National Exams May 2018

17-Pet-A2, Petroleum Reservoir Fluids

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. This is a CLOSED BOOK exam.
3. One of two calculators is permitted any Casio or Sharp approved models.
4. FIVE (5) questions constitute a complete exam paper.
5. The first five questions as they appear in the answer book will be marked.
6. All questions are of equal value unless otherwise stated and all parts in a multipart question have equal weight.
7. Clarity and organization of your answers are important, clearly explain your logic.
8. Pay close attention to units, some questions involve oilfield units, and these should be answered in the field units. Questions that are set in other units should be answered in the corresponding units.
9. A formula sheet is provided at the end of questions

Question 1 (20 Marks)

a) Name major non-hydrocarbon impurities in oil and gas reservoir fluids (**1 point**).
b) Define the following terms (**4 points**).
   - Gas hydrate
   - Waxes
   - Asphaltene
   - Bitumen
c) Draw schematics of pressure-temperature (PT) diagram for a pure component and show different phase regions, critical point, triple point, melting point curve, and sublimation point curve (**5 points**).
d) Draw schematic pressure-volume (PV) diagram for a pure component and compare it with PV diagram of a multi-component system. Show isotherms ($T<T_c$, $T=T_c$ and $T>T_c$) where T_c is the critical point. Also, indicate various phase regions (**5 points**).
e) Draw schematic pressure-temperature (PT) diagram of a multi-component system and indicate critical point, bubble point curve, dew point curve, phase regions, cricondenbar and cricondentherm (**5 points**).

Question 2 (20 Marks)

A ternary mixture of methane, carbon-dioxide, and n-butane having a fixed overall composition in a PVT cell enters a two-phase region at certain pressure and temperature. The equilibrium compositions of methane and carbon dioxide in the vapor phase and liquid phase are measured as given in the following.

- vapor phase: 85% methane and 12% carbon-dioxide,
- liquid phase: 15% methane and 30% carbon-dioxide.

a) Determine the composition of n-butane in vapor phase and liquid phase.
b) Use Gibb's phase rule and determine degree of freedom of the described system,
c) Calculate the equilibrium k-values for each component,
d) What is the vapor phase fraction (mole) if the CO_2 overall mole fraction in the PVT cell is 0.25?

Question 3 (20 Marks)

A PVT test on Athabasca bitumen has shown a solution gas-oil-ratio (GOR) of 4 standard m^3 of gas /one standard m^3 of bitumen (4 Sm^3/Sm^3). The bitumen density at standard condition is 1005 kg/m^3 and the molecular weights of the dissolved gas (methane) and bitumen are 16 and 550 g/mole, respectively.

a) Calculate mole fraction of methane (dissolved gas) in the reservoir. Assume volume of one mole of gas at standard conditions is 22.4 Liters,
b) Calculate formation volume factor of bitumen at reservoir condition if the bitumen density at reservoir condition is 990 kg/m^3. **Hint**: start with the definition of the formation volume factor and $V=m/\rho$, where V is volume, m is mass and ρ is density.

Question 4 (20 Marks)

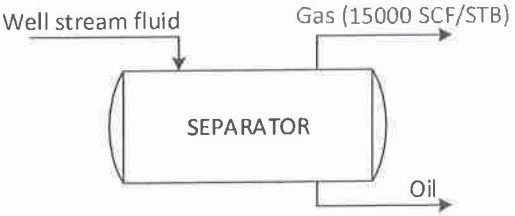
PVT data for an oil reservoir is given in the following table. Use the provided data to answer the following questions.

a) The initial pressure for this reservoir is estimated to be 3000 psia. Is this oil saturated or undersaturated?
b) What is the bubble point pressure of this oil?
c) What are the oil formation volume factor and solution gas oil ratio at the bubble point pressure?
d) What is the total (or two-phase) formation volume factor in rbbl/STB for this oil at 1614.7 psia and 2780 psia?
e) What is the coefficient of isothermal oil compressibility above the bubble point pressure?
f) Estimate relative expansion in the oil volume (V/V_i) if the reservoir pressure drops from 3000 psia to the bubble point pressure.

