Principle

Liquids expand to different extents when heated. The test liquid is held in an Erlenmeyer flask, which is heated up in a water bath. The temperature measurement should be made directly in the test liquid. Water and alcohol are used as test liquids. As alcohol is easily inflammable, heating it using an open flame should be avoided. It is therefore suggested, that you first determine the expansion of water on heating it and then, after waiting for about 5 to 10 minutes (so that the holder and the water bath can cool a little), heat up the flask containing alcohol in the hot water bath. The two test liquids should have the same initial temperature and be filled to the same height, so that the results for the two liquids can be clearly presented next to each other on the board.

Equipment

2	Clamp holder, *d* = 28… 36 mm	02151-06
1	Scale for demonstration board	02153-00
1	Pointers for demonstration board	02154-01
1	Marker points for demonstration board	02154-02
1	Holder for Cobra4, magnetic	02161-10
1	Burner holder on fixing magnet	02162-00
1	Wire gauze holder on fixing magnet	02163-00
1	Wire gauze with ceramic 160 x 160 mm	33287-01
1	Beaker, PP, low form, 100 ml	36011-01
1	Glass beaker, short, 400 ml	36014-00
2	Erlenmeyer flask, 100 ml, SB 29	36428-00
1	Glass tubes, *l* = 375 mm, 2 pieces	36701-67
2	Rubber stopper 26/32	39258-13
1	Funnel, *d* = 50 mm, PP	36890-00
1	Mikro spoon, steel	33393-00
1	Marker, black	46402-01

Additional equipment

1	Demo physics board with stand	02150-00
1	Cobra4 Mobile-Link 2	12620-10
1	Cobra4 Display-Connect	12623-00
1	Cobra4 Sensor-Unit 2x Temperature	12641-00

Fig. 1: Experiment set-up

1	Immersion probe NiCr-Ni, steel	13615-03	1	Boiling beads, 200 g	36937-20
1	Large-scale display, digital	07157-93	1	Denaturated alcohol (spirit for burning))	31150-70
1	Butane burner Labogaz 470	47536-00			
1	Butane cartridge CV300 Plus	47538-01		Matches	
1	Patent blue-V, 25 g	48376-04		Right-angled Triangle	
1	Glycerol, 250 ml	30084-25			

Set-up and procedure

- Position the holder for the burner down at the bottom of the board.
- When a butane burner is to be used, position the holder for the wire gauze on the board at the marked height 240 and place the wire gauze on it (when a Bunsen burner is to be used, select height 180).
- Place the glass beaker on the wire gauze.
- Attach the holder for Cobra4 to the board as shown in Fig. 1.
- Connect the Cobra4 Mobile-Link to the Cobra4 Display-Connect transmitter and to the Sensor-Unit 2x temperature NiCr-Ni and push it into the holder (Fig. 1).
- Connect the Cobra4 Display-Connect receiver to the large-scale display and fasten the latter to the upper area of the board.
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Prepare the Erlenmeyer flasks to hold water and alcohol:

- Insert an immersion probe and a glass tube in each rubber stopper, using glycerol.
- Check the depth at which the immersion probes are held when the rubber stoppers are fitted on the still empty Erlenmeyer flasks. The tips of the probes should be about 1 cm above the bottom of the flasks.
- Fill the Erlenmeyer flasks up to approx. 5 mm below the rims, one with coloured water, the other with coloured alcohol.
- Fit the stoppers on the Erlenmeyer flasks.
- The liquids rise up inside the glass tubes; there should be no air bubbles under the stoppers.
- Press the stoppers so far in the Erlenmeyer flasks, that the liquid levels are about 10 cm up the tubes.
- The filling heights in the glass tubes should be as equal as possible. Adjusted them as necessary by lightly pressing the stoppers.
- Check the initial temperature of the water and alcohol.
- Mark the heights of the liquids in the glass tubes on the tubes with a pen.
- Hold the Erlenmeyer flask containing water with a clip and lower it as far as possible into the glass beaker.
- Fill the beaker completely with water and add two boiling stones.
- Project the height of the liquid level in the glass tube onto the board, using the right-angled triangle, and mark it with a line and a blue arrow (cold starting condition). Position the rule with its zero mark at this height.
- Connect the temperature sensor to the Sensor-Unit.

