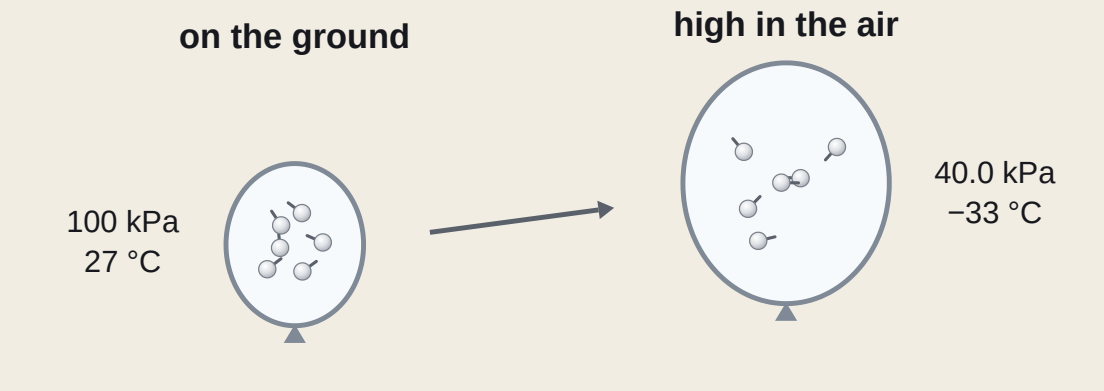
B5 · The combined gas law · Completed notes

Goals: Sort the values in a gas question into "before" and "after". Rearrange the combined gas law for any one value. Use the combined gas law, with kelvin temperatures and matching units.

These are the completed notes. The blanks are filled in and each question is worked.

Slide 1 of 6 · When pressure and temperature both change

Boyle's law in lesson B3 and Charles's law in lesson B4 each changed one thing. Today two things change at once.



Key ideas

In real life, pressure and temperature often **change together**.

Lower pressure lets the balloon **grow**.

Lower temperature makes the balloon **shrink**.

Example

A weather balloon rises. The air pressure around it drops. What does that do to its volume?

1. Lower pressure lets the balloon grow.
2. So its volume gets bigger.

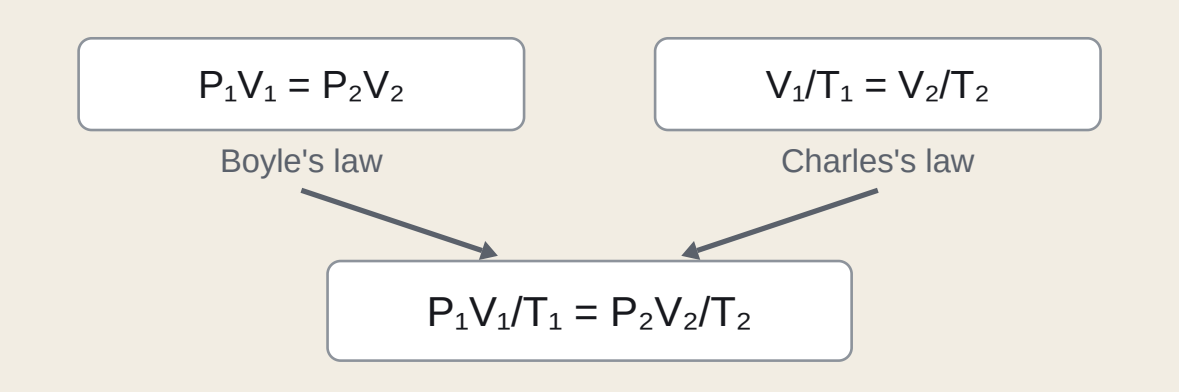
Try it

A weather balloon rises. The air around it gets colder. What does that do to its volume?

1. Lower temperature makes the balloon shrink.
2. So its volume gets smaller.

Slide 2 of 6 · Joining Boyle's law and Charles's law

The last slide needed one law for two changes. Both laws you know contain volume, so they can be joined.



Key ideas

Boyle's law and Charles's law both have **volume** in them.

The joined formula is called the **combined gas law**.

Only the **amount** of gas must not change.

Example

Which part of the combined gas law comes from Boyle's law?

1. Boyle's law is $P_1V_1 = P_2V_2$.
2. So the top of each side, pressure times volume, comes from it.

Try it

The temperature of a gas does not change. Which law does the combined gas law turn into?

1. T_1 and T_2 are equal, so they cancel.
2. $P_1V_1 = P_2V_2$ is left. That is Boyle's law.

Slide 3 of 6 · Sorting the values into before and after

The last slide gave the combined gas law. Before you can use it, you must sort the values in the question.

	before (1)	after (2)
pressure	P_1 = 100 kPa	P_2 = 40.0 kPa
volume	V_1 = 25.0 L	V_2 = ?
temperature	T_1 = 27 °C	T_2 = −33 °C

Change both temperatures to kelvin before you calculate.

Key ideas

A question gives **five** values and asks for one.

Sort the values into a **before** column and an after column.

Mark the value that is not given with a **question mark**.

Example

A gas at 95.0 kPa, 2.00 L and 20 °C changes to 3.00 L and 50 °C. Name the "before" values, the "after" values and the unknown.

1. Before: P_1 = 95.0 kPa, V_1 = 2.00 L, T_1 = 20 °C.
2. After: V_2 = 3.00 L, T_2 = 50 °C.
3. The unknown is P_2.

Try it

A gas at 110 kPa, 5.00 L and 30 °C changes to 90.0 kPa and 10 °C. Name the "before" values, the "after" values and the unknown.

