Solutions to Exercises Reservoir Engineering II

PVT analysis

Exercise 1

a) Described in fig. 1.2.

b) Derivation is shown in chapter 1.4.

c) To find initial gas in place (IGIP) we plot P_{res}/Z_{res} against G_p. According to the equation in b), this gives a straight line. IGIP is found as the intersection with this line and the horizontal axis ($P_{res}/Z_{res} = 0$). G_p is found in column 3, and P_{res}/Z_{res} is calculated from column 1 and 2, and given in column 6.

From the plot shown below we see that the slope of the line is $-1.995 \cdot 10^{-8}$, and for G_p = 0 P_{res}/Z_{res} is 5120.1. For G_p at $P_{res}/Z_{res} = 0$ we then get:

$$G_p = \text{IGIP} = \frac{5120.1}{1.995 \cdot 10^{-8}} = 2.566 \cdot 10^{11}\ \text{(SCF)}$$

d) We now have to convert the stock tank oil and the water into gas equivalents. This is done by multiplying the representative liquid volume by its gas equivalent factor. For stock tank oil the gas equivalent factor is given by:

$$GE_{STO} = 133000 \frac{\gamma_{STO}}{M_{STO}} \frac{(SCF)}{(SBL)} = 133000 \frac{0.72}{72} \frac{(SCF)}{(SBL)} = 1330 \frac{(SCF)}{(SBL)}$$

The volumes of gas resulting from the stock tank oil (G_{STO} in column 7) is obtained by multiplying GE_{STO} with the corresponding values in column 4.

For water the gas equivalent factor is given by:

$$GE_W = 133000/18 \frac{(SCF)}{(SBL)} = 7389 \frac{(SCF)}{(SBL)}$$

The volumes of gas resulting from the stock tank oil (G_W in column 8) is obtained by multiplying GE_W with the corresponding values in column 5.

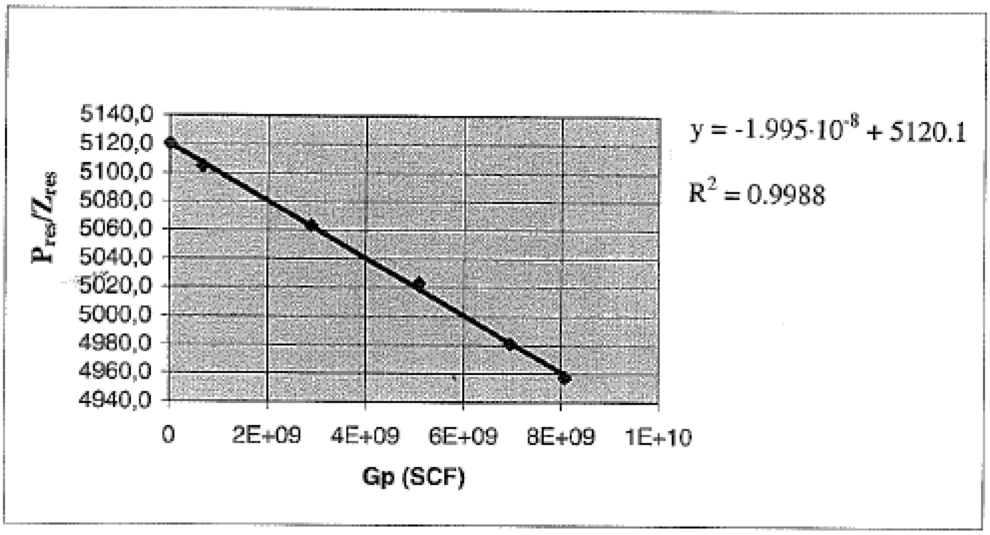

Fig. 1: Plot of P_{res}/Z_{res} against G_p, volume of produced liquids excluded.

