

Clement-Desormes Method for Adiabatic Index γ

The Clement-Desormes method for adiabatic index γ employs a large bottle of air, a water manometer, and a rubber pressurizing bulb. The air sample at slightly elevated pressure undergoes a rapid adiabatic expansion followed by isochoric warming back to room temperature. This experimental method, from the results, allows determining the molecular structure of the investigated gas.

Determining the ratio of the specific heat capacities $\gamma = \frac{C_p}{C_v}$ for air according to the

method of Clement-Desormes implies some thermodynamic processes: a compression (h_1), an adiabatic expansion and an isochoric warming back to room temperature (h_2). The adiabatic process (isocaloric process) is described by the mathematical statement $pV^\gamma = \text{const.}$, where

$\gamma = \frac{C_p}{C_v}$ and $C_p = \left(\frac{\delta Q}{dT}\right)_p$ is the (molar) heat capacity at constant pressure and

$C_v = \left(\frac{\delta Q}{dT}\right)_v$ is the (molar) heat capacity at constant volume, and $C_p = C_v + R$ is the

Robert-Mayer relationship. No heat is transferred to or from working fluid. An adiabatic process which is also reversible is called an isentropic process.

Also, $C_v = \frac{i}{2}R$ and $C_p = \frac{i+2}{2}R$ and $\gamma = \frac{i+2}{i}$ with i the number of degrees of

freedom. For monatomic gases $\gamma = \frac{5}{3}$, for diatomic gases $\gamma = \frac{7}{5} = 1,4$ and for polyatomic

gases $\gamma = \frac{8}{6} = 1,3$. The isochoric process (*isometric process*) is the thermodynamic process at

constant volume $V = \text{const.}$

In the case of the air, from experiments it results that the adiabatic index has values close to 1,4 (because of the great number of molecules of diatomic gases and of the configuration of the molecule of carbon dioxide which has only 2 degrees of freedom from rotation).

After the aforementioned thermodynamic processes, the compression (h_1), the adiabatic expansion and the isochoric warming back to room temperature (h_2), one obtains for the adiabatic index:

$$\gamma = \frac{h_1}{h_1 - h_2}. \quad (1)$$

Apparatus and Equipment

- a large, isolated glass bottle of air with a stop cock
- liquid (water) manometer for reading the pressure differential with respect to the outside air pressure
- colored water mixture, which is used as manometer liquid. The pressure in the bottle of air is increased by using a small rubber-ball hand pump

Measurements

1. Using the rubber pump to produce an overpressure (compression).
2. After the increasing of the pressure one has to wait until the temperature of the gas has again reached room temperature T_1 (V_1 less than the volume of the bottle of air) and the overpressure has stabilized. This is the adiabatic compression of the air, because there are no changes of heat with the surroundings. The stop cock is rotated to obtain the connection of the bottle of air with the manometer (h_1).
3. Taking out the stop cock and put it very rapidly at its place (adiabatic expansion). The temperature is $T_2 < T_1$ and the volume increases to V_2 which is equal to the volume of the bottle of air. The thermal equilibrium is reached by following an isochoric warming back to room temperature (h_2). Connection with the manometer.

4. Picking up experimental data measuring (h_1) and (h_2) and calculate the adiabatic index γ with (1).
5. Evaluation of the errors.

Results and errors

No. crt.	h_1 (mm)	h_2 (mm)	γ

average value $\bar{\gamma}$

(root) mean-square error E_a

confidence interval $\gamma \in [\bar{\gamma} - E_a, \bar{\gamma} + E_a]$

percentage error E_r