Physics Thermodynamics Tutorial

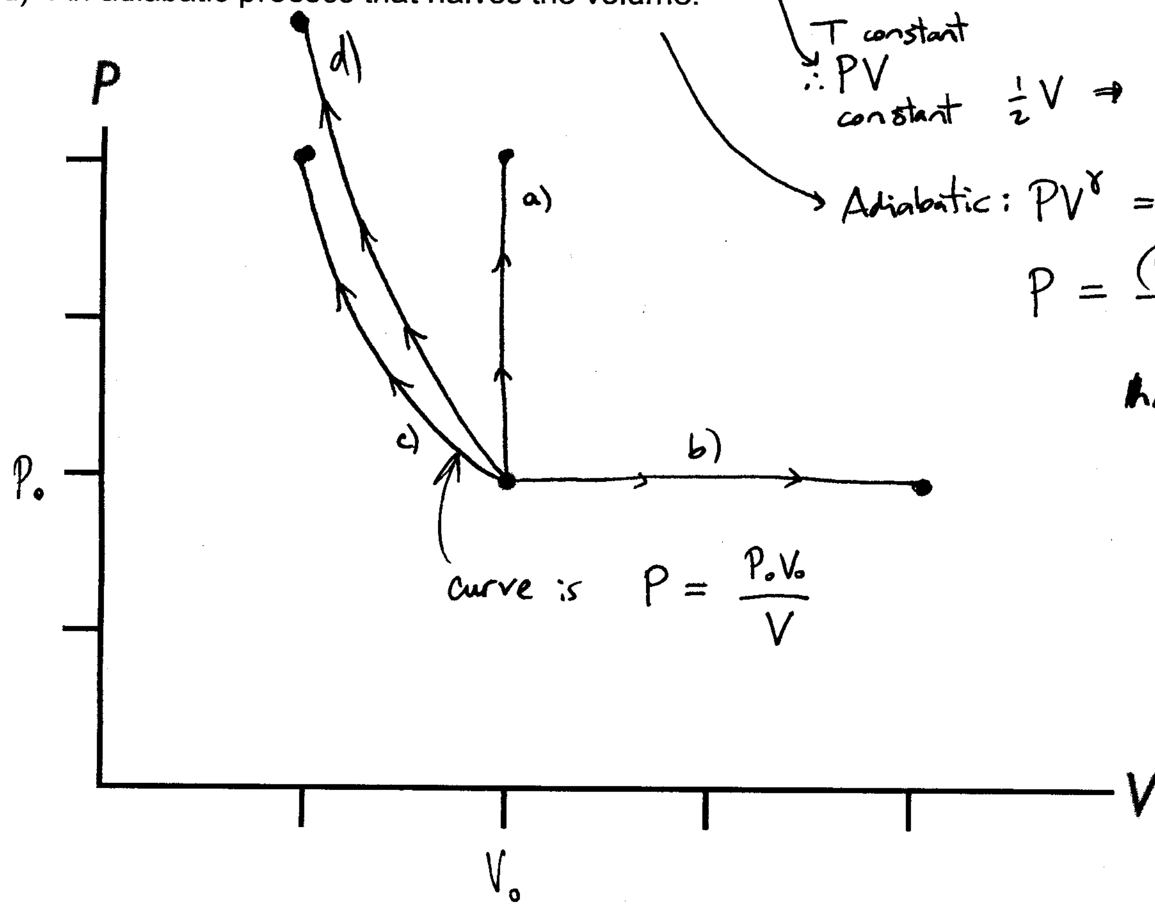
Question 1

The graph below shows the initial state of a gas. On it, draw the following processes.

a) An isochoric process that doubles the pressure. → constant volume
b) An isobaric process that doubles the temperature. → const pressure $\therefore \frac{T}{V}$ constant $\therefore 2\times T \Rightarrow 2\times V$
c) An isothermal process that halves the volume. → T constant $\therefore PV$ constant $\frac{1}{2}V \Rightarrow 2\times P$
d) An adiabatic process that halves the volume. → Adiabatic: PV^{γ} = constant

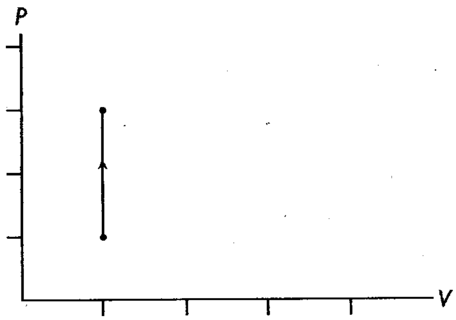
$$P = \frac{(P_0 V_0^{\gamma})}{V^{\gamma}}$$

half $V \Rightarrow 2^{\gamma} \times P$ (more than double pressure)



Question 2

For the following PV diagrams, state the name of the process, the *factors* by which *P*, *V* and *T* change, and whether ΔE, *Q* and W are *positive*, *negative* or *zero*.