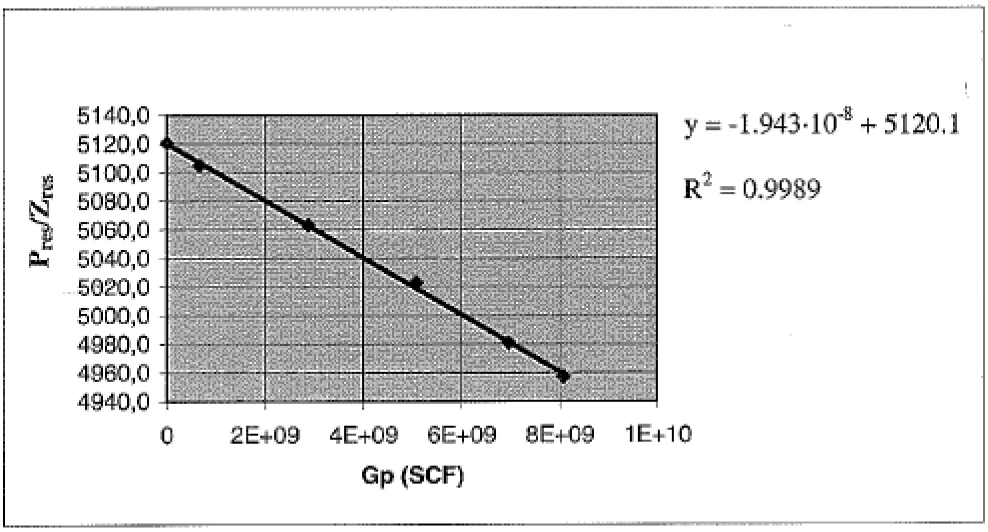

Fig. 2: Plot of P_{res}/Z_{res} against G_p, volume of produced liquids included.

Table 1: Data given.

Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**
P_{res} (psia)	**Z_{res}**	**Cumulative separator gas = G_p (10^6SCF)**	**Cumulative stock tank oil (SBL)**	**Cumulative water (SBL)**
5392	1.0530	0	0	0
5368	1.0516	661.272	12314	3
5301	1.0470	2883.114	47674	762
5245	1.0442	5073.370	83132	2054
5182	1.0404	6957.608	112902	3300
5147	1.0383	8070.262	144035	4644

Table 2: Data calculated.

Column 6	**Column 7**	**Column 8**	**Column 9**
P_{res}/Z_{res}	**Cumulative G_{STO} (10^6SCF)**	**Cumulative G_W (10^6SCF)**	**$(G_p)_{tot} = G_p + G_{STO} + G_W$ (10^6SCF)**
5120.6	0	0	0
5104.6	16.378	0.022	677.671
5063.0	63.406	5.630	2952.151
5023.0	110.566	15.177	5199.112
4980.8	150.160	24.383	7132.150
4957.1	191.567	34.314	8296.143

To find the total well stream volume as gas, you have to use the same procedure as in 1c. Plot Pres/Zres vs. Gp,tot, as in Fig. 2. Extrapolate the straight line to Pres/Zres =0. The intersection point with the x-axis gives the total well stream volume present as gas; Gi.

$G_i = 5120.1/1.943\cdot10^{-8} = 2.64\cdot10^{11}$ (SCF)

Exercise 2

a) At Pb we have: ∑yi =∑ziKi = 1. Calculate ziKi for each component. Calculate the sum for all components. Pb then, is the pressure where this sum is (closest to)1.

Component	**z_iK_i at 2500 psia**	**z_iK_i at 2000 psia**	**z_iK_i at 1900 psia**	**z_iK_i at 1800 psia**
C_1	0.6113	0.8150	0.8490	0.8830
C_2	0.0646	0.0648	0.0691	0.0711
C_3	0.0651	0.0602	0.0602	0.0592
n-C_4	0.0191	0.0165	0.0156	0.0152
n-C_5	0.0083	0.0067	0.0064	0.0061
C_6	0.0048	0.0036	0.0033	0.0033
C_{7+}	0.0059	0.0035	0.0031	0.0029
Sum	0.7791	0.9733	1.0067	1.0407
	$P_b < 2500$	$P_b < 2000$	$P_b \approx 1900$	$P_b > 1800$

Conclusion: P_b slightly higher than 1900 psia.

