Fuel and combustion

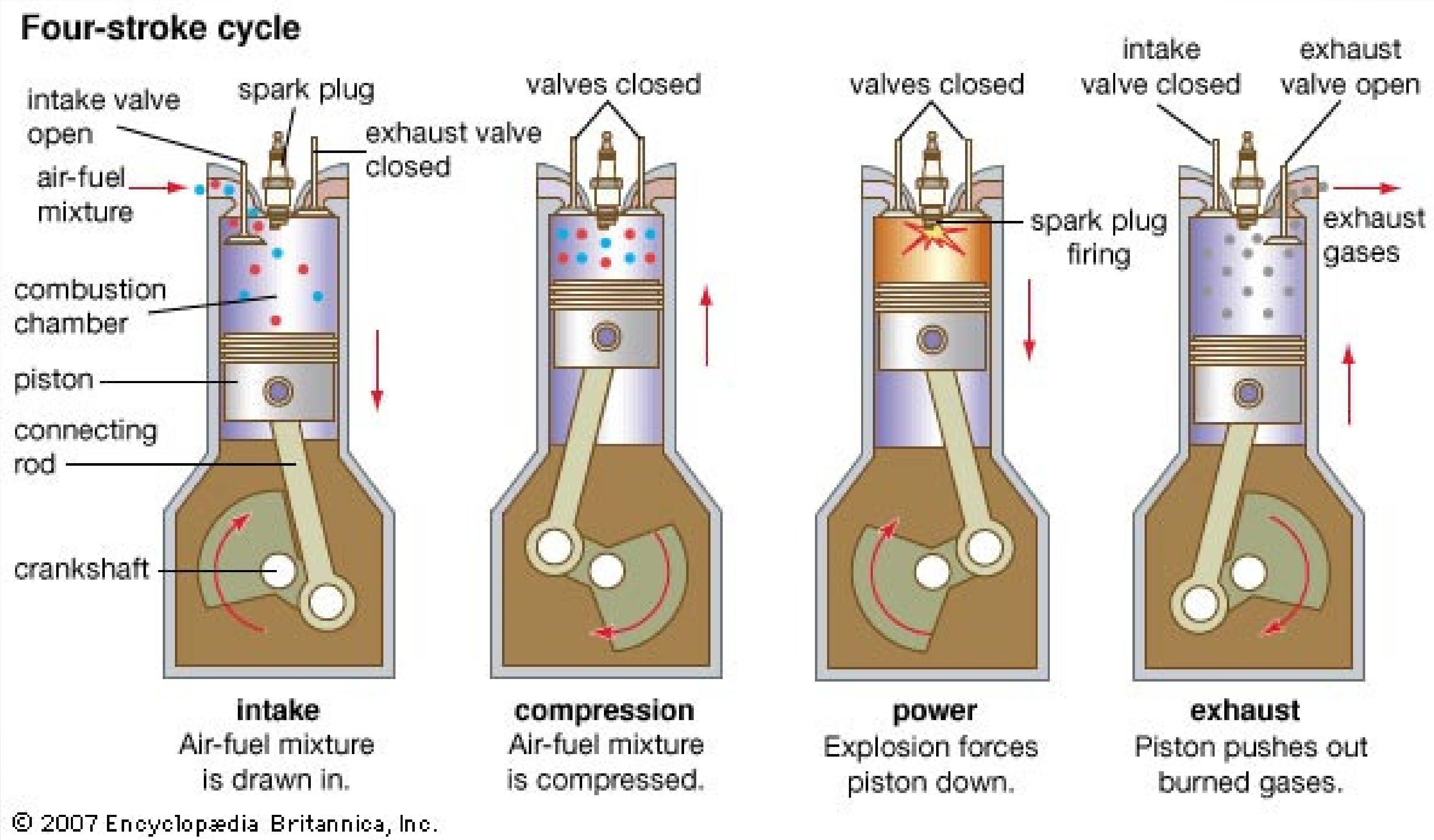
Fuel & Combustion

- In combustion reactions, rapid oxidation of combustible elements of the fuel results in energy release as combustion products are formed.

