UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2010/2011 Academic Session

April/May 2011

EKC 111 – Mass Balance
[Imbangan Jisim]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains SEVEN printed pages before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi TUJUH muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instruction: Answer **ALL** questions.

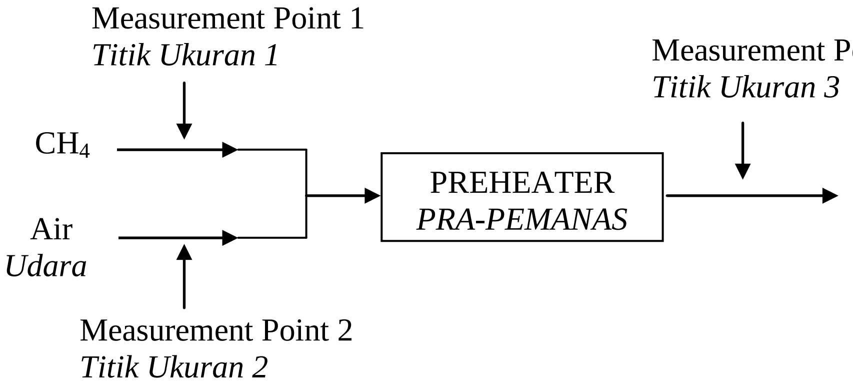
*[**Arahan:** Jawab **SEMUA** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai].

1. Streams of methane and air (79% mole of N_2, the balance is O_2) are combined at the inlet of a combustion furnace preheater. The pressures of each stream are measured with open end mercury manometers, the temperatures are measured with resistance thermometers, and the volumetric flow rates are measured with orifice meters.

Aliran metana dan udara (79% mol N_2, bakinya ialah O_2) dicampurkan pada salur masuk relau pra-pemanas pembakaran. Tekanan bagi setiap saliran diukur dengan menggunakan manometer raksa hujung terbuka, suhu pula diukur dengan menggunakan jangkasuhu rintangan, dan kadar aliran isupadu diukur menggunakan meter oritis.



<u>Data:</u>

Flowmeter 1: V_1 = 947 m^3/h
Flowmeter 2: V_2 = 195 m^3/h
Manometer 1: h_1 = 232 mm
Manometer 2: h_2 = 156 mm
Manometer 3: h_3 = 74 mm
Resistance thermometer 1: r_1 = 26.159 ohms
Resistance thermometer 2: r_2 = 26.157 ohms
Resistance thermometer 3: r_3 = 44.789 ohms
Atmospheric pressure: A sealed-end mercury manometer reads h = 29.76 in

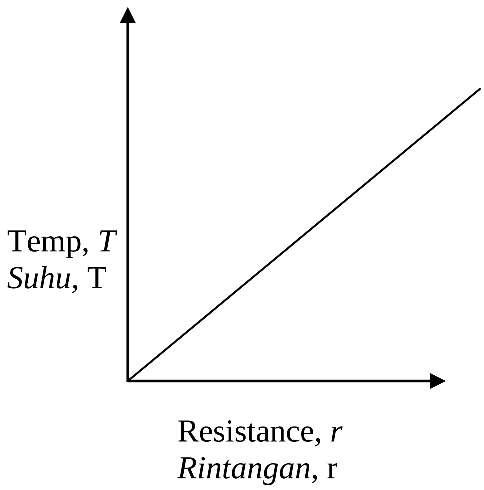
<u>Data:</u>

Meter aliran 1: V_1 *= 947 m^3/h*
Meter aliran 2: V_2 *= 195 m^3/h*
Manometer 1: h_1 *= 232 mm*
Manometer 2: h_2 *= 156 mm*
Manometer 3: h_3 *= 74 mm*
Jangkasuhu rintangan 1: r_1 *= 26.159 ohms*
Jangkasuhu rintangan 2: r_2 *= 26.157 ohms*
Jangkasuhu rintangan 3: r_3 *= 44.789 ohms*
Tekanan atmosfera: Sebuah manometer raksa hujung tertutup mengukur h *= 29.76 inci*

The resistance thermometers were calibrated by measuring their resistance at the freezing and boiling points of water, with the following results:

Jangkasuhu rintangan ditentukur dengan mengukur rintangan pada titik beku dan titik didih air, dengan keputusan berikut:

T = 0 °C: r = 23.624 ohms
T = 100 °C: r = 33.028 ohms



A straight-line relationship between T and r may be assumed.

