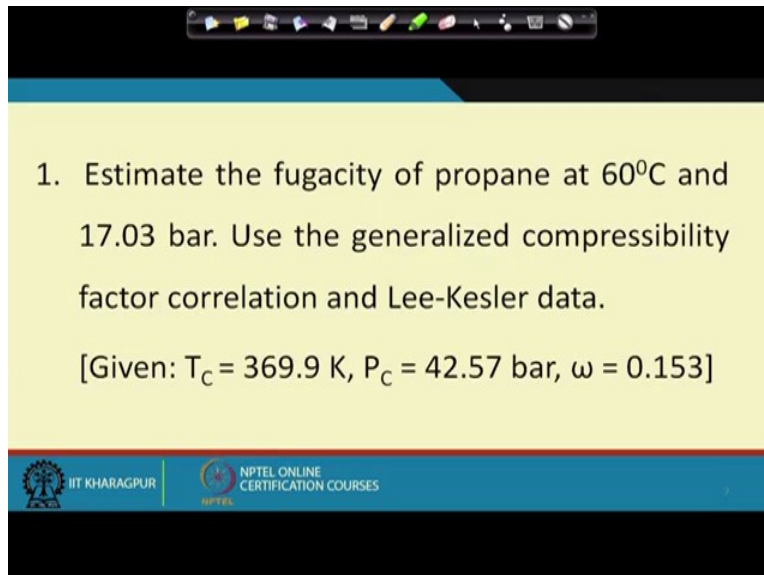


Phase Equilibrium Thermodynamics
Tutorial
Module 5
Lecture 32

Good morning everybody my name is Alex Koshy, I am the TA for the course phase equilibrium thermodynamics. So today I will be discussing a few problems that deals with the contents of week 5 of this course there are a couple of problems that deals with the fugacity coefficient estimation and there is one problem after that, that deals with the estimation of molar volume of a mixture from Amagat's law as well as from Dalton's law.

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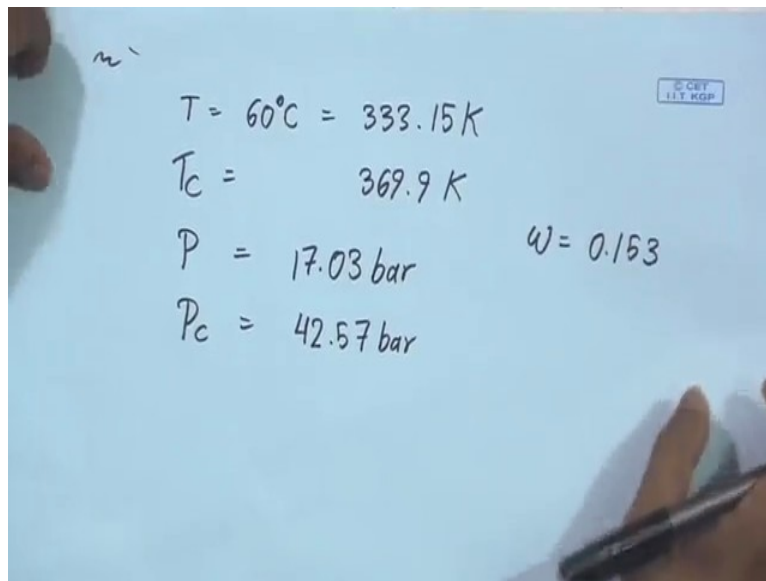
1. Estimate the fugacity of propane at 60°C and 17.03 bar. Use the generalized compressibility factor correlation and Lee-Kesler data.

[Given: $T_c = 369.9$ K, $P_c = 42.57$ bar, $\omega = 0.153$]

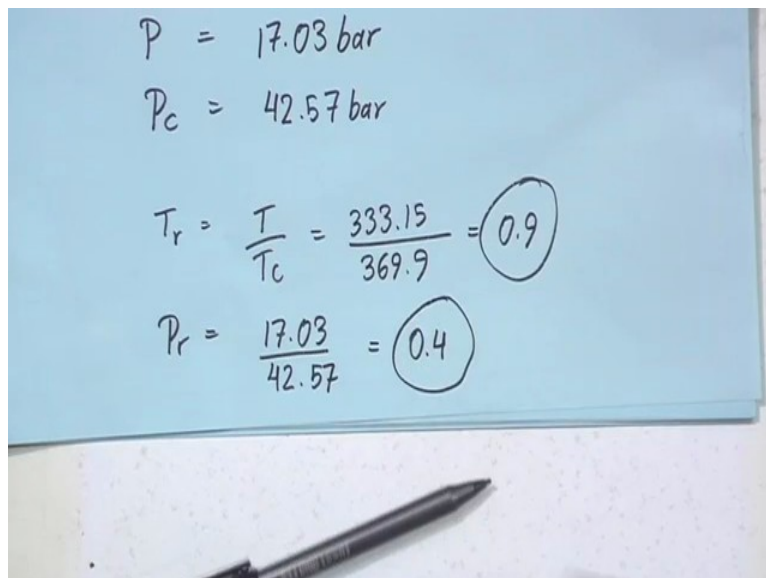
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So let me go to the problem first of all. So the first problem I am going to read it out, estimate the fugacity of propane at 60 degree celsius and 17.03 bar. Use the generalized compressibility factor correlation and Lee-Kesler data. So the critical temperature and critical pressure are given T_c is equal to 369.9 kelvin and P_c is equal to 42.57 bar, the acentric factor is given and it is 0.153.

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$T = 60^{\circ}\text{C} = 333.15\text{ K}$
 $T_c = 369.9\text{ K}$
 $P = 17.03\text{ bar}$
 $P_c = 42.57\text{ bar}$
 $w = 0.153$

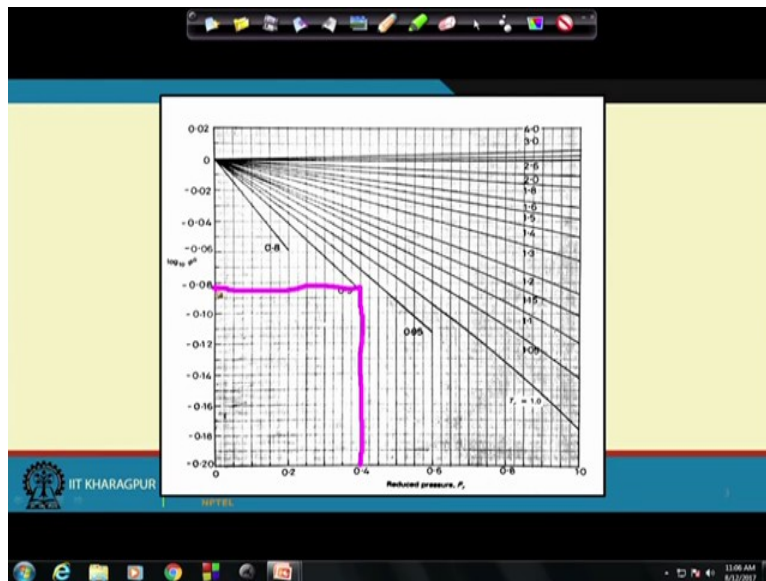


$P = 17.03\text{ bar}$
 $P_c = 42.57\text{ bar}$
 $T_r = \frac{T}{T_c} = \frac{333.15}{369.9} = 0.9$
 $P_r = \frac{17.03}{42.57} = 0.4$

So the first thing that we need to do is we need to list out the values that are given to us. So I am going to do that, T is given, that is 60 degree celsius that is 333.15 kelvin, T_c critical temperature is given and that is 369.9 kelvin, pressure is given and that is 17.03 bar, critical pressure is given 42.57 bar and acentric factor is also given 0.153. So the first thing that we need to find out is, we need to find out the reduced temperature as well as the reduced pressure using these values.

