Chemical Process Utilities
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Lecture – 49
Pressure Level and Terminology - II

Welcome to the next aspect of pressure level and terminology and that is the part 2 of the previously discussed, pressure level and terminology under the aegis of chemical process utilities. Now, in the previous lecture, we discussed about the different aspect of pressures, different type of terminology which are being used in this particular chemical process, utility aspect then we discussed about the behavioural aspect of gas.

We discussed about the different laws associated with the prediction of the gases behaviour Charles law, Boyle's law, then combined law, Gay-Lussac law, etcetera. Then, we had discussed about 2 numerical problems which are directly associated with this particular chapter. Now, in this particular chapter we are going to discuss couple of more numerical problems which are directly attributed to this particular theme.

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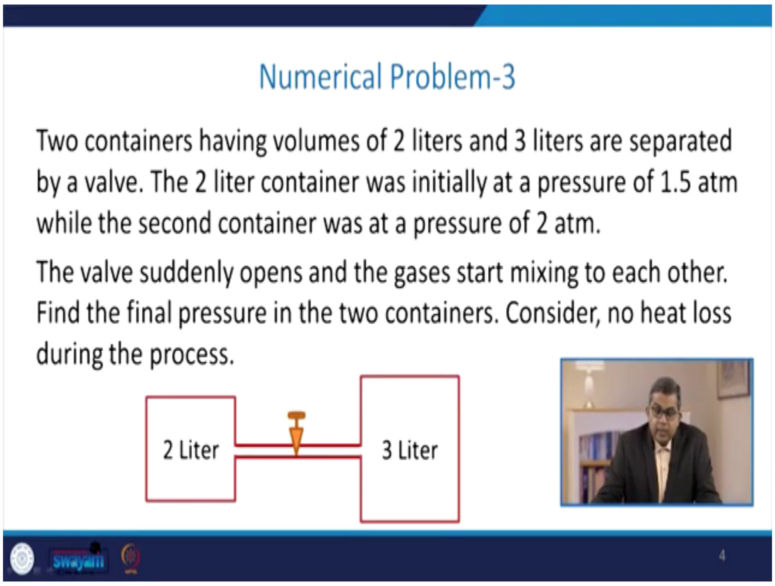

So, let us start with the numerical problem number 3. Because 2 problems we have already discussed in the previous chapter. Now here the 2 containers they are having the volume of 2 liters and 3 liters and they are separated by a valve as depicted in this particular figure and you see that we have the valve. Now this 2-liter container was initially at a pressure of 1.5 atmosphere, while the second container is having the pressure of say 2 atmosphere.

And the wall suddenly opens and the gases they start mixing to each other. Now you need to find the final pressure in 2 containers assuming that there is no heat loss during the process. So, let us solve this particular problem. Now this particular problem can be solved using both; either Boyle's law or Ideal gas law.

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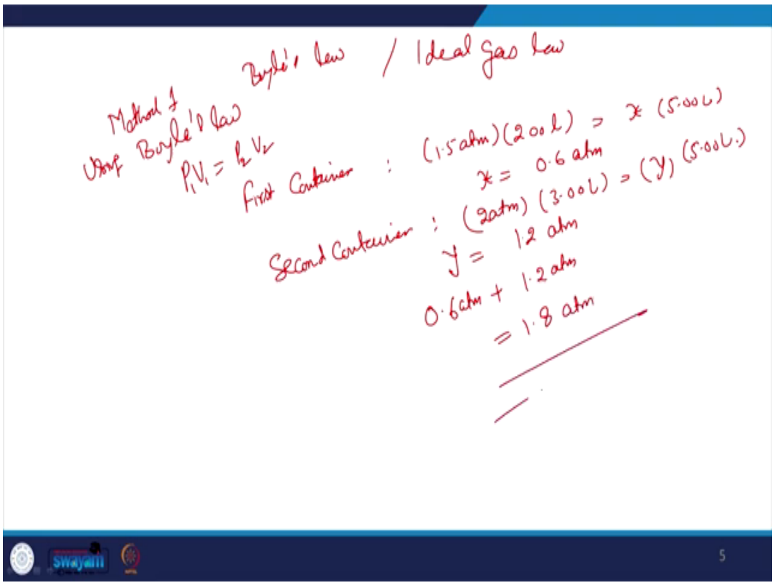

So, let us talk about the first method using law. So, it is P 1 V 1 = P 2 V 2. So, the first container 1.5 into 2.0 liter equal to x pressure into 5 liter. So, x comes out to be 0.6. Now, second container 2 atmosphere into 3.0 liter this is equal to y. That is the pressure 2 for the second container into 5.0. Then y is equal to 1.2 atom. If you sum up both the containers, then both the pressures that is P 1 and P 2 to 0.06 atmosphere plus.1.2 atmosphere and that is 1.8 atmosphere.

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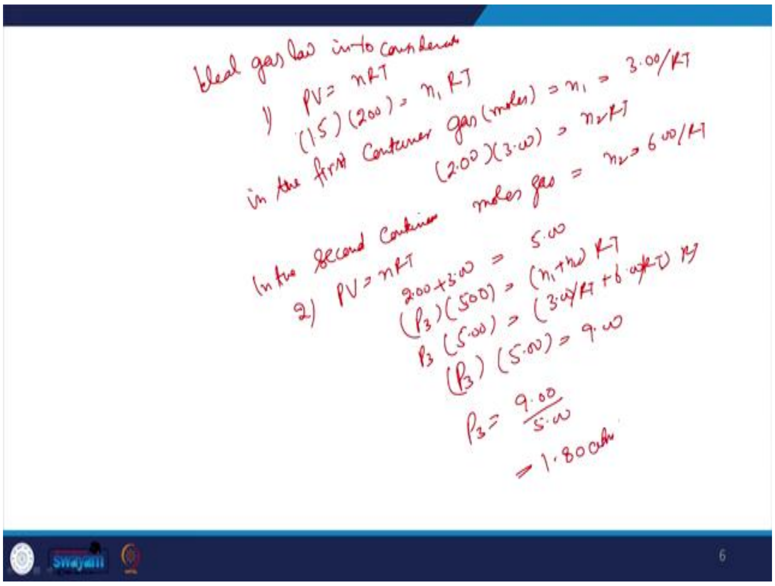

