Adiabatic process

"Adiabatic process" is a process in which no heat or matter is transferred between a system and its surroundings. Using our earlier notation in which ΔQ denotes the transfer of heat, adiabatic process means

$$\Delta Q = 0 \tag{1}$$

Notice that this does *not* mean that the temperature of the system is constant. To see this, recall that $\Delta Q = P\Delta V + \Delta U$. If ΔQ is zero, so that there is no heat transfer and ΔV is positive, so that the gas in the system is expanding, ΔU must be negative, which implies that the temperature of the gas must drop. In other words, if there is no heat transfer, and gas is expanding, it means that it is doing work, whose source of energy is the internal energy of the gas; the temperature of the gas must decrease.

We will calculate by how much the temperature drops during the adiabatic process. We have

$$\begin{aligned}
0 &= P\Delta V + \Delta U && (2)\\
&= P\Delta V + nC_v\Delta T && (3)\\
&= P\Delta V + nC_v\Delta(\frac{PV}{nR}) && (4)\\
&= P\Delta V + \frac{C_v}{R}\Delta(PV) && (5)\\
&= P\Delta V + \frac{C_v}{R}(P\Delta V + \Delta PV) && (6)\\
&= \frac{C_p}{R}P\Delta V + \frac{C_v}{R}\Delta PV && (7)\\
&= \frac{\Delta P}{P} + \frac{C_p}{C_v}\frac{\Delta V}{V} && (8)\\
&= \Delta(\ln P + \frac{C_p}{C_v}\ln V)) && (9)\\
&= \Delta(\ln(PV^{C_p/C_v})) && (10)
\end{aligned}$$

which, using the notation $\gamma \equiv C_p/C_v$, implies

$$PV^\gamma = \text{constant} \tag{11}$$

Now, from this equation, it is easy to derive (**Problem 1.**)

$$TV^{\gamma-1} = \text{constant} \tag{12}$$

Since C_p is always bigger than C_v, $\gamma - 1$ is always positive. Therefore, the above formula makes sense. During an adiabatic expansion, the temperature of the gas drops. In our later article, we will see that (11) is crucial in deriving the speed of sound.

Summary

- Adiabatic process is defined by $\Delta Q = 0$. i.e. No energy is transferred to the system.
- If a gas adiabatically expands its temperature drops because it is doing work which implies that the internal energy must decrease because of the conservation of energy.