Unit 8 – Gas Laws

Progress Tracker

Test Date: _____

Webassign Due *Score*

_____ _____
_____ _____
_____ _____

Packet Progress Checks

_____ _____
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Test Readiness Checks:

- ☐ My webassign scores indicate I am ready for the test.
- ☐ I went to ASP for Webassign help when needed.
- ☐ I have completed the unit review AND checked my answers.
- ☐ I am aware that I cannot retake the test unless my webaassign and packet progress checks are all above 80%.

Essential Vocabulary:

- ✓ Ideal gas
- ✓ Pressure (atmospheres)
- ✓ Volume
- ✓ Temperature (Kelvin and Celsius)
- ✓ Barometer
- ✓ Partial pressure
- ✓ Gas constant (R = 0.0821 L *atm/mol*K)
- ✓ mmHg
- ✓ Torr
- ✓ Atmosphere
- ✓ kilopascals

Essential Outcomes:

- ✓ Describe the differences between solids, liquids, and gases on the molecular level.
- ✓ Know the meaning of vibration, rotation, and translation as modes of molecular motion.
- ✓ Interconvert mmHg, torr, atmospheres, kPa
- ✓ Interconvert Celsius and Kelvin
- ✓ Define absolute zero and describe molecular motion at absolute zero.
- ✓ Define the principles of the Kinetic Molecular Theory.
- ✓ Perform calculations with gas laws: Boyle's, Charles', Gay-Lussac's, Avogadro's, Combined, and the ideal gas law.
- ✓ Perform calculations with the ideal gas law to find the molar mass of the gas.
- ✓ Perform stoichiometry calculations for reactions which produce gases.
- ✓ Perform calculations with Dalton's Law of partial pressures.
- ✓ Perform calculations for gases collected over water

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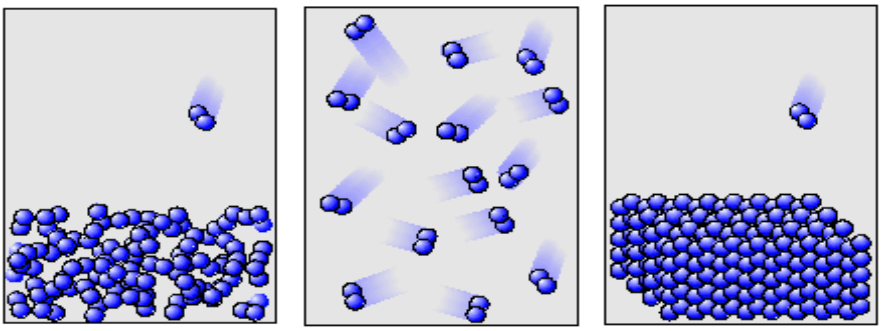
States of Matter Prior Knowledge Check

1. Label each of the following diagrams as a solid, liquid, or gas.



_____ _____ _____

2. In the previous question you labeled the 3 states of matter. Which of the 3 would have the lowest kinetic energy?

3. In your own words, what does "kinetic energy" mean?

4. Match each term below with the phase change that it represents:

____Condensation

____Melting

____Sublimation

____Evaporation or vaporization

____Deposition

____Fusion

A. Liquid becomes a gas
B. Liquid becomes a solid
C. Gas becomes a liquid
D. Gas becomes a solid directly
E. Solid becomes a liquid
F. Solid becomes a gas directly.

5. What are the names of the 3 phase changes in question 4 that require you to add energy to get them to happen?

_____ _____ _____

6. Explain how you determined your answer to the previous question.

States of Matter Simulation Lab

Procedure:

- Open the internet browser and enter the address: http://phet.colorado.edu
- Click on "Play with Sims" and select "Chemistry" from the menu on the left.
- Open the "States of Matter-Basic" Simulation and select "Run Now"

INVESTIGATE:

1. Use the menu on the right side of the program to select Water and Solid. Draw and describe what you see in the space below.

Diagram	Description

2. Now, use the slider on the bottom of the program to add heat. Notice the thermometer at the top of the program. What temperature scale is this thermometer showing? _____

3. What happens to the water as you increase the temperature? _____
_____
_____
_____

4. What is the melting/freezing point of water in Kelvin? _____

5. Add heat until the temperature is just below and then just above the melting point of water. How is water different below its melting point and above it? _____
_____
_____
_____

Draw and describe what water looks like as a liquid.

