Introduction to Physical Science

The Ideal Gas Law

Presented by Robert Wagner

Behavior of Gases

- Composed of atoms and molecules
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- Gases are easily compressed
  - Particles are very spread out relative to their sizes
- Standard Temperature and Pressure (STP)
  -

Figure 13.17 Atoms and molecules in a gas are typically widely separated, as shown. Because the forces between them are quite weak at these distances, the properties of a gas depend more on the number of atoms per unit volume and on temperature than on the type of atom.

Image Credit: OpenStax College Physics - Figure 13.17 CC BY 4.0

Relation of Pressure, Temperature and Volume

- Inflating a tire
  - First volume increases
  - Next, pressure increases
  - Increased temperature will give an increase in pressure
- Ideal Gas Law relates these
  -
  - ; Boltzmann Constant

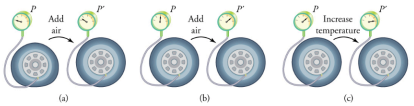

Figure 13.18 (a) When air is pumped into a deflated tire, its volume first increases without much increase in pressure. (b) When the tire is filled to a certain point, the tire walls resist further expansion and the pressure increases with more air. (c) Once the tire is inflated, its pressure increases with temperature.

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Example

- Calculate the number of molecules in a cubic meter of gas at STP (Standard temperature and pressure)
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

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$T = 0^oC(273\,K)\,;\ P = 1.01x10^5\,Pa\,;$
$V = 1.00\,m^3\,;\ k = 1.38x10^{-23}\,J/K$

$$PV = NkT$$

$$N = \frac{PV}{kT}$$

$$N = \frac{(1.01x10^5\,Pa)(1.00\,m^3)}{(1.38x10^{-23}(273K)}$$

$$N = 2.68x10^{25}\,molecules$$

Moles and Avogadro's Number

- Because the number of molecules is so large, we come up with another unit
  - One mole is defined to be the number of atoms in exactly 12 graphs of carbon-12
  - This is known as Avogadro's number ( )
  -
- For all gases there are - see example 13.8 in the textbook for how this is determined.

Ideal Gas Law (moles)

- The Ideal Gas Law can be restated in terms of moles.
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  -
  -
  -

Example

- How many moles of gas are in a bike tire with a volume of , a pressure of at a temperature of ?
  - Draw a sketch
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

Example

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  - Enter values in the equation and solve

$P = 7.00x10^5\ Pa\ ;\ V = 2.00x10^{-3}\ m^3$
$T = 18.0^oC(291\ K)\ ;\ R = 8.31\ J/mol \cdot K$

$$n = \frac{PV}{RT}$$

$$n = \frac{(7.00x10^5\ Pa)(2.00x10^{-3}m^3)}{(8.31\ J/mol \cdot K)(291\ K)}$$

$$n = 0.579\ mol$$

Problem Solving Strategies

- Determine that an ideal gas is involved
- List the known values and convert to SI units
- Determine the unknown
- Which form of ideal gas law to use?
  - Do you know molecules or moles?
- Manipulate the equation as needed to solve for unknown
- Substitute in known values
- Check to make sure the answer is reasonable

Phase Diagrams

- Matter can be in the solid, liquid or gas phase
- A phase diagram plots temperature and pressure
  - Boundaries between phases
  - Critical point - liquid phase no longer exists
  - Triple point - all three phases exist
  - Sublimation - phase change from solid to gas

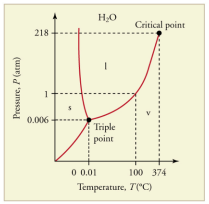

Figure 13.28 The phase diagram (PT graph) for water. Note that the axes are nonlinear and the graph is not to scale. This graph is simplified—there are several other exotic phases of ice at higher pressures.

Summary

- The ideal gas law relates pressure, temperature and volume of an ideal gas
- Avogadro's number give the number of molecules in a specified quantity of matter
- A phase diagram shows at which temperatures and pressures the different phases will exist