Key Solution

CHEN 490 – Fundamentals of Petroleum Engineering
HW # 1 – due 1/10/2013

1. Given the analysis in the table below of a natural gas produced from an oil well.

Component	(1) Mol %	(2) M wt.	(3) (1)X(2)	(4) P_c, psia	(5) T_c R	(6) (1)X(4)	(7) (1)X(5)
Methane	79.05	16.04	12.70	673	344	531	272
Ethane	10.85	30.07	3.26	709	550	77.0	59.7
Propane	4.61	44.09	2.03	~~618~~ 666	~~615~~	28.5	30.7
Iso-butane	1.28	58.12	0.74	~~550~~ 733	~~530~~	6.8	9.4
n-butane	2.04	58.2	1.19	~~551~~ 766	~~551~~	11.2	15.6
iso-pentane	0.21	72.15	0.15	~~482~~ 536	~~482~~	1.0	1.7
n-pentane	0.34	72.15	0.25	~~485~~ 847	~~485~~	1.6	2.9
hexane	0.84	86.17	0.72	~~434~~ 915	~~434~~	3.6	7.7
heptanes +	0.78	140.0	1.09	~~405~~ 1172	~~405~~	3.2	9.2
	100.0		22.13			664 psia	409 R

Compute:

a) The gas gravity
b) The pseudo-critical pressure & temperature
c) The compressibility factor, z, (use Standing & Katz chart)

M wt. C_7+ =140
Sp. gravity of C_7+ = 0.85

2. What volume will 100 lb of the above gas occupy at p = 300 psig, T = 170 F?
3. (a) What is the density of a miscellaneous 0.90 gravity gas at 2000 psia and 150 F?
   (b) What is the specific volume at these conditions?

4. A cylindrical tank contains miscellaneous 0.8 gravity gas at 2500 psia and 100 F. The volume of the tank is 10 ft^3.

a) How many moles of gas in the tank?
b) What standard volume of gas is this?
c) 1000 scf of gas is released from the tank. This causes the temperature to fall to 60 F. What is the final tank pressure?

Solution:

1(a) Column (1) is given. Column (2) is obtained from Table (Physical Properties of Light Paraffins), and the molecular weight of the mixture is the total of column (3).

$$\text{Gas gravity} = G_g = \frac{\text{density of gas at std. Cond.}}{\text{density of air at std. Cond.}}$$

Since one mole of any gas occupies the same volume at std. conditions (379 ft^3),

$$G_g = \frac{22.13/379}{29/379} = \frac{22.13}{29} = \underline{0.76}$$

where 29 = mol wt of air.

(b) The C_7+ fraction is itself a mixture, and the Pseudo-Critical properties must be obtained from Figure 1.5 attached. The other values in columns (4) and (5) are from Table.

$$_pP_c = \underline{664}\ \text{psia},\quad \overline{pT_c} = \underline{409}\ ^\circ R$$

2 $PV = ZnRT$

$$V = \frac{ZnRT}{P},\qquad n = \frac{m}{M} = \frac{100}{22.1} = 4.52\ \text{moles}$$

To obtain Z from the Chart (Standing & Katz)

$$\text{Reduced pressure, } P_r = \frac{P}{_pP_c} = \frac{3015}{664} = 4.54$$

$$\text{Reduced temp., } T_r = \frac{T}{\overline{pT_c}} = \frac{630}{409} = 1.54$$

From this, $Z \cong 0.81$ and

$$V = \frac{(0.81)(4.52)(10.7)(630)}{3015} = \underline{8.2\ ft^3}$$

3(a) $Z \cong 0.67$ from attached figure 0.90 gravity (1.11) natural gas; then using eq.

$$\rho = \frac{PM}{ZRT} = \frac{(2000)(29)(0.90)}{(0.67)(10.73)(610)}$$

$$= \underline{11.9\ lb/ft^3}$$

(b) $$v = \frac{1}{\rho} = \frac{1}{11.9} = \underline{0.084\ \frac{ft^3}{lb}}$$

4 (a) $$n = \frac{PV}{ZRT} = \frac{(2500)(10)}{(0.67)(10.7)(560)} = \underline{6.2}$$

(b) $$V_s = (6.2)(379) = \underline{2350}\ scf$$

or

$$\frac{P_s V_s}{T_s} = \frac{PV}{ZT}$$

$$V_s = \frac{PV}{ZT} \times \frac{T_s}{P_s} = \frac{(2500)(10)(526)}{(0.67)(560)(14.7)}$$

$$= \underline{2350\ scf}$$

(c) Mol remaining $= 6.2 - \frac{1000}{379} = 3.6$ moles

$$P = \frac{ZnRT}{V}$$

But Z = function of P, ∴, the solution requires trial and error.

