ChemQuest 38

Partial Pressures

Name: ______________________
Date: _______________
Hour: _____

Information: Collecting Gas Over Water

When gas is collected in a container, it is often collected using a technique called, "water displacement." In water displacement, a container is filled with water and then gas is bubbled into the container. In this way, the container can be filled with relatively pure gas without air in it.

Figure 1A: A beaker is filled with water and then turned upside down in a bucket of water. Rubber tubing is attached to a source of gas so that the gas is bubbling up through the water in the beaker. These gas bubbles force some of the water out of the beaker.

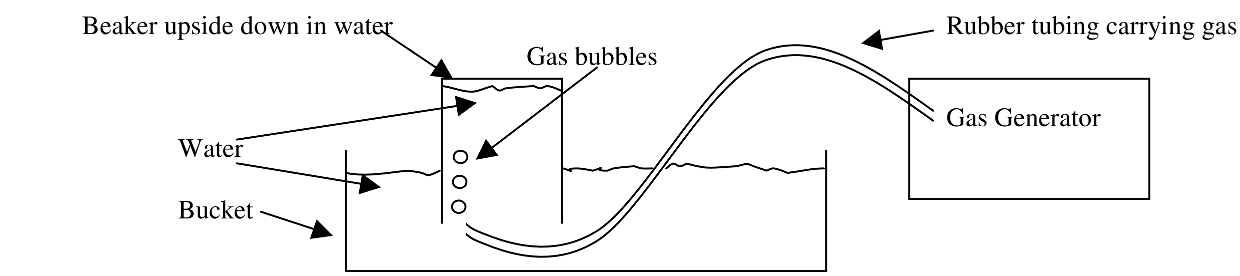
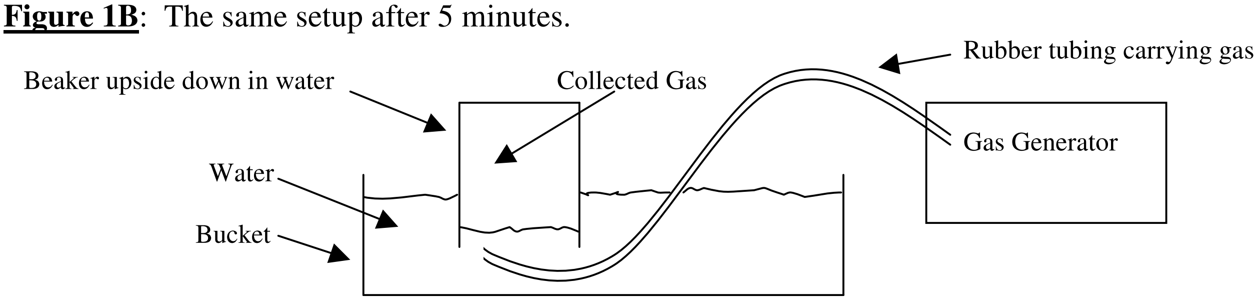


Figure 1B: The same setup after 5 minutes.



Critical Thinking Questions

1. To collect the gas, why is the beaker first filled completely with water? What purpose does the water serve?
   By filling the beaker with the water you are making sure that there is no air in the beaker.

2. Examine the beaker in Figure 1A and 1B. What causes the water level to go down after 5 minutes?
   The gas has replaced the water and the water has gone into the bucket.
3. In Figure 1B, is the gas in the beaker pure? Explain.
   It is quite pure; however, there is some water vapor left behind.

Information: Dry Gas

The gas that is collected is not "dry" because there is some water vapor left behind in the beaker. If you attempt to collect pure oxygen, you will actually get mostly pure oxygen with a little water vapor. You can get an idea of how much water is left behind by examining the water vapor pressure at various temperatures.

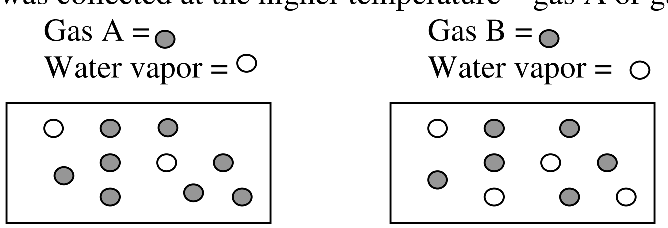
Table 1: Vapor pressure of water at various temperatures.

