National Exams May 2018

17-Pet-A7, Secondary and Enhanced Recovery

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. An approved Casio or Sharp model calculator is permitted. One Aid sheet written on both sides is permitted.
3. Four (4) questions constitute a complete exam paper. Marks for each question and its components are given in parentheses.
4. All the necessary formulas for calculations are provided.

Question 1: (20%)

Write you answer with explanation, and figures if required. Each question has equal weights.

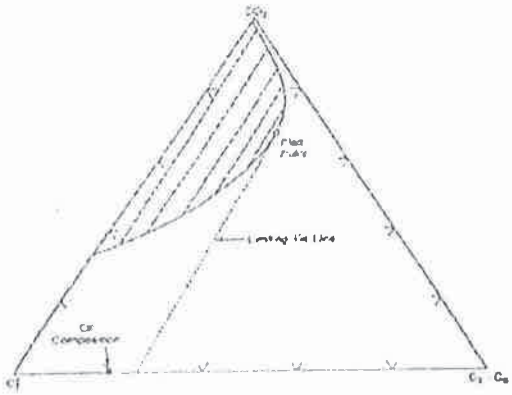
1. Explain the Snap-off effect.
2. Indicate two different methods to characterize reservoir wettability in a laboratory? For oil-wet and water-wet list the key numbers or indicators for each method.
3. Explain the effect of oil viscosity on breakthrough recovery during water flooding using fractional flow curves.
4. What is gravity segregation, what should be considered to minimize the effect of gravity segregation?
5. Explain the need for optimal salinity in surfactant/chemical flood design.

Question 2: (20%)

Write you answer with explanation, and figures if required. Each question has equal weights.

A CO_2 displacement test is conducted in a slim-tube apparatus. A pseudo-ternary phase diagram for the fluid system is shown in the figure below. The oil composition is indicated on the diagram. A displacement test is conducted with a fluid that is 96% CO_2 and 4% C2-C6.

(a) Will miscibility be achieved in this displacement? Explain why?
(b) When the injected gas first breaks through at the exit end of the core, what will its composition be? Show this point on the ternary diagram. (Neglect any effects of dispersion)
(c) Consider a location near the entrance of the slim tube. Several PV's of gas will have flowed through this position by end of the run. What will be the final oil composition at this position near the entrance? Show the composition point on the ternary diagram.
(d) If the injected gas composition is changed to 70% of CO_2 and 30% of C2-C6, what can you say about miscibility?



Question – 3 (30%)

Given the following data from a miscible flood carried out in 5-spot pattern with inter-well spacing between wells of 1000 ft:

a) State which of the two: gravity segregation or viscous instability - dictates the displacement performance? .... **(10%)**

k_v = 100 mD k_h = 400 mD

Daily gas injection volume = 1500 bbl of reservoir volume

Density: oil = 0.75 g/cm^3, gas = 0.50 g/cm^3

Viscosity: oil = 1.2 cP, gas = 0.04 cP

Formation thickness = 50 ft

b) What if the formation were tighter with a permeability of 5 mD (K_h and K_v) and thinner with a thickness of only 10 ft? (Which of two will dictate the performance) ..... **(10%)**

c) In which of these two projects (project-a or project-b), sweep efficiency will be higher and why? .... **(5%)**

d) As an EOR engineer, what are your recommendations to improve recovery performance for the project which has lower recovery (project-a or project-b, identified in part-c). **(5%)**

The viscous to gravity ratio is defined as:

$$R_{v/g} = \frac{2050 v \mu_o L}{k \, \Delta\rho h}$$

μ_o = viscosity of oil, cP,

v = velocity, bbl/day-ft^2,

$\Delta\rho$ = density difference, g/cm^3,

h = ft,

K = permeability, mD,

i = injection rate in bbl/day and

L is the inter-well distance, ft

- $if \quad k_H \neq k_V, \quad then \quad k = \sqrt{k_V k_H}$
- $data\ is\ for\ linear\ flow$

  $-\ for\ a\ 5-spot,\ v = 1.25\frac{i}{hL}$

  $-\ for\ a\ line\ drive,\ v = \frac{i}{hL}$

Question 4: (30%)

A reservoir in Texas with following properties is under water flood.

Oil formation volume factor Bo = 1.0 bbl/STB
Water formation volume factor Bw = 1.0 bbl/STB
Formation thickness h = 20 ft
Cross-sectional area A = 26,400 ft
Porosity = 25%
Water Injection rate = 900 bbl/day
Distance between producer and injector (L) = 600 ft
Oil viscosity = 2.0 cp
Water viscosity = 1.0 cp
Dip angle = 0°
Connate water saturation S_{wc} = 20%
Initial water saturation S_{wi} = 20%
Residual oil saturation S_{or} = 25%

a. Calculate the time to breakthrough **(10%)**
b. Determine the cumulative water injected at breakthrough **(5%)**
c. Amount of Oil produced at breakthrough **(5%)**
d. Calculate the water saturation profile after 240 days **(10%)**

Use the data provided in the table below (do not use any correlation of relative perms).

Sw	Kro/krw	fw	dfw / dSw
0.25	30.23	0.062	0.670
0.3	17	0.105	10.84
0.35	9.56	0.173	1.647
0.40	5.38	0.271	2.275
0.45	3.02	0.398	2.759
0.50	1.7	0.541	2.859
0.55	0.96	0.677	2.519
0.60	0.54	0.788	1.922
0.65	0.30	0.869	1.313
0.70	0.17	0.922	0.831
0.75	0.10	0.956	0.501

$$f_w = \frac{1}{1+\left(\frac{k_o}{k_w}\right)\left(\frac{\mu_w}{\mu_o}\right)} = \frac{1}{1+\left(\frac{1}{M}\right)}$$

$$f_w' = \frac{df_w}{dS_w} \approx \frac{\Delta f_w}{\Delta S_w} = \frac{1-f_{w2}}{\overline{S_{w2}} - S_{w2}}$$

$$Q_i = \frac{1}{\left(\frac{\partial f_w}{\partial S_w}\right)_{Sw2}} = \frac{\overline{S_{w2}} - S_{w2}}{1-f_{w2}}$$

$$N_P = V_P\left(\overline{S_{w2}} - S_{iw}\right)$$

$$x_{Sw} = \frac{5.615 q_i t}{A\phi}\left(\frac{\partial f_w}{\partial S_w}\right)_{S_w}$$

$$q_{w2} = \frac{f_{w2} q_t}{B_w}$$

$$q_{o2} = \frac{f_{o2} q_t}{B_o} = \frac{(1-f_{w2}) q_t}{B_o}$$

$$Q_i = \frac{5.615 W_i}{A\phi L}$$

$$t = \frac{Q_i}{5.615 q_i / A\phi L}$$

$$WOR = \left(\frac{f_{w2}}{f_{o2}}\right)\left(\frac{B_o}{B_w}\right) = \left(\frac{f_{w2}}{1-f_{w2}}\right)\left(\frac{B_o}{B_w}\right)$$

f_w = fraction flow of water

S_w = water saturation

$\overline{S_w}$ = water saturation at breakthrough

S_{w2} = saturations after breakthrough

Qi = Pore volume of water injected

qi = injection rate (bbl/day)

Wi = Total volume of water injected

N_P = Cumulative oil Produced (bbl)

V_p = Pore volume (bbl) = AφL/5.615

t = Time required for Displacement (injection rate is constant)

q_{w2} = water production rates for each of the S_w

q_{o2} = oil production rates for each of the S_w

x_{sw} = location of front at s_w saturation