B8 · The ideal gas law, PV = nRT · Completed notes

Goals: State the ideal gas law and what each symbol stands for. Put every value into the units that match the gas constant. Use the ideal gas law to find a volume, a pressure, an amount or a mass.

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

Slide 1 of 6 · A gas that is not at STP or SATP

In lesson B7 the molar volume linked moles and litres. It only worked at STP and SATP. Today you get a law that works anywhere.

What is the volume of one mole?

STP	SATP	another gas
0 °C	25 °C	22 °C
101.325 kPa	100 kPa	150 kPa
22.4 L/mol	24.8 L/mol	? L/mol

Key ideas

The molar volume is **22.4** L/mol at STP.

Most gases in a lab are at some other **pressure** and temperature.

The **combined gas law** can change a gas to STP, but that is slow.

Example

Can you use 24.8 L/mol for a gas at 150 kPa and 22 °C? Say why or why not.

1. No. 24.8 L/mol is only for SATP.
2. SATP is 100 kPa and 25 °C, and this gas is not at SATP.

Try it

Name the two things from earlier lessons that you could use together for a gas that is not at STP.

1. First the combined gas law, to change the gas to STP.
2. Then the molar volume at STP.

Slide 2 of 6 · The ideal gas law

The last slide asked for one law that works at any pressure and temperature. This slide gives it.

$$PV = nRT$$

P	V	n	T
pressure, kPa	volume, L	amount, mol	temperature, K

R = 8.314 kPa·L/(mol·K)

R is the gas constant.

Key ideas

The ideal gas law is **PV = nRT**.

The letter n is the **amount** of gas in moles.

R is a fixed number called the **gas constant**.

R = **8.314** kPa·L/(mol·K).

Example

Write the ideal gas law. Say what each of P, V, n and T stands for.

1. PV = nRT.
2. P is pressure and V is volume.
3. n is the amount in moles and T is the kelvin temperature.

Try it

Use PV = nRT, with R = 8.314 kPa·L/(mol·K), and T (K) = t (°C) + 273. STP is 0 °C and 101.325 kPa. Use the law to find the volume of 1.00 mol of gas at STP.

1. T = 273 K.
2. V = nRT / P = (1.00 mol × 8.314 × 273 K) / 101.325 kPa = 22.4 L.
3. That is the molar volume at STP.

Slide 3 of 6 · The units must match R

The last slide gave the gas constant R with its units. Those units decide the units of everything else.

symbol	unit	if the question gives something else
P	kPa	change atm or mm Hg to kPa (lesson B1)
V	L	divide mL by 1000
n	mol	change grams with the molar mass
T	K	add 273 to °C (lesson B2)

Key ideas

Pressure must be in **kPa**.

Volume must be in **litres**.

Temperature must be in **kelvin**.

To change millilitres to litres, divide by **1000**.

Example

A question gives a volume of 250 mL and a temperature of 22 °C. What do you change before you use the ideal gas law?

1. 250 mL ÷ 1000 = 0.250 L.
2. 22 + 273 = 295 K.

Try it

Use 1 atm = 101.325 kPa. A question gives a pressure of 1.20 atm. What is it in kPa, ready for the ideal gas law?

1. Pressure must be in kPa.
2. 1.20 atm × 101.325 kPa / 1 atm = 122 kPa.

Slide 4 of 6 · Finding a volume or a pressure

The last slide set the units. Now you use the ideal gas law to find a volume, then a pressure.

n = 0.500 mol, P = 125 kPa, T = 30 + 273 = 303 K

V = nRT / P

V = (0.500 mol × 8.314 × 303 K) / 125 kPa

V = 10.1 L

Key ideas

To find a volume, divide both sides by **P**.

So V = **nRT / P**.

To find a pressure, divide both sides by **V**.

Example

Use PV = nRT, with R = 8.314 kPa·L/(mol·K), and T (K) = t (°C) + 273. What is the volume of 1.00 mol of gas at 150 kPa and 27 °C?