Exercise 3

a) We use the Newton-Raphson method, which is illustrated on fig. 1. The following equations are needed:

Equation 1: L + V = 1

Equation 2: $$F(L) = \left(\sum_{i=1}^{m} x_i\right) - 1 = \left(\sum_{i=1}^{m} \frac{z_i}{L+VK_i}\right) - 1 = 0$$

Equation 3: $$F'(L) = \sum_{i=1}^{m} \frac{(K_i - z_i)}{\left[L+(1-L)K_i\right]^2}$$

To calculate the mole fraction of liquid and gas (L_{s1} and V_{s1}), and the liquid composition from the first separator, we assume a value for L_1, and use equation 1,2 and 3 to calculate F(L) and F´(L). Then, according to the Newton-Raphson method the next value in the iteration process (L_2) is given by:

Equation 4: $$L_2 = L_1 - \frac{F(L_1)}{F'(L_1)}$$

Mole fraction of each component then have to be calculated. For C_1 we get from eq. 2, using $L_1 = 0.5$.:

$$x_1 = \frac{0.3396}{0.5+0.5\cdot 61} = 0.011$$

x_i for the other components is shown in table 1 together with $\sum x_i$ and F(L).

To calculate F´(L) we use equation 3 for each component, find x'_i, and then calculate the sum: For C_1 we get:

$$x'_1 = \frac{(61-1)\cdot 0.3396}{\left[0.5+(1-0.5)\cdot 61\right]^2} = 0.0212$$

x'_i for the other components is shown in table 1, together with F´(L).

Now L_2 can be calculated using eq. 4:

$$L_2 = L_1 - \frac{F(L_1)}{F'(L_1)} = 0.5 - \frac{0.03395}{(-1.67995)} = 0.5202$$

The above procedure is repeated with L2 = 0.5202 (see results in table below), and L3 is determined:

$$L_3 = L_2 - \frac{F(L_2)}{F'(L_2)} = 0.5202 - \frac{0.001389}{(-1.52584)} = 0.5211$$

Calculation of $F(L_3)$ gives 0.00015 (see table 2), and $L_3 = 0.5211$ is accepted as the correct value for L_{s1}. We then get:

$$L_{s1} = 0.5211$$

$$V_{s1} = 0.4789.$$

The composition of the separator oil, shown in table 2 (column 3), is identical to the x_i values used to calculate $F(L_2)$ (column 2).

Table 1.

Component	$x_i = \frac{z_i}{L+VK_i}$	$x'_i = \frac{(K_i-1)z_i}{\left[L+(1-L)K_i\right]^2}$		$x_i = \frac{z_i}{L+VK_i}$	$x'_i = \frac{(K_i-1)z_i}{\left[L+(1-L)K_i\right]^2}$
C_1	0.01095	0.02120		0.01140	0.02296
C_2	0.01292	0.02067		0.01335	0.02208
C_3	0.06169	0.04627		0.06264	0.04770
n-C_4	0.05391	-0.02611		0.05339	-0.00653
n-C_5	0.05560	-0.08203		0.05399	-0.07735
C_6	0.05797	-0.10810		0.05587	-0.10039
C_{7+}	0.78090	-1.55184		0.75075	-1.4343
Sum	1.03395	-1.67995		1.00139	-1.52584
L_1	0.5	0.5	L_2	0.5202	0.5202
$F(L_1)$	0.03395		$F(L_2)$	0.00139	
$F'(L_1)$		-1.67995	$F'(L_2)$		-1.52584
L_2		0.5202	L_3		

Table 2

Component	$x_i = \frac{z_i}{L + VK_i}$	Composition Separator 1 oil.	Composition STO(=Sep. 2).	M_{STO}
C_1	0.01142	0.01142	0.0028	0.1832
C_2	0.01337	0.01337	0.0095	0.4020
C_3	0.06268	0.06268	0.0577	2.7636
n-C_4	0.05337	0.05337	0.0529	3.1017
n-C_5	0.05392	0.05392	0.0546	3.8901
C_6	0.05577	0.05577	0.0569	4.8061
C_{7+}	0.74945	0.74945	0.7656	197.1043
Sum	0.999985	0.999985	1.0000	212.2509
L_3	0.5211			
$F(L_3)$	0.000015			