We know the reduced temperature is T by T_c that is 333.15 divided by 369.9 and I have already calculated these values I got the value as 0.9 and then I calculated P_r that is reduced pressure 17.03 divided by 42.57 that is 0.4. So we have the value of T_r , we have the value of P_r .

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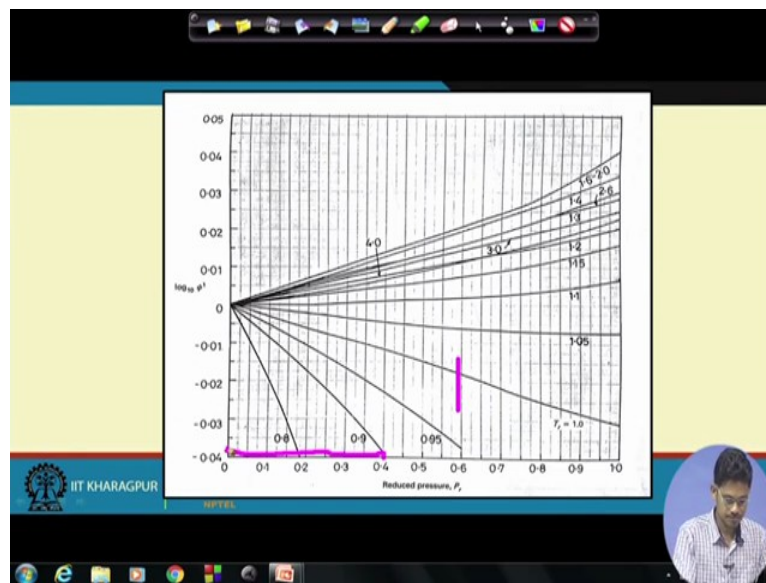
Now from Lee-Kesler chart we need to find out the value of log $10 \phi^0$, where ϕ is the fugacity coefficient. So we take this graph here in the x axis reduced pressure is plotted and all these lines corresponds to a different values of reduced temperature. So here we know that our reduced temperature value is 0.9 and reduced pressure value is 0.4, so we start from 0.4. We start going up and when we reaches the reduced temperature line of 0.9 we stop and then we go horizontally to the log ϕ^0 value.

(Refer Slide Time: 3:36)

The image shows a handwritten equation on a piece of paper: $\log_{10} \phi^0 = -0.086$. A pen is visible in the foreground, pointing towards the equation. In the top right corner of the paper, there is a small stamp that reads "SCET I.T.KGP".

And we got log ϕ^0 value as minus 0.086. So we keep that value there. Now as we are using a three parameter model we need to find out the log ϕ^1 value as well.

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$$\begin{aligned}
 T &= 60^\circ\text{C} = 333.15\text{ K} \\
 T_c &= 369.9\text{ K} \\
 P &= 17.03\text{ bar} \\
 P_c &= 42.57\text{ bar} \\
 T_r &= \frac{T}{T_c} = \frac{333.15}{369.9} = 0.9 \\
 P_r &= \frac{17.03}{42.57} = 0.4
 \end{aligned}$$

$w = 0.153$

$$\begin{aligned}
 \log_{10} \phi^0 &= -0.086 \\
 \log_{10} \phi' &= -0.039 \\
 \log_{10} \phi &= \log_{10} \phi^0 + w \cdot \log_{10} \phi' \\
 &= -0.086 + 0.153 \times (-0.039) \\
 &= -9.1967 \times 10^{-2}
 \end{aligned}$$

$$\log_{10} \phi' = -0.039$$

$$\log_{10} \phi = \log_{10} \phi^0 + \omega \cdot \log_{10} \phi'$$

$$= -0.086 + 0.153 \times (-0.039)$$

$$= -9.1967 \times 10^{-2}$$

$$\phi = 0.809$$

So we go to the next chart. Here we are having reduced pressure 0.4, we go up we reach the reduced temperature line 0.9 and we go horizontally and we get the value of log phi 1 around say (point) negative 0.039, so we got log phi 0 value, we got log phi 1 value. So we need to find log phi value that is log phi 0 plus omega that is acentric factor which is equal to and omega value we already know we have written it down here. So we write that value here, so we get the value of log phi as minus 9.1967 into 10 raised to minus 2.

So we all know how to find out an anti-log of a value using a calculator, so we find the anti-log of this value and we get the value of phi as 0.809.

(Refer Slide Time: 5:36)

$$\phi, \text{ fugacity coefficient} = \frac{f}{P}$$

$$\therefore f = \phi \times P = 0.809 \times 42.57 \text{ bar}$$

$$f = 13.78 \text{ bar}$$

$$\begin{aligned}
 T &= 60^\circ\text{C} = 333.15\text{ K} \\
 T_c &= 369.9\text{ K} \\
 P &= 17.03\text{ bar} \\
 P_c &= 42.57\text{ bar} \\
 w &= 0.153 \\
 T_r &= \frac{T}{T_c} = \frac{333.15}{369.9} = 0.9
 \end{aligned}$$

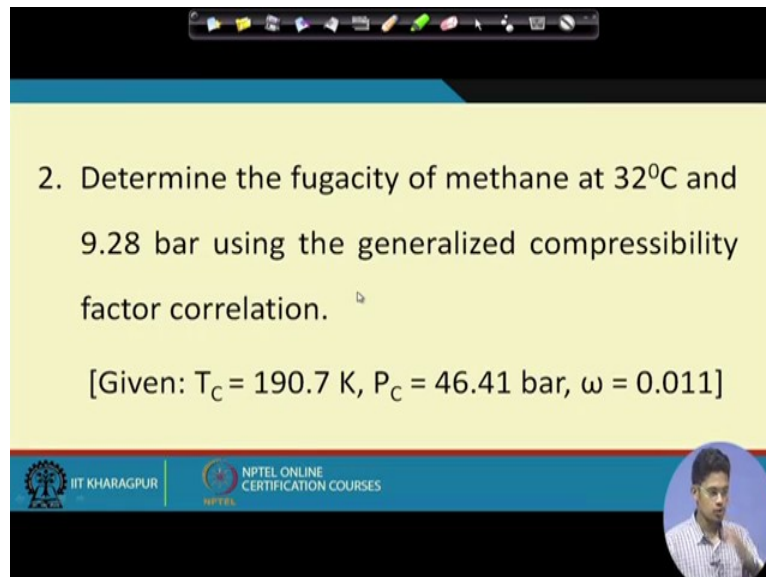
$$\begin{aligned}
 \phi, \text{ fugacity coefficient} &= \frac{f}{P} \\
 \therefore f &= \phi \times P = 0.809 \times 17.03\text{ bar} \\
 f &= 13.78\text{ bar}
 \end{aligned}$$

Now we know phi that is the fugacity coefficient is nothing but the ratio of f that is fugacity by pressure. Therefore fugacity that we need to be we need to estimate fugacity is equal to phi into pressure. We know the value of phi 0.809 and we know the value of pressure that is given earlier 42.57 bar. So solving this we get the value of fugacity f as 13.78 bar, alright. I am sorry about this value this is critical pressure. So the pressure that is given the pressure of the system is 17.03 bar so we substitute it here 17.03 phi into P that we get as 13.78 bar, okay.

