University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

Date: December 18. 2009.

SUBJECT: PVT-analysis MPE 510

Time: 4 hours
Helps: Calculator

The exam consists of 3 pages

REMARKS: Additions: 1

Problem 1.

A bottom hole sample (BHS) is taken from a reservoir and brought to a PVT-lab.
Given reservoir data:

Temperature:	$T_{res} = 130\ ^oC$
Pressure:	$P_i = 450$ bara
	$P_b = 332.5$ bara
Porosity:	$\Phi = 0.25$
Initial water:	$S_{wi} = 0.25$
Bulk res. volume:	$10^6\ m^3$

The BHS undergoes a single flash to standard conditions, and the following data are given:

GOR = 382 Sm^3/Sm^3
$(B_o)_b = 2.29\ m^3/Sm^3$
$M_{STO} = 187$
$\rho_{STO} = 839{,}4\ kg/m^3$
$\gamma_g = 0.837$
$(M_o)_{res} = 59.5$
Comp. of STO as molefractions: x_i $(i = C_1 - C_{10+})$
Comp.of gas as molefractions: y_i $(i = C_1 - C_{10+})$

a.

1. Characterize the reservoir fluid by means of a PT-diagram.
2. M_{STO} is determined experimentally. Describe shortly the principles of the analysis. Use formula.

3. The weight % of each of the components in STO is experimentally determined by gas chromatography. Give a short description of the principles of the analysis. Use formulas.
4. Derive a formula to calculate M_{C10+} for STO; $M_{C10+} = f((w\%)_i, (wt\%)_{C10+}, M_i)$ where $i=C_1$- C_9 for x_i and $i=C_1$- C_9 for M_i.
5. Derive a formula for ρ_{C10+} for STO; $(\rho_{C10+})_{STO} = f(\rho_i, M_i, x_i)$ where $i=C_1$-C_{10+} for M_i and x_i and $i=C_1$-C_9 for ρ_i.
6. Calculate the composition as molefraction of reservoir fluid; $z_i = f(x_i, y_i)$.

A Constant Mass Expansion (CME) was performed, and the data from the analysis are presented below.

Constant Mass Expansion at 130 °C

Pressure Bara	**Rel. Vol V/V_b**	**Compress 1/bara**	**Y Factor**	**Density g/cm^3**
500.00	0.9261	3.563E-04		0.5808
450.00	0.9439	4.073E-04		-
425.00	0.9539	4.379E-04		0.5638
400.00	0.9648	4.728E-04		0.5575
375.00	0.9768	5.130E-04		0.5506
350.00	0.9899	5.598E-04		0.5433
332.51	1.0000	5.973E-04		-
325.00	1.0091		2.53	
300.00	1.0443		2.45	
250.00	1.1455		2.27	
200.00	1.3174		2.09	
150.00	1.6378		1.91	

b.

1. Verify that P_b is correctly determined.
2. Calculate the density of reservoir fluid at P_b and P_i at T_{res}.
   (Answers: $\rho_{ob} = 537.5$ kg/m^3; $\rho_{oi} = 563.5$ kg/m^3)
3. Based on the given reservoir bulk volume and supposing the reservoir fluid is produced to the surface by a single flash to standard conditions, calculate IOIP (Sm^3) and IGIP (Sm^3).
   (Answers: IOIP = 8.674×10^4 Sm^3; IGIP =3.3134×10^7 Sm^3)
4. Suppose that the fluid production in the pressure interval P_i to P_b is only related to the expansion of reservoir fluid, i. e. a closed reservoir. Calculate the recovery of STO (Sm^3) and gas (Sm^3) from the reservoir for this pressure decline.
   What is the corresponding recovery factor in %?

Below the saturation point, a differential gas liberation analysis is performed, and the data are shown below.

