KEY

GAS LAWS, CONCEPTUAL MODEL

Chapter 11 continues our work with the Kinetic Molecular Theory as it relates specifically to gases. To understand and predict the bahavior of a contained gas in a *quantitative* manner, we need to recognize that there are only 4 physical properties involved:

(1) Quantity of gas - usually expressed as moles, symbol *n*
(2) Volume of gas - which describes amount of space occupied by gas, symbol *V*
(3) Temperature of gas which describes Avg. Kinetic Energy, symbol *T*
(4) Pressure of gas - which describes # of collisions, symbol *P*

With your partner, consider each of the following situations. Decide how each of the four properties listed above is involved. Indicate as follows: I = increases, D = decreases, C = remains constant, no change Be prepared to share your answers with the class.

1. On a very cold day in December you take a basketball outside to shoot hoops in the driveway. After several minutes the basketball does not bounce as well. For the gas inside the ball does each property I, D, or C? Has atmospheric pressure changed during this period of time?
(1) quantity C (2) volume D (3) temperature D (4) pressure D

2. On a cold autumn morning, a camper's air mattress seems flatter than it was the aftenoon before. Does each property (I), (D) , or (C)?
(1) quantity C (2) volume D (3) temperature D (4) pressure D

3. You notice that one of your tires seems a little flat one morning, and decide to fill it with air at a gas station. By the time you get to the gas station it looks fine, and the pressure is normal. What has happened to the air in the tire?
(1) quantity C (2) volume I (3) temperature I (4) pressure I

Is the air pressure in the tire (equal to, less than , or greater than) atmospheric pressure?
(less than → would be flat; greater than → would pop)

4. You buy a bouquet of mylar helium balloons to surprise a friend for her (December) birthday. You leave the balloons in your car overnight and the next day they are soft and deflated. For the helium in the balloons:
(1) quantity C (2) volume D (3) temperature D (4) pressure D

Is the helium pressure in the "deflated" balloons (equal to, less than, or greater than) the pressure of the atmosphere?

5. In a cryogenics lab, a scientist takes a small partially-filled balloon out of a canister of liquid nitrogen. (Extremely cold) As the balloon rests on a table, it grows in size. Evaluate each property for the gas in the balloon.
(1) quantity C (2) volume I (3) temperature I (4) pressure I

6. A scuba diver has her tank filled at the dive shop one summer morning. She then leaves the tank in the trunk of her car for a few hours. For the gas in the filled scuba tank:
(1) quantity C (2) volume C (3) temperature I (4) pressure I
(→ Solid container can't expand/contract)

7. One of your bike's tires has a slow leak. For the air inside the tire:
(1) quantity D (2) volume D (3) temperature C (4) pressure D

If the leak continues, will all of the air come out? Explain.
→ only until pressure inside = atmospheric pressure

8. A welder uses oxygen for the combustion reaction in his oxyacetylene torch. At the beginning of the work day the gauge of the tank indicates that the pressure of the oxygen is 2250 psi. Evaluate the oxygen at the end of the day:
(1) quantity D (2) volume C (3) temperature C (4) pressure D
(→ Solid container can't expand/contract)

Key

101.3 kPa = 1 atm = 760 mm Hg

Gas Laws Review

1. The balloon used by Charles in his historic flight in 1783 was filled with about 1300 mol of hydrogen gas. If the temperature of the gas was 23°C, and its pressure was 750 mm Hg, what was the volume of the balloon?

$PV = nRT$

$\frac{750\ mmHg}{1} \times \frac{101.3\ kPa}{760\ mmHg} = 100\ kPa = 0.99\ atm$

$V = \frac{nRT}{P} = \frac{(1300\ mol)(8.314)(296\ K)}{100\ kPa}$

V = 31,992.3 L

2. The nitrogen gas in an air bag, with a volume of 65 L, exerts a pressure of 829 mm Hg at 25°C. What quantity of nitrogen gas (in moles) is in the air bag?

$PV = nRT$

$\frac{829\ mmHg}{1} \times \frac{101.3\ kPa}{760\ mmHg} = 110.5\ kPa = 1.09\ atm$

$n = \frac{PV}{RT} = \frac{(110.5\ kPa)(65\ L)}{(8.314)(298\ K)} = 2.9\ mol$

3. You have a 22 L cylinder of helium at a pressure of 150 atm and at 31°C. What will the volume of helium be on a day when the atmospheric pressure is 755 mm Hg and the temperature is 22°C? With this volume of helium, how many 5 L balloons can you fill?

