Clase 58 17 Noviembre 2021

Título de la nota 17/11/2021

Datos

Temperatura = 300 K

Volumen = 150 L

N_2 = 80 g

O_2 = 20 g

CO_2 = 10 g

- Cálculos para la obtención de moles

$$ni\ N_2 = \frac{80\ g}{28 g/mol} = 2.8571\ mol\ de\ N_2$$

$$ni\ O_2 = \frac{20\ g}{32 g/mol} = 0.625\ mol\ de\ O_2$$

$$ni\ CO_2 = \frac{10\ g}{44 g/mol} = 0.2272\ mol\ de\ CO_2$$

n total = (2.8571 mol de N_2) + (0.625 mol de O_2) + (0.2272 molde CO_2)

n total = 3.7093mol

- Cálculos para la obtención de la fracción mol de los componentes

$$yi = \frac{ni}{n\ totales}$$

$$yi\ N_2 = \frac{2.8571 mol\ de\ N2}{3.7093\ \text{mol}} = 0.7702$$

$$yi\ O_2 = \frac{0625 mol\ de\ N2}{3.7093\ \text{mol}} = 0.1684$$

$$yi\ CO_2 = \frac{0.2272 mol\ de\ N2}{3.7093\ \text{mol}} = 0.0612$$

$$\text{pi} = \frac{(ni)\,(R)\,(T)}{V}$$

$$\text{pi } N_2 = \frac{(2.8571\,mol)\left(0.082\,\frac{atm*L}{mol*K}\right)(300K)}{150\,L}$$

$$\text{pi } N_2 = \frac{70.28466\,atm*L}{150\,L}$$

$$\text{pi } N_2 = 0.4685 \text{ atm}$$

$$\text{pi } O_2 = \frac{(0.625\,mol)\left(0.082\,\frac{atm*L}{mol*K}\right)(300K)}{150\,L}$$

$$\text{pi } O_2 = \frac{15.375\,atm*L}{150\,L}$$

$$\text{pi } O_2 = 0.1025 \text{ atm}$$

$$\text{pi } CO_2 = \frac{(0.2272\,mol)\left(0.082\,\frac{atm*L}{mol*K}\right)(300K)}{150\,L}$$

$$\text{pi } CO_2 = \frac{5.58912\,atm*L}{150\,L}$$

$$\text{pi } CO_2 = 0.0372 \text{ atm}$$

- **LEY DE DALTON**

→ Cálculos para la presión total por suma

$$\text{p total} = \sum_{i=1}^{n} pi$$

$$\text{p total} = (0.4685 \text{ atm } N_2) + (0.1025 \text{ atm } O_2) + (0.0372 \text{ atm } CO_2)$$

$$\text{p total} = 0.6082 \text{ atm}$$

→ Cálculos para la presión total por fórmula

$$\text{p total} = \frac{(n\,total)\,(R)(T)}{Vtotal}$$

$$\text{p total} = \frac{(3.7093\,mol)\left(0.082\frac{amt*L}{mol*K}\right)(300K)}{150\,L}$$

$$\text{p total} = \frac{91.24878\,atm*L}{150\,L}$$

$$\text{p total} = 0.6083 \text{ atm}$$

- **LEY DE AMAGAT**

➔ Cálculos para el volumen parcial de los componentes

$$Vi = \frac{(ni)\,(R)\,(T)}{ptotal}$$

$$Vi\ N_2 = \frac{(2.8571\ mol)\left(0.082\frac{atm*L}{mol*K}\right)(300K)}{0.6083\ atm}$$

$$Vi\ N_2 = \frac{70.28466\ atm*L}{0.6083\ atm}$$

$$Vi\ N_2 = 115.5427\ L$$

$$Vi\ O_2 = \frac{(0.625\ mol)\left(0.082\frac{atm*L}{mol*K}\right)(300K)}{0.6083\ atm}$$

$$Vi\ O_2 = \frac{15.375\ atm*L}{0.6083\ atm}$$

$$Vi\ O_2 = 25.2753\ L$$

$$Vi\ CO_2 = \frac{(0.2272\ mol)\left(0.082\frac{atm*L}{mol*K}\right)(300K)}{0.6083}$$

$$Vi\ CO_2 = \frac{5.58912\ atm*L}{0.6083\ atm}$$

$$Vi\ CO_2 = 9.1880\ L$$

→ Cálculos para obtener ΔS_M

$$\Delta S_M = - [n\ total\ R\ (yN2\ ln\ yN2 + yO2\ ln\ yO2 + yCO2\ ln\ yCO2]$$

$$\Delta S_M = - [(3.7093 mol)\ (1.9886 \frac{cal}{molK})\ (0.7702\ In\ 0.7702\ +\ 0.1684\ In\ 0.1684\ +\ 0.0612\ In\ 0.0612)]$$

$$\Delta S_M = - \left[(3.7093 mol)\ \left(1.9886 \frac{cal}{molK}\right)(-0.672061909\ )\right]$$

$$\Delta S_M = - \left[\ \left(7.37631398 \frac{cal}{K}\right)(-0.672061909\ )\right]$$

