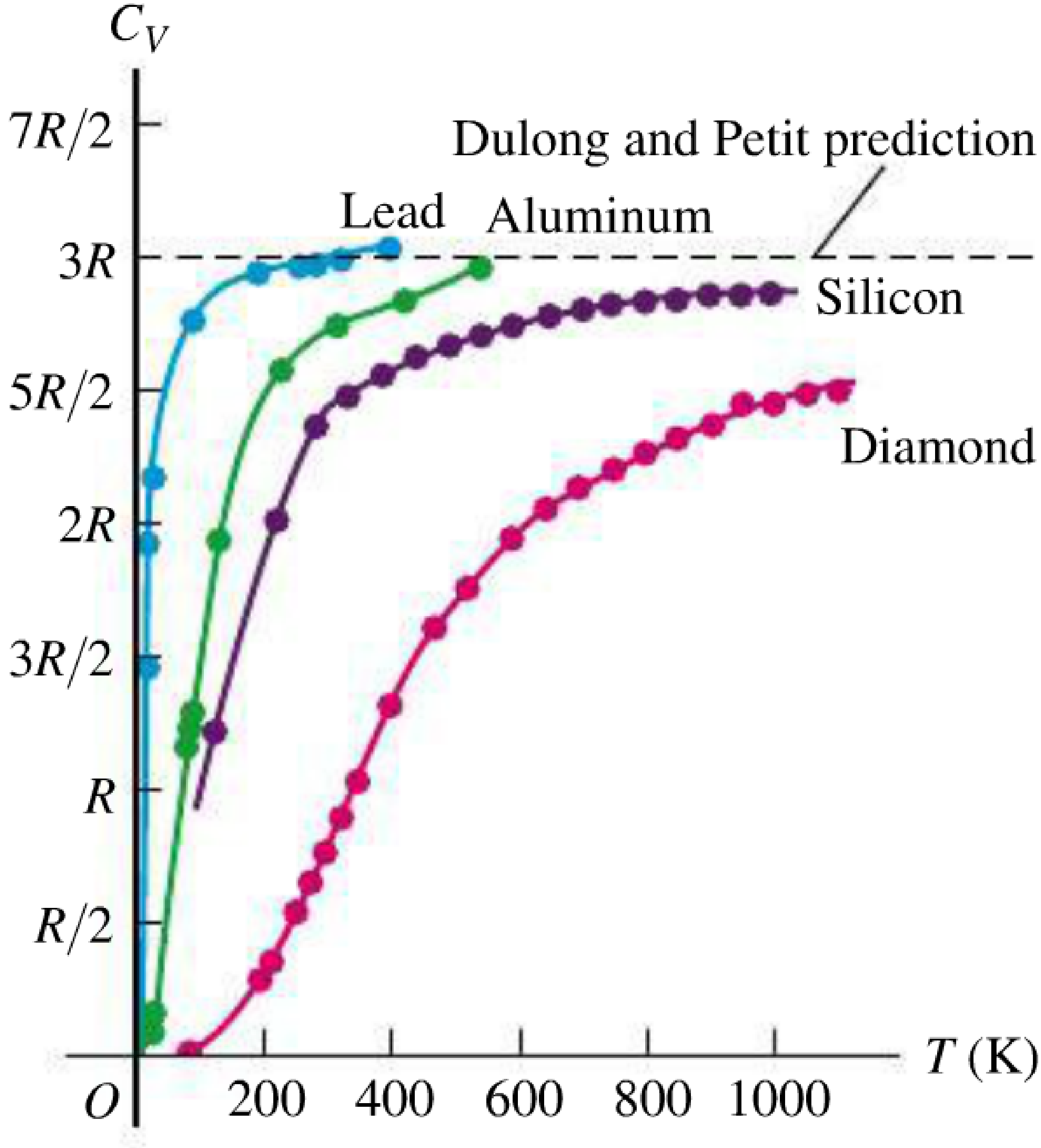
1. Gas A
2. Gas B
3. Same
4. Need more information

ANS: **1**—Gas A does more work.

Both gases expand isobarically (constant pressure). In such processes the work done by the gas is $W = P\Delta V$. Both gases have the same volume increase, but gas A has the greater pressure and therefore does the greater amount of work.

Another way to look at this is to recognize that the work done by a gas is the area under the curve representing the process on a *P*-*V* diagram (the integral of *P* with respect to *V*). It is clear from the diagram that there is more area under the line representing gas A than under the line representing gas B.

Molar Heat Capacity of a Solid



Warmup Question

You want to raise the temperature of a fixed amount of gas using the smallest amount of heat. Should you use a process that keeps the gas at constant volume or a process that keeps the gas at constant pressure?

ANS: You should keep the gas at constant volume, so the gas will not expand. This guarantees that no work is done, and all of the heat will be used to increase the internal energy and therefore the temperature. If you use a constant pressure process, the gas will expand and do work on its surroundings (negative work done on the gas). Only part of the heat you put into the gas will be used to increase the internal energy (and, in proportion, temperature). The rest will be used to expand the gas.

Warmup Question

Estimate the volume of ordinary air that must be compressed to fill your tires of your car to three times atmospheric pressure. Explain your reasoning.

ANS: You would need to compress a volume of air equal to three tire volumes. I would guess that the volume of a tire is approximately 10 liters, so you would need to start with 30 liters of air at 1 atmosphere of pressure, and then compress it to a volume of 10 liters to raise its pressure to 3 atmospheres.

Warmup Question

If you know a thermodynamic process is neither isobaric nor isothermal nor isovolumetric, then what kind of process must it be?

1. Isochoric
2. Adiabatic
3. Isolated
4. None of these - it could be anything

ANS: **4**—It could be anything.

A thermodynamic process could be any path that connects two points on a *PV* diagram. There are an infinite number of these paths. All of the listed choices in the question, and the first two answer choices, are specific therodynamic processes corresponding to specific paths.