So what have we done here in this problem we first of all listed out the values that we have we listed out temperature, we listed out pressure, we know the values of critical temperature and critical pressure from these values we found out the reduced temperature as well as the reduced pressure and from the values of reduced temperature and reduced pressure we found

out $\log \phi_1$ and $\log \phi_0$ and from these values using the acentric factor value we found out $\log \phi$ and from the value of $\log \phi$ we take the anti-log and we found out the value of ϕ and from the value of ϕ we just found out the value fugacity by multiplying ϕ with the pressure.

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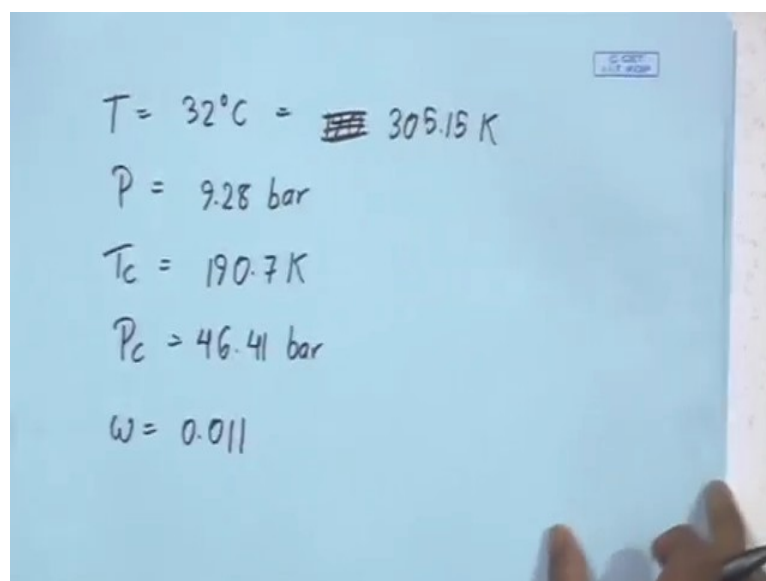
2. Determine the fugacity of methane at 32°C and 9.28 bar using the generalized compressibility factor correlation.

[Given: $T_c = 190.7$ K, $P_c = 46.41$ bar, $\omega = 0.011$]

The slide is a screenshot of a presentation. It has a yellow background with black text. At the top, there is a toolbar with various icons. At the bottom, there is a blue banner with the IIT Kharagpur logo and the text 'NPTEL ONLINE CERTIFICATION COURSES'. On the right side of the banner, there is a small circular video feed showing a person.

So I am going to do a similar problem that is our second problem, I am going to read out the problem determine the fugacity of methane at 32 degree celsius and 9.28 bar using the generalized compressibility factor correlation. The T_c , P_c and acentric factor values are given. So we proceed in the same way we did in the last problem.

(Refer Slide Time: 8:00)



$T = 32^\circ\text{C} = \cancel{305.15} \text{ K}$
 $P = 9.28 \text{ bar}$
 $T_c = 190.7 \text{ K}$
 $P_c = 46.41 \text{ bar}$
 $\omega = 0.011$

The image shows a person's hand writing on a blue board. The text is written in black ink. The first line is $T = 32^\circ\text{C} = \cancel{305.15} \text{ K}$, where the 305.15 is crossed out. The second line is $P = 9.28 \text{ bar}$. The third line is $T_c = 190.7 \text{ K}$. The fourth line is $P_c = 46.41 \text{ bar}$. The fifth line is $\omega = 0.011$. In the top right corner of the board, there is a small white label that says 'COP'.

Handwritten calculations on a blue notepad:

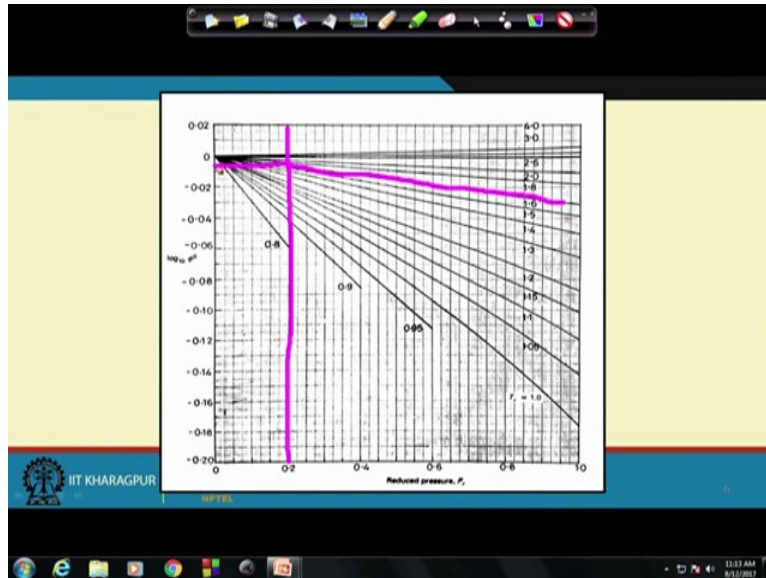
- $T = 32^{\circ}\text{C} = \cancel{190} 305.15 \text{ K}$
- $P = 9.28 \text{ bar}$
- $T_c = 190.7 \text{ K}$
- $P_c = 46.41 \text{ bar}$
- $a = 0.011$
- $T_r = \frac{305.15}{190.7} = 1.6$
- $P_r = \frac{9.28}{46.41} = 0.2$

First thing we write down the values T is equal to 32 degree Celsius that is (190) I am sorry that is 305.15 Kelvin, P 9.28 bar, T_c 190.7 Kelvin, P_c 46.41 bar and the acentric factor 0.011, okay. Now we calculate the reduced temperature and reduced pressure values, reduced temperature value we got it as 1.6, reduced pressure value we got it as 0.2. Now we have the reduced temperature value, we have the reduced pressure value so we go to the chart.