Pressure (psia)	Gas formation volume factor (ft^3/SCF)	Solution gas oil ratio (SCF/STB)	Oil formation volume factor (rbbl/STB)
2780		740	1.464
2500		740	1.468
2144.7	0.007232	740	1.473
2014.7	0.007704	702	1.456
1814.7	0.008568	645	1.43
1614.7	0.009714	588	1.405
1414.7	0.011258	532	1.381

Question 5 (20 Marks)

A separator test has been conducted on a well producing from a wet gas reservoir and the following information are gathered.
Gas specific gravity (air=1), γ_{gass}=0.7,
Oil specific gravity (water=1), γ_o = 0.8,
Oil molecular weight, Mw_o=80 lb_{mass}/lb_{mole}.



Calculate the specific gravity of the well stream fluid using the given data.

Hint: Use 1 STB of oil as basis, $\gamma_{wf} = Mw_{gas} / Mw_{air}$ and $Mw = m/n$ where m and n are mass in lb_{mass} and number of moles in lb_{mole}, respectively.
Other information required: 1 lb_{mass} of gas =379.4 SCF, 1 STB of oil =350γ_o lb_{mass}, Molecular weight of air =28.97 lb_{mass}/lb_{mole}.

Question 6 (20 Marks)

A wellhead stream fluid is flashed in a separator. The molar composition of the separator gas and separator liquid were measured using gas chromatography and are given in the following table. The separator gas and separator oil mass ratio is determined to be 0.5 lb_{mass} of gas to 1 lb_{mass} of oil. Determine the recombined composition the well stream fluid.

Component	Gas phase (mole %)	Liquid phase (mole %)	Molecular weight (lb_{mass}/lb_{mole})
Methane	71	7	16.043
Ethane	10	5	30.074
Propane	9	15	44.097
i-Butane	3	7	58.123
n-Butane	4	25	58.123
i-Pentane	2	18	72.150
n-Pentane	1	23	72.150
	100	100	

Question 7 (20 Marks)

Calculate the gas formation volume factor in ft^3/SCF and the gas density in lb_{mass}/ft^3 for the following gas phase composition at 4000 psia and 180 °F. Note that molecular weight of air is 28.97 lb_{mass}/lb_{mole}.

Component	Gas phase (mole %)	Molecular weight (lb_{mass}/lb_{mole})
Methane	71	16.043
Ethane	10	30.074
Propane	9	44.097
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n-Butane	4	58.123
i-Pentane	2	72.150
n-Pentane	1	72.150
	100	

Formula Sheet

Real gas law

$pV = ZnRT$

where p in psia, T in °R, V in ft^3, R=10.732 psi-ft^3/(lb$_{mole}$-°R)

Pseudo critical pressure and temperature

$T_{pc} = 168 + 325\gamma_g - 12.5\gamma_g^2$ in ^oR

$p_{pc} = 677 + 15.0\gamma_g - 37.5\gamma_g^2$ in *psia*

Reduced temperature: $T_r = \frac{T}{T_c}$

Reduced pressure: $p_r = \frac{p}{p_c}$

where γ_g is the gas specific gravity (air=1)

Average molecular weight: $MW_{av} = \sum y_i MW_i$

Pseudo critical Temperature: $T_{pc} = \sum y_i T_{pc_i}$

Reduced temperature: $T_r = \frac{T}{T_c}$

Pseudo critical pressure: $p_{pc} = \sum y_i p_{pc_i}$

Reduced pressure: $p_r = \frac{p}{p_c}$

Gas density: $\rho = \frac{pMW}{ZRT}$

where ρ is gas density in lb$_{mass}$/ft^3, p in psia, T in R, MW is molecular weight in lb$_{mass}$/lb$_{mole}$ (MW of Air =28.97 lb$_{mass}$/lb$_{mole}$), R=10.732 psi-ft^3/(lb$_{mole}$-°R)

Gas formation volume factor, $B_g = 0.02827\frac{ZT}{p}$ in ft^3/SCF, where p in psia, T in °R.

Total or two-phase formation volume factor: $B_t = B_o + B_g\left(R_{sob} - R_{so}\right)$

Coefficient of isothermal oil compressibility: $c = -\frac{1}{B_{ob}}\left(\frac{dB_o}{dP}\right)_T$

Phase equilibrium relations: $\sum_i \frac{z_i}{1+V\left(K_i - 1\right)} = 1, \quad x_i = \frac{z_i}{1+V\left(K_i - 1\right)}$

Conversion Factors

1 m^3 = 6.28981 bbl =35.3147 ft^3

1 atm =14.6959488 psi =101.32500 kPa=1.01325 bar

1 m = 3.28084 ft = 39.3701 inch

1kg = 2.20462 lb$_{mass}$

Handbook of Natural Gas Engineering