

# SUPRA™

## MODULE STRUCTURE

**SUPRA**  
**UNIQUE SELF-LEARNING SYSTEM**  
consists of series of modules,  
each with the following structure:

- 1. Learning Outcomes
- 2. Concepts
- 3. Quickies
- 4. Examples
- 5. Problems
- 6. Quizzes and Tests
- 7. Summary




**SUPRA LEARNING SOLUTIONS**

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# 1 Learning Outcomes


What you are expected to learn and be able to accomplish in each unit is defined in a clear, concise, and simple terms



Module  
**3**

## Gases, Vapors, and Liquids

### 3. Real Gases




**Learning Outcomes**

**Study Time:**  
( 13 1/2 hr )

**Concepts:**  
( 150-170 min )

**Examples:**  
( 280-300 min )


**Problems:**  
( 340-360 min )





- define for a process flow sheet, the **state** of each stream (pure vapor/ gas and their mixtures entering or leaving a process or a process unit) completely - P, T, volume, volumetric or mass flow rates, assuming **real gas** behavior, for a variety of processes - isothermal, isobaric, isochoric (these processes you will find in most of the flow sheets)
- represent graphically, behavior of  $Z$  versus P, T, and calculate compressibility factors for pure substances and mixtures, using Virial and other Equations of State (EOS), by defining appropriate mixing rules for each EOS
- draw P-V-T diagram using computer program, for a pure substance using different Equations of State and compare performance of these EOS under different P & T conditions, to enable one to choose a particular EOS for specific use
- use the real gas EOS, to compute various stream parameters - mass/ mol, P, T, volumes, for pure substances & mixtures, in a given process, from the given information


More specifically,


- understand difference between ideal gas and real gas in terms of intermolecular forces, and compression (compressibility) factor, Z


  
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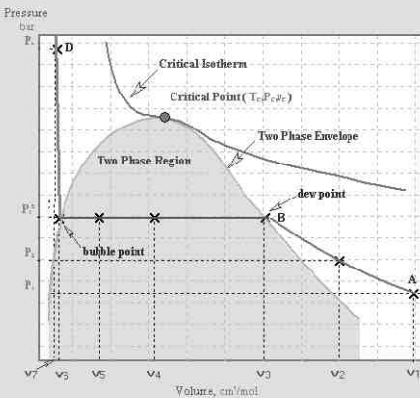
  
Next

# 2 Concepts

Fundamental concepts are developed for your understanding and to simplify the learning process

P-V-T diagram      Gases, Vapors, and Liquids      Vapor Pressure & Enthalpy


**P-V-T Diagram & Two-Phase Region For n-Octane**



Pressure, bar

Volume, cm<sup>3</sup>/mol

**A P-V-T Experiment at one Isotherm**  
Push The Piston Up/D



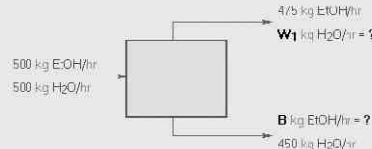
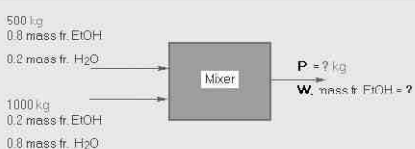
P4 V7  
Temperature T1 is Constant

If this procedure is repeated at other temperatures from  $T_1$  to  $T_c$ , we will develop the two phase region as shown. You notice at  $T_1$  the saturation pressure is  $P_1^s$ . Similarly at other temperatures  $T_i$  we will get corresponding  $P_i^s$ . In this fashion you will develop the entire vapor pressure (Saturation pressure) curve over the entire temperature region upto  $T_c$ .

