B.TECH II (WINTER SEMESTER) EXAMINATION
PETROCHEMICAL ENGINEERING
NATURAL GAS PROCESSING
PK 315 N

Maximum Marks: 60
Credits: 04
Duration: Three Hours

Answer all the questions.
If any suitable data is missing,
the equations used have their usual meaning.

Question

1(a) Comment on the statement given below-

"Natural Gas as the fuel of the century"

1(b) What is Gibbs's phase rule? A gaseous mixture of CH₄, C₂H₆, C₃H₈ and H₂ consists of
four constituents. However, the amounts of these substances are related by two
independent chemical equations-

\[ 2CH_4(g) = C_2H_6(g) + H_2(g) \]

\[ C_2H_6(g) + CH_4(g) = C_3H_8(g) + H_2(g) \]

Determine the degrees of freedom for this system

1(c) The analysis of a sweet gas, in mole %, is known to be as follows:

\[ N_2 = 1.40, \ CH_4 = 93.0, \ C_2H_6 = 3.29, \ C_3H_4 = 1.36, \ n-C_4H_{10} = 0.37, i-C_4H_{10} = 0.23, \]
\[ n-C_5H_{12} = 0.10, i-C_5H_{12} = 0.12, C_6H_{14} = 0.08 \text{ and } C_7H_{16}^+ = 0.05. \]

Find out density of the mixture at 2500 psia and 650 °R. Assuming C₇⁺ fraction to
exhibit the same properties as that of n-C₉.

OR

1(c') Find the viscosity of the gaseous mixture at 2000 psia and 200 °F, if the composition of
the gaseous mixture (in mole %) is given as follows-

\[ N_2 = 1.40, \ CH_4 = 93.0, \ C_2H_6 = 3.29, \ C_3H_4 = 1.36, \ n-C_4H_{10} = 0.37, i-C_4H_{10} = 0.23, \]
\[ n-C_5H_{12} = 0.10, i-C_5H_{12} = 0.12, C_6H_{14} = 0.08 \text{ and } C_7H_{16}^+ = 0.05 \]
Assume C₇⁺ fraction to exhibit the same properties as that of n-C₁₀.

...
2(a) What are common NGL products? List down their applications. [04]
2(b) Write down various advantages, limitations and ideal use for a vertical separator. [04]
2(c) Derive the expression for the size of the smallest droplet that can be removed by a centrifuge. [07]

OR

2(c') What are various gas liquid separation mechanisms? Derive Souders and Brown relationship for droplet velocity for gravity settling. [07]

3(a) What are gas hydrates? List the factors that promote hydrate formation. [03]
3(b) What are advantages and limitations of solid-desiccant dehydration. [03]
3(c) What is meant by hydrate inhibition? Write Hammerschmidt correlation for inhibitor requirements. [03]
3(d) A water saturated gas at 80 °F and 400 psia had a 70 °F dew point depression after passing through a dehydration plant. How many gallons of water removed per million standard cubic feet of gas measured at 60 °F and 14 psia. [06]

OR

3(d') Determine the equilibrium water vapour content in a sour gas which contain 66% Hydrocarbon gas, 21 mole % H₂S and 13 mole % CO₂, contacting with an aquifer that contains 3 mole % of NaCl. Gas gravity is 0.86, Temperature of 100 °F and pressure of 2000 psia. [06]

4(a) Write the reactions involved in Iron Sponge process of acid gas treatment. [03]
4(b) Describe the process flow diagram of a typical Amine process for gas treatment. What are the operating issues with Amine Process? [06]

4(c) Write a short note on any two of the followings- [06]
   i. LNG chain
   ii. Transportation by Marine CNG
   iii. Depleted gas/oil reservoirs for storage of Natural Gas