Now, if we take the ideal gas law into consideration. One that is PV is equal to nRT. So, we need to use this particular formula twice. So, 1.5 into 2 liter is equal to n 1 RT. So, in the first container, the gas moles is equal to n1 3.0 upon RT or 2.00 into 3.00 is equal to n2RT. Now, in the second container, moles of gas is equal to n2 is equal to 6.00 RT. Now second, aspect that is PV is equal to nRT.

So, the total volume 2.00 + 3.00 = 5.0 and the P 3 5.00 is equal to n1 + n2 RT and P 3 is equal to 5.0, is into 3.00 upon RT plus 6.00 over RT to RT. And P 3 is 5.0 into 9.00 and P 3 is comes out to be 9.00 upon 5.00 and that is 1.80 atmosphere. Now this is again, if you see that we have got the 1.8 atmosphere, both from ideal gas law as well as Boyle's law.

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Method 1;

Using Boyle's law

$$P_1V_1 = P_2V_2$$

First container: (1.5 atm) (2.00 L) = (x) (5.00 L)

x = 0.6 atm

Second container: (2 atm) (3.00 L) = (y) (5.00 L)

y = 1.2 atm

Summing both: 0.6 atm + 1.2 atm = 1.8 atm

Method 2;

Solution using the Ideal Gas Law:

1) PV = nRT twice:

(1.50) (2.00) = n_1RT

in the first container moles gas = n_1 = 3.00/RT

(2.00) (3.00) = n_2RT

in the second container moles gas = n_2 = 6.00/RT

2) PV = nRT for a third time

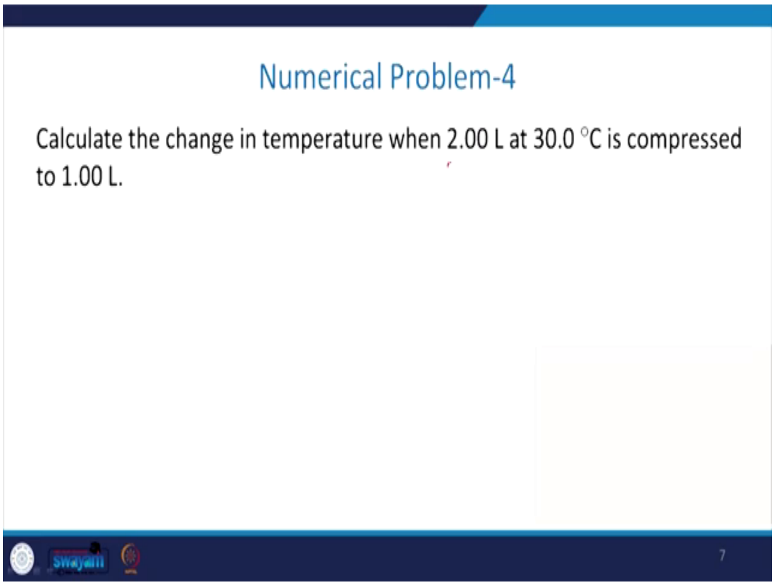
total volume = 2.00 + 3.00 = 5.00

(P_3) (5.00) = (n_1 + n_2)RT

(P_3) (5.00) = (3.00/RT + 6.00/RT)RT

(P_3) (5.00) = 9.00

P_3 = 9.00 / 5.00 = 1.80 atm



Now let us take up another problem. That is, you need to calculate the change in the temperature when 2 liter gas at 30 degree Celsius is compressed to 1 liter.

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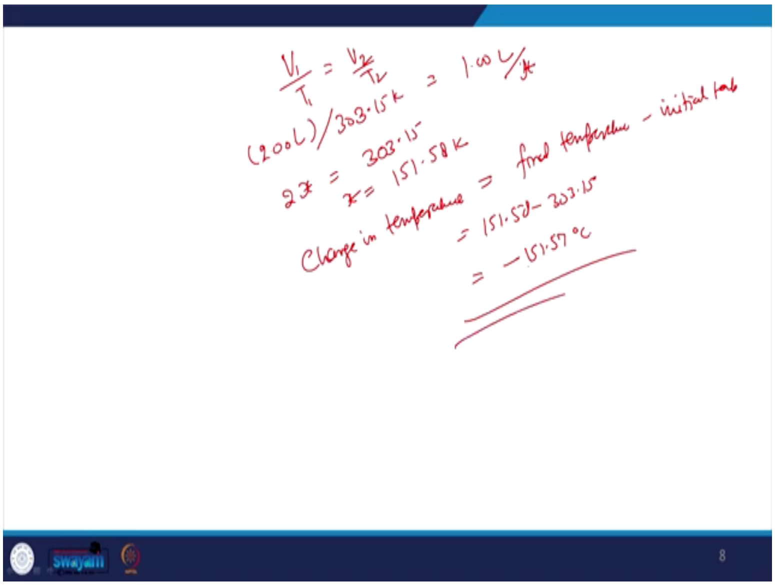

Now here you see that we will utilize V 1 over T 1 is equal to V 2 over T 2 and 2.0 liter over 303.15 kelvin and in is equal to 1.0 over x. Now, if we cross multiply, then we get 2 x is equal to 303.15 or x is equal to 151.58 kelvin. Now, change in temperature is equal to final temperature minus initial temperature. So, this is 151.58 − 303.15 and that comes out to be 151.57 degree Celsius and that is my answer.