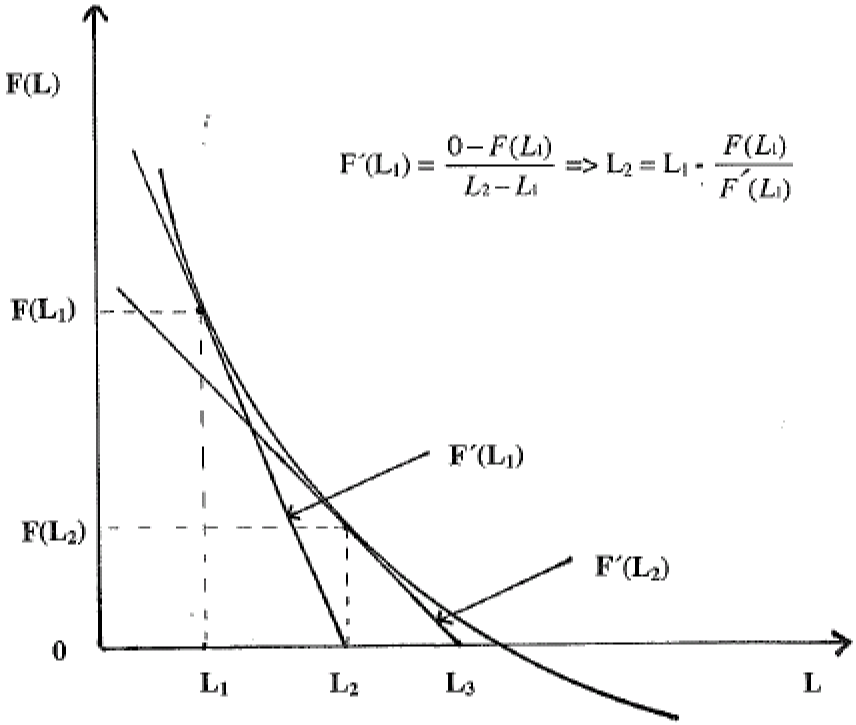

Fig.1: Illustration of the Newton-Raphson iteration method

b) The oil from separator 1 is the feed to separator 2, and therefore this composition, together with the K_i-values for the conditions of separator 2, is used to calculate the mole fractions of liquid and gas in separator 2 (L_{s2} and V_{s2}). Assuming $L_1 = 0.95$, and performing a Newton-Raphson iteration as in exercise a) gives:

$$L_{s2} = 0.9789$$

$$V_{s2} = 0.0211$$

The composition of STO of separator 2 is given in table 2.

c) Based on 1 mole feed to each separator, the GOR for separator i is given by (see text):

$$GOR_{sepi} = \frac{V_i V_m \rho_{STO}}{(L_i L_{i+1} \ldots L_k) M_{STO}}$$

The molecular weight of the stock tank oil is obtained by multiplying the molecular weight of each fraction, en then taking the sum:

$$M_{STO} = \sum_{i=1}^{m} x_i M_i = 212.2509 \text{ (see table 2)}$$

$$GOR_{sep1} = \frac{V_1 V_m \rho_{STO}}{(L_i L_2) M_{STO}} 5.615 \frac{SCF}{SBL} = \frac{0.4789 * 380{,}69 * 53.5}{0.5211 * 0.9789 * 212.25} 5.615 \frac{SCF}{SBL} = 496.7 \frac{SCF}{SBL}$$

$$GOR_{sep2}\,(tank) = \frac{V_2 V_m \rho_{STO}}{L_2 M_{STO}} 5.615 \frac{SCF}{SBL} = \frac{0.0211 \cdot 380.69 \cdot 53.5}{0.9789 \cdot 212.25} 5.615 \frac{SCF}{SBL} = 11.6 \frac{SCF}{SBL}$$

$$GOR_{tot} = GOR_{sep1} + GOR_{sep2} = 508.3 \frac{SCF}{SBL}$$

d) Based on 1 mole of reservoir fluid, B_o is expressed as:

$$B_o = \frac{(M_o)_{res} (\rho_o)_{STO}}{L_1 L_2 (M_o)_{STO} (\rho_o)_{res}} = \frac{122.17 \cdot 53.5}{0.5211 \cdot 0.9789 \cdot 212.25 \cdot 46.6} = 1.296$$

Exercise 5

Column 2: Calculation of $(\Delta G_p)_i$.

