PHYWE excellence in science

Kinetic gas theory apparatus

09060.00

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Operating instructions

CE The unit complies with the corresponding EC guidelines.

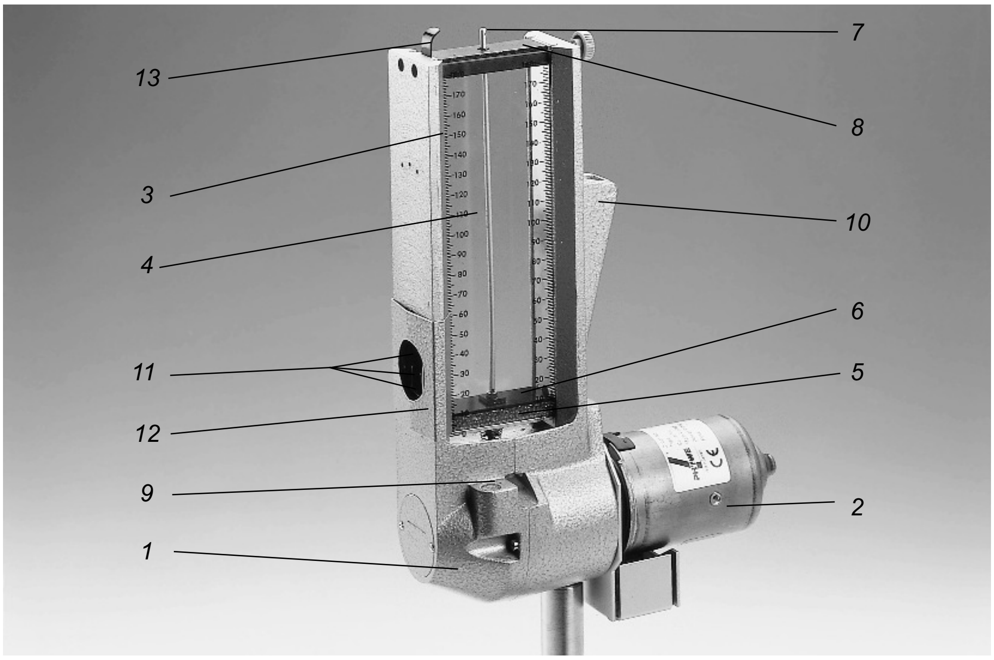


Fig. 1: Kinetic gas theory apparatus 09060.00.

1 SAFETY PRECAUTIONS

- Carefully read these operating instructions completly before operating this instrument. This is necessary to avoid damage to it, as well as for user-safety.
- Only use the instrument in dry rooms in which there is no risk of explosion.
- Do not start up this instrument in case of visible signs of damage to it.
- Only use the instrument for the purpose for which it was designed.

2 PURPOSE AND DESCRIPTION

The kinetic gas theory apparatus utilizes random movement of small balls or beads to demonstrate thermal effects on liquids and gases on a model basis.
It not only enables qualitative experiments on thermal movement, evaporation and distillation to be carried out on liquids, but also measurements of variations in density, and from these, a statistical examination and numerical representation of the barometric altitude formula and the pressure-volume law, for a model gas.
When the receiver with recording chamber or the plate with circular sectors (see the List of Equipment) is used, the distribution function for the velocity of particles of a model gas can be experimentally determined and, from this, the average energy calculated.
The model particles, steel balls or glass beads, are brought to random movement in a projectable chamber by an oscillating bottom plate, which can be oscillated at various frequencies. In this model, an increase in the oscillating requency of the bottom plate represents an increase in temperature of the particles.

3 FUNCTIONAL AND OPERATING ELEMENTS

The following functional and operating elements are to be seen in Fig. 1:

1 *Housing*
with incorporated cam drive and a solid grip which, together with the hollow grip supplied, allows height variation of the apparatus.

2 *Electric motor, 12 V-*

3 *Side walls of the chamber frame*

4 *Removable glass windows*
one of these has a 0...180 mm height scale for projection purposes.

5 *Bottom plate*
which can be oscillated at various frequencies by the cam drive.

6 *Covering plate*
whose height can be varied by means of the guide rod (7).