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Solution;

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

(2.00 L) / 303.15 K) = (1.00 L) / (x)

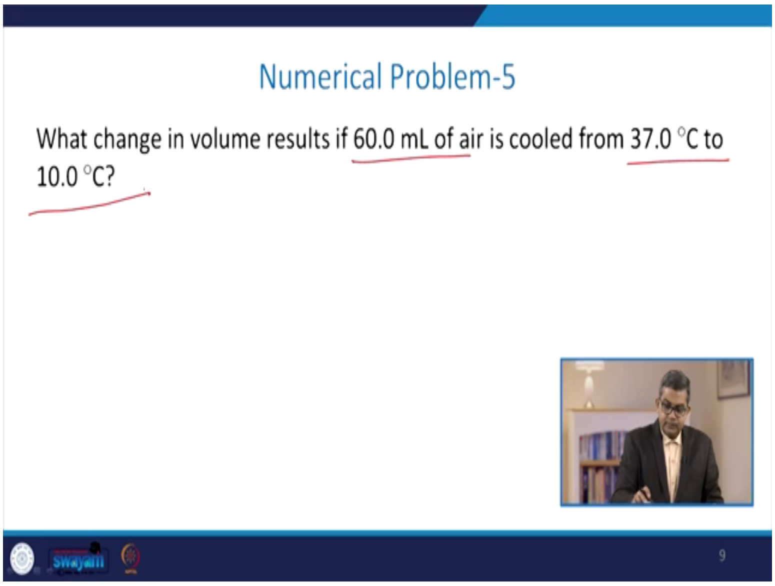
cross multiply to get:

2x = 303.15

x = 151.58 K

Change in temperature = final temperature – initial temperature

= 151.58- 303.15 = -151.57 deg.C



Now let us take up another problem that is the problem number 5. Here you need to find out that what change in the volume results if 60 ml of air is cooled from 37 degree Celsius to 100 degree Celsius.

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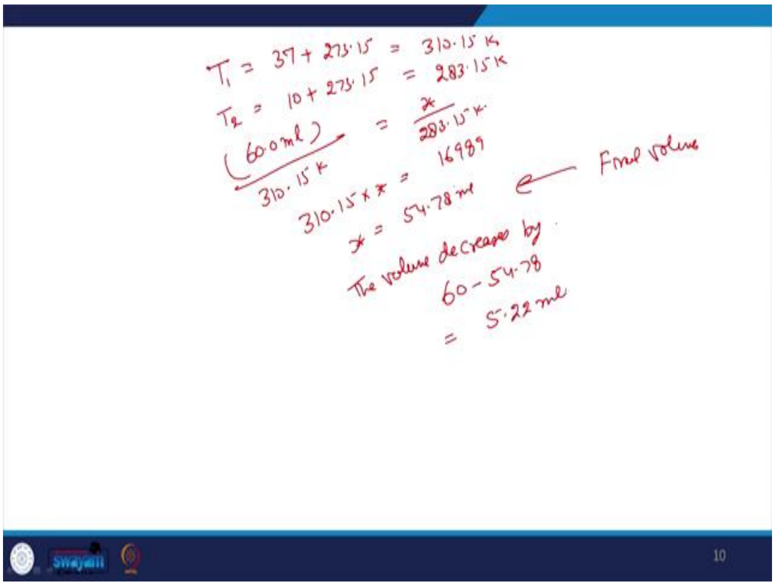

Now let us discuss the solution. Now here T 1 = 37 + 273.15 = 310.15 kelvin and T 2 = 10 + 273.15 this is equal to 283.15 kelvin. 60 ml over 310.15 kelvin this is x over 283.15 kelvin. Now, if we cross multiply, then we will get 310.15 into x is equal to 16989 or x is equal to 54.78 ml and this is the final volume. So, the volume decreases by 60 − 54.78 and that comes out to be 5.22 ml.

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Solution:

T_1= 37+ 273.15 = 310.15 K

T2 = 10 +273.15 = 283.15 K

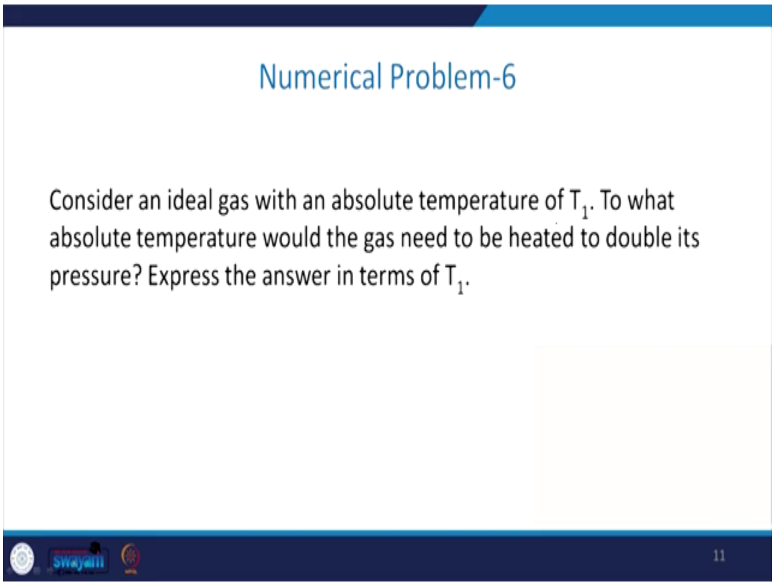
(60.0 mL) / (310.15 K) = (x) / (283.15 K)

Cross multiply to get:

310.15x = 16989

x = 54.78 mL <--- final volume

The volume decreases by 60-54.78 = 5.22 mL.



