

<b>FOCUS</b>	CHEMISTRY
<b>KNOWLEDGE AREA</b>	MATTER AND MATERIALS
<b>TOPIC</b>	7 Ideal gases and thermal properties
<b>SUBTOPIC</b>	7.2 Ideal gas law
<b>NAME OF ASSET</b>	7.2.2 Investigate the relationships between pressure, volume and temperature for a fixed amount of gas

<b>TYPE OF ASSET</b>	SIMULATION: Change parameters and observe
<b>SUBTYPE</b>	4P1E
<b>OBJECTIVE</b>	Use sliders to choose a fixed amount of gas and then investigate the relationships between pressure, volume and temperature.

**SUBHEADING:** Choose a fixed amount of gas. Then use the sliders to investigate the relationships between pressure, volume and temperature.

## TEXT FOR BUTTONS

### Instructions

1. Choose a fixed AMOUNT OF GAS by dragging the slider.
2. Observe the PRESSURE, TEMPERATURE and VOLUME of the enclosed gas.
3. Click the lock to keep one variable constant.
4. Drag the sliders to change one of the other variables.
5. Observe the effect on the last variable.
6. Click the reset button to start again.
7. Click on the name of a law to see its formulation.

## USER INTERACTION

- Please use graphics that look sophisticated. Use 3D look if at all possible.
- Apparatus:
  - Container with gas particles inside.
  - Some kind of pressure meter attached to the container. It is not necessary that the user takes readings from the meter. The needle of the meter must just move as the pressure changes.
  - Gas particles can be represented by spheres – they do not have to look like the molecules of a specific gas.
  - The volume of the container must be able to change with the clamp is released. With the clamp is pressed, the volume will NOT change.
- The gas particles must move constantly throughout the simulation. The speed of the motion depends ONLY on the temperature.
- Next to the container, must be three spaces. As values change, the correct readings must be shown in the blanks. The correct units are very important. Something like this:  
 Pressure: [BLANK] Pa  
 Volume: [BLANK] m<sup>3</sup>

Temperature: [BLANK] K

- There must be FOUR sliders that the user can use to change the variables. Show the correct units clearly on the sliders.

AMOUNT OF GAS [Unit:]mol

To make things less complicated, maybe just allow for four fixed choices here, e.g. 0,5 mol, 1 mol, 1,5 mol and 2 mol. Each sphere in the container must represent a specific number of particles and this must be kept constant throughout the simulation. The visual shows the number of particles for 1 mol to be around 40. For 0,5 mol the number of particles should be 20, for 1,5 mol the number of particles should be 60 and for 2,0 mol the number of particles should be 80 particles. **This works as a master slider. It will NOT change when the other 3 sliders are changed.**

**One of the following three variables MUST be fixed before the user can investigate the effect of the second variable on the third variable. When the simulation loads, the TEMPERATURE variable is fixed by default. This is shown as a lock next to the slider with the temperature value highlighted clearly, and the slider disabled to show that it can't be changed. The user can unlock the TEMPERATURE slider by clicking one of the open locks next to the other 2 sliders to fix one of them instead. When the VOLUME variable is fixed, the clamp in the visual must be pressed. When a different variable is fixed, the clamp in the visual must be released.**

PRESSURE [Unit:]Pa

The user must be able to drag the slider up and down to increase or decrease the pressure. When this is done, the temperature OR the volume changes accordingly, based on which one of them has been fixed.

TEMPERATURE [Unit:]K

The user must be able to drag the slider up and down to increase or decrease the temperature. When this is done, the pressure OR the volume changes accordingly, based on which one of them has been fixed.

VOLUME [Unit:]m<sup>3</sup>

The user must be able to drag the slider up and down to increase or decrease the volume. When this is done, the pressure OR the temperature changes accordingly, based on which one of them has been fixed.

- When the simulation loads, show a prompt message: *“One of the three variables pressure, volume and temperature must be kept constant. Click a lock to keep that variable constant.”*
- Default values: Use the following as default values, i.e. they stay as is, unless the user changes them.  
 $p = 1 \times 10^5 \text{ Pa}$   
 $V = 0,023 \text{ m}^3$  [Exact calculated value is 0,022698585 m<sup>3</sup>]  
 $n = 1 \text{ mol}$   
 $T = 273 \text{ K}$

- From the default values, the user must be able to choose higher and lower values for any variable. Include as big a range as possible for pressure, volume and temperature.
- As soon as one variable (among  $p$ ,  $V$  and  $T$ ) is changed with the second variable FIXED, the third must immediately change accordingly. Use  $pV = nRT$  with  $R = 8,3145$  to calculate the corresponding values.
- The displayed values in the three boxes in response to change in any variable must be rounded values (2 decimal places for  $p$ , 3 decimal places for  $V$ , 0 decimal places for  $T$ ) whereas the actual calculated position of the slider buttons must be accurate.
- The user can set values for the different variables through sliders only at the marked values (whether labelled or not) within the **active range**.

