

Gas laws, kinetic theory and thermal energy

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems build from kelvin conversions and moles to multi-stage gas and heating calculations. They cover $pV = nRT$, the kinetic energy of molecules, internal energy, specific heat capacity and latent heat. They suit A Level, IB Physics and CBSE Class 11-12 students, and the final five problems need several linked steps.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB B.1-B.3

Problem 1 Kelvin conversions (easy)

A thermometer in a freezer at a fish market in Accra reads $-18\text{ }^{\circ}\text{C}$. Answer these conversions.

1. Convert $37\text{ }^{\circ}\text{C}$ to kelvin.
2. Convert 85 K to degrees Celsius.
3. A gas warms by $25\text{ }^{\circ}\text{C}$. State the change in kelvin.

Problem 2 Moles and molecules (easy)

Chiamaka fills a small lab bottle with 3.2 g of oxygen gas, O_2 (molar mass 32 g/mol), and a second bottle with 0.75 mol of carbon dioxide, CO_2 (44 g/mol).

1. Calculate the amount of oxygen in mol.
2. Calculate the number of oxygen molecules ($N_A = 6.02 \times 10^{23}\text{ mol}^{-1}$).
3. Calculate the mass of the carbon dioxide.

Problem 3 Pressure from the equation (easy)

A flask of volume 2.0 L contains 0.080 mol of nitrogen at $27\text{ }^{\circ}\text{C}$. Calculate the pressure in pascals, using $R = 8.31\text{ J/(mol K)}$.

Problem 4 Boiling water for tea (easy)

Wanjiru in Nairobi heats 2.0 kg of water from $20\text{ }^{\circ}\text{C}$ to $100\text{ }^{\circ}\text{C}$ in a pan. The specific heat capacity of water is 4180 J/(kg K) . Calculate the energy needed, ignoring losses.

Problem 5 Cool box ice (easy)

A seller in Lagos packs 0.60 kg of ice at $0\text{ }^{\circ}\text{C}$ in a cool box. The latent heat of fusion of ice is $3.34 \times 10^5\text{ J/kg}$. Calculate the energy the ice absorbs while it melts completely.

Problem 6 Ideas behind the model (easy)

1. State three assumptions of the ideal gas model.
2. Explain why the internal energy of an ideal gas depends only on its temperature.

Problem 7 Diver's cylinder (medium)

Emma in Leeds checks a 10 L cylinder of nitrogen ($M = 28 \text{ g/mol}$) at a pressure of $2.0 \times 10^6 \text{ Pa}$ and 20°C .

1. Calculate the amount of gas in the cylinder.
2. Calculate the mass of nitrogen in grams.

Problem 8 Helium at the fair (medium)

At a fair in Pune, a vendor's balloon holds 0.50 mol of helium at 27°C . Helium is monatomic.

1. Calculate the mean kinetic energy of one helium atom.
2. Calculate the internal energy of the gas in the balloon.

Problem 9 Light atoms move fast (medium)

Compare helium ($M = 0.0040 \text{ kg/mol}$) and argon ($M = 0.040 \text{ kg/mol}$) at 300 K.

1. Calculate the r.m.s. speed of helium atoms.
2. Calculate the ratio $c_{\text{rms}}(\text{He}) / c_{\text{rms}}(\text{Ar})$.

Problem 10 Motorbike tyre (medium)

Bilal in Lahore measures the absolute pressure in a motorbike tyre as $2.20 \times 10^5 \text{ Pa}$ at 25°C . After a long ride the tyre is at 55°C . Assume the volume and amount of air stay constant. Calculate the new pressure.

Problem 11 Metal block heater (medium)