Satu hubungan garis lurus di antara T *dan* r *boleh diandaikan.*

The relationship between the total molar flow rate of a gas and its volumetric flow rate is, to a good approximation, given by a form of the ideal gas equation of state:

Hubungan antara jumlah kadar aliran molar sesuatu gas dan kadar aliran isipadu, diberi melalui bentuk persamaan keadaan gas ideal berikut:

$$\mathring{\eta}\left(\frac{kmol}{s}\right) = \frac{12.186\,P(atm)\,\dot{V}\left(m^{3/8}\right)}{T(K)} \qquad (1.1)$$

where P is the absolute pressure of the gas.
di mana P adalah tekanan mutlak sesuatu gas.

[a] Derive the resistance thermometer calibration formula for T (°C) in terms of r (ohm).
Terbitkan rumus tertentukuran jangkasuhu rintangan bagi T *(°C) dalam bentuk* r *(ohm).*

[b] Convert the given gas law expression for $\mathring{\eta}$ (kmol/min) in terms of P (mm Hg), T (°C), and $\dot{V}$ (m^3/min).
Ubahkan ungkapan hukum gas yang diberi bagi $\mathring{\eta}$ *(kmol/min) dalam bentuk* P *(mm Hg),* T *(°C), dan* $\dot{V}$ *(m^3/min).*

[c] Calculate the temperatures and pressures at points 1, 2, and 3.
Kirakan suhu dan tekanan pada titik 1, 2, dan 3.

[d] Calculate the molar flow rate of the combined gas streams.
Kirakan kadar aliran molar gabungan aliran gas tersebut.

[e] Calculate the reading of flowmeter 3 in m^3/min.
Kirakan bacaan meter aliran 3 dalam m^3/min.

[f] Calculate the total mass flow rate and the mass fraction of the methane at point 3.
Kirakan jumlah kadar aliran jisim dan nisbah jisim metana pada titik 3.

[25 marks/markah]

2. In an absorption tower (or absorber), a gas is contacted with a liquid under conditions such that one or more species in the gas dissolve in the liquid. A stripping tower (or stripper) also involves a gas contacting a liquid, but under conditions such that one or more components of the feed liquid come out of solution and exit in the gas leaving the tower.

Dalam sebuah menara penyerapan (atau penyerap), satu gas disentuhkan dengan suatu cecair di bawah satu keadaan yang mana satu atau lebih spesis dalam aliran gas tersebut larut di dalam cecair. Satu menara pelucutan (atau pelucut) juga melibatkan suatu proses bersentuhan dengan suatu cecair, tetapi di bawah satu keadaan yang mana satu atau lebih komponen cecair tersebut terlucut daripada larutan dan keluar melalui gas keluaran menara tersebut.

A process consisting of an absorption tower and a stripping tower is used to separate the components of a gas containing 30.0 mole % carbon dioxide and the balance is methane. A stream of this gas is fed to the bottom of the absorber. A liquid contain 0.50 mole % dissolve CO_2 and the balance methane is recycled from the bottom of the stripper and fed to the top of the absorber. The product gas leaving the top of the absorber contains 1.0 mole% CO_2 and essentially all of the methane fed to the unit. The CO_2 rich liquid solvent leaving the bottom of the absorber is fed to the top of the stripper and a stream of nitrogen gas is fed to the bottom. 90 mole % of the CO_2 in the liquid feed to the stripper comes out of solution in the column, and the N_2-CO_2 stream leaving the column passes out to the atmosphere through a stack. The liquid stream leaving the stripping tower is the 0.5 mole % CO_2 solution recycled to the absorber.