Diagram	Description

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6. What is the boiling/condensation point of water in Kelvin? _____

7. Continue to add heat until you are just below and then just above the boiling point of water. How is water different below its boiling point and above it? _____
_____
_____
_____

8. Draw and describe what water looks like as a gas.

Diagram	Description

9. When describing the movement of molecules, we generally use 3 terms:
   a. Vibration = jiggling a little
   b. Rotation = spinning in circles
   c. Translation = movement in across a room.

Some phases of matter may use all 3 types of movement, others may use just one. Describe the modes of movement that you observe in each:

Gases: _____
Liquids: _____
Solids: _____

10. Choose one of the other three substances listed in the menu on the right. Investigate what happens when you add and remove heat from this substance. Use the buttons on the right to see this substance as a solid, liquid, and gas. Draw and describe its properties in the table below.

Substance Selected: _____

	Solid	Liquid	Gas
Diagram of molecules			
Sentence explaining how molecules are moving.			

Kinetic Molecular Theory

1. In your own words, summarize each of the 4 assumptions of the KMT.

2. Each of the following statement refer to ways that gases differ from solid or liquids. Explain the meaning of each phrase in a simpler way.

   Gases are <u>expandable</u>

   Gases have low <u>density</u>

   Gases are highly <u>compressible</u>

   Gases <u>diffuse</u> throughout a room

3. Real gases behave most like an ideal gas when their molecules are far apart. Explain why this makes a gas more "ideal".

4. Real gases behave most like an ideal gas when their molecules are non-polar. Which of the following gases is most likely to behave like an ideal gas. Explain why.

   SO_2 N_2 HF

5. Real gases will deviate from ideal behavior the most when the pressure in the container is high. Explain why.

6. Real gases will deviate from ideal behavior the most when the temperature is low. Explain why.

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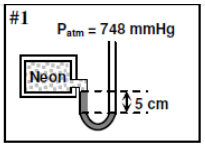
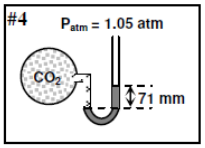
Manometer Practice

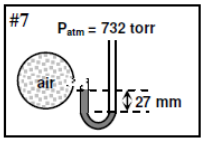
Solve the following problems. Draw a picture of the manometer for each problem.



1. What is the pressure of the neon gas sample in the manometer shown to the right?
2. A container of helium is connected to a manometer and the mercury level is 145 mm lower on the side open to the atmosphere. Atmospheric pressure is 775 mm Hg. Find the pressure of the helium.
3. The mercury in a manometer is 38 mm lower on the side connected to sample of oxygen gas. If the atmospheric pressure is 95.2 kPa determine the pressure of the oxygen.



4. What is the pressure of the carbon dioxide in the manometer shown to the right?
5. The atmosphere has a pressure of 680 torr. An air-filled container has a pressure of 18.9 PSI and is connected to a manometer. Draw a picture of the manometer and determine the height of the mercury column supported by the air.
6. A basketball is attached to a manometer and the mercury is 18 mm higher on the side connected to the atmosphere. The pressure of the atmosphere is 0.95 atm. Find the pressure in the basketball.



7. What is the pressure in pascals for the air sample in the manometer pictured to the right?
8. A gas container is connected to a manometer. The mercury in the manometer is 7.2 cm lower on

Pressure Conversions Practice

Show your work on all calculations. This means drawing train tracks showing all units and checking significant figures. The following information may be useful:

1 atm = 760 mm Hg = 760 torr = 101.3 kPa = 14.69 psi

1. Freon-12 (CF_2Cl_2) is commonly used as the refrigerant in central home air conditioners. The system is initially set to a pressure of 70.0 psi. Express this pressure in each of the following units.

   a. mm Hg

   b. atm

   c. kPa

2. An aerosol can contains gases under a pressure of 4.5 atm at 20.0 °C. What would the pressure inside the can be in torr?

3. A balloon filled with helium gas has a pressure of 780 torr. What is this pressure in atm?

4. A paint can is discarded on a sandy beach. Over the course of the day, the pressure inside the can increases to 4.80 atm. What is this pressure in kPa?

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5. A. Here in Colorado the atmospheric pressure is roughly 680 mm Hg. What is this pressure in psi?

