Unit 9 Part 4: Other Gas Laws

Gas Laws

- Mathematical relationship between **pressure, volume, temperature,** and **quantity (# of moles)** of a gas.

→ Units must be the same on both sides of the equation! ←

☆ **→ Temperature must be in Kelvin! ←** ☆

Combined Gas Law

- The most awesome of all the gas laws (because it's the only one you ever really need)

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

→ If any three of these variables are the same**, the fourth must also be the** same**! ←**

Boyle's Law

- Assumes temperature and quantity (moles) are constant
- Assumes flexible container (so V can change)
- Pressure and volume are inversely related
  - If P ↑ then V ↓

$$P_1V_1 = P_2V_2$$

Charles' Law

- Assumes pressure and quantity (moles) are constant
- Assumes flexible container (so V can change)
- Temperature and volume are directly related
  - If T ↑ then V ↑

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

must be in K!

Gay-Lussac's Law

- Assumes volume and quantity (moles) are constant
- Assumes a rigid container (so V CAN'T change)
- Temperature and pressure are directly related
  - If T ↑ then P ↑

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

must be in K!

Avogadro's Law

- Assumes temperature and pressure are constant
- Assumes flexible container (so V can change)
- Quantity (moles) and volume are directly related
  - If n ↑ then V ↑

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

→ If MOLES of gas is the same, then PARTICLES of gas is the same! ←

Examples:

flexible container

1. A sample of nitrogen gas is contained in a piston with a freely moving cylinder. At 0.00 °C, the volume of the gas is 375 mL. To what temperature must the gas be heated to occupy a volume of 0.500 L?

V_1 = 375 mL; T_2 = ?; V_2 = 500. mL; 0.00 °C + 273 = T_1

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \frac{(375\,mL)}{273.00\,K} = \frac{500.\,mL}{T_2}$$

$$\frac{375\,mL \times T_2}{375\,mL} = \frac{(273.00\,K)\times(500.\,mL)}{375\,mL}$$

$T_2 = 364\,K$

2. A helium-filled balloon has a volume of 50.0 L at STP. What volume will it have a 0.855 atm and 10. °C?

V_1 = 50.0 L; T_1 = 0 °C = 273 K; P_1 = 1 atm; P_2 = 0.855 atm; 10. °C + 273 = T_2

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{283\,K}{0.855\,atm} \times \frac{(1\,atm)(50.0\,L)}{273\,K} = \frac{(0.855\,atm)(V_2)}{283\,K} \times \frac{283\,K}{0.855\,atm}$$

$V_2 = 60.6\,L$

3. If we increase the volume of a gaseous system by a factor of 4 and increase the temperature by a factor of 8, what will happen to the pressure of the system (assuming other variables remain constant)?

