National Exams December 2015

98-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. Any non-communicating calculator is permitted.

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)

Explain (briefly in one or two sentences or a simple equation) the following concepts.

a) Flash calculations
b) Black-oil
c) Bitumen
d) Dry gas
e) Retrograde condensation
f) Dead oil
g) Live oil
h) Kay's mixing rules
i) Dew point pressure
j) Bubble point pressure

Question 2 (20 Marks)

A PVT cell contains a single-phase natural gas produced from a gas well in a dry gas reservoir at 1400 psia and 200°F. The PVT cell volume is determined to be 12 ft\(^3\). The gas specific gravity is 0.6. Calculate the following:

a) Gas deviation factor, \(Z_g\),
b) Gas density in \(\text{lb}_{\text{mass}}/\text{ft}^3\),
c) Gas volume at standard conditions (\(p_{sc}=14.7\) and \(T_{sc}=60^\circ\text{F}\)),
d) Number of mole of gas in the PVT cell.

Question 3 (20 Marks)

A separator test has been conducted on a gas well producing from a gas condensate reservoir and the following data have been collected. Use these data and the schematic shown below to find the specific gravity of the produced well stream fluid.

*Hint: Use mass of 1STB of oil as a basis. Mass of one STB of water is about 350 \(\text{lb}_{\text{mass}}\).*

Separator producing gas-oil ratio, GOR \(\quad 40000\ \text{SCF/STB}\)
Oil API gravity, API \(\quad 50\)
Separator gas specific gravity, \(\gamma\) \(\quad 0.6\)
Separator oil molecular weight, \(M_w\) \(\quad 144\ \text{lb}_{\text{mass}}/\text{lb}_{\text{mole}}\)
One mole of gas at standard conditions is 379.4 SCF.

![Separator schematic diagram]

Separator gas

Well stream fluid

Separator liquid
Question 4 (20 Marks)

The following PVT data are available from a laboratory test carried out on a black oil sample at 225°F. Use the provided data to calculate:

a) The bubble point pressure of the oil sample
b) The total formation volume factor, \( B_t \) at 2682 psia.
c) The coefficient of isothermal compressibility of the oil at 3500 psia.
d) The total formation volume factor, \( B_t \) at 800 psia in bbl/STB.

<table>
<thead>
<tr>
<th>Pressure (psia)</th>
<th>Oil formation volume factor ( B_o ) (bbl/STB)</th>
<th>Gas deviation factor ( Z )</th>
<th>Solution gas-oil ratio ( R_s ) (SCF/STB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4500</td>
<td>1.3474</td>
<td>-</td>
<td>632</td>
</tr>
<tr>
<td>4000</td>
<td>1.3575</td>
<td>-</td>
<td>632</td>
</tr>
<tr>
<td>3500</td>
<td>1.3686</td>
<td>-</td>
<td>632</td>
</tr>
<tr>
<td>3000</td>
<td>1.3811</td>
<td>-</td>
<td>632</td>
</tr>
<tr>
<td>2682</td>
<td>1.4040</td>
<td>-</td>
<td>632</td>
</tr>
<tr>
<td>2500</td>
<td>1.3782</td>
<td>0.8140</td>
<td>584</td>
</tr>
<tr>
<td>2200</td>
<td>1.3369</td>
<td>0.8165</td>
<td>509</td>
</tr>
<tr>
<td>2000</td>
<td>1.3109</td>
<td>0.8208</td>
<td>460</td>
</tr>
<tr>
<td>1800</td>
<td>1.2864</td>
<td>0.8269</td>
<td>414</td>
</tr>
<tr>
<td>1600</td>
<td>1.2634</td>
<td>0.8347</td>
<td>369</td>
</tr>
<tr>
<td>1400</td>
<td>1.2416</td>
<td>0.8440</td>
<td>326</td>
</tr>
<tr>
<td>1200</td>
<td>1.2208</td>
<td>0.8548</td>
<td>285</td>
</tr>
<tr>
<td>1000</td>
<td>1.2002</td>
<td>0.8670</td>
<td>245</td>
</tr>
<tr>
<td>800</td>
<td>1.1791</td>
<td>0.8808</td>
<td>205</td>
</tr>
<tr>
<td>600</td>
<td>1.1566</td>
<td>0.8964</td>
<td>163</td>
</tr>
<tr>
<td>400</td>
<td>1.1315</td>
<td>0.9140</td>
<td>119</td>
</tr>
<tr>
<td>200</td>
<td>1.1024</td>
<td>0.9339</td>
<td>70</td>
</tr>
</tbody>
</table>

Question 5 (20 Marks)

Gaseous solvents have been used in oil recovery. One important factor in selection of solvent is the amount of solvent required.

a) Calculate the number of mole of solvent(s) required to be mixed with oil (o) in a PVT cell that results in two phase mixture with \( L=0.8 \) and \( V=0.2 \), where \( L \) and \( V \) are liquid- and gas-phase fractions. The equilibrium constants (\( K \)-values) for oil and solvent are estimated from a correlation to be 10 and 0.01, respectively.

b) Determine the equilibrium composition (mole fractions, \( x_s, x_o, y_s, y_o \)) of gas and liquid phases in the PVT cell.
Question 6 (20 Marks)
The original reservoir pressure in a gas field was 2500 psia and the reservoir temperature was 190°F. For a gas of the following composition, what would be the reservoir pressure when one-half of the gas has been withdrawn from the reservoir? Assume constant reservoir volume and temperature.