contd... 3
Figure: Compressibility factor for natural gases as a function of reduced pressure and temperature. (After Standing and Katz, 1942; courtesy of SPE of AIME)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Molecular Weight</th>
<th>Critical Pressure (psia)</th>
<th>Critical Temp. (°R)</th>
<th>Crit. Comp. Factor (Z_0)</th>
<th>Acoustic Factor (c/â)</th>
<th>Eyring Mol Refraction (EMR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH_4</td>
<td>16.043</td>
<td>867.8</td>
<td>343.1</td>
<td>0.289</td>
<td>0.015</td>
<td>13.584</td>
</tr>
<tr>
<td>C_2H_6</td>
<td>30.070</td>
<td>967.6</td>
<td>459.0</td>
<td>0.265</td>
<td>0.0069</td>
<td>23.512</td>
</tr>
<tr>
<td>C_6H_12</td>
<td>84.158</td>
<td>967.6</td>
<td>459.0</td>
<td>0.241</td>
<td>0.145</td>
<td>34.314</td>
</tr>
<tr>
<td>i-C_4H_10</td>
<td>58.184</td>
<td>967.6</td>
<td>459.0</td>
<td>0.279</td>
<td>0.120</td>
<td>44.788</td>
</tr>
<tr>
<td>n-C_4H_10</td>
<td>58.184</td>
<td>967.6</td>
<td>459.0</td>
<td>0.283</td>
<td>0.176</td>
<td>44.788</td>
</tr>
<tr>
<td>n-C_8H_18</td>
<td>114.232</td>
<td>967.6</td>
<td>459.0</td>
<td>0.259</td>
<td>0.353</td>
<td>86.103</td>
</tr>
<tr>
<td>n-C_6H_14</td>
<td>128.289</td>
<td>967.6</td>
<td>459.0</td>
<td>0.251</td>
<td>0.443</td>
<td>96.557</td>
</tr>
<tr>
<td>n-C_8H_18</td>
<td>142.288</td>
<td>967.6</td>
<td>459.0</td>
<td>0.247</td>
<td>0.4902</td>
<td>106.859</td>
</tr>
<tr>
<td>H_2</td>
<td>2.016</td>
<td>967.6</td>
<td>459.0</td>
<td>0.304</td>
<td>-0.2237</td>
<td>4.450</td>
</tr>
<tr>
<td>H_2O</td>
<td>18.016</td>
<td>967.6</td>
<td>459.0</td>
<td>0.326</td>
<td>0.382</td>
<td>-</td>
</tr>
</tbody>
</table>

** From McLeod and Campbell (1969).
1 u = 0.0 used in most correlations.

Contd... 4
Figure 2. Viscosity of paraffinic hydrocarbon gases at 1.0 atmosphere. (After Carr et al., 1954; courtesy of SPE of AIME.)

Figure 3. Viscosity ratio versus pseudoreduced temperature. (After Carr et al., 1954; courtesy of SPE of AIME.)
Figure 1. The McKetta-Wehe correlation for water content of natural gases, with corrections for water salinity and gas gravity. (After McKetta and Wehe, 1958; reprinted from Engineering Data Book, 1981; courtesy of GPSA.)
Figure 5 Water content correction for sour natural gas (Wichert and Wichert, 2003)

\[
\% H_2S \text{ equivalent} = \text{mole}\% H_2S + 0.7 \text{mole}\% CO_2
\]
2014-15
B.TECH. WINTER SEMESTER EXAMINATION
(PETROCHEMICAL ENGINEERING)
SEPARATION PROCESSES IN H.C. INDUSTRIES
PK-322N
Credits: 03.

Maximum Marks: 60
Duration: Three Hours.

Answer all the questions.
Assume suitable data if missing.
Notations used have their usual meaning.

Q No 1
(a) Draw vapor liquid equilibrium diagram and explain the important points on the 5.0 diagram.

OR

(a') What do you understand by q line? Draw the q line equation for different feed conditions in the x-y diagram.

(b) What is the assumption of McCabe Thiele method? Explain with the help of neat sketch. 5.0

OR

(b') Explain any one of the following.
1. Azeotropic distillation
2. Extractive distillation

(c) A mixture of saturated liquid of A & B with 45 mol% A is entering in distillation column. It is desired to obtain 98 mol % A from top and 03 mol % A from bottom. Find out minimum no of trays using Fenske's equation if mean relative volatility of A is 2.75. 5.0

(d) A mixture of A & B with 60 moles % of A at temperature of 50 °C is entering in distillation column. If the bubble point temperature of feed is 95 °C, then find the... 5.0

contd... 2
value of "q".

The required data for the A & B is given below:

<table>
<thead>
<tr>
<th>Component</th>
<th>Boiling Pt °C</th>
<th>Heat Capacity KJ/Kg mol °C</th>
<th>Latent Heat KJ/Kg mol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Liquid</td>
<td>Vapor</td>
</tr>
<tr>
<td>A</td>
<td>80</td>
<td>138</td>
<td>96</td>
</tr>
<tr>
<td>B</td>
<td>110</td>
<td>167</td>
<td>138</td>
</tr>
</tbody>
</table>

Q No 2

(a) Define the following terms for multi component system.
   1. Light Components
   2. Heavy Components
   3. Light Key Component
   4. Heavy Key Component

(b) Discuss any one commercial equipment used for liquid liquid extraction process with the help of neat sketch.