Process Isochoric

P changes by × 3

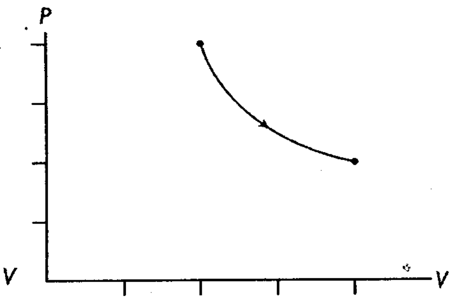
V changes by × 1

T changes by × 3

ΔE is positive

Q is positive

W is 0



Process isothermal

P changes by × ½

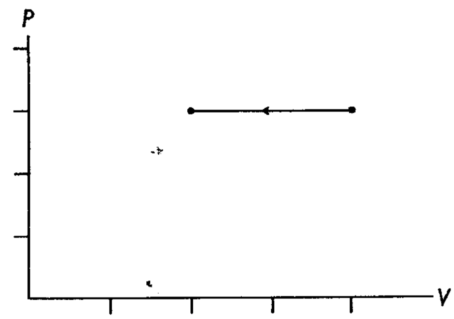
V changes by × 2

T changes by × 1

ΔE is 0

Q is positive

W is negative



Process isobaric

P changes by × 1

V changes by × $\frac{1}{2}$

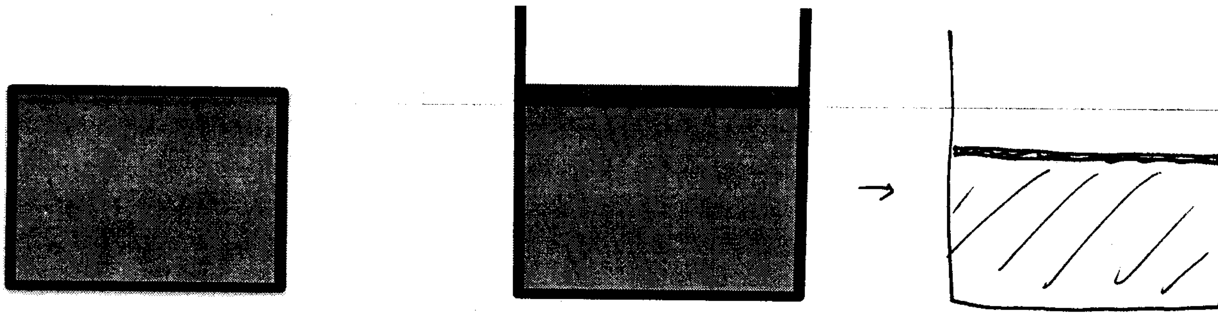
T changes by × $\frac{1}{2}$

ΔE is negative

Q is negative.

W is positive

Question 4



Two containers each contain one mole of neon at 350K. The containers are placed in cold water and slowly cooled to 275K, one at constant volume and the other at constant pressure. Compared to the amount of heat that flows out of the constant volume container (i.e. the magnitude of Q), the amount of heat that flows out of the constant pressure container is

W +ve since gas compressed

A) Larger
B) Smaller
C) The same

const V: $\Delta E = Q$ so $Q = nC_V \Delta T$

const P: $\Delta E = Q + W$ so $Q = nC_V \Delta T - W$

negative ~~positive~~ ↑ +ve.

Explain.

$|Q|$ is larger for constant P.

Question 5

One mole of helium and one mole of molecular hydrogen are in containers of equal volume. The average speed of the helium molecules is the same as the average speed of the hydrogen molecules.

Which gas has greater temperature?

$$T = (E_K)_{avg} = \frac{1}{2} m (v^2)_{avg}.$$

∴ T grater for He since m bigger.

Which gas has greater pressure?

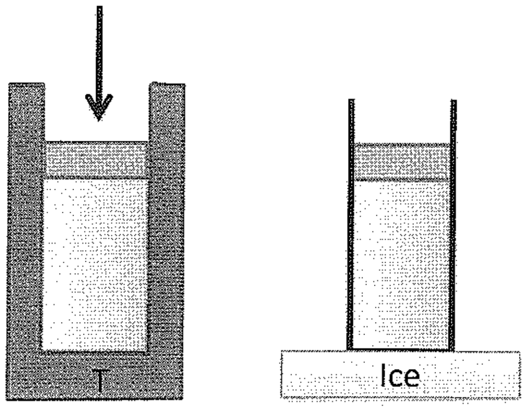
same # collisions/sec.

