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**IA Stepanov**
Institute of Science and Innovative Technologies, Liepaja University, Liela 14, Liepaja, LV-3401, Latvia

**Corresponding Author:**
**IA Stepanov**
Institute of Science and Innovative Technologies, Liepaja University, Liela 14, Liepaja, LV-3401, Latvia

# Description of adiabatic expansion and compression of gases

## IA Stepanov

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**Abstract**
**Background:** It is interesting to check whether an equation of the mechanocaloric effect in condensed phases can be applied for the description of adiabatic compression and expansion of gases. It is also useful to derive the equation for adiabatic compression and expansion of gases using the value of adiabatic heat capacity earlier obtained by the author.
**Methods:** Clément-Desormes method, Theory.
**Significant Findings:** A new equation for the description of adiabatic processes is derived which gives a good description for real gases. The accuracy of this equation is the same one as that of the traditional one. It is shown that an equation of the mechanocaloric effect also can be used for the description of adiabatic compression and expansion of gases.

**Keywords:** Adiabatic expansion, adiabatic compression, the mechanocaloric effect, clément-desormes method, real gases

**Introduction**
There is the equation of the adiabatic process [1].

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\left(\gamma-1/\gamma\right)}, \qquad (1)$$

Where $\gamma = C_P/C_V$ is the ratio of isobaric and isochoric heat capacity. One can check Eq. (1) experimentally.
There is a modified Clément-Desormes method for determination heat capacities of gases [2]: "A gas is maintained in a closed bottle, fitted with a stopcock and a manometer, at room temperature $T_1$ and at a pressure $P_2$ above atmospheric pressure $P_1$. When the stopcock is opened, the gas expands almost adiabatically to atmospheric pressure. During this expansion the gas cools from $T_1$ to $T_2$. Then the stopcock is closed again, and the gas is allowed to return to thermal equilibrium with surroundings. To determine the heat capacity one can, measure $P_1$, $P_2$, and $T_1$, and $T_2$". In Table 1 there are many experimental values of $P_i$ and $T_i$ for some gases. In the notations of Table 1, Eq. (1) will have the following form:

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\left(\gamma-1/\gamma\right)}, \qquad (2)$$

**Theory**
One can also apply the approach developed in [3] (thermoelastic).
During the adiabatic deformation, the enthalpy of the sample changes at ΔH (S, P) = ΔH (S, T). It follows that.

$$\left(\frac{\partial H}{\partial T}\right)_S \mathrm{d}T = \left(\frac{\partial H}{\partial P}\right)_S \mathrm{d}P \tag{3}$$

According to the tables of thermodynamic derivatives [3].

$$\left(\frac{\partial H}{\partial T}\right)_S = \frac{C_P}{\alpha T} \tag{4}$$

Where $C_P$ is the isobaric heat capacity, and $\alpha$ is the thermal expansion coefficient which is $1/T$ for an ideal gas. And from the same tables:

$$\left(\frac{\partial H}{\partial P}\right)_S = V \tag{5}$$

From these equations, the equation for the mechanocaloric effect follows.

$$\mathrm{d}T = \frac{\alpha T V}{C_P} \mathrm{d}P \tag{6}$$

Now let us check its correctness using the data from Table 1 and comparing with Eq. (2). One can assume that in Eq. (6) $\mathrm{d}T = T_2 - T_1$ and $\mathrm{d}P = P_2 - P_1$, and calculate $T_2/T_1$. Let us derive the equation of an adiabatic process analogously to [1]. During adiabatic expansion or compression.

$$C_A dT = -P\mathrm{d}V \tag{7}$$

Here $C_A = C_V$ is the adiabatic heat capacity [4].

Adiabatic expansion in the Clément-Desormes method is almost an isobaric process [2], therefore Eq. (7) can be written as.

$$C_A dT = -P\mathrm{d}V = -\frac{RT}{V}\mathrm{d}V \tag{8}$$

If $C_A$ is independent of temperature, and if one introduces $\kappa = R/C_A$, one can obtain from Eq. (8)

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\kappa} \tag{9}$$

And then:

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\kappa/(\kappa+1)} \tag{10}$$

In the notations of Table 1, Eq. (10) will have the following form:

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\left(\kappa/_{\kappa+1}\right)}, \tag{11}$$

Calculations with Eqs. (2). (6) and (11) are presented in Table 1. Equation (11) gives a very good agreement with the experiment.

**Table 1:** Measurements with a modified clément-desormes method and calculations with Eqs. (2). (6) and (11) for some gases heated by compression [2]

| Gas | $P_1$, Pa | $P_2$, Pa | $T_1$, K | $T_2$, K | $T_1 / T_2$, | $T_1 / T_2$, Eq.(2) | $T_1 / T_2$, Eq.(6) | $T_1 / T_2$, Eq.(11) |
|---|---|---|---|---|---|---|---|---|
| Air [2] | 101445 | 110084.3 | 287.03 | 280.40 | 1.02364 | 1.02363 | 1.03241 | 1.02363 |
| Air [2] | 100578.41 | 109041.714 | 285.98 | 279.47 | 1.02329 | 1.02335 | 1.03204 | 1.02335 |
| $O_2$ [2] | 101005,04 | 115178,544 | 288.11 | 277.63 | 1.03775 | 1.03768 | 1.05070 | 1.03768 |
| $H_2CO_3$ [2] | 10079172 | 112657.417 | 284.36 | 277.24 | 1.02568 | 1.02562 | 1.03197 | 1.02562 |
| $H_2$ [2] | 10076506 | 115835.823 | 288.75 | 277.38 | 1.04099 | 1.04087 | 1.05537 | 1.04087 |
| Air [2] | 100791,725 | 109770.988 | 292.99 | 285.98 | 1.02451 | 1.02444 | 1.03342 | 1.02444 |
| Air [2] | 100258 | 108539.089 | 293.12 | 286.55 | 1.02293 | 1.02293 | 1.03148 | 1.02293 |
| $CO_2$ [2] | 100858.39 | 110865,564 | 293.12 | 286.85 | 1.02186 | 1.02183 | 1.02744 | 1.02183 |
| Air [2] | 118243.63 | 101578.33 | 288.91 | 276.66 | 1.04428 | 1.04436 | 1.07023 | |
| Air [2] | 116729.083 | 100311.76 | 288.81 | 276.54 | 1.04437 | 1.04426 | 1.07005 | |

## Conclusions and Discussions

It is shown that compression and expansion of gases can be successfully described by an equation for the mechanocaloric effect. Formerly we thought that in an isobaric process a change in the enthalpy is equal to the heat of the process. Here the conclusion of [5] is confirmed: in all processes a change in the enthalpy is equal to the heat of the process. An alternative equation of an adiabatic process is derived which also gives a good description of compression and expansion of gases. It is obvious that this alternative equation is not worse than the traditional one.

## Statements and Declarations

### Competing Interests

The author declares that he has no competing interests or personal relationships that could have appeared to influence the work reported in this paper.

**Conflict of Interest Statement:** The author has no relevant financial or non-financial interests to disclose.

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