(Refer Slide Time: 9:14)

Handwritten calculations on a blue notepad:

- $T = 32^{\circ}\text{C} = \cancel{190} 305.15 \text{ K}$
- $P = 9.28 \text{ bar}$
- $T_c = 190.7 \text{ K}$
- $P_c = 46.41 \text{ bar}$
- $a = 0.011$
- $T_r = \frac{305.15}{190.7} = 1.6$
- $P_r = \frac{9.28}{46.41} = 0.2$



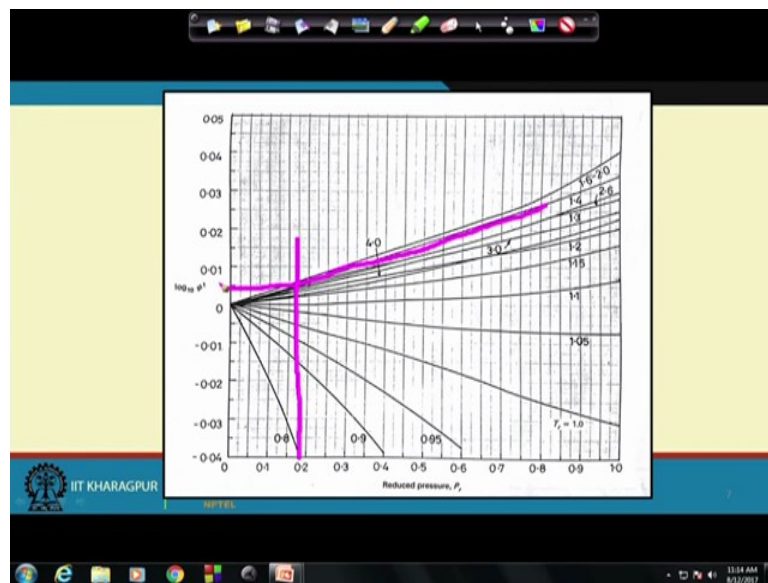
We proceed from reduced pressure value that is (1 point) I am sorry 0.2 we go up. Now we go up. Now we know that the value of reduced temperature is 1.6, so we need to find out the line for 1.6 here it is this line, so it meets somewhere here then we go horizontally to left.

(Refer Slide Time: 10:04)

$$\log_{10} \phi^0 = -0.006$$

So we get the value of log phi 0 we get the value of log phi 0 as minus 0.006.

(Refer Slide Time: 10:28)



$$\begin{aligned} \log_{10} \phi' &= 0.007 \\ \omega &= 0.011 \\ \log_{10} \phi &= \log_{10} \phi^0 + \omega \cdot \log_{10} \phi' \\ &= -0.006 + 0.011 \times 0.007 \\ &= -5.923 \times 10^{-3} \end{aligned}$$

And in the same way we need to find out the value of log phi 1, we go to the next chart we start from 0.2 that is this point, so 1.6 curve is here it meet somewhere here and we get the value of log phi 1 as 0.007. So we know these two values, we know the value of acentric factor. So log phi and we get the final value of log phi as minus 5.923 into 10 raised to minus 3.

(Refer Slide Time: 11:42)

$$\phi = 0.9865$$
$$f = \phi \times P = 0.9865 \times 9.28$$
$$= 9.155 \text{ bar}$$

We take the anti-log so we get the value of phi as 0.9865 and we find out the fugacity as phi into P as we did in the last problem and that is 0.9865 into 9.28 is equal to 9.155 bar that is the value that we got. So we have almost familiarized with what we need to do when we get charts and when we get reduced temperature and critical temperature values, etc to find out the fugacity and fugacity coefficient.

(Refer Slide Time: 12:24)

3. Estimate the molar volume of a mixture of 40 mole percent propane and 60 mole percent *n*-pentane at 500 K and 50 bar using

a) Amagat's Law

b) Dalton's Law

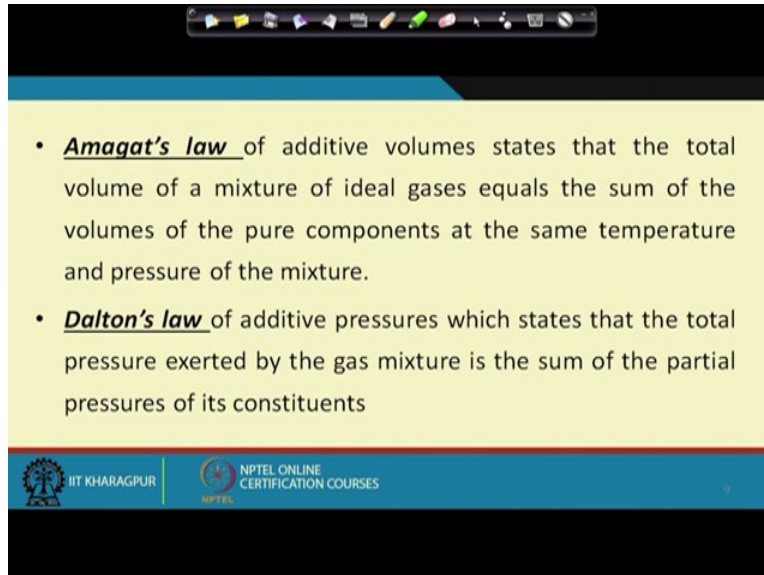
	T_c (K)	P_c (bar)	ω
Propane (1)	369.9	42.57	0.153
<i>n</i> -pentane (2)	469.8	33.75	0.251

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So we move onto the next problem, I read out the problem. Estimate the molar volume of a mixture of 40 mole percent propane and 60 mole percent *n*-pentane at 500 Kelvin and 50 bar using one Amagat's Law, two Dalton's Law. So the values of critical temperature, critical

pressure and acentric factor all are given we do not need acentric factor here because we are dealing with two parameter model so we simply avoid these values.

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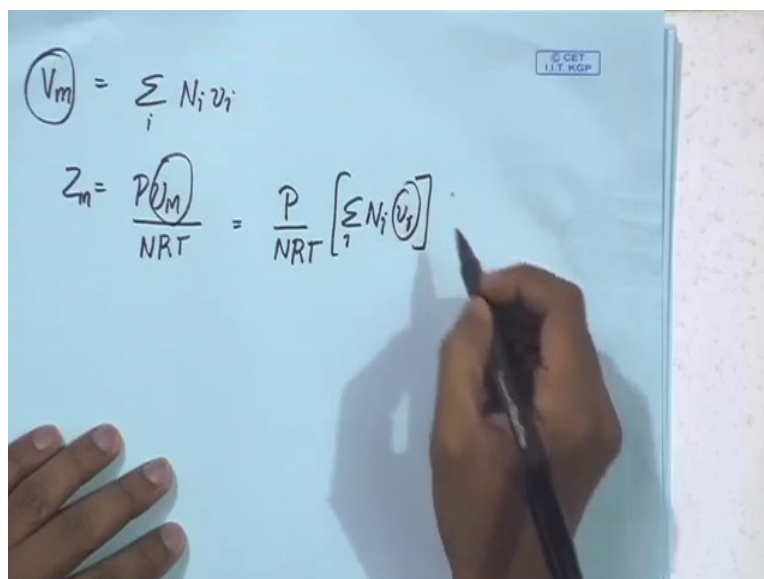
The slide contains two bullet points on a yellow background. The first bullet point describes Amagat's law of additive volumes, stating that the total volume of a mixture of ideal gases equals the sum of the volumes of the pure components at the same temperature and pressure of the mixture. The second bullet point describes Dalton's law of additive pressures, stating that the total pressure exerted by the gas mixture is the sum of the partial pressures of its constituents. At the bottom of the slide, there are logos for IIT Kharagpur and NPTEL Online Certification Courses.