   B. How much below standard atmospheric pressure is this? (in atm)

6. A boy pumped his bike tire to a pressure of 120 psi before it exploded. What would this pressure be in atm?

7. Convert the following to mm of Hg:

   a. 1.25 atm

   b. 2.48×10^{-3} atm

   c. 538 kPa

   d. 800. torr

   e. 19.0 psi

Boyle's Law Practice

1) If I have 5.6 liters of gas in a piston at a pressure of 1.5 atm and compress the gas until its volume is 4.8 L, what will the new pressure inside the piston be?

2) I have added 15 L of air to a balloon at sea level (1.0 atm). If I take the balloon with me to Denver, where the air pressure is 0.85 atm, what will the new volume of the balloon be?

3) I've got a car with an internal volume of 12,000 L. If I drive my car into the river and it implodes, what will be the volume of the gas when the pressure goes from 1.0 atm to 1.4 atm?

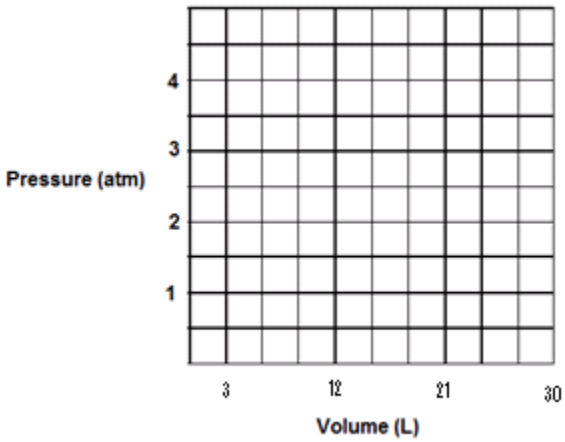
4) The relationship between pressure and volume is A) linear and B) inversely proportional. Explain what these terms mean:

   a. linear:

   b. inversely proportional:

5) A gas is at the pressure and volume shown in row 1 in the table. (A) Calculate the new volume for each pressure in the table. (B) Plot the data in the table and draw best fit line.

Condition	Pressure	Volume
1	1.0 atm	22.4 L
2	1.4 atm	
3	2.1 atm	
4	3.6 atm	



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Charles's Law Practice

1) Convert 0.0 °C to K.

2) Convert 314K to °C

3) Convert -40 °C to K.

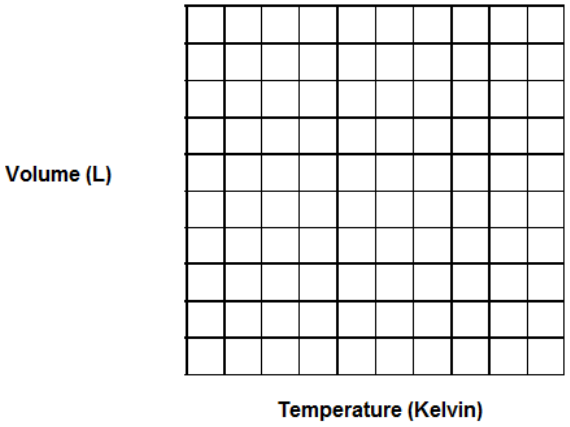
4) If I have 45 liters of helium in a balloon at 25^0 C and increase the temperature of the balloon to 55^0 C, what will the new volume of the balloon be?

5) Calcium carbonate decomposes at 1200^0 C to form carbon dioxide and calcium oxide. If 25 liters of carbon dioxide are collected at 1200^0 C, what will the volume of this gas be after it cools to 25^0 C?

6) A gas is at the volume and temperature shown in row 1 in the table. (A) Calculate the new temperature for each volume in the table. (B) Plot the data in the table and draw best fit line.

Condition	Volume	Temperature
1	2.0 L	25 ºC
2	1.8 L	
3	1.4 L	
4	0.4 L	

7) Based on the graph, Is Charles Law inversely or directly proportional? Explain. based on your graph.



Hints: Label the axis with numbers.

Are your temperature units correct?

The combined gas law

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

Use the combined gas law to calculate volume-temperature-pressure changes. (convert your temperature to °K!!!)

Remember to : List the variables and list the constants (if there are any)

1) A sample of oxygen gas has a volume of 150.0 mL when its pressure is 0.947 atm. What will the volume of the oxygen be at a pressure of 0.987 atm if the temperature remains constant?