So, in another problem, you consider an ideal gas with an absolute temperature of say T 1. Now to what absolute temperature would the gas need to be heated to double its pressure. You need to express the answer in terms of T 1.

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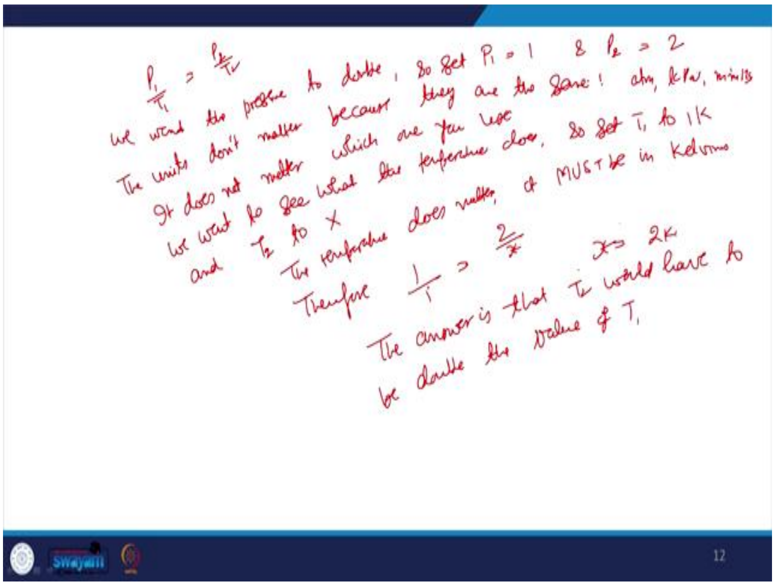

Now here the P 1 over T 1 is equal to P 2 over T 2. Now we want the pressure to double. So, set P 1 = 1 and P 2 = 2. The units do not matter because they are the same that is atmosphere kilopascal, whatever mmHg torr. It does not matter which one you use. Now we want to see what the temperature does? So, set T 1 to 1 kelvin and T 2 to let us say x, the temperature does matter, it must be in kelvin.

So, therefore, 1 over 1 is equal to 2 over x or x, is equal to 2 k. So, the answer is that T 2 would have to be double the value of T 1.

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Solution:

$P_1 / T_1 = P_2 / T_2$

We want the pressure to double, so set $P_1 = 1$ and $P_2 = 2$.

The units don't matter because they are the same: atm, kPa, mmHg, torr. It does not matter which one you use.

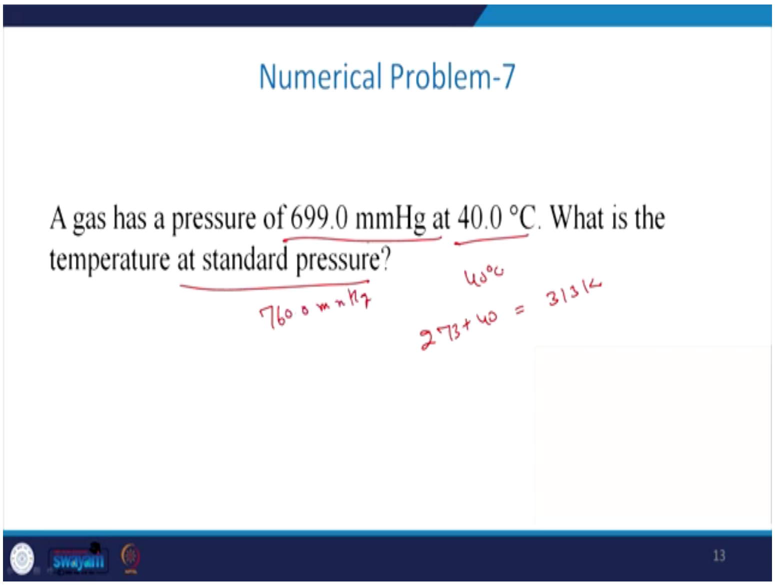
We want to see what the temperature does, so set T_1 to 1 K and T_2 to x. The temperature does matter, it MUST be in Kelvins.

Therefore:

$1 / 1 = 2 / x$

$x = 2$ K

The answer is that T_2 would have to be double the value of T_1.



Now in another problem, a gas has a pressure of 699 millimeter of mercury at 40 degree Celsius, then you need to find out that what is the temperature at standard pressure? Now here, the temperature, the pressure is given as 699 millimeter of hg and the temperature is 40 degree Celsius and that is 273 plus 40. It comes out to be 313 kelvin and you need to have the standard pressure. What is the temperature? So, standard pressure is 760 mm of Hg.

