# A Guide to Ideal Gases

## Teaching Approach

This section builds on an understanding of phases and properties of matter and their microscopic explanation using kinetic theory. This is revised in lesson 1. The relationships between these various properties are discussed in lessons 2-5. For each relationship, both conceptual, and practical, approaches are used. For the relationship between temperature and volume, as summarised by Charles' Law (lesson 6), both conceptual and practical approaches are covered in a single lesson. For the other relationships, separate lessons are assigned to each approach. These relationships are summarised mathematically within each lesson, and these equations combined to derive the Universal Gas Equation and Universal Gas Constant, in lesson 7. The learners are given practice solving problems using this equation in lesson 8. Differences between real and ideal gases are covered in lesson 9. The task lesson can be used for formative or summative assessment.

## Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

### 1. Kinetic Theory

Models of the microscopic nature of the phases of water are simulated. Explanations of gas temperature and pressure are given in terms of microscopic understanding and kinetic theory.

### 2. Boyle's Law Concepts

An introduction to Boyle's Law that focuses development of conceptual understanding by use of a simulation and inverse proportion patterns in simplified data.

### 3. Boyle's Law Practical

We observe learners performing and processing the results from three variations of Boyles' Law demonstrations in the laboratory.

### 4. Gay-Lussac's Law Practical

We observe learners performing and discussing the results from a laboratory demonstration about the effect of temperature on pressure for a trapped gas at constant volume. Questions are raised which will be answered in Lesson 5.

### 5. Gay-Lussac's Law Concepts

In this lesson we look for patterns in temperature-pressure data and derive and use the equation: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$. We explain why pressure is directly proportional to temperature in Kelvin, but not in degrees Celsius.

### 6. Charles' Law

We look for patterns in temperature-volume data and derive and use the equation $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ .

7. **Gas Equations**

   We derive the equation: $\frac{P_2V_2}{T_2} = \frac{P_2V_2}{T_2}$. We reason that pressure must be directly proportional to amount of gas, n, and so adjust the gas equation to $\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$. From this we derive the universal gas equation, PV=nRT and deduce that the universal gas constant, R, has a value of 8,3.

8. **Universal Gas Equation**

   We derive the units of the universal gas constant, R, and practise solving problems with the universal gas equation, PV=nRT.

9. **Real and Ideal Gases**

   The concept of an ideal gas is explained, differences between real and ideal gases are named and explained on a microscopic level.

# Resource Material

| | | |
|---|---|---|
| **1. Kinetic Theory** | http://phet.colorado.edu/en/simulation/states-of-matter-basics | The PhET simulation introduced in this lesson. |
| | http://www.slideshare.net/AngelaStott/kinetic-theory-29681801 | A Slideshare presentation containing the visuals used in this lesson. |
| | http://socratic.org/chemistry/the-behavior-of-gases/kinetic-theory-of-gases | Socratic Chemistry: Videos about Kinetic Theory |
| **2. Boyle's Law Concepts** | http://www.slideshare.net/AngelaStott/boyles-law-29731900 | A Slideshare presentation containing the visuals used in this lesson. |
| | http://phet.colorado.edu/en/simulation/gas-properties | A PhET simulation about gas properties. |
| | http://www.youtube.com/watch?v=ZoGtVVu3ymQ | Tyler DeWitt teaches about Boyle's Law. |
| **3. Boyle's Law Practical** | http://www.youtube.com/watch?v=OKTGTIZfM1o | Youtube video: Cape Town Science Centre practical experiment: Boyle's Law |
| | http://www.nuffieldfoundation.org/practical-physics/boyles-law | Instructions on how to demonstrate Boyle's law in the laboratory |
| | http://www.youtube.com/watch?v=JZSajBakGK4 | Youtube video: Boyle's Law – Cool Science Experiment |
| **4. Gay-Lussac's Law Practical** | http://www.phs.d211.org/science/smithcw/Chemistry%20332/Quarter%204%20Unit%201/3%20Gay%20Lussac's%20Law%20and%20temperature.pdf | A pdf with illustrated notes, worked examples and questions. |
| | http://www.youtube.com/watch?v=_oZBp4wxUjE | A You-Tube movie showing a simple demonstration of Gay-Lussac's Law, using an egg. |
| **5. Gay-Lussac's Law Concepts** | http://www.slideshare.net/AngelaStott/temperatures-effect-on-gas-pressure. | A Slideshare presentation containing the visuals used in this lesson. |
| | http://socratic.org/chemistry/the-behavior-of-gases/kelvin-temperatures-and-absolute-zero | Socratic Chemistry: Absolute Zero |
| **6. Charles' Law** | http://www.youtube.com/watch?v=oIfFoiwRCVE | Tyler DeWitt teaches about Charles's Law |

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| | http://www.wikihow.com/Demonstrate-Charles's-Law | Instructions on how to demonstrate Charles's Law using a balloon. |
| | http://www.phs.d211.org/science/smithcw/Chemistry%20332/Quarter%204%20Unit%201/4%20Charles'%20Law%20and%20Volume.pdf | A pdf with illustrated notes and worked examples. |
| **7. Gas Equations** | http://socratic.org/chemistry/the-behavior-of-gases/gas-laws. | Socratic Chemistry: Gas Laws |
| | http://www.slideshare.net/AngelaStott/gas-equations | A SlideShare presentation with the visuals used in this lesson and in Lesson 08 |
| **8. Universal Gas Equation** | http://socratic.org/chemistry/the-behavior-of-gases/ideal-gas-law | Socratic Chemistry: Ideal Gas Law |
| | https://www.khanacademy.org/science/chemistry/ideal-gas-laws/v/ideal-gas-equation--pv-nrt | Khan Academy: Ideal gas equation |
| **9. Real and Ideal Gases** | http://www.slideshare.net/AngelaStott/real-and-ideal-gases | A SlideShare presentation with the visuals used in this lesson |
| | https://everythingscience.co.za/grade-11/07-ideal-gases/07-ideal-gases-02.cnxmlplus | Siyavula Gr 11 Everything Science: Ideal gases |

# Task

## Question 1

A helium balloon has a volume of 5 $dm^3$ when the atmospheric pressure is 100 kPa. When the balloon is released it rises and expands to 7,5 $dm^3$.

