

## Experiment C-30 Boyle's Law



### Objectives

- To study the behavior of ideal gases.
- To investigate the relationship between volume and pressure according to Boyle's law.

### Modules and Sensors

- PC + NeuLog application
- USB-200 module 
- NUL-210 Pressure logger sensor 

### Equipment and Accessories

- 50 ml syringe
- The syringe is included in the NeuLog Utility accessories, UTL-KIT.

## Introduction

An ideal gas can be characterized by three parameters: pressure, volume and temperature, for a certain amount of gas. The law that shows the relationship between these factors is called the **Ideal Gas Law:  $PV = nRT$**  where **P** is the pressure of the gas (in atm units), **V** is its volume (in L units), **n** is the number of moles (one mol= $6.022 \times 10^{23}$  molecules), **R** is the gas constant (atm\*L)/(mol\*K) and **T** is its temperature (in K units).

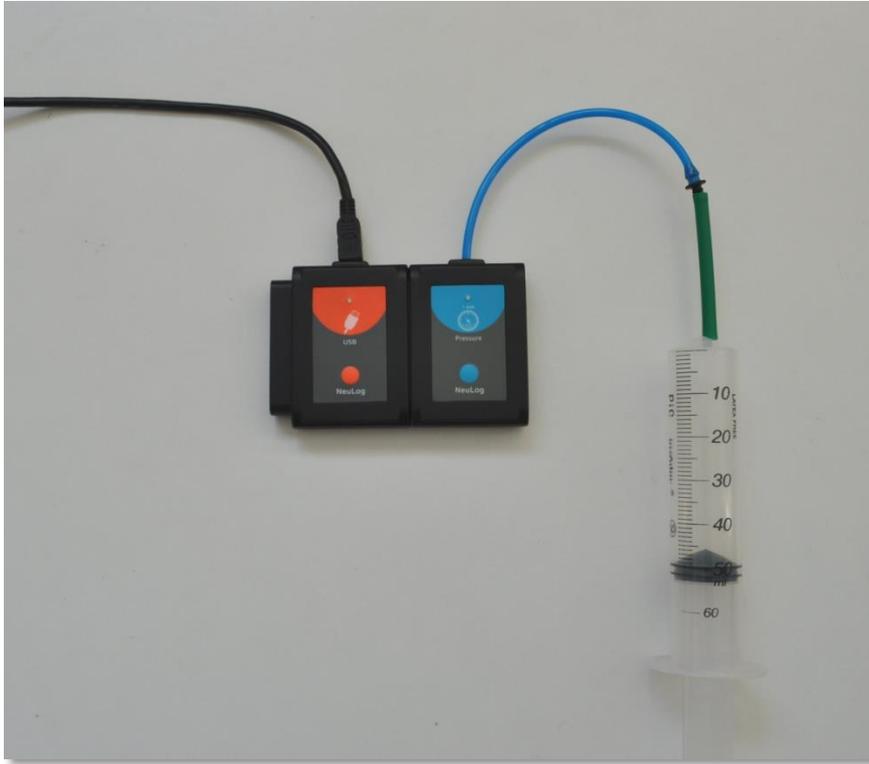
**Boyle's law** states that the volume and pressure of a gas with a constant temperature (and amount), are inversely proportional to each other. In these conditions  **$PV=k$**  or  **$P_1V_1 = P_2V_2$**  ( $nRT$  is constant). According to this equation, when the pressure increases the volume decreases, and when the volume increases the pressure decreases.

In this activity, we will change the volume of the air inside a syringe in order to measure how it affects its pressure (in kPa).

## Procedure

### Experiment setup

1. Set up the experiment as shown in the picture below.



2. Pull the syringe's plunger up to the 50 ml position and tightly connect the syringe to the sensor using the adaptor tube.

### Sensor setup

3. Connect the USB-200 module  to the PC.
4. Check that the pressure sensor  is connected to the USB-200 module.

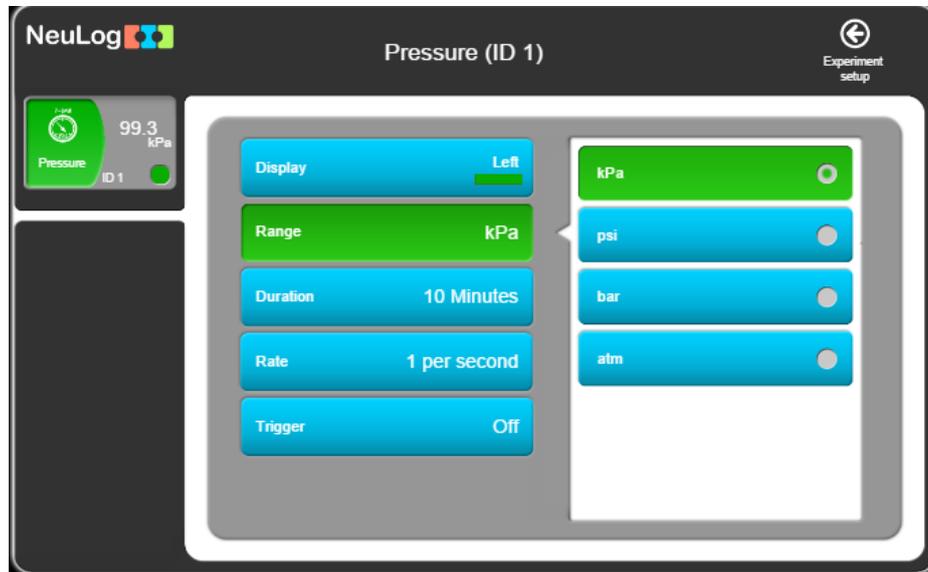
#### Note:

The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

5. Run the NeuLog application and check that the pressure sensor is identified.

## Settings

6. Click on the pressure **sensor's module** box.
7. Select the kPa button to set the sensor's mode.



8. Click on the  icon to go back to the graph.
9. This experiment is done in single step mode so the experiment duration and sample rate will not be set.

## Testing and measurements

10. Make sure there is no air leakage; press on the syringe's plunger, the plunger should go back to the initial location.
11. Click on the **Single Step** icon  and measure the initial pressure (at the 50 ml position).
12. Click on the **Table** icon  on the bottom part of the screen. A table will be displayed for data record.
13. Press the syringe's plunger to the 45 ml position, hold it there and click again on the **Single Step** icon . If possible, one student should press the plunger while the other clicks on the **Single Step** icon  each time.
14. Continue with the measurements according to the following table:

Measurement number	Volume [ml]
1	50
2	45
3	40
4	35
5	30

15. Click on the **Manual values** icon  and insert “Volume” for the Column name and “ml” for the Units.

Add a manual values column

Column name:  
Volume

Axis maximum:  
100

Axis minimum:  
0

Units:  
ml

Cancel Add

16. Insert each relevant volume in the "Volume [ml]" column (50, 45, etc.)
17. Your data should be similar to the following:

NeuLog  Freeze Single step

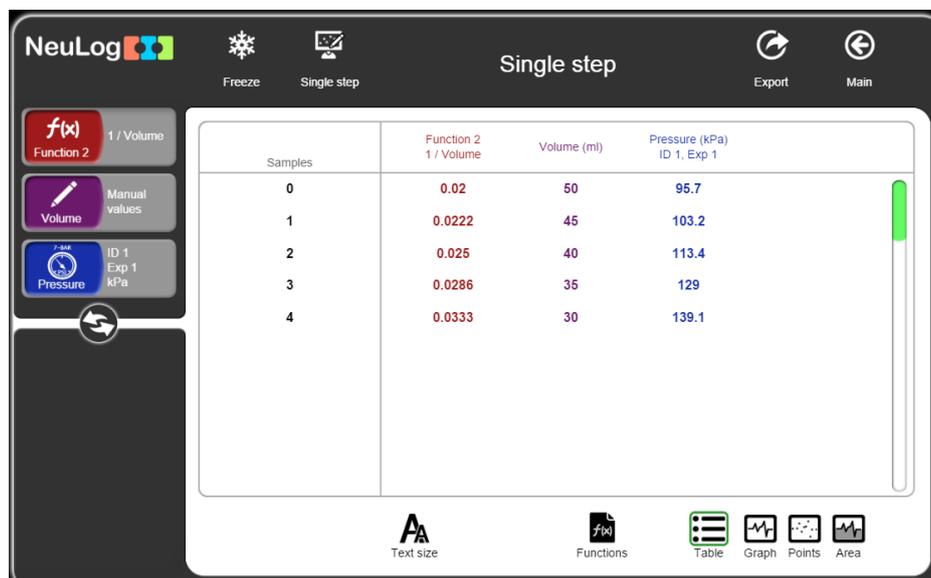
Manual values  
Volume

7-BAR ID 1 Exp 1  
Pressure kPa

Samples	Volume (ml)	Pressure (kPa) ID 1, Exp 1
0	50	95.7
1	45	103.2
2	40	113.4
3	35	129
4	30	139.1