- The three major combustible chemical elements in most common fuels are carbon, hydrogen, and sulfur.

- Although sulfur is usually a relatively unimportant contributor to the energy released, it can be a significant cause of pollution and corrosion.

Internal Combustion engine



Combustion Reactions

1. Complete combustion of carbon:

- $C+O_2 \longrightarrow CO_2$ + Heat(33.7Mega joule/Kg).

2. Incomplete combustion of carbon :

- $C+1/2\ O_2 \longrightarrow CO$ + Heat(10.5 Mega joule/Kg).

3. Hydrogen Combustion:

- $H_2+1/2O_2 \longrightarrow H_2O$ + Heat(65.4Mega joule/Kg).

4. Sulfur combustion:

- $S+O2 \longrightarrow SO2$ + Heat(9.11Mega joule/Kg).

Combustion of Carbon (complete)

- **Deduce the complete combustion Equation of Carbon :**
- C + O_2 ⟶ CO_2 + Heat(33.7Mega joule/Kg).
- 1mole 1mole 1mole
- (At.wt*1) (M.wt*1) (M.wt*1)
- (1*12) (1*2*16) (1*(12+2*16))
- 12Kg 32Kg 44Kg
- Divide the weight of the each by 12:
- 1Kg 8/3 Kg 11/3 Kg
- **1Kg C + 8/3 Kg O_2 ⟶ 11/3 Kg CO_2 + (33.7 MJ/Kg)**

Combustion of Carbon (Incomplete)

- **Deduce the incomplete combustion Equation of Carbon :**
- C + ½ O_2 $\longrightarrow$ CO + Heat(10.5Mega joule/Kg).
- 1mole ½ mole 1mole
- (At.wt*1) (M.wt*1/2) (M.wt*1)
- (1*12) (0.5 *2*16) (1*(12+16))
- 12Kg 16Kg 28Kg
- Divide the weight of the each by 12:
- 1Kg 4/3 Kg 7/3 Kg
- **1Kg C + 4/3 Kg O_2 $\longrightarrow$ 7/3 Kg CO_2 + (10.5 MJ/Kg)**

Combustion of Hydrogen:

- **Deduce the combustion Equation of Hydrogen :**

H_2 + ½ O_2 ⟶ H_2O + Heat(65.4Mega joule/Kg).

- 1mole ½ mole 1mole
- (M.wt*1) (M.wt*1/2) (M.wt*1)
- (1*2*1) (0.5 *2*16) (1*((2*1)+16))
- 2Kg 16Kg 18Kg
- Divide the weight of the each by 2:
- 1Kg 8 Kg 9 Kg
- **1Kg H_2 + 8 Kg O_2 ⟶ 9 Kg H_2O + (65.4MJ/Kg)**

Combustion of Sulfur

- **Deduce the combustion Equation of Sulfur:**
- S + O2 ⟶ SO2 + Heat(9.11Mega joule/Kg).
- 1mole 1mole 1mole
- (M.wt*1) (M.wt*1) (M.wt*1)
- (1*32) (1*2*16) (1*(32+2*16))
- 32Kg 32 Kg 64Kg
- Divide the weight of the each by 32:
- 1Kg 1 Kg 2 Kg
- **1Kg S + 1 Kg O_2 ⟶ 2 Kg SO_2 + (9.11 MJ/Kg).**

Combustion of methane

- **Deduce the combustion Equation of methane :**
- CH_4 + $2\ O_2$ $\longrightarrow$ CO_2 + $2\ H_2O$ + Heat
- 1mole 2 mole 1mole 2 mole
- (M.wt*1) (M.wt*2) (M.wt*1) (M.wt*2)
- (1*12)+(4*1) (2*2*16) (1*(12+(2*16))) (2*(2*1)+16)
- 16Kg 64Kg 44Kg 36Kg
- Divide the weight of the each by 16:
- 1Kg 4 Kg 11/4 Kg 9/4 Kg
- **1Kg CH4 + 4 Kg O_2 $\longrightarrow$ 11/4 Kg CO_2 + 9/4 Kg H2O + Heat**