- **Amagat's law** of additive volumes states that the total volume of a mixture of ideal gases equals the sum of the volumes of the pure components at the same temperature and pressure of the mixture.
- **Dalton's law** of additive pressures which states that the total pressure exerted by the gas mixture is the sum of the partial pressures of its constituents

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So before going into the problem we need it has been already taught but I just want to revise it little bit so that you will be understanding this problem better. We want to look back to what is Amagat's law and what is Dalton's law. So Amagat's law of additive volume states that the total volume of a mixture of ideal gases equals the sum of volumes of pure components at the same temperature and pressure as that of the mixture.

(Refer Slide Time: 13:26)



The image shows a person's hands writing equations on a whiteboard. The first equation is $V_m = \sum_i N_i v_i$. The second equation is $Z_m = \frac{P(V_m)}{NRT} = \frac{P}{NRT} \left[\sum_i N_i v_i \right]$. A small logo in the top right corner of the whiteboard reads "© CEE I.I.T. KGP".

$$V_m = \sum_i N_i v_i$$
$$Z_m = \frac{P(V_m)}{NRT} = \frac{P}{NRT} \left[\sum_i N_i v_i \right]$$

$$Z_m = \frac{P V_m}{NRT} = \frac{P}{NRT} \left[\sum_i N_i V_i \right]$$

$$V_i = Z_i \frac{RT}{P}$$

$$Z_m = \frac{P}{NRT} \cdot \sum_i N_i Z_i \frac{RT}{P}$$

$$= \sum_i \frac{N_i}{N} Z_i = \sum_i y_i Z_i$$

So basically it means the total volume of the mixture V_m it is summation of molar volumes of each components means the volumes of each component that constitutes the mixture. So we can write Z_m that is the compressibility factor of the mixture as $P V_m$ by NRT , where N is the total number of moles. We can substitute the value of V_m here and now here instead of V_i we can write, so we can substitute this value V_i here.

Therefore mixture compressibility factor becomes, this RT and this RT cancels out, this P and this P cancels out. This N comes into the summation part. We know N_i by N is nothing but the mole fraction of the component in the gas.

(Refer Slide Time: 15:02)

3. Estimate the molar volume of a mixture of 40 mole percent propane and 60 mole percent *n*-pentane at 500 K and 50 bar using

a) Amagat's Law

b) Dalton's Law

	T_c (K)	P_c (bar)	ω
Propane (1)	369.9	42.57	0.153
<i>n</i> -pentane (2)	469.8	33.75	0.251

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$$Z_m = \sum_i y_i Z_i$$

$$T = 500 \text{ K} \quad P = 50 \text{ bar}$$

$$T_{c1} = 369.9 \quad P_{c1} = 42.57$$

$$T_{c2} = 469.8 \quad P_{c2} = 33.75$$

$$T = 500 \text{ K} \quad P = 50 \text{ bar}$$

$$T_{c1} = 369.9 \quad P_{c1} = 42.57$$

$$T_{c2} = 469.8 \quad P_{c2} = 33.75$$

$$T_{r1} = \frac{500}{369.9} = 1.35 \quad P_{r1} = \frac{50}{42.57} = 1.175$$

$$T_{r2} = \frac{500}{469.8} = 1.06 \quad P_{r2} = \frac{50}{33.75} = 1.482$$

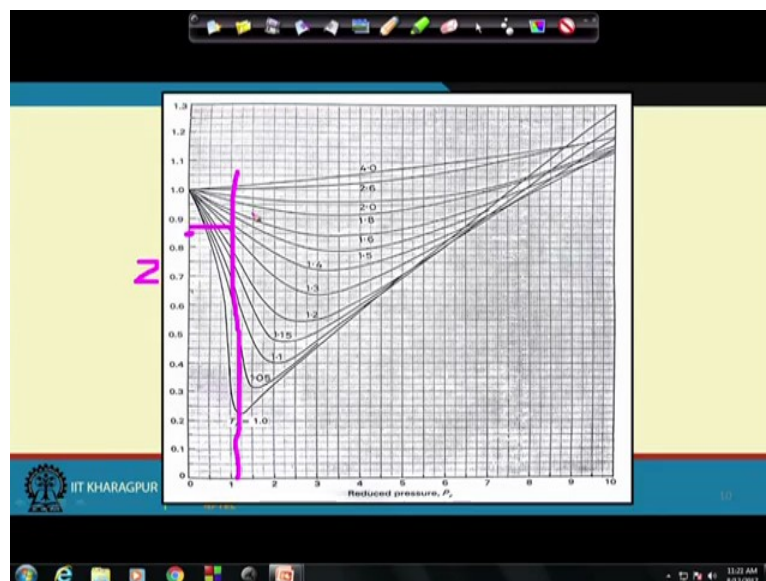
So I am writing it fresh here, here this is the compressibility factor of each constituent of that constitutes the mixture and here Z_i is calculated at the same temperature and same pressure as that of the mixture where Z_m is calculated. So let me go to the problem here we are having we are given temperature, temperature is 500 Kelvin, we are given pressure it is 50 bar, we are given critical temperature, critical temperature of component 1. I have mentioned propane as component 1 and n-pentane as component 2. So critical pressure temperature of component 1 is 369.9, component 2 is 469.8, critical pressure of component 1 is 42.57 and that of component 2 is 33.75, okay.

So we need to find out the reduced temperatures and reduced pressures of both these components, where 369.9 is the critical temperature of the first component we get the value as 1.35, P_{r1} is equal to 50 by 42.57 we get the value as 1.175, T_{r2} is equal to 500 divided by

469.8 that is 1.06, P_{r2} is equal to 50 by 33.75 that is 1.482. So we got the value of T_{r1} , T_{r2} , P_{r1} and P_{r2} .

(Refer Slide Time: 17:30)

$$\begin{aligned}
 T_{C1} &= 369.7 & P_{C1} &= 42.57 \\
 T_{C2} &= 469.8 & P_{C2} &= 33.75 \\
 T_{r1} &= \frac{500}{369.7} = 1.35 & P_{r1} &= \frac{50}{42.57} = 1.175 \\
 T_{r2} &= \frac{500}{469.8} = 1.06 & P_{r2} &= \frac{50}{33.75} = 1.482
 \end{aligned}$$



$$T_{r2} = \frac{30}{469.8}$$

$$= \sum_i \frac{N_i}{N} Z_i = \sum_i y_i Z_i$$

$$Z_1 = 0.84$$

$$Z_2 = 0.35$$

So now we have a chart and from there we need to find the value of Z_1 and Z_2 . This is the chart here reduced pressure is plotted at the x axis and all these lines corresponds different reduced temperatures and the y axis is Z , it is actually Z_0 but since we are dealing with two parameter model I simply mention it as Z . So we need to find out Z_1 and Z_2 for both components.

