Flammersfeld Oscillator

Thermal Physics and Statistical Mechanics

Operating Instructions

Never Stand Still | Science | School of Physics

Table of Contents

1 Safety

The experiment implies using of compressed gases. Follow the steps described below. Experimental equipment also contains fragile glass volumes. Be careful using them.

1.1 Personal safety

During the experiment it is your responsibility to observe safety rules.

1.2 Responsible equipment use

- Keep any part of equipment well clear from the edge of the table so that they can't fall on the floor.
- Do not look at the emitter of light counter. The optical path is composed of non-visible infrared radiation.

2 Operating instructions

Please read the Student Notes (SN) before you start these instructions. It is assumed that you are familiar with the aims and physics behind this experiment. Figure 1 shows a view of the actual setup for the full experiment. Below we will talk about how to put things together in a way that works properly.

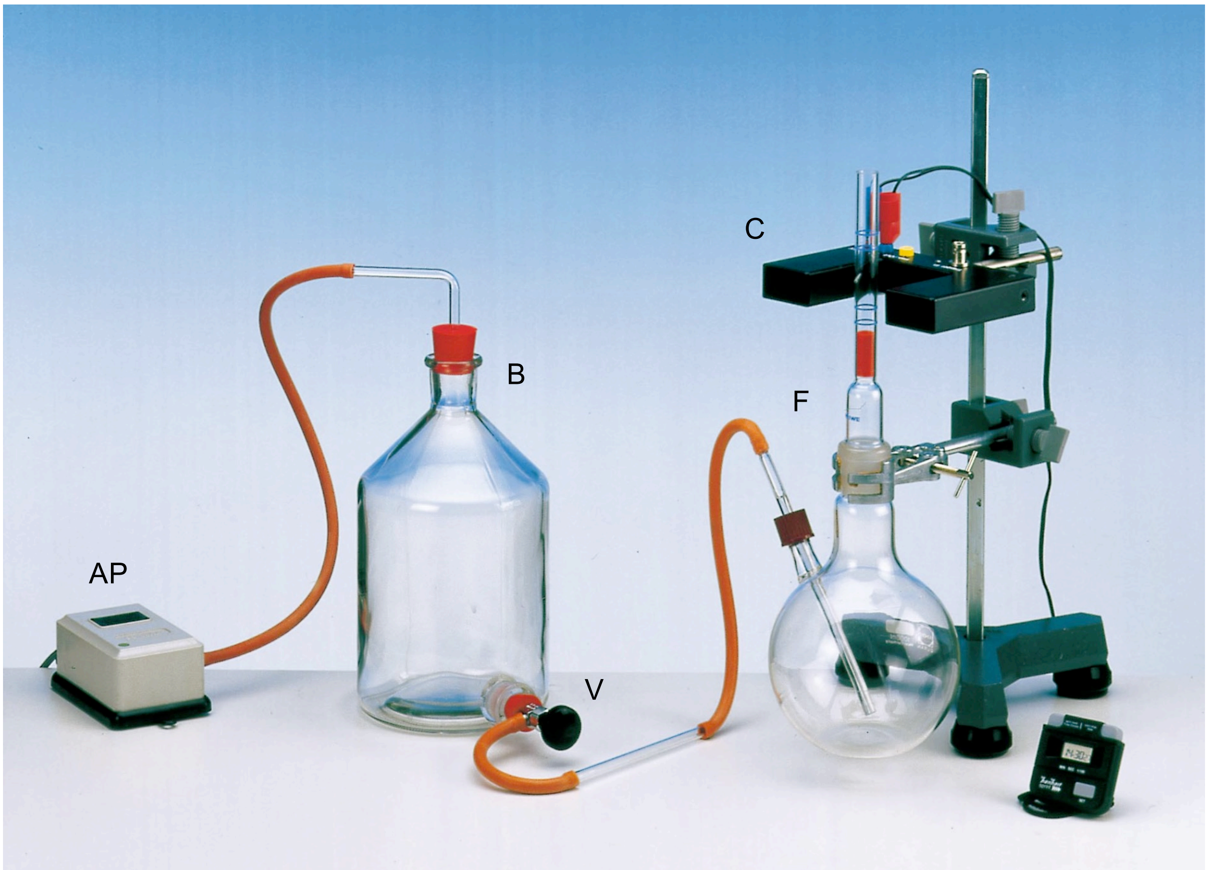

Figure 1. Complete Flammersfeld setup. AP stands for aquarium pump, B stands for aspirator bottle, V stands for air control valve, C stands for light counter, F stands for Flammersfeld oscillator.

2.1 Idea of the experiment

The simplest setup is described in the Student Notes. You just need a corked bottle of gas with sufficiently long narrow neck. Hitting the cork will initiate its oscillations and the period of oscillations is used to determine the adiabatic coefficient of the gas. However, we need our measurements be very precise here. In other words, we require many oscillations (up to 300) to measure the period reliably. Of course, this simple setup does not allow us precise measurements because of damping of oscillations. In order to overcome this issue, we use the neck with a little hole and let the gas flow through the bottle slowly. Until the cork blocks the hole, it ascends by the flow that pushes it up. At some moment the cork will get higher than the hole and the pressure in the bottle will equalize with the atmospheric pressure. It will lead to a fall of the cork back. Then the pressure gets higher and the process repeats. This is the auto-oscillation regime. In principle, the finite flow of gas can slightly change the period of oscillations. There are two important points here: 1) the equilibration time of the pressure inside and outside the bottle when the hole is open is much smaller than the oscillation period; 2) the flow of gas is sufficiently small. One can show explicitly that this correction to Eq. (2.8) is vanishing for diatomic gases for any reasonable flow but somewhat important for CO_2. Even though this question is far beyond this simple experiment, try to make the CO_2 flow as small as possible.

