AMERICAN Journal of Engineering, Mechanics and Architecture
Volume 3, Issue 3, 2025 ISSN (E): 2993-2637

Determination of the Volume Expansion Coefficient of Liquids

Chorshanbiyeva Nigina Abdullayevna
Termiz State University

Abstract: This article analyzes the methods of determining the volume expansion coefficient of a liquid. The volume expansion coefficient represents the relative change in the volume of a liquid depending on the temperature change. Formulas for calculating the coefficient of volume expansion for various liquids are presented in the framework of the study, and the methods of their experimental determination are discussed. Volumetric expansion applies not only to liquids, but also to solids and gases. Factors affecting the accuracy of experimental results and ways to reduce them are also considered. The obtained information is of great importance in researching the physical properties of liquids and their application in various fields.

Keywords: Volume expansion, dilatometer, temperature, type of liquid, ethanol liquid, volume expansion of ethanol, volume expansion of water, difference between volume expansions of water and ethanol.

Introduction

The volumetric expansion of liquids is a fundamental physical phenomenon that occurs due to the increase in molecular distance with rising temperature. This property plays a crucial role in various scientific and engineering applications, including thermometry, material science, and industrial processes. The coefficient of volumetric expansion determines the relative change in volume per unit temperature increase and varies for different substances. This study focuses on analyzing the methods for determining the volumetric expansion coefficient of liquids, particularly water and ethanol. Experimental procedures using a dilatometer are employed to measure the expansion of these liquids at different temperatures. The findings contribute to a better understanding of liquid behavior under thermal influence, providing essential insights for practical applications in physics, engineering, and environmental sciences.

Methodology

This study employs experimental methods to determine the volumetric expansion coefficient of liquids using a dilatometer. The experiment involves measuring the volume change of water and ethanol at different temperatures.

A dilatometer with a capillary tube is used to observe liquid expansion.

Initial mass of the empty dilatometer is recorded, followed by measuring the mass after filling it with water.

Temperature variations are applied using a controlled heating system, and the corresponding volume changes are measured.

Formula calculations are used to determine the volumetric expansion coefficient of both liquids.

Comparison is made between the expansion coefficients of water and ethanol, analyzing the differences based on molecular structure and thermal properties.

The results provide insights into the thermal behavior of liquids and their practical applications in scientific and industrial fields.

Objectives:

- Determine the volume V0 of the dilatometer.
- Measure the volumes of water and ethanol as a function of temperature and determine their coefficients of volumetric expansion.
- Compare the coefficients of volumetric expansion of water and ethanol.

Required tools and equipment

1 dilatometer

- 1 thermometer, -10 to 110 or
- 1 NiCr-Ni temperature sensor
- 1 Digital thermometer with single input
- 1 Training laboratory scale
- 1 Heater with a diameter of d = 150 mm and a power of 1500 W
- 1 Beaker made of durable glass, volume 400 ml
- 1 Tripod with a V-shaped base
- 1 Tripod column 47 cm long
- 2 Multi-clamp Leybold

2 Universal clamps with a diameter of 0÷80 mm

Theoretical information

Volumetric expansion is the phenomenon of an increase in the volume of a substance when its temperature increases. This phenomenon manifests itself in different ways in gases, liquids, and solids.

The volumetric expansion of solids, liquids, and gases is as follows.

1. Volumetric expansion in solids:

Volumetric expansion in solids is very small because the molecules are densely packed.

Expansion in metals is of significant technical importance, for example, it leaves a gap in railway tracks and bridge structures.

2. Volumetric expansion in liquids:

Liquids expand more than solids because the distance between molecules is greater than that between molecules in solids.

Different liquids have different coefficients of expansion. For example, the expansion in mercury and alcohol thermometers is used due to its properties.

3. Volumetric expansion in gases

Volumetric expansion in gases is much greater than that of liquids and solids.

The volume of a gas expands according to the ideal gas law when the temperature increases and the pressure remains constant.

Practical application of the concept of volumetric expansion:

Thermometers – use the volumetric expansion of mercury or alcohol.

Metal structures – take into account thermal expansion and leave compensation seams.

Engines and mechanical devices – are specially designed to prevent damage due to the volumetric expansion of materials under the influence of temperature.

Volumetric expansion is an important concept in physics and is also of great importance in technology and engineering.Hajmiy kengayishning asosiy tushunchalari:

Thermal expansion - when a substance is exposed to heat, the distance between its molecules increases, resulting in an increase in volume.

The coefficient of volumetric expansion is a physical quantity that expresses the relative change in volume of a substance when its temperature increases by one degree. This coefficient has a specific value for each substance.