Temperature (^{o}C)	**Vapor Pressure (kPa)**
0	0.6
5	0.9
10	1.2
15	1.6
20	2.3
25	3.2
30	4.2
35	5.6
40	7.4
45	9.8

Critical Thinking Questions

4. Why is it logical to expect that the vapor pressure of water would increase as the temperature increases?
   As the temperature increases, water is more likely to evaporate and the evaporated molecules move faster, colliding with more force (or pressure).

5. Examine the two containers below. Both contain gases that were collected over water. Which one was collected at the higher temperature—gas A or gas B? Explain your answer.



   Gas B was collected at higher temperatures because there is more water vapor mixed with the gas and the water vapor pressure increases as the temperature increases.

6. Consider Gas A from question 5. The total pressure in the container is 104 kPa. If the temperature of the container is 20^{o}C, calculate the pressure of Gas A when it is "dry". Hint: find the vapor pressure of water at 20^{o}C from Table 1 and then subtract it from the total pressure in the container.
   104 – 2.3 = 101.7 kPa

7. Consider Gas B from question 5. The total pressure in the container is 110 kPa. If the temperature of the container is 35^{o}C, calculate the pressure of Gas B when it is "dry".
   110 – 5.6 kPa = 104.4 kPa

Information: Dalton's Law of Partial Pressures

John Dalton was one of the first scientists to quantitatively state a mathematical relationship involving the total gas pressure in a container and the individual gases in the container. Dalton's law states that the total pressure of any mixture of gases in a container is the sum of all the individual gas's partial pressures. In equation form, Dalton's law can be written as:

$$P_{Total} = P_{Gas\ A} + P_{Gas\ B} + P_{Gas\ C} + \ldots$$

Critical Thinking Questions

8. A container of gas with a pressure of 450 kPa contained three different gases—hydrogen, oxygen and nitrogen. If the partial pressure of hydrogen was 210 kPa and the partial pressure of oxygen was 125 kPa, what was the partial pressure of nitrogen?

   450 – (210 + 125) = 115 kPa

9. A tank held neon gas at a pressure of 350 kPa, helium at a pressure of 275 kPa and argon at a pressure of 410 kPa. What was the pressure in the tank?

   350 + 275 + 410 = 1035 kPa

10. A certain gas was collected over water. The total pressure of the container was 100.0 kPa. The pressure of the dry gas was 94.4 kPa. At what temperature was the gas collected?

    100.0 – 94.4 = 5.6 kPa (the water vapor pressure)→This corresponds to a temperature of 35°C

11. Hydrogen gas was collected over water at a pressure of 102.5 kPa and a temperature of 25°C. After sealing the container, it was heated to 210°C. What is the final pressure of the dry hydrogen gas? (Hints: You must first find P_1 for the gas by subtracting out the water vapor from the given pressure; solve for P_2 using the combined gas law with constant volume.)

    P_1 = 102.5 kPa – 3.2 kPa = 99.3 kPa; T_1 = 25°C + 273 = 298K; T_2 = 210°C+273= 483 K

    $$\frac{P_1}{T_1} = \frac{P_2}{T_2} \rightarrow \frac{99.3}{298} = \frac{P_2}{483} \rightarrow P_2 = 160.9\ kPa$$

12. Oxygen gas was collected over water at 30°C. The pressure in the 2.5 L container was 110 kPa. If the container was allowed to expand to 7.0 L and if the temperature was decreased to -30°C, what is the final pressure of the dry oxygen gas?

    P_1=110-4.2 = 105.8 kPa; T_1 = 30°C+273 = 303 K; T_2 = -30°C + 273 = 243 K

    $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \rightarrow \frac{105.8(2.5)}{303} = \frac{P_2(7.0)}{243} \rightarrow 30.3\,kPa$$

13. A quantity of oxygen gas was collected over water at 30°C in a 475 mL container. The pressure in the container was measured to be 105 kPa. How many grams of oxygen gas were collected?

P = 105 – 4.2 = 100.8 kPa; molar mass of O_2 = 32.0g/mol; V = 0.475 L (not mL); T = 303 K

MPV = mRT → (32.0)(100.8 kPa)(0.475) = m(8.31)(303) → **m = 0.608 g**