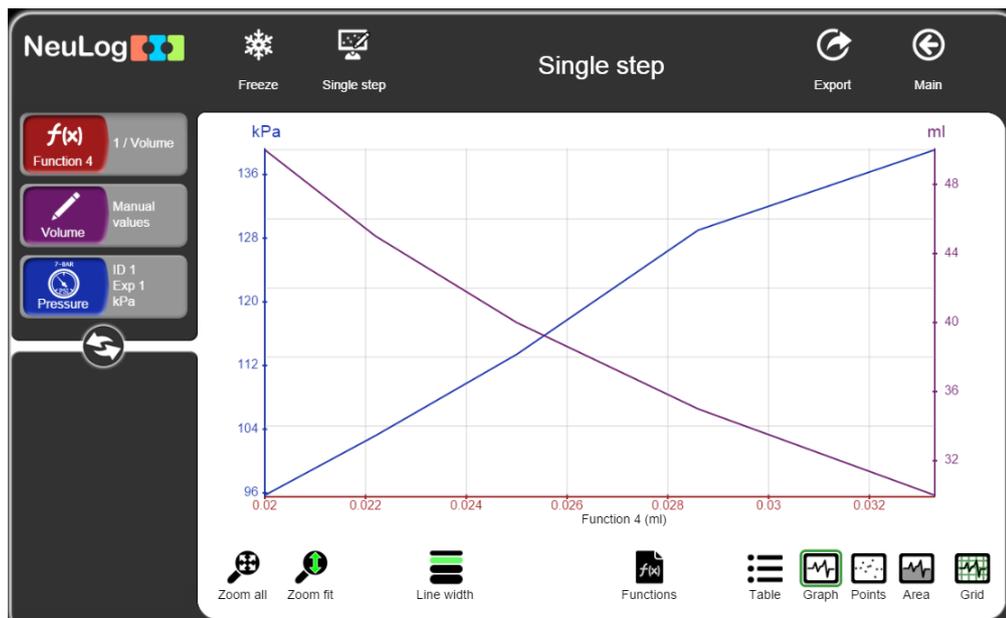
18. Click on the **Export** Icon  and then on the **Save value table (.CSV)** button to save your graph.
19. Click on the  icon to go back to the table.
20. We can see that the pressure increases as the volume decreases.

21. In order to investigate the relationship between volume and pressure, click on the **Functions** icon  and choose Volume as parameter **A**. Click on the **Functions** button and choose the  $1/A$  function.
22. A '1/Volume' column should appear in your table.



23. Click on the **Functions** icon , click on the X axis button and choose the function (1/A) as the X axis.
24. Click on the  icon to go back to the table.
25. Click on the **Graph** icon .
26. Click on the **Zoom fit** icon .

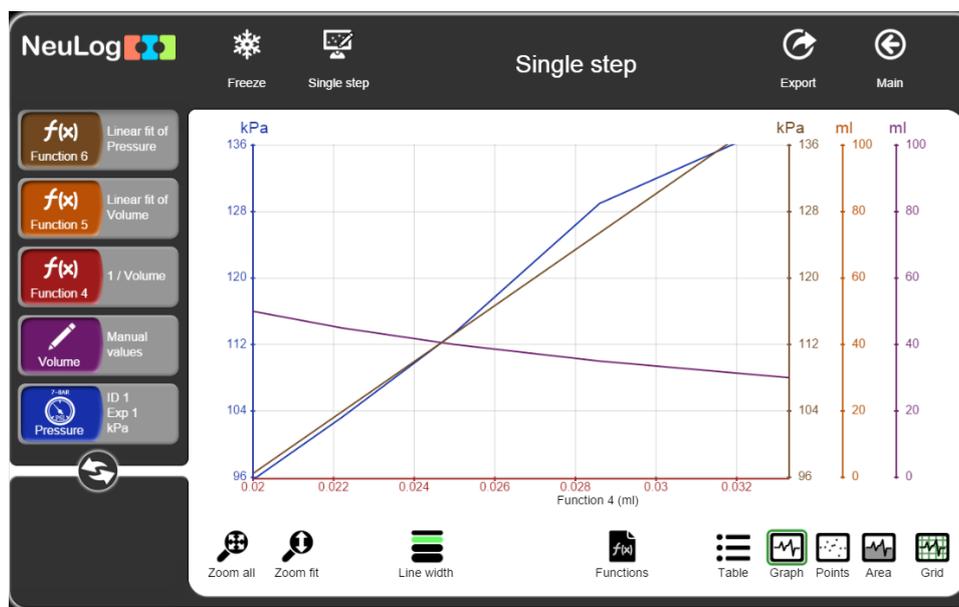
27. Your graph should be similar to the following:



28. Click on the **Functions** icon  and choose **Pressure** as parameter A.

29. Click on the **Functions** button and choose **Linear fit of A**.

30. Your graph should be similar to the following:



31. Click on the module box **Linear fit of Pressure** to see the equation.

Linear fit of Pressure  
3373.2933X+28.9816

32. After replacing  $x$  and  $y$  with  $1/V$  and  $P$ , we get the following equation (we neglect the  $b$  part of the equation):

$$P = 3373 \text{ kPa} * ml / V$$

or

$$P * V = 3373 \text{ kPa} * ml$$

### Challenge research

33. Repeat the experiment, but now start with placing the syringe's plunger at the 30 ml position and pull it towards the 50 ml position.

### Summary questions

34. Did the pressure values increase or decrease during the challenge experiment? Explain.
35. Point out whether it became more or less difficult to push the plunger in the first experiment? What about pulling the plunger in the challenge experiment? Explain.
36. What are the two other laws derived from the ideal gas law? Which experiments would you conduct for studying these laws?