♥ TOPIC-5: VOLUME AND PRESSURE MEASUREMENTS

In experimenting with gases, an accurate method of measuring the temperature, the volume, and the pressure of the gas is required. The temperature is easy to measure using a thermometer. The volume and pressure, however, can be difficult.

To simplify the measurement of the volume of a fluid (gas or liquid), we will use a syringe. The syringe is an easy and convenient way to measure the volume of a gas in the laboratory.

A mercury barometer is used to measure atmospheric (air) pressure. However, it is difficult to measure the pressure of a gas with a barometer. Instead, a manometer is easier and more convenient to use.

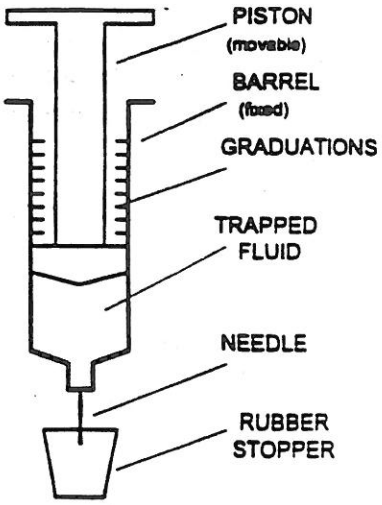
Below is a short review of a syringe, a barometer, and a manometer which are the basic instruments used in the upcoming experiments designed to study the behavior of gases.

THE SYRINGE

A **syringe** consists of three major parts; a movable piston, a fixed barrel (a graduated cylindrical container), and a needle. Note that the barrel may contain any fluid (gas or liquid).

When the piston is fully pressed, the volume is zero. When the piston is pulled upwards, fluid enters the barrel. The exact volume of the fluid trapped within the barrel can be read directly from the graduations on the barrel of the syringe. As the piston is pressed, the contents of the barrel is ejected.

It is important to note that the gas contained in a syringe will exert a pressure on the movable piston. Indeed, the piston may be difficult to push or pull depending on the pressure of the trapped gas and it may even be necessary to clamp the piston to prevent it from moving when constant volume is required.

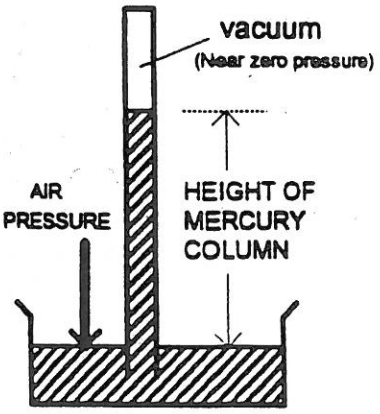


THE MERCURY BAROMETER

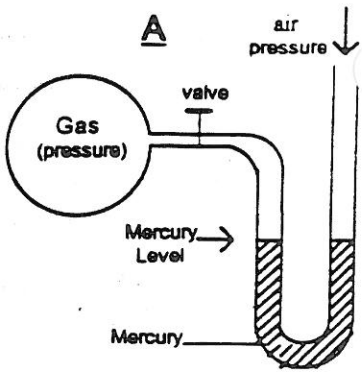
A **barometer** consists of a vessel of mercury with an inverted tube of mercury in it. The principle of the barometer is simple. As air pressure pushes down on the mercury in the vessel, the pressure in the liquid mercury pushes the column of mercury up the column of the tube. In effect, a state of equilibrium exists where the weight of the column of mercury pushing downwards, (see diagram for the "height of mercury column") equals the atmospheric pressure (force) pushing upwards.

Because there is a direct relationship between the air pressure and the height of the mercury column, we can determine the air pressure simply by measuring the "height of mercury column". In fact, every millimetre along the column of mercury represents 0.133 kPa of pressure.

NOTE: STP refers to Standard Temperature and Pressure where the standard temperature is 0^{o} C and standard pressure is 101.3 kPa.