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# 3 Quickies

Short objective questions to check your understanding of the concepts

| Quickies 4  |   | Material Balances   |   | Without Chemical Reaction |  |
|---|---|---|---|---------------------------|--|
| 1.  | Tick <input checked="" type="checkbox"/> the correct answer.<br>Consider the following process.<br>Calculate the unknown quantities |   | <input type="checkbox"/> $W_1=50 \text{ kg/hr}; B=50 \text{ kg/hr}$ <input type="checkbox"/> $W_1=50 \text{ kg/hr}; B=25 \text{ kg/hr}$ <input type="checkbox"/> $W_1=25 \text{ kg/hr}; B=25 \text{ kg/hr}$ |                           |  |
| 2.  | Calculate the product amount<br>and composition   |  | <input type="checkbox"/> $P=1500 \text{ kg}; W_{EtOH}=0.4$ <input type="checkbox"/> $P=1000 \text{ kg}; W_{EtOH}=0.5$ <input type="checkbox"/> $P=1500 \text{ kg}; W_{EtOH}=0.5$                            |                           |  |
| <input type="button" value="Exit"/> <input type="button" value="Help"/> <input type="button" value="Data"/> <input type="button" value="Programs"/> <input type="button" value="Calculator"/> <input type="button" value="Topics"/> <input type="button" value="Go-To"/> <input type="button" value="Main Menu"/> <input type="button" value="Menu"/> |   | <input type="button" value="←"/> <input type="button" value="→"/>                   |   |                           |  |

# 4 Examples

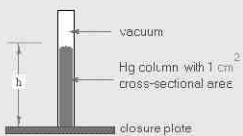
Application of concepts with step-by-step solutions to test what you have learnt

Pressure Basic Information & Stoichiometry Pressure & Temperature

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**Example** 1

Let us now calculate the pressure exerted by a column of mercury on a cross-section of  $1 \text{ cm}^2$ .



vacuum  
Hg column with  $1 \text{ cm}^2$  cross-sectional area  
closure plate

The pressure exerted on a  $1 \text{ cm}^2$  section of the closure plate by the column of mercury is:  $p = F/A = \rho g h$ .

Where

- F = force, N
- A = cross sectional area,  $\text{cm}^2$
- $\rho$  = density of mercury,  $13.55 \text{ g/cm}^3$
- g = gravitational acceleration,  $980.7 \text{ cm/s}^2$
- h = height of the column of mercury, cm

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**Solution**

If the height  $h = 100 \text{ cm}$  then,  $p = \frac{\rho, 13.55 \text{ g}}{\text{cm}^3} \cdot \frac{g, 980.7 \text{ cm}}{\text{s}^2} \cdot h, 100 \text{ cm} = 13.29 \times 10^5 \text{ g/cm s}^2$

We need to convert  $13.29 \times 10^5 \text{ g/cm s}^2$  into  $\text{N/m}^2$  or Pa

$1 \text{ N/m}^2 = 1 \text{ Pa} = 1.329 \text{ kg/m s}^2$

$$p = \frac{13.29 \times 10^5 \text{ g}}{\text{cm s}^2} \cdot \frac{1 \text{ kg}}{1000 \text{ g}} \cdot \frac{100 \text{ cm}}{1 \text{ m}} \cdot \frac{1 \text{ Pa}}{1 \text{ kg/m s}^2} = 1.329 \times 10^5 \text{ N/m}^2 = 1.329 \times 10^5 \text{ Pa} = 1.329 \text{ bar}$$


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# 5 Problems

If you understood the concepts and examples, it should be easy for you to solve problems on your own. Solutions are provided

Mass, Mole, & Volume Fraction      Basic Information & Stoichiometry      Mass, Density, Volume, & Mole

**Problem 1**  
 A 0.5 molar aqueous solution of  $\text{CH}_3\text{CHO}$  flows into a process unit at  $1.25 \text{ m}^3/\text{min}$ .  
 The specific gravity of the solution is 0.89.  
 Calculate: (a) mass concentration of  $\text{CH}_3\text{CHO}$  in  $\text{kg}/\text{m}^3$ .  
 (b) Mass flow rate in  $\text{kg}/\text{s}$ .  
 (c) mass fraction of  $\text{CH}_3\text{CHO}$ .

**Solution for Problem 1**

Let us recapitulate the definition of molar concentration and mass concentration.

**molar concentration:** of a component is the number of moles of the component per unit volume of the mixture ( $\text{kmol}/\text{m}^3$ ,  $\text{mol}/\text{cm}^3$ ,  $\text{kmol}/\text{m}^3$ ,  $\text{mol}/\text{litre}$ ).

