# UNIT-IV: REAL GAS MODELS AND PERFECT GAS MIXTURES

## 1. Real Gas Models

### Definition

A **real gas** is a gas whose behavior deviates from the Ideal Gas Law because molecules occupy space and experience intermolecular forces.

### Ideal Gas Equation

PV=mRTPV = mRTPV=mRT

Ideal gas assumptions:

- Molecules have negligible volume.
- No intermolecular forces.
- Elastic collisions.
- Valid at low pressure and high temperature.

### Real Gas Behavior

Real gases deviate from ideal behavior:

- High pressure
- Low temperature
- Near liquefaction

Examples:

- Steam
- $CO_2$
- $NH_3$
- Refrigerants

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# 2. Van der Waals Equation of State

### Equation

For one mole,

(P+aV2)(V−b)=RT\left(P+\frac{a}{V^2}\right)(V-b)=RT(P+V2a)(V−b)=RT

For n moles,

(P+an2V2)(V−nb)=nRT\left(P+\frac{an^2}{V^2}\right)(V-nb)=nRT(P+V2an2)(V−nb)=nRT

Where

- P = Pressure
- V = Volume
- T = Temperature
- R = Gas constant
- a = Attraction constant
- b = Volume correction constant

### Significance of Constants

### a (Pressure Correction)

Represents intermolecular attractive force.

Larger value of **a**

- Strong attraction
- Gas easily liquefies

### b (Volume Correction)

Represents actual molecular volume.

Larger molecules have larger b.

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# Assumptions

- Molecules attract each other.
- Molecules occupy finite volume.
- Corrects Ideal Gas Law.

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### Limitations

Not accurate near critical point.

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# 3. Compressibility Charts

## Compressibility Factor (Z)

Z=PVRTZ=\frac{PV}{RT}Z=RTPV

For Ideal Gas

Z=1Z=1Z=1

For Real Gas

Z≠1Z\neq1Z優=1

### Interpretation

- Z = 1 → Ideal Gas
- Z > 1 → Repulsive forces dominate
- Z < 1 → Attractive forces dominate

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## Reduced Properties

Reduced Pressure

Pr=PPcP_r=\frac{P}{P_c}Pr=PcP

Reduced Temperature

Tr=TTcT_r=\frac{T}{T_c}Tr=TcT

Where

- PcP_cPc = Critical pressure
- TcT_cTc = Critical temperature

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## Compressibility Chart

Plots:

- Z vs Reduced Pressure
- Different Reduced Temperatures

**Uses**

- Determine Z
- Calculate real gas volume
- Thermodynamic property estimation

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# 4. Variable Specific Heats

Specific heat changes with temperature.

## At Constant Pressure

Cp=f(T)C_p=f(T)Cp=f(T)

## At Constant Volume

Cv=f(T)C_v=f(T)Cv=f(T)

Relationship

Cp−Cv=RC_p-C_v=RCp−Cv=R

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## Importance

Accurate calculations in

- Gas turbines
- Compressors
- Internal combustion engines
- High-temperature gases

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# 5. Gas Tables

Gas tables provide:

- Enthalpy
- Internal Energy
- Entropy
- Specific Heat
- Pressure
- Temperature

### Applications

- Thermodynamic analysis
- Power cycles
- Refrigeration
- Heat transfer

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# 6. Mixtures of Perfect Gases

### Definition

A mixture containing two or more ideal gases.

Examples:

- Air
- Natural gas
- Combustion products

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# 7. Mass Fraction

Mass fraction of component i

$$w_i=\frac{m_i}{m_{total}}$$

Properties

$$\sum w_i=1$$

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## Example

$O_2$ = 8 kg

$N_2$ = 32 kg

Total = 40 kg

Mass fraction

$O_2$

w=840=0.2w=\frac{8}{40}=0.2w=408=0.2

$N_2$

w=3240=0.8w=\frac{32}{40}=0.8w=4032=0.8

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# 8. Mole Fraction

xi=nintotalx_i=\frac{n_i}{n_{total}}xi=ntotalni

Where

n = number of moles

Properties

∑xi=1\sum x_i=1∑xi=1

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## Example

$O_2$ = 2 kmol

$N_2$ = 8 kmol

Total = 10 kmol

$O_2$

$x=\frac{2}{10}=0.2$

$N_2$

$x=\frac{8}{10}=0.8$

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# 9. Gravimetric Analysis

Analysis based on **mass**.