$$\Delta S_M = 4.9573 \frac{cal}{K}$$

→ Cálculos para obtener ΔG_M

O

$$\Delta G_M = \Delta H_M - T\Delta S_M$$

$$\Delta H_M = 0$$

$$\Delta G_M = - T\Delta S_M$$

$$\Delta G_M = - (300K)\ (\ 4.9573 \frac{cal}{K})$$

$$\Delta G_M = -1487.19\ cal$$

→ Cálculos para obtener q_M

$$q_M = -\Delta G_M$$

$$q_M = -(-1487.19\ cal) = 1487.19\ cal$$

$$w_M = q_M$$

$$w_M = 1487.19\ cal$$

→ Cálculos para obtener w_M

$$w_M = q_M$$

$$w_M = 1487.19\ cal$$

→ Cálculos para obtener M_M

$$M_M = \sum_{i=1}^{n} Mi$$

$$M_M = yN_2MN_2 + yO_2MO_2 + yCO_2MCO_2$$

$$M_M = (0.7702)\left(28\frac{g}{mol}\right) + (0.1684)\left(32\frac{g}{mol}\right) + (0.0612)\left(44\frac{g}{mol}\right)$$

$$M_M = 29.6548\frac{g}{mol}$$

- **Cálculos para la obtención de Cp de mezcla**

N_2

a) 6.4500e+000
b) 1.4100e-003
c) -8.1000e-008

O_2

a) 6.1000e+000
b) 3.2500e-003
c) -1.0200e-006

CO_2

a) 6.4000e+000
b) 1.0200e-002
c) -3.5600e-006

N_2

a) (6.4500e+000) (0.7702) = 4.96779
b) (1.4100e-003) (0.7702) = 1.085982x10-03
c) (-8.1000e-008) (0.7702) = -6.23862x10-08

O_2

a) (6.1000e+000) (0.1684) = 1.02724
b) (3.2500e-003) (0.1684) = 5.473x10-4
c) (-1.0200e-006) (0.1684) = -1.71768x10-07

CO_2

a) (6.4000e+000) (0.0612) = 0.39168
b) (1.0200e-002) (0.0612) = 6.2424x10-04
c) (-3.5600e-006) (0.0612) = -2.17872x10-07

$$a = aN2 + aO2 + aCO2$$

$$a = (4.96779) + (1.02724) + (1.45408)$$

$$a = 6.386 \frac{cal}{molK}$$

$$b = bN2 + bO2 + bCO2$$

$$b = (1.085982x10^{-03}) + (5.473x10^{-4}) + (6.2424x10^{-04})$$

$$b = 2.257x10^{-3} \frac{cal}{molK}$$

- **Funciones de estado y trayectoria (cálculos)**

→ Variación o cambio de entalpía

$$\Delta H = n[a(T2 - T1) + \frac{b}{2}(T2^2 - T1^2) + \frac{c}{3}(T2^3 - T1^3)]$$

$$\Delta H = 3.7093mol[6.386\frac{cal}{molk}(600\,K - 300\,K) + \frac{2.257x10^{-3}\frac{cal}{molk^2}}{2}(600^2K - 300^2K) + \frac{-4.520x10^{-7}\frac{cal}{molk^3}}{3}(600^3K - 300^3K)]$$

$$\Delta H = 3.7093mol\ [(2234.274\frac{cal}{mol})] = 8287.5925\text{ cal}$$

$$8287.5925\text{ cal }(\frac{4.186J}{cal}) = 34691.8624\text{ J}$$

→ Variación o cambio de energía interna

$$\Delta U = n[(a - R)(T2 - T1) + \frac{b}{2}(T2^2 - T1^2) + \frac{c}{3}(T2^3 - T1^3)]$$

$$\Delta U = 3.7093mol[(6.386\frac{cal}{molk} - 1.9861\frac{cal}{molk})(600K - 300K) + \frac{2.257x10^{-3}\frac{cal}{molk^2}}{2}(600^2K - 300^2K) + \frac{-4.520x10^{-7}\frac{cal}{molk^3}}{3}(600^3K - 300^3K)]$$

$$\Delta U = 3.7093mol\ [(1638.444\frac{cal}{mol})\ (\frac{4.186J}{cal})] = 5045.2606\text{ cal}$$

$$5045.2606\text{ cal }(\frac{4.186J}{cal}) = 21119.4608\text{ J}$$

$$\Delta S = n[(a - R)\, In \frac{T2}{T1} + b(T2 - T1) + \frac{c}{2}(T2^2 - T1^2)]$$

$$\Delta S = 3.7093mol[(6.386\frac{cal}{molk} - 1.9861\frac{cal}{molk})In\left(\frac{600K}{300K}\right) + 2.257x10^{-3}\frac{cal}{molk^2}(600K - 300K) + \frac{-4.520x10^{-7}\frac{cal}{molk^3}}{2}(600^2K - 300^2K)]$$

$$\Delta S = 3.7093mol\,[(3.78789827\frac{cal}{molK})\,(\frac{4.186J}{cal})] = 14.0504\ cal/K$$

$$14.0504\frac{cal}{K}(\frac{4.186J}{cal}) = 59.2335\ J/K$$

MEZCLADO DE GASES

Modelo perfecto e ideal

Insertar en las celdas de color amarillo los valores correspondientes	Los resultados en las celdas de color verde

Constantes de Cp como función de T (cal/molK)