Differential Gas Depletion at 130 °C

Pressure Bara	Oil FVF B_{od}	R_{sd} Sm^3/Sm^3	Gas FVF B_{gd}	Oil Dens g/cm^3	Z FactorGas
332.51	3.081	566.7		0.5378	
300.00	2.634	436.1	4.470E-03	0.5662	0.939
250.00	2.249	317.7	5.151E-03	0.6025	0.903
200.00	1.997	237.5	6.318E-03	0.6354	0.887
150.00	1.809	176.8	8.413E-03	0.6668	0.886
100.00	1.655	127.7	1.279E-02	0.6978	0.898
50.00	1.516	84.9	2.632E-02	0.7301	0.923
1.01	1.069	0.0	1.437E+00	0.8102	0.986
1.01	1.000			0.8663	

c.

1. Describe shortly the principles of differential gas liberation analysis and its application.
2. Define the parameters: B_{od}, R_{sd} and B_{gd}.
3. Suppose the reservoir is produced by just a pressure depletion process from P_i to an abandon pressure of 100 bara. Make a schematic drawing of:
   a. GOR vs. P
   b. μ_o vs. P.
   c. μ_g vs. P.

   Give very short comments to the figures.
4. Describe by formula how the Z-factor of the equilibrium gas is calculated based on the "Corresponding State Theorem".

d.

The reservoir fluid is going to be produced through a 3-step separator system, and flash calculations gave the following results:

1. step:	V_1=0.5216	L_1=0.4784
2. step:	V_2=0.3254	L_2=0.6746
3. step (sc):	V_3=0.2517	L_3=0.7483

$(\gamma_g)_{average}$ = 0.7977
M_{STO} = 173.8
ρ_{STO} = 828.7 kg/Sm^3

Based on previous data and data from the separator calculations, the following calculations are to be performed:

1. Calculate the total GOR, (Sm^3/Sm^3)
2. Calculate the GOR for separator 2 (2. step) (Sm^3/Sm^3)
3. Calculate the B_{ob}, m^3/Sm^3. (Answer B_{ob} = 2.18 m^3/Sm^3)
4. Why is $(B_{ob})_{single\ flash}$ = 2.29 > $(B_{ob})_{separator}$ =2.18? Give a short comment.

e.

Draw a schematic "block" diagram of a PVT-simulator, and describe shortly what the different "blocks" symbolize/contain

Addition 1.
Important formula/correlations in PVT-Analysis.

Temperature:

$^oK = 273.15 + {^oC}$
$^oF = 1.8 \times {^oC} + 32$
$^oR = {^oF} + 459.69$

Pressure:

1atm = 1013.250 mBar = 1.013250 bar = 101.3250 kPa = 0.1013250 MPa = 14.69595 psia
psia = 14.69595 + psig
1 atm = 760.002 mmHg at 0 ^oC

Density:

1 g/cm^3 = 62.43 lb/ft^3 = 350.54 lb/bbl
1 lb/ft^3 = 16.0185 kg/m^3
ρ_w = 0.999015 g/cm^3 (60 ^oF, 1 atm)
ρ_w = 0.9991 g/cm^3 (15 ^oC, 1 atm)

Specific density:

For liquids: Determined relative to water at sc.
For gases: Determined relative to air at sc.

$$\gamma_o = \frac{\rho_o}{\rho_w} = \frac{141.5}{131.5 + {^oAPI}}$$

$$^oAPI = \frac{141.5}{\gamma_o} - 131.5$$

Cragoe`s formula (empirical formula giving molecular weight of hydrocarbons):

$$M_o = \frac{6084}{^oAPI - 5.9}$$

$$\gamma_g = \frac{M_g}{M_{air}} = \frac{M_g}{28.96}$$

Volume:

1 bbl = 5.615 ft^3 = 0.15898 m^3
1 ft^3 = 0.0283 m^3
1 US Gallon = 3.785 litre
1 Imp. Gallon = 4.546 litre
Molar volume of gas at standard conditions:
V_m = 379.51 SCF/lb mole (60 ^oF and 14.69595 psia)
V_m = 23644.7 cm^3/g mole = 23.6447 m^3/kg mole (15 ^oC and 101.3250 kPa)

Air:

Z_{air} = 0.9959 (60 ^oF, 14.69595 psia)
M_{air} = 28.96

Gas constant:

R = 10.732 (psia, ft^3, ^oR, lb mole)
R = 0.082054 (atm, litre, ^oK, g mole)
R = 8.3145 (kPa, m^3, ^oK, kg mole)