Variables: *Constant:* *Equation to use:*

2) A sample of neon gas has a volume of 752 mL at 25 °C. What will the volume of the gas be at 50 °C if the pressure remains constant? HINT: 1504 mL is wrong.

Variables: *Constant:* *Equation to use:*

3) The gas in a deodorant container is at a pressure of 3.00 atm at 25 °C. Directions on the container warn the user not to keep it in a place where the temperature exceeds 52 °C. What would the gas pressure in the container be at 52 °C?

Variables: *Constant:* *Equation to use:*

4) A helium-filled balloon has a volume of 50.0 L at 25 °C and 1.08 atm. What volume will it have at 0.885 atm and 10.0 °C?
Variables: *Constant:* *Equation to use:*

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6) A balloon filled with nitrogen gas is placed in a freezer at 0 °C, and 1 atm. The balloon has a volume of 255 mL in the freezer. Once it is removed from the freezer it is placed in warm water. The balloon warms to the temperature of the water and it expands to a volume of 400 mL. The resulting pressure in the balloon increases to 2.5 atm? What is the final temperature of the balloon?

What's wrong with this problem?

Combined Gas Law Practice #2

Answer the following questions in the space provided. SHOW YOUR WORK ON CALCULATIONS! (This means: a) List info. given in problem, b) state formula you will use, c) plug values into formula, d)state answer with correct units and sig. figs.)

1) If I initially have 4.0 L of a gas at a pressure of 1.1 atm, what will the volume be if I increase the pressure to 3.4 atm?

2) A toy balloon has an internal pressure of 1.05 atm and a volume of 5.0 L. If the temperature where the balloon is released is 20^0 C, what will happen to the volume when the balloon rises to an altitude where the pressure is 0.65 atm and the temperature is -15^0 C?

3) A small research submarine with a volume of 1.2×10^5 L has an internal pressure of 1.0 atm and an internal temperature of 15^0 C. If the submarine descends to a depth where the pressure is 150 atm and the temperature is 3^0 C, what will the volume of the gas inside be if the hull of the submarine breaks?

4) People who are angry sometimes say that they feel as if they'll explode. If a calm person with a lung capacity of 3.5 liters and a body temperature of 36^0 C gets angry, what will the volume of the person's lungs be if their temperature rises to 39^0 C. Based on this, do you think it's likely they will explode?

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Combined Gas Law Practice #3

Answer the following questions in the space provided. <u>SHOW YOUR WORK ON CALCULATIONS!</u> (This means: a) List info. given in problem, b) state formula you will use, c) plug values into formula, d)state answer with correct units and sig. figs.)

1) A bag of potato chips is packaged at sea level (1.00 atm) and has a volume of 315 mL. If this bag of chips is transported to Denver (0.775 atm), what will the new volume of the bag be?

2) A Los Angeles class nuclear submarine has an internal volume of eleven million liters at a pressure of 1.250 atm. If a crewman were to open one of the hatches to the outside ocean while it was underwater (pressure = 15.75 atm), what be would the new volume of the air inside the submarine?

3) A child has a toy balloon with a volume of 1.80 liters. The temperature of the balloon when it was filled was 20^0 C and the pressure was 1.00 atm. If the child were to let go of the balloon and it rose 3 kilometers into the sky where the pressure is 0.667 atm and the temperature is -10^0 C, what would the new volume of the balloon be?

4) A commercial airliner has an internal pressure of 1.00 atm and temperature of 25^0 C at takeoff. If the temperature of the airliner drops to 17^0 C during the flight, what is the new cabin pressure?

5) If divers rise too quickly from a deep dive, they get a condition called “the bends” which is caused by the expansion of very small nitrogen bubbles in the blood due to decreased pressure. If the initial volume of the bubbles in a diver’s blood is 15 mL and the initial pressure is 12.75 atm, what is the volume of the bubbles when the diver has surfaced to 1.00 atm pressure?

Deriving the Gas Equations

Each of the individual gas laws can be discovered from the ideal gas law. For each situation, do not solve the problem, just derive the gas law that would be used. SHOW EACH STEP OF YOUR ALGEBRA!

1. CO_2 gas is contained in a fixed volume container. The temperature is raised from 240K to 800K. If the pressure was at 1.2 atm before the temperature increase, what would the pressure be afterwards?

