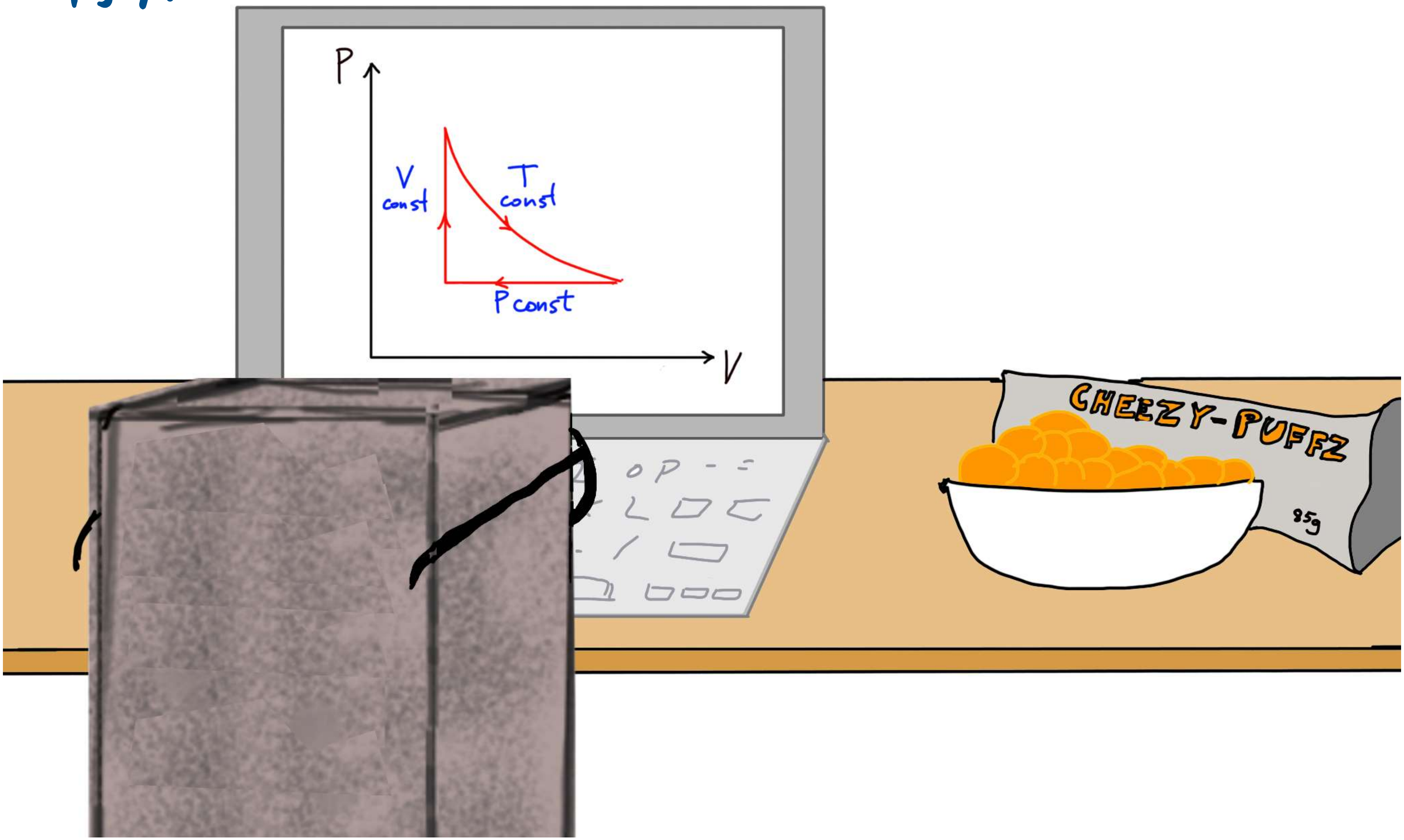
Office hours today:

- After class in Remo
- 4-5pm, 8-9pm in Zoom

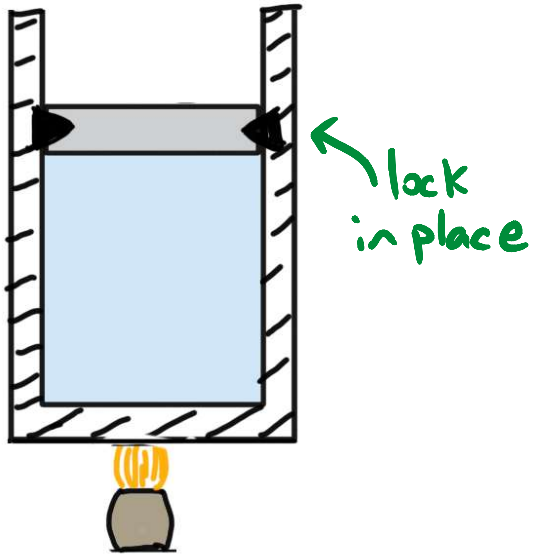
Learning goals:

- For isochoric, isobaric, isothermal, and adiabatic processes, to calculate final temperatures, pressures, and volumes given initial temperatures, pressures and volumes
- For isochoric, isobaric, isothermal, and adiabatic processes, to calculate work done, change in internal energy, and heat added during the process
- Describe qualitatively the difference between adiabatic and isothermal compression and distinguish the graphs of these processes on a PV diagram

Last time in Physics 157...



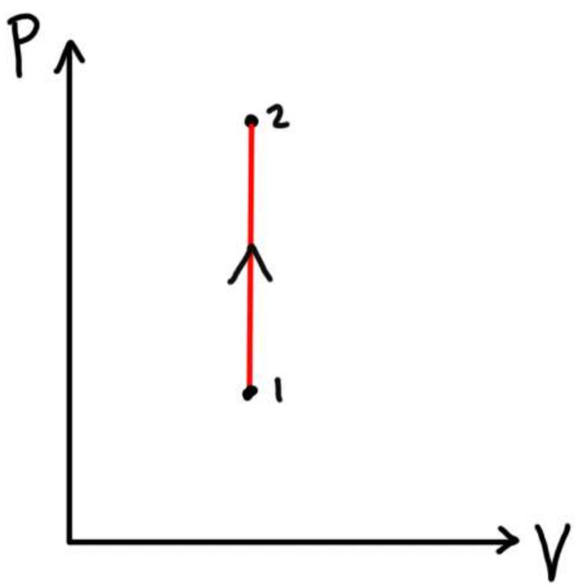
Constant Volume:



Ideal gas law $\Rightarrow$ $\dfrac{T_2}{T_1} = \dfrac{P_2}{P_1}$

$W = 0$ so

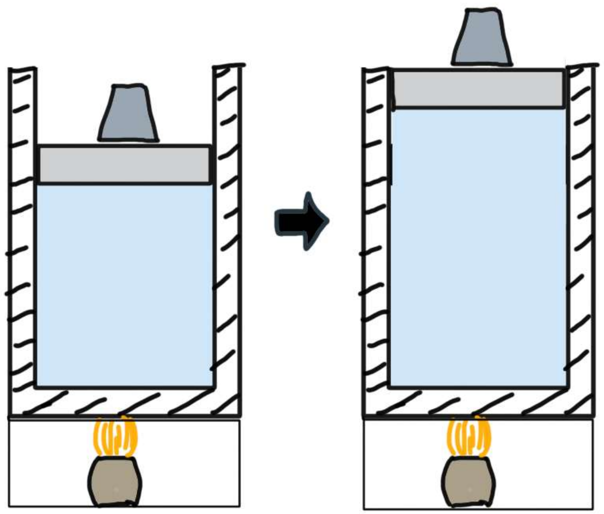
$Q = \Delta U = nC_v \Delta T$



"isochoric"

