# Unit 7 · Gas Laws

**HARDER PRACTICE QUESTIONS**

Full marks 40

Write your answers on separate paper. Show your working. Temperatures in kelvin: T = t + 273. 1 atm = 760 mmHg ≈ 101.3 kPa.

## 1 Spot the error [3]

Anusha was asked for the volume at 77 °C and 600 mmHg of a gas that fills 300 cm³ at 27 °C and 720 mmHg. She wrote:

"$V_2 = \dfrac{720 \times 300 \times 77}{27 \times 600} = \mathbf{1{,}027\ cm^3}$."

Find her mistake and work out the right answer. How could she have seen that 1,027 cm³ was too much, without working it out?

## 2 Check the readings [4]

Prabin sealed a syringe and read the volume of its air at five pressures, at a steady temperature.

| Pressure (kPa) | 100 | 125 | 150 | 200 | 250 |
|---|---|---|---|---|---|
| Volume (cm³) | 40 | 32 | 26.7 | 24 | 16 |

He wrote: **"The syringe must have started to leak air at 200 kPa."**

i. Find *PV* for each reading. Which reading doesn't fit Boyle's law? What should it have been?

ii. Would a leak give this pattern? Use the reading at 250 kPa in your answer.

## 3 Find absolute zero yourself [3]

A gas is warmed at constant pressure. On a graph of volume against temperature in °C, the readings lie on a straight line: 58.6 cm³ at 20 °C and 74.6 cm³ at 100 °C.

i. By how many cm³ does the volume grow for each 1 °C?

ii. Extend the line backward. At what temperature would the volume reach zero?

iii. Why can the line only be extended, and not measured, down there?

## 4 Two flasks [3]

A 2.0 L flask holds air at 150 kPa. It is joined by a closed tap to a 3.0 L flask holding air at 50 kPa, at the same temperature. The tap is opened and the temperature stays the same. Find the final pressure. (Use Boyle's law for the air from each flask as it spreads through all 5.0 L. The two pressures add, since the walls take the hits of both.)

## 5 From the bottom of a lake [4]

A bubble of 2.0 cm³ leaves the mud at the bottom of a high lake, 18 m deep (made up for this question). The water there is at 4 °C, and at the surface at 17 °C, where the air pressure is 0.80 atm. Take 10 m of water to press with about 1 atm.

i. Find the pressure at the bottom.

ii. Find the bubble's volume at the surface.

iii. Which matters more to the bubble's growth, the change in pressure or the change in temperature? Show it with numbers.

## 6 Work backwards [4]

In a tube like the one in the unit, with plugs 100 cm apart, ammonia (M = 17) is at one end and a gas X at the other. The white ring forms 60 cm from the ammonia end.

i. Find the molar mass of X.
ii. A student says X must be hydrogen chloride (M = 36.5). Is that fair? Why might the answer differ?
iii. What would happen to the ring's place if the whole tube were warmer? Explain.

## 7 What if? [3]

At 27 °C, a nitrogen molecule (M = 28) moves at about 500 m/s on average.

i. At what average speed does a hydrogen molecule (M = 2) move at 27 °C? (Every gas has the same average kinetic energy at the same temperature.)
ii. How fast does the nitrogen molecule move at 327 °C?
iii. It would cover 30 km in a minute. Why does a smell take minutes to cross a room?

## 8 Compare two separations [3]

Find how many times faster the lighter gas diffuses in each pair: **(a)** hydrogen ($H_2$, M = 2) against heavy hydrogen ($D_2$, M = 4); **(b)** the two uranium hexafluorides (M = 349 and 352). Why did enriching uranium by diffusion take thousands of walls?

## 9 Which explanation fits the evidence? [3]

At 50 °C, the value of $PV \div nRT$ for carbon dioxide drops far below 1, lowest near 120 atm, and only rises again at much higher pressure. For hydrogen it rises slowly above 1 from the start.
**Bipana:** "Both curves show the molecules' own volume."
**Deepak:** "The carbon dioxide dip shows attraction; the rises show the molecules' volume."
Which explanation does the evidence support? Say what each change in the value means for how easily the gas can be squeezed.

## 10 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

Anisha wrote: "When a gas is heated, its molecules get bigger, and that is why it expands. Each time a molecule hits a wall it loses some energy, so a gas in a closed jar slowly loses pressure. Hydrogen at room temperature is an ideal gas."

## 11 Design a fair test [4]

Lhamu wants to test whether a balloon of helium goes flat sooner than a balloon of air, and about how much sooner. She has two balloons, a helium cylinder, a thread and a ruler. Plan a fair test.

i. What will she change, and what will she measure?
ii. Name two things she must keep the same.
iii. How can she make her results more reliable?
iv. What result would support Graham's law, and what number would she compare it with? (M of helium = 4, M of air about 29.)

## 12 Think [3]

A room of 60 $m^3$ is heated from 7 °C to 27 °C. It has a gap under the door, so the air pressure inside stays the same as outside. What volume of the room's air, measured at 27 °C, is pushed out? What fraction of the air is that? How does this explain a hot air balloon's rise?