Combustion of ethane

- **Deduce the combustion Equation of ethane :**
- C_2H_6 + 7/2 O_2 $\longrightarrow$ $2CO_2$ + 3 H_2O + Heat
- 1mole 7/2 mole 2 mole 3 mole
- (M.wt*1) (M.wt*7/2) (M.wt*2) (M.wt*3)
- (2*12)+(6*1) ((7/2)*2*16) (2*(12+(2*16))) (3*((2*1)+16))
- 30Kg 112Kg 88Kg 54Kg
- Divide the weight of the each by 30:
- 1Kg 3.73 Kg 2.93 Kg 9/5 Kg

- **1Kg C_2H_6 + 3.73 Kg O_2 $\longrightarrow$ 2.93 Kg CO_2 + 9/5 Kg H2O + Heat**

Combustion of propane

- **Deduce the combustion Equation of propane:**
- C_3H_8 + 5 O_2 $\longrightarrow$ $3CO_2$ + 4 H_2O + Heat
- 1mole 5 mole 3 mole 4 mole
- (M.wt*1) (M.wt*7/2) (M.wt*2) (M.wt*3)
- (3*12)+(8*1) (5*2*16) (3*(12+(2*16))) (4*((2*1)+16))
- 44Kg 160Kg 132Kg 72Kg
- Divide the weight of the each by 44:
- 1Kg 3.63 Kg 3 Kg 1.6 Kg

- **1Kg C_2H_6 + 3.63 Kg O_2 $\longrightarrow$ 3 Kg CO_2 + 1.6 Kg H2O + Heat**

Comparison between combustion of carbon, hydrogen, sulfur

	Carbon complete	Carbon incomplete	Hydrogen	Sulfur
Combustion reactions				
Amount of oxygen needed to burn 1 kg of the combustible component	8/3 Kg	4/3 Kg	8 Kg	1 Kg
Amount of heat released	33.7 MJ	10.5 MJ	65.4MJ	9.11 MJ
combustion Products	CO_2	CO	H_2O	SO_2
Environmental impact	pollutant	Toxic and pollutant	No impact	Pollutant and corrosive.

Air supply

- Air supply = amount of air added to combustion engine to burn the fuel inside the engine.
- Air supply = total amount of oxygen * (100/23)
- Air supply = (O_2 **C(complete)** + O_2 **C(incomplete)** + O_2 **Hydrogen** + O_2 **Sulfur** – O_2 **Fuel**) * (100/23)
- Amount of O_2 needed for each element = (% of element * wt. of the fuel * conversion factor)

- Air supply = ((wt. $_{fuel}$ * % $_C$ *% $_{complete}$ *8/3) + (wt. $_{fuel}$ * % $_C$ *% $_{incomplete}$ *4/3) + (wt. $_{fuel}$ * % $_{Hydrogen}$ * 8) + (wt. $_{fuel}$ * % $_{Sulfur}$ *1) – (wt. $_{fuel}$ * % $_{Oxygen}$)) * (100/23)

Excess Air

- Actual air added = (1+X)*Theoretical Air.
- $X = \frac{\text{Percentage of excess air}}{100}$
- **Example:** calculate the actual air if the percentage of excess is 40% of the theoretical air (5 Kg)
- Solution:
- Actual air = (1+X)*Theoretical Air.
- **Actual air = (1+ (40/100))*5 =7 Kg.**

Energy released by burning the fuel:

- Energy released = amount of energy produced due to combustion of the fuel inside the engine (its unit is Mega joule).

