Combustion Stoichiometry

Air: Oxygen 21%, Nitrogen (nitrogen + argon) 79%
Fuel: Hydrocarbons (C_aH_b), oxygenates ($C_aH_bO_c$)

Examples:		LHV
Gasoline	$C_nH_{1.87n}$	44 MJ/kg
Diesel fuel	$C_nH_{1.75n}$	43 MJ/kg
Natural gas (mostly methane)	$CH_{3.8}$	45 MJ/kg
Coal	$C_nH_{0.8n}$	30 MJ/kg
Methanol	CH_3OH	20 MJ/kg
Ethanol	C_2H_5OH	26 MJ/Kg

(LHV = Energy released per unit mass of fuel without recovery of the heat of vaporization of the water vapor in the combustion products)

Stoichiometric Combustion

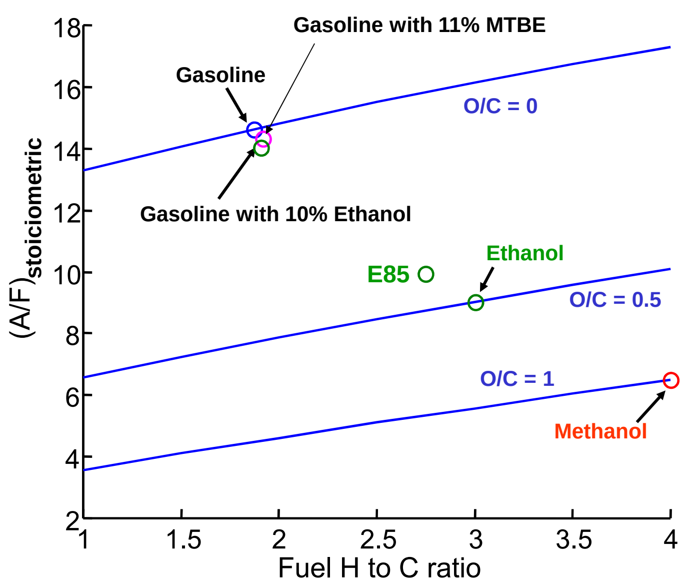
$$C_aH_bO_c + \frac{1}{2}\left(2a + \frac{b}{2} - c\right)(O_2 + 3.773\ N_2)$$

$$\rightarrow aCO_2 + \frac{b}{2}H_2O + \frac{1}{2}\left(2a + \frac{b}{2} - c\right)x3.773\ N_2$$

For typical petroleum based fuel (c=0):

$(A/F)_{stoich}$ ~ 14.6 (range 14.2 to 15)

Stoichiometric requirement for different fuels



Lean and rich combustion

Fuel-lean combustion

- major products: CO_2, H_2O, O_2, N_2
- minor products: HC, CO, H_2, NO

Fuel-rich combustion

- major products: CO_2, H_2O, CO, H_2, N_2
- minor products: HC, O_2, NO

Equivalence ratio: Normalized A/F or F/A ratios:

Fuel-air equivalence ratio, Φ

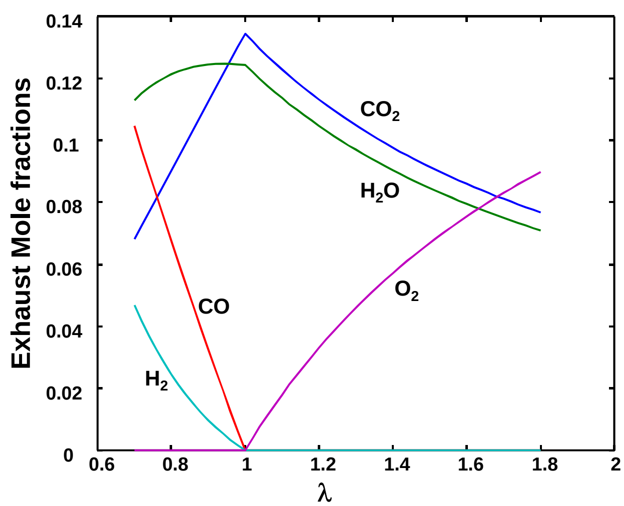
$$\Phi = \frac{F/A}{(F/A)_{stoichiometric}}$$