1.1. Calculate the pressure of the gas inside the balloon after it has risen.

1.2. Explain why the pressure and volume change as the balloon rises, in terms of the kinetic molecular theory.

1.3. How are volume and pressure related to one another? Give your answer:

- 1.1.3 in words
- 1.1.4 in a mathematical expression
- 1.1.5 in a sketch graph
- 1.1.6 Name the law which describes the relationship between a gas's pressure and its volume

## Question 2

A trapped gas has volume V, pressure P and temperature (in Kelvin) T.

2.1 If the gas's volume increases by 25%, how will the gas's pressure change?

2.2 If the gas's volume is changed to ½ V and its temperature to 2T, what will the gas's pressure be?

2.3 If the gas's volume is changed to 4 V and its pressure to ¼ V, what will its temperature be?

## Question 3

A 2 $cm^3$ gas bubble rises from the bottom of the sea, where the pressure is 275 kPa and the temperature 5°C. The bubble reaches the surface, where the temperature is 28°C and 101,3 kPa.

3.1 What happens to the volume as the bubble as it rises?

3.2 Explain your answer in terms of the kinetic molecular theory.

3.3 Calculate the volume of the bubble at the surface of the sea.

3.4 Explain why you did not need to convert the volume of 2 $cm^3$ into the SI unit $m^3$ to answer 3.3., but if you had used the universal gas equation you would have had to convert to $m^3$.

3.5 Explain why you had to convert temperature into the SI unit Kelvin to answer 3.3 correctly.

## Question 4

Calculate the volume of 132 g of $CO_2$ at a pressure of $9 \times 10^5$ Pa and at a temperature of 300 K.

# Task Answers

## Question 1

1.1. $P_1V_1 = P_2V_2$

$100 \cdot 5 = P_2 \cdot 7{,}5$

$P_2 = \frac{500}{7{,}5}$

$P_2 = 66{,}67$ kPa

1.2. The atmospheric pressure decreases as the balloon rises, therefore the helium gas expands. Atmospheric pressure decreases therefore there are fewer collisions with the air molecules and the walls of the balloon. The fewer collisions there are, the less force the molecules exert on the walls of the balloon. This decreases the pressure the helium exerts, until the pressure it exerts on the inside of the balloon equals the pressure the atmosphere exerts on the outside of the balloon. At that point, the balloon stops expanding since equilibrium has been reached.

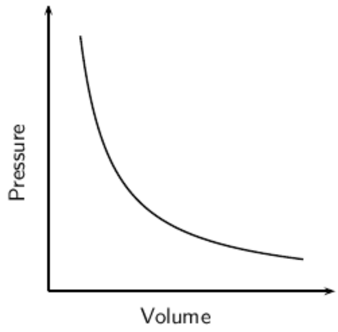
1.3.

1.3.1 Volume is inversely proportional to pressure (and pressure is inversely proportional to volume)

1.3.2 $P \propto \frac{1}{V}$

$V \propto \frac{1}{P}$

1.3.3




1.4. Boyle's Law

## Question 2

PV=nRT

2.1 The gas's pressure decreases by 25%.

2.2 The pressure changes to 4P:

$P = \frac{nRT}{V}$

$4P = \frac{nR2T}{\frac{1}{2}V}$

2.3. The temperature remains unchanged (at T):

$T = \frac{PV}{nR}$

$1T = \frac{\frac{1}{4}P4V}{nR}$

## Question 3

3.1 Its volume will increase.

3.2 As the gas's temperature increases, the average kinetic energy of the gas molecules increases, so the gas molecules move faster, on average. Therefore the molecules collide with the sides of the bubble (the surrounding water) more frequently, expanding the volume. Also, as the pressure exerted on the bubble by the surrounding water decreases, the bubble's volume increases.

3.3 $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

$\frac{275 \cdot 2}{278} = \frac{101{,}3 \cdot V_2}{301}$

$V_2 = \frac{275 \cdot 2 \cdot 301}{278 \cdot 101{,}3}$

$V_2$ = 5,89 $cm^3$

3.4 The proportionality constant, R, is in SI units, and so all units should be in SI units when using the universal gas equation. We solved this question proportionally between two states, so their volumes must just have the same unit as one another, but this need not be the SI unit.

3.5 Temperature is only proportional to pressure and volume if it is in Kelvin, therefore proportional reasoning (as is involved in this equation) will not work if temperature is in degrees Celsius.

## Question 4

PV = nRT

n = 132 g $CO_2$ x $\frac{1\,mol}{44\,g}$ = 3 mol

PV = nRT

V = $\frac{nRT}{P}$

V = $\frac{3 \bullet 8{,}3 \bullet 300}{9x10^5}$

V = 0,0083 $m^3$

V = 8,3 $dm^3$

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