Gases	a	b	c	d	e	mi (g)	ni (mol)	yi	Mi (g/mol)	pi (atm)	Vi (L)
N2	6.4500e+000	1.4100e-003	-8.1000e-008	0.0000e+000	0.0000e+000	80.0000	2.8571	0.7702	28.0000	0.4686	115.5361
O2	6.1000e+000	3.2500e-003	-1.0200e-006	0.0000e+000	0.0000e+000	20.0000	0.6250	0.1685	32.0000	0.1025	25.2735
Ne	4.9715e+000			0.0000e+000	0.0000e+000	0.0000	0.0000	0.0000	20.1700	0.0000	0.0000
Ar	4.9715e+000			0.0000e+000	0.0000e+000	0.0000	0.0000	0.0000	39.9400	0.0000	0.0000
CO2	6.4000e+000	1.0200e-002	-3.5600e-006	0.0000e+000	0.0000e+000	10.0000	0.2273	0.0613	44.0000	0.0373	9.1904
						ntotal	3.7094	1.0000			

p_{total} (atm)	0.6083
V_{total} (L)	150.00

Cp_M como función de T (cal/molK)								
a	b	c	d	e	R (cal/molK)	T (K)	p_{total} (atm)	V_{total} (L)
6.3880e+0	2.2586e-3	-4.5237e-7	0.0000e+0	0.0000e+0	1.9886	300	0.6083	150.00

Cv_M como función de T (cal/molK)				
a	b	c	d	e
4.3994e+0	2.2586e-3	-4.5237e-7	0.0000e+0	0.0000e+0

M_M (g/mol)	29.6543	ΔH_M (cal)	0	ΔU_M (cal)	0	ΔS_M (cal/K)	4.9587	ΔG_M (cal)	-1487.6119

q_M (cal)	1487.6119	w_M (cal)	1487.6119

Dr. Juan Carlos Vázquez Lira 2020

Con apoyo del programa DGAPA-UNAM-PAPIME PE-200419

→ Obtención de moles de etano que se tienen

Obtención del número de moles de etano

$$masa\ molar_{C_2H_6} = 30.070\,\frac{g}{mol}$$

$$200\ g\left(\frac{1\ mol}{30.070\ g}\right) = 6.65115\ mol$$

→ Obtención de la temperatura (T) de acuerdo al modelo ideal

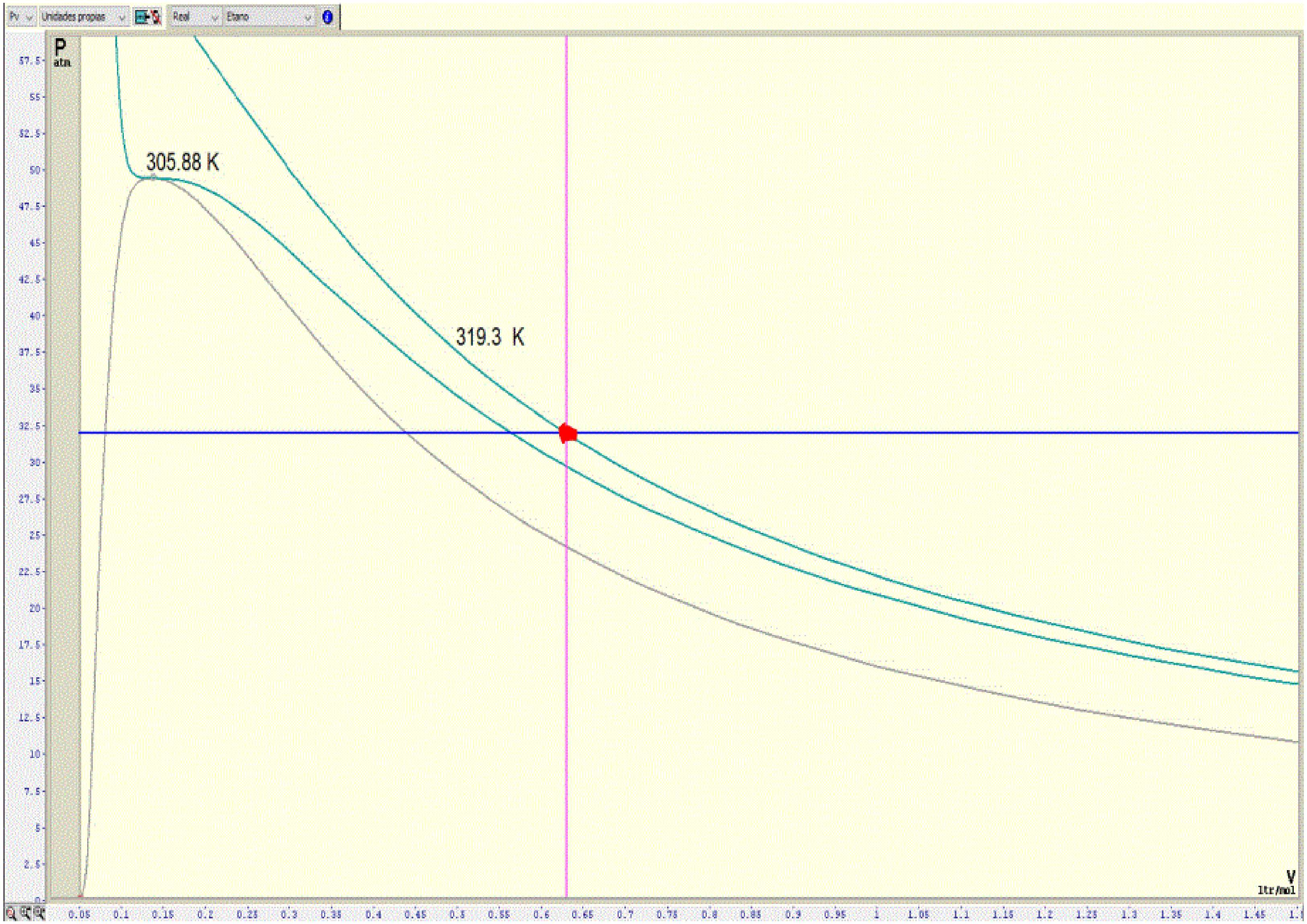
$$p * V = n * R * T$$

$$T = \frac{p * V}{n * R}$$

$$T = \frac{(32\ atm)(4.2\ L)}{(6.65115\ mol) * \left(0.082\,\frac{atm * L}{mol * K}\right)}$$