The ratio between the volume of gas produced, and the volume of gas in the reservoir, is equal to the ratio between the volume of gas liberated in the PVT-cell and the volume of the PVT-cell. This will be the case at any conditions of temperature and pressure, as long as they are the same; also for standard conditions (sc). Hence we can write, for each pressure step i:

$$\frac{(\Delta G_p)_{isc}}{(V_{HCPV})_{sc}} = \frac{(\Delta V_g)_{isc}}{(V_{cell})_{sc}} \quad => \quad (\Delta G_p)_{isc} = (V_{HCPV})_{sc}\frac{(\Delta V_g)_{isc}}{(V_{cell})_{sc}}$$

The three volumes on the right side of the equation can be found by first finding the number of moles of gas in the volume, using the real gas law (PV=ZnRT), and then multiplying this by the molar volume at sc (V_m).

$$(V_{HCPV})_{sc} = \frac{P_d(V_{HCPV})_{res}}{Z_dRT_{res}}V_m = \frac{2960\cdot 7623}{0.771\cdot 10.732\cdot 654.69}379.5 \text{ SCF} = 1581 \text{ kSCF}$$

$$(\Delta V_g)_{isc} = \frac{P_i(\Delta V_g)_{ires}}{Z_iRT_{res}}V_m = \frac{2500\cdot 0.0062}{0.794\cdot 10.732\cdot 654.69}379.5 \text{ SCF} = 1.05 \text{ SCF}$$

$$(V_{cell})_{sc} = \frac{P_d(V_{cell})_{res}}{Z_dRT_{res}}V_m = \frac{2960\cdot 0.0335}{0.771\cdot 10.732\cdot 654.69}379.5 \text{ SCF} = 6.94 \text{ SCF}$$

and:

$$(\Delta G_p)_{isc} = 1581\,\frac{1.05}{6.94} \text{ kSCF} = 240 \text{ kSCF}$$

Column 3: Calculation of $\sum(\Delta G_p)_i$

Simply add the values for each step from column 2.

Column 4: Calculation of $(\Delta V_g)_i$

To find the volume of separator gas at sc, we need to subtract the volume of gas that is converted to liquid. The mole fraction of liquid produced in a given pressure step ($(\Delta n_L)_i$) is obtained by multiplying the mole fractions (z_i) of each liquid component (C_4, C_5, C_6 and C_{7+}) with the liquid recovery factor from the well stream:

$$(\Delta n_L)_i = 0.25(z_{C4})_i + 0.50(z_{C5})_i + 0.75(z_{C6})_i + 1.0(z_{C7+})_i$$

For the first pressure step (P_i = 2500 psia) we get:

$$(\Delta n_l)_1 = 0.25\cdot 0.028 + 0.50\cdot 0.019 + 0.75\cdot 0.016 + 1.0\cdot 0.031 = 0.0625$$

Since the volume of gas is proportional to the number of moles of gas, the volume of gas becoming liquid ($(\Delta G_L)_i$) is obtained by multiplying the wellstream volume with the liquid mole fraction:

$$(\Delta G_L)_i = (\Delta n_L)_i \ (\Delta G_p)_i$$

and for pressure step 1 we get:

$$(\Delta G_L)_1 = (\Delta n_L)_1 \ (\Delta G_p)_1 = 0.0625 \cdot 240 \text{ kSCF} = 15.0 \text{ kSCF}$$

The volume of separator gas is then obtained by subtracting the volume becoming liquid from the total volume. For step 1 we get:

$$(\Delta V_g)_1 = (\Delta G_p)_1 - (\Delta G_L)_1 = (240 - 15) \text{ kSCF} = 225 \text{ kSCF}$$