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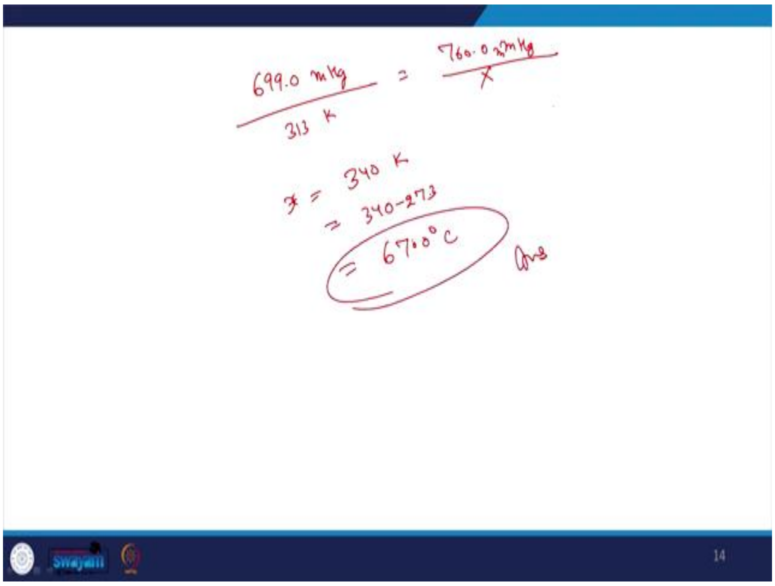

So, let us solve this small problem and that is so we can write that 699.0 mmHg over 313 kelvin. This is 760.0 mmHg that is standard pressure over. Let us say that x is the desired temperature. So, upon solving. We get, this is 340 kelvin or 340 − 273. This comes out to be 67.0 degree Celsius and that is our desired answer.

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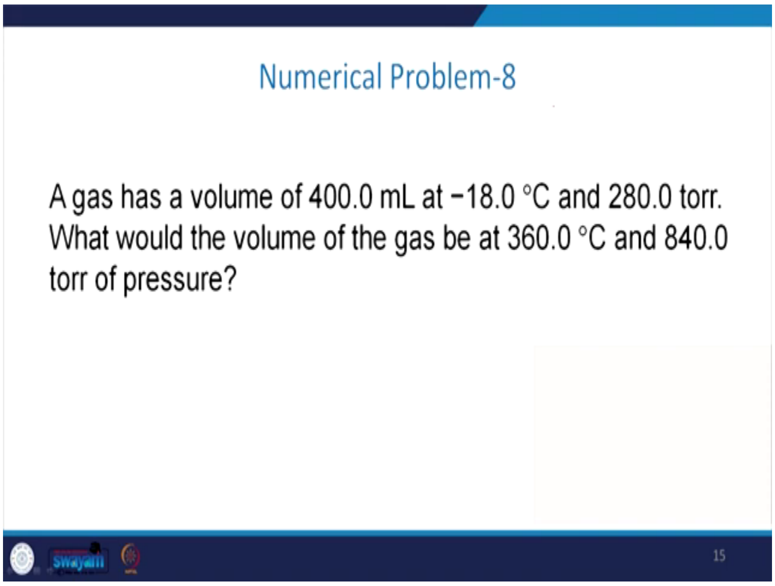
Solution:

$$\frac{\mathbf{699.0\ mmHg}}{\mathbf{313}} = \frac{\mathbf{760.0 mmHg}}{\boldsymbol{x}}$$

X= 340K (or 67.0 ^{o}C)



Now, in another problem, a gas has a volume of 400 milliliter at −18 degree Celsius and 280 torr. Then what would be the volume of the gas or to be at 360 degree Celsius and 840 torr of the pressure?

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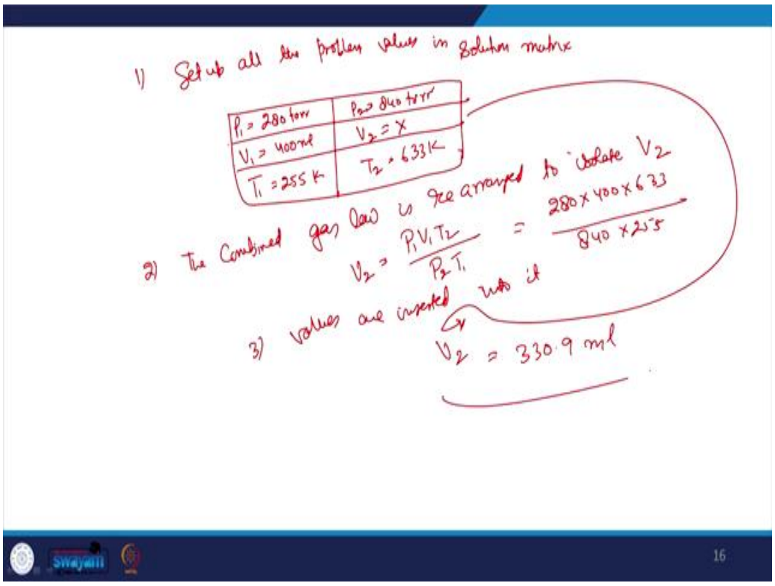

So, let us discuss the solution now. There are various steps in this particular solution. One is that set up all the problem values in solution matrix. So, let us form a small table for this. One here, P 1 = 280 torr, P 2 = 840 torr that is given in the problem. Then V 1 is equal to 400 ml and V 2 you need to calculate. So, if you see that we are having 400 ml and T 1 = 255 kelvin and T 2 = 633 kelvin you see this and this.

So, the second step is the combined gas law is rearranged to isolate V 2. So, V 2 is equal to P 1. V 1 over T 2 upon P 2 T 1 and that is 280 into 400 into 633 upon 840 into 255. The third stage values are inserted into it and V 2 which is desired one. V 2 is comes out to be 330.9 ml and that is the answer.