$$T = \frac{134.4\ atm * L}{0.5453943\ \frac{atm * L}{K}}$$

$$T = 246.42722\ K$$


Pv
Unidades propias
Real
Etano
P
atm
305.88 K
319.3 K
V
ltr/mol

→ Obtención de la temperatura (T) de acuerdo al modelo de Van der Waals dependiente de Vc

Obtención de a de Van der Waals (dependiente de Vc)

$$a = 3p_c\bar{V}_c^{\,2}$$

$$a = 3(48.2\ atm)\left(0.1480\frac{L}{mol}\right)^2$$

$$a = 3.16732\frac{atm * L^2}{mol^2}$$

Obtención de b de Van der Waals (dependiente de Vc)

$$b = \frac{\bar{V}_c}{3}$$

$$b = \frac{0.1480\frac{L}{mol}}{3}$$

$$b = 0.0493\frac{L}{mol}$$

Obtención de a de Van der Waals (independiente de Vc)

$$a = \frac{27 * R^2 * T_c^2}{64p_c}$$

$$a = \frac{27 * \left(0.082 \frac{atm * L}{mol * K}\right)^2 * (305.4\ K)^2}{64(48.2atm)}$$

$$a = 5.48912\ \frac{atm * L^2}{mol^2}$$

Obtención de b de Van der Waals (independiente de Vc)

$$b = \frac{R * T_c}{8p_c}$$

$$b = \frac{\left(0.082 \frac{atm * L}{mol * K}\right)(305.4\ K)}{(8)(48.2\ atm)}$$

$$b = 0.064945\ \frac{L}{mol}$$

Temperatura de acuerdo con el modelo de Van der Waals dependiente de Vc

$$p = \frac{n * R * T}{V - n * b} - \frac{a * n^2}{V^2}$$

$$p + \frac{a * n^2}{V^2} = \frac{n * R * T}{V - n * b}$$

$$\left(p + \frac{a * n^2}{V^2}\right)(V - n * b) = n * R * T$$

$$\frac{\left(p + \frac{a * n^2}{V^2}\right)(V - n * b)}{n * R} = T$$

$$T = \frac{\left(32\ atm + \frac{\left(3.16732 \frac{atm * L^2}{mol^2}\right)(6.65115 mol)^2}{(4.2\ L)^2}\right)\left(4.2\ L - (6.65115\ mol)\left(0.0493 \frac{L}{mol}\right)\right)}{(6.65115\ mol)\left(0.082 \frac{atm * L}{mol * K}\right)}$$

$$T = 283.58086\ K$$

Temperatura de acuerdo con el modelo de Van der Waals independiente de Vc

$$p = \frac{n*R*T}{V-n*b} - \frac{a*n^2}{V^2}$$

$$p + \frac{a*n^2}{V^2} = \frac{n*R*T}{V-n*b}$$

$$\left(p + \frac{a*n^2}{V^2}\right)(V-n*b) = n*R*T$$

$$\frac{\left(p + \frac{a*n^2}{V^2}\right)(V-n*b)}{n*R} = T$$

$$T = \frac{\left(32\ atm + \frac{\left(5.48912\frac{atm*L^2}{mol^2}\right)(6.65115 mol)^2}{(4.2\ L)^2}\right)\left(4.2\ L - (6.65115\ mol)\left(0.064945\frac{L}{mol}\right)\right)}{(6.65115\ mol)\left(0.082\frac{atm*L}{mol*K}\right)}$$

$$T = 316.18768\ K$$

Propiedades | Vol real Independiente de Vc | Vol real dependiente de Vc | T y p dependiente de Vc

Obtención de Temperatura y presión comportamiento tipo Van der Waals

Introducir los valores en las celdas de color amarillo

Volumen (L)	4.2000
moles (n)	6.6667
presión (atm)	32.0000
a_M ($atmL^2/mol^2$)	3.1673
b_M (L/mol)	0.0493
R (atmL/molK)	0.082