7 *Guide rod for the covering plate*
The outer end of the rod has a ring and a bored hole. The ring allows the loading of weights. The boring allows a silk thread to be attached, so that a dynamometer can be connected for the continuous measurement of the pressure forces acting on the covering plate.

8 *Sealing piece*
with a hole through which the guide rod runs, and a milled screw for fixing the position of the guide rod.

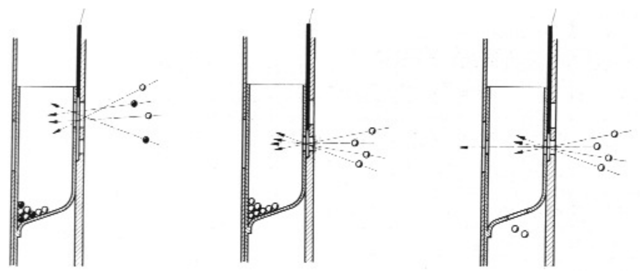
9 *Level indicator*
or checking that the chamber is positioned vertically, as required.

10 *Filling funnel*
with low level inlet, for filling the steel balls or glass beads into the chamber.

11 *3 circular side outlets*
of different diameters. The closing bar (*13*), which can be moved to any one of three set positions, enables the top outlet (diameter 10 mm) to be opened or closed alone, or together with the middle outlet (5 mm). The bottom outlet (7 mm) is at the same height as the inlet of the filling funnel on the opposite side.

12 *Holding piece*
with slit, for holding a trapping or filter chamber.

13 *Closing bar*
with which the outlet openings can be opened or closed.



a) Trapping chamber I b) Trapping chamber II c) Filter chamber III

Fig. 2: Various Chambers.

Fig. 2 shows the various available chambers. Trapping chamber I has, on the side which fits onto the holding piece of the apparatus, an opening of the same diameter and at the same height as the top outlet from the apparatus chamber. Trapping chamber II has an opening which matches the middle outlet from the apparatus chamber. The filter chamber also has an opening which matches the middle outlet, but, in addition to this, an outlet slit on the opposite side and a circular hole in the base.

4 HANDLING

4.1 Preparing for use

Use the rod supplied to mount the basic apparatus on a tripod base with leveling feet, placed on a noise reducing mat, and adjust the apparatus to the vertical position. When, as in most cases, one of the two trapping chambers supplied is to be used, draw up the holding piece, fit on the trapping chamber and set the closing bar so that the apparatus chamber and the trapping chamber are closed off from each other.
Prior to the first filling, we recommend that the balls or beads be cleaned in lukewarm water containing a little detergent and subsequently well dried.
The operating voltage for the electric motor is supplied by an adjustable transformer with rectifier. The connecting cord should not be longer than 1 meter. Adjust the required motor revs, and the oscillating frequency of the bottom plate which is dependant on them, by means of the operating voltage. If necessary, measure the oscillating frequency with a stroboscope. To do this, illuminate the bottom plate with the stroboscope, set the flashing frequency, for example, to 50 Hz (3.000/min), and slowly increase the motor revs. When the motor reaches the frequency set on the stroboscope, the illuminated bottom plate appears to be standing still, or, at a slight difference, to move slowly up and down.

4.2 Filling and emptying

When the model is to be used to represent liquids, then 1000 to 2000 beads/balls are to be used, according to the experiment. A filling of 400 beads/balls has been found to be optimal when properties of gases are to be simulated. Instead of counting the beads/balls out, first determine the mass of 100 beads (and of 100 balls) by weighing them, and subsequently use appropriate masses of them. The accuracy achieved in this way is sufficient for all experiments.
We recommend that a few test tubes, each containing 200 or 400 beads/balls, be prepared and kept ready for use. In experiments on velocity distribution, the number of beads/balls which are forced out (about 45 per minute) must be re-added to maintain starting conditions. Here also, prepare the necessary number of test tubes (about 10) containing the corresponding number of beads/balls.
Filling of the beads/balls is best done by adding them through the filling funnel with the motor running. To completely empty the chamber, and to collect the beads/balls in a beaker, tilt the basic apparatus a little and slide up the glass window on the side of the bottom groove.