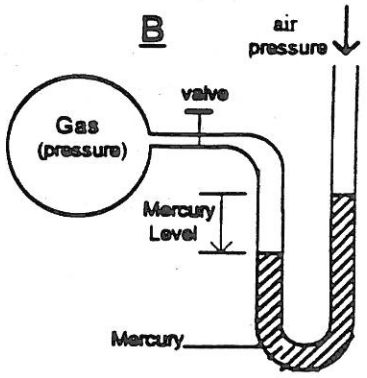


THE MANOMETER



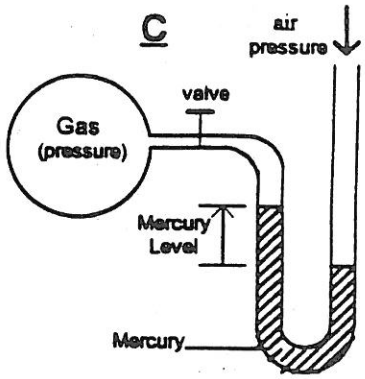
The manometer is a device consisting of a U-shaped tube with mercury in it. The tube on the left side of the U-tube is called the "left arm" and the tube on the right side is called the "right arm" of the manometer.

Unlike the barometer which gives us an absolute value, the manometer gives us a relative measure. That is to say, the manometer gives us the difference in height between the column of mercury in the left arm and the column of mercury in the right arm. The operation of the manometer is similar to that of a see-saw. If the mercury on one side is pressed down, the mercury on the other side goes up and vice-versa. This means that if we know the pressure on either side, we know the pressure on the other side. Of course, when the pressure on the left arm equals the pressure on the right arm, the difference in the levels is zero.



In using the manometer, one arm is left open (at air pressure) while the other end is connected to a container filled with a gas. The gas pressure will either be equal to, be less than, or be greater than the air pressure outside the container. Knowing the difference between the two mercury levels and the atmospheric pressure of the room, we can calculate the pressure of the gas in the container. Thus, unlike the barometer which gives us a direct (or absolute) reading, the manometer provides us with the means to calculate the pressure of a gas.

↳ *Note*: Every millimetre difference between the two levels of mercury equals 0.133 kPa of pressure.



When the level of mercury is lower at the open ended tube, the air pressure is greater than the gas pressure. In this case, we must subtract the mercury level difference from the atmospheric air pressure. On the other hand, when the level of mercury is higher at the open ended tube, the air pressure outside the container is lower than the pressure of the gas in the container. In this case, we must add the mercury level difference to the atmospheric air pressure. Study the following examples.

Assume that atmospheric air pressure is 760 mm or 101 kPa (that's 760 x 0.133).

Example-A: Consider a gas causing the manometer to rest as shown in diagram-A In this case, the gas pressure equals atmospheric air pressure which is 101 kPa.

Example-B: Now consider a gas causing the manometer to rest as shown in diagram-C. In this case, the gas pressure is greater than atmospheric pressure since the arm connected to the container indicates a mercury level lower than the arm open to the atmosphere. If the difference in the mercury levels is 15 mm. This is a pressure difference of 2 kPa (15 x 0.133). The pressure of the gas is, therefore, 101 kPa + 2 kPa or 103 kPa.

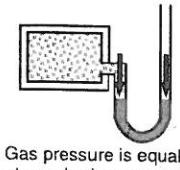
Example-C: Consider a gas causing the manometer to rest as shown in diagram-B. In this case, the gas pressure is less than atmospheric pressure since the arm connected to the container indicates a mercury level higher than the arm open to the atmosphere. If the difference in the mercury levels is 15 mm. This is a pressure difference of 2 kPa (15 kPa x 0.133). The pressure of the gas is, therefore, 101 kPa - 2 kPa or 99 kPa.

Manometers

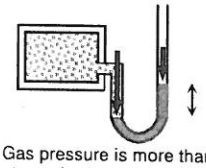
Chem Worksheet 13-2

Name _____

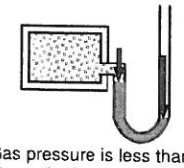
A manometer is a device that measures the pressure of a gas in an enclosed container. It is made from a U-shaped tube filled with mercury. The pressure of the gas in the container is compared to the pressure from the atmosphere. If the gas pressure is the same as the atmospheric pressure the level of mercury in both sides of the U-tube will be the same. If the gas is at a higher pressure than the atmosphere the mercury level on the side open to the atmosphere will be higher. If the gas is at a lower pressure than the atmosphere the mercury level on the side open to the atmosphere will be lower.



