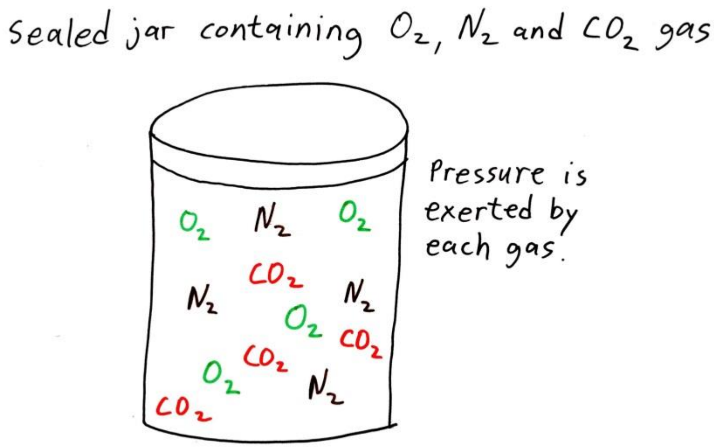
Chemistry Lecture #70: Dalton's Law of Partial Pressures

If a sealed glass jar contains several types of gases, the pressure in the jar is equal to the pressure exerted by each gas.



To find the pressure in the jar, just add the pressure of each gas. This is Dalton's law of partial pressures. Mathematically, it is expressed as

$P_T = P_1 + P_2 + P_3 \ldots$

P_T = total pressure
P_1 = pressure exerted by 1st gas
P_2 = pressure exerted by 2nd gas
P_3 = pressure exerted by 3rd gas and so on

For example, suppose a sealed glass jar contains oxygen, nitrogen and carbon dioxide gas. Oxygen exerts a pressure of 15 kPa, nitrogen exerts 42 kPa, and carbon dioxide exerts 33 kPa of pressure. Find the total gas pressure inside the jar.

P_T = ? P_{Oxygen} = 15 kPa $P_{nitrogen}$ = 42 kPa
$P_{carbon\ dioxide}$ = 33 kPa

$P_T = P_{oxygen} + P_{nitrogen} + P_{carbon\ dioxide}$
P_T = 15 kPa + 42 kPa + 33 kPa
P_T = 90 kPa

A sealed jar contains a mixture of 3 gases: oxygen, nitrogen and carbon dioxide. The total pressure inside the jar is 105 kPa. Oxygen exerts a pressure of 22 kPa, and carbon dioxide exerts a pressure of 14 kPa. What is the pressure exerted by nitrogen?

P_T= 105 kPa P_{oxygen} = 22 kPa $P_{carbon\ dioxide}$ = 14 kPa
$P_{nitrogen}$ = ?

$P_T = P_{oxygen} + P_{nitrogen} + P_{carbon\ dioxide}$
105 kPa = 22 kPa + $P_{nitrogen}$ + 14 kPa
$P_{nitrogen}$ = 105 - 22 - 14
$P_{nitrogen}$ = 69 kPa

Dalton's law of partial pressures is used for problems when "a gas is collected over water." This is just a way of saying that the gas is produced in a water-based solution. After the gas is produced, the gas bubbles rise to the surface, creating a mixture of gas and water vapor above the solution. Vinegar mixed with baking soda is an example of this type of reaction.

Vinegar is acetic acid dissolved in water. When vinegar is mixed with baking soda, bubbles of carbon dioxide are produced in the vinegar. The bubbles rise to the surface, producing a mixture of carbon dioxide and water vapor above the mixture. This gas mixture is called a wet gas. If water vapor is removed from the gas mixture, the remaining gas is called a dry gas.

A mixture of vinegar & baking soda. The CO_2 above the liquid is mixed with water vapor.

The amount of vapor pressure above the water depends on the temperature. If the water is at a higher temperature, there will be more water vapor above the liquid. For some problems, you'll have to consult a chart showing the vapor pressure of water at different temperatures.