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

$\frac{755\ mmHg}{1} \times \frac{1\ atm}{760\ mmHg} = 0.99\ atm$

$\frac{(150\ atm)(22\ L)}{304\ K} = \frac{(0.99\ atm)V_2}{295\ K}$ **$V_2 = 3235\ L$**

$\frac{3235\ L}{1} \times \frac{x\ balloons}{5\ L} =$ **647 balloons**

4. Helium-filled balloons are used to carry scientific instruments high into the atmosphere. Suppose that a balloon is launched when the temperature is 22.5°C and the barometric pressure is 754 mm Hg. If the balloon's volume is 4.19 x 10^3 L (and no helium escapes from the balloon), what will the volume be at a height of 20 ~~moles~~ miles, where the pressure is 76 mm Hg and the temperature is –33°C? (5280 feet = 1 mile)

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

$\frac{(754\ mmHg)(4.19 \times 10^3\ L)}{295.5\ K} = \frac{(76\ mmHg)V_2}{240\ K}$

$V_2 = 3.38 \times 10^4\ L$

33761.8 L

5. Suppose you have a sample of CO_2 in a gas-tight syringe. The gas volume is 25 mL at room temperature (20°C). What is the final volume of the gas if you hold the syringe in your hand to raise the temperature to 37°C?

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

$\frac{25\ mL}{293\ K} = \frac{V_2}{310\ K}$ **$V_2 = 26.5\ mL$**

6. A sample of gaseous nitrogen in a 65 L automobile air bag has a pressure of 745 mm Hg. If this sample is transferred to a 25 L bag with the same temperature as before, what is the pressure of the gas in the new bag?

$P_1V_1 = P_2V_2$

$(745\ mmHg)(65\ L) = P_2(25\ L)$ **$P_2 = 1937\ mmHg$**

7. A sample of carbon dioxide gas has a pressure of 55 mm Hg in a volume of 125 mL. The sample is compressed so that the new pressure of the gas is 78 mm Hg. What is the new volume of the gas? (The temperature does not change in this process).

$P_1V_1 = P_2V_2$

$(55\ mmHg)(125\ mL) = (78\ mmHg)V_2$ **$V_2 = 88.1\ mL$**

101.3 kPa = 1 atm = 760 mm Hg

8. Convert a pressure of 635 mm Hg into its corresponding value in units of atmospheres and kilopascals.

$\frac{635 \text{ mmHg}}{1} \times \frac{1 \text{ atm}}{760 \text{ mmHg}} = 0.84 \text{ atm}$, 84.6 kPa

9. 12.0 g of oxygen gas are required to inflate a balloon to what volume at 27°C and a pressure of 79.8 kPa?

$PV = nRT$

$\frac{12 g}{1} \times \frac{1 mol}{32 g} = 0.375 \text{ mol}$

$V = \frac{nRT}{P} = \frac{(0.375 mol)(8.314)(300 K)}{79.8 kPa} = 11.7 L$

10. Methane burns in oxygen to produce carbon dioxide and water, according to the equation:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

If 22.4 L of gaseous CH_4 is burned, what volume of $O_2(g)$ is required for complete combustion? What volumes of carbon dioxide and water are produced? Assume all gases have the same temperature and pressure.

$CH_4 : CO_2$ (1:1)
$CH_4 : H_2O$ (1:2)

$\frac{22.4 L \ CH_4}{1} \times \frac{1 mol \ CH_4}{22.4 L} \times \frac{2 mol \ O_2}{1 mol \ CH_4} \times \frac{22.4 L}{1 mol} = 44.8 L \ O_2$

$22.4 L \ CO_2$

$44.8 L \ H_2O$

11. Halothane has the formula $C_2HBrClF_3$. It is a nonflammable, nonexpolsive, nonirritating gas that is commonly used as an inhalation anesthetic. Suppose you mix halothane vapor with a partial pressure of 80.2 mm Hg with oxygen gas that has a partial pressure of 755 mm Hg. What is the total pressure of the mixture of gases?

$P_{Tot} = P_{Ho} + P_{O_2}$

$= 80.2 \text{ mmHg} + 755 \text{ mmHg}$

$P_{Tot} = 835.2 \text{ mmHg}$

12. You have a sample of gas in a flask with a volume of 250 mL. At 25.5°C the pressure of the gas is 360 mm Hg. If you decrease the temperature to –5°C, what is the gas pressure at the lower temperature? V constant

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

$\frac{360 \text{ mmHg}}{298.5 K} = \frac{P_2}{268 K}$

$P_2 = 323.2 \text{ mmHg}$

13. One of the cylinders of an automobile engine has a volume of 400 cm³. The engine takes in air at a pressure of 1.0 atm and a temperature of 15°C and compresses it to a volume of 50 cm³ at 77°C. What is the final pressure of the gas in the cylinder? *Hint: What is the relationship between cm³ and mL?* 1 mL = 1 cm³

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

$V_1 = 400 mL$, $P_1 = 1 atm$, $T_1 = 288 K$

$V_2 = 50 mL$, $T_2 = 350 K$, $P_2 = ?$

$\frac{(1 atm)(400 mL)}{288 K} = \frac{P_2 (50 mL)}{350 K}$

$P_2 = 9.7 atm$

14. Air-filled balloons at room temperature are placed in liquid nitrogen (77 K). What happens to the volume of the balloons? What happens to the speed and movement of the molecules in the balloon? - As T↓, vol. ↓ ∴ balloon gets smaller.

- movement slows (lower KE), less collisions ∴ pressure should also decrease

15. During the demo with the vacuum pump, why did the marshmallows expand when the air was pumped out of the bell jar?

no atm. pressure pushing on marshmallow ∴ marshmallow (air inside) is pushing out & causing it to expand.