T ideal (K)	245.85
T real (K)	283.11

→ **Obtención del número de moles de etano y propano**

Obtención del número de moles de etano

$$masa\ molar_{C_2H_6} = 30.070\,\frac{g}{mol}$$

$$35\ g\left(\frac{1\ mol}{30.070\ g}\right) = 1.16395\ mol$$

Obtención del número de moles de propano

$$masa\ molar_{C_3H_8} = 44.097\,\frac{g}{mol}$$

$$350\ g\left(\frac{1\ mol}{44.097\ g}\right) = 7.93705\ mol$$

→ **Obtención de la fracción molar del etano y propano**

Fracción mol del etano

$$y_{C_2H_6} = \frac{1.16395\ mol_{C_2H_6}}{9.101\ mol}$$

$$y_{C_2H_6} = 0.127893$$

Fracción mol del propano

$$y_{C_3H_8} = \frac{7.93705\ mol_{C_3H_8}}{9.101\ mol}$$

$$y_{C_2H_6} = 0.872107$$

→ **a y b para propano y etano dependientes de Vc**

- **Propano**

Obtención de a de Van der Waals (dependiente de Vc) para el propano

$$a = 3p_c\overline{V}_c^{\,2}$$

$$a = 3(41.9\ atm)\left(0.2030\frac{L}{mol}\right)^2$$

$$a = 5.17997\ \frac{atm * L^2}{mol^2}$$

Obtención de b de Van der Waals (dependiente de Vc) para el propano

$$b = \frac{\overline{V}_c}{3}$$

$$b = \frac{0.2030\frac{L}{mol}}{3}$$

$$b = 0.0676\ \frac{L}{mol}$$

- **Etano**

Obtención de a de Van der Waals (dependiente de Vc) para etano

$$a = 3p_c\bar{V}_c^{\,2}$$

$$a = 3(48.2\ atm)\left(0.1480\frac{L}{mol}\right)^2$$

$$a = 3.16732\frac{atm * L^2}{mol^2}$$

Obtención de b de Van der Waals (dependiente de Vc) para etano

$$b = \frac{\bar{V}_c}{3}$$

$$b = \frac{0.1480\frac{L}{mol}}{3}$$

$$b = 0.0493\frac{L}{mol}$$

→ **Obtención de a_M y b_M dependientes del Vc**

Obtención de a_M de Van der Waals (dependiente de Vc)

$$a_M = \sum_{i=1}^{n} a_{ci}$$

$$a_M = \left(y_{etano} * a_{etano}^{\frac{1}{2}} + y_{propano} * a_{propano}^{\frac{1}{2}}\right)^2$$

$$a_M = \left(0.127893\left(3.16732\frac{atm * L^2}{mol^2}\right)^{\frac{1}{2}} + 0.872107\left(5.17997\ \frac{atm * L^2}{mol^2}\right)^{\frac{1}{2}}\right)^2$$

$$a_M = 4.16734\ \frac{atm * L^2}{mol^2}$$

Obtención de b_M de Van der Waals (dependiente de Vc)

$$b_M = \sum_{i=1}^{n} b_i$$

$$b_M = y_{etano} b_{etano} + y_{propano} b_{propano}$$

$$b_M = (0.127893)\left(0.0493 \frac{L}{mol}\right) + (0.872107)\left(0.0676 \frac{L}{mol}\right)$$

$$b_M = 0.0652595 \frac{L}{mol}$$

→ Obtención de la presión del modelo de Van der Waals (dependiente de Vc)

Presión de acuerdo con el modelo de Van der Waals dependiente de Vc

$$p = \frac{n * R * T}{V - n * b} - \frac{a * n^2}{V^2}$$

$$p = \frac{(9.101 mol)\left(0.082\ \frac{atm * L}{mol * K}\right)(300\ K)}{(10\ L) - (9.101 mol)\left(0.0652595 \frac{L}{mol}\right)} - \frac{\left(4.16734 \frac{atm * L^2}{mol^2}\right)(9.101 mol)^2}{(10\ L)^2}$$

$$p = 20.3504\ atm$$

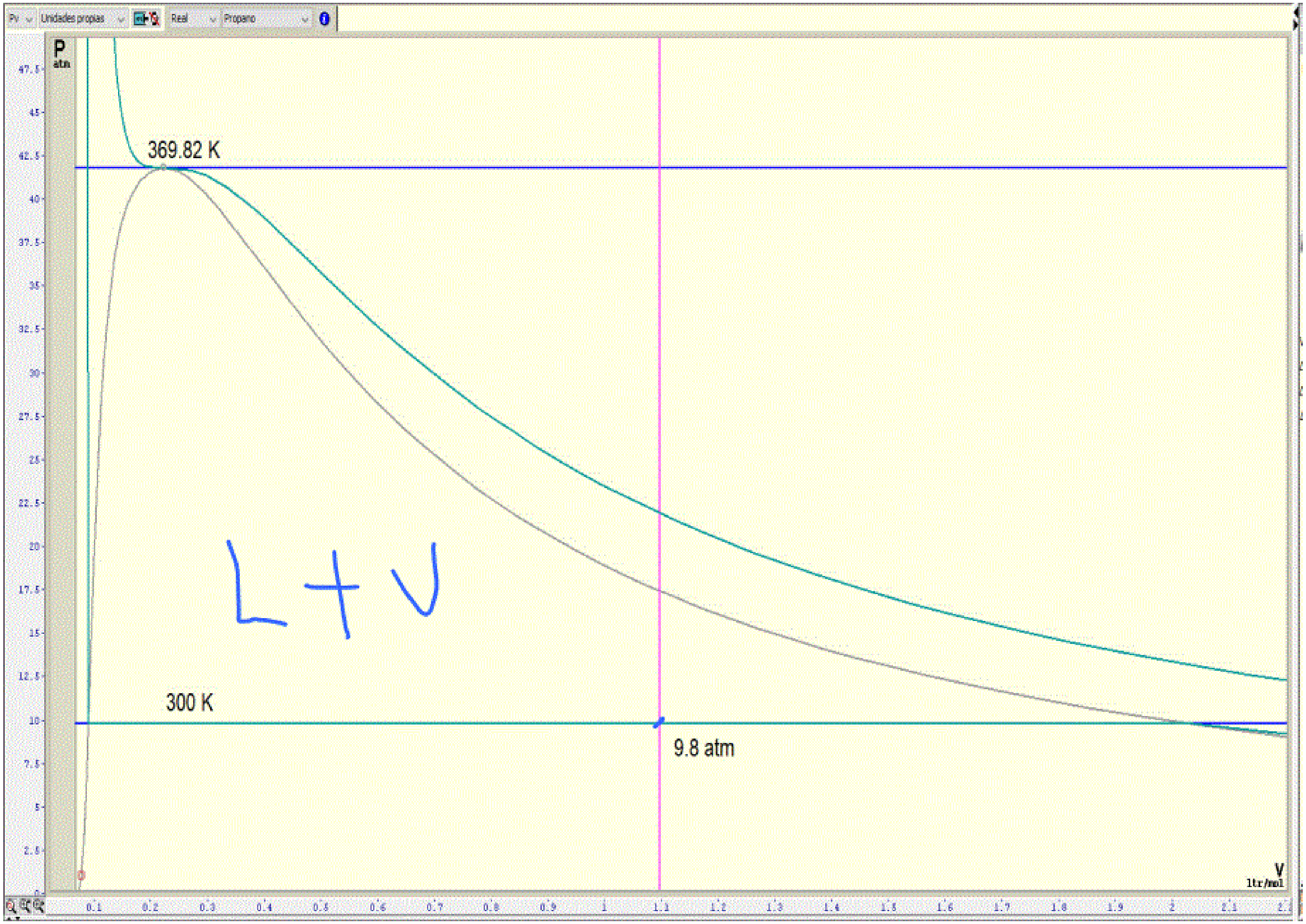
→ **Obtención de la presión del modelo de Van der Waals (independiente de Vc)**