Relative air-fuel ratio λ

$$\lambda = \frac{A/F}{(A/F)_{stoichiometric}}$$

$$\lambda = \frac{1}{\Phi}$$

Exhaust composition (fuel $CH_{1.85}$)



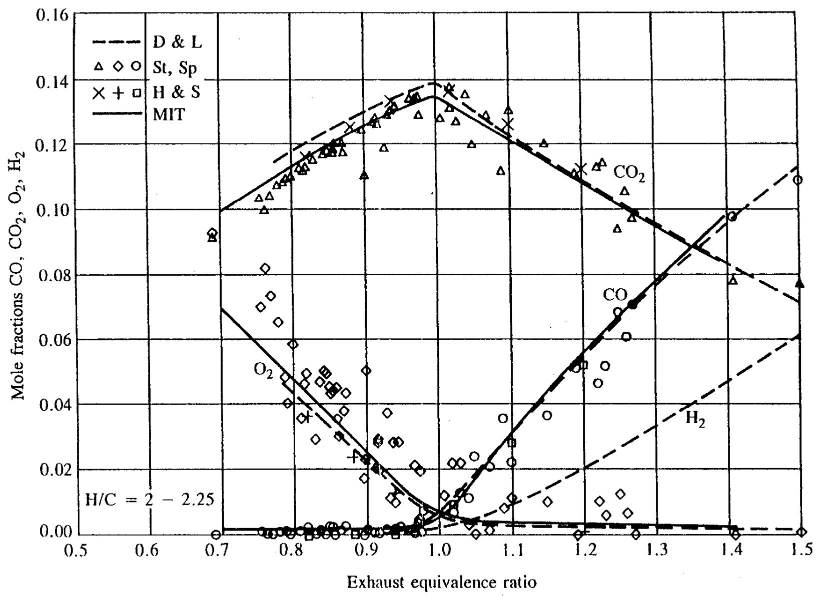


Figure 4-20 Spark-ignition engine exhaust gas composition data in mole fractions as a function of fuel/air equivalence ratio. Fuels: gasoline and isooctane, H/C 2 To 2.25. (From D'Alleva and Lovell,[24] Stivender,[25] Harrington and Shishu,[26] Spindt,[27] and data from the author's laboratory at MIT.)

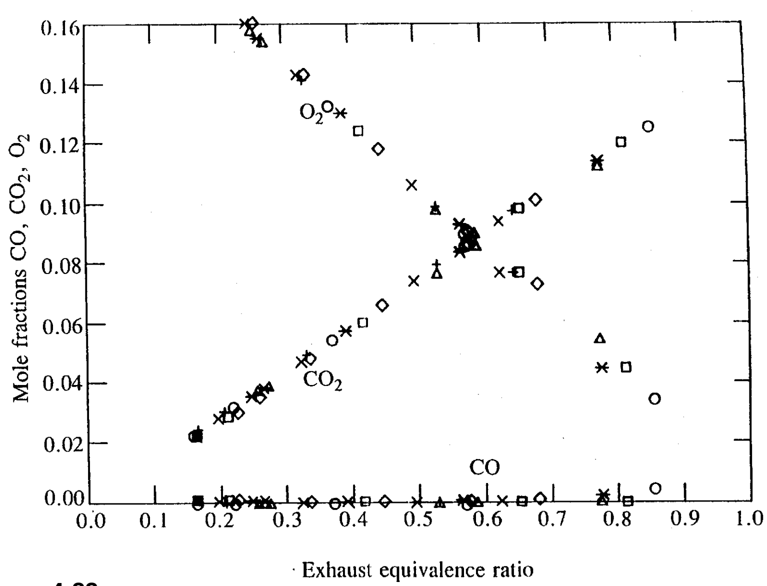
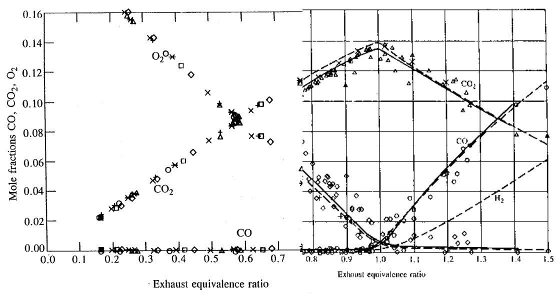