5 EXPERIMENTS

5.1 Visualizing distillation

To realize a model of a mixture of two liquids, fill 1000 glass beads and 1000 steel balls into the chamber, after a trapping chamber of type I has been attached to the side of the chamber, the closing bar so positioned that the two chambers are closed off from each other, and the covering plate drawn right up. Slowly increase the frequency of the oscillating bottom plate up to 3000/min. An increase in the thermal movement , and so an increase in temperature, is to be observed. Now open up the hole to the trapping chamber (see Fig. 2a). The glass beads, having the lower „molecular weight“, preferentially „distil“ into the trapping chamber.

5.2 Barometric altitude formula

Fill the chamber with 400 steel balls and set an oscillating frequency of 3000/min. Position the movable covering plate to a low height (about 6 cm). The moving balls appear to be evenly distributed within the available volume. Now position the covering plate to the maximum height. It can be clearly seen, that because of the unavoidable influence of the earth's gravitational field, the density decreases with increasing height. With the help of a forked light barrier and a counter, for example, at constant frequency, the number of particles n at the position h above the bottom in a time unit and a spatial unit can be determined, and from this the barometric altitude formula experimentally verified for the model gas.

$$n = n_0 \cdot e^{-\frac{mg(h-h_0)}{kT}}$$

(m = particle mass; n and n_0 = number of particles at the

height h and h_0 respectively; g = acceleration from gravity; k = the Boltzmann constant and T = temperature).
As the probability of multiple beads/balls passage just above the vibrating plate is very high, we recommend that measurements are first started at about 3 cm above it.

5.3 Velocity distribution in the model gas

Fit the filter chamber in position, fill the chamber with 400 glass beads, adjust the chamber height to 6 cm and set the oscillating frequency to 3000/min.
Only those beads whose velocity vector is horizontal, or at a slight angle to this, can now pass through the filter chamber to the outside (see Fig. 2c). All other beads which enter the filter chamber are caught and led back to the chamber via the base hole.
The emergent beads closely realize a horizontal throw, whereby the distance thrown is a measure of the velocity c of the beads. The beads are collected on a horizontal surface at a height h below the outlet from which they emerged. From the distance thrown s and the dropping height h:

$$c = \frac{s}{t} = s\sqrt{\frac{g}{2h}}$$

Count the beads at each interval (c, $c + \Delta c$) to obtain a distribution function of the velocity.

a When using the plate with circular sectors (see List of Equipment and Fig. 3), use a brush to cover the plate with an approximately 1 mm thick layer of water soluble adhesive. Position the plate horizontally, exactly touching the wall of the filter chamber and 80 mm below the outlet slit of the filter chamber. Open the closing bar and start a stopwatch. Fill 45 beads into the filling funnel after each minute. Stop the experiment when there is no more room for emergent beads on the plate.
The concentric sectors on the plate generate neighbouring divided areas on which beads whose velocity is between $c + c$ stick. Count the number of beads in each sector and plot them against the distances thrown. The resulting curve should correspond to Maxwell's distribution function.

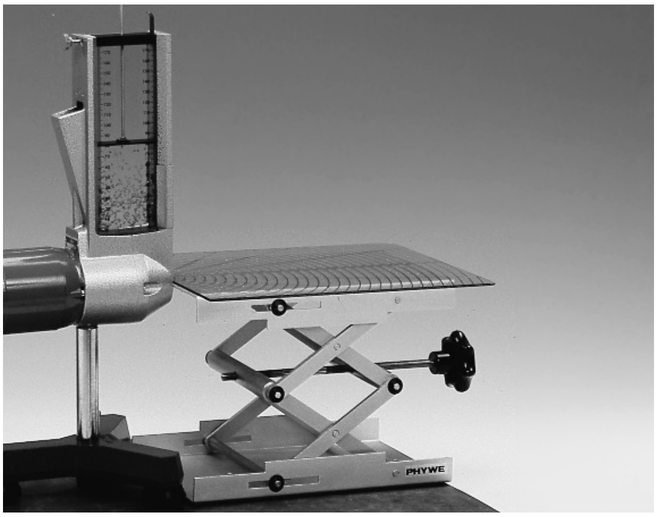


Fig. 3: Plate with circular sectors 09062.00.

b The receiver with recording chamber (see List of Equipment and Fig. 4) can be used for the determination of the distance thrown, instead of the the plate with circular sectors. With the help of the tripod base and the level indicator, adjust the recording chamber so that it is horizontal. The difference in height between the outlet slit of the filter chamber and the top of the collector must again be 80 mm. The further experimental conditions are

Fig. 4: Experimental set-up.

as in 5.3 a.
At the end of the experiment, the heights of the layers of beads collected in the individual cells of the chamber show a stepped curve, which can be graphically approximated using a constant function, so that a comparison with Maxwell's distribution function can again be made.

