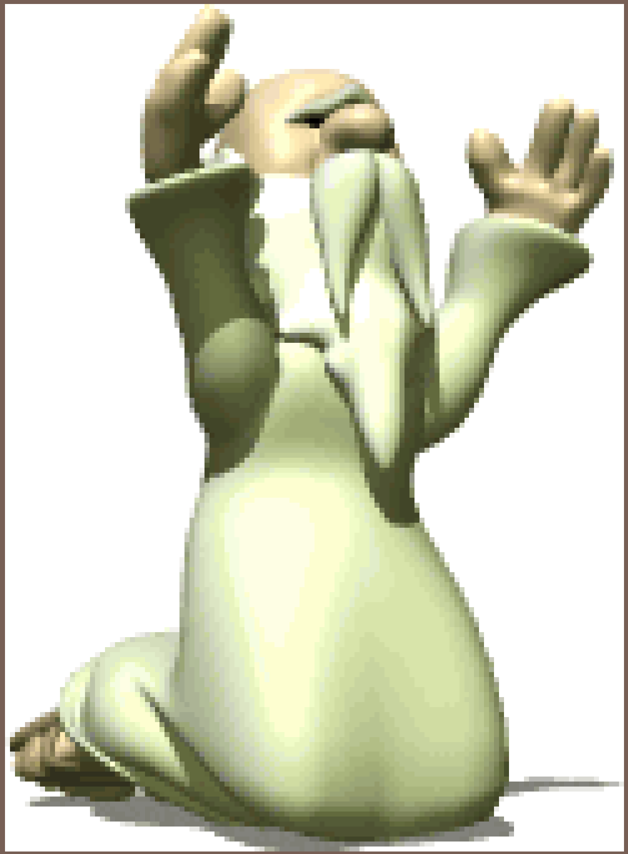

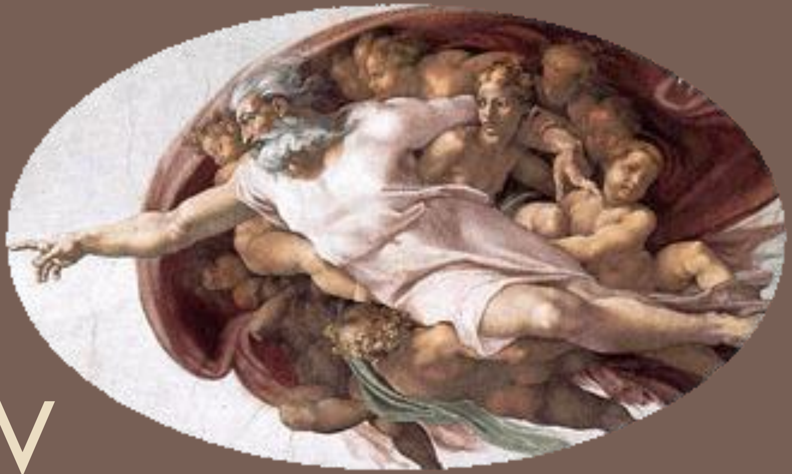

THE IDEAL GAS LAW

Outcome 3.14

Ideal Gases

An "ideal" gas exhibits certain theoretical properties. Specifically, an ideal gas …

- Obeys all of the gas laws under all conditions.
- Does not condense into a liquid when cooled.
- Shows perfectly straight lines when its V and T & P and T relationships are plotted on a graph.

In reality, there are no gases that fit this definition perfectly. We assume that gases are ideal to simplify our calculations.

Ideal-Gas Equation

- So far we've seen that

$$V \propto 1/P \quad \text{(Boyle's law)}$$
$$V \propto T \quad \text{(Charles' law)}$$
$$V \propto n \quad \text{(Avogadro's law)}$$

- Combining these, we get

$$V \propto \frac{nT}{P}$$

WHAT DOES THIS MEAN?

$$V \propto \frac{nT}{P}$$

V	$\propto \frac{nT}{P}$
0	0
1	0.5
2	1
3	1.5
4	2
5	2.5
6	3

- What is the pattern or the proportionality of the data on the left?
- Is there a number you could multiply the right column by so that its values are EQUAL TO the volumes?
- **R = 2**

Ideal-Gas Equation

The relationship

$$V \propto \frac{nT}{P}$$

then becomes

$$V = R\frac{nT}{P}$$

or

$$PV = nRT$$

The Ideal Gas Law

PV = nRT

P = Pressure (in kPa)

V = Volume (in L)

T = Temperature (in K)

n = moles

$$R = 8.31 \frac{kPa \cdot L}{K \cdot mol}$$

R is constant. If we are given three of P, V, n, or T, we can solve for the unknown value.