Presión de acuerdo con el modelo de Van der Waals independiente de Vc

$$p = \frac{n * R * T}{V - n * b} - \frac{a * n^2}{V^2}$$

$$p = \frac{(9.101 mol)\left(0.082\ \frac{atm * L}{mol * K}\right)(300\ K)}{(10\ L) - (9.101 mol)\left(0.101397 \frac{L}{mol}\right)} - \frac{\left(7.34123 \frac{atm * L^2}{mol^2}\right)(9.101 mol)^2}{(10\ L)^2}$$

$$p = 18.58393\ atm$$


Pv
Unidades propias
Real
Propano
P
atm
369.82 K
L + V
300 K
9.8 atm
V
ltr/mol

Propiedades | Vol real Independiente de Vc | Vol real dependiente de Vc | T y p dependiente de Vc | T y p Independiente de Vc

Obtención de parámetros de mezclado binario y ternario

Introducir los valores en las celdas de color amarillo

Componente	M (g/mol)	m (g)	pc (atm)	Tc (K)	Vc (L(mol)	ni
Metano	16.00	0.00	45.40	190.60	0.0990	0.0000
Etano	30.00	35.00	48.20	305.40	0.1480	1.1667
Propano	44.00	350.00	41.90	369.80	0.2030	7.9545
					n total	9.1212

R (atmL/molK): 0.0820

	Dependiente de Vc			Independiente de Vc		
Componente	a (atmL^2/mol^2)	b (L/mol)	yi	a (atmL^2/mol^2)	b (L/mol)	y
Metano	1.3349	0.0330	0.0000	2.2699	0.0430	1.0000
Etano	3.1673	0.0493	0.1279	5.4891	0.0649	
Propano	5.1800	0.0677	0.8721	9.2583	0.0905	

Dependiente de Vc

a_M (atmL^2/mol^2)	b_M (L/mol)	pc_M (atm)	Tc_M (K)	Vc_M (L/mol)
4.8951	0.0653	42.7058	361.5628	0.1960

Independiente de Vc

a_M (atmL^2/mol^2)	b_M (L/mol)	pc_M (atm)	Tc_M (K)	Vc_M (L/mol)
8.7216	0.0872	42.7058	361.5628	0.1960

FES ZARAGOZA

Volumen (L)	10.0000
Temperatura (K)	300.00
moles (n)	9.1212
a_M ($atmL^2/mol^2$)	4.8951
b_M (L/mol)	0.0653
R (atmL/molK)	0.0820

p ideal (atm)	22.4382
p real (atm)	19.7871

Dr. Juan Carlos Vázquez Lira UNAM FES Zaragoza 2020

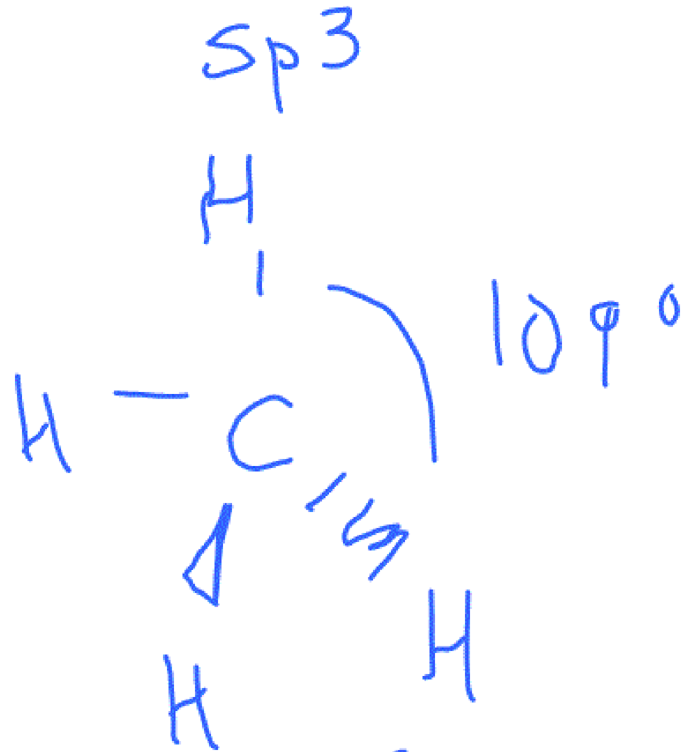
Con apoyo del programa UNAM-DGAPA-PAPIME PE-200419