Figure 4-22

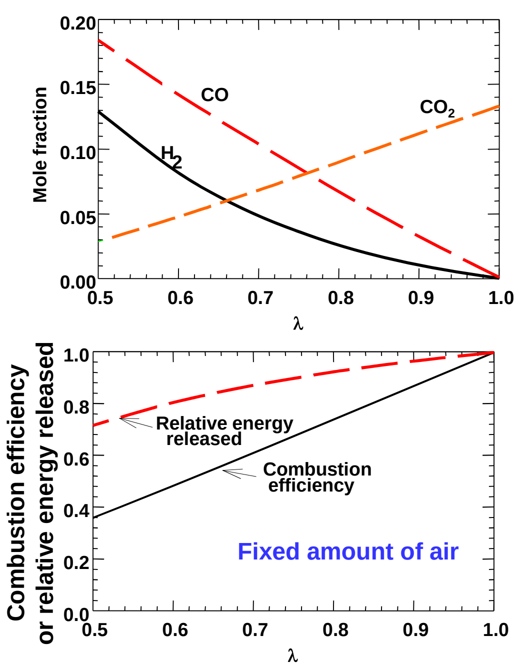
Exhaust gas composition from several diesel engines in mole fractions on a dry basis as a function of fuel/air equivalence ratio.[31]

Φ dependence of exhaust major species

Diesel Spark Ignition



Superposition of Figures 4-20 and 4-22



Gasoline fuel-rich combustion

For fuel rich combustion, empirically

$$\frac{[H_2O][CO]}{[H_2][CO_2]} = 3.5 \text{ to } 3.7$$

where [ ] denotes molar concentration

Value corresponds to equilibrium composition of water-shift reaction at ~ 1740°K

$H_2O + CO \leftrightarrow H_2 + CO_2$

Equilibrium combustion products: Dissociation effects

P=30 atmospheres

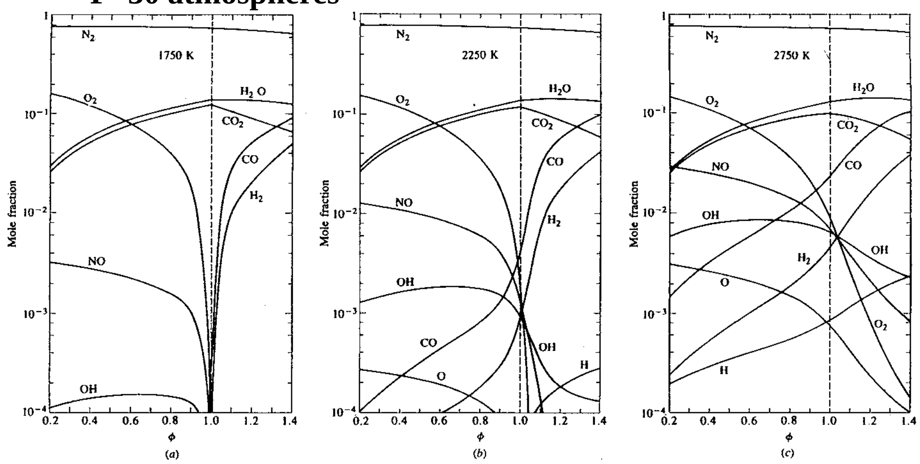


FIGURE 3-10
Mole fractions of equilibrium combustion products of isooctane-air mixtures as a function of fuel/air equivalence ratio at 30 atmospheres and (*a*) 1750 K; (*b*) 2250 K; and (*c*) 2750 K.