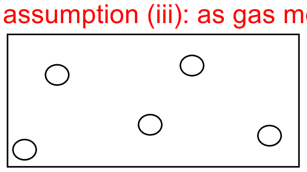
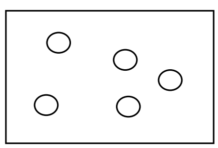
Objective 13: States of matter – gases: relate kinetic theory of gases to gas variables (P, V, T, and n). Apply ideal gas law.
Quiz Practice problems
Key ideas:
Gases are described by the kinetic theory of gases.
Four properties (pressure, temperature, volume, and moles) describe a gas. These properties are related by the ideal gas law:
PV = nRT
where P = pressure in atm, V = volume in liters, n = moles, R = gas constant = 0.082 l atm/mole K, T = temperature in K.
If you are comparing 2 conditions, you can use $P_1V_1/n_1T_1 = P_2V_2/ n_2T_2$.
Ideal gas conditions are low pressure and high temperature.
Skills: relate the assumptions of the kinetic theory of gases to T, P, V, and n.
Use algebra to manipulate the ideal gas equation to solve for one variable.
Given gas conditions (T, P, V, and n), predict what happens when one or more conditions change.
Use gas laws to explain situations involving gases.

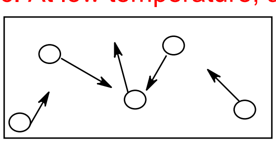
1. The three assumptions of the kinetic theory of gases are:
   i. gas molecules move very fast and in constant, random motion.
   ii. gas molecules are "point-sized" (distance between gas molecules is much greater than size of gas molecule).
   iii. no attractive or repulsive forces between gas molecules

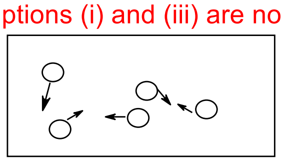
a. A gas that is subjected to high enough pressure will condense to a liquid. Which assumption(s) in the kinetic molecular theory are no longer valid at high pressure? Draw a picture of gas molecules as P increases.
b. Based on the assumptions of the kinetic molecular theory, is it possible for an ideal gas to condense? Give reasons.
c. A gas that is subjected to a low enough temperature will condense to a liquid. Which assumption(s) in the kinetic molecular theory are no longer valid at low temperature? Draw a picture of gas molecules as T decreases.
d. When the three assumptions are valid, a gas is considered an ideal gas. The conditions under which a gas is ideal are high temperature and low pressure conditions. Explain why these conditions make a gas an ideal gas.
Answers:
a. At high pressure, assumptions (ii) and (iii) are no longer valid.
assumption (ii): gas molecules move close together so gas molecules are no longer point-sized.
assumption (iii): as gas molecules mover closer, they start to attract and repel each other.


low P


high P

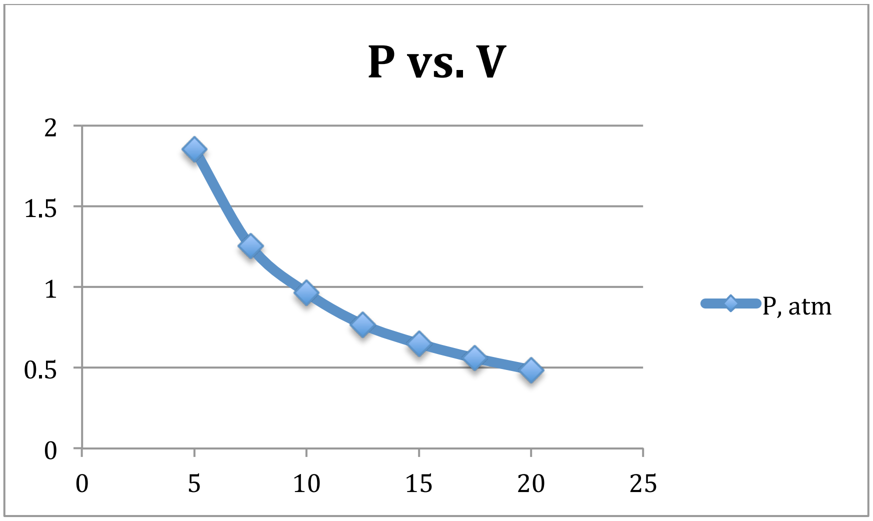
b. It is not possible for an ideal gas to condense because an ideal gas does not have any attractive or repulsive forces between gas molecules.
c. At low temperature, assumptions (i) and (iii) are no longer valid.