So here we know T_{r1} is 1.35 and P_{r1} is 1.175, same in the same way as we have done in the last problem we just find out the value of Z_1 from this graph 1.175 will come somewhere here we go up, 1.35 there is a value of reduced temperature is coming somewhere here. So we get the value of Z_1 as I have made a small mistake here it will come somewhere over here. So the value of Z_1 is 0.84, in the similar way we calculate the value of Z_2 from the values of critical temperature and critical pressure for component 2 and the value of Z_2 we got it as 0.35.

(Refer Slide Time: 19:06)

$$Z_m = \sum_i y_i Z_i$$
$$T = 500 \text{ K}$$
$$369.9$$
$$P = 50 \text{ bar}$$
$$P_{c1} = 42.57$$
$$P_{c2} = 33.75$$
$$P_{r1} = \frac{50}{42.57} = 1.175$$
$$0.35$$

3. Estimate the molar volume of a mixture of 40 mole percent propane and 60 mole percent *n*-pentane at 500 K and 50 bar using

a) Amagat's Law

b) Dalton's Law

	T_c (K)	P_c (bar)	ω
Propane (1)	369.9	42.57	0.153
<i>n</i> -pentane (2)	469.8	33.75	0.251

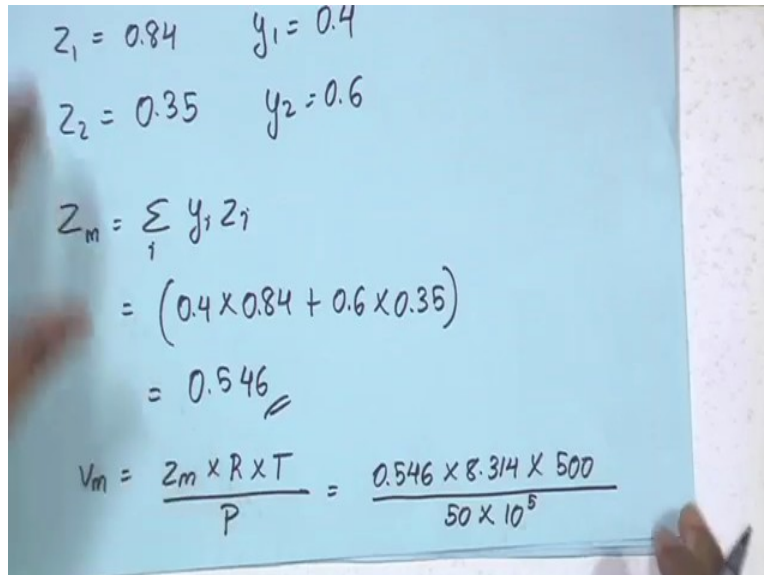


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$$T_{r2} = \frac{500}{469.8} = 1.06$$
$$Z_1 = 0.84 \quad y_1 = 0.4$$
$$Z_2 = 0.35 \quad y_2 = 0.6$$
$$Z_m = \sum_i y_i Z_i$$
$$= (0.4 \times 0.84 + 0.6 \times 0.35)$$
$$= 0.546$$

So here we know we have (calculated) we have proved it earlier for Amagat's law Z_m is equal to summation of y_i and z_i . Here y_1 here we know mole percent of propane is 40 and mole percent of n-pentane is 60, so y_1 is 0.4 and y_2 is 0.6. So we simply do the summation here 0.4 into 0.84 plus 0.6 into 0.35 and we get the value of Z_m as 0.546.

(Refer Slide Time: 20:03)



Handwritten calculations on a blue sheet of paper:

$$z_1 = 0.84 \quad y_1 = 0.4$$

$$z_2 = 0.35 \quad y_2 = 0.6$$

$$Z_m = \sum_i y_i z_i$$

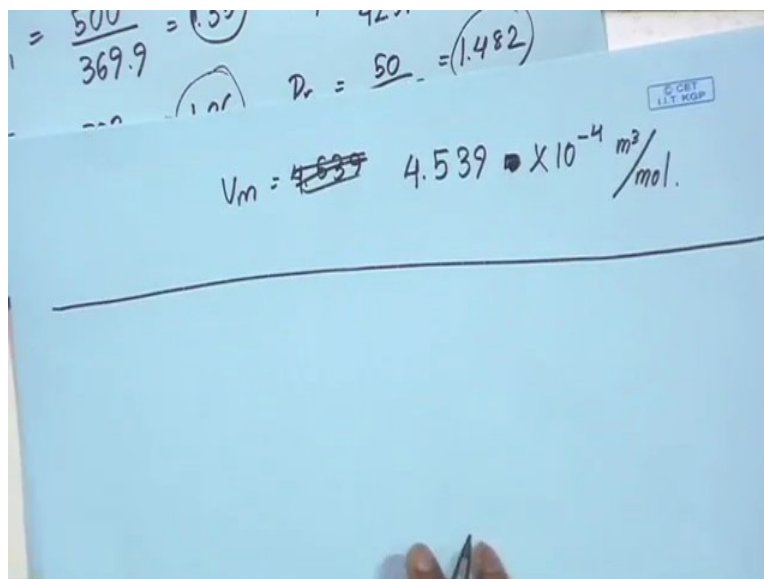
$$= (0.4 \times 0.84 + 0.6 \times 0.35)$$

$$= 0.546$$

$$V_m = \frac{Z_m \times R \times T}{P} = \frac{0.546 \times 8.314 \times 500}{50 \times 10^5}$$

Now we need to find out the molar of volume of the mixture we know V_m is equal to Z_m into R into T by P , so we know all the values P , T , R and everything we know we just substitute the values, the value of P is 50 bar we need to calculate in SI units, we need to put it in SI units. So we write it in Pascals 50 into 10 raise to 5 Pascal.

(Refer Slide Time: 20:44)



Handwritten calculations on a blue sheet of paper:

$$V_m = \frac{500}{369.9} = 1.35$$

$$P_r = \frac{50}{1.01} = 1.482$$

$$V_m = \frac{4.539}{1.482} \times 10^{-4} \text{ m}^3/\text{mol}$$

3. Estimate the molar volume of a mixture of 40 mole percent propane and 60 mole percent *n*-pentane at 500 K and 50 bar using

a) Amagat's Law

b) Dalton's Law

	T_c (K)	P_c (bar)	ω
Propane (1)	369.9	42.57	0.153
<i>n</i> -pentane (2)	469.8	33.75	0.251

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So we get the value of V_m value of V_m that is measured is 4.539 into 10 raised to minus 4 meter cube per mole, okay. Now we need to go to the second part of the problem that is the estimation of the molar volume of the mixture using Dalton's Law.

(Refer Slide Time: 21:14)

- **Amagat's law** of additive volumes states that the total volume of a mixture of ideal gases equals the sum of the volumes of the pure components at the same temperature and pressure of the mixture.
- **Dalton's law** of additive pressures which states that the total pressure exerted by the gas mixture is the sum of the partial pressures of its constituents

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So Dalton's law of additive pressures states that the total pressure exerted by the gas mixture is the sum of the partial pressures of its constituents.