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Solution:

1) **Set up all the problem values in a solution matrix:**

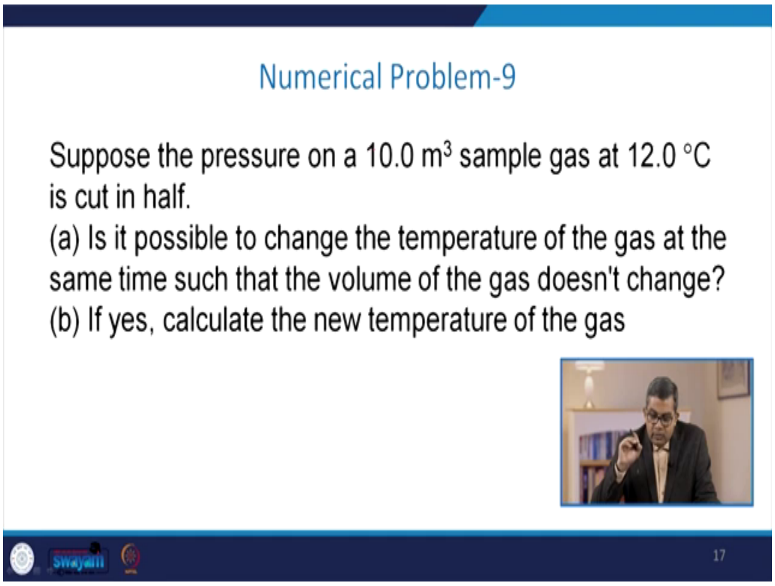
P_1 = 280 torr	**P_2 = 840 torr**
V_1 = 400 ml	**V_2 = x**
T_1 = 255 K	**T_2 = 633 K**

2) The combined gas law is rearranged to isolate V_2:

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1} = \frac{280 * 400 * 633}{840 * 255}$$

3) Values are inserted into the proper places:

V_2 = 330.9 mL



Now another problem, suppose the pressure on a 10.0 meter cube sample gas at 12 degree Celsius is cut in half. Now there are 2 part, one is that is it possible to change the temperature of the gas at the same time such that the volume of the gas does not change. Now, second part is that if yes, then calculate the new temperature of the gas.

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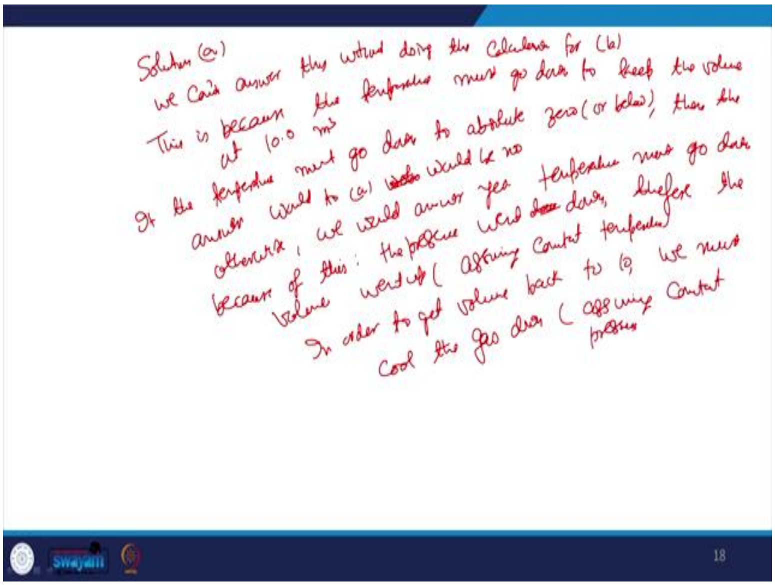

So, let us solve this particular problem. The solution to the problem statement number 1. Now we cannot answer this without doing the calculation for part b. Now this is because the temperature must go down to keep the volume at 10-meter cube. Now if the temperature must go down to absolute 0 or below, then the answer would to a; would be no. Otherwise we would answer yes, temperature must go down because of this the pressure went down.

Therefore, the volume went up assuming constant temperature. Now, in order to get volume back to 10, we must cool the gas down. Let us again taking one assumption constant pressure.

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Solution to (a):

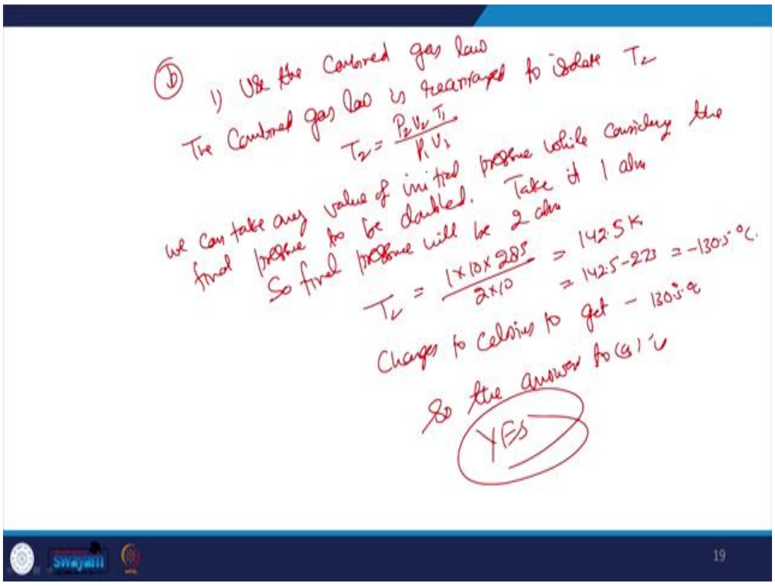
We can't answer this without doing the calculation for (b).

This is because the temperature must go down to keep the volume at 10.0 m^3.

If the temperature most go down to absolute zero (or below), then the answer would to (a) would be no. Otherwise, we would answer yes.

temperature must go down because of this: the pressure went down, therefore the volume went up (assuming constant temperature).

In order to get the volume back to 10, we must cool the gas down (assuming constant pressure).