Column 5: Calculation of $\sum(\Delta V_g)_i$

Add the values for each step from column 4

Column 6: Calculation of $(\Delta V_o)_i$

Here we have to calculate the liquid volume for each component, and then add the volumes of each component (C_4, C_5, C_6 and C_{7+}). This is done by first determining the the volume of gas becoming liquid ($(\Delta G_L)_i$), as in column 4. The liquid volume (in Gal (US Gallon)) is found by multiplying this gas volume by the conversion factor for gas volume to liquid volume, given for each component. For C_4, in step 1 we get:

$$(V_L)_{C4} = (0.25(z_{C4})_i \cdot (\Delta G_p)_i \cdot 32.04)$$

$$= 0.25 \cdot 0.028 \cdot 240 \text{ kSCF} \cdot 32.04 \text{ Gal/kSCF} = 53.8 \text{ Gal}$$

Calculating the liquid volume for the other components, and adding them together gives:

C_4 = 53.8 Gal
C_5 = 82.8 Gal
C_6 = 118.1 Gal
C_{7+} = 389.1 Gal
Total = 643.8 Gal

Converting to SBL (1 bbl = 42.117 Gal) gives 15.3 SBL.

Column 7: Calculation of $\sum(\Delta V_o)_i$

Add the values for each step from column 6.

Column 8: Calculation of $(GOR)_i$

The initial GOR is given by:

$$(GOR)_{initial} = \frac{IGIP}{IOIP}$$

Using the initial wellstream compositions, the gas and liquid volumes, IGIP and IOIP, are calculated using the procedure described under column 4 (gas) and 6 (liquid). To get the liquid volume we therefore have to calculate the liquid volume for each component and add them together. For C_4 we get:

$$(V_L)_{C4} = 0.25 \cdot 0.031 \cdot 1581 \text{ kSCF} \cdot 32.04 \text{ Gal/kSCF} = 392 \text{ Gal}$$

Calculating V_l for the other components by the same procedure, and adding them together gives:

C_4 = 392 Gal
C_5 = 632 Gal
C_6 = 1070 Gal
C_{7+} = 3922 Gal
Total = 6016 Gal

IOIP results from converting to SBL (1 bbl = 42.117 Gal), which gives 142.8 SBL.

IGIP is obtained by calculating the mole fraction of liquid, and then find the corresponding gas volume:

$$\begin{aligned} n_L &= 0.25z_{C4} + 0.50z_{C5} + 0.75z_{C6} + 1.0z_{C7+} \\ &= 0.25 \cdot 0.031 + 0.50 \cdot 0.022 + 0.75 \cdot 0.022 + 1.0 \cdot 0.052 = 0.08725 \end{aligned}$$

The volume of gas (at sc) becoming liquid, is $(V_{HCPV})_{sc}$ multiplied with the above mole fraction. $(V_{HCPV})_{sc}$ was calculated under column 2, and is 1581 kSCF, and we get:

$$G_L = 0.08725 \cdot 1581 \text{ kSCF} = 139.9 \text{ kSCF}$$

And for IGIP we get:

$$IGIP = (V_{HCPV})sc - G_L = 1442.8 \text{ kSCF}$$

The initial GOR then becomes:

$$(GOR)_{initial} = \frac{1442.8kSCF}{142.8SBL} = 10104 \text{ SCF/SBL.}$$

The same procedure is used to calculate the GOR for each step.