(Refer Slide Time: 21:32)

$$V_m = \cancel{4.539} \quad 4.539 \times 10^{-4} \text{ m}^3/\text{mol}$$

Dalton's law

$$P_m = \sum_i P_i$$

$$Z_m = \frac{P_m V}{NRT} = \frac{V}{NRT} \sum_i P_i =$$

$$\frac{\sum_i P_i V \times N_i}{NRT \times N_i} = \sum_i \left(\frac{P_i V}{N_i RT} \right) \frac{N_i}{N}$$

$$Z_m = \sum_i Z_i y_i$$

$$Z_i$$

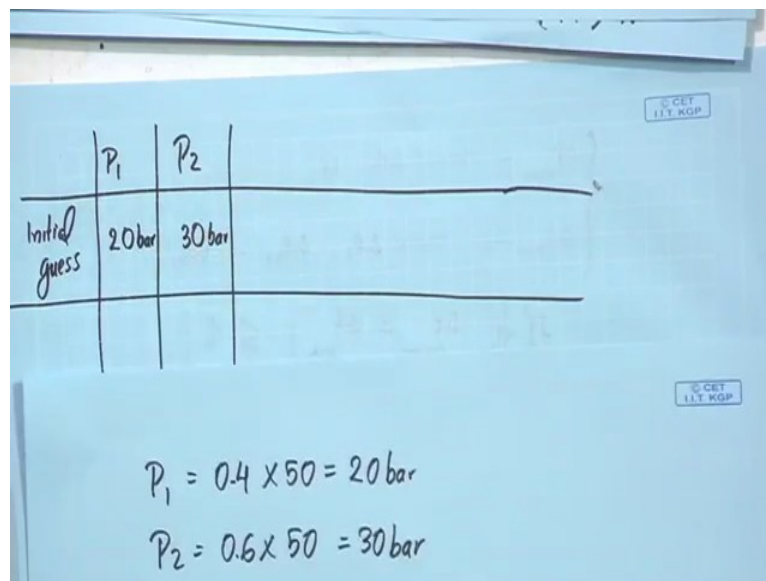
So what are we doing here total pressure of the mixture exerted by the gas mixture is the summation of the partial pressures P_i , so Z_m we know it is $P_m V$ by NRT which is equal to V by NRT , we substitute the value of P_m here and we bring these values inside the summation part, here we multiply both the numerator and denominator with an N_i and then we rearrange this this term. So we know this term corresponds to I am going over here over the next page.

This term we know it corresponds to Z_i and N_i by N it corresponds to y_i that is the mole fraction. So similarly we get almost a same expression that we got in Amagat's law in Amagat's law we got the means we got something like this but in Amagat's law the Z_i that is calculated was at the same temperature and same pressure as that of the mixture but the Z_i

calculated in the case of Dalton's law it is at the same temperature as that of the mixture but it is at a different pressure.

The mixture pressure is different and this Z_i is calculated at pure component pressures, so we move with the problems. So before starting we need to estimate the values of Z_1 and Z_2 , so for that we need to know the pure component pressures but that we do not know. So as an initial guess we take the pure component pressures as the partial pressures of each component.

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The image shows a handwritten table and calculations on a blue grid background. The table has two columns labeled P_1 and P_2 . The first row is labeled 'Initial guess' and contains the values '20 bar' and '30 bar'. Below the table, the calculations are written: $P_1 = 0.4 \times 50 = 20 \text{ bar}$ and $P_2 = 0.6 \times 50 = 30 \text{ bar}$. There are two small blue stamps on the right side of the page, each reading '© CET 1.1.1 KGP'.

	P_1	P_2
Initial guess	20 bar	30 bar

$P_1 = 0.4 \times 50 = 20 \text{ bar}$
 $P_2 = 0.6 \times 50 = 30 \text{ bar}$

So P_1 I am just writing it in the tabular form. So P_1 we take it as the partial pressure of the component that is our initial guess that is 20 bar and P_2 is 0.6 into 50 that is 30 bar. So we take those as our initial guess for pure component pressures.

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$$P_1 = 0.4 \times 50 = 20 \text{ bar} \quad P_{C1} = 42.57 \text{ bar}$$
$$P_2 = 0.6 \times 50 = 30 \text{ bar} \quad P_{C2} = 33.75 \text{ bar}$$
$$T_{r1} = \frac{500}{369.9} = 1.35 \quad T_{r2} = \frac{500}{469.8} = 1.06$$
$$P_{r1} = \frac{20}{42.57} = 0.47 \quad P_{r2} = \frac{30}{33.75} = 0.89$$

	P_1	P_2	z_1	z_2	z_m	V_m
Initial guess	20 bar	30 bar	0.94	0.68	0.784	

$$P_2 = 0.6 \times 50 = 30 \text{ bar} \quad P_{C2} = 33.75 \text{ bar}$$
$$T_{r1} = \frac{500}{369.9} = 1.35 \quad T_{r2} = \frac{500}{469.8} = 1.06$$
$$P_{r1} = \frac{20}{42.57} = 0.47 \quad P_{r2} = \frac{30}{33.75} = 0.89$$
$$z_1 = 0.94 \quad z_2 = 0.68$$
$$z_m = (0.4 \times 0.94) + (0.6 \times 0.68) = 0.784$$

Now we know the P_c value we know the T_c value everything, so T_r reduced temperature value is same as that of the one we measured for the Amagat's law case that is 500 by 369.9 this is the critical temperature so that we got as 1.35. Now using these values these P_1 and P_2 values we know the P_{c1} and P_{c2} values. So we find out the P_{r1} and P_{r2} values, P_{r1} value we got it as 20 by 42.57.

Now from these values we can calculate Z_1 and Z_2 using the chart that we have done earlier so I am not going into it I am simply writing down the value Z_1 here we got it as 0.94, Z_2 we got it as 0.68. So I am writing down the values here. Now from these values we can calculate Z_m that is 0.4 into 0.94 plus 0.6 into 0.68 we get the Z_m value as 0.784.

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	P_1	P_2	Z_1	Z_2	Z_m	V_m
Initial	...					

$$V_m = \frac{0.784 \times 8.314 \times 500}{50 \times 10^5} = 6.518 \times 10^{-4} \frac{\text{m}^3}{\text{mol}}$$

$$= 6.518 \times 10^{-4} \frac{\text{m}^3}{\text{mol}}$$

Z_2	Z_m	V_m
0.68	0.784	6.518×10^{-4}

Now we need to calculate V_m , we do in the same way as we have done for Amagat's law we know the Z_m value that is 0.784 into R 8.314 into T that is 500 Kelvin divided by the total pressure we get the value of V_m as 6.518×10^{-4} meter cube per mole I'm writing it here.

Now I told you earlier we have assumed that we assumed the pure component pressures as the partial pressures of each component. So that was our assumption we need to cross check whether our assumption was right or wrong.