Constant Pressure

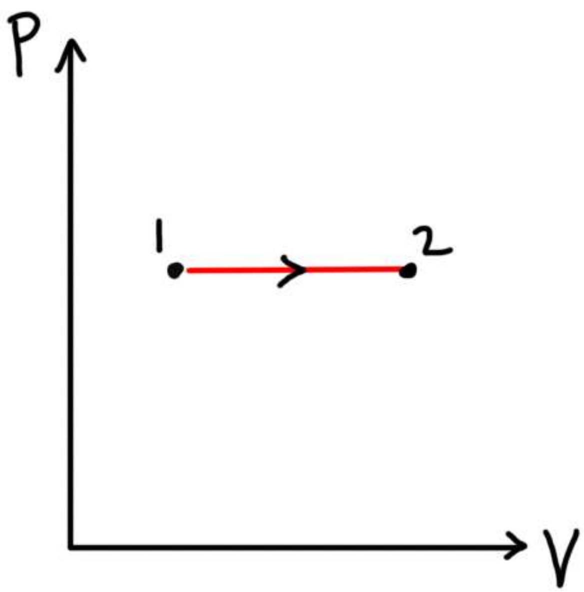
Ideal Gas Law $\Rightarrow \frac{T_2}{T_1} = \frac{V_2}{V_1}$



$$W = P\Delta V$$

$$Q = n C_p \Delta T$$

$C_v + R$

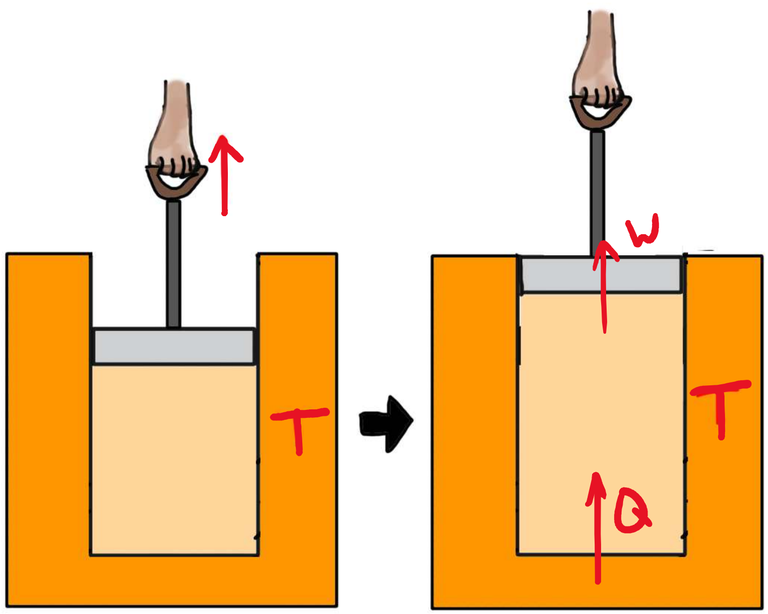


"isobaric"