The next page is a chart of the vapor pressure of water at temperatures ranging from 0 °C to 100 °C. The pressure is given in torr.

Vapor Pressure of Water (in torr) from 0 ^oC to 100 ^oC

760 torr = 101.325 kPa = 1 atm

T ^oC	P(torr)	T ^oC	P(torr)	T ^oC	P(torr)
0	4.6	42	61.5	84	416.8
1	4.9	43	64.8	85	433.6
2	5.3	44	68.3	86	450.9
3	5.7	45	71.9	87	468.7
4	6.1	46	75.7	88	487.1
5	6.5	47	79.6	89	506.1
6	7.0	48	83.7	90	525.8
7	7.5	49	88.0	91	546.1
8	8.1	50	92.5	92	567.0
9	8.6	51	97.2	93	588.6
10	9.2	52	102.1	94	611.0
11	9.8	53	107.2	95	634.0
12	10.5	54	112.5	96	658.0
13	11.2	55	118.0	97	682.0
14	12.0	56	123.8	98	707.3
15	12.8	57	129.8	99	733.2
16	13.6	58	136.1	100	760.0
17	14.5	59	142.6		
18	15.5	60	149.4		
19	16.5	61	156.4		
20	17.5	62	163.8		
21	18.7	63	171.4		
22	19.8	64	179.3		
23	21.1	65	187.5		
24	22.4	66	196.1		
25	23.8	67	205.0		
26	25.2	68	214.2		
27	26.7	69	223.7		
28	28.4	70	233.7		
29	30.0	71	243.9		
30	31.8	72	254.6		
31	33.7	73	265.7		
32	35.7	74	277.2		
33	37.7	75	289.1		
34	39.9	76	301.4		
35	42.2	77	314.1		
36	44.6	78	327.3		
37	47.1	79	341.0		
38	49.7	80	355.1		
39	52.4	81	369.7		
40	55.3	82	384.9		
41	58.3	83	400.6		

Carbon dioxide gas is collected over water in a sealed container at 49 °C. The gas pressure in the container is 615 torr. Find the pressure exerted by the dry gas.

Solution

To solve this problem, we need to know the pressure exerted by the water vapor that's been mixed with the carbon dioxide. If you look on the chart, you'll see that water exerts a pressure of 88.0 torr at 49 °C. This is the partial pressure of water. We can now solve the problem.

P_T = 615 torr $P_{water\ vapor}$ = 88.0 torr $P_{carbon\ dioxide}$ = ?

$P_T = P_{carbon\ dioxide} + P_{water\ vapor}$

$615 = P_{carbon\ dioxide} + 88.0$

$P_{carbon\ dioxide} = 615 - 88$

$P_{carbon\ dioxide}$ = 527 torr

Dalton's law problems are sometimes combined with Boyle's law problems.

A wet gas collected over water has a volume of 888 mL at 14 °C and a pressure of 700 torr. Find the volume of the dry gas at standard atmospheric pressure (or 760 torr).

Solution

This problem asks for the volume of the *dry* gas, so we need to find its pressure when the water vapor has been removed. If you look at the chart, you'll find that the vapor pressure of water at 14 °C is 12.0 torr.

P_T = 700 torr

$P_{water\ vapor}$ = 12.0 torr

P_{gas} = ?

$P_T = P_{gas} + P_{water\ vapor}$

$700 = P_{gas} + 12.0$

$P_{gas} = 700 - 12.0$

P_{gas} = 688 torr. This is the initial pressure of the dry gas.

We now use Boyle's law to find the new volume when the pressure changes.

P_1 = 688 torr $\quad$ P_2 = 760 torr

V_1 = 888 mL $\quad$ V_2 = ?

$P_1V_1 = P_2V_2$ ➔ $(688)(888) = 760\ V_2$ ➔ $V_2 = \frac{(688)(888)}{760}$

➔ V_2 = 803.8 or 804 mL