Column 9: Calculation of cumulative %ΔG_p

Found as: $$\frac{\Sigma(\Delta G_p)_i}{(V_{HCPV})_{sc}}100\%$$

Column 10: Calculation of cumulative %ΔV_g

Found as: $$\frac{\Sigma(\Delta V_g)_i}{IGIP}100\%$$

Column 11: Calculation of cumulative %ΔV_g

Found as: $$\frac{\Sigma(\Delta V_o)_i}{IOIP}100\%$$

Table 1: Data to be calculated

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
P_{res} (psia)	**(ΔGp)i (kSCF)**	**∑(ΔGp)i (kSCF)**	**(ΔVg)i (kSCF)**	**∑(ΔVg)i (kSCF)**	**(ΔVo)i (SBL)**	**∑(ΔVo)i (SBL)**	**GOR (SCF/SBL)**	**%ΔGp (cumulative)**	**%ΔVg (cumulative)**	**%ΔVo (cumulative**
2960	0	0	0	0	0	0	10600	0	0	0
2500	240.1	240.1	225.1	225.1	15.3	15.3	14700	15.2	15.6	10.7
2000	245.2	485.3	232.3	457.4	13.1	28.4	17730	30.7	31.7	19.8
1500	266.0	751.3	252.8	710.2	13.3	41.7	19010	47.6	49.3	29.1
1000	270.8	1022.1	256.9	967.1	14.0	55.7	18350	64.7	67.1	38.9
500	248.7	1270.8	233.0	1200.1	15.9	71.6	14650	80.4	83.3	50.0

Exercise 6

a)

In exercise 5 it was shown that $(\Delta G_p)_{isc}$ could be expressed as follows:

$$(\Delta G_p)_{isc} = (V_{HCPV})_{sc} \frac{(\Delta V_g)_{isc}}{(V_{cell})_{sc}}$$

It was also shown that:

$$(\Delta V_g)_{isc} = \frac{P_i (\Delta V_g)_{ires}}{Z_i R T_{res}} V_m$$

$$(V_{cell})_{sc} = \frac{P_d (V_{cell})_{res}}{Z_d R T_{res}} V_m$$

From this follows:

$$\frac{(\Delta V_g)_{isc}}{(V_{cell})_{sc}} = \frac{P_i Z_d (\Delta V_g)_{ires}}{P_d Z_i (V_{cell})_{res}}$$

For step 1 we have:

$$\frac{(\Delta V_g)_{1sc}}{(V_{cell})_{sc}} = \frac{3500 \cdot 0.867 \cdot 224}{4000 \cdot 0.799 \cdot 3958.14} = 0.0537$$

Since $(V_{HCPV})_{sc}$ is given as 10^6 SCF, we get:

$$(\Delta G_p)_{1sc} = 0.0537 \cdot 10^6 \text{ SCF} = 53.7 \text{ kSCF}$$

The volume of oil in step 1 is calculated using the given value for the amount of liquid formed (gallon) for each kSCF wellstream produced (GPM):

$$(\Delta V_o)_1 = (GPM)_1 \cdot (\Delta G_p)_{1sc} = 4.578 \text{ Gal/kSCF} \cdot 53.7 \text{ kSCF} = 245.8 \text{ Gal} = 5.84 \text{ SBL}$$

Finally the gas volume is determined from the oil volume and the GOR given:

$$(\Delta V_g)_1 = (\Delta V_o)_1 (GOR)_1 = 5.84 \text{ SBL} \cdot 8283 \text{ SCF/SBL} = 48.4 \text{ kSCF}$$

b)

First we calculate IOIP using the initial GPM:

$$\text{IOIP} = (V_{HCPV})_{sc} \cdot (GPM)_{initial} = 1000 \text{ kSCF} \cdot 5.254 \text{ Gal/kSCF}$$

$$= 5254 \text{ Gal} = 124.7 \text{ SBL}$$

Then we calculate IGIP using the initial GOR:

$$\text{IGIP} = \text{IOIP} \cdot (\text{GOR})_{initial} = 124.7 \text{ SBL} \cdot 7127 \text{ SCF/SBL}$$

$$= 889.1 \text{ kSCF}$$

c)

For $(\Delta G_p)_{isc}$ we use the same expression as in a):

$$(\Delta G_p)_i = (V_{HCPV})_{sc} \frac{(\Delta V_g)_{isc}}{(V_{cell})_{sc}} = 1.17 \text{ SCF } \frac{P_i(\Delta V_g)_{res}}{Z_i(V_{cell})_{res}}$$

$(\Delta V_o)_i$ in SBL is given by (as in a)):

$$(\Delta V_o)_i = (\text{GPM})_i \cdot (\Delta G_p)_i / 42.117 \text{ SBL/Gal}$$