CONSTANT TEMPERATURE

Ideal Gas Law $\Rightarrow PV = \text{const.}$

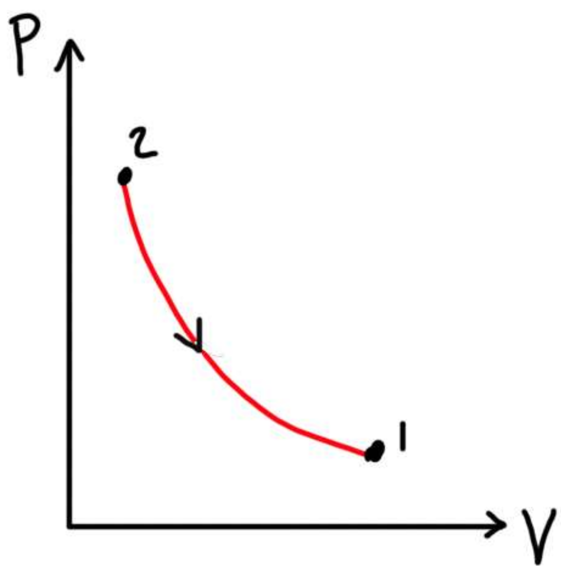
so $P \propto \dfrac{1}{V}$



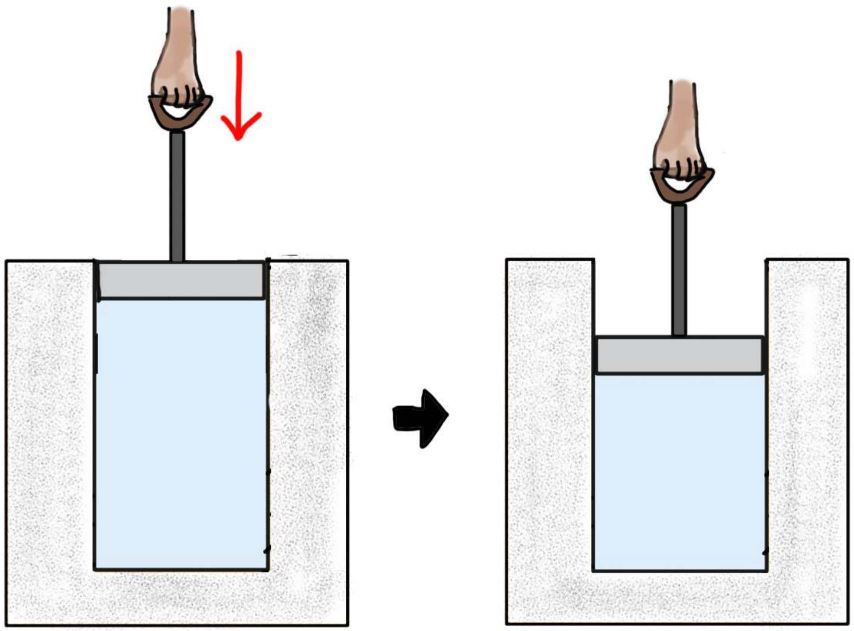
$$\Delta U = 0$$

$$Q = W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

$$\int_{V_i}^{V_f} P(V)\, dV$$



"isothermal"



Gas in a perfectly insulated cylinder is compressed. During this process, we can say that

A) Q is positive and $\Delta T = 0$.

B) $Q = 0$ and ΔT is positive.

C) $Q = 0$ and ΔT is negative.

D) $Q = 0$ and $\Delta T = 0$.

E) Q is positive and ΔT is positive.

$Q = 0$

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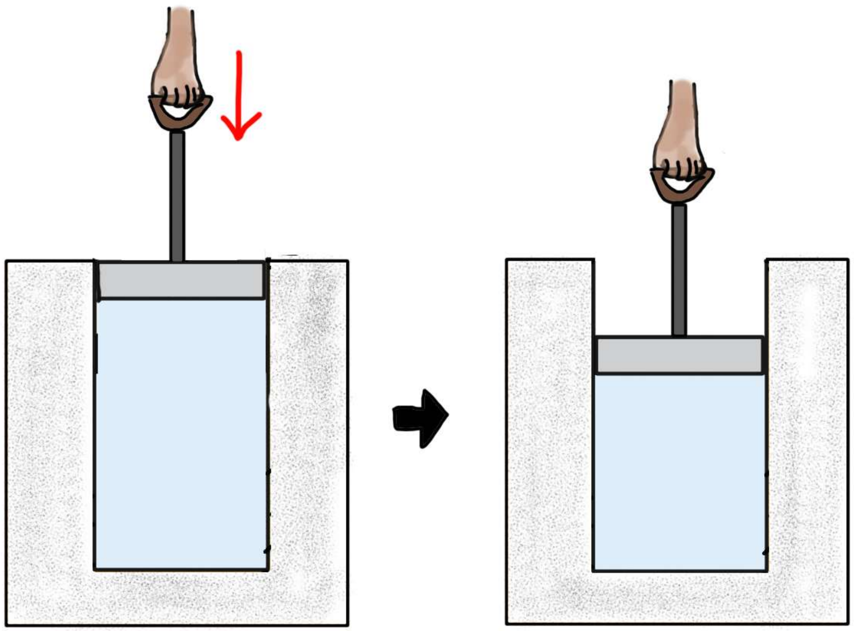


A) Q is positive and $\Delta T = 0$.

B) $Q = 0$ and ΔT is positive.

C) $Q = 0$ and ΔT is negative.

D) $Q = 0$ and $\Delta T = 0$.

E) Q is positive and ΔT is positive.