- Total energy = ((wt.*E)$_{C(complete)}$ + (wt.*E)$_{C(incomplete)}$ + (wt.*E) $_{Hydrogen}$ + (wt.*E) $_{Sulfur}$)

- Energy = ((wt. $_{fuel}$ * % $_{C}$ *%$_{complete}$ *33.7) + (wt. $_{fuel}$ * %$_{C}$ *%$_{incomplete}$ *10.5) + (wt. $_{fuel}$ * % $_{Hydrogen}$ * 65.4) + (wt. $_{fuel}$ * % $_{Sulfur}$ *9.11))

- **Example:** Calculate the Air supply needed to burn 2Kg of the fuel which consists of :
  1. 30%wt. carbon
  2. 50%wt. hydrogen
  3. 5%wt. sulfur
  4. 5%wt. oxygen
  5. 9%wt. water
  6. 1%wt. ashes
- **If the combustion is 90% complete.**
- **If the percentage of excess is 40%.**

- **Solution:**
- Air supply = ((wt. $_{fuel}$ * % $_{C}$ *%$_{complete}$ *8/3) + (wt. $_{fuel}$ * %$_{C}$ *%$_{incomplete}$ *4/3) + (wt. $_{fuel}$ * % $_{Hydrogen}$ * 8) + (wt. $_{fuel}$ * % $_{Sulfur}$ *1) – (wt. $_{fuel}$ * % $_{Oxygen}$)) * (100/23)
- Theo. Air supply = ((2*0.3*0.9*8/3) + (2*0.3*0.1*4/3) + (2 * 0.5* 8) + (2*0.05*1) – (2*0.05)) * (100/23)
- Theo. Air supply = (1.44 + 0.08 + 8 + 0.1 – 0.1) * (100/23)
- theoretical Air supply = 41.39 Kg of air
- Actual air supply = (1+X)*Theoretical Air.
- **Actual air supply = (1+0.4)*41.39 = 57.94 Kg of air.**

- **Then calculate the heat energy released?**
- **Solution:**

- Energy = $((wt._{fuel} * \%_{C} * \%_{complete} * 33.7) + (wt._{fuel} * \%_{C} * \%_{incomplete} * 10.5) + (wt._{fuel} * \%_{Hydrogen} * 62.4) + (wt._{fuel} * \%_{Sulfur} * 9.11))$

- Energy = ((2*0.3*0.9*33.7) + (2*0.3*0.1*10.5) + (2 * 0.5* 65.4) + (2*0.05*9.11))= 85.139 MJ

- **Example:** calculate the air needed to burn 3 Kg of fuel of (50% methane, 50% propane).
- If the excess of air is 30% of the theoretical air.
- **Solution:**

1. Oxygen needed to burn the methane:

- CH_4 + $2\ O_2$ $\longrightarrow$ CO_2 + $2\ H_2O$
- 1mole 2 mole 1mole 2 mole
- (M.wt*1) (M.wt*2) (M.wt*1) (M.wt*2)
- (1*12)+(4*1) (2*2*16) (1*(12+(2*16))) (2*(2*1)+16)
- 16Kg 64Kg 44Kg 36Kg
- Divide the weight of the each by 16:
- **1Kg CH4 + 4 Kg O_2 $\longrightarrow$ 11/4 Kg CO_2 + 9/4 Kg H2O**
- 1Kg 4 Kg 11/4 Kg 9/4 Kg
- (3*0.5)Kg **?** Kg

- **Oxygen needed to burn the methane = 4*1.5 = 6 Kg**

2. Oxygen needed to burn the propane:

- C_3H_8 + 5 O_2 $\longrightarrow$ $3CO_2$ + 4 H_2O + Heat
- 1mole 5 mole 3 mole 4 mole
- (M.wt*1) (M.wt*7/2) (M.wt*3) (M.wt*4)
- (3*12)+(8*1) (5*2*16) (3*(12+(2*16))) (4*((2*1)+16))
- 44Kg 160Kg 132Kg 72Kg
- Divide the weight of the each by 44:
- **1Kg C_3H_8 + 3.63 Kg O_2 $\longrightarrow$ 3 Kg CO_2 + 1.6 Kg H2O**
- 1Kg 3.63 Kg 3 Kg 1.6 Kg
- 1.5 Kg ? Kg

- **Oxygen needed to burn the propane =1.5*3.63= 5.445Kg**

- Total amount of theo. air = (6 + 5.445) * (100/23) = 49.76 Kg of air.
- Total amount of actual air = 49,76*(1+ 0.3) = 64.689 Kg of air.

Thank you ☺