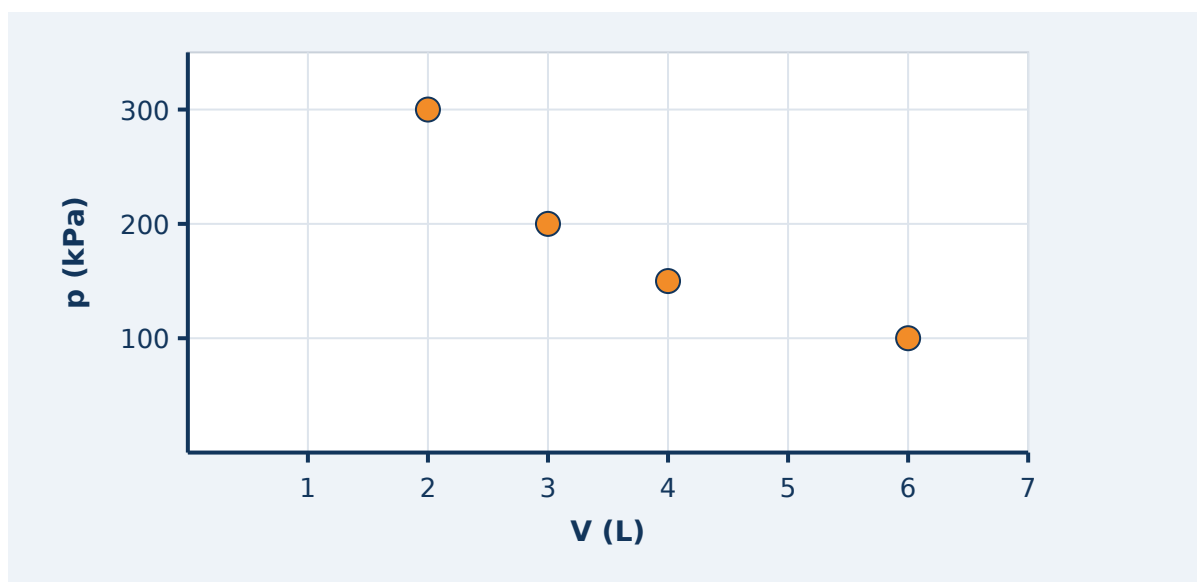
In a school lab, a 60 W electric heater warms a 0.50 kg metal block for 5.0 minutes. Its temperature rises by 40 K. No energy is lost to the surroundings. Calculate the specific heat capacity of the metal and suggest which metal it is (aluminium 900, copper 385, iron 450 J/(kg K)).

Problem 12 Tea and milk (medium)

Mix 0.20 kg of tea at 90°C with 0.050 kg of cold milk at 5°C . Treat both liquids as water and ignore losses. Calculate the final temperature.

Problem 13 Reading a pressure-volume set (medium)

Mei in Singapore compresses a gas slowly at a constant 290 K and records the points shown.



Four measurements of a gas at constant temperature: (6.0 L, 100 kPa), (4.0 L, 150 kPa), (3.0 L, 200 kPa), (2.0 L, 300 kPa).

1. Show that the temperature is constant by calculating $p \times V$ for each point.
2. Calculate the amount of gas in the syringe.
3. Predict the pressure when the volume is 2.4 L.

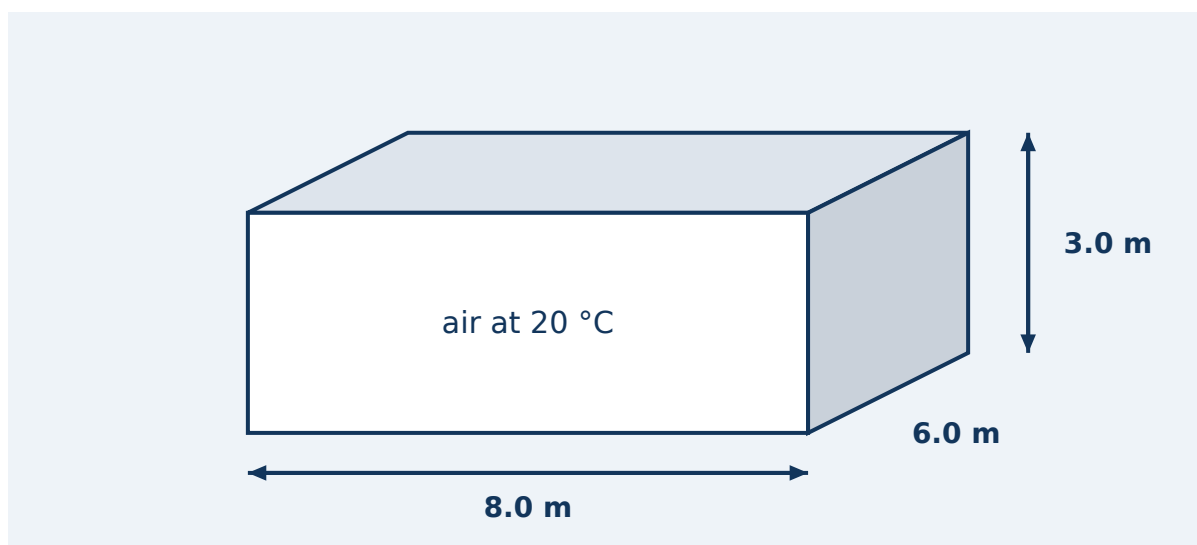
Problem 14 Spot the error (medium)

A student calculates the pressure of 0.20 mol of gas in a 4.0 L flask at 27 °C as $p = (0.20 \times 8.31 \times 27) / 4.0 = 11 \text{ Pa}$.

1. Identify the two mistakes.
2. Calculate the correct pressure.

Problem 15 Air in a classroom (medium)

Air at 20 °C and $1.01 \times 10^5 \text{ Pa}$ has a molar mass of 0.0290 kg/mol.