Have: $\Delta U = -W$

W -ve (compression)

so $\Delta U > 0$ $\Delta U = n C_v \Delta T$ so $\Delta T > 0$

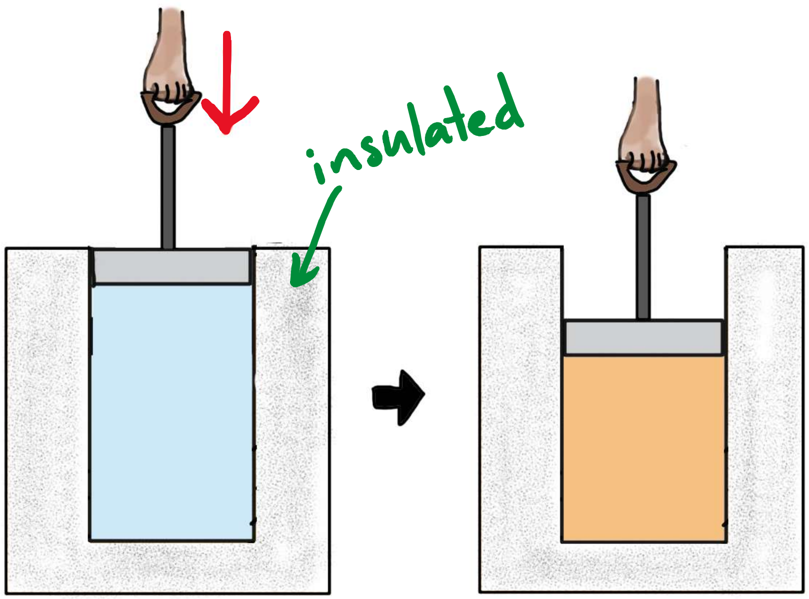
Intuitively: we are doing work & adding energy to gas, so $T \uparrow$

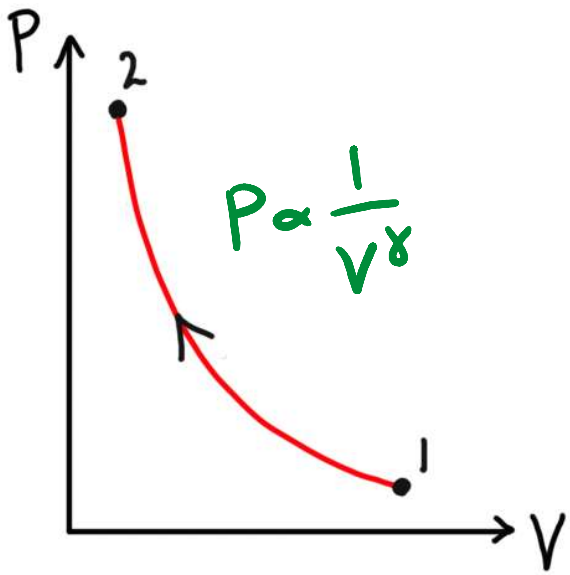
Adiabatic processes: $Q = 0$

2 cases: ① gas is well-insulated from environment.

② process happens very quickly, so not enough time for significant heat transfer

ADIABATIC: $Q = 0$





First Law: $\Delta U = -W$

compressed gas heats up!

$$nC_v \, \Delta T = -W$$

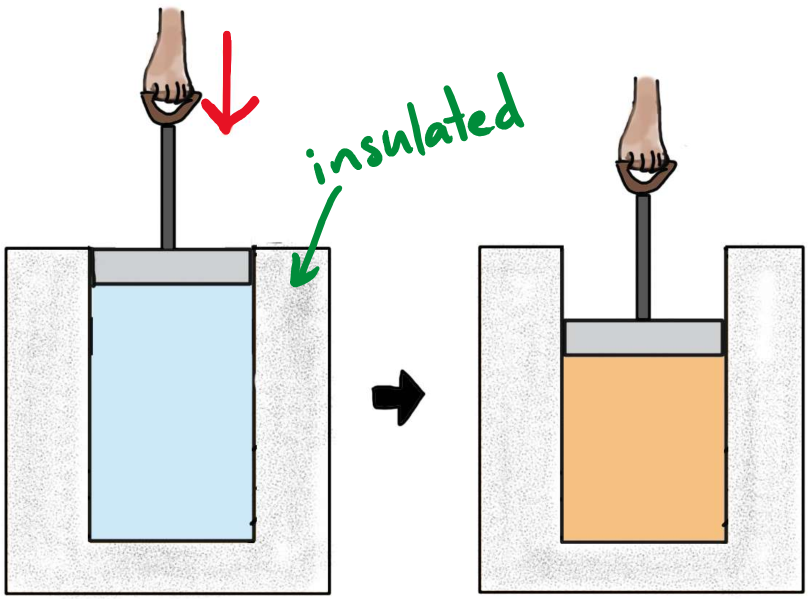
Ideal gas law: $\frac{PV}{T}$ constant.