Volumen (L)	10.0000
Temperatura (K)	300.00
moles (n)	9.1212
a_M ($atmL^2/mol^2$)	8.7216
b_M (L/mol)	0.0872
R (atmL/molK)	0.082

p ideal (atm)	22.4382
p real (atm)	17.1210

Dr. Juan Carlos Vázquez Lira UNAM FES Zaragoza 2020

Con apoyo del programa UNAM-DGAPA-PAPIME PE-200419

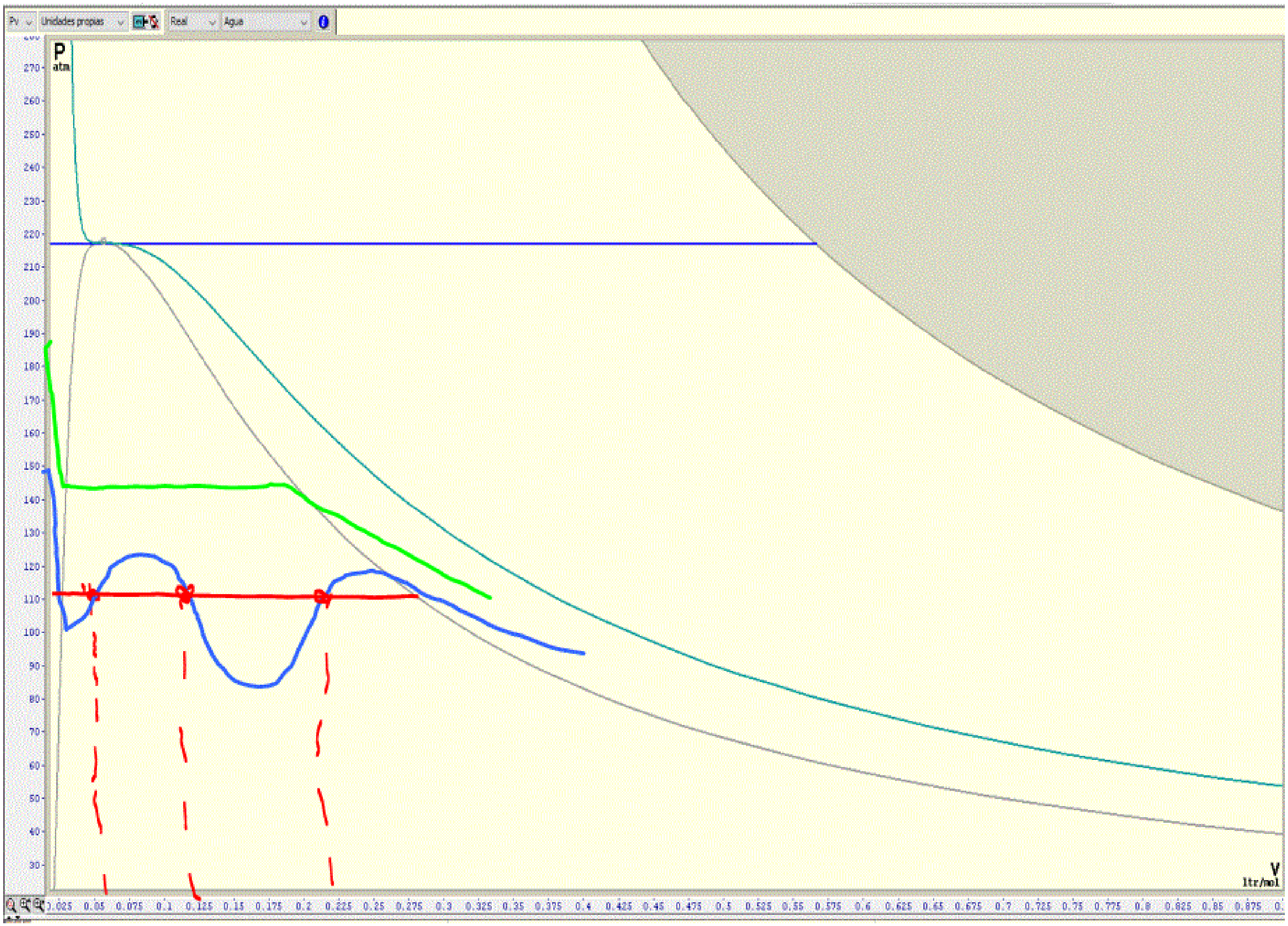


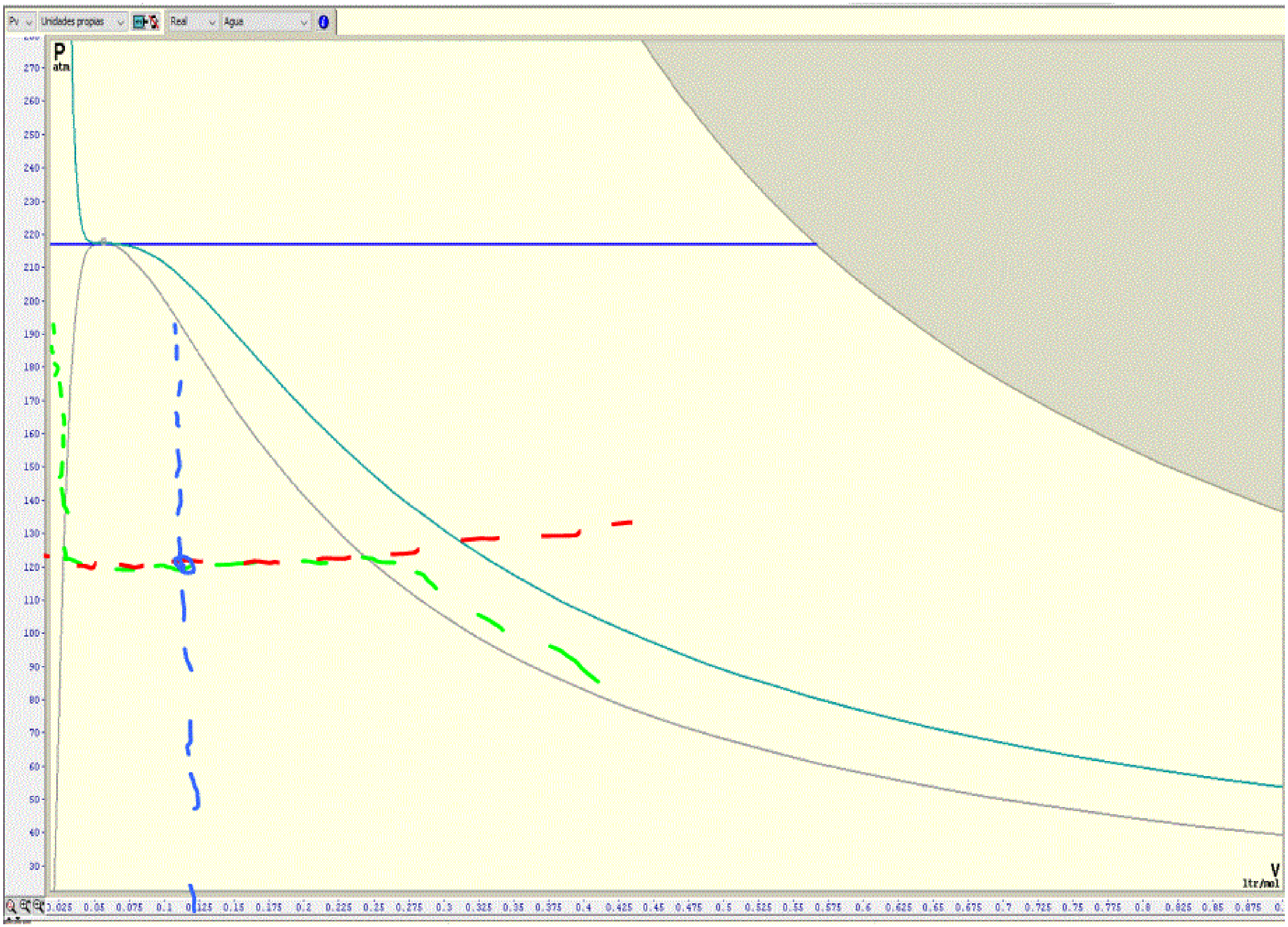
Polar $\mu_D > 0$

Tetrahedro

$\mu_D = 0$

no polar


Pv
Unidades propias
Real
Agua
P
atm
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
V
ltr/mol
0.025
0.05
0.075
0.1
0.125
0.15
0.175
0.2
0.225
0.25
0.275
0.3
0.325
0.35
0.375
0.4
0.425
0.45
0.475
0.5
0.525
0.55
0.575
0.6
0.625
0.65
0.675
0.7
0.725
0.75
0.775
0.8
0.825
0.85
0.875


Unidades propias
Real
Agua
P
atm
V
ltr/mol

$$P = \frac{nRT}{V - nb} - \frac{an^2}{V^2}$$