PV=nRT (circle the things that are variables)

Do algebra to get all the variable on one side and all constants on the other:

2. A balloon filled with 3 moles of hydrogen gas at 1.6 atm in a rigid container is filled to a total of 5.2 moles. What would be the pressure of the container?

PV=nRT (circle the things that are variables)

Do algebra to get all the variable on one side and all constants on the other:

3. 5) A hydrogen-filled zeppelin used on bombing missions in WW I had a volume of 4550 m^3 at 25 °C and 101 kPa. What volume will it have if it flies into a low pressure zone with a pressure of 95kPa and 20.0 °C?

PV=nRT (circle the things that are variables)

Do algebra to get all the variable on one side and all constants on the other:

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Ideal Gas Law Practice

Answer the following questions in the space provided. SHOW YOUR WORK ON CALCULATIONS! (This means: a) List info. given in problem, b) state formula you will use, c) plug values into formula, d)state answer with correct units and sig. figs.)

1) How many moles of gas does it take to occupy 120 liters at a pressure of 2.3 atmospheres and a temperature of 340 K?

2) If I have a 50 liter container that holds 45 moles of gas at a temperature of 200^0 C, what is the pressure inside the container?

3) It is not safe to put aerosol canisters in a campfire, because the pressure inside the canisters gets very high and they can explode. If I have a 1.0 liter canister that holds 2 moles of gas, and the campfire temperature is 1400^0 C, what is the pressure inside the canister?

4) How many moles of gas are in a 30 liter scuba canister if the temperature of the canister is 300 K and the pressure is 200 atmospheres?

5) I have a balloon that can hold 100 liters of air. If I blow up this balloon with 3 moles of oxygen gas at a pressure of 1 atmosphere, what is the temperature of the balloon?

Gas Stoichiometry

Answer the following questions in the space provided. ***<u>SHOW YOUR WORK ON CALCULATIONS!</u>***

1. Nitric acid can be produced by the reaction of gaseous nitrogen dioxide with water.

   $$3NO_{2(g)} + H_2O_{(l)} \rightarrow 2HNO_{3(l)} + NO_{(g)}$$

   If 708 L of NO_2 gas at 315K and 0.87 atm react with excess water how many grams NO gas will be produced?

2. What volume of oxygen gas is needed to react completely with 280 g of carbon monoxide gas, CO, to form gaseous carbon dioxide? Assume all volume measurements are made at STP *(Hint: Write a balanced equation first.)*

3. What mass of sulfur must be used to produce 12.61 L of gaseous sulfur dioxide at -30 ^oC and 790 mmHg? *(Balance the equation first.)*

   $$S_{8(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

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4. How many liters oxygen gas in liters can be collected at 0.987 atm pressure and 25.0 °C when 30.6 g of $KClO_3$ decompose by heating according to the following equation:

$$2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$$

5. If 29.0 L of methane, CH_4, reacts with 34 grams of O_2 at 0.961 atm and 20.0 °C, how many grams of water are produced? *(Balance the equation first!)*

$$CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$$

6. Nitroglycerine explodes to form several gases:

$$4C_3H_5O_9N_3 \rightarrow 12CO_{2(g)} + O_{2(g)} + 6N_{2(g)} + 10H_2O_{(g)}$$

A sealed 10.0 mL container filled with 5.00 g of nitroglycerine is detonated. Assuming room temperature (27.0 °C) and assuming that the container would not break upon detonation, what is the pressure inside the container in atmospheres?

Dalton's Law of Partial Pressures Practice

1. If I place 3 moles of N_2 and 4 moles of O_2 in a 35 L container at a temperature of 25^0 C, what will the pressure of the resulting mixture of gases be?

2. What's the partial pressure of carbon dioxide in a container that holds 5 moles of carbon dioxide, 3 moles of nitrogen, and 1 mole of hydrogen and has a total pressure of 1.05 atm?

3. A flask contains nitrogen and oxygen at total pressure of 730 mmHg. If the mole fraction of nitrogen is 0.72, what is the pressure of each gas?

