Chapter 2. Study of Gas Laws

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Solution 1:

An ideal gas can be characterized by three state variables:

1. Absolute pressure (P),
2. Volume (V), and
3. Absolute temperature (T).

Solution 2:

Boyle's law states that "At a constant temperature the volume of a fixed mass of gas is inversely proportional to its pressure."

$$V \alpha \frac{1}{P} \qquad \text{(At constant temperature)}$$

Solution 3:

At constant temperature, volume of a given mass of a gas is inversely proportional to its pressure.

$$V \alpha \frac{1}{P}$$

$$\therefore V = \frac{K}{P}$$

Where, K is the constant of proportionality.

Solution 4:

Charles' law states that "At constant pressure, the volume of a given mass of a dry gas is directly proportional to its absolute temperature (Kelvin).

$$V \alpha T \qquad \text{(At constant pressure)}$$

Solution 5:

Kelvin zero is – 273.15 ^{o}C.

Solution 6:

According to Boyle's law,

$$V \propto \frac{1}{P} \quad \text{(At constant temperature)}$$

$$\text{or} \quad PV = K \quad \ldots\ldots\ldots\ldots(1)$$

According to Charles' law'

$$V \propto T \quad \text{(At constant pressure)}$$

$$\text{or} \quad \frac{V}{T} = K \quad \ldots\ldots\ldots\ldots(2)$$

On combining the above laws,

$$\frac{PV}{T} = K \quad \ldots\ldots\ldots\ldots(3)$$

Where, K is a constant.

Let us suppose that, for a given mass of a gas, the initial pressure, volume and temperature are P_1, V1 and T_1 which changes to P_2, V2 and T_2 respectively. Then,

$$\frac{P_1V_1}{T_1} = K \text{ and } \frac{P_2V_2}{T_2} = K$$

Therefore,

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \ldots\ldots\ldots\ldots(4)$$

Equation (4) is called combined gas law equation.

Solution 7:

The standard temperature and pressure (STP) by general convention are 0 ^{o}C(273 K) and 1 atm(760 mm Hg).

Solution 8:

1. The value of standard temperature is (i) 0 ^{o}C and (ii) 273 K
2. The value of standard pressure is (i) 1 atm, (ii) 760 mm of Hg, (iii)76 cm of Hg, (iv)760 torr

Solution 9:

$P_1 = 240$ mm Hg , $P_2 = 720$ mm Hg

$V_1 = 45.6\ cm^3$, $V_2 = ?$

According to Boyle's law, at constant temperature,

$$P_1V_1 = P_2V_2$$

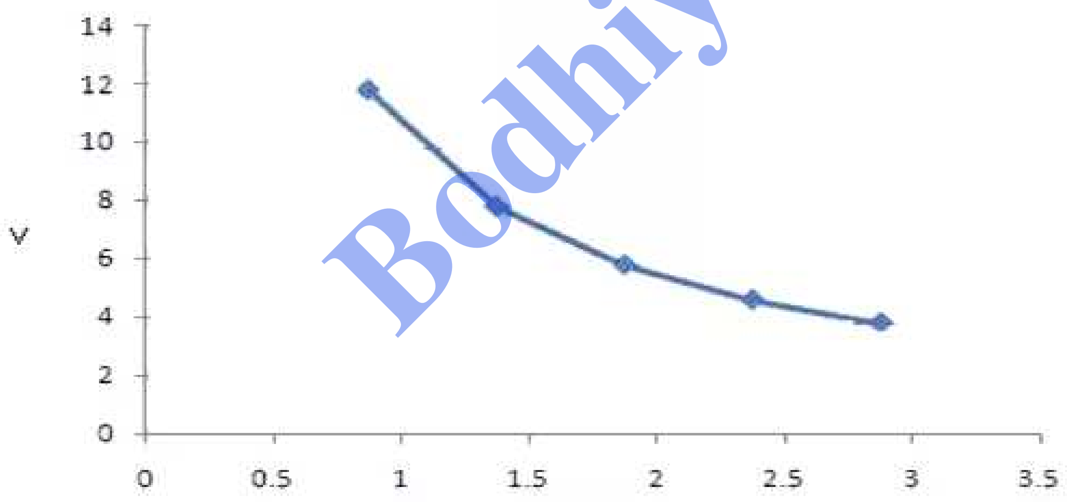
$$240 \times 45.6 = 720 \times V_2$$

$$V_2 = \frac{240 \times 45.6}{720} = \frac{10944}{720} = 15.2\ cm^3$$

Solution 10:

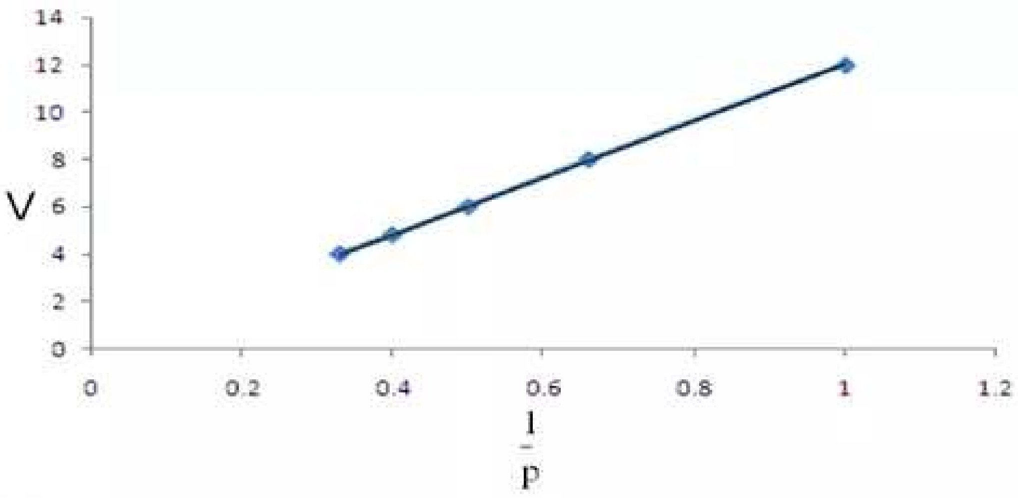
(i)

V	P
12.0	1
8.0	1.5
6.0	2.0
4.8	2.5
4.0	3.0



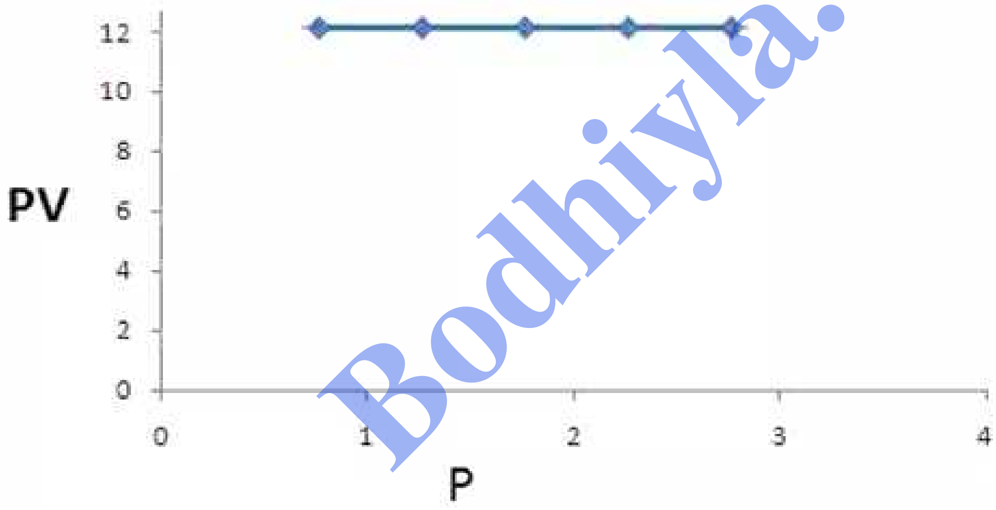
(ii) V vs 1/P,

V	P	1/P
12	1.0	1
8.0	1.5	0.66
6.0	2.0	0.5
4.8	2.5	0.4
4.0	3.0	0.33



(iii)PV vs P

P	V	PV
1.0	12	12
1.5	8.0	12
2.0	6.0	12
2.5	4.8	12
3.0	4.0	12



Solution 11:

Number of moles of ammonia gas $= \frac{6}{22.4} = 0.26$ moles

3 moles of hydrogen form=2 mole of ammonia

0.26 moles of hydrogen form $= \frac{2 \times 0.26}{3} = 0.17$ moles of ammonia

Volume of ammonia gas formed= 0.17 x 22.4=3.8 litres

Solution 12:

There is simultaneous effect of temperature and pressure changes on the volume of a given mass of a gas. So, when stating the volume of a gas, the pressure and temperature should also be given.

Solution 13:

Yes, it is possible to change the temperature and pressure of a fixed mass of a gas without changing its volume. For a given fixed mass of gas, number of moles of gas (i.e. n) remains constant. If the pressure and temperature of a given mass of a gas are changed simultaneously such that ratio of T and P remains constant, then volume will remain unchanged.

$$PV = nRT$$

$$V = \frac{nRT}{P} \quad \text{(where R is constant)}$$

Solution 14:

1. Volume of a gas would be reduced to zero at 0 K ($-273\ ^0C$).All temperatures on the Kelvin scale are positive, so Kelvin scale has been adopted for chemical calculation.
2. At absolute zero temperature, volume of a gas would be reduced to zero. Theoretically,this is the lowest temperature that can be reached. At this temperature all molecular motions cease. Thus, practically this temperature is impossible to attain because on cooling gases liquefy and Charles' law is no more applicable.
3. According to combined gas law equation, there is simultaneous effect of temperature and pressure changes on the volume of a given mass of a gas. So, when stating the volume of a gas, the pressure and temperature should also be given.

Solution 15:

Given:

$V_1 = 4$ litres; $V_2 = ?$

$T_1 = 27^0C = 273 + 27 = 300K$; $T_2 = 150K$

According to Charles' law, at constant pressure,

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

$$\frac{4}{300} = \frac{V_2}{150};$$

$$\therefore V_2 = \frac{4x150}{300} = 2 \text{ litres}$$

Solution 16:

Given;

$P_1 = 12$ atm ; $P_2 = 14.9$ atm

$T_1 = 27^0C = 273+27 = 300°K$; $T_2 = ?$

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

$$\frac{12}{300} = \frac{14.9}{T_2};$$

$$T_2 = \frac{14.9 \times 300}{12} = 372.5\ K = 372.5 - 273 = 99.5\ ^0C$$

Solution 17:

Given;

$P_1 = 760$ mm Hg ; $P_2 = \frac{3}{2} \times 760 = 1140$ mm Hg

$V_1 = 100\ cm^3$; $V_2 = ?$

$T_1 = 0^0C = 273$ K ; $T_2 = \frac{6}{5} \times 273 = 327.6$ K

Now $$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2};$$

$$\frac{760 \times 100}{273} = \frac{1140 \times V_2}{327.6};$$

$$V_2 = \frac{760 \times 100 \times 327.6}{273 \times 1140} = 80\ \text{litres}$$

Solution 18:

1. True
2. False
3. False
4. False
5. False

Solution 19:

Boyle's law-

From Kinetic theory of gases,

$$\frac{1}{2}m\overline{u^2} = \frac{3}{2}kT;$$

$$p = \frac{1}{3}(N/V)m\overline{u^2};$$

$$p = \frac{2}{3}(N/V)\frac{1}{2}m\overline{u^2};$$

$$p = \frac{2}{3}(N/V)(3/2)kT;$$

$$pV = NkT;$$

$$\text{Therefore } p \propto \frac{1}{V}$$

Which is Boyle's law.

Charles' law-

From gas law,

PV = NkT

At constant pressure and constant amount of gas, volume is directly proportional to the temperature which is the statement of Charles' law.