Combining these, can show $PV^{\gamma} = \text{constant}$

see video derivation

$$\gamma = \frac{C_p}{C_v}$$

ADIABATIC: $Q = 0$ (insulated or very fast)



First Law: $\Delta U = -W$

compressed gas heats up!

$$nC_v \Delta T = -W$$

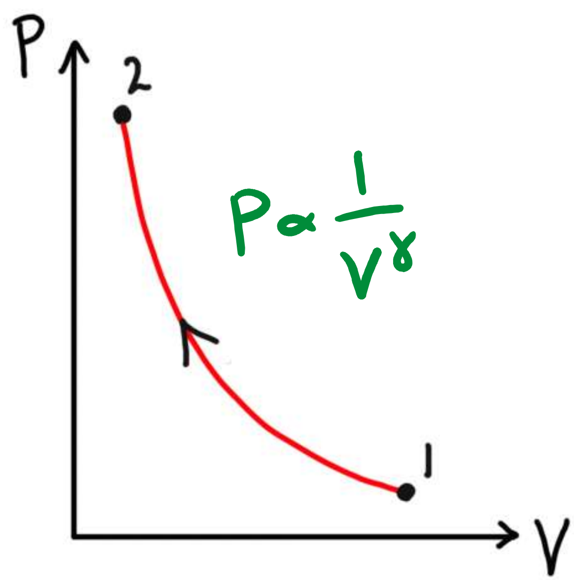
+ ideal gas law

$\frac{PV}{T} =$ constant

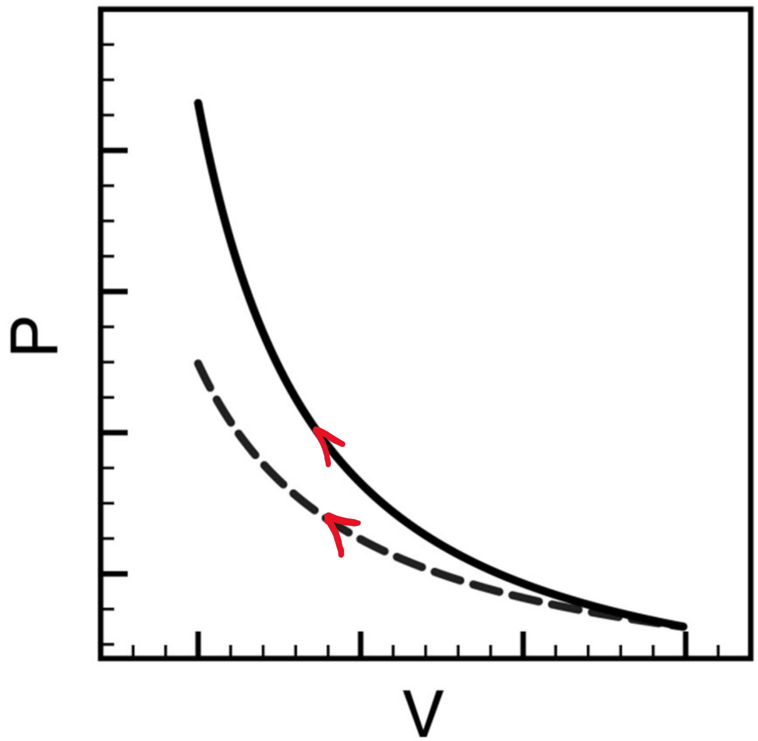
$$PV^{\gamma} = \text{constant}$$

$$TV^{\gamma-1} = \text{constant}$$

see 19.8 or video derivation



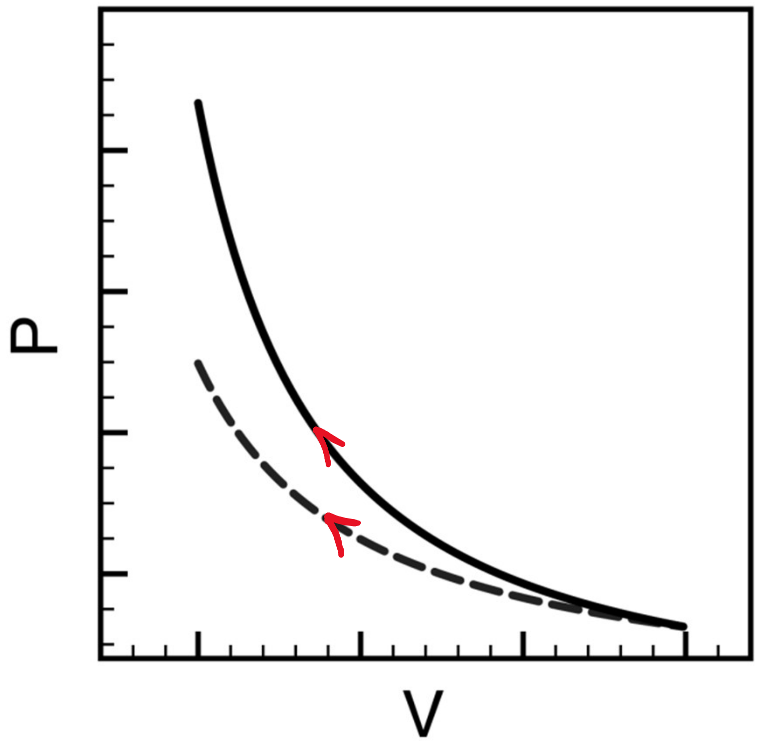
$$\gamma = \frac{C_p}{C_v}$$



In the two processes shown, gas is compressed adiabatically in one case and isothermally in the other. We can say that