If the temperature of a liquid with a volume of V_0 inside a container changes by Δt, the same phenomenon occurs in solids, that is, its volume changes by ΔV_0.

$$\Delta V = \alpha \cdot V_0 \cdot \Delta T$$

(1) in the formula α is the coefficient of volumetric expansion, V_0 is the initial volume of the dilatometer, ΔT is the difference between the initial and subsequent temperatures, and it is equal to ΔT = T2 – T1.

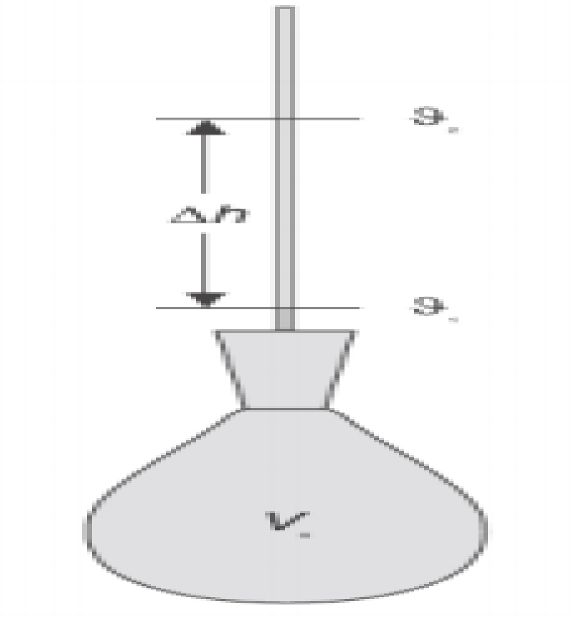

Figure 1. Dilatometer - a device for determining the coefficient of volumetric expansion of liquids.

In practice, the coefficient of volumetric expansion α does not depend on the temperature of the liquid, but it does depend on the type of liquid. Liquids generally expand more than solids. The coefficient of volumetric expansion can be determined using a dilatometer.

A dilatometer is a glass tube with a narrow mouth, which is fixed to an open capillary of radius r. The height h of the liquid is determined by a millimeter scale drawn on the side of the capillary tube. If the glass tube is heated uniformly in a water bath, the height of the liquid in the capillary increases due to the expansion of the liquid. The change in the height of the liquid corresponds to the change in volume Δh, i.e.

$$\Delta V = \pi \cdot r^2 \cdot \Delta h.$$

Δh is the difference between the initial and subsequent water levels. In this formula, the dilatometer is the inner radius of the capillary tube, which is r = (1.5 ± 0.08) mm.

However, we must take into account that the dilatometer itself expands when heated. This expansion resists the change in liquid height.

Thus, the change in liquid volume can be determined using the following formula:

$$\Delta V_0 = \Delta V + \Delta V_D$$

In this formula, ΔV_D is the volume change of the dilatometer and is defined by the following formula:

$$\Delta V_D = \alpha_D V_0 \Delta T$$

Here α_D=$0.84 \cdot 10^{-4}$ is equal to K^{-1}.

Using formulas (1), (3) and (4), we can obtain the formula for determining the coefficient of volumetric expansion of a liquid:

$$\alpha = \frac{\Delta V}{V_0 \cdot \Delta t} \alpha_D.$$

The volume V_0 must be determined. It is determined as follows: the mass of the empty dry dilatometer m_1 is measured, after which the mass of the dilatometer filled with water m_2 close to the lower mark of the open capillary is measured. Using the density of water for different temperatures (see Table 1), the volume of the dilatometer is determined by the following formula:

$$V_0 = \frac{m_2 - m_1}{\rho}$$

The temperature-dependent properties of the density of pure water are presented in the literature

Table 1.

T	**ρ g/sm³**	**T**	**ρ g/sm³**
15 ^{0}S	0,999099	23 ^{0}S	0,997540
16 ^{0}S	0,998943	24 ^{0}S	0,997299
17 ^{0}S	0,998775	25 ^{0}S	0,997047
18 ^{0}S	0,998596	26 ^{0}S	0,996785
19 ^{0}S	0.998406	27 ^{0}S	0,996515
20 ^{0}S	0.998205	28 ^{0}S	0,996235
21 ^{0}S	0,997994	29 ^{0}S	0,995646
22 ^{0}S	0,997772	30 ^{0}S	0,995649

Structure of the laboratory device.