<table>
<thead>
<tr>
<th>Components</th>
<th>Mole %</th>
<th>Molecular weight (lb mass/lb mole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>91.32</td>
<td>16.04</td>
</tr>
<tr>
<td>Ethane</td>
<td>4.43</td>
<td>30.07</td>
</tr>
<tr>
<td>Propane</td>
<td>2.12</td>
<td>44.10</td>
</tr>
<tr>
<td>Butane</td>
<td>1.36</td>
<td>58.12</td>
</tr>
<tr>
<td>Pentane</td>
<td>0.42</td>
<td>72.15</td>
</tr>
<tr>
<td>Hexane</td>
<td>0.15</td>
<td>86.18</td>
</tr>
<tr>
<td>Heptanes and plus</td>
<td>0.20</td>
<td>104.00</td>
</tr>
</tbody>
</table>

Question 7 (20 Marks)
Critical points of methane (C₁) and normal butane (n-C₄) are shown in the following plot. Use this plot and draw expected approximate pressure-temperature (PT) diagram for pure methane, pure normal butane, and the following mixtures of C₁ and n-C₄:

a) Mixture of 80% C₁+20% n-C₄,
b) Mixture of 20% C₁+80% n-C₄.

Hint: Cricondentherm for mixtures of C₁ and n-C₄ can reach as high as 2000 psia.
**Formula Sheet**

**Real gas law**

\[ pV = ZnRT \]

where \( p \) in psia, \( T \) in \(^\circ R\), \( V \) in ft\(^3\), \( R = 10.732 \) psi-ft\(^3\)/lbmol-\(^\circ R\)

**Pseudo critical pressure and temperature**

\[ T_{pc} = 168 + 325 \gamma_g - 12.5 \gamma_g^2 \quad \text{in} \, ^{\circ}R \]

\[ p_{pc} = 677 + 15.0 \gamma_g - 37.5 \gamma_g^2 \quad \text{in} \, \text{psia} \]

**Reduced temperature:**

\[ T_r = \frac{T}{T_c} \quad \text{Reduced pressure:} \quad p_r = \frac{p}{p_c} \]

where \( \gamma_g \) is the gas specific gravity (Air=1)

**Average molecular weight:**

\[ M_{av} = \sum \gamma_i M_i \]

**Pseudo critical Temperature:**

\[ T_{pc} = \sum \gamma_i T_{pc_i} \]

**Reduced temperature:**

\[ T_r = \frac{T}{T_c} \]

**Pseudo critical pressure:**

\[ p_{pc} = \sum \gamma_i p_{pc_i} \]

**Reduced pressure:**

\[ p_r = \frac{p}{p_c} \]

**Gas density:**

\[ \rho = \frac{pM}{ZRT} \]

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

**Gas formation volume factor,** \( B_g = 0.02827 \frac{ZT}{p} \text{ in } \frac{ft^3}{SCF} \), where \( p \) in psia, \( T \) in \(^{\circ}R\).

**Total or two-phase formation volume factor:** \( B_t = B_o + B_g \left( R_{sub} - R_{ro} \right) \)

**Coefficient of isothermal oil compressibility:**

\[ c = \frac{1}{B_{eb} \left( \frac{dB_o}{dP} \right)_T} \]

\[ \sum_i \frac{z_i}{1 + V(K_i - 1)} = 1, \quad x_i = \frac{z_i}{1 + V(K_i - 1)}, \quad \sum_i x_i = 1, \]

**Phase equilibrium relations:**

\[ \sum_i y_i = 1, \quad \sum_i z_i = 1, \quad K_i = \frac{y_i}{x_i}, \quad L + V = 1 \]

**Coefficient of isothermal oil compressibility:**

\[ c_g = \frac{1}{p} \frac{1}{Z} \left( \frac{dZ}{dP} \right)_T \]

**Oil API gravity:**

\[ API = \frac{141.5}{\gamma_o} - 131.5 \] , where \( \gamma_o \) is oil specific gravity.
Fig. 4.16. Compressibility factor for natural gases. (Standing and Katz, 4-87. Courtesy AIME.)