ESO 201A: Thermodynamics

2016-2017-I semester

Chemical Reaction: part 1

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Learning Objectives

- Give an overview of fuels and combustion.
- Apply the conservation of mass to reacting systems to determine balanced reaction equations.
- Define the parameters used in combustion analysis, such as air–fuel ratio, percent theoretical air
- Apply energy balances to reacting systems for both steady-flow control volumes and fixed mass systems.
- Calculate the enthalpy of reaction, enthalpy of combustion, and the heating values of fuels.
- Determine the adiabatic flame temperature for reacting mixtures.

Fuel and Combustion

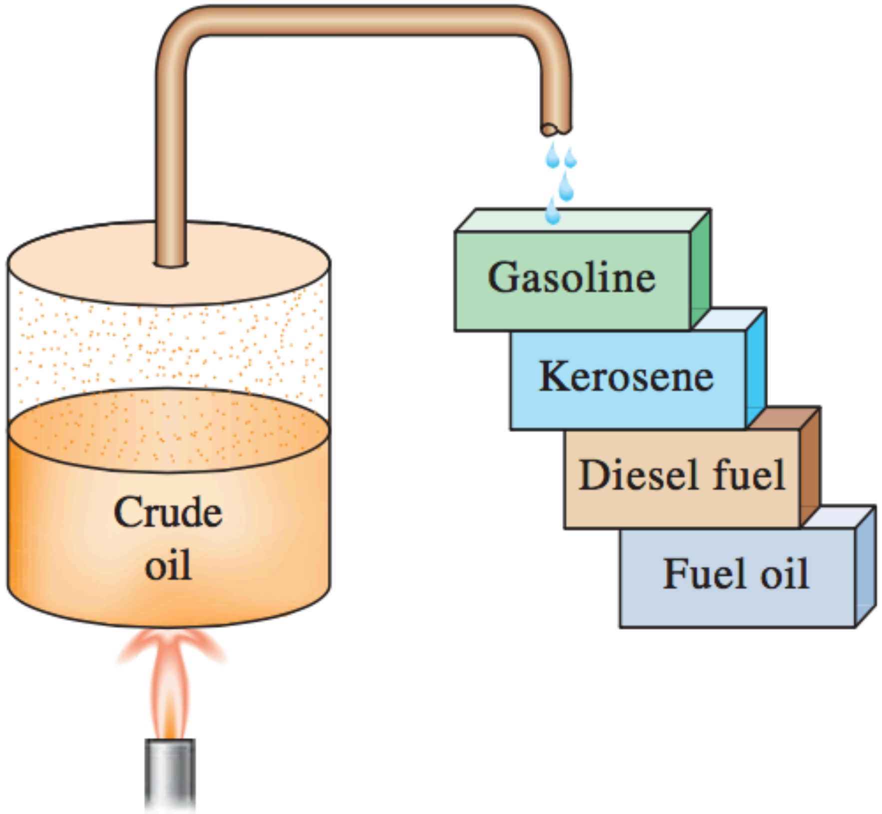
Fuel: Any material that can be burned to release thermal energy.

Most familiar fuels consist primarily of hydrogen and carbon.

They are called **hydrocarbon fuels** and are denoted by the general formula $\mathbf{C}_n\mathbf{H}_m$.

Hydrocarbon fuels exist in all phases, some examples being coal, gasoline

(usually treated as octane C_8H_{18}), and natural gas.



Most liquid hydrocarbon fuels are obtained from crude oil by distillation.

Energy content

Alternative fuels is now in demand which are friendlier to the environment such as natural gas, alcohols (ethanol and methanol), liquefied petroleum gas (LPG), and hydrogen

TABLE 15–1

A comparison of some alternative fuels to the traditional petroleum-based fuels used in transportation