(c) The liquid feed of 100 mol/h at the boiling point is fed to a distillation tower. The composition in mol fractions is as follows: A=40%, B=25% C=20% & D =15%. This feed is to be fractionated so that 90% of the B is recovered in the distillate and 90% of the C in the bottoms. Calculate the following.
   1. Moles per hour and composition of distillate and bottoms.
   2. If top temperature is 67 °C and bottom temperature is 132 °C, then find out minimum stages for total reflux and distribution of other components in the distillate and bottoms.

The relation between K values and temperature (°C) are given below;

\[ K_A = 0.0002 T^2 + 0.0066 T + 0.3180 \]
\[ K_B = 0.0001 T^2 - 0.0014 T + 0.1250 \]
\[ K_C = 0.0001 T^2 - 0.0102 T + 0.3167 \]
\[ K_D = 0.00009 T^2 - 0.0098 T + 0.3381 \]
Where T is in °C

OR

(e') Pure isopropyl ether (C) of 450 kg/h is being used to extract an aqueous solution of 150 kg/h with 30 wt % acetic acid (A) by countercurrent multistage extraction. The exit acid concentration in the aqueous phase is 10 wt %. Calculate the number of stages required.
Q No 3

(a) Define leaching process, along with its commercial application with examples. How the solid (animal and vegetable materials) feed can be prepared in leaching process.

OR

(a') Discuss the merits and demerits of membrane separation processes.

(b) Discuss the adsorption equilibrium isotherm with the help of governing equations.

(c) Using molecular sieves, water vapors are removed from nitrogen gas in a packed bed. The column height is 0.268 m and bulk density of solid bed is 712.8 kg/m³. The initial concentration of water in gas is $926 \times 10^{-6}$ kg water/kg nitrogen. The mass velocity of nitrogen is 4052 kg/m²h. The breakthrough data is as follows:

<table>
<thead>
<tr>
<th>t (h)</th>
<th>0</th>
<th>9</th>
<th>9.2</th>
<th>9.6</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>c (kg H₂O/kg N₂ × 10⁶)</td>
<td>&lt;0.6</td>
<td>0.6</td>
<td>2.6</td>
<td>21</td>
<td>91</td>
</tr>
<tr>
<td>t (h)</td>
<td>10.8</td>
<td>11.25</td>
<td>11.5</td>
<td>12.0</td>
<td>12.5</td>
</tr>
<tr>
<td>c (kg H₂O/kg N₂ × 10⁶)</td>
<td>418</td>
<td>630</td>
<td>717</td>
<td>855</td>
<td>906</td>
</tr>
</tbody>
</table>

The break point value is $C/Co = 0.02$. Calculate the following:

- Find out break point time, fraction of total capacity used up to break point, the length of unused bed, the saturation loading capacity of solid.
- For the new column height of 0.4 m, calculate the break point time and fraction of total capacity used.
Maximum Marks: 60

1. (a) List two value added petrochemical from C₁, C₂, C₃ and acetylene with the help of a line diagram with reference to chemical reactions involved and commercial applications of the products formed. [3+3+4=13]

(b) Mention the petrochemicals derived from benzene or syngas. [02]

2. (a) List the various processes available in the manufacture of linear alkyl benzene and acetone. [04]

(b) Through the conversion of isopropanol to acetone is 100 percent yet the yield is hardly 60% why? [02]

(c) Explain role of steam in the manufacture of acetone from isopropanol dehydrogenation process. [01]

(d) Describe the manufacture of Cumene OR Acrylonitrile with the help of a process flow sheet with reference to chemical reactions involved, catalyst and major engineering problems involved in the process. [08]

3. (a) Describe the manufacture of formaldehyde with the help of a process flowsheet with reference to reactions involved. List the catalyst and operating conditions for direct oxidation and partial oxidation combined with dehydrogen processes. [08]

(b) Explain with the help of schematic diagrams the manufacture of vinyl chloride monomer from balanced scheme if (i) equimolar amount of ethylene and acetylene are available as feed stock and if (ii) equimolar amounts of ethylene dichloride and acetylene are available as feedstocks. [07]

3’. (a) Explain the two main generations of processes available for the manufacture of methanol with reference to operating conditions and catalyst. [05]

Contd.....2
(b) Explain the oxy chlorination reaction for the manufacture of VCM.

