UNIVERSITI
TEKNOLOGI
PETRONAS

FINAL EXAMINATION
MAY 2024 SEMESTER

COURSE	:	**YBB2103 - HYDROCARBON AND PETROCHEMICAL**
DATE	:	**7 AUGUST 2024 (WEDNESDAY)**
TIME	:	**9:00 AM - 12:00 NOON (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **TEN (10)** pages in this Question Booklet including the cover page .

ii. **DOUBLE-SIDED** Question Booklet.

1. a. A variety of carbon feedstocks can be utilized to generate syngas, which is a precursor of one carbon (C1) for higher liquid hydrocarbons. It has often been produced using natural gas or coal. Two approaches to C1 conversion are shown in **FIGURE Q1**.

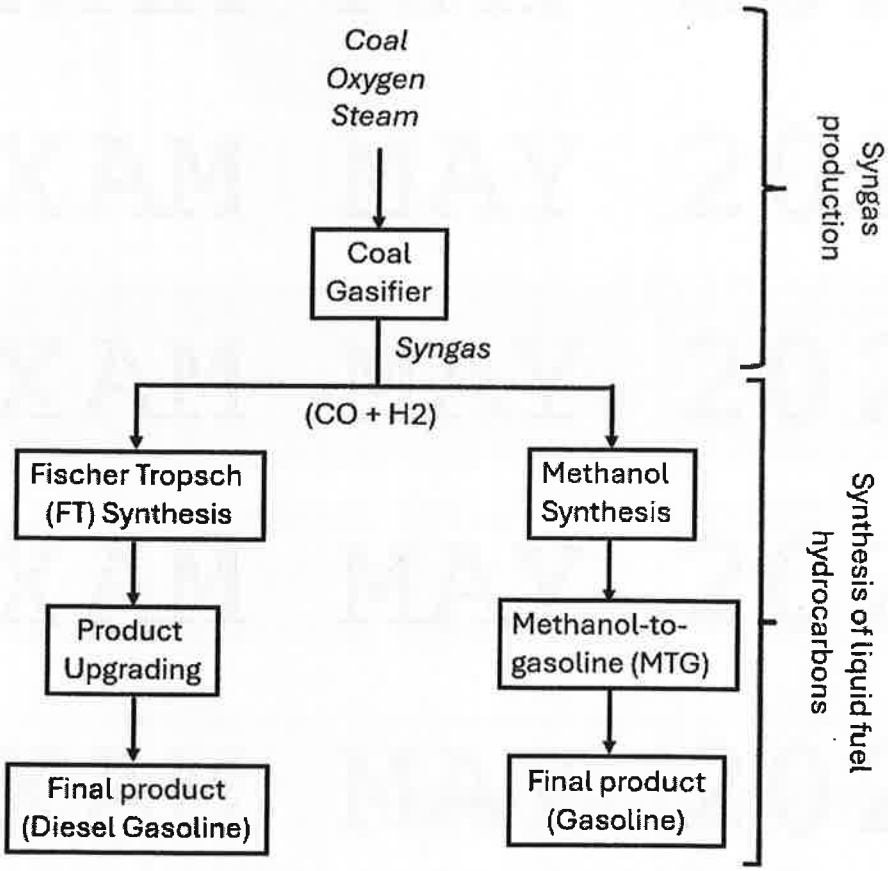


FIGURE Q1. Fischer-Tropsch (FT) and Methanol-To-Gasoline (MTG) process flow.

i. The process of Fischer-Tropsch is used to create large hydrocarbon molecules. Draw a detailed reaction mechanism to illustrate the synthesis of these hydrocarbon molecules, assuming n = 15.

[7 marks]

ii. Describe the function of zeolite catalysts in the MTG process, including their importance in determining product distribution and quality. Discuss the reactions of methanol dehydration, oligomerization, and hydrocarbon production using zeolite catalysts, using appropriate chemical formulae.

[4 marks]

iii. The term "C1 conversion" refers to the transformation of a C1 precursor, like syngas, into a molecule with a longer carbon chain. Discuss regarding the way carbon dioxide might be used to convert C1 to another form. Assumptions and chemical equations should be provided to support your answers.

[4 marks]

b. Isopropanol (2-propanol) is second largest volume alcohol after methanol of great synthetic utility. Examine any chemical equation(s) and processing parameters for the **TWO (2)** general methods to produce isopropanol from propylene. Outline **ONE (1)** use of isopropanol.

[5 marks]

2. a. A 19 million kilogram per year cumene (isopropylbenzene) plant is being built and sold out by Company X. **TABLE Q2** displays the material balance for the relevant reaction, market, and products. Their cumene plant's operating costs are $1.54 per kg of products. Given the density of benzene is 0.857 kg/L.

TABLE Q2. Cumene plant

Feed	Amount (kg)	Cost (US$)	Product	Amount (kg)
Benzene	308	0.42/L	Cumene	454
Propylene	166	0.55/kg	Heavies	22

i. Write a balanced chemical equation for formation of cumene.

[2 marks]

ii. Calculate the total costs of all feedstocks for the cumene production.

[3 marks]

iii. Calculate the total net cost (inclusive of plant operating cost and cost of feedstock).

[3 marks]

iv. Calculate the production cost per kg of cumene ($/kg).

[2 marks]

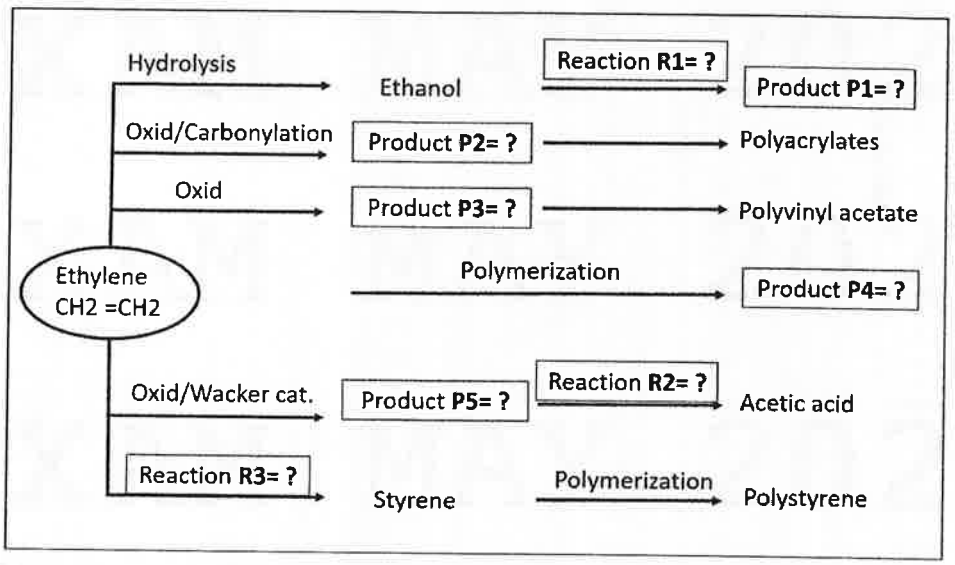
b. Coal is an example of a fossil fuel formed from the remains of plants that lived in swamps millions of years ago. Over time, these plant materials were subjected to heat and pressure, eventually transforming into coal. Compare and contrast the **FOUR (4)** main types or ranks of coal.

[4 marks]

c. Non-fossil fuel alternatives are used as a source of energy to replace the current fossil-based fuels. However, there are challenges associated with non-fossil fuel alternatives. List any **THREE (3)** advantages and **THREE (3)** disadvantages from non-fossil fuel alternatives.

[6 marks]

3. a. **FIGURE Q3** shows reactions of ethylene with various reagents to form useful compounds. Ethane can be cracked by steam at 850°C to generate ethylene.



Note: Oxid = oxidation; cat. = catalyst

FIGURE Q3. Reactions of ethylene.

i. Identify the missing information in **FIGURE Q3** as indicated by the reactions, **R1-R3** and products, **P1-P5**.

[8 marks]

ii. Explain the **TWO (2)** challenges related to ethane transportation.

[2 marks]

b. Propylene, often referred to as propene, ranks as the second most widely used hydrocarbon intermediate after ethylene in the production of various chemicals. It serves as a crucial building block in the manufacture of a diverse range of products. Its versatility and widespread application make it an indispensable component in the chemical industry, contributing significantly to the global economy.

i. Justify the significance of propylene as a hydrocarbon intermediate in the chemical industry. Provide examples of products derived from propylene.

[3 marks]

ii. Compare and contrast the production processes of propylene with ethylene.

[3 marks]

iii. Evaluate the industrial Sohio process from the point of introducing the raw materials into the reactor until the stage of isolating the acrolein product.

[4 marks]

4. a. Methane is the main component of natural gas, a gaseous hydrocarbon-based fossil fuel. **TABLE Q4** shows the composition of the related natural gas as discovered in a reservoir, as well as the minimum weight fractions required to achieve specific commercial natural gas quality standards.

TABLE Q4: Associated natural gas compositions and quality requirements.

Component	**Chemical formula**	**Weight fraction (%)**	**Minimum weight fraction for specific quality requirements (%)**
Methane	CH_4	60.0	97.0
C_2-C_5	C_2H_6 - C_5H_{12}	34.4	1.0
Carbon dioxide	CO_2	1.5	0.5
Water vapour	H_2O	2.8	0.5
Helium	He	1.0	0.5
Nitrogen	N_2	0.3	0.5

i. Describe the necessity of purifying natural gas.

[2 marks]

ii. Create a flow diagram for purifying the associated natural gas based on **Table Q4**. Explain the function of the purification processing units. Provide the procedures and chemicals used in at least **TWO (2)** of the identified processing units.

[6 marks]

b. Evaluate a detailed step-by-step production of a synthesis gas mixture from methane. Extend your answer by using chemical equation(s) for each step for the formation of the synthesis gas mixture.

[6 marks]

c. Utilizing ammonia and carbon dioxide recommend the two-step process for urea production. Highlight the prilling phase within this process, detailing the chemical reactions involved, as well as the necessary conditions.

[6 marks]

5. a. In creating products with a high-octane number, isobutane is usually blended with an alkene or mixed alkene streams in alkylation operations. Alkylating isobutane with butylene yields the greatest octane ratings.

i. Determine the advantages and challenges associated with alkylating isobutane with butylene compared to other alkene feedstocks. Consider factors such as reactivity, product yield, process economics, and environmental impact.

[6 marks]

ii. Compare and contrast the alkylation of isobutane with various alkene streams such as propylene, and isobutylene in terms of octane number enhancement. Consider factors such as reactivity and selectivity, feedstock availability and cost, and alkylate quality requirements.

[6 marks]

iii. Technological advances and new ideas are aimed at optimizing alkylation processes for optimal octane number increase. Illustrate recent advances in catalyst design, process optimization, and feedstock utilization.

[8 marks]

-END OF PAPER-