Moles and volume

This resource is from the **Johnstone's triangle** series, which can be viewed at: rsc.li/43jMfSn. In this series you will also find our Johnstone's triangle worksheet which introduces the triangle in the context of moles of xenon found in car headlights: rsc.li/3N8CFxx.

Learning objectives

LO	Objective	Where assessed
1	Use the particle model to explain the compressibility of gases.	Q1
2	Recognise that an equal volume of any gas (at the same temperature and pressure) contains the same number of molecules (or atoms if a noble gas).	Q2
3	Recognise that one mole of a gaseous substance occupies 24 dm^3 at room temperature and pressure.	Q3
4	Calculate the volume occupied by a given number of moles of a gas.	Q4
5	Calculate the number of moles of a gas in a given volume.	Q5

How to use this resource

When to use?	Introduce	**Develop**	**Revise**	Assess
	Use after initial teaching or discussion of this topic to develop ideas further. You can also use as a revision activity.			
Group size?	**Independent**	**Small group**	**Whole class**	**Homework**
	Suitable for independent work either in class or at home. Or use the questions for group or class discussions.			
How long?			15–30 mins	

This resource aims to develop learners' understanding of the idea that equal volumes of gases contain an equal number of molecules (or atoms if noble gases). The questions encourage learners to think about the relationship between volume (the macroscopic level) and the number of moles of molecules (the sub-microscopic level). As a result, learners should develop more secure mental models to support their thinking about this topic.

Johnstone's triangle

Johnstone's triangle is a model of the three different conceptual levels in chemistry: macroscopic, sub-microscopic and symbolic. You can use Johnstone's triangle to build a secure understanding of chemical ideas for your learners.

Find further reading about Johnstone's triangle and how to use it in your teaching at rsc.li/4q4ZEI6.

Johnstone's triangle and this resource

The icons in the margin indicate which level of understanding each question is developing to help prompt learners in their thinking.

Macroscopic: what we can see. Think about the properties that we can observe, measure and record.

Sub-microscopic: smaller than we can see. Think about the particle or atomic level.

Symbolic: representations. Think about how we represent chemical ideas including symbols and diagrams.

The levels are interrelated, for example, learners need visual representation of the sub-microscopic in order to develop mental models of the particle or atomic level. Our approach has been to apply icons to questions based on what the learners should be thinking about.

Questions may be marked with two or all three icons, indicating that learners will be thinking at more than one level. However, individual parts of the question may require learners to think about only one or two specific levels at a time.

Support

This worksheet is ramped so that the earlier questions are more accessible. The activity becomes more challenging in the later questions. You can give extra explanations for the more challenging questions. If completing as an in-class activity it is best to pause and check understanding at intervals, as often one question builds on the previous one.

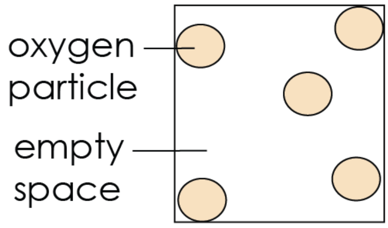
It is useful for learners to observe macroscopic properties first-hand. You could show an example of a specified volume of gaseous substance in the classroom (e.g. in a sealed gas jar).

Additional support may be needed for any learners still lacking in confidence in the required symbolic representation. Examples include sharing and explaining a digital simulation that can show the arrangement and movement of the atoms or molecules of a substance in the gas state.

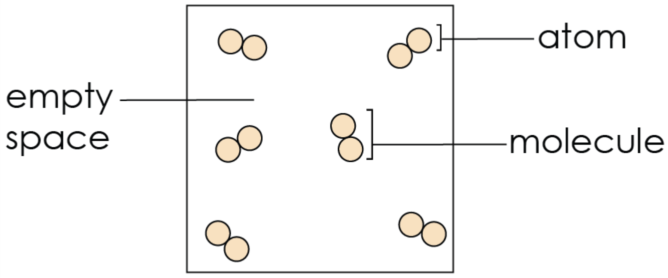
Answers

1. *Guidance note*: This question develops learners' understanding of the particle model for the gas state (sub-microscopic understanding) and how it may be used to explain the compressibility of gases (macroscopic understanding). This question assumes familiarity with the meaning of the terms atom and molecule.

