Experiment 8

Determining the volumetric expansion coefficient of water as liquid

1- Objects of the experiment

Measuring the volume expansion of water as a function of the temperature and determining the volumetric expansion coefficient γ.

2- Principles

If the temperature T of a liquid of volume V_0 is changed by ΔT, then the volume will change by

$$\Delta V_0 = \gamma\, V_0 . \Delta T \qquad (1)$$

The volumetric expansion coefficient γ is practically independent of the temperature T, but it does depend on the material.

The volumetric expansion coefficient can be determined by means of a dilatometer. A dilatometer consists of a glass flask with a capillary of known radius *r* at the opening as a riser tube. The level *h* of the liquid in the riser tube is read from a mm-scale. It increases when the glass flask is uniformly warmed in a water bath and the volume of the liquid expands.

The change in the liquid level *Δh* corresponds to a change in volume:

$$\Delta V = \pi . r^2 . \Delta h \qquad (2)$$

with $r = (1.5 \pm 0.08)\ mm$

However it has to be taken into account that the dilatometer itself also expands because of the warming. This expansion counteracts the change in the liquid level. The change in volume of the liquid thus is

$$\Delta V_0 = \Delta V + \Delta V_D \qquad (3)$$

where the volume change ΔV_D of the dilatometer is

$$\Delta V_D = \gamma_D V_0 \Delta T \qquad (4)$$

with $\gamma_D = 0.84 \times 10^{-4} K^{-1}$ $\gamma_D = 0.84\,.10^{-4} K^{-1}$

From Equations (1), (3), and (4), the volumetric expansion coefficient of the liquid is found to be

$$\gamma = \frac{1}{V_0} \cdot \frac{\Delta V}{\Delta T} + \gamma_D \qquad (5)$$

There is still the volume V_0 V_0 of the dilatometer to be determined. This is done by determining the masses m_1 of the empty, dry dilatometer and m_2 of the dilatometer filled with pure water up to the lower end of the riser tube.

$$V_0 = \frac{m_2 - m_1}{\rho} \qquad (6)$$

where the density ρ ρ of water is taken to be approximately equal to $0.9975 g.cm^{-3}$

3- List of Equipments

Apparatus	Catalogue Number
1 dilatometer	382 15

1 thermometer, -10 to 110°C	382 34
1 lab. balance	315 05
1 hot plate, 150 mm dia., 1500 W	666 767
1 beaker, 400 ml	664 104
1 stand base, V-shape	300 02
1 stand rod, 47 cm	300 42
2 multiclamp	301 01
2 universal clamp, 0 … 80 mm dia.	666 555
in addition necessary: Distilled or demineralized water	

4- Setup and carrying out the experiment

a) Calibration of the dilatometer:

- Determine the mass m_1 of the empty dilatometer.

- Fill the flask with pure water up to the bottom third of the ground opening.

- To eliminate air bubbles, heat the dilatometer in the water bath almost to boiling without the riser tube attached.

Note: After the hot plate has been switched off, the heating of the liquid continues for some time so that the dilatometer may run over. Switch the hot plate early enough.

- Allow the water bath to cool off to room temperature, top off the liquid level as necessary. Take down the temperature

- Attach the riser tube, press your finger on the opening, then remove the riser tube and allow it to drain.

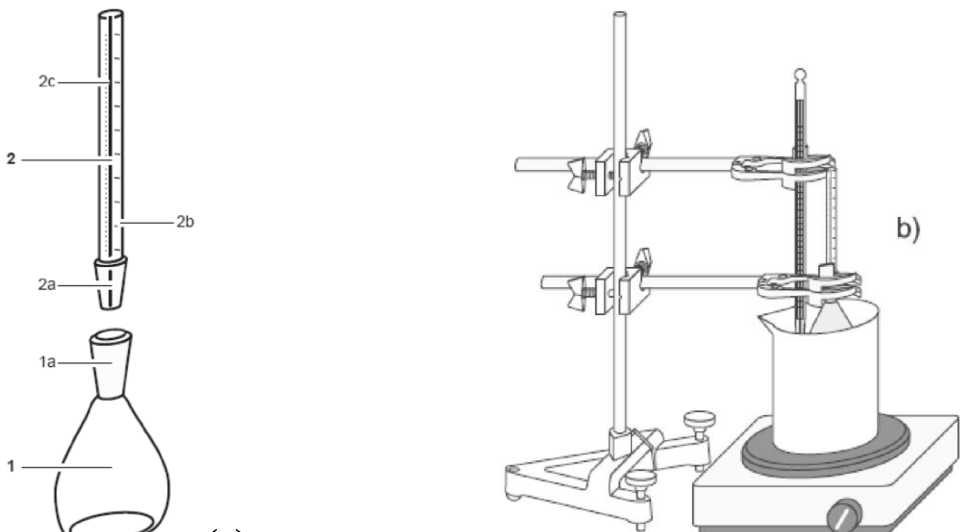
- Replace the riser tube on the flask, dry the dilatometer and measure the mass m_2 m_2 of the water-filled dilatometer.

- Calculate V_0 from Equation (6)

b) Measuring the volume expansion of water:

The experimental setup is illustrated in Fig. 1.

- Dip the dilatometer into the heating bath so that the riser tube sticks out.
- Switch the hot plate on at the lowest step, and switch it off when the liquid level in the dilatometer is just below the highest mark of the scale.
- Wait until the liquid level has reached its maximum, and then allow the water bath to cool down.
- Let the water bath continue cooling down, and determine the level *h* of the water in the riser tube as a function of the temperature (see Table 1).



(a) (b)

Figure 1. (a) Dilatometer (1. Glassflask; 1a. ground opening; 2. Riser tube; 2a. Ground joint; 2b. mm-scale; 2c. Capillary.) (b) Experimental setup for the determination of the volumetric expansion coefficient of liquids.

Table 1. The level h of pure water as a function of the temperature. The level h_0 is determined at $T_0 = 35°C$.

$T\ (^0C)$	$\Delta T = T - 35$ (K)	$h\ (mm)$	Δ h $\Delta h = h - h_0$ (mm)	ΔV $\Delta V\ (mm^3)$ (Eq. 2)

60	25	--------		
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35		-------- = h_0		

- Prepare a sheet of graph paper for plotting ΔV versus ΔT. You should make ΔV the vertical axis and ΔT the horizontal axis. Each axis should be labeled and appropriate units indicated. The graph should have a title.

- Plot your data on the graph.

- Determine the slope and the y-intercept point by using the least square method (see appendix).

- Draw best fit line to the points on your graph.

- Determine the value of the volumetric expansion coefficient of the pure water by using the slope and Equation (5).

- Discuss your results