$$\frac{P}{Z} = \frac{(3.6)(10.7)(520)}{10} = 2000$$

Assume

1) $P = 1500$, then $Z = 0.581$*

$\frac{P}{Z} = 2580$ (high)

2) $P = 1300$, then $Z = 0.617$*

$\frac{P}{Z} = 2100$ (high)

(3) $P = 1250$, then $Z = 0.627$*

$\frac{P}{Z} = 1955 \cong 2000$ (close enough)

final $P = 1250$ psia

* Values of Z are obtained at 60°F at the assumed pressures from the 0.80 gravity chart (attached).

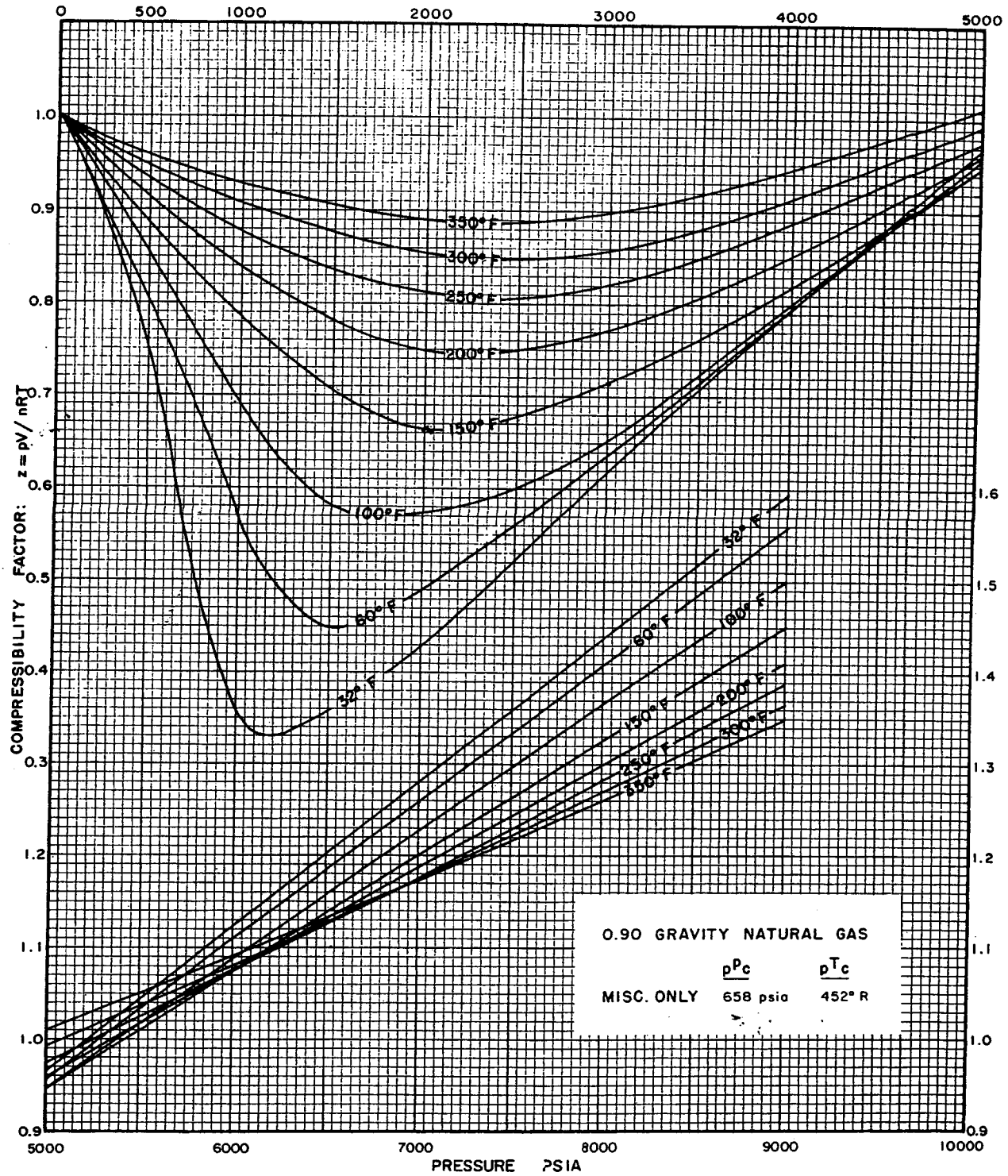

Fig. 1.11. 0.90 gravity natural gas, miscellaneous only.