2.2 Plan of the experiment

In this section we divide the work into set of several simple steps.

1. You have to perform the experiment for three different gases, namely air, nitrogen N_2 and carbon dioxide CO_2.

2. In all three cases you will measure the period of Flammersfeld oscillator. According to Eq. (2.8) in the Student Notes (SN), it will allow you to calculate adiabatic constants of these gases.
3. After that you will compare your results with theoretical prediction, Eq. (2.9) in SN.
4. The second part of this work is to determine the bending vibration excitation energy for CO_2 molecules. In order to do this, you calculate the difference in the heat capacity using just measured value of the adiabatic constant, Eq. (2.15) in SN.
5. Then you address this difference to vibrational modes of CO_2 (namely, to two-fold degenerate bending modes). Using Fig. 3 of SN, you find the corresponding value of $z = \hbar\omega/T$. Multiplying z on the laboratory temperature expressed in Kelvins, we get the experimental value of the excitation energy $\hbar\omega$ of bending vibrational mode of CO_2.

2.3 Instructions for the experiments

With air

Let us consider the air experiment in detail. Most things will be already connected before you start the lab. The only thing you will have to connect is the aspirator bottle (B), see Fig. 1, with the aquarium pump (AP) for the air experiment or gas lines (Fig. 2) for CO_2 or N_2 experiments. After you connected AP to B, plug the light counter (C) in the power socket. Do not change the position of the "count" button. In order to start the counter, just push the "set" button. In order to stop or reset it back to zero, push this button again. This is the only button of the counter you have to use. Now you are ready for the experiment:

1. The bottle neck is a cylinder with a hole. Adjust the counter emitter in such a way that the optical path crosses the bottle neck and the height of the emitter is of the same level as the hole. It will already be adjusted before you start the experiment but you need to check it anyway.
2. The oscillator (red cylinder) can be initially inserted in the bottle neck.
3. Plug the aquarium pump (AP) into the power socket. AP does not have any buttons, it will start working right after you plug it in. In order to turn it off, you have to plug it out.
4. Adjust the valve (V) in order to get the right air flow to the Flammersfeld bottle (F). If the flow is too intense, the cylinder cork will jump out of the bottle F. So, adjust the flow in order to get steady oscillations.
5. Press the "set" button of the counter. You will see increasing number of counted oscillations on the display. Use stopwatch to measure the time of 300 oscillations.
6. Repeat the Step 5 three times.
7. Unplug the AP.

With Nitrogen and Carbon Dioxide

Nitrogen and Carbon Dioxide are supplied from the gas cylinders which are kept outside the building. The regulators in the lab allow to set up the pressure of the gases entering the experimental apparatus. To select a gas (N_2 or CO_2), the two gas lines have been connected to the Flammersfeld oscillator apparatus via a two-way the selector valve (T-piece tubing with a large black valve that has an arrow head on one side). Point the black arrow of the valve towards the desired gas inlet. If the arrow on the valve points at your direction the valve is closed.

Before starting the experiment check that the pressure gauges of the regulators for N_2 and CO_2 read zero. If that is not a case, you have to open the selector valve and release the residual pressure and ensure that the regulator knob is turned fully anticlockwise (do not force the knob when it reaches the limit position).

When measuring the adiabatic constants of N_2 and CO_2, you first have to connect the aspirator bottle to the gas line (Figure 2).

In order to adjust the right pressure, follow the steps:

1. Select a gas using the gas selector valve.
2. Close gently the fine control valve and then open it (anticlockwise) again by 1/4-1/2 a turn.
3. Close completely the aspirator bottle valve **(do not apply excessive force!)** and open it again anticlockwise by 3-5 turns**.**
4. Put the red oscillator cylinder into the bottle F.
5. Rotate the gas regulator knob slowly (clockwise), observing the oscillator, and stop rotating when the oscillator starts to go up. Adjust gas flow in a way to get steady oscillations by slowly adjusting the aspirator bottle valve.
6. Let a gas to flow for about 10 minutes making sure that there is no previous gas left in the system.
7. Measure the duration of 300 oscillations, repeat as required.
8. When you finish the experiment, please reduce the pressure, turning the regulator knob slowly (anticlockwise). **Do not force the knob when it reaches the limit position.** Wait until the pressure drops to 0 and close the selector valve, turning it perpendicularly with the arrow pointing at you.

Figure 2. Connections to the gas lines

After that you perform the experiment with CO_2 following the same steps.

You will need the physical parameters of your experimental apparatus. Use the sliding weight balance to measure the oscillator's mass. Record the atmospheric pressure with the aneroid barometer. Register the laboratory temperature.

For everybody's convenience, the flask volume is pre-given: $V = 1.155$ L, and the oscillator's radius is $5.95 \cdot 10^{-3}$m

The actual value of the activation energy of bending vibrations: $\hbar\omega = 960$ K.

Now you have a complete data set to get a result.