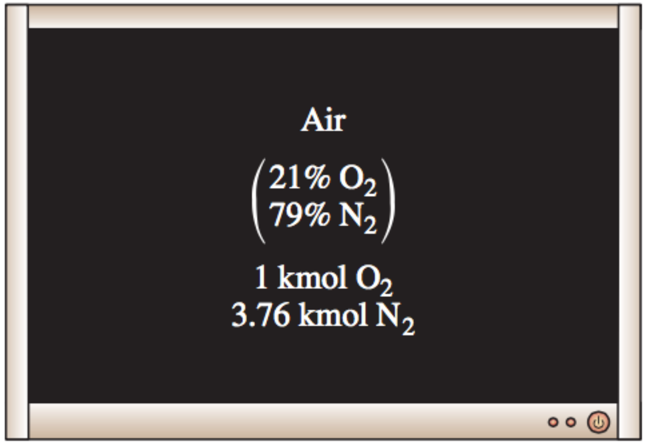
Fuel	Energy content kJ/L	Gasoline equivalence,* L/L-gasoline
Gasoline	31,850	1
Light diesel	33,170	0.96
Heavy diesel	35,800	0.89
LPG (Liquefied petroleum gas, primarily propane)	23,410	1.36
Ethanol (or ethyl alcohol)	29,420	1.08
Methanol (or methyl alcohol)	18,210	1.75
CNG (Compressed natural gas, primarily methane, at 200 atm)	8,080	3.94
LNG (Liquefied natural gas, primarily methane)	20,490	1.55

**Amount of fuel whose energy content is equal to the energy content of 1-L gasoline.*

Combustion

Combustion

- A chemical reaction during which a fuel is oxidized and a large quantity of energy is released is called **combustion**.
- The oxidizer most often used in combustion processes is air
- O2 is used as an oxidizer only in some specialized applications, such as cutting and welding, where air cannot be used



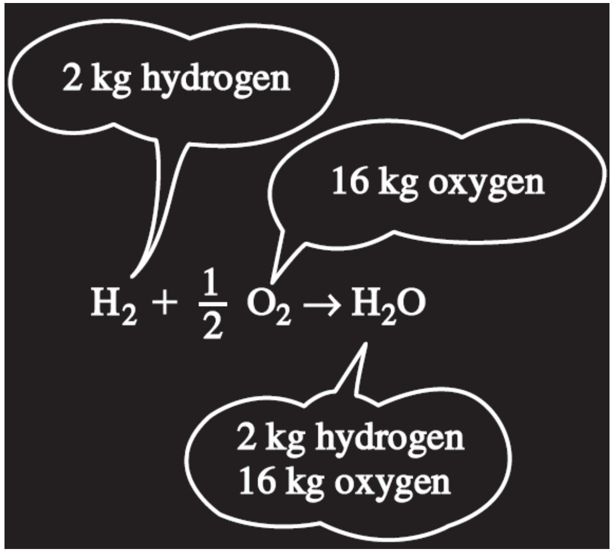
$$1 \text{ kmol } O_2 + 3.76 \text{ kmol } N_2 = 4.76 \text{ kmol air}$$

Combustion of air

- Nitrogen behaves as an inert gas.
- Nitrogen usually enters a combustion chamber in large quantities at low temperatures and exits at considerably higher temperatures, absorbing a large proportion of the chemical energy released during combustion.

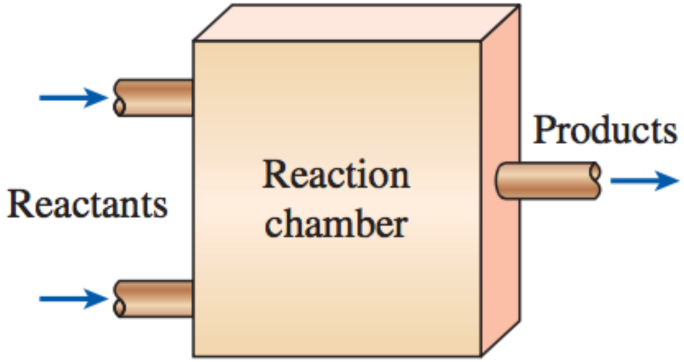
Conservation of mass during a chemical reaction

$$C + O_2 \rightarrow CO_2$$



$$m = NM$$

m mass
N number of moles
M molar mass



The total number of moles is not conserved during a chemical reaction.