$$P = \frac{RT}{\bar{V} - b} - \frac{a}{\bar{V}^2}$$

$$P + \frac{a}{\bar{V}^2} = \frac{RT}{\bar{V} - b}$$

$$p + \frac{a}{\bar{v}^2} = \frac{RT}{\bar{v} - b}$$

$$\frac{p\bar{v}^2 + a}{\bar{v}^2} = \frac{RT}{\bar{v} - b}$$

$$(p\bar{v}^2 + a)(\bar{v} - b) = \bar{v}^2 RT$$

$$p\bar{v}^3 - p\bar{v}^2 b + a\bar{v} - ab = \bar{v}^2 RT$$

$$p\bar{v}^3 - p\bar{v}^2 b + a\bar{v} - ab = \bar{v}^2 RT$$

$$p\bar{v}^3 - p\bar{v}^2 b + a\bar{v} - ab - \bar{v}^2 RT = 0$$

$$\frac{p\bar{v}^3 - \bar{v}^2 (pb + RT) + a\bar{v} - ab = 0}{p}$$

$$\bar{v}^3 - \bar{v}^2 \left(b + \frac{RT}{p}\right) + \frac{a\bar{v}}{p} - \frac{ab}{p} = 0$$

$$\bar{V}^3 - \bar{V}^2\left(b_m + \frac{RT}{P}\right) + \frac{a_m\bar{V}}{P} - \frac{a_m b_m}{P} = 0$$

$$a^3 - b^2 + c - d = 0$$