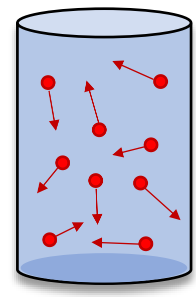
CONCEPT: IDEAL GASES AND THE IDEAL GAS LAW



● **Ideal Gas** = A simplified, "perfect" gas that satisfies the following conditions**:**

1) The gas has a *low* __________, i.e. particles very spread out (low pressure, high temperature)

2) There are *no* __________ between the gas particles

3) Particles have *zero* ________, so we can treat them as points

4) Particles move in straight lines and *collide* __________ (energy is conserved)

- Under everyday conditions, most real gases already behave very much like ideal gases**.**

● The **IDEAL GAS LAW** relates Pressure **(P)**, Volume **(V)**, Temperature **(T)**, and moles **(n)** for *any* ideal gas**:**

Use when given ***n***

_____ = ______

OR

Use when given ***N***

_____ = ______

n = # moles ← $\boxed{n = \frac{N}{N_A} = \frac{N}{6.02\times10^{23}}}$ → ***N*** = # of particles

R = 8.314 [$\frac{J}{mol\ K}$] (universal gas constant)

T must be in K

k_B = 1.38×10^{-23} [$\frac{J}{K}$] (Boltzmann constant)

● **"STP"** (**S**tandard **T**emperature & **P**ressure) is a common set of conditions defined as T=0°C=273K, P=1atm=1.01×10^5Pa

EXAMPLE**:** What is the volume that exactly 1 mole of an ideal gas occupies at **STP**?

Volume Conversions
1 cm^3 = 1 mL
1 m^3 = 1000 L

● 1 mole of *ANY* ideal gas at STP has a volume of exactly _______**.** This is sometimes called "Molar Volume at STP"

PROBLEM: 3 moles of an ideal gas fill a cubical box with a side length of 30cm. If the temperature of the gas is 20°C, what is the pressure inside the container?

A) 2.7×10^5 Pa
B) 0.27 Pa
C) 1.85×10^4 Pa
D) 8.12×10^3 Pa

IDEAL GAS EQs & Constants
$PV = nRT = Nk_BT$
$R = 8.314 \frac{J}{mol\cdot K}$ $k_B = 1.38\times10^{-23} \frac{J}{K}$ $N_A = 6.02\times10^{23} \frac{\text{particles}}{\text{mol}}$

PROBLEM: Hydrogen gas behaves very much like an ideal gas. If you have a sample of Hydrogen gas with a volume of 1000 cm^3 at 30°C with a pressure of 1×10^5 Pa, calculate how many hydrogen atoms (particles) there are in the sample.

A) 2.42×10^{22}
B) 2.39×10^{22}
C) 2.39×10^{28}

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CONCEPT: SOLVING IDEAL GAS PROBLEMS WITH CHANGING STATES

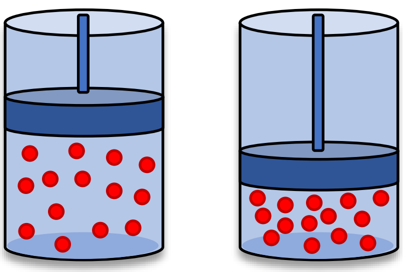
● In some ideal gas problems, you'll have to compare an initial & final "state" of a gas.

- In *most* of these problems, ___ of the 4 variables remain constant.

____________ = ____________ ⇒ $\boxed{\text{———} = \text{———}}$

EXAMPLE: You fill an insulated container with 2 moles of an ideal gas such that no gas can leak out. The container is then compressed with a piston at constant temperature. The initial pressure is 1×10^5 Pa. If the initial volume is 0.05m^3 and the gas is compressed to 0.01m^3, calculate the final pressure.

INITIAL FINAL



IDEAL GAS LAW
1) Write $\frac{P_iV_i}{n_iT_i} = \frac{P_fV_f}{n_fT_f}$
2) Cancel out "constant" variables
3) Solve for Target

● There are 3 "special cases" of the ideal gas law (historically called **The Gas Laws**) where ***n*** & *another variable* are fixed.

- **Boyle's Law:** If *T* constant, ***P*** is *inversely proportional* to ***V***. $\frac{P_iV_i}{n_iT_i} = \frac{P_fV_f}{n_fT_f} \Rightarrow \boxed{P_iV_i = \text{constant} = P_fV_f}$

- **Charles's Law:** If ***P*** constant, ***V*** is *directly proportional* to ***T***. $\frac{P_iV_i}{n_iT_i} = \frac{P_fV_f}{n_fT_f} \Rightarrow \boxed{\frac{V_i}{T_i} = \text{constant} = \frac{V_f}{T_f}}$

- **Gay-Lussac's Law:** If ***V*** constant, ***P*** is *directly proportional* to ***T***. $\frac{P_iV_i}{n_iT_i} = \frac{P_fV_f}{n_fT_f} \Rightarrow \boxed{\frac{P_i}{T_i} = \text{constant} = \frac{P_f}{T_f}}$

PROBLEM: A balloon contains 3900cm^3 of a gas at a pressure of 101 kPa and temperature of –9°C. If the balloon is warmed such that the temperature rises to 28°C, what volume will the gas occupy? Assume the pressure remains constant.

A) 0.012 m^3
B) 0.0041 m^3
C) 0.39 m^3
D) 0.0044 m^3

IDEAL GAS LAW PROBLEMS

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2) Cancel out "constant" variables
3) Solve for Target

IDEAL GAS EQs & Constants

$PV = nRT = Nk_BT$

$R = 8.314 \frac{J}{mol \cdot K} = 0.08206 \frac{L \cdot atm}{mol \cdot K}$
$k_B = 1.38 \times 10^{-23} \frac{J}{K}$
$N_A = 6.02 \times 10^{23} \frac{\text{particles}}{\text{mol}}$

PROBLEM: An ideal gas in a sealed container with a volume of 2.8 L, pressure of 0.15 atm and a temperature of 40°C is warmed until the pressure and volume both double. **a)** What is the final temperature? **b)** How many moles of gas are there?

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● You may be given volume units of ***L*** and pressure units of ***atm***. Useful conversions to know:

1 L = 0.001 m^3

1 atm = 1.01×10^5 Pa