UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2012/2013 Academic Session

June 2013

# 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].*

…2/-

Answer ALL questions.
*Jawab SEMUA soalan.*

1. [a] Explain the main differences between a chemist and a chemical engineer in term of their job responsibilities.
*Huraikan perbezaan-perbezaan utama di antara seorang ahli kimia dan seorang jurutera kimia, berdasarkan tugas dan tanggungjawab pekerjaan.*
*[5 marks/markah]*

[b] Briefly explain the following
*Huraikan secara ringkas perkara-perkara berikut:*

[i] Steady state process
*Proses keadaan mantap*

[ii] Transient process
*Proses fana*

[iii] Batch process
*Proses berkelompok*

[iv] Semi batch process
*Proses separuh kelompok*

[v] Continuous process
*Proses berterusan*

*[10 marks/markah]*

2. [a] The terminal settling velocity of particles during the settling process in wastewater treatment plant is generally calculated using the following equation:

*Halaju pengenapan terminal zarah-zarah ketika proses pengenapan di loji rawatan air sisa lazimnya dikira menggunakan persamaan berikut:*

$$v_s = \frac{g(\rho_s - \rho)d^2}{18\mu}$$

where $v_s$ = terminal settling velocity (m/s), $\rho_s$= density of particle (kg/m$^3$), $\rho$ = density of fluid (kg/m$^3$), $g$ = acceleration due to gravity (m/s$^2$), $d$= diameter of particle (m), $\mu$ =dynamic viscosity (Pa.s).

*di mana* $v_s$ *= halaju pengenapan terminal (m/s),* $\rho_s$*= ketumpatan zarah (kg/m$^3$),* $\rho$ *= ketumpatan bendalir (kg/m$^3$),* $g$ *= pecutan disebabkan oleh graviti (m/s$^2$),* $d$*= diameter zarah (m),* $\mu$ *=kelikatan dinamik (Pa.s).*

[i] Calculate the terminal settling velocity in ft/min for a particle with a radius of 0.00158 in. and a specific gravity of 2.65. Assume the density of water is 62.43 $lb_m/ft^3$, the dynamic viscosity is 0.955 mPa.s, and acceleration due to gravity is 9.8 $m/s^2$.

*Kirakan halaju pengenapan terminal dalam kaki/min bagi zarah berjejari 0.00158 in. dan graviti tentu 2.65. Anggapkan ketumpatan air ialah 62.43 $lb_m/kaki^3$, kelikatan dinamik ialah 0.955 mPa.s, dan pecutan graviti ialah 9.8 $m/s^2$.*

[ii] Derive a formula for $v_s$ (ft/min) as a function of $g$ ($m/s^2$), $\rho_s$ ($lb/ft^3$), $\rho$ ($lb/ft^3$), $d$ (ft) and $\mu$ (Pa.s).

*Terbitkan formula untuk* $v_s$ *(kaki/min) sebagai fungsi* g *($m/s^2$),* $\rho_s$ *($lb/kaki^3$),* ρ *($lb/kaki^3$),* d *(kaki) dan* μ *(Pa.s).*

*[13 marks/markah]*

[b] Biomass combustion is recognized as a serious threat to the environment. Table Q.2.[b]. shows the distribution of carbon containing compounds released to the atmosphere worldwide from all combustion sources as well as the portion coming from the biomass burning.

*Pembakaran biojisim diiktiraf sebagai ancaman yang serius kepada alam sekitar. Jadual S.2.[b]. menunjukkan taburan sebatian yang mengandungi karbon yang terlepaskan ke atmosfera di seluruh dunia daripada semua sumber pembakaran termasuk bahagian yang terhasil dari pembakaran biojisim.*

Table Q.2.[b].
*Jadual S.2.[b].*

| Compound<br>*Sebatian* | Metric Tons C, All Sources<br>*Tan Metrik C, kesemua sumber* | Metric Tons C, % from Biomass<br>*Tan Metrik C, % dari biojisim* |
|---|---|---|
| $CO_2$ | 8700 | 40 |
| CO | 1100 | 26 |
| $CH_4$ | 380 | 10 |

The numbers in the middle column reflect annual quantities of carbon released