Fuel & Advanced Combustion

Lecture (1) Fuel(2)

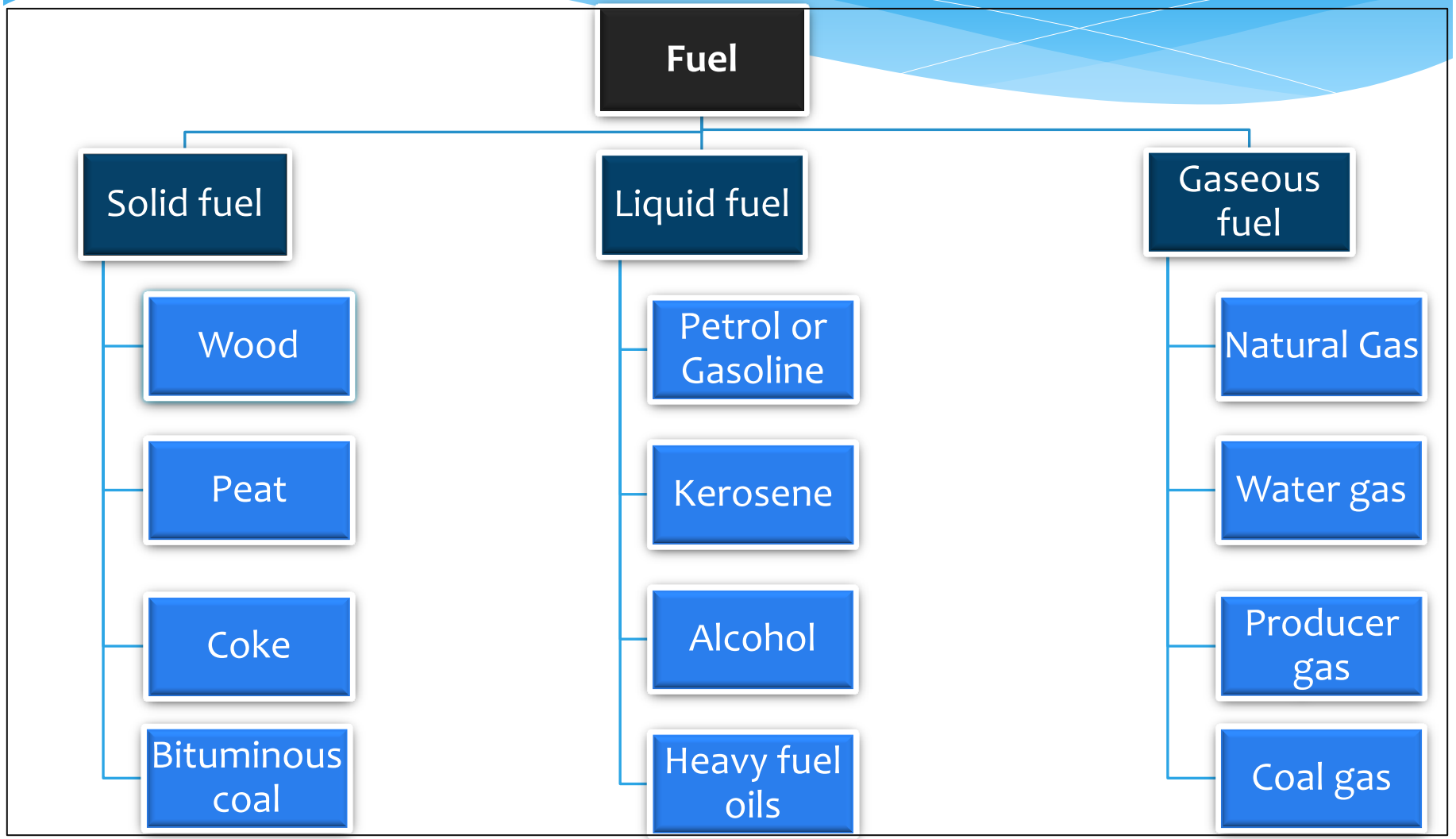
The Fuel Properties

INTRODUCTION:-

- Energy from the Sun is converted into chemical energy by photosynthesis.
- when burn dried plants or wood, producing energy in the form of heat and light, which are the Sun's energy originally stored in that plant or in that wood through photosynthesis.
- in most of the world today, wood is not the main source of fuel. The use of natural gas or oil in our homes, and use mainly oil and coal to heat the water to produce the steam to drive the turbines for our huge power generation systems. These fuels - coal, oil, and natural gas - are often referred to as fossil fuels.
- The various types of fuels (like liquid, solid and gaseous fuels) that are available depend on various factors such as costs, availability, storage, handling, pollution and landed boilers, furnaces and other combustion equipment.

- The knowledge of the fuel properties helps in selecting the right fuel for the right purpose and for the efficient use of the fuel.

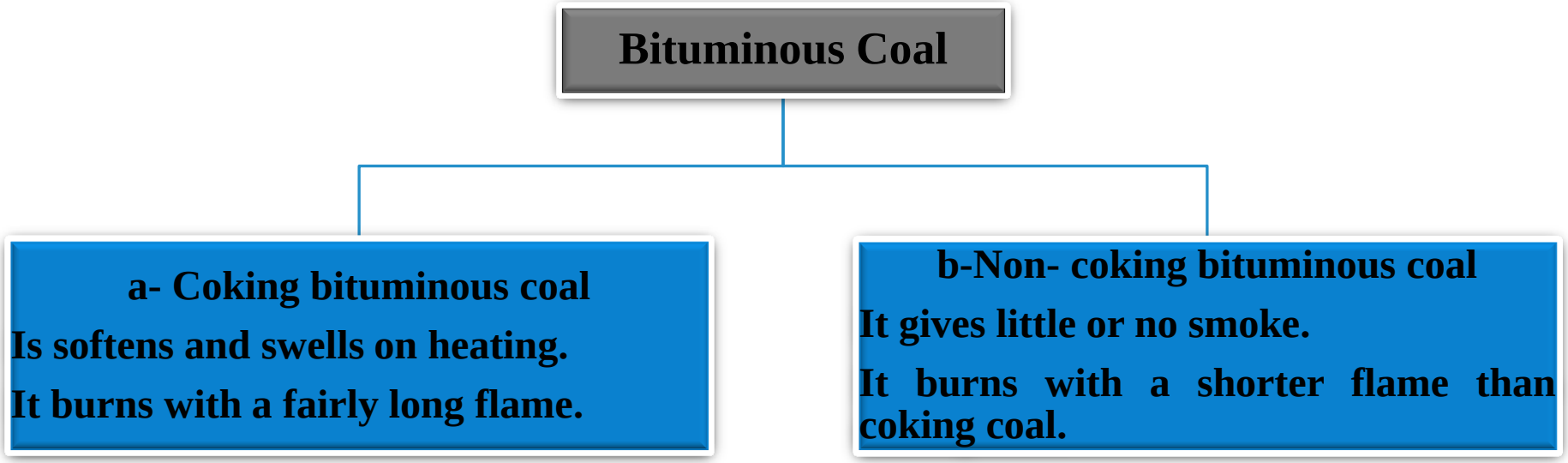
TYPE OF FUELS:-



The solid fuel:

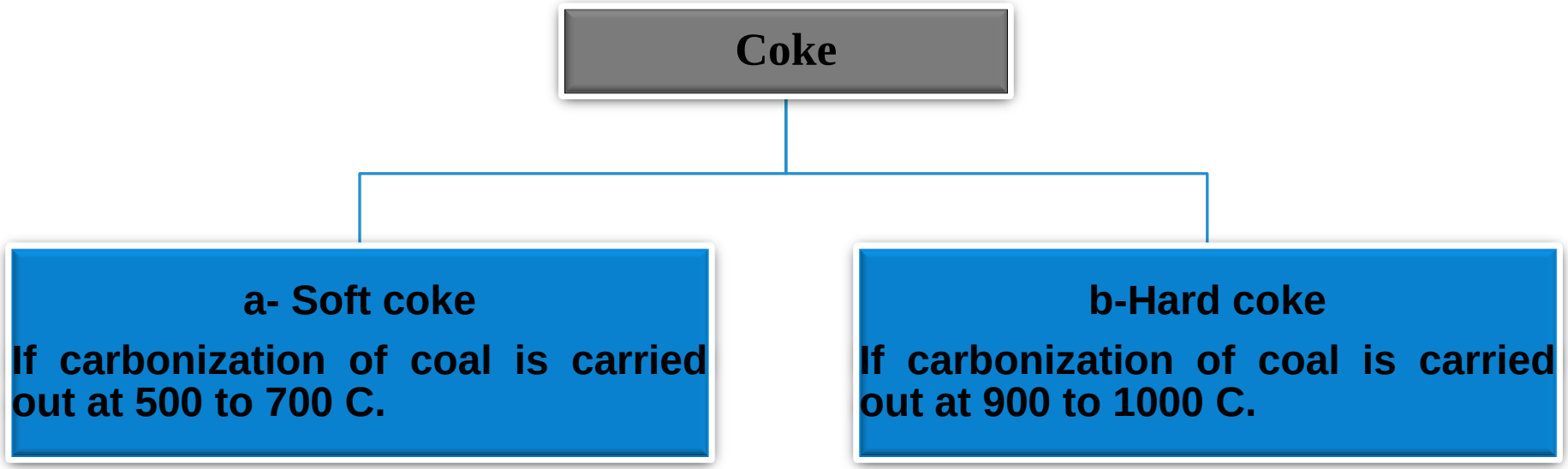
- Natural solid fuel: as Wood, Coal, and Peat.
- Prepared solid fuel: as Coke, and Pulverited coal.

- ✓ Wood – is used as fuel and it consists of mainly carbon and hydrogen, it is converted to coal when burnt in the absence of air.
- ✓ Bituminous Coal – is represents the next stage of lignite in the coal formation and consist very little moisture and 75 to 90% of carbon.



The solid fuel:

✓**Coke – is produced when coal is strongly heated continusly for 24 to 48 hr. in absence of air in closed vessel (this process means Carbonization).**



The liquid fuel:

Liquid fuel is including Petroleum and its derivatives as gasoline, kerosene oil, gas oil, and light diesel oil.

- **The advantages of liquid fuel over solid fuel:**
  - **Higher calorific value.**
  - **Lower storage capacity required.**
  - **Non-corrosion of boiler plates.**
  - **Higher efficiency.**
  - **Practically no ashes.**
  - **Better economy in handling.**
  - **Better control of consumption by using valves.**

- **The disadvantages of liquid fuel over solid fuel:**
  - **Higher cost.**
  - **Greater risk of fire.**
  - **Costly containers are required for storage and transport.**

The classification of fuel oil by API (American Petroleum Institute)

Gaseous fuel:

- **Natural: as Natural gas.**
- **Prepared: as Coal gas, Blast furnace, Water gas, and Producer gas.**
  - ✓ **Natural gas – comes out of gas wells and petroleum wells and it composed of methane 85%, ethane 10%, and other hydrocarbon 5%.**
  - ✓ **Coal gas – is a product obtained the destructive distillation of coal. its composition CH_4 35%, H 45%, CO 8%, N 6%, CO_2 2% and other hydrocarbons 4%.**
  - ✓ **Blast furnace gas – is obtained as a by product from blast furnace used for the production of pig iron. Its composition CO 30%, N_2 52 %, H_2 13%, CO_2 2%, and CH_4 3%.**
  - ✓ **Water gas – is obtained by passing a blast of steam through a deep bed of red hot coke.**
  - ✓ **Producer gas – is produced during incomplete combustion of coke in a current of air. Its composition N_2 62%, CO 23%, CO_2 3%, H_2 6% and CH_4 4%.**

Gaseous fuel:

- **The advantages of gaseous fuel over solid fuel:**
  - ✓ **Gaseous can easily flow through supply pipe.**
  - ✓ **Uniform distribution of fuel in case of multi cylinder engine.**
  - ✓ **Eliminate most of the starting problems associated with liquid fuel.**
  - ✓ **They are free from solid and liquid impurities.**
  - ✓ **They do not produce ash or smoke.**

- **The disadvantages of liquid fuel over solid fuel:**
  - ✓ **They require large storage capacity.**
  - ✓ **They are readily inflammable.**

The Fuel Properties:-

❑ The Calorific Value of Fuels

The calorific value is the amount of heat given out by the complete combustion of 1 Kg of fuel.

- **There are two types of calorific value:**
  - ✓ **Higher calorific value.** — **H_2O liquid form in exhaust**
  - ✓ **Lower calorific value.** — **H_2O vapour form in exhaust**

- **Experimental determination of Higher Calorific Value:**

Here: a known weight of fuel is burnt in a suitable calorimeter, and heat so evolved is found by measuring the rise in temperature of the surrounding water.

Calorimeter:

A- Bomb Calorimeter

B- Boy's Gas Calorimeter

❑ Relative Density or Specific Gravity:

- **Is the ratio between the density of fuel to the density of water. Or**
- **It is a measure of the density of liquid fuels at 15.6 C as compared with water at the same temperature.**

$$\text{Specific gravity at } \frac{t_1}{t_2} = \frac{\text{Density of fuel at } t_1}{\text{Density of distilled water at } t_2}$$

- **The classification of fuel oil by API (American Petroleum Institute) here:**

$$API = \frac{141.5}{S_g} - 131.5$$

❑ Flash Point:

It is given an indication of fire risk in storage under ambient conditions.
It depend on fuel type (Volatility)

❑ Self- Ignition Temperature:

It is the minimum temperature to which the fuel must be heated in the presence of air to promote ignition spontaneously, that is in the absence of ignition source.

- **The cloud point:**

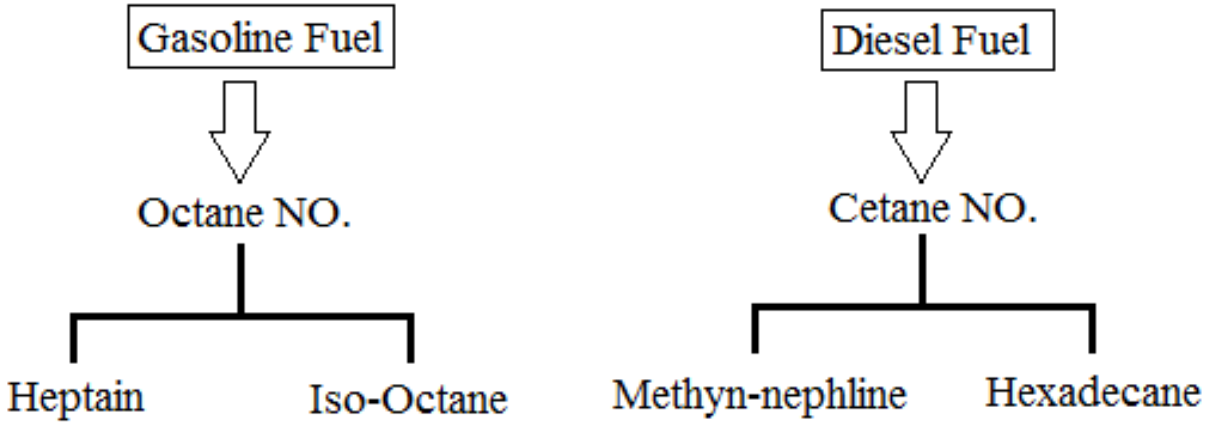
  Is the temperature at which haziness appears on cooling without stirring due to the initial formation of wax.

- **The pour point:**

  Is the temperature of 3 C° above the level at which the fuel appears to be completely frozen.

Note:

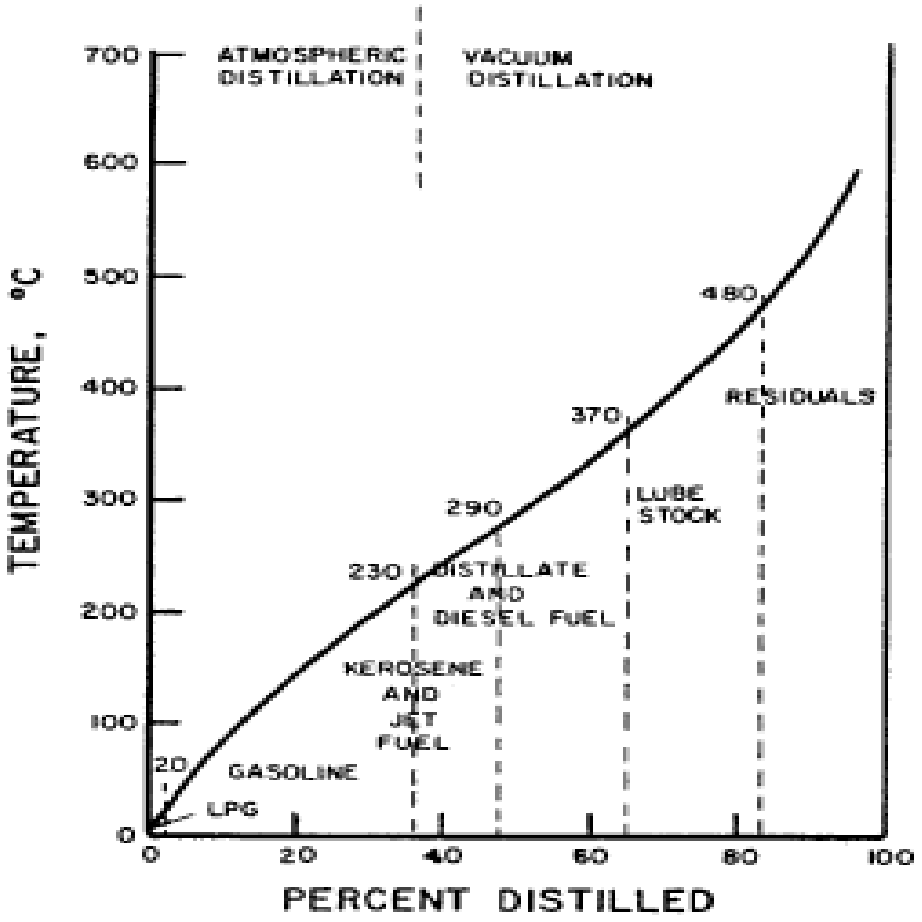
- **The quality of fuel used in cars determine by known:**
  - **Spark ignition engine or Petrol engine ----------Octane Number.**
  - **Compression ignition engine or Diesel engine---------Cetane Number.**



- **Distillation:**

Corresponding reading of vapor temperature and condensate recovered are made at prescribed intervals, and the results plotted in form of a distillation curve. The extent of the distillation range for any given fuel is representative of availability of that fuel from the parent crude oil.

Distillation Temperatures
30 to 230 C for Gasoline.
230 to 370 C for Diesel.



❑ ***Dew point temperature:***

- **Dew point temperature is the temperature at which the water vapor starts to condense if it is cooled at constant pressure.**

(هى درجه الحرارة التى يبدأ عندها بخار الماء الموجود فى العادم فى التكثف)

- **لحساب قيمة نقطة الندى لبخار الماه الموجود فى العادم (نواتج الاحتراق):**
  - ✓ **نحصل على قيم تحليل العادم.(عن طريق معادلات الاحتراق)**
  - ✓ **نحصل على قيمة الكسر المولى للمياه فى العادم.X_{H2O}**
  - ✓ **نحصل على الضغط الجزيئى للمياه فى العادم من المعادله الأتيه**

$$P_{H_2O} = X_{H_2O} \times P_{total}$$

- ✓ **من الجداول الخاصة ببخار المياه نحصل على درجه الحرارة المناظره لهذا الضغط و تكون هى نقطه الندى.**

Note:

- **<u>The effect of water vapor in air on the combustion process:</u>**
- **<u>تأثير كميه بخار المياه الموجود فى الهواء على عمليه الحريق:</u>**

لا يتفاعل كيميائيا مع اى من أنواع الوقود. و لكنه يمتص جزء من الطاقه المنطلقه أثناء الاحتراق. و يرفع درجه حراره نقطه الندى.

Ex: 1

A certain natural gas has the following volumetric analysis: 72 percent CH_4, 9 percent H_2, 14 percent N_2, 2 percent O_2, and 3 percent CO_2. This gas is now burned with the stoichiometric amount of air that enters the combustion chamber at 20°C, 1 atm, and 80 percent relative humidity. Assuming complete combustion and a total pressure of 1 atm, determine the dew-point temperature of the products.

Solution:

1 Solve the combustion equation with dry air.

$$0.72CH_4 + 0.09H_2 + 0.14N_2 + 0.02O_2 + 0.03CO + X(O_2 + 3.76N_2) \rightarrow aCO_2 + bH_2O + kN_2$$

Balance:

C balance:	0.72+0.03 = a	a = 0.75
H balance:	4*0.72 + 2*0.09 = 2*b	b = 1.53
O balance:	2 * 0.02 + 0.03 + 2*X = 2*a + b	X = 1.465
N_2 balance:	2*0.14 + 3.76 * X = k	k = 5.648

2 Find the amount of water vapor in air.

The partial pressure of the moisture in the air is $P_{v,\text{air}} = P_{\text{sat @ 20°C}} = 1.871$ kPa

$$N_{v,air} = N_{total} \times \left(\frac{P_{v,air}}{P_{total}} \right) = \left(N_{dry,air} + N_{v,air} \right) \times \left(\frac{P_{v,air}}{P_{total}} \right) = \left(6.97 + N_{v,air} \right) \times \left(\frac{1.871}{101.325} \right)$$

$$\therefore N_{v,air} = 0.131 \ \text{kmol}$$

3 Get the dew point temperature.

$$P_{H_2O} = X_{H_2O} \times P_{total} = \frac{N_{v,air} + N_{v,Combustion}}{N_{total,combustion} + N_{v,air}} \times P_{total}$$

$$P_{H_2O} = \frac{0.131 + 1.53}{7.928 + 0.131} \times 101.325 = 20.88 \ \text{kPa}$$

$$\therefore \mathrm{T_{dp}} = 60.9^{o}C$$