TABLE 4-4. PHYSICAL CONSTANTS OF HYDROCARBONS

(Values from CNGA and NGAA. Modified for standard conditions of 60°F and 14.65 psia)

	Methane	Ethane	Propane	Iso-butane	Normal butane	Iso-pentane	Normal pentane	Normal hexane	Normal heptane	Heptanes plus C_{7+}
Molecular formula	CH_4	C_2H_6	C_3H_8	i-C_4H_{10}	n-C_4H_{10}	i-C_5H_{12}	n-C_5H_{12}	n-C_6H_{14}	n-C_7H_{16}	
Molecular weight	16.042	30.068	44.094	58.120	58.120	72.146	72.146	86.172	100.198	M
Critical temp, °F abs	343	550	666	733	765	830	847	914	972	
Critical pressure, psia	673	708	617	530	551	482	485	434	397	
Critical density, lb/gal	1.351	1.695	1.888	1.945	1.891	1.955	1.935	1.958	1.957	
Critical volume, (cu ft/lb-mole)	1.586	2.371	3.123	3.990	4.130	4.930	4.98	5.88	6.84	
SG gas (air = 1.00)	0.554	1.038	1.522	2.006	2.006	2.491	2.491	2.975	3.459	$M/28.966$
Cu ft/lb gas	23.73	12.66	8.63	6.55	6.55	5.28	5.28	4.42	3.80	$380.69/M$
Cu ft gas/gal of liquid	59.18	39.43	36.56	30.75	31.89	27.50	27.76	24.46	21.77	$3170\ S/M$
Lb Mcf of gas	42.14	78.98	115.83	152.67	152.67	189.51	189.51	226.36	263.20	$2.6268\ M$
Gal liquid per Mcf of gas	16.87	25.36	27.38	32.57	31.41	36.41	36.07	40.94	45.94	$0.3155\ M/S$
Bbl liquid/MMcf of gas	401.6	603.9	651.9	775.4	747.5	867.0	858.8	974.8	1094	$7.511\ M/S$
SG liquid (60/60)	0.3	0.374	0.508	0.563	0.584	0.625	0.631	0.664	0.688	S
Lb/gal liquid at 60°F	2.5	3.11	4.23	4.69	4.86	5.20	5.25	5.53	5.73	$8.327\ S$
Lb/bbl liquid at 60°F	105	130.6	177.7	197.0	204.1	218.4	220.5	232.3	240.7	$349.7\ S$
Lb/cu ft liquid at 60°F	18.70	23.26	31.64	35.08	36.35	38.90	39.27	41.36	42.86	$62.29\ S$
Cu ft liquid/lb at 60°F	0.0535	0.0430	0.0316	0.0285	0.0275	0.0257	0.0254	0.0242	0.0233	$0.01605/S$
Gal/lb-mole at 60°F	6.4	9.64	10.41	12.38	11.94	13.84	13.71	15.57	17.47	$0.120\ M/S$

Constants Used in Calculations

1 cu ft = 28.316 liters
1 cu ft = 7.480 gal
1 gal = 3,785.53 ml
760 mm Hg = 14.696 psi

0°F = 459.58°R
Density of water at 60°F = 8.327 lb per gal
Molecular weight of air = 28.966
1 mole = 380.69 cu ft of perfect gas at 14.65 psia and 60°F

Physical Properties of Light Paraffin Hydrocarbons and Miscellaneous Components

Compounds Abbreviation of formula	Name	Molecular weight	Critical pressure psia	Critical Temperature Rankine
C_1	Methane	16.04	673	344
C_2	Ethane	30.07	709	550
C_3	Propane	44.09	618	666
iC_4	iso-Butane	58.12	530	733
nC_4	normal-Butane	58.12	551	766
iC_5	iso-Pentane	72.15	482	830
nC_5	n-Pentane	72.15	485	847
nC_6	n-Hexane	86.17	434	915
nC_7	n-Heptane	100.2	397	973
nC_8	n-Octane	114.2	370	1025
nC_9	n-Nonane	128.3	335	1073
nC_{10}	n-Decane	142.3	312	1115
-	Air	28.97	547	239
N_2	Nitrogen	28.02	492	227
O_2	Oxygen	32.00	732	278
CO_2	Carbon Dioxide	44.01	1072	548
H_2S	Hydrogen Sulfide	34.08	1306	673
H_2O	Water	18.02	3206	1165

[redacted] – AUB –THH [redacted]