P greater for He : (more momentum transferred per collision)

For which gas is more energy required to increase the temperature by 10K?

C_V larger for H_2 since diatomic (some energy → rotational energy)

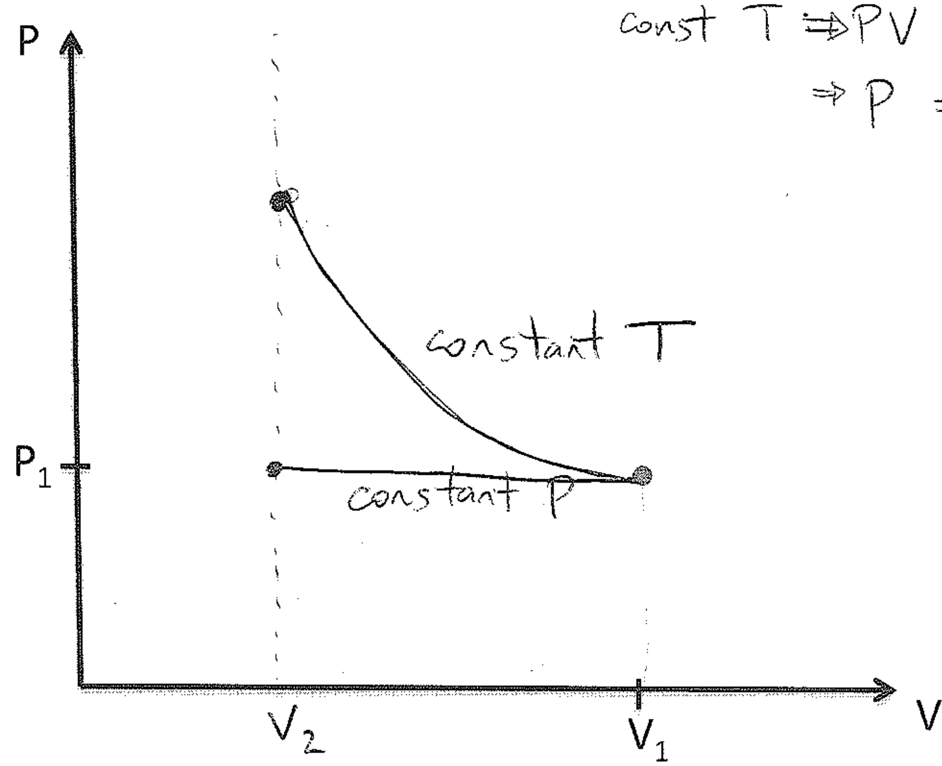
Question 3



Two containers each contain one mole of oxygen, each with the same initial volume, temperature, and pressure. One is compressed while being kept at constant temperature, while the other is cooled with a freely moving piston. If the volume of each decreases by the same amount, draw points on the graph below to represent the endpoint of each process and paths to indicate the intermediate stages for each process.

Const $T \Rightarrow PV$ constant

$\Rightarrow P = \dfrac{P_0 V_0}{V}$



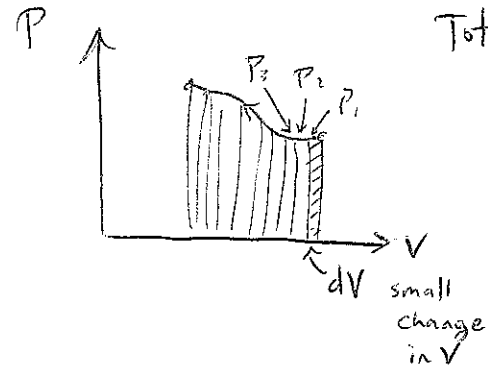
b) In terms of the initial volume V_1 and initial pressure P_1, how much work is done on the gas during the process on the right with the free piston?

$P(V_1 - V_2)$

c) What is the area on the graph under the path you drew for this process?