$(\Delta V_g)_i$ in SCF is given by (as in a)):

$$(\Delta V_g)_i = (\Delta V_o)_i \, (\text{GOR})_i$$

Results are presented in the table below:

i	$(\Delta G_p)_i$ (kSCF)	$\sum(\Delta G_p)_i$ (kSCF)	$\%(\Delta G_p)_i$	$(\Delta V_g)_i$ (kSCF)	$\sum(\Delta V_g)_i$ (kSCF)	$\%(\Delta V_g)_i$	$(\Delta V_o)_i$ (SBL)	$\sum(\Delta V_o)_i$ (SBL)	$\%(\Delta V_o)_i$
1	53.7	53.7	5.37	48.4	48.4		5.84	5.84	
2	100.7	154.4	15.44	93.0	141.4		8.00	13.84	
3	196.8	351.2	35.12	189.13	330.5		7.26	21.10	
4	226.2	577.4	57.74	220.9	551.4		4.48	25.58	
5	191.1	768.5	76.85	186.2	737.6	83.0	4.06	29.64	23.8

d)

The reservoir hydrocarbon pore volume is given by:

$$(V_{HCPV})_{res} = (V_{bulk})_{res}(1-S_{wr})\Phi = 43560\ (1-0.2)0.1\text{ft}^3 = 3485 \text{ ft}^3$$

Since the number of moles are the same at sc and at reservoir conditions, we have, using the equation of state:

$$n_{res} = n_{sc} \Rightarrow \frac{P_{res}(V_{HCPV})_{res}}{Z_{res}T_{res}} = \frac{P_{sc}(V_{HCPV})_{sc}}{Z_{sc}T_{sc}}$$

Solving for $(V_{HCPV})_{sc}$ gives:

$$(V_{HCPV})_{sc} = \frac{P_{res}Z_{sc}T_{sc}(V_{HCPV})_{res}}{P_{sc}Z_{res}T_{res}} = \frac{4000 \cdot 1.0 \cdot 520 \cdot 3485}{14.7 \cdot 0.902 \cdot 646} \text{ SCF} = 863 \text{ kSCF}$$

Since this is 86.3% of the volume used in exercise 6c), the cumulative recoveries is obtained by multiplying the cumulative recoveries in exercise 6c) by 0.863. Hence we get:

$\sum(\Delta G_p)_i = 663.2$ kSCF $\quad \sum(\Delta V_g)_i = 636.5$ kSCF $\quad \sum(\Delta V_o)_i = 25.58$ SBL

e)

If S_{or} is 0.15, oil will be produced at $S_o > 0.15$. From the given values of $\%(V_L)_{cell}$ we see that this will happen at a pressure around 3000 psia. Since the CVD-analysis is based on the flow of only gas, the production of STO will be underestimated at pressures below 3000 psia.

f)

If the initial pressure P_{in} is higher than $P_d = 4000$ psia, the number of moles of fluid in the reservoir will be higher, which results in increased production. The increase in in the number of moles is calculated from the equation of state:

$$\Delta n = n_{Pin} - n_{Pd} = \left(\frac{P_{in}}{Z_{in}} - \frac{P_d}{Z_d}\right)\frac{(V_{HCPV})_{res}}{R \cdot T_{res}} = \left(\frac{5713}{1.107} - \frac{4000}{0.902}\right)\frac{3485}{10.73 \cdot 646} = 275 \text{ moles}$$

Increase in wellstream gas production is obtained by multiplying by the molar volume at sc:

$\Delta G_{well} = \Delta n \cdot V_m = 275 \cdot 379.5$ SCF = 104.4 kSCF

which gives:

$\Delta V_{STO} = (GPM)_i \cdot \Delta G_{well} / 42.117$ SBL/Gal = $5.254 \cdot 104.4 / 42.117$ SBL = 13.0 SBL

and since the GOR is the same as the dew-point GOR at 4000 psia:

$\Delta V_g = (GOR)_{in} \cdot \Delta V_{STO} = 7127 \cdot 13.0$ SCF = 92.7 kSCF