Variable	Active range of slider	Increments	Note	Extended range of slider values
Amount of gas (mol)	0,5 to 2	0,5	This is a master slider	0,5 to 2
$p$ (Pa)	$1 \times 10^5$ to $4 \times 10^5$	$0,5 \times 10^5$	The user cannot set this variable below $1 \times 10^5$ or above $4 \times 10^5$ on the slider but the position on the slider <b>can be lower</b> than $1 \times 10^5$ or <b>higher than</b> $4 \times 10^5$ on the slider based on the calculated value by setting the other variables.	$0,5 \times 10^5$ to $5 \times 10^5$
$V$ (m <sup>3</sup> )	0,005 to 0,050	0,005	The user cannot set this variable below 0,005 or above 0,050 on the slider but the position on the slider <b>can be lower</b> than 0,005 or <b>higher than</b> 0,050 on the slider based on the calculated value by setting the other variables.	0,000 to 0,055
$T$ (K)	243 to 303	10	The user cannot set this variable below 243 or above 303 on the slider but the position on the slider <b>can be lower</b> than 243 or <b>higher than</b> 303 on the slider based on the calculated value by setting the other variables.	233 to 313

- The range of the slider given in the above table is the **active range** which the user can change. However, there should be values on either side as per “**Extended range of slider**” in order for the calculated values to be set through code.
- The user can change the values on each of the sliders to the nearest increment. If the user leaves a slider button in between 2 increments, the slider button will jump to the nearest increment.
- If a slider button position is in the extended portion of the range and the user tries to change it, the button will jump to the nearest marked position in the active range. So, all values of variables set by the user will always be in the active range.
- When a slider has been fixed by clicking on the lock, the scale above the slider will turn grey and the slider button will be disabled (both look and function). **There must be a red line on the slider scale at the exact value where the slider button is positioned and the text value corresponding to the red line above the slider scale must be in black.**
- **If a variable calculated in response to another variable is then fixed by the user by clicking the lock, there must be a red line on the slider scale at the exact value where the slider button is position but no value needs to be made black.**
- **When the AMOUNT OF GAS slider is changed, the “Fixed” variable (among  $p$ ,  $V$  and  $T$ ) will stay “Fixed” and one of the other 2 variables should stay the same value on the slider to calculate the last variable and reset its position. For this, use the order  $p > T > V$  to set a slider value and calculate the other value.**
  - If  $T$  has been fixed and the user then increases the AMOUNT OF GAS, keep the  $p$  slider the same and increase the  $V$ , both on the slider and the calculated value. The visual should also respond to it by increasing the  $V$ .
  - If  $p$  has been fixed and the user then increases the AMOUNT OF GAS, keep the  $T$  slider the same and increase the  $V$ , both on the slider and the calculated value. The visual should also respond to it by increasing the  $V$ .
  - If  $V$  has been fixed and the user then increases the AMOUNT OF GAS, keep the  $p$  slider the same and decrease the  $T$ , both on the slider and the calculated value. The visual should also respond to it by decreasing the  $T$  and the gas particles should move slower.
- Refer to the excel document for the different values of  $p$ ,  $V$  and  $T$  and the calculation.
- Visual effects:
 

Amount of mol changes – number of spheres in container must change accordingly (one other variable will also change accordingly); number of particles represented by one sphere must be fixed

Temperature changes –needle of thermometer must move accordingly; gas particles must move faster (increase) or slower (decrease)

Volume changes – size of the container must change accordingly

Pressure changes – needle of pressure meter must move accordingly
- Reset button must allow user to start over.
- Somewhere on the screen must be the following buttons. The user must be able to click on any button any time and then see the text given below.

[BUTTON] Boyle's Law [Text] The volume occupied by an enclosed gas at a constant temperature is inversely proportional to its pressure:  $pV = k$

[BUTTON] Charles' Law [Text] The volume occupied by an enclosed gas at a constant pressure is directly proportional to its kelvin temperature:  $\frac{V}{T} = k$

[BUTTON] Guy Lussac's Law [Text] The pressure of an enclosed gas that occupies a fixed volume is directly proportional to its kelvin temperature:  $\frac{p}{T} = k$