Now we can discuss the solution to part b. Now, use the combined gas law. Now the combined gas law is rearranged to isolate T 2. Now T 2 is equal to P 2 V 2 T 1 over P 1 V 1. Now we can take any value of initial pressure while considering the final pressure to be doubled. Now, take it 1 atmosphere. So, final pressure will be 2 atmosphere. So, T 2 is equal to 1 into 10 into 285 upon 2 into 10 and that is 142.5 kelvin and this is 142.5 − 273 and that is −130.5 degree Celsius. Now changes to Celsius to get −130.5 degree Celsius. So, the answer to part a is yes.

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Solution to (b):

1) **Use the combined gas law:**

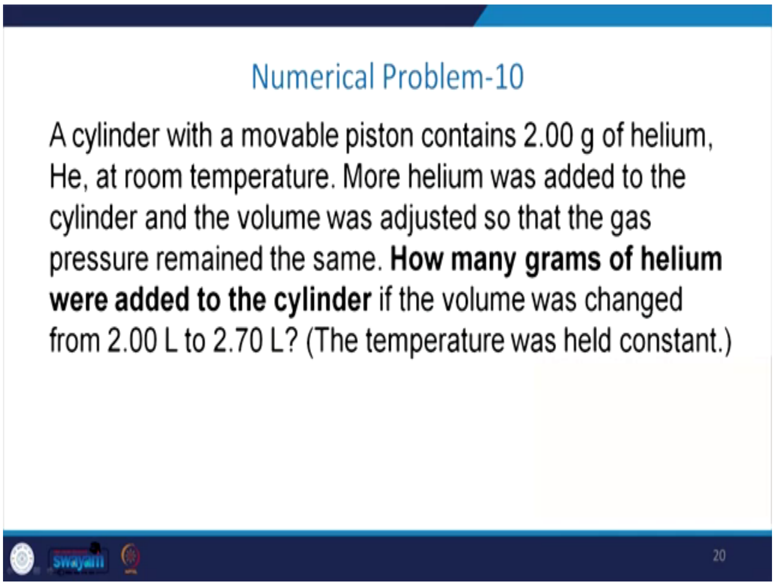
The combined gas law is rearranged to isolate T_2:

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

We can take any value of initial pressure while considering the final pressure to be double. Take it 1 atm. So final pressure will be 2 atm

$$T_2 = \frac{1 * 10 * 285}{2 * 10} = 142.5\,K = 142.5 - 273 = -130.5\,degC$$

3) Change to Celsius to get −130.5 °C. So, the answer to (a) is yes.



Now let us talk about the next problem. Now here, a cylinder with a movable piston contains 2 gram of helium at room temperature. More helium was added to the cylinder and the volume was adjusted so, that the gas pressure remained the same. Then how many grams of helium were added to the cylinder if the volume was changed to from 2 liter to 2.7 liter and temperature? You may assume that the temperature was held constant throughout the process.

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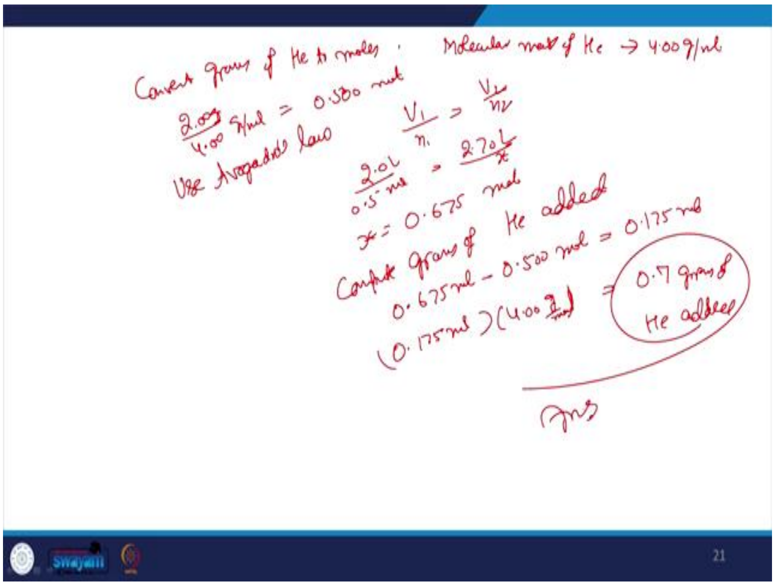

Now let us talk about this one. Now convert first thing, convert grams of helium to moles. So, first thing we need that the molecular mass of helium is 4.00 gram per mol. So, 2 gram upon 4 gram that is comes out to be 0.500 mol. Then second thing is that you can use the Avogadro's law. So, V 1 over N 1 is equal to V 2 over N 2 and that is 2 upon 0.0 upon 0.5 mole equal to 2.70 liter upon x.

So, x is equal to 0.67 mol then compute grams of helium added and that is 0.675 mol − 0.500 mol and that is 0.175 mol. So, 0.175 mol into 4.00 gram per mol which is equal to 0.7 grams of helium added and that is my answer.