**mass concentration:** of a component of a mixture or solution is the mass of this component per unit volume of the mixture ( $\text{kg}/\text{cm}^3$ ,  $\text{g}/\text{cm}^3$ ,  $\text{kg}/\text{m}^3$ ,  $\text{g}/\text{litre}$ ).

**Step 1:** Given: molar concentration, flow rate, and specific gravity of aqueous solution of  $\text{CH}_3\text{CHO}$ .

**Step 2:** Find: (a) mass concentration of  $\text{CH}_3\text{CHO}$  in  $\text{kg}/\text{m}^3$ .

**Step 3:** Additional information required: Mol Wt of  $\text{CH}_3\text{CHO} = 44.05$

**Basis:** 0.5 molar aqueous solution of  $\text{CH}_3\text{CHO}$

$$\text{mass conc. of } \text{CH}_3\text{CHO} \text{ in } \text{kg}/\text{m}^3 = \frac{0.5 \text{ mol } \text{CH}_3\text{CHO}}{\text{litre}} \times \frac{\text{MW, } 44.05 \text{ g}}{\text{mol}} \times \frac{1 \text{ kg}}{1000 \text{ g}} \times \frac{10^3 \text{ litre}}{1 \text{ m}^3}$$

$$= 22.0 \text{ kg}/\text{m}^3$$

# 6 Quizzes and Tests

Objective-type multiple-choice questions involving some calculations for you to test extent of your understanding, learning, and proficiency of the subject matter

Quiz 1
Ideal Gases
00:09

Page: 3/3 Tick  the correct answer. 90 Min.

5. Consider the following process for drying a chemical.

Calculate:

a) Volumetric flow rate of inlet air  
b) Amount of dried chemical

Chemical  
70% H<sub>2</sub>O (mass%)

Air 150 °C  
-30 cm H<sub>2</sub>O pressure

**Drier**

wet air  
300 m<sup>3</sup>/min at 60 °C  
& 1.01 bar.

Water evaporation = 250 kg/hr

dried chemical = ?

a) 366 m<sup>3</sup>/min  
b) 6 kg/min

c) 366 m<sup>3</sup>/min  
b) 1.8 kg/min

a) 305 m<sup>3</sup>/min  
b) 6 kg/min

6.

Hot air 80 °C  
1.5 bar

F<sub>1</sub>

System 1

↓ 1. CO<sub>2</sub> 0.015 m<sup>3</sup>/s  
20 °C; 2.1 bar

F<sub>2</sub>  
1.2% CO<sub>2</sub>

Calculate flow rate of hot air entering the pipeline.

2.15 m<sup>3</sup>/s

1.2 m<sup>3</sup>/s

2.07 m<sup>3</sup>/s

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# 7 Summary

It enables you to self-evaluate your proficiency. It is an assurance you need about how well you have understood the unit

Module

## Gases, Vapors, and Liquids

3

### 3. Real Gases



#### Summary

For a real gas and real gas mixture learnt the following:

- The concept of real gas, intermolecular forces, compression (compressibility) factor, equation of state (EOS), Virial coefficients.
- Different Equations of State
  - Virial equation and van der Waals equation as the basis of a number of EOS commonly used by engineers and scientists.
  - How to use the 'Programs' and 'Database' for calculating required quantities such as  $v$  given  $P$  &  $T$ ,  $P$  given  $v$  &  $T$ , etc, compressibility factor,  $Z$ , Virial coefficient  $B_V$  and  $B_C$  constants of various EOS.

- When to use which EOS for solving problems
- The basis of mixing rules for each EOS in order to apply the EOS for mixtures- binary, ternary, and multi component.
- Solved real life process problems dealing with pure components and mixtures with the use of appropriate EOS for pure components and mixing rules for binary and multi component mixtures.
- Familiarized with the various EOS - Virial form and the cubic form.
- Developed the capability to tackle a variety of process problems.

If you have studied & understood this part, You can solve:

Tests : 4, 5  
Quiz : 6