A) The solid line represents the isothermal process
B) The solid line represents the adiabatic process
C) We don't have enough information to tell which process is which.

EXTRA: Can you give a conceptual explanation for your answer?



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Method 1:

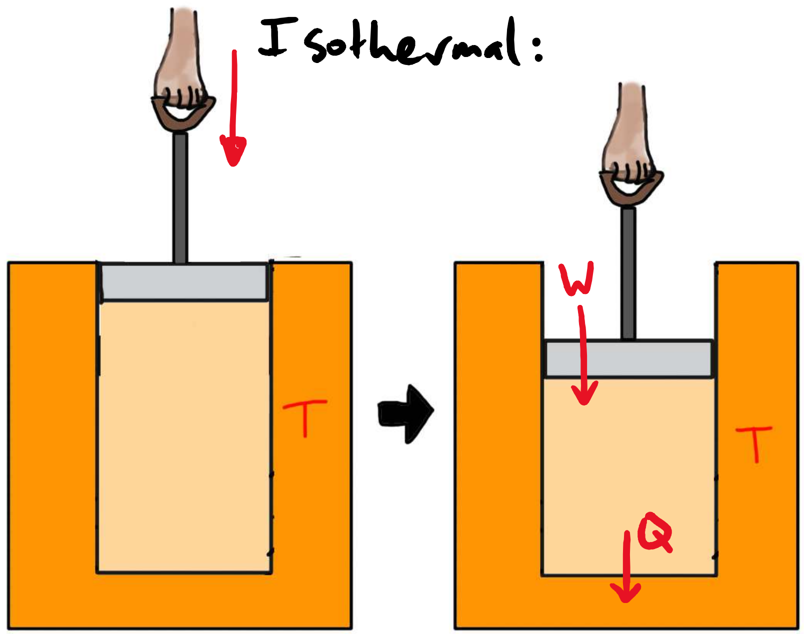
$P \propto \frac{1}{V}$ for isothermal

$P \propto \frac{1}{V^\gamma}$ for adiabatic $\gamma > 1$ so P increases more quickly as V decreases

EXTRA: Can you give a conceptual explanation for your answer?

conclusion: adiabatic is solid

Isothermal:



$\Delta U = 0$

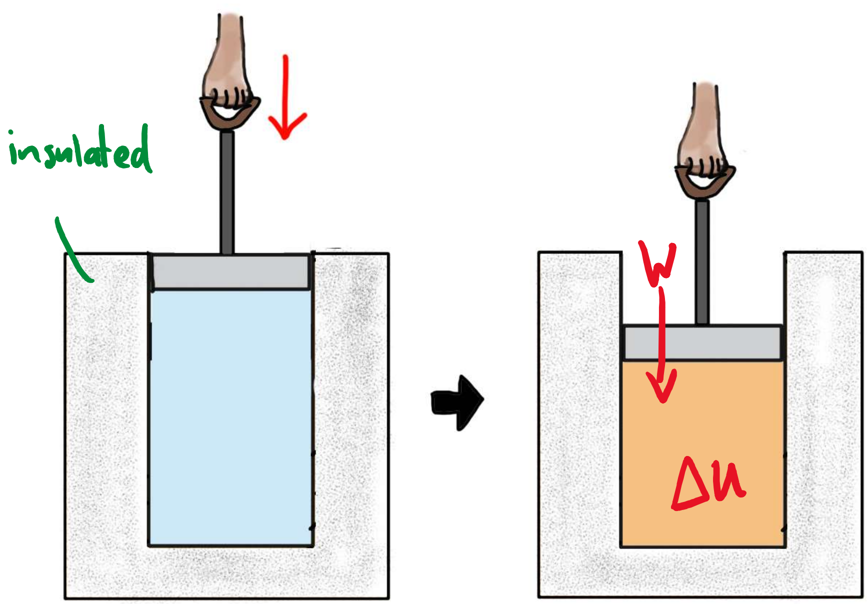
Method 2:

- same final volume
- higher T

higher final P for adiabatic

Answer is

B



$\Delta U > 0$ so $T \uparrow$

Adiabatic

Gas with C_V = 3 R, initially at room temperature, is compressed very rapidly in a cylinder. The **compression ratio** is 15.

a) Estimate the final temperature of the gas.

b) If the tube contains 0.0004 moles of gas, how much work was required to compress the gas?

Gas with $C_V = 3\ R$, initially at room temperature, is compressed very rapidly in a cylinder. The **compression ratio** is 15.

a) Estimate the final temperature of the gas.

The final temperature of the gas is

A) $293K \cdot (15)^{5/3}$
B) $293K \cdot (15)^{4/3}$
C) $293K \cdot (15)$
D) $293K \cdot (15)^{2/3}$
E) $293K \cdot (15)^{1/3}$

Gas with $C_V = 3$ R, initially at room temperature and atmospheric pressure, is compressed very rapidly in a cylinder. The **compression ratio** is 15.

a) **Estimate the final temperature of the gas.**

b) If the tube contains 0.0004 moles of gas, how much work was required to compress the gas?

$$\gamma = \frac{C_P}{C_V} = \frac{C_V + R}{C_V} = \frac{4R}{3R} = \frac{4}{3}$$

Have $TV^{\gamma-1}$ constant

$$T_2 V_2^{\gamma-1} = T_1 V_1^{\gamma-1}$$

$$T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma-1} = 293\text{K} \cdot (15)^{\frac{1}{3}}$$

$$= 723\text{K}$$

$\Rightarrow$ answer E

Demo!

https://youtu.be/9iXLeD5eV9g

https://youtu.be/e39qy5flzpU

Gas with $C_V = 3\,R$, initially at room temperature and atmospheric pressure, is compressed very rapidly in a cylinder. The **compression ratio** is 15.

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Have $Q = 0$ so:

$$\Delta U = -W_{gas} = W_{\text{done on gas}}$$

So work done equals $\Delta U = n C_v \Delta T$

$$= 0.0004 \cdot 3 \cdot 8.31 \cdot 430\,J$$

$$= 4.3\,J$$

What are you trying to calculate? n: use $PV = nRT$

T, V, or P: use $\frac{PV}{T} = \text{const}$

adiabatic: also have $TV^{\gamma-1} = \text{const}$

$PV^{\gamma} = \text{const}$

ΔU: have $\Delta U = nC_v \Delta T$ always

W or Q: have $W = P\Delta V$ const P

$W = nRT \ln\left(\frac{V_f}{V_i}\right)$ const T

all others: use $Q = \Delta U + W$

(gives $Q = nC_p \Delta T$ const P)