Thermodynamics

4 – Ideal Gases

Chemistry!! :)

A mole is a unit that allows us to measure the amount of something.

1 mole of a substance = 6.02×10^{23} particles of that substance

Example:
A system contains 200.0 g of nitrogen gas. How many moles does it contain? How many molecules? N_2!!

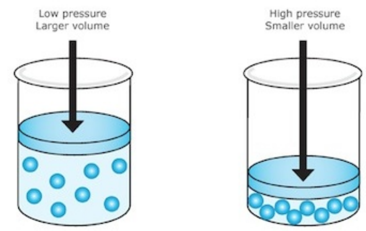
$$200.0\,g \times \frac{1\,mol}{28.02\,g} = \boxed{7.138\,mol\ N_2}$$

$$200.0\,g \times \frac{1\,mol}{28.02\,g} \times \frac{6.02\times10^{23}\,molec}{1\,mol} = \boxed{4.29\cancel{4}\times10^{24}\ molec\ N_2}$$

(3 → sig figs! :))

Ideal Gases

Unlike solids and liquids… gases are compressible.



If you increase the temperature of a gas it should make sense that the average Kinetic energy also increases.

Energy of the Particles: Temperture *is a direct measure of the* average *Kinetic Energy of the particles.*

In fact we can describe the relationship between temperature and kinetic energy with the following equation…

$$K_{avg} = \frac{3}{2}k_bT$$

Where: k_{avg} = AVERAGE Kinetic Energy J
k_b = Boltzman's Constant (1.38×10^{23} J/k) = $\frac{R}{N_0}$
T = Temperature (k) → KELVIN!!!

And…

$$E_T = \frac{3}{2}Nk_bT \ldots E_T = \frac{3}{2}nRT$$

Where: E = TOTAL Energy (J)
N = # of particles
n = moles
R = Ideal gas constant $8.31\,\frac{J}{mol\cdot K}$

Example:
A science classroom contains 7.0 x 10^{27} molecules of air. Find the energy required to raise the temperature from 11 °C to 25 °C. How long would it take if the radiator operates at 960 watts and is 90% efficient?

Why science teachers should not be given playground duty.

$$\Delta E = \frac{3}{2}Nk_b\Delta T = \frac{3}{2}(7.0\times10^{27}\,molec)(1.38\times10^{-23}\,J/k)(25°C - 11°C)$$

$$\Delta E = 2030\,kJ$$

$$t = \frac{\Delta E}{\Delta P \cdot 90\%} = \frac{2030000\,J}{(960\,J/s \cdot 0.90)} = \boxed{2350\,s\ \text{or}\ 39\,mins}$$

If pressure in a gas is due to collisions of a particle with the walls of a container… *determine the following relationships.*

When ***temperature*** of the gas particles increases, ***pressure*** will…	When ***volume*** of a container increases, ***pressure*** will…	When the ***number of gas particles*** increases, ***pressure*** will…
INCREASE	DECREASE	INCREASE
$P \alpha T$	$P \alpha \frac{1}{V}$	$P \alpha N$

Therefore…

$$P = C\frac{NT}{V}$$

Where: C = constant value

in fact $C = k_b$!!!

$$PV = k_b NT$$

More traditionally written as….

$$PV = nRT$$ *

Where: N = # of particles

k_b = Boltzman's Constant

Where: n = # of moles

R = Universal Gas Constant ($8.31\ J/mol\cdot K$)

Example:	Example:
What volume (in litres) is occupied by 2.0 moles of an ideal gas at 2.00 atm and a temperature of -2.0 °C? 2.00 atm → 2.02×10^5 Pa; -2.0 °C → 271.15 K $PV = nRT$ $V = \frac{nRT}{P} = \frac{(2.0)(8.31)(271.15)}{(2.02\times10^5)} = 0.0223\ m^3$ $V = 22.3\ L$	A cylindrical container of radius 15 cm and height 0.30 m contains 0.60 mol of gas at 433 K. Find both the pressure (in kPa) in the container and force extered on the lid of the container. $V = \pi r^2 h = \pi(0.15)^2(0.30) = 0.0212\ m^3$ $P = \frac{nRT}{V} = \frac{(0.60)(8.31)(433)}{0.0212\ m^3} = 1.02\times10^5\ Pa$ $1.02\times10^2\ kPa$ $F = P\cdot A = P\cdot\pi r^2 = (1.02\times10^5\ N/m^2)\pi(0.15\ m)^2$ $F = 7.2\times10^3\ N$