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Solution:

1) Convert grams of He to moles: Molecular mass of He is 4.00 g/mol

2.00 g / 4.00 g/mol = 0.500 mol

2) Use Avogadro's Law:

$V_1 / n_1 = V_2 / n_2$

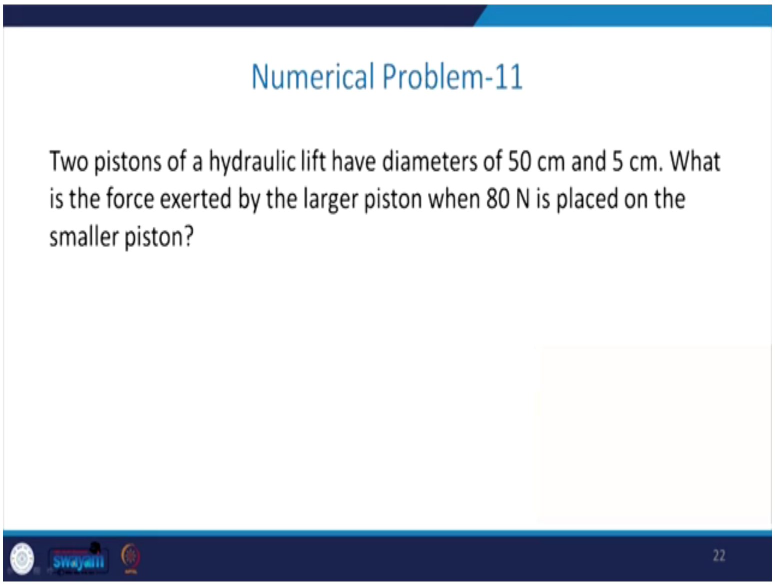
2.00 L / 0.500 mol = 2.70 L / x

x = 0.675 mol

3) Compute grams of He added:

0.675 mol − 0.500 mol = 0.175 mol

(0.175 mol) (4.00 g/mol) = 0.7 grams of He added



Now the last problem for this particular chapter is that 2 piston of hydraulic lift. They have the dimension of 50 centimeters and 5 centimeters. What is the force exerted by the larger piston when 80 newton is placed on the smaller piston?

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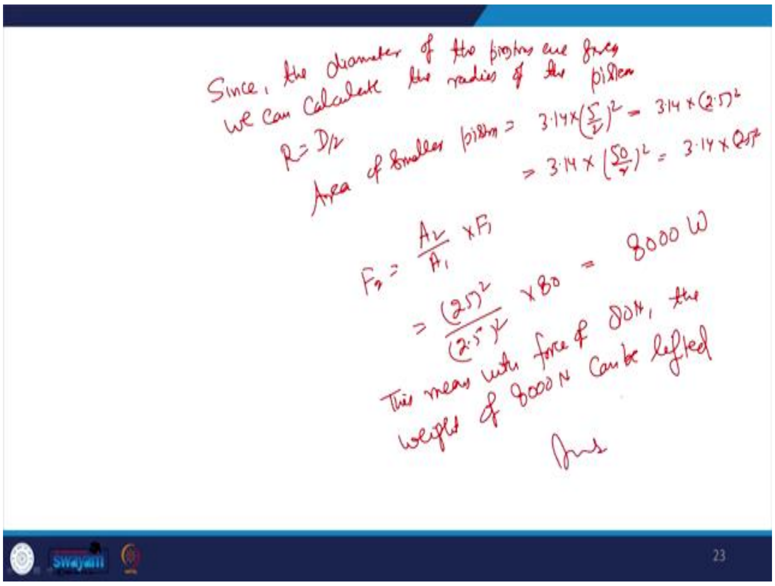

Now solution of this particular problem that since the; diameter of the pistons are given. So, we can calculate the radius of the piston and that is R over T by 2. So, the; area of smaller piston that is 3.14 into 5 by 2 whole square that is 3.14 into 2.5 square. Then 3.14 for the second aspect, 50 by 2 square and that is 3.14 into 25 square. So, F2 is equal to that is force in the second aspect, A 2 upon a A 1 into F 1 and that is 25 square upon 2.5 square into 80 and that comes out to be 8000 watt.

Now this means with force of 80 Newton, the weight of 8000 newton can be lifted. So, that is it. That is the answer. So, in this particular chapter we discussed the different type of numerical problems which were related to the pressure and the gas law. Now, if you wish to have a further study.

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Solution;

Since, the diameter of the pistons are given, we can calculate the radius of the piston

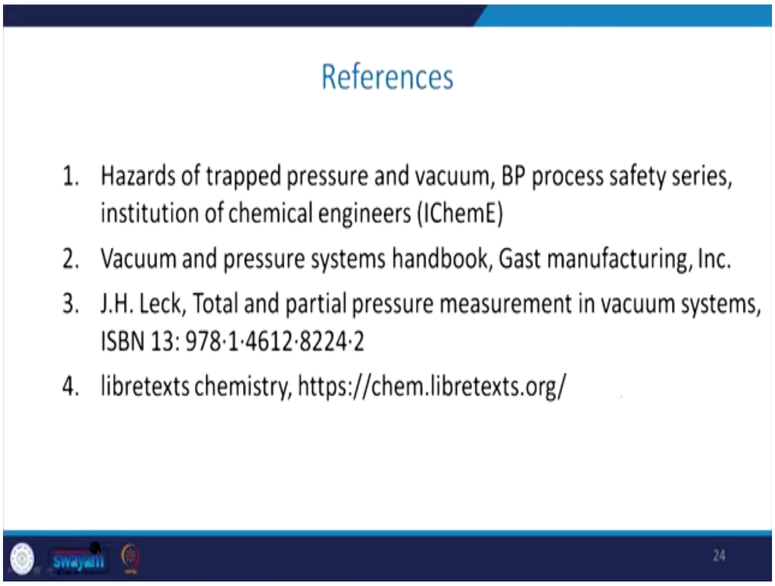
R=D/2

Area of smaller piston = 3.14 x $(5/2)^2$ = 3.14 x $(2.5)^2$

Area of smaller piston = 3.14 x $(50/2)^2$ = 3.14 x $(25)^2$

$$F_2 = \frac{A_2}{A_1} \times F_1 = \frac{(25)^2}{(2.5)^2} \times 80 = 8000N$$

This means with force of 80N, the weight of 8000 N can be lifted.



Then we have enlisted different references you can utilize the things given in these references for your need. Thank you very much.