Chemical equations are balanced on the basis of the conservation of mass principle (or the mass balance), which can be stated as follows: The total mass of each element is conserved during a chemical reaction

Ignition temperature

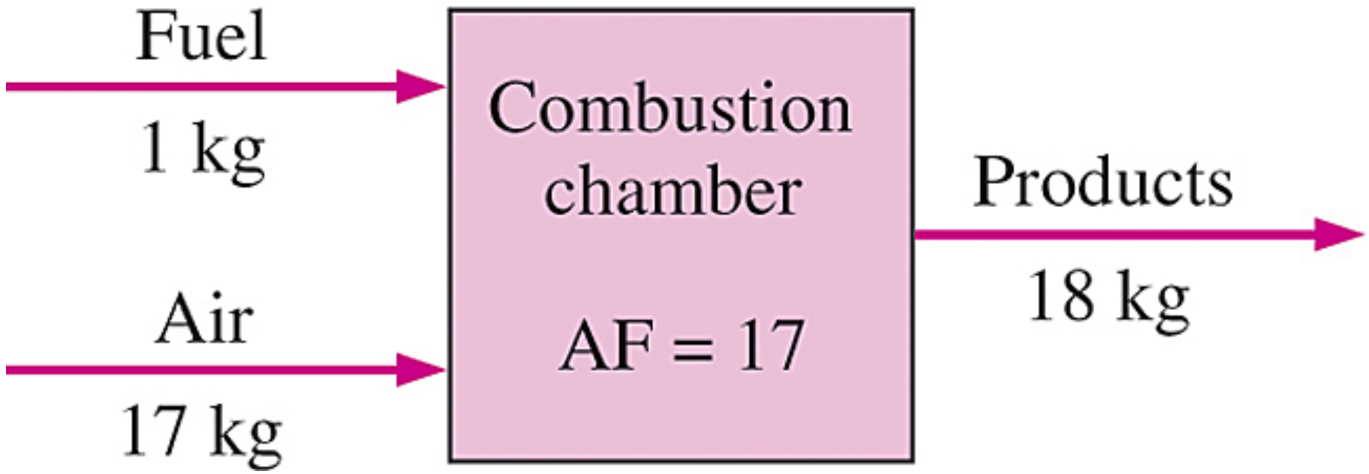
- The fuel must be brought above its **ignition temperature** to start the combustion. The minimum ignition temperatures in atmospheric air are approximately “
  - 260°C for gasoline,
  - 400°C for carbon,
  - 580°C for hydrogen,
  - 610°C for carbon monoxide, and
  - 630°C for methane.
- Proportions of the fuel and air must be in the proper range for combustion to begin. For example, natural gas does not burn in air in concentrations less than 5% or greater than about 15%.

Air-fuel ratio

Air-fuel ratio (AF) is usually expressed on a mass basis and is defined as *the ratio of the mass of air to the mass of fuel* for a combustion process

$$\mathrm{AF} = \frac{m_{\mathrm{air}}}{m_{\mathrm{fuel}}}$$

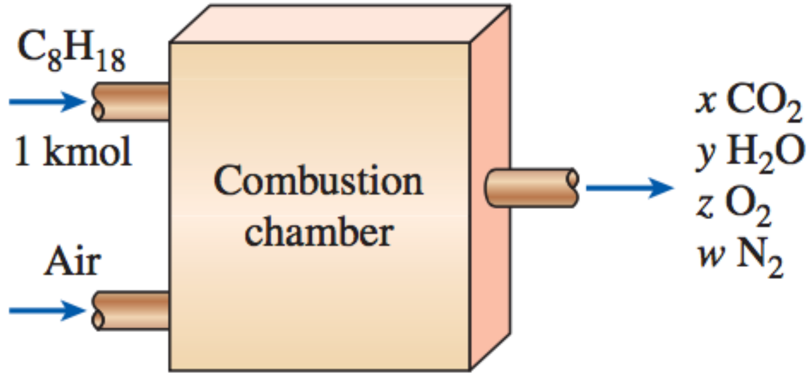
Fuel–air ratio (FA): The reciprocal of air–fuel ratio.



The air–fuel ratio (AF) represents the amount of air used per unit mass of fuel during a combustion process.

Balancing the combustion equation

One kmol of octane (C_8H_{18}) is burned with air that contains 20 kmol of O_2, as shown in Figure below. Assuming the products contain only CO_2, H_2O, O_2, and N_2, determine the mole number of each gas in the products and the air–fuel ratio for this combustion process.



Next lecture

- Give an overview of fuels and combustion.
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