4. What is the mole fraction of fluorine gas in a flask that contains 520 mmHg fluorine and 120 mmHg hydrogen?

5. Two flasks are connected with a stopcock. The first flask has a volume of 5 liters and contains nitrogen gas at a pressure of 0.75 atm. The second flask has a volume of 8 L and contains oxygen gas at a pressure of 1.25 atm. When the stopcock between the flasks is opened and the gases are free to mix, what will the pressure be in the resulting mixture?

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Partial Pressures

Name: _____

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.

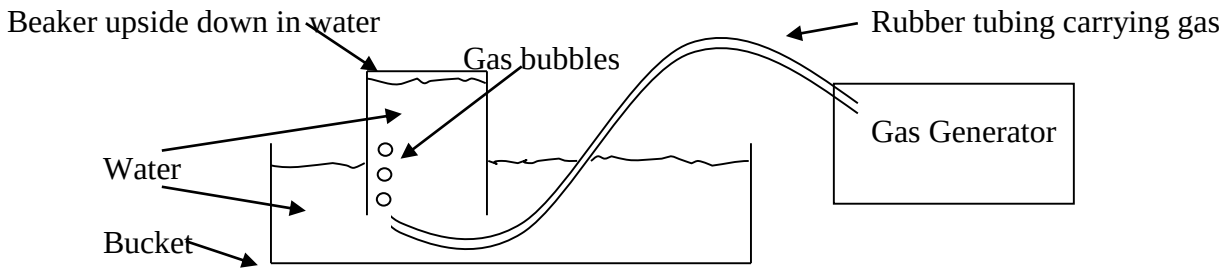
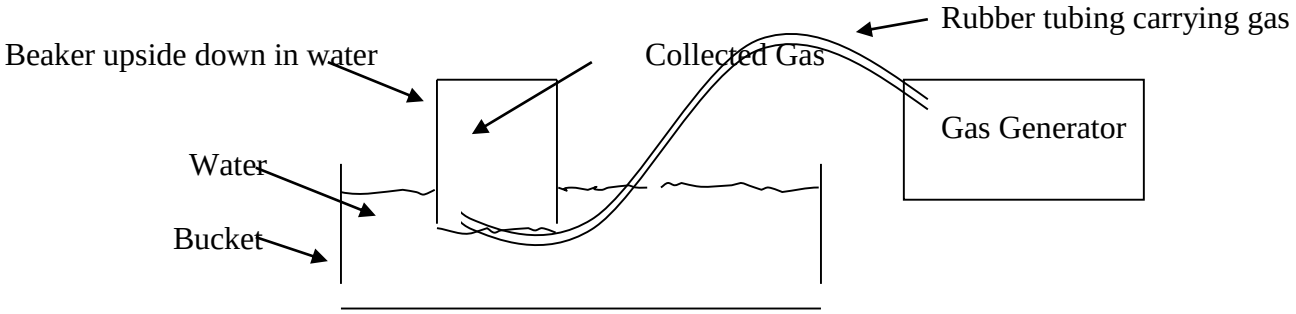


Figure 1B: The same setup after 5 minutes.



Critical Thinking Questions

1. To collect the gas, why is the beaker first filled completely with water? What purpose does the water serve?

2. Examine the beaker in Figure 1A and 1B. What causes the water level to go down after 5 minutes?

3. In Figure 1B, is the gas in the beaker pure? Explain.

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.

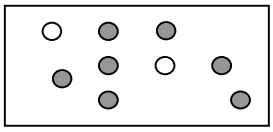
Temperature (ºC)	Vapor Pressure (kPa)
0	0.6
5	0.9
10	1.2
15	1.6
20	2.3
25	3.2
30	4.2
35	5.6
40	7.4
45	9.8

Critical Thinking Questions

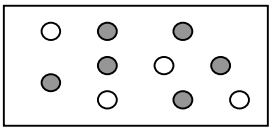
4. Why is it logical to expect that the vapor pressure of water would increase as the temperature increases?

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 A = ●
Water vapor = ○



Gas B = ●
Water vapor = ○



6. Consider Gas A from question 5. The total pressure in the container is 104 kPa. If the temperature of the container is 20ºC, calculate the pressure of Gas A when it is "dry". Hint: find the vapor pressure of water at 20ºC from Table 1 and then subtract it from the total pressure in the container.

7. Consider Gas B from question 5. The total pressure in the container is 110 kPa. If the temperature of the container is 35ºC, calculate the pressure of Gas B when it is "dry".

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

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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?

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?

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?

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.)

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?

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?