Ideal-Gas Equation

Units	Numerical Value
L-atm/mol-K	0.08206
J/mol-K*	8.314
cal/mol-K	1.987
m^3-Pa/mol-K*	8.314
L-torr/mol-K	62.36

*SI unit

1. How many moles of H_2 molecules are in a 3.1 L sample of H_2 measured at 300 kPa and 20°C? What is the mass of that sample?

P = 300 kPa

T = 20°C + 273 = 293K

V = 3.1 L

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

Isolate "n"

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

$$n = \frac{(300\ \text{kPa})(3.1\ \text{L})}{(8.314)(293\text{K})} = 0.38\ \text{mol } H_2$$

$$n = 0.38\ \cancel{\text{mol}}\ H_2 \times \frac{2.02\ \text{g}}{1\ \cancel{\text{mol}}}$$

= 0.77 g

2. At 150 C and 100 kPa, 1.00 L of a compound has a mass of 2.506 g. **Calculate its molar mass.**

P = 100 kPa

T = 150°C + 273 = 423K

V = 1.00 L

m = 2.506 g

$$\frac{PV}{RT} = \frac{n\cancel{RT}}{\cancel{RT}}$$ Isolate "n"

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

$$n = \frac{(100\ kPa)(1.00\ L)}{(8.314)(423K)}$$

n = 0.028 mol

$$n = \frac{\cancel{0.028\ mol}}{\cancel{0.028\ mol}} \times \frac{?\ g}{1\ mol} = \frac{2.506\ g}{0.028\ mol}$$

$$\frac{?\ g}{1\ mol} = \frac{2.506\ g}{0.028\ mol} = 89.5\ g/mol$$

Ideal Gas Law Questions

1. How many moles of CO_2(g) are in a 5.6 L sample of CO_2 measured **<u>at STP</u>**?
2. a) Calculate the volume of 4.50 mol of SO_2(g) measured **<u>at STP</u>**. b) What volume would this occupy at 25 C and 150 kPa?
3. How many grams of Cl_2(g) can be stored in a 10.0 L container at 1000 kPa and 30 C?
4. 98 mL of an unknown gas weighs 0.087 g at STP. Calculate the molar mass of the gas. Can you determine the identity of this unknown gas?

1. Moles of CO_2 is in a 5.6 L at STP?

P=101.325 kPa, V=5.6 L, T=273 K PV = nRT

(101.3 kPa)(5.6 L) = n (8.31 kPa•L/K•mol)(273 K)

$$n = \frac{(101.325 \text{ kPa})(5.6 \text{ L})}{(8.31 \text{ kPa}\cdot\text{L/K}\cdot\text{mol})(273 \text{ K})} = \mathbf{0.25 \text{ mol}}$$

2. a) Volume of 4.50 mol of SO_2 at STP.

P= 101.3 kPa, n= 4.50 mol, T= 273 K   PV=nRT

(101.3 kPa)(V)=(4.5 mol)(8.31 kPa•L/K•mol)(273 K)

$$V = \frac{(4.50\ \text{mol})(8.31\ \text{kPa}\cdot\text{L/K}\cdot\text{mol})(273\ \text{K})}{(101.3\ \text{kPa})} = \mathbf{10\underline{0}.8\ L}$$

b) Volume at 25 C and 150 kPa?

Given: P = 150 kPa, n = 4.50 mol, T = 298 K

$$V = \frac{(4.50\ \text{mol})(8.31\ \text{kPa}\bullet\text{L/K}\bullet\text{mol})(298\ \text{K})}{(150\ \text{kPa})} = \mathbf{74.3\ L}$$

3. How many grams of $Cl_2(g)$ can be stored in a 10.0 L container at 1000 kPa and 30 C?

PV = nRT   P= 1000 kPa, V= 10.0 L, T= 303 K

$$\frac{(1000\ \text{kPa})(10.0\ \text{L})}{(8.31\ \text{kPa}\bullet\text{L/K}\bullet\text{mol})(303\ \text{K})} = 3.97\ \text{mol}$$

Cl_2 = 70.9 g/mol

3.97 mol x 70.9 $^{g}/_{mol}$ **= 282 g**

4. 98 mL of an unknown gas weighs 0.081 g at STP. Calculate the molar mass.

PV = nRT P= 101.3 kPa, V= 0.098 L, T= 273 K

$$\frac{(101.3\text{ kPa})(0.098\text{ L})}{(8.31\text{ kPa}\bullet\text{L/K}\bullet\text{mol})(273\text{ K})} = n = 0.003\underline{9}6\text{ mol}$$

$$0.004378\text{ mol} \quad \times \quad \frac{?\text{ g}}{\text{mol}} \quad = \quad 0.081\text{ g}$$

? = 19.88 g/mol

It's probably neon

(neon has a molar mass of 20.18 g/mol)