if V × 4, then P will be 1/4

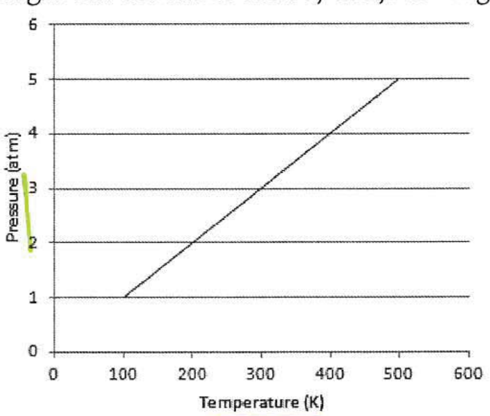
if T × 8, then P will be × 8

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

P will double

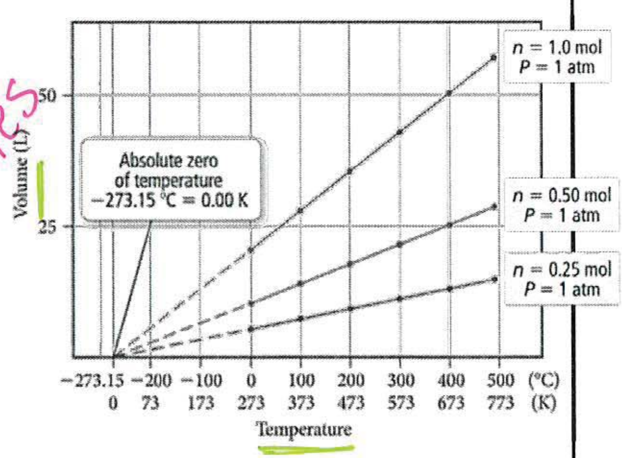
4. Which gas law describes each of the following graphs?

Gay-Lussac



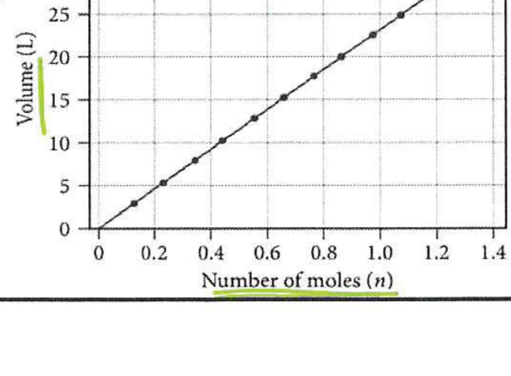
a.

Charles



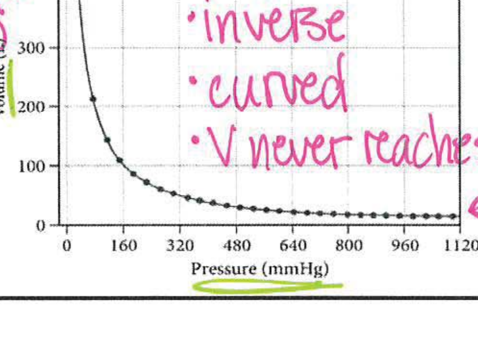
b.

Avogadro



Boyle

weird b/c:
- inverse
- curved
- V never reaches 0



d

Practice Makes Perfect!

Free Response Practice

1. If we increase the temperature of a gaseous system by a factor of 4 and increase the pressure by a factor of 8, what will happen to the volume of the system (assuming other variables remain constant)?

if T × 4, then V × 4
if P × 8, then V → $\frac{1}{8}$

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

V will decrease to ½

2. The gas in an aerosol can is at a pressure of 3.00 atm at 25.0 °C. Directions on the can warn the user not to keep the can in a place where the temperature exceeds 52.0 °C. What would the gas pressure be in the can at 52.0 °C?

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$325.0\,K \times \frac{3.00\,atm}{298.0\,K} = \frac{P_2}{325.0\,K} \times 325.0\,K$

$P_2 = 3.27$ atm

3. A sample of oxygen gas has a volume of 150. mL when its pressure is 0.947 atm. What will the volume of the gas be at a pressure of 750. mmHg if the temperature remains constant?

$P_1V_1 = P_2V_2$

$P_2 = 750.\,mmHg \times \frac{1\,atm}{760\,mmHg} = 0.987\,atm$

$\frac{(0.947\,atm)(150.\,mL)}{0.987\,atm} = \frac{(0.987\,atm)(V_2)}{0.987\,atm}$

$V_2 = 144$ mL

4. A gas sample occupies 8.77 L at 20.0°C. What is the pressure, in atmospheres, given that there are 1.45 mol of gas in the sample?

→ $R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

no duplicate values, so PV = nRT!

$\frac{P(8.77L)}{8.77L} = \frac{(1.45\,mol)(0.08206 \frac{L \cdot atm}{mol \cdot K})(293.0\,K)}{8.77\,L}$

P = 3.98 atm

5. A balloon filled with helium gas has a volume of 500. mL at a pressure of 1.0 atm. The balloon is released and reaches an altitude of 6.5 km, where the pressure is 0.50 atm. Assuming that the temperature has remained the same, what volume does the gas occupy at this height?