$P(V_1 - V_2)$

d) Hopefully you found the same result for b and c: when a gas compresses at constant pressure, the work done on the gas is the area under the path on the PV graph. In fact, this holds for any process, even if the pressure isn't constant. Explain how you could show this (*Hint: for a more general process, the pressure will be almost constant for very small changes in volume*):



Total work

$= \sum$ work for each little step

$= \sum P_i \, dV$ (since P almost constant for each step)

in limit $dV \to 0$

$=$ Sum of areas of rectangles

$=$ area under curve.

d) Calculate the work done on the gas in the constant temperature process on the previous page. Answer in terms of the initial volume V_1 and initial pressure P_1.

$$W = \int_{V_2}^{V_1} P \, dV$$

$$= \int_{V_2}^{V_1} \frac{P_1 V_1}{V} \, dV$$

$$= P_1 V_1 \ln(V) \Big|_{V_2}^{V_1}$$

$$= P_1 V_1 \ln\left(\frac{V_1}{V_2}\right)$$

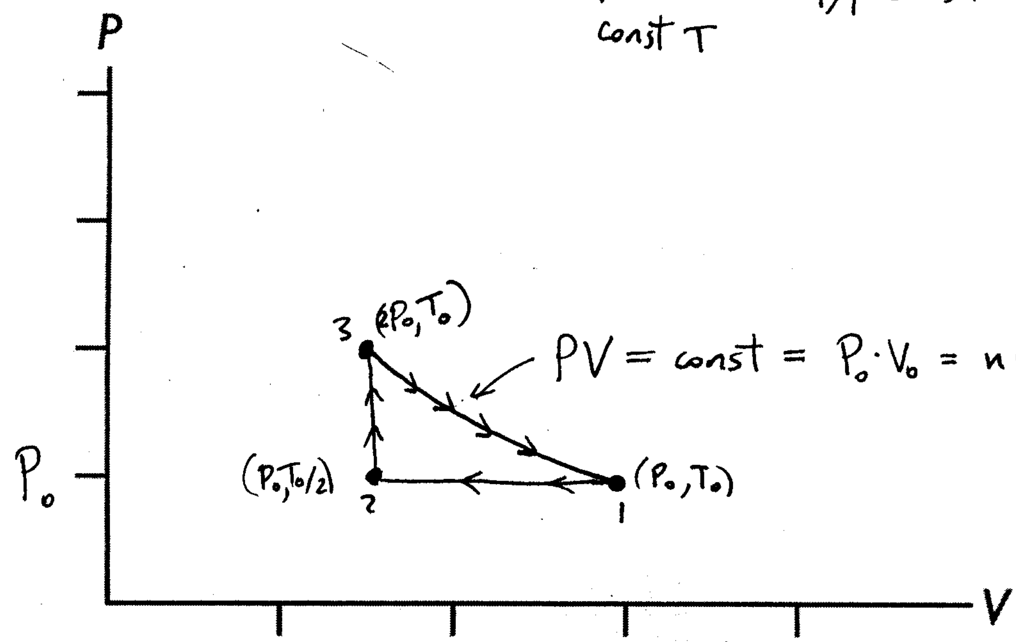
Question 3

- const. pressure.
- T/V const $\therefore V \to V/2$

A cylinder of gas with a movable piston initially has a temperature T_0 and pressure P_0. The gas is cooled slowly to a temperature $T_0/2$ while the piston is free to move. Then the piston is locked and the gas is heated back to a temperature of T_0. Finally, the piston is released, and the gas expands at a constant temperature back to its original volume.

const V
P/T const $\therefore P \times 2$

const T



$V_0 = \frac{nRT}{P}$

a) Draw the process on the graph above.
b) For each segment with work done, calculate the work (with the correct sign)
c) Calculate the heat added during the step where the temperature increases.
d) What is the ratio of (net work done) / (heat added) for the cycle? Your answer should be in terms of R and C_V only.

b): $W_{1\to2} = -P\Delta V = +P_0\left(\frac{V_0}{2}\right) = +\frac{1}{2}nRT_0$

$W_{2\to3} = 0 \qquad W_{3\to1} = -\int_{V_0/2}^{V_0} P\,dV = -\int_{\frac{V_0}{2}}^{V_0} \frac{nRT_0}{V}\,dV$

$= -nRT_0 \ln(V)\Big|_{\frac{V_0}{2}}^{V_0} = -nRT_0\ln(2)$

c) $Q_{2\to3} = \Delta E = nC_V\Delta T = \frac{1}{2}nC_VT_0$

d) Q is also +ve for $3\to1$: $Q_{3\to1} = \Delta E - W_{3\to1}$
$= -W_{3\to1} = nRT_0\ln(2)$

$$\therefore \frac{\underset{\text{by gas}}{\overset{-(W_{1\to2}+W_{2\to3}+W_{3\to1})}{\overset{\parallel}{\text{net work done}}}}}{\text{heat added}} = \frac{-\frac{1}{2}nRT_0 + nRT_0\ln(2)}{\frac{1}{2}nC_VT_0 + nRT_0\ln(2)} = \frac{2\ln(2)-1}{2\ln(2)+C_V/R}$$