Solution 20:

Given;

$V_1=320$ ml ; $V_2=450$ ml

$T_1=47^0C=47+273=320$ K ; $T_2=?$

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

$$\frac{320}{320} = \frac{450}{T_2};$$

$$T_2 = 450\,K$$

$$= (450-273)\,^0C$$

$$= 177\,^0C$$

Solution 21:

We trap a definite quantity of air in the closed vessel. At any point, the pressure on the air is equal to the atmospheric pressure plus the pressure due to the excess mercury column

in the open end tube. By pouring mercury in the tube, we increase the pressure on the air and measure its volume under that pressure. We thus obtain a set of data for the volume of a fixed mass of air under different pressures.
For a given mass of air at constant temperature, the following observations are made-

1. The volume of air decreases with increasing pressure and vice versa.
2. The proportion by which the volume decreases or increases is the same by which the pressure increases or decreases.

Solution 22:

1. Pressure will also be doubled.
2. Pressure will be double.

Solution 23:

1. 273
2. absolute zero
3. absolute temperature
4. the average kinetic energy

Solution 24:

(a) According to Boyles' law,

$P_1 = 760$ mm Hg ; P2=?

$V_1 = 2$ litres ; $V_2 = 4\ dm^3 = 4$ Litres

$$P_1V_1 = P_2V_2$$

$$760 \times 2 = P_2 \times 4$$

$$P_2 = \frac{760 \times 2}{4} = 380\ \text{mm Hg}$$

(b) According to Boyles' law,

$P_1 = 760$ mm Hg ; P2=?

$V_1 = 2$ litres ; $V_2 = \frac{3}{2}V_1 = 1.5 \times 2 = 3.0$ L

$$\text{Now, } P_1V_1 = P_2V_2$$

$$760 \times 2 = P_2 \times 3$$

$$P_2 = \frac{760 \times 2}{3} = 506.66\ \text{mm Hg}$$

Solution 25:

Given;

$V_1 = 28\ cm^3$; $P_1 = 750$ mm Hg

$V_2 = ?$; $P_2 = 12$ mm Hg

$$P_1V_1 = P_2V_2$$

$$750 \times 28 = 12 \times V_2$$

$$V_2 = \frac{750 \times 28}{12} = 1750\ cm^3$$

Solution 26:

(a) Given;

$P_1 = 100$ cm Hg ; $T_1 = 273$ K

$P_2 = 10$ cm Hg ; $T_2 = ?$

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

$$\frac{100}{273} = \frac{10}{T_2};$$

$$T_2 = \frac{273 \times 10}{100} = 27.3\ K$$

(b) Given;

$P_1 = 100$ cm Hg ; $T_1 = 273$ K

$P_2 = ?$; $T_2 = 100^0C = 273 + 100 = 373$ K

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

$$\frac{100}{273} = \frac{P_2}{373};$$

$$P_2 = \frac{373 \times 100}{273};$$

$$P_2 = 136.63\ cm\ Hg$$

Solution 27:

Given;

$V_1 = 750\ cm^3$; $T_1 = -23^0C = 273-23 = 250\ K$; $P_1 = 800\ mm\ Hg$

$V_2 = 720\ cm^3$; $T_2 = -3^oC = 273-3 = 270\ K$; $P_2 = ?$

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2};$$

$$\frac{800 \times 750}{250} = \frac{P_2 \times 720}{270};$$

$$P_2 = \frac{270 \times 800 \times 750}{250 \times 720} = 900\,mm\,Hg$$

Solution 28:

As weather balloon go higher into the atmosphere, the air becomes less dense, so air pressure drops. Because of this, the air that is already inside the balloon expands to cope with the difference in pressure. The end result is that the balloon expands making it larger.

Solution 29:

$P_1 = 20\ atm$; $T_1 = 27^0C = 273+27 = 300\ K$

$P_2 = 20 + 20 \times \frac{20}{100} = 24\ atm$; $T_2 = ?$

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

$$\frac{20}{300} = \frac{24}{T_2};$$

$$T_2 = \frac{300 \times 24}{20} = 360\,K$$

$$= 360 - 273 = 87\,^0C$$