Ideal gas law

An ideal gas is a theoretical gas composed of many randomly moving point particles whose only interactions are collisions with one another and with the walls of the container in which the gas is enclosed. In the case of an ideal gas, all collisions between atoms or molecules are perfectly elastic and in which there are no intermolecular attractive forces. In most usual conditions, most real gases behave qualitatively like an ideal gas. The state of an ideal gas can be characterized by three state variables: by its **pressure**, **volume**, and **temperature**. The ***ideal gas law*** is the equation of state for an ideal gas. The most frequently introduced form of the ideal gas law is:

$$pV = nRT$$

where:

- *p* is the pressure of the gas,
- *V* is the volume of the gas,
- *n* is the amount of substance of gas (in moles),
- *R* is the universal gas constant, 8.314 $J \cdot K^{-1} \cdot mol^{-1}$
- *T* is the absolute temperature of the gas (in kelvin)

The gas constant value is:

$$R = 8.314 \frac{J}{mol\ K} = 8.314 \frac{Pa\ m^3}{mol\ K} = 8.314 \frac{kPa\ dm^3}{mol\ K}$$

Absolute temperature:
It uses the kelvin scale for measurement and selects the triple point of water at 273.16 K as the fundamental fixing point.

Example: 25 ^oC = 25 + 273 = 298 K

Pressure of the gas:
The standard pressure is defined as exactly 10^5 Pa (100000 Pa, 100 kPa, 1 bar).

Normal state of a gas: T = 0 ^oC = 273 K, *p* = 10^5 Pa
Standard state of a gas: T = 25 ^oC = 298 K, *p* = 10^5 Pa

Examples:

1.) Calculate the weight of 300 cm^3 argon gas at 80 ^oC and 40 kPa.

Solution: Convert the units as appropriate:
T = 80 + 273 = 353 K
V = 0.3 dm^3
p = 40 kPa

Rearrange and use the gas law for the amount of gas:

$$n = \frac{pV}{RT} = \frac{0.3 \cdot 40}{8.314 \cdot 353} = 0.0041 \text{ mol} = 4.1 \cdot 10^{-3} \text{ mol}$$

The atomic weight of argon is: 39.95 g/mol. Calculation of the weight of the gas:

$m = n \cdot M = 4.1 \cdot 10^{-3}$ mol · 39.95 g/mol = **0.16 g**

2.) Calculate the number of atoms as well.

Solution:

Use the Avogadro constant (N_A) for the calculation:

$N(Ar) = N_A \cdot n = 6.02 \cdot 10^{23} \cdot 4.1 \cdot 10^{-3} =$ $\mathbf{2.5 \cdot 10^{21}}$

3.) Calculate the weight of 1580 cm^3 ammonia at *p* = 96 kPa and *T* = 30 ^oC

Molar mass of ammonia is 17 g/mol.

Solution: 1.0 g NH_3

4.) Calculate the weight of 2.69 dm^3 oxygen at *normal state.*

Molar mass of oxygen is 32 g/mol.

Normal state of a gas means: T = 273 K and *p* = 100 kPa

Solution: 3.8 g O_2

5.) Calculate the weight of 2.69 dm^3 oxygen at *standard state.*

Molar mass of oxygen is 32 g/mol.

Standard state of a gas means: T = 298 K and *p* = 100 kPa

Solution: 3.5 g O_2

6.) A balloon with 2 dm^3 is filled with 0.5 g helium gas. What is the pressure of the gas at 27 ^oC?

Solution:

Data needed for the calculations:
V = 2 dm^3
T = 27 ^oC = 300 K
Weight of helium gas: 0.5 g
Atomic weight of helium: 4 g/mol.

Convert the weight of helium to moles: 0.5/4 = 0.125 mol

Rearrange the gas law to pressure:

$$p = \frac{nRT}{V} = \frac{0.125 \cdot 8.314 \cdot 300}{2} = \mathbf{156\ kPa}$$

7.) Calculate the density of helium in the balloon too.

Solution:

ρ = 0.5/2 = **0.25 g/dm^3**