Gas pressure is equal to atmospheric pressure



Gas pressure is more than atmospheric pressure



Gas pressure is less than atmospheric pressure

USEFUL EQUATIONS

1.00 atm = 101300 Pa	1.00 atm = 101.3 kPa	1.00 atm = 14.7 psi
1.00 atm = 760 torr	1.00 atm = 760 mmHg	1 cm = 10 mm

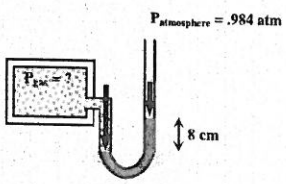
example

An enclosed container of gas is connected to a manometer. The mercury level is 8 cm lower on the side connected to the gas sample. If atmospheric pressure is .984 atm find the pressure of the gas in the container.

- draw a picture

- convert all measurements to mm Hg

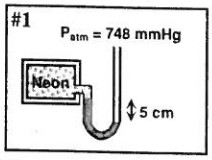
$$\frac{8\ \cancel{cm}}{1} \times \frac{10\ mm}{1\ \cancel{cm}} = 80\ mm \qquad \frac{.984\ \cancel{atm}}{1} \times \frac{760\ mmHg}{1.00\ \cancel{atm}} = 748\ mmHg$$



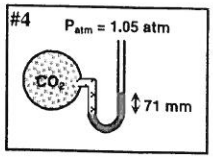
- add or subtract the measurements based on the drawing

748 mmHg + 80 mmHg = 828 mmHg

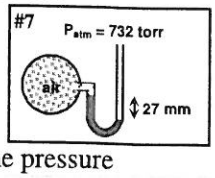
Solve the following problems. Draw a picture of the manometer for each problem.



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 the side open to the atmosphere. Atmospheric pressure is measured to be 755 mm Hg. What is the pressure of the gas in atmospheres?

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Chem Gas Worksheet #1. Blk ____ Name _____

Data to know & use! 1atm=760.mmHg=101.325kPa=14.7lb/in^2, or by 1989 definition
Standard Pressure = 100.kPa=750.1mmHg=14.5lb/in^2 = 0.987atm= 1Bar.
1mole gas @STP = 22.4L =22,400cm^3. STP=0°C, 1atm. 0 K = -273.15°C = -459.67°F.
1mole gas @ SATP = 24.8L =24,800cm^3, Standard Ambient Temp. & Pressure= 100.kPa, 25°C.

A. Pressures. Show a unit cancellation setup. WATCH SIG. FIGS.

a. 412 mmHg = _____ atm.

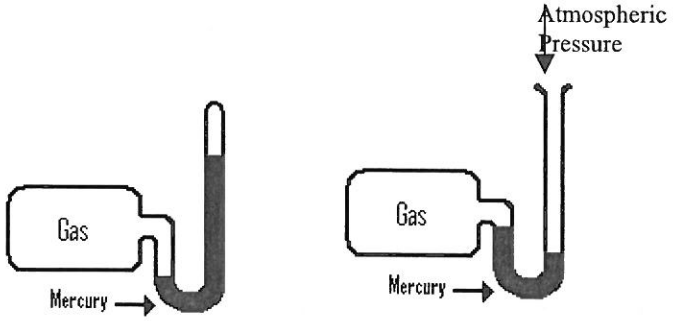
b. 760. KPa = _____ mmHg

c. 14.7 atm = _____ kPa

d. 101.325 lb/in^2 = _____ kPa

e. 22.4 mmHg = _____ kPa

B. Manometers.



Closed end manometer Open end manometer

a. In a closed end manometer, the mercury level was 690. mm higher on the closed end than on the gas side. What was the pressure of the gas?

_____ mmHg

b. In a closed end manometer, the Hg levels were 419 mm different. What was the gas pressure?