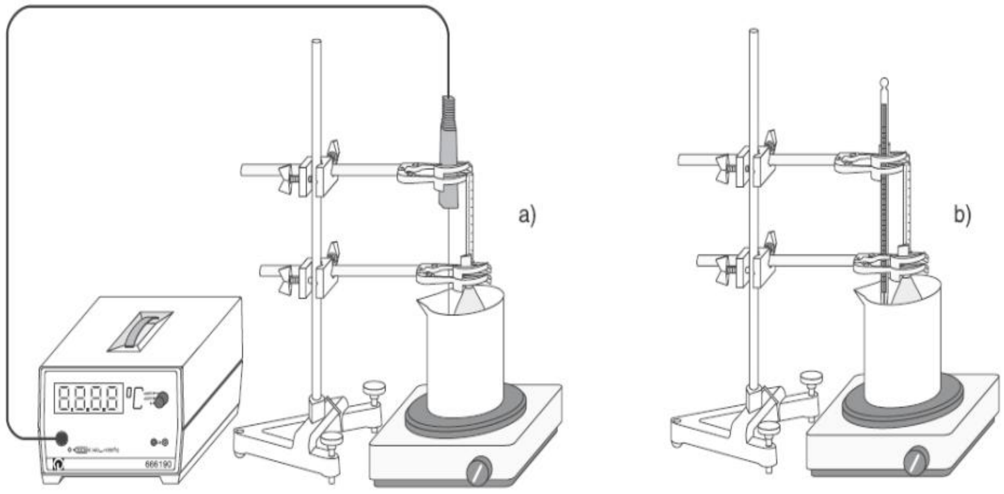

Figure 2. The structure of a scale experiment to determine the coefficient of volumetric expansion of liquids is shown in Figure 2.

a) when using a temperature sensor.

b) when using a thermometer.

Notes: Due to the influence of various forces, significant errors can occur in the measurement of liquid height. To avoid this situation, clean the capillary with a clean solution and, if necessary, with appropriate cleaning solutions. After cleaning, rinse it with distilled water.

Procedure for performing laboratory work:

a) The dilatometer is prepared for measurement:

- Determine the mass of the empty dilatometer, m1.
- Pour one-third of the water into the open side of the flask.
- Heat the dilatometer to boiling point in a water bath before the capillary tube hardens to prevent the formation of water bubbles.
- Let the water bath cool to room temperature, then fill it to the required height with water and liquid. Record the temperature of the liquid.
- Replace the capillary tube. Remove the capillary tube by pressing your finger on the open end of the tube and do not allow the liquid to flow out of the line.

Replace the capillary tube in the flask, dry the dilatometer and fill it with water, measure the mass of the filled dilatometer in m_2.

b) Measuring the volume of water and ethanol:

Note that the liquid continues to heat up for some time after the heater is turned off, and therefore the liquid may overflow the dilatometer. In particular, if the flask is filled with ethanol, turn off the heater before boiling to prevent the ethanol from spilling out.

Lower the dilatometer into the heated water bath, so that it rises above the water level in the capillary bath.

If the heater does not change from the lowest point on the scale, turn it off when the liquid level in the dilatometer reaches the highest mark on the scale.

Wait until the liquid level reaches the maximum level and then allow the bath to cool by about 1-2 K.

After the water bath has cooled, determine the liquid level (h) in the tube as a function of temperature (see Table 2).

The height of fresh water depends on temperature

Table 2.

T, ^{0}C	**h, sm**	**T, ^{0}C**	**h, sm**
60 ^{0}S	9.5	45 ^{0}S	4.25
59 ^{0}S	9.3	44 ^{0}S	3.9
58 ^{0}S	8.9	43 ^{0}S	3.55
57 ^{0}S	8.6	42 ^{0}S	3.2
56 ^{0}S	8.2	41 ^{0}S	2.9
55 ^{0}S	7.85	40 ^{0}S	2.6
54 ^{0}S	7.5	39 ^{0}S	2.3
53 ^{0}S	7.1	38 ^{0}S	2.0
52 ^{0}S	6.75	37 ^{0}S	1.7
51 ^{0}S	6.4	36 ^{0}S	1.4
50 ^{0}S	6.0	35 ^{0}S	1.1
49 ^{0}S	5.7	34 ^{0}S	0,8
48 ^{0}S	5.3	33 ^{0}S	0,55
47 ^{0}S	4.9	32 ^{0}S	0.3
46 ^{0}S	4.6		

Ethanol as a function of elevated temperature

Table 3.

T, ^{0}C	**h, sm**	**T, ^{0}C**	**h, sm**
38 ^{0}S	9.9	32 ^{0}S	4.6
37 ^{0}S	9.1	31 ^{0}S	3.7
36 ^{0}S	8.25	30 ^{0}S	2.7
35 ^{0}S	7.4	29 ^{0}S	1.8
34 ^{0}S	6.5	28 ^{0}S	0,9
33 ^{0}S	5.55		

Calculation and results

a) Determine the dimensions of the dilatometer:

m2 -m1 =56.72 g

t = 22 0C

ρ = 0.9978 g/cm3 (from Table 1).