1. Before: P_1 = 110 kPa, V_1 = 5.00 L, T_1 = 30 °C.
2. After: P_2 = 90.0 kPa, T_2 = 10 °C.
3. The unknown is V_2.

Slide 4 of 6 · Rearranging for the unknown

On the last slide you sorted the values and found the unknown. Now you rearrange the formula to get the unknown alone.

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

$$V_2 = \frac{P_1V_1T_2}{T_1P_2}$$

T_2 moved to the top. P_2 moved to the bottom.

Key ideas

To get V_2 alone, multiply both sides by **T_2**.

Then divide both sides by **P_2**.

Temperatures must be in **kelvin**.

The two pressures must be in the **same unit**.

Example

Use the combined gas law, $P_1V_1/T_1 = P_2V_2/T_2$. Rearrange it to get P_2 alone.

1. Multiply both sides by T_2.
2. Then divide both sides by V_2.
3. $P_2 = P_1V_1T_2 / (T_1V_2)$.

Try it

Use the combined gas law, $P_1V_1/T_1 = P_2V_2/T_2$. Rearrange it to get V_2 alone.

1. Multiply both sides by T_2.
2. Then divide both sides by P_2.
3. $V_2 = P_1V_1T_2 / (T_1P_2)$.

Slide 5 of 6 · Using the combined gas law

The last slide got the formula ready. Now you put the numbers in.

$T_1 = 27 + 273 = 300$ K, $T_2 = -33 + 273 = 240$ K

$V_2 = P_1V_1T_2 / (T_1P_2)$

$V_2 = (100 \text{ kPa} \times 25.0 \text{ L} \times 240 \text{ K}) / (300 \text{ K} \times 40.0 \text{ kPa})$

$V_2 = 50.0$ L

Key ideas

Change the temperatures to **kelvin** first.

Then put the numbers into the **formula**.

In the weather balloon question, the drop in **pressure** won.

Example

Use the combined gas law, $P_1V_1/T_1 = P_2V_2/T_2$, and T (K) = t (°C) + 273. The amount of gas does not change. A gas fills 8.00 L at 120 kPa and 27 °C. It changes to 90.0 kPa and 87 °C. What is the new volume?

1. $T_1 = 300$ K and $T_2 = 360$ K.
2. $V_2 = P_1V_1T_2 / (T_1P_2)$.
3. $V_2 = (120 \text{ kPa} \times 8.00 \text{ L} \times 360 \text{ K}) / (300 \text{ K} \times 90.0 \text{ kPa}) = 12.8$ L.

Try it

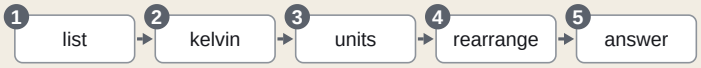
Use the combined gas law, $P_1V_1/T_1 = P_2V_2/T_2$, and T (K) = t (°C) + 273. The amount of gas does not change. A gas fills 3.00 L at 100 kPa and 127 °C. It changes to 150 kPa and 27 °C. What is the new volume?

1. $T_1 = 400$ K and $T_2 = 300$ K.
2. $V_2 = P_1V_1T_2 / (T_1P_2)$.
3. $V_2 = (100 \text{ kPa} \times 3.00 \text{ L} \times 300 \text{ K}) / (400 \text{ K} \times 150 \text{ kPa}) = 1.50$ L.

Slide 6 of 6 · Method: how to answer a gas law question

You just answered two combined gas law questions. Each time you did the same five things.

1. **List** the values as "before" and "after".
2. **Change** temperatures to kelvin.
3. **Match** the units on both sides.
4. **Rearrange** for the unknown.
5. **Calculate** and round.



Check: the answer moves the way you expect.

Used again in: lesson B8 and Unit D

Key ideas

Step 1: **list** the values as "before" and "after".

Step 2: **change** temperatures to kelvin.

Step 3: **match** the units on both sides.

Step 4: **rearrange** for the unknown. Step 5: calculate and round.

Example

Use the combined gas law, $P_1V_1/T_1 = P_2V_2/T_2$, and T (K) = t (°C) + 273. The amount of gas does not change. Use the five steps. A gas fills 6.00 L at 80.0 kPa and 7 °C. It changes to 100 kPa and 77 °C. What is the new volume?

1. Step 1: P_1 = 80.0 kPa, V_1 = 6.00 L, P_2 = 100 kPa.
2. Step 2: T_1 = 280 K and T_2 = 350 K. Step 3: both pressures are in kPa.
3. Step 4: $V_2 = P_1V_1T_2 / (T_1P_2)$.
4. Step 5: put the numbers in and round.
5. V_2 = (80.0 kPa × 6.00 L × 350 K) / (280 K × 100 kPa) = 6.00 L.

Try it

Use the combined gas law, $P_1V_1/T_1 = P_2V_2/T_2$, and T (K) = t (°C) + 273. The amount of gas does not change. Use the five steps. A gas fills 10.0 L at 200 kPa and 47 °C. It changes to 100 kPa and 15 °C. What is the new volume?

1. Step 1: P_1 = 200 kPa, V_1 = 10.0 L, P_2 = 100 kPa.
2. Step 2: T_1 = 320 K and T_2 = 288 K. Step 3: both pressures are in kPa.
3. Step 4: $V_2 = P_1V_1T_2 / (T_1P_2)$.
4. Step 5: put the numbers in and round.
5. V_2 = (200 kPa × 10.0 L × 288 K) / (320 K × 100 kPa) = 18.0 L.