Suatu proses mengandungi satu menara penyerap dan satu menara pelucut digunakan untuk memisahkan komponen-komponen gas yang mengandungi 30.0 mol % karbon dioksida dan selebihnya adalah metana. Satu aliran gas ini disuap ke bawah penyerap tersebut. Satu cecair mengandungi 0.50 mol % CO_2 terlarut dan bakinya metana, dikitarkan daripada bawah pelucut dan disuapkan ke atas penyerap. Gas produk tersebut yang keluar dari atas penyerap mengandungi 1.0 mol % CO_2 dan kesemua metana yang disuapkan ke unit tersebut. Cecair pelarut yang kaya dengan CO_2 tersebut yang keluar dari bawah penyerap disuapkan ke atas pelucut dan satu aliran gas nitrogen disuapkan pada bawahnya.

90% mol CO_2 di dalam cecair yang disuapkan kepada pelucut keluar dari larutan dalam turus, dan aliran N_2-CO_2 keluar dari turus tersebut melalui satu paip tumpu ke amosfera. Aliran cecair yang keluar daripada menara pelucut adalah larutan 0.5 mol % CO_2 yang dikitarkan ke penyerap.

The absorber operates at temperature T_a and pressure P_a and the stripper operates at T_s and P_s. Methane may be assumed to be non-volatile - that is, none enters the vapor phase in either column and N_2 may be assumed insoluble in methane.

Penyerap beroperasi pada suhu T_a *dan tekanan* P_a, *dan pelucut beroperasi pada* T_s *dan* P_s. *Gas metana boleh diandaikan tidak meruap - iaitu tiada yang memasuki ke fasa wap di dalam kedua-dua turus dan N_2 boleh diandaikan tidak larut di dalam metana.*

[a] Explain in your own words the functions of the absorber and stripper in the process.

Terangkan dalam ayat anda sendiri fungsi penyerap dan pelucut di dalam proses di atas.

[b] Taking a basis of 100 mol/h of gas fed to the absorber, draw and label a flowchart or process block diagram of the process. (For the stripper outlet gas, label the component molar flow rates rather than the total flowrate and mole fractions).

Dengan mengambil 100 mol/jam gas suapan ke penyerap, lukis dan labelkan carta alir atau gambarajah blok proses tersebut. [Bagi aliran keluar gas pelucut, labelkan kadar aliran molar komponen berbanding jumlah kadar aliran dan nisbah-nisbah mol].

[c] Calculate the fractional CO_2 removal in the absorber (moles absorbed/mole in gas feed) and the molar flow rate and composition of the liquid feed to the stripping tower.

Kirakan nisbah penyingkiran CO_2 dalam penyerap (mol yang terserap/mol dalam suapan), kadar aliran molar dan komposisi suapan cecair ke menara pelucut.

[d] As a Chemical Engineer, would you guess that T_s would be higher or lower than T_a? Explain.

Sebagai seorang Jurutera Kimia, adakah anda akan menjangkakan T_s akan lebih tinggi atau rendah berbanding T_a? Jelaskan.

[25 marks/markah]

3. A natural gas contains 95 wt % CH_4 and the balance C_2H_6. Five hundred cubic meters per hour of this gas at 50 ^oC and 10.0 atm is to be burned with 25 % excess air. The air flow meter is calibrated to read the volumetric flow rate at standard temperature and pressure. What should the meter read (in SCMH) when the flow rate is set to desired value? Treat as the real gas using available data.