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	P_1	P_2	z_1	z_2	z_m	V_m
Initial guess	20 bar	30 bar	0.94	0.68	0.784	6.518×10^{-4}

$V_m = \frac{0.784 \times 8.314 \times 500}{50 \times 10^5} = 6.518 \times 10^{-4} \frac{\text{m}^3}{\text{mol}}$
 $P_1 = \frac{z_1 N_1 R T}{V} =$

$$\frac{0.784 \times 8.314 \times 500}{50 \times 10^5} = 6.518 \times 10^{-4} \frac{\text{m}^3}{\text{mol}}$$

$$\frac{z_1 N_1 R T}{V} = \frac{0.94 \times 0.4 \times 8.314 \times 500}{6.518 \times 10^{-4}} = 23.98 \text{ bar}$$

$$\frac{z_2 N_2 R T}{V} = \frac{0.68 \times 0.6 \times 8.314 \times 500}{6.518 \times 10^{-4}} = 26.02 \text{ bar}$$

	P_1	P_2	z_1	z_2	z_m	V_m
guess	20 bar	30 bar	0.94	0.68	0.784	6.518×10^{-4}
1st iteration	23.98	26.02				

So we need to recalculate P_1 value and P_2 value using z_1 and z_2 values that we have got. So I am doing that, P_1 you know it is $z_1 N_1 RT$ by V we assume one mole. So z_1 is 0.94 I am taking it from here, N_1 is 0.4, R is 8.314 and T is 500 Kelvin and V it is the V_m value that we have got from here it is 6.518 into 10 raised to minus 4 and we get the value of P_1 as we get the value as 23.98 bar I am writing here the value first iteration and we get the value of P_2 in the similar way, we substitute these all these values z_2 we know it is 0.68, we get the value as 26.02 bar, I am writing down the value here.

So if we just notice we can find out that here there is a deviation from our initial guess around 4 bar deviation is there 20 to 23.98 and here also around 4 bar deviation is there 30 to 26.02. So our initial guess was not exact means it was not very good guess.

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$$P_1 = \frac{z_1 N_1 RT}{V} = \frac{0.94 \times 0.4 \times 8.314 \times 500}{6.518 \times 10^{-4}} = 23.98 \text{ bar}$$

$$P_2 = \frac{z_2 N_2 RT}{V} = \frac{0.68 \times 0.6 \times 8.314 \times 500}{6.518 \times 10^{-4}} = 26.02 \text{ bar}$$

$$P_{r1} = P_{r2} = T_{r1} = T_{r2} =$$

$$z_1 = z_2 =$$

	P_1	P_2	z_1	z_2	z_m	V_m
Initial guess	20 bar	30 bar	0.94	0.68	0.784	6.518×10^{-4}
1st iteration	23.98	26.02	0.93	0.73	0.81	6.734×10^{-4}

$$z_m = (0.4 \times 0.93) + (0.6 \times 0.73) = 0.81$$

$$V_m = \frac{0.81 \times 8.314 \times 500}{50 \times 10^5} = 6.734 \times 10^{-4}$$

$$z_m = (0.4 \times 0.93) + (0.6 \times 0.73) = 0.81$$

$$V_m = \frac{0.81 \times 8.314 \times 500}{50 \times 10^5} = 6.734 \times 10^{-4} \frac{\text{m}^3}{\text{mol}}$$

So we need to recalculate the whole thing with our (second) first iteration values, so we know P_1 , we know P_2 we find out P_{r1} again and we find out P_{r2} again and from these P_{r1} and P_{r2} value we know the T_{r1} and T_{r2} values already that is the initial value itself there is no change for T_{r1} and T_{r2} values and from these values we use the graph and we find out our Z_1 and Z_2 again.

I am not going deep into the calculation because there is a time limit for me, so I am just writing down the values of Z_1 and Z_2 as calculated earlier, Z_1 value it is point 0.93, Z_2 value it is 0.73 and we can calculate Z_m as I told earlier just a minute. So I am writing down the value Z_1 the new Z_1 value that I have got and V_m we know it is 0.81 that is the new value that we have got, so we get a new value for V_m that is molar volume of the mixture, write down the value here.

So we continue these iterations till we get least deviation between these P means these P values that is here we got deviation of 4 bars so these deviation reduces with iteration and finally we have to be satisfied with that point that where were these gap has come down to a very small value.

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1st iteration	23.98	26.02	0.93	0.73	0.81	6.734×10^{-4}
2nd iteration						

$$P_1 = \frac{0.93 \times 0.4 \times 8.314 \times 500}{6.734 \times 10^{-4}} = 22.96 \text{ bar}$$

$$P_2 = 27.04 \text{ bar}$$

$P_{r1}, P_{r2}, T_{r1}, T_{r2}$

$$Z_1 = Z_2$$

Now as we have got the value of V_m after our first iteration, so we need to do our second iteration. So we need to calculate P_1 and P_2 again from the new values of Z_1 and Z_2 . So I am going to that here. The new value of Z_1 is 0.93 and the new value of V_m is 6.734 into 10 raised to minus 4 and we get the new value of P_1 as 22.96 bar, similarly we get the new value of P_2 as 27.04 bar.

So we know the new value of P_1 , we know the new value of P_2 , we calculate P_{r1} , P_{r2} again. The values of T_{r1} and T_{r2} are the same that we calculated earlier. So from the chart we can find out the new values for Z_1 and Z_2 we do that again.

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	P_1	P_2	Z_1	Z_2	Z_m	V_m
Initial guess	20 bar	30 bar	0.94	0.68	0.784	6.518×10^{-4}
1st iteration	23.98	26.02	0.93	0.73	0.81	6.734×10^{-4}
2nd iteration	22.96	27.04	0.93	0.73	0.81	6.734×10^{-4}

$P_2 = 27.04 \text{ bar}$
 $P_{r1}, P_{r2}, T_{r1}, T_{r2}$
 $Z_1 = Z_2$

	P_1	P_2	Z_1	Z_2	Z_m	V_m
2nd iteration	22.96	27.04	0.93	0.73	0.81	6.734×10^{-4}

$6.734 \times 10^{-4} = 22.96 \text{ bar}$
 $P_2 = 27.04 \text{ bar}$
 $P_{r1}, P_{r2}, T_{r1}, T_{r2}$
 $Z_1 = Z_2$
 $V_m = 6.734 \times 10^{-4} \text{ m}^3/\text{mol}$

So we got the values of Z_1 and Z_2 as I am writing the values of P_1 and P_2 here, we did the calculations and we got the value of Z_1 as 0.93 and Z_2 as 0.73 we did the calculations and we found out the value of Z_m as 0.81 and if we just simply compare we can see that here the value of Z_1 is 0.93, here also it is 0.93, 0.73, 0.73, 0.81 and 0.81. So there is no difference after the (second iteration) means after the first iteration when we come to the first iteration to second iteration there is no difference in these values. These values are exactly the same.

And the value of V_m when we calculate it again we get it again as 6.734×10^{-4} meter cube per mole. So since there is no difference after this iteration we fix the value V_m as 6.734×10^{-4} meter cube per mole. So this is how we calculate the molar volume of the mixture using Dalton's law.

So in this problem we have found out how we calculate molar volume of the mixture using Amagat's law as well as Dalton's law. So that is for that is all for this tutorial and if you are having any doubts regarding this problems just let us know we will be helping you, so that is all thank you, thank you so much.