

## Chapter-2 Combustion

A diabatic flame temperature  
Combustion is a sequence of exothermic  
Chemical reactions between fuel & oxidizer  
to release usually Thermal energy.

Fuel: A substance, which contains Chemical  
energy, which can be released in the  
form of heat. Example Methane, Gasoline

Oxidizer: A substance which helps/promotes Combustion by providing  $O_2$  to chemical reactions. Example: Liquid Oxygen, Hydrogen peroxide ( $H_2O_2$ ) (LOX)

Gas mixture: Number of species

Mole: A mole is an amount of substance, which contains  $6.02252 \times 10^{23}$  number of atoms/molecules.  
Avagadro number.

Molar mass/molecular weight: Mass of one mole of any substance.  $\text{g/mol}$ ,  $\text{kg/kmol}$

1 mole of  $\text{H}_2$  — 2 g  
Molar mass  $M_{\text{W}\text{H}_2} = 2 \text{ g/mol}$  or  $2 \text{ kg/kmol}$

$M_{\text{WC}} = 12 \text{ kg/kmol}$ ,  $M_{\text{WO}_2} = 32 \text{ kg/kmol}$

Mole fraction:  $X_i$ ,  $i$ th species.

$$X_i = \frac{\text{No. of moles of } i\text{th species}}{\text{Total no. of moles in the gas mixture}}$$

$$= \frac{N_i}{\sum_{j=1}^n N_j}, \quad n - \text{total no. of species.}$$

$$\sum_{i=1}^n X_i = 1$$

Mass fraction of  $i$ th species,  $Y_i$

$$Y_i = \frac{\text{Mass of } i\text{th species}}{\text{Total mass of gas mixture}} = \frac{m_i}{\sum_{j=1}^n m_j}$$

$m_i$  - mass of  $i$ th species

$$\sum_{i=1}^n Y_i = 1$$

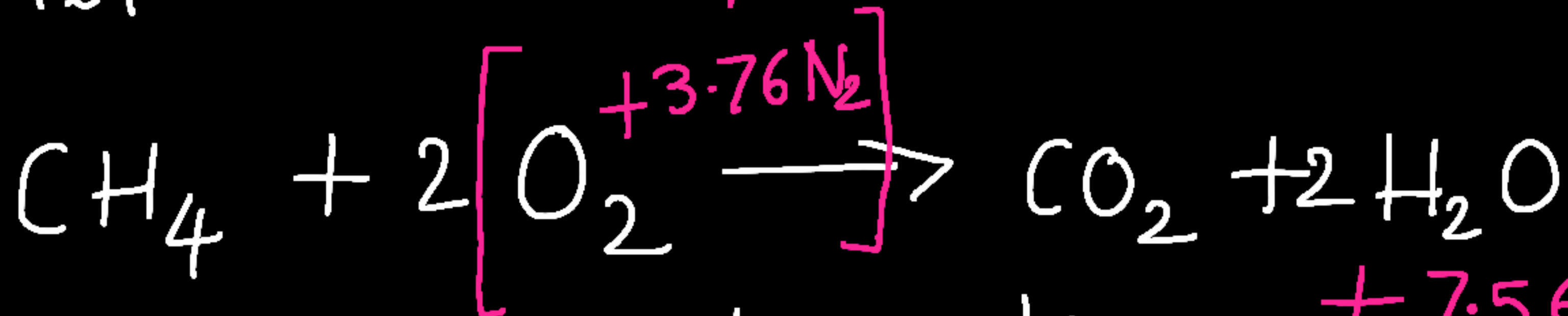
$$Y_i = \frac{x_i M_{w_i}}{M_{w_{\text{mix}}}}, \quad x_i = \frac{Y_i M_{w_{\text{mix}}}}{M_{w_i}}$$

$$M_{w_{\text{mix}}} = \sum_j x_j M_{w_j} = \frac{1}{\sum_j (Y_j / M_{w_j})}$$

Stoichiometry is a calculation of the amount of reactants & products in a chemical reaction.

Stoichiometric quantity of oxidizer is the amount of oxidizer just required to completely burn a given amount of fuel

Methane +  $O_2$  ~ Air



Balanced chemical reaction  $+ 7.56 N_2$

Stoichiometric quantity of oxidizer

to burn one molecule of  $CH_4$  is 2  
1 mole of  $CH_4$  requires 2 moles of  $O_2$

Burnir. y in air

$O_2 - 21\%$  ] Volume fraction

$N_2 - 79\%$  ] Mole fraction

$$\frac{x_{N_2}}{x_{O_2}} = \frac{79}{21} = 3.76$$

$> 2 \rightarrow$  fuel lean

$< 2 \rightarrow$  fuel rich

Air to fuel ratio at stoichiometric

conditions.  $A/F|_s = \frac{\text{Amount of Oxidizer required (mass)}}{\text{Amount of fuel required (mass)}}$

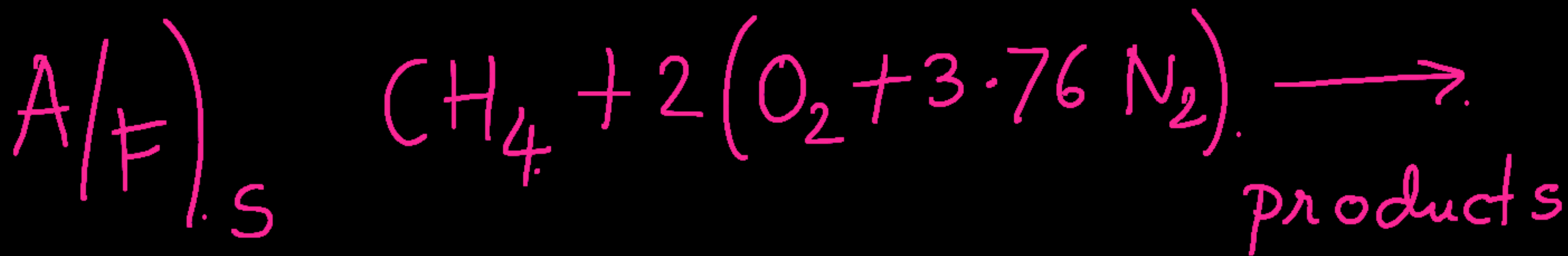
$$A/F|_s = \frac{\text{No. moles of Oxidizer} \times M_{w \text{ Oxidizer}}}{\text{No. of moles of fuel} \times M_{w \text{ fuel}}}$$

Stoichiometric  
Combustion

$$= \frac{2 \times 32}{1 \times (16)} = 4$$

$$M_{w \text{ C}_4\text{H}_4} = 12 + 4 = 16$$





Equivalence ratio,  $\phi$        $\phi > 1$  fuel rich condition

$$\phi = \frac{(A/F)_s}{A/F} = \frac{F/A}{(F/A)_s}$$

$\phi = 1 \Rightarrow$  stoichiometric condition  
 $\phi < 1$  fuel lean condition