Used to determine:

- Mass fraction
- Total mass
- Component mass

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# 10. Volumetric Analysis

Analysis based on **volume**.

For ideal gases,

Volume fraction = Mole fraction

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# 11. Dalton's Law of Partial Pressure

### Statement

The total pressure of a gas mixture equals the sum of the partial pressures of individual gases.

$P=P_1+P_2+P_3+\cdots$

Partial pressure

$P_i=x_iP$

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## Applications

- Atmospheric air
- Combustion
- HVAC
- Gas turbines

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# 12. Amagat's Law of Partial Volume

### Statement

The total volume equals the sum of individual partial volumes.

$$V=V_1+V_2+V_3$$

Partial volume

$$V_i=x_iV$$

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## Difference Between Dalton and Amagat

| Dalton's Law | Amagat's Law |
|---|---|
| Based on Pressure | Based on Volume |
| Constant Volume | Constant Pressure |
| Total Pressure = Sum of Partial Pressures | Total Volume = Sum of Partial Volumes |

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# 13. Equivalent Gas Constant

Gas constant of mixture

$$R_m=\sum x_iR_i$$

or

$$R=\frac{R_u}{M}$$

Where

- $R_u$ = Universal gas constant
- M = Molecular weight

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# 14. Molecular Internal Energy

For gas mixture

$u=\sum x_i u_i$

Where

- $u_i$ = Internal energy of each gas

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# 15. Enthalpy of Gas Mixture

$h=\sum x_i h_i$

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# 16. Specific Heat of Gas Mixture

At Constant Pressure

$C_{pm}=\sum x_i C_{pi}$

At Constant Volume

$C_{vm}=\sum x_i C_{vi}$

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# 17. Entropy of Gas Mixture

Entropy depends on:

- Temperature
- Pressure
- Mixing process

General expression:

$S=\sum x_i S_i$

Entropy increases after mixing.

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# 18. Gases and Vapour

## Gas

A substance that cannot be liquefied by pressure alone at ordinary temperature.

Examples:

- Oxygen
- Nitrogen
- Hydrogen

## Vapour

A gaseous substance below its critical temperature that can be liquefied by compression.

Examples:

- Steam
- Refrigerants
- Alcohol vapour

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## Difference Between Gas and Vapour

| Gas | Vapour |
|---|---|
| Above critical temperature | Below critical temperature |
| Difficult to liquefy | Easily liquefied |
| Permanent gas | Temporary gaseous phase |

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# Important Formula Sheet

### Ideal Gas

PV=mRTPV=mRTPV=mRT

## Van der Waals Equation

(P+aV2)(V−b)=RT\left(P+\frac{a}{V^2}\right)(V-b)=RT(P+V2a)(V−b)=RT

## Compressibility Factor

Z=PVRTZ=\frac{PV}{RT}Z=RTPV

## Mass Fraction

wi=mimw_i=\frac{m_i}{m}wi=mmi

## Mole Fraction

xi=ninx_i=\frac{n_i}{n}xi=nni

## Dalton's Law

P=∑PiP=\sum P_iP=∑Pi Pi=xiPP_i=x_iPPi=xiP

## Amagat's Law

V=∑ViV=\sum V_iV=∑Vi

## Equivalent Gas Constant

Rm=∑xiRiR_m=\sum x_iR_iRm=∑xiRi

## Mixture Enthalpy

h=∑xihih=\sum x_ih_ih=∑xihi

## Mixture Internal Energy

u=∑xiuiu=\sum x_iu_iu=∑xiui

## Specific Heat

Cpm=∑xiCpiC_{pm}=\sum x_iC_{pi}Cpm=∑xiCpi Cvm=∑xiCviC_{vm}=\sum x_iC_{vi}Cvm=∑xiCvi