- Note the initial temperature of the water in the Erlenmeyer flask.
- Heat the water with a small burner flame.
- At the temperatures 25℃, 30℃, 35℃, 40℃ ... to 70℃, mark the liquid level on the glass tube and use the right-angled triangle to mark it alongside the rule. To illustrate the thermal expansion, label each 10℃ step marking with a point marker on which the temperature is written (Fig. 2).
- Finish the measurement series at 70℃.

- Wait 5-10 minutes before starting to measure alcohol, so that the holder can cool down. The heated water bath has a temperature of approx.80℃ and only cools down very slowly. The evaluation of the measurement series for water can be made during this wait, and, if appropriate, the arrangement on the board can also be completed for the subsequent comparison with alcohol.
- Remove the Erlenmeyer flask containing water from the beaker. The magnetic grip of the clip to the board is very strong. Because the water bath is hot, it is therefore recommended that you open the clip carefully and remove the Erlenmeyer flask from the front of it.
- Note the initial temperature of the alcohol.
- Lower the Erlenmeyer flask containing alcohol into the hot water bath.
- The alcohol heats up quickly at first, then slower. As the temperature display of the immersion probe reacts slower than the liquid level in the glass tube, a correct correlation between the temperature and liquid level is not given until after about 5 minutes, at which time the temperature only increases very slowly.
- Mark the liquid level on the glass tube at a temperature of 45℃, for example, and use the right-angled triangle to correspondingly mark the board.
- Place the labelled point marker on the other side of the rule, so that the volume expansions of alcohol and of water can be clearly seen opposite each other on the board (Fig. 2) and can be compared with each other.

Results

Fig. 2: Liquid level in dependence on temperature (as seen on the board); water on the right, alcohol on the left.