(a)



(b)

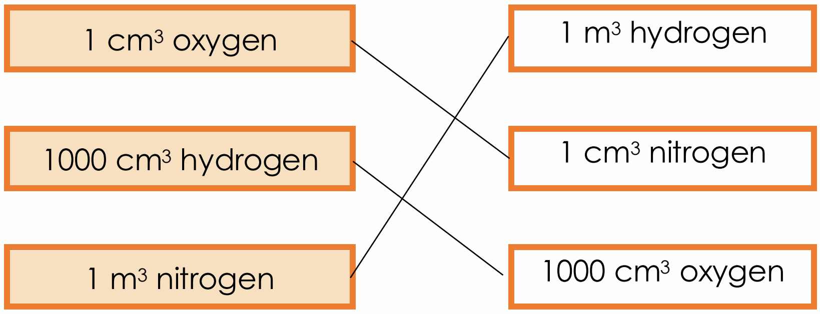


(c) Oxygen can be compressed because there is **empty space** between the **molecules**. This means that the **molecules** can be pushed closer together.

(d) In the liquid state the molecules are already touching and there is not empty space between them. The molecules cannot be pushed together.

2. *Guidance note*: This question develops learners' understanding of the idea that there are an equal number of molecules (sub-microscopic understanding) in an equal volume of any gas (macroscopic understanding). This is true at the same temperature and pressure and for any gas that is made up of molecules. The number of molecules will be equal to the number of atoms of a noble gas (which are made up of individual atoms).

(a)



(b) 1cm^3

(c) Oxygen is made up of molecules. Each molecule is made up of two atoms. There are the same number of molecules of oxygen in 1 cm^3 as atoms of helium but two times as many atoms.

(d) There is so much empty space that the size of the atoms does not affect the number of atoms in 1000 cm^3.

3. *Guidance note:* This question develops learners' understanding of the volume (macroscopic understanding) occupied by one mole (sub-microscopic understanding) of any gas. It then supports learners to connect the number of moles of a gas with the volume that will be occupied at room temperature and pressure. This question assumes familiarity with the idea that one mole of a gas is made up of 6.02×10^{23} molecules (or atoms if a noble gas). The question provides the information that 1 dm^3 is equal to 1000 cm^3 but assumes that learners have met dm^3 before.

(a)
- i. Oxygen: 24 dm^3
- ii. Nitrogen: 24 dm^3

(b)
- i. Helium: 24 dm^3
- ii. Neon: 24 dm^3

(c)
- i. One mole of oxygen molecules: 24 dm^3
- ii. Two moles of neon atoms: 48 dm^3
- iii. 0.5 moles of nitrogen molecules: 12 dm^3

4. *Guidance note:* This question develops learners' understanding of how to connect the number of moles of a gas (sub-microscopic understanding) with the volume this occupies in dm^3 (macroscopic understanding). This question uses a diagram to support learners in developing their understanding of the meaning of the mathematical formula volume = volume of one mole x number of moles. If appropriate learners could be taught that the volume of one mole if called the molar gas volume.

(a) 24 dm^3
(b) Two moles
(c) 24 x 2 = 48 dm^3
(d) 72 dm^3
(e) 2.4 dm^3
(f) 36 dm^3
(g) 48 dm^3

5. *Guidance note:* This question develops learners' understanding of how to determine the number of moles of a gas (sub-microscopic understanding) in a given volume (macroscopic understanding). This question uses a diagram to support learners in developing their understanding of the mathematical formula needed to calculate the number of moles from the volume and volume of one mole of a gas.

(a) 24 dm^3
(b) 36 dm^3
(c) 36 / 24 = 1.5 moles
(d) 6 / 24 = 0.25 moles