5.4 Model experiment on Boyle's law

Fill the chamber with approx. 400 glass beads and leave the covering plate freely movable. This results in a burdening of the gas. The change in the impulses of all the beads which hit the underside of the covering plate in time is then the cause of the pressure of the model gas. When the external pressure on the gas is increased by the addition of pieces of mass, then a decrease in volume is seen. On increasing the oscillating frequency, which corresponds to an increase in temperature in the model, then an increase in volume at constant pressure occurs. Further to this, on additionally increasing the burden on the covering plate, the case of a pressure increase in a gas at constant volume under increasing temperature can be demonstrated.

5.5 Compensation and decay processes in model experiments

Trapping chamber II can be used to examine how many beads leave the chamber within a certain time after opening the locking bolt. The *n*-*t*- values determined here give the course of a logarithmic curve,

$$n = n_0(1 - e^{-kt})$$

which, for example, describes temperature compensation in the form of Newton's law of cooling or the behaviour of potential over time on charging a condenser.
On the other hand, with the number $N = n_0 - n$ of the glass beads still in the chamber after the time t, the equation

$$N = N_0 e^{-kt}$$

can be verified, with which, for example, the course of radioactive decay with time or the discharging of a condenser can be described.

6 RECOMMENDED LITERATURE

Handbook Laboratory Experiments Physics	16502.32
Laboratory Experiments Chemistry	16504.12

7 LIST OF EQUIPMENT

Kinetic gas theory apparatus incl. 4 trapping and 1 filter chambers 1000 steel balls, 10000 glass beads	09060.00
Plate with circular sectors incl. 2 bags of cold adhesive	09062.00
Receiver with recording chamber	09061.00
Power supply var.15 VAC/12 VDC/5 A	13530.93
Tripod base -PASS-	(2 x) 02002.55
Digital stroboscope	21809.93
Lab jack, 200 x 230 mm	02074.01
Light barrier, compact	11207.20
Digital counter, 4 decades	13600.93

Replacement materials

Steel balls, d = 2 mm, 1000 pcs	09060.02
Glass beads, d = 2 mm, 10000 pcs	09060.01

8 NOTES ON OPERATION

This high-quality instrument fulfills all of the technical requirements that are compiled in current EC guidelines. The characteristics of this product qualify it for the CE mark.
This instrument is only to be put into operation under specialist supervision in a controlled electromagnetic environment in research, educational and training facilities (schools, universities, institutes and laboratories).

9 TECHNICAL SPECIFICATIONS

Flat chamber	(60 x 180 x 20) mm
Max. operating voltage	15 V-
Current required	approx. 1.3 A
Steel balls	d = 2 mm ±0.08 mm
Glass beads	d = 2 mm ±0.2 mm
Plate with circular sectors	(230 x 300 x 3) mm
Weight	0.54 kg
Receiver with recording chamber	(240 x 5 x 120) mm
Weight	2.4 kg

10 NOTES ON THE GUARANTEE

We guarantee the instrument supplied by us for a period of 24 months within the EU, or for 12 months outside of the EU. Excepted from the guarantee are damages that result from disregarding the Operating Instructions, from improper handling of the instrument or from natural wear.
The manufacturer can only be held responsible for the function and technical safety characteristics of the instrument, when maintenance, repairs and alterations to the instrument are only carried out by the manufacturer or by personnel who have been explicitly authorized by him to do so.

11 WASTE DISPOSAL

The packaging consists predominately of environmentally compatible materials that can be passed on for disposal by the local recycling service.

Should you no longer require this product, do not dispose of it with the household refuse. Please return it to the address below for proper waste disposal.

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