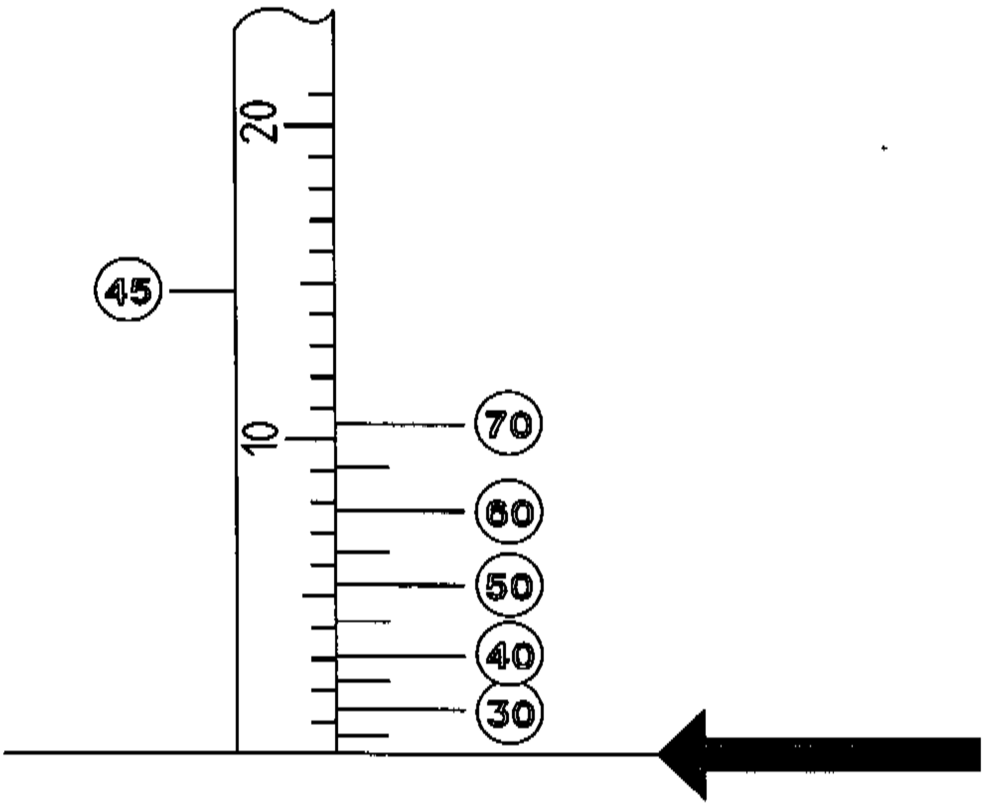

Fig. 2: Markings on the board

ϑ / °C	Δl / cm
21.5	0.0
25.0	0.5
30.0	1.3
35.0	2.2
40.0	3.1
45.0	4.1
50.0	5.3
55.0	6.5
60.0	7.8
65.0	9.2
70.0	10.6

Table 1: The volume expansion of water

ϑ / °C	Δl / cm
21.5	0.0
45.0	14.8

Table 2: Volume expansion of alcohol

The markings on the board clearly show the expansion of water with increase in temperature (Fig. 2). Water expands only a little at first, and the expansion is greater at higher temperatures. The change in volume of alcohol is much larger than that of water.

Evaluation

The temperature scale written on the board is not linear. In this connection, the anomaly of water can be pointed out. Water has its highest density at 4°C, i.e. the liquid level in the glass tube would be at its lowest at this temperature. The volume changes in this temperature region are so small, however, that the effect can only be shown using a capillary tube.

Determination of the coefficients of volume expansion:

For quantitative evaluation, the change in volume ΔV is calculated from the change in the liquid level in the glass tube Δl

$$\Delta V = \frac{di^2}{4} \cdot \pi \cdot \Delta l \quad (1)$$

The inner diameter d_i of the glass tube can be most exactly determined by filling it with water and weighing it (see experiment WT 1.5). A measurement gave a value of d_i = 0.576 cm.

The following relationship is given for the change in volume:

Water level change	corresponds to	volume change
Δl = 1 cm	≙	ΔV = 0,26 cm^3

The volume expansion is described by the following equation:

$$\Delta V = \gamma \cdot V_0 \cdot \Delta \vartheta \quad (2)$$

There V_0 is the initial volume and γ the coefficient of volume expansion. The coefficient of volume expansion is not constant for water, but temperature dependent. We shall determine it, for example, for the range between the initial temperature of 21.5°C and 30°C.

At the start of the experiment, the Erlenmeyer flask was filled with a total of 130 cm^3 of water. (The accuracy of this value suffices for this experiment; otherwise the volume must be determined by filling with water and weighing.)

The volume expansion coefficient for water (between 21.5°C and 30°C)

V_0 = 130 cm^3

$\Delta\vartheta$ = 8.5 K

ΔV = 0.34 cm^3

γ = 0.31·10^{-3} K^{-1}

The volume expansion coefficient for alcohol:

V_0 = 130 cm^3

$\Delta\vartheta$ = 23.5 K

ΔV = 3.84 cm^3

γ = 1.26·10^{-3} K^{-1}

ϑ / °C	γ / 10^{-3} K^{-1}
0	-0.07
10	-0.088
20	+0.207
30	+0.303
40	+0.385
50	+0.457
60	+0.523
70	+0.585

Table 3: Volume expansion coefficient for water

Values for the volume expansion coefficient for water found in the literature are given in table 3.

Note

Should you want to make more measurements with alcohol, e.g. to show that the volume expansion is linear with temperature, then the heating up in the water bath must be made stepwise. Remove the wire gauze holder and wire gauze so that the water bath can be hand-held under the Erlenmeyer flask. When the temperature has risen to 25°C, for example, then remove the water bath. The temperature will rise further to 30°C and the liquid level can be determined. Carry on similarly fur further values. This procedure is time-consuming, however, as some minutes must be waited for each measurement.