1. T = 300 K.
2. V = nRT / P.
3. V = (1.00 mol × 8.314 × 300 K) / 150 kPa = 16.6 L.

Try it

Use PV = nRT, with R = 8.314 kPa·L/(mol·K), and T (K) = t (°C) + 273. 0.500 mol of gas is in a 10.0 L tank at 27 °C. What is the pressure?

1. T = 300 K.
2. P = nRT / V.
3. P = (0.500 mol × 8.314 × 300 K) / 10.0 L = 125 kPa.

Slide 5 of 6 · Finding moles, then mass

The last slide found a volume and a pressure. The ideal gas law can also tell you how much gas there is.

P = 150 kPa, V = 8.00 L, T = 295 K

n = PV / (RT)

n = (150 kPa × 8.00 L) / (8.314 × 295 K) = 0.4893 mol

m = 0.4893 mol × 28.02 g/mol

m = 13.7 g of N_2

Key ideas

To find the amount, n, divide both sides by **RT**.

So n = **PV / (RT)**.

Moles change to grams with the **molar mass**.

Example

Use PV = nRT, with R = 8.314 kPa·L/(mol·K), and T (K) = t (°C) + 273. The molar mass of N_2 is 28.02 g/mol. What is the mass of 4.00 L of nitrogen gas at 100 kPa and 25 °C?

1. T = 298 K.
2. n = PV / (RT) = (100 kPa × 4.00 L) / (8.314 × 298 K) = 0.1614 mol.
3. m = 0.1614 mol × 28.02 g/mol = 4.52 g.

Try it

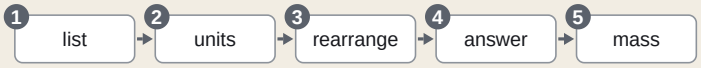
Use PV = nRT, with R = 8.314 kPa·L/(mol·K), and T (K) = t (°C) + 273. The molar mass of CO_2 is 44.01 g/mol. What is the mass of 2.00 L of carbon dioxide at 150 kPa and 30 °C?

1. T = 303 K.
2. n = PV / (RT) = (150 kPa × 2.00 L) / (8.314 × 303 K) = 0.1191 mol.
3. m = 0.1191 mol × 44.01 g/mol = 5.24 g.

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

You just used the ideal gas law four times. Each time you did the same things. Here they are as steps.

1. **List** P, V, n and T. One is unknown.
2. **Change** to kPa, L, mol and K.
3. **Rearrange** PV = nRT for the unknown.
4. **Calculate** and round.
5. **Change** moles to grams, if asked.



Check: at SATP, one mole fills about 24.8 L.

Used again in: gas questions in Unit D

Key ideas

Step 1: **list** P, V, n and T. One is unknown.

Step 2: **change** to kPa, L, mol and K.

Step 3: **rearrange** PV = nRT for the unknown.

Step 4: **calculate** and round. Step 5: change moles to grams, if asked.

Example

Use PV = nRT, with R = 8.314 kPa·L/(mol·K), and T (K) = t (°C) + 273. Use the steps. What is the volume of 3.00 mol of gas at 250 kPa and 50 °C?

1. Step 1: n = 3.00 mol, P = 250 kPa, T = 50 °C. V is unknown.
2. Step 2: T = 323 K.
3. Step 3: V = nRT / P.
4. Step 4: V = (3.00 mol × 8.314 × 323 K) / 250 kPa = 32.2 L.

Try it

Use PV = nRT, with R = 8.314 kPa·L/(mol·K), and T (K) = t (°C) + 273. Use the steps. How many moles of gas are in 25.0 L at 100 kPa and 27 °C?

1. Step 1: P = 100 kPa, V = 25.0 L, T = 27 °C. n is unknown.
2. Step 2: T = 300 K.
3. Step 3: n = PV / (RT).
4. Step 4: n = (100 kPa × 25.0 L) / (8.314 × 300 K) = 1.00 mol.