Classroom of the air problem: length 8.0 m, width 6.0 m, height 3.0 m.

1. Show that the density of the air is 1.20 kg/m^3 .

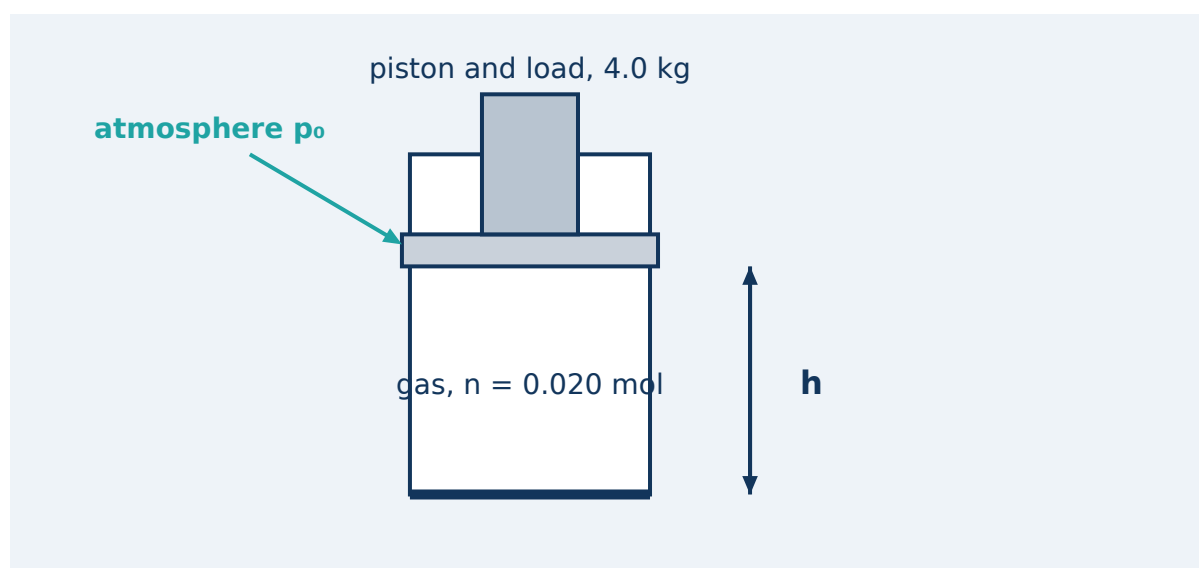
2. Calculate the mass of air in the classroom.

Problem 16 Two flasks, two temperatures (hard)

Flask A (3.0 L) holds gas at 2.0×10^5 Pa and 300 K. Flask B (5.0 L) holds the same gas at 1.0×10^5 Pa and 400 K. A tap between them is opened, and the combined 8.0 L is brought to 350 K. Calculate the final pressure.

Problem 17 Piston lifting a load (hard)

Diego in Texas traps 0.020 mol of gas under a piston of area $5.0 \times 10^{-3} \text{ m}^2$. The piston plus load has a mass of 4.0 kg and the atmosphere pushes down with 1.01×10^5 Pa. Take $g = 9.81 \text{ N/kg}$.



Vertical cylinder: piston area $5.0 \times 10^{-3} \text{ m}^2$, piston and load together 4.0 kg.

1. Calculate the pressure of the gas.
2. The gas is heated at constant pressure from 300 K to 360 K. Calculate how far the piston rises.
3. Calculate the work done by the gas.

Problem 18 Heating gas against water (hard)

Mei in Singapore heats 1.0 mol of monatomic ideal gas in a rigid container from 300 K to 400 K using a 50 W heater that transfers all its energy to the gas.

1. Calculate the increase in internal energy.
2. Calculate the time the heater needs.
3. Calculate the energy needed to warm 1.0 mol of liquid water (0.018 kg) by the same 100 K, and give the ratio to part 1.

Problem 19 Ice for a cold drink (hard)

Kofi in Accra pours 0.30 kg of water at 25 °C into an insulated jug and adds ice at -5°C . He

wants everything to end at exactly 0 °C with all the ice melted. Calculate the mass of ice needed.

Problem 20 Why hydrogen escapes (hard)

The escape speed from Earth is 11.2 km/s. A molecule can leave the atmosphere only if its speed is of that order.

1. Calculate the temperature at which the r.m.s. speed of hydrogen molecules ($M = 0.0020$ kg/mol) equals 11.2 km/s.
2. Repeat for nitrogen molecules ($M = 0.028$ kg/mol).
3. Use your answers to explain why Earth has lost most of its hydrogen but kept its nitrogen.