Unit 9 Part 3: Ideal Gas Law

Ideal Gas Law

- P = pressure (variable units)
- V = volume (MUST be in L)
- n = quantity (MUST be in mol)
- R = universal gas constant (variable units)
- T = temperature (MUST be in K, of course)

PV = nRT

for when you have only one of each variable

Universal Gas Constant, R

- Value depends on the units for pressure!
- Values are given on the formula chart!
- R relates the energy scale in physics to the temperature scale: super important!

on formula chart!

Gas Constant, R, Values
$= 0.08206\ L\ atm\ mol^{-1}K^{-1}$
$= 62.36\ L\ mmHg\ mol^{-1}K^{-1}$
$= 62.36\ L\ torr\ mol^{-1}K^{-1}$
$= 8.314\ L\ kPa\ mol^{-1}K^{-1}$
$= 0.08206\ L\ atm\ mol^{-1}K^{-1}$

$\frac{L \cdot atm}{mol \cdot K}$

→ GAS CONSTANT MUST MATCH ALL THE UNITS!!!!!! ←

Examples:

1. *What is the pressure in atmospheres exerted by a 0.500 mol sample of nitrogen gas in a 10.0 L container at 298 K?*

P = ? atm so $R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$
n = 0.500 mol
V = 10.0 L
T = 298 K

PV = nRT

$$\frac{P(10.0\ L)}{10.0\ L} = \frac{(0.500\ mol)(0.08206 \frac{L \cdot atm}{mol \cdot K})(298\ K)}{10.0\ L}$$

$$\boxed{P = 1.22\ atm}$$

2. *What is the volume, in liters, of 8.00 g of oxygen gas at 20.0°C and 740.24 mmHg pressure?*

V — use for n — T-fish — P — L → $R = 62.36 \frac{L \cdot mmHg}{mol \cdot K}$

$$\frac{8.00\ g\ O_2}{} \left| \frac{1\ mol\ O_2}{32\ g\ O_2} \right. =$$

$n = 0.250\ mol\ O_2$

PV = nRT

$$\frac{(740.24\ mmHg)(V)}{740.24\ mmHg} = \frac{(0.250\ mol)(62.36 \frac{L \cdot mmHg}{mol \cdot K})(293.0\ K)}{740.24\ mmHg}$$

$$\boxed{V = 6.17\ L}$$

3. *What mass of chlorine gas, Cl_2, in grams, is contained in a 10.0 L tank at 27.0°C and 3.50 atm of pressure?*

get from n — V — +273 = T — → R = 0.08206

$$\frac{(3.50\ atm)(10.0\ L)}{(0.08206 \frac{L \cdot atm}{mol \cdot K})(300.0\ K)} = \frac{n(0.08206 \frac{L \cdot atm}{mol \cdot K})(300.0\ K)}{(0.08206 \frac{L \cdot atm}{mol \cdot K})(300.0\ K)}$$

$$n = \frac{1.42\ mol\ Cl_2}{} \left| \frac{70.90\ g\ Cl_2}{1\ mol\ Cl_2} \right. = \boxed{101\ g\ Cl_2}$$

→ PV=nRT can also be used to describe relationships between pressure, volume, number of moles, and temperature! ←

Inversely related if on same side.
Directly related if on opposite sides.

Examples:

4. *If we decrease the volume of a gaseous system by a factor of 3, what will happen to the pressure of the system (if all other variables remain constant)?*

$PV = nRT$ same side, so inversely related

if V decreases by a factor of 3, P will increase by a factor of 3 (triple)

5. *If we increase the temperature of a gaseous system by a factor of 2, what will happen to the volume of the system (if all other variables remain constant)?*

$PV = nRT$
opposite sides, so directly related

if T increases by a factor of 2, P increases by a factor of 2 (doubles)

6. *If we lower the temperature of a gaseous system by a factor of 4 and increase the volume by a factor of 2, what will happen to the pressure of the system (if all other variables remain constant)?*

T ÷ 4 means P will decrease to 1/4
V × 2 means P will decrease to 1/2

$\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$

P decreases by a factor of 8, to 1/8 the original

Practice Makes Perfect!

$\rightarrow R = 62.36 \frac{L \cdot torr}{mol \cdot K}$

1. What pressure, in torr, is exerted by 0.325 mol of hydrogen gas in a 4.08 L container at 35.0°C?

P n V +273 = T

$$\frac{P(4.08 L)}{4.08 L} = \frac{(0.325 mol)(62.36 \frac{L \cdot torr}{mol \cdot K})(308.0 K)}{4.08 L}$$

$\boxed{P = 1530 \text{ torr}}$

2. If we increase the temperature of a gaseous system by a factor of 2 and increase the volume by a factor of 4, what will happen to the pressure of the system (if all other variables remain constant)?

T × 2 means P will increase × 2

V × 4 means P will decrease to 1/4

$2 \times \frac{1}{4} = \frac{1}{2}$

P decreases by a factor of 2, to 1/2 the original

3. What is the mass, in grams, of oxygen gas in a 12.5 L container at 45.0°C and 731.39 kPa?

get from n V +273 P $\rightarrow R = 8.314$

$$\frac{(731.39 kPa)(12.5 L)}{(8.314 \frac{L \cdot kPa}{mol \cdot K})(318.0 K)} = \frac{n(8.314 \frac{L \cdot kPa}{mol \cdot K})(318.0 K)}{(8.314 \frac{L \cdot kPa}{mol \cdot K})(318.0 K)}$$

$n = 3.46 \text{ mol } O_2 \times \frac{32 \text{ g } O_2}{1 \text{ mol } O_2} = \boxed{111 \text{ g } O_2}$