$P_1V_1 = P_2V_2$

$\frac{(1.0\,atm)(500.\,mL)}{0.50\,atm} = \frac{(0.50\,atm)(V_2)}{0.50\,atm}$

$V_2 = 1000$ mL = **1.0 L**

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

$T \div 2$, $P \div 2$ (to $\frac{1}{2}$)

$V \div 4$, $P \times 4$

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

P will increase by a factor of 2 (double)

7. Consider three identical flasks filled with different gases:

   Flask A: CO at 760 torr and 0 °C

   Flask B: N_2 at 250 torr and 0 °C

   Flask C: H_2 at 100 torr and 0 °C

   a. In which flask will the molecules have the greatest average kinetic energy and why?

   All same T, so all same average KE

   b. In which flask will the molecules have the greatest velocity and why?

   C - smallest mass at same average KE will be highest v → $KE = \frac{1}{2}mv^2$

   c. Which flask has the greatest number of gas molecules and why?

   A - identical flasks (same V) at same temp, so highest P means highest n (& therefore highest # particles)

8. A sample of neon gas occupies a volume of 752 mL at STP. What volume will the gas occupy at 50.0 °C if the pressure remains constant?

V_1 $T_1 = 0°C = 273\ K$ ~~$P_1 = 1$ atm~~ $+273 = T_2$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$323\ K \times \frac{752\ mL}{273\ K} = \frac{V_2}{323\ K} \times 323\ K$$

$V_2 = 890.\ mL$

9. A 700. mL gas sample containing 0.0312 mol of the gas at STP is compressed to a volume of 200. mL and the temperature is increased to 30.0 °C. What is the new pressure of the gas in atm?

V_1 ~~A~~ $T_1 = 0°C = 273\ K$, $P_1 = 1$ atm V_2 $+273 = T_2$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

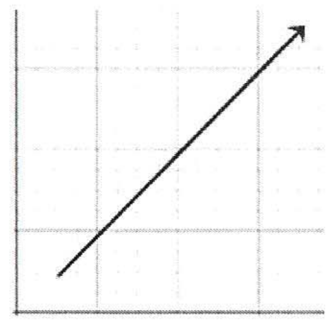
$$\frac{303\ K}{200\ mL} \times \frac{(1\ atm)(700.\ mL)}{273\ K} = \frac{P_2(200.\ mL)}{303\ K} \times \frac{303\ K}{200\ mL}$$

$P_2 = 3.88$ atm

10. A sample that contains 4.38 mol of a gas at 250. K has a pressure of 86.84 kPa. What is the volume in liters?

Multiple Choice Practice

11. The unlabeled graph shown to the right is a correct representation of the relationship between each pair of variables below except:



   a. Temperature and pressure
   b. Pressure and volume
   c. Temperature and volume
   d. Number of moles and volume

12. In an ideal gas, the Kelvin temperature:
   a. Fluctuates widely when the gas is in a sealed container
   b. Is inversely proportional to the kinetic energy of the gas
   c. Is directly proportional to the kinetic energy of the gas
   d. Is a measure of the potential energy of the gas

13. According to the kinetic molecular theory, gases are compressible because:
   a. Their particles are in constant, random motion
   b. Collisions between particles are elastic
   c. Attractive forces between particles are insignificant
   d. The volume of their particles is very small compared to the total volume of the container

14. At constant volume, decreasing the temperature of a gas (in Kelvin) by half would result in:
   a. The pressure decreasing by half
   b. No change in the pressure
   c. The pressure doubling
   d. A ½ increase in pressure

15. In the ideal gas law, this variable is inversely proportional to pressure:
   a. temperature in Celsius
   b. temperature in Kelvin
   c. volume
   d. number of moles