_____ mmHg

c. In a closed end manometer, the Hg levels were 1273 mm different. What was the gas pressure IN ATM?

_____ atm

d. Open end manometer: atmospheric pressure 760. mmHg, and the mercury level was 120. mm higher on the right side than the left. What was the gas pressure?

_____ mmHg

e. Open end manometer, atmospheric pressure 755 mmHg, Hg level 75 mm higher on the left. What was the gas pressure?

_____ mmHg

f. Open end manometer, with the atmospheric pressure 97.2 kPa. Mercury level 35 mm higher on the left. What is the gas pressure?

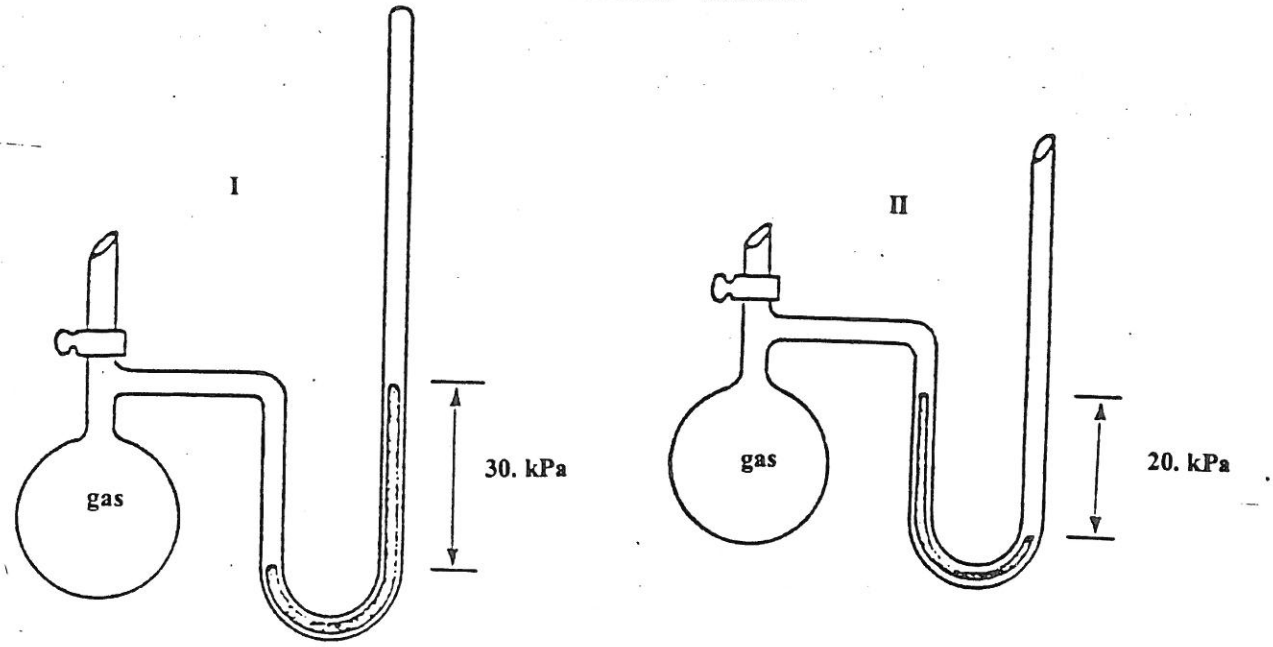
_____ kPa

C. Temperatures. a. 25°C = _____K b. -147°C = _____K c. 926K = _____°C

d. 35.2K = _____°C e. –2.8°C = _____K f. 12,780,000K = _____°C

1. A barometer measures _____ pressure. A manometer measures _____ pressure. There are 2 types of manometers. They are _____ ended and _____ ended. The _____ ended manometer is read directly.