Then, from expression (6), we determine that V0 = 56.85 cm3.

b) Determine the coefficient of volumetric expansion of water and ethanol.

Using the data in Table 2-3, the graph of the change in liquid volume ΔV versus the temperature difference ΔT =T - T0 is shown in Figure 3 (respectively. T0 = 32 0C). For water and ethanol, 28 0C, compare Tables 2 and 3). For water, the straight line passing through the origin is ΔV/ΔT=22.9 mm3/K, and for ethanol, the straight line displacement is ΔV/ΔT=65.0 mm3/K. Using formula (5), we can find the coefficients of volumetric expansion for water and ethanol:

α = 4.9×10-4 K-1 (water), α = 12.3×10-4 K-1 (ethanol).

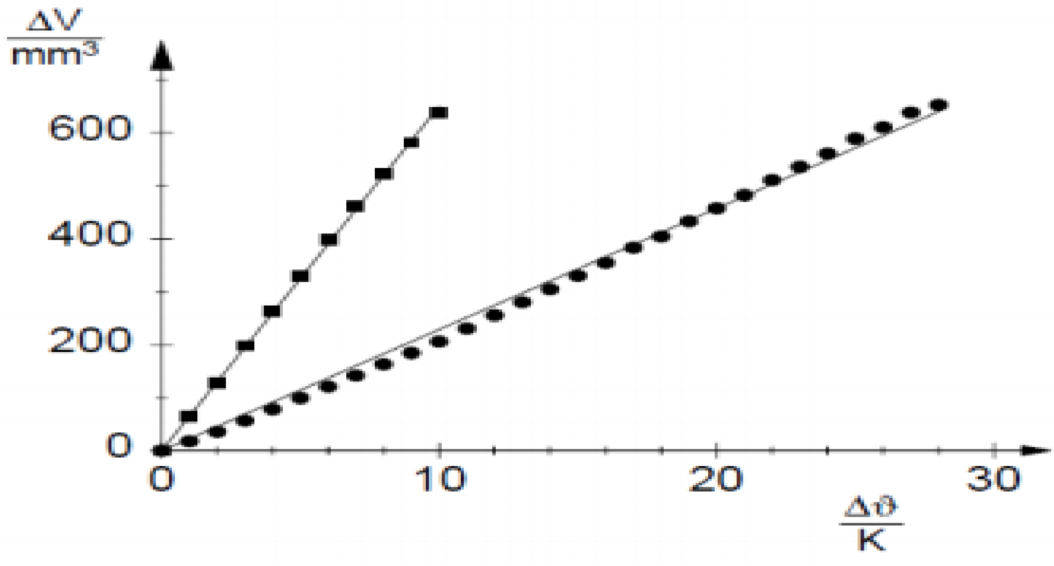

Figure 3. Volume expansion of water ΔV (circles) and ethanol volume (squares) as a function of t.

Conclusion

Volumetric expansion of a liquid is a physical phenomenon based on the expansion of the volume of substances as a result of an increase in temperature, which occurs due to an increase in the distance between the molecules of the liquid. The coefficient of volumetric expansion for each liquid depends on the temperature and the properties of the substance, and its value is determined experimentally.

There are systematic deviations from the linear variation of the measured properties for water. The coefficient of volumetric expansion of water is not a constant value and, as shown in experiments, increases with increasing temperature from 30 ^{0}C to 60 ^{0}C. The coefficient of volumetric expansion of ethanol is much larger than the coefficient of expansion of water. This coefficient is stable over a large temperature range. Therefore, ethanol is used as a liquid for thermometers.

In nature and technology, the volumetric expansion of liquids is important in various fields. For example, this phenomenon must be taken into account in the design of heat engines, industrial equipment, and building structures. Also, in meteorology and oceanology, the temperature-dependent changes in liquids affect climatic processes.

Volumetric expansion of liquids is an important factor in their storage and use, and various technologies are used to control this process. Accurate calculation of volumetric expansion helps to increase the efficiency of liquid use and ensure safety.

Literature

1. E.N. Nazirov, Z.A. Khudaiberganova, N.Kh. Safiullina “Practical course on mechanics and molecular physics”. M.: T. “O’zbekiston” 2001 288p.
2. D.V. Sivukhin “General Physics Course”. M.: T. “Teacher” 1984 520p.
3. A.K. Kikoin, I.K. Kikoin “Molecular Physics”. M.: T. “Teacher” 1978 509p.
4. J.A. Toshkhonova, M.N. Olmasova, I. Ismoilov, T. Rizayev, H.M. Makhmudova “Practical in Physics” M.: T. 2006 271b
5. V.I. Iveronova “Physics practical course” (Mechanics and molecular physics). Moscow: T. 1973 379b.