(c) Though the catalytic process is available for the manufacture of VCM from pyrolysis of ethylene dichloride yet it could not be commercialized, why?

(d) Describe the manufacture of Methanol from ICI process OR ethylene oxide from direct oxidation process with the help of a process flow sheet. Why chlorohydrination process become obsolete though the yield was better than direct oxidation process.

4. (a) Explain the help of a schematic diagram the basic petrochemical feedstocks and its sources. [05]

(b) Explain the structure of the Petrochemical Industry. With the help of a schematic diagram emphasizing the high value addition across various sectors vis a vis value added. [06]

(c) Explain why catalytic steam reforming process can not be employed for heavier fractions for the production of syngas. [1.5]

(d) Differentiate between dry and wet natural gas. Which is better and why? [2.5]

OR

4'. (a) Describe the manufacture of olefins from steam reforming process employing naphtha as feed stock with the help of a process flow sheet with reference to yield operating parameter, steam and tube diameter in the furnaces. [10]

(b) Explain the Maharashtra Gas Cracker Plant operational scheme with the help of a schematic / line diagram. [05]
2014-15
B.TECH. (WINTER SEMESTER) EXAMINATION
PETROCHEMICAL ENGINEERING
HEALTH SAFETY and ENVIRONMENT in HYDROCARBON INDUSTRY
PK-343

Maximum Marks: 60 Credits: 04 Duration: Three Hours

Answer all the questions. Assume suitable data if missing. Notations used have their usual meaning.

<table>
<thead>
<tr>
<th>Q.No.</th>
<th>Question</th>
<th>M.M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(a)</td>
<td>What is process safety? How the concept of safety, health and environment are related to each other?</td>
<td>[4]</td>
</tr>
<tr>
<td>1(b)</td>
<td>What is Hazard? What are the various hazards that one may encountered in laboratory courses like petroleum testing lab and unit operation lab.</td>
<td>[6]</td>
</tr>
<tr>
<td>1(c)</td>
<td>What is Fire? Discuss various fire detection systems.</td>
<td>[5]</td>
</tr>
<tr>
<td></td>
<td><strong>OR</strong></td>
<td></td>
</tr>
<tr>
<td>1(e')</td>
<td>What is arson and smouldering? Discuss various fire extinguishing systems.</td>
<td>[5]</td>
</tr>
<tr>
<td>2(a)</td>
<td>What is Explosion? Discuss vapour cloud and boiling liquid expanding vapour explosion along with its difference.</td>
<td>[7]</td>
</tr>
<tr>
<td>2(b)</td>
<td>Discuss Detonation and Deflagration? Explain various stages on a plot of pressure versus time curve during blast due to overpressure.</td>
<td>[8]</td>
</tr>
<tr>
<td>3(a)</td>
<td>What is toxicity? How toxicants enters into the biological organisms. Also discuss various indices of measurement of toxicity along with its type.</td>
<td>[5]</td>
</tr>
<tr>
<td>3(b)</td>
<td>Discuss in detail the concept of Occupation Safety and Health.</td>
<td>[10]</td>
</tr>
<tr>
<td></td>
<td><strong>OR</strong></td>
<td></td>
</tr>
<tr>
<td>3(b')</td>
<td>What is HAZOP? Perform a HAZOP analysis on the reaction ( A + B \rightarrow C ) occurring in a batch reactor. The reaction is highly exothermic and the reaction temperature is controlled using cooling water circulating in the limpet of the batch reactor.</td>
<td>[10]</td>
</tr>
<tr>
<td>4(a)</td>
<td>Discuss vertical dispersion of a parcel of air based on the different condition prevailing in the atmosphere.</td>
<td>[8]</td>
</tr>
<tr>
<td></td>
<td><strong>OR</strong></td>
<td></td>
</tr>
<tr>
<td>4(a')</td>
<td>Discuss in brief the principles on which the air pollution control devices operate.</td>
<td>[8]</td>
</tr>
<tr>
<td>4(b)</td>
<td>Explain the classification water pollutants. For each type of pollutant, discuss their adverse effects on the receiving water body when discharged alongwith effluents.</td>
<td>[7]</td>
</tr>
</tbody>
</table>