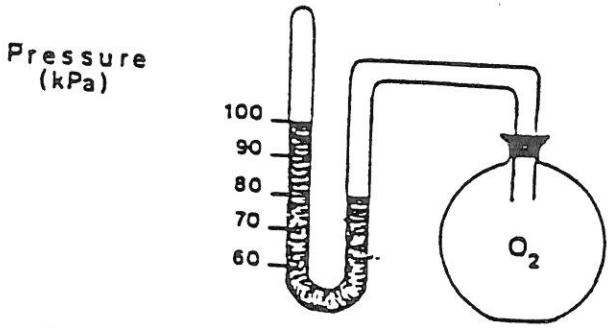
2. Air Pressure = **100. KPa**



In figure I the gas pressure = _____

In figure II the gas pressure = _____

3. A sample of oxygen gas is placed in a container attached to a closed end manometer as represented below:



If the external pressure is 100 kPa, what is the pressure exerted by the oxygen gas in the vessel?

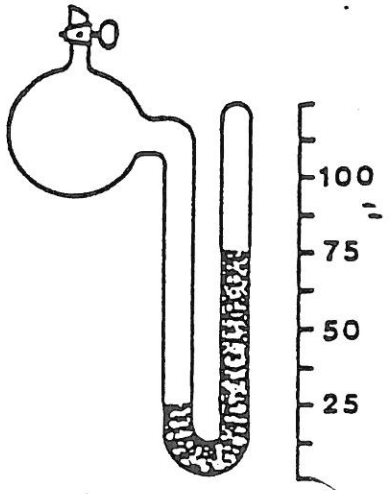
a) 20 kPa
b) 80 kPa
c) 100 kPa
d) 120 kPa

4. With respect to the kinetic energy of SO_2 and CH_4 gas at the same temperature:

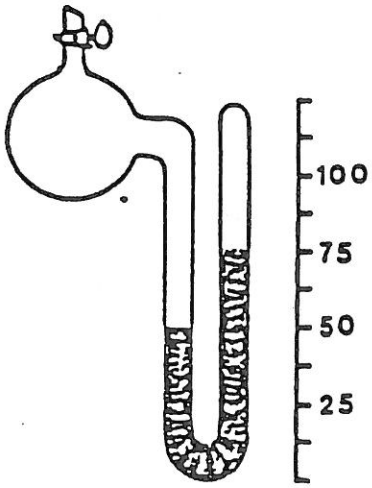
a)both have the same kinetic energy
b)the kinetic energy of SO_2 is four times that of CH_4
c)the kinetic energy of SO_2 is twice that of CH_4
d)the kinetic energy of SO_2 is half that of CH_4

5. Identify the diagram which illustrates a gas having a pressure of 50 kPa.

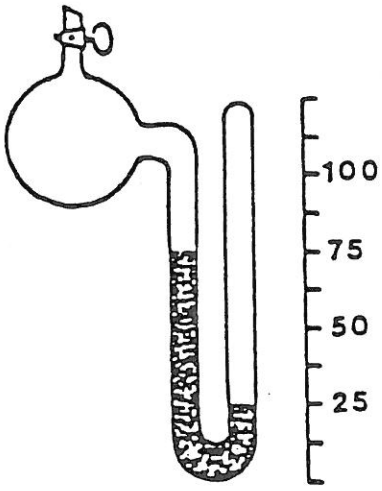
(A)



(C)



(B)



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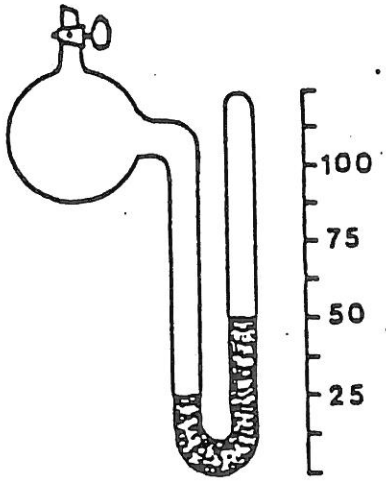

6. Gases can be distinguished from solids and liquids because they are compressible. The kinetic theory explains this characteristic by proposing that in gases:

a)the molecules are continually moving in a straight line
b)the molecules have large spaces between them
c)the molecules collide with each other and the walls of their container
d)the collisions of the molecules are elastic