high T


low T

d. High temperature fits assumption (i) gas molecules move very fast and in constant, random motion.
Low pressure fits assumption (ii) gas molecules are "point-sized" (distance between gas molecules is much greater than size of gas molecule).
Low pressure fits assumption (iii) no attractive or repulsive forces between gas molecules

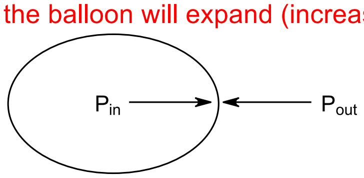
2. A pressure vs. volume graph for a fixed moles of gas at 25^{o}C is shown below.



a. Is P directly or inversely proportional to V?
b. Write the math relationship between P and V.
Answers:
a. P is inversely proportional to V. As volume increases, pressure decreases.
b. P α 1/V

3. a. Assume a bike tire has a fixed volume and the temperature of the air in the tire does not change. As you pump more air into the tire, what happens to the pressure?
b. Is P directly or inversely proportional to n (moles)?
c. Before you pump air into the tire, the moles of air in the tire is 0.5 moles and pressure of air in the tire is 1.5 atm. You pump 0.3 moles of air into the tire. Calculate the new pressure. (Answer: between 2.3 and 2.5 atm)
d. Why don't you need to know V and T?
Answers:
a. Pressure increases.
b. P is directly proportional to n.
c. Compare 2 conditions: $P_1V_1/n_1T_1 = P_2V_2/ n_2T_2$.
Assume V and T do not change (V and T are constant so $V_1 = V_2$ and $T_1 = T_2$) so $P_1/n_1 = P_2/ n_2$.
P_1 =1.5 atm, n_1 = 0.5 moles, n_2 = 0.5 + 0.3 moles = 0.8 moles so
1.5 atm/0.5 moles = P_2/ 0.8 moles.
Solve for P_2 = 2.4 atm.
d. V and T are constant so $V_1 = V_2$ and $T_1 = T_2$.

4. You blow air into a balloon and tie the balloon. Then, you put the balloon into a hot oven.
a. What happens to the balloon?
b. What 2 gas variables (P, V, T, n) stay constant? (Answer: n is constant. The other variable that does not change is ____.)
c. What 2 gas variables (P, V, T, n) change?
d. Write the math relationship between ____ and ____.
e. You blow 0.06 moles of air at 310 K into a balloon and the balloon expands to 1.5 liters, T = 300 K.
(i) Calculate the pressure of air in the balloon. (What equation should you use?) (Answer: approximately 1 atm)
(ii) You put the balloon into a 300°F = 420 K hot oven and P = 1 atm and n = 0.06 moles. What is the new volume? (What equation should you use?)
Answers:
a. Balloon expands (volume increases).
b. n and P are constant. No air enters or escapes from the balloon so n does not change. As T increases, P increases and the balloon will expand (increase V) until the P inside the balloon is the same as the P outside the balloon.



c. V and T change.
d. T α V

e. n_1 = 0.06 moles of air, V_1 = 1.5 liters, T_1 = 300 K.
(i) Pressure of air in the balloon = 1 atm. P inside the balloon is the same as the P outside the balloon
(ii) T_2 = 420 K hot oven and P_2 = 1 atm and n_2 = 0.06 moles. V_2 = ?
Use equation: $P_1V_1/n_1T_1 = P_2V_2/ n_2T_2$.
P and n are constant so $P_1 = P_2$ and $n_1 = n_2$.
$V_1/T_1 = V_2/ T_2$.
1.5 l/300 K = V_2/420 K
solve for V_2 = 2.1 l

5. You blow air into a steel ball. Then, you put the steel ball into a hot oven.
a. What happens to the air inside the ball?
b. What 2 gas variables (P, V, T, n) stay constant?
c. What 2 gas variables (P, V, T, n) change?
d. Write the math relationship between ____ and ____.
e. When you blow air into the steel ball, P = 1.3 atm, V = 2.0 liters, T = 300 K.
(i) Calculate the moles of air in the ball. (Answer: between 0.10 and 0.12 moles) (What equation should you use?)
(ii) You put the balloon into a 300°F = 420 K hot oven and V = 2.0 liters and n = 0.11 moles. What is the new pressure? (What equation should you use?)
Answers:
a. T and P increases.
b. V and n stay constant.
c. T and P change.
d. T α P
e. (i) PV = nRT
Solve for n = PV/RT = (1.3 atm)(2.0 l)/(0.082 l atm/mole K)(300 K) = 0.11 moles
(ii) Use equation: $P_1V_1/n_1T_1 = P_2V_2/ n_2T_2$.
V and n are constant so $V_1 = V_2$ and $n_1 = n_2$.
$P_1/T_1 = P_2/ T_2$.
1.3 l/300 K = P_2/420 K
solve for P_2 = 1.8 atm

6. Explain what happens in the situations described below. Identify the variables and the specific gas law that is involved.
a. Marshmallow when heated.
b. Marshmallow when placed in a closed filter flask attached to a vacuum cleaner.
c. Tire pressure in the summer compared to the winter.
d. Hot air rises. Relate density to molar mass.
e. Think of two situations that involve gas laws.
f. (i) You half fill a 2 liter flexible plastic soda bottle with hot water and cap it tightly. Use gas laws to explain what happens to the bottle as the water inside the bottle cools.
(ii) Will the same thing happen to the bottle if you half fill a bottle with room temperature water in Lake Tahoe and drive to Salinas? Give reasons.
Answers:
a. Volume increases. Compare marshmallow to a balloon. P and n stay constant. V and T change. V α T
b. Volume increases. Compare marshmallow to a balloon. T and n stay constant. P and V change. P α 1/V
c. Pressure increases. V and n stay constant. P and T change. P α T
d. density of a gas = (Molar mass) P / RT
As T increases, density decreases so hot air rises.
e. Situation 1: tire pressure is low so pump air (n increases) into tire.
Situation 2: Helium filled balloon rises because density of He is less than density of air.
f. (i) Hot water in the bottle increases the T of air in the bottle.
As T decreases, P decreases but the bottle will contract (decrease V) until the P inside the bottle is the same as the P outside the bottle.
(ii) In Lake Tahoe (high altitude, P <1 atm), the atmospheric pressure is lower than in Salinas (sea level, P = 1 atm).
In Lake Tahoe, the pressure of air inside the bottle is less than 1 atm.
As you drive toward Salinas, the atmospheric pressure increases on the outside of the bottle so the bottle contracts (volume decreases) until the P inside the bottle is the same as the P outside the bottle.

7. Using your knowledge of gas laws, explain the breathing process (inhalation and exhalation).
Inhalation (inspiration):
i. diaphragm (the muscle sheet that separates the thoracic cavity (heart and lungs) from the abdominal cavity) contracts,
ii. the thoracic cavity expands (the volume of the lungs _____),

iii. the pressure inside the lungs decreases below the pressure outside the lungs (atmospheric pressure),
iv. pressure difference forces air into lungs.

a. What gas law is involved in Steps ii and iii?

b. Describe the Exhalation (expiration) process in 4 steps:

Answers:

a. P α 1/V

i. diaphragm (the muscle sheet that separates the thoracic cavity (heart and lungs) from the abdominal cavity) expands,
ii. the thoracic cavity contracts (the volume of the lungs decreases
iii. the pressure inside the lungs increases above the pressure outside the lungs (atmospheric pressure),
iv. pressure difference forces air out of lungs.