Gas asli mengandungi 95 % berat CH_4 dan selebihnya adalah C_2H_6. Lima ratus meter padu setiap jam gas ini pada 50°C dan 10.0 atm dibakar dengan 25 % udara berlebihan. Tolok aliran udara telah ditentukurkan pada bacaan kadar aliran isipadu. Tertentukur gas ini adalah pada suhu dan tekanan piawai. Apakah bacaan tolok tersebut (dalam SCMH) apabila kadar aliran ditentukan pada nilai yang dikehendaki? Anggapkan sebagai gas tulen menggunakan data yang diberikan.

Methane : T_c = 190.7 K and P_c = 45.8 atm;
Metana : T_c *= 190.7 K dan* P_c *= 45.8 atm;*

Ethane : T_c = 305.4 K and P_c = 48 atm
Etana : T_c *= 305.4 K dan* P_c *= 48 atm*

[25 marks/markah]

4. Sucrose can be converted to glucose and fructose by the inversion process as follows:

Sukrosa boleh ditukarkan ke glukosa dan fruktosa melalui proses penyongsangan seperti berikut:

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$
[sucrose] [glucose] [fructose]

$$C_{12}H_{22}O_{11} + H_2O \rightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$
[sukrosa] [glukosa] [fruktosa]

The combined quantity glucose plus fructose is called inversion sugar. The following Figure Q.4. shows how the process occurs.

Kuantiti tergabung glukosa dan fruktosa dipanggil gula penyongsangan. Rajah S.4. yang berikut menunjukkan bagaimana proses tersebut berlaku.

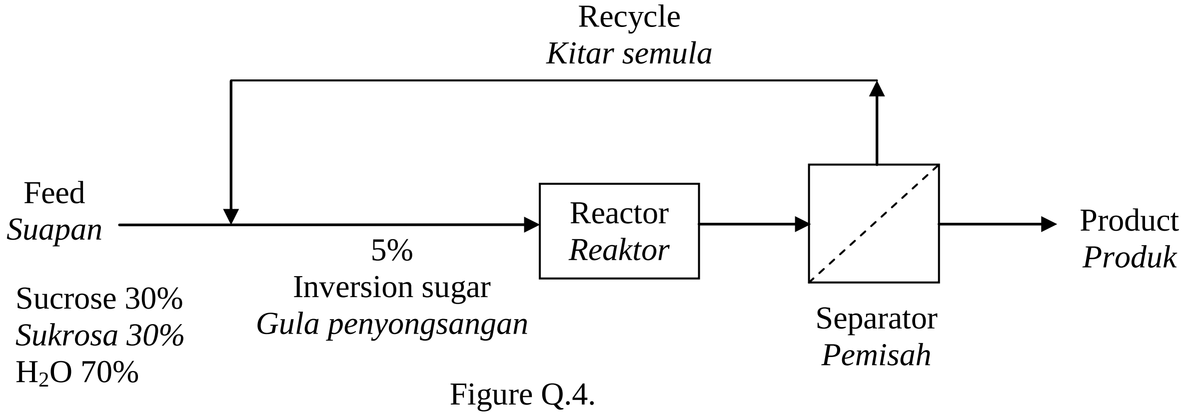


Figure Q.4.
Rajah S.4.

…7/-

[a] If 90% conversion of sucrose occurs on one pass through the reactor, what would be the recycle stream flow per 100 pounds (lb) fresh feed of sucrose solution entering the process?

Jika penukaran 90% sukrosa berlaku menerusi satu laluan reaktor, apakah aliran kitaran semula per 100 paun (lb), suapan baru larutan sukrosa yang memasuki proses tersebut?

[b] Calculate the concentration of inversion sugar in the recycle stream and in the product stream.

Kirakan kepekatan gula penyongsangan dalam aliran kitaran semula dan dalam aliran produk.

Note: The concentrations of components in the recycle stream and the product stream are the same.

Nota : Kepekatan komponen-komponen dalam aliran kitaran semula dan aliran produk adalah sama.

[25 marks/markah]

- oooOooo -