CAIE Physics A-level

15 - Ideal Gases

Flashcards

What is the SI unit for the amount of a given substance?

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Amount of substance is measured in moles, given the unit ‘mol’.

How many molecules comprise one mole of a substance?

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One mole of any substance contains Avogadro's number of constituent molecules: 6.02×10^{23} molecules (Avogadro's number of molecules).

What is an ideal gas?

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An ideal gas is one that can be considered to obey the principle that the product of the pressure and volume of the gas will be proportional to its temperature ($pV \propto T$).

What are the key assumptions in the kinetic theory of gases?

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- There are a large number of molecules in random, rapid motion.
- Particles have a negligible volume compared to the total volume of the gas.
- All collisions are perfectly elastic.
- The time taken for a collision is negligible compared to the time between collisions.
- Between collisions there are no forces between particles.

Why do gases exert a pressure on the container they're in?

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- Gas particles collide with the surfaces of the container.
- The container exerts a force on the particles to change their direction - the particles exert an equal and opposite force on the container.
- Pressure is force applied (in total, by all particles) per unit area.

What is the ideal gas equation?

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$$pV = nRT$$

p - pressure, Pa

R - is the Molar Gas constant, 8.31 $Jmol^{-1}K^{-1}$

n - the number of moles, mol

T - temperature, K

V - volume, m^3

Give an alternative form of the ideal gas equation.

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$$pV = NkT$$

p - pressure, Pa

k - Boltmann constant, $Jmol^{-1}$

n - the number of molecules

T - temperature, K

V - volume, m^3

Define the Boltzmann constant k.

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$$k = \frac{R}{N_A}$$

R is the gas constant, $8.31 Jmol^{-1}$.

N_A is the avogadro constant (the number of particles in a mole) equal to 6.02×10^{23}.

Explain how increasing the temperature of a balloon, while keeping the volume the same, will increase the pressure on the gas.

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- As the temperature increases, the average kinetic energy of particles increases, so the particles travel at a higher speed.
- This results in more frequent collisions.
- Which would cause an increased rate of change of momentum.
- Which means the particles would exert a greater force.
- Therefore the pressure is increased.

True or false? ‘All collisions between particles and between particles and the wall are elastic’ is an assumption of an ideal gas?

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True.

State an assumption of an ideal gas related to time?

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The time for each collisions is negligible in comparison to the time between collisions.

Describe 3 other assumptions of the ideal gas equation.

Describe 3 other assumptions of the ideal gas equation.

3 of the following:

- The particles move randomly.
- They follow Newton's laws of motion.
- No intermolecular forces between particles.
- Volume of container is negligible compared to the volume of the particles.

Use the kinetic theory of gases to explain why a temperature increase leads to an increase in pressure of a gas that is contained within a container of invariant volume.

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- A temperature increase means the particles have more kinetic energy.
- More kinetic energy means a greater change in momentum during collisions with the container. There are also more frequent collisions.
- Change in momentum is proportional to force applied, and therefore to pressure as well.

What equation links N, V, p, m and c?

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$$pV = \frac{1}{3}Nm\overline{c^2}$$

Where p = pressure, V = volume, N = number of particles, m = molecular mass of a particle, ‘c’ = mean square speed.

What is meant by the root mean square speed?

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The square root of the mean of the squares of the speeds of the molecules.

$$C_{rms} = \left(\frac{(c_1^2 + c_2^2 + \ldots c_n^2)}{N} \right)^{½}$$

What equation is used to determine the number of moles?

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The number of moles, n:

$$n = m / M$$

Where m is the mass of the substance, and M is the **molar mass** (in grams, which is the same as the nucleon number for the atom/molecule) of the particles that make up the substance.

Derive the relationship:

$$pV = \frac{1}{3} Nm(c^2)$$

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Imagining a cube, length L, and a single molecule, velocity c. In 3D (x y z) the molecule's momentum is mc_x for x direction.

Hitting the edge of the cube this will produce an elastic collision, momentum $-mc_x$, giving change in momentum 2mcx, for distance 2L.

Speed=Distance/Time so Time =2L/cx.

Using the equation F = Δmomentum/Δt = 2mcx/(2L/cx) = $mcx^{2/L}$.

Pressure $P=F/A = F/L^2 = (mcx^2/L)/L^2 = mcx^2/L^3 = mcx^2/V$ so $PV=mcx^2$

$cx^2 = cy^2 = cz^2$ $c = cx^2 + cy^2 + cz^2 = 3cx^2$ so $cx^2 = 1/3c^3$

Now for N molecules of gas we have $PV=1/3Nmc^3$

Show that the mean kinetic energy of gas molecules is proportional to T.

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We can relate the two pressure equations, $pV=NkT$ and $pV = \frac{1}{3}Nmc^2$ to produce the equation

$$kT=1/3mc^2$$

The equation for kinetic energy is $1/2mv^2$, so by adjusting the equation, we can produce

$$3/2kT=1/2mc^2$$

This shows that $E_k=3/2kT$, where E_k is the mean kinetic energy of the gas molecules and proportional to T

Show that the total translational kinetic energy of a mole of a monatomic gas is $E_k = 3/2RT$.

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We can relate the two pressure equations, $pV = nRT$ and $pV = ⅓Nmc^2$ to produce the equation

$$nRT = ⅓Nmc^2$$

The equation for kinetic energy is $E_k=1/2mv^2$, in this specific case only N=n as we are fixing the amount, so by adjusting the equation, we can produce

$$nRT = ⅓N\,2E_k$$

$$3RT = 2E_k$$

This shows that $E_k=3/2RT$, where E_k is the mean kinetic energy of the gas molecules.

Assuming constant volume, how are the pressure and temperature of a gas related?

Assuming constant volume, how are the pressure and temperature of a gas related?

They're directly proportional.

ie. P/T = constant

True or false? ‘The internal energy of an ideal gas is proportional to absolute temperature.’

True or false? ‘The internal energy of an ideal gas is proportional to absolute temperature.’

True.

In an ideal gas there is no ‘potential energy’ component in the internal energy. This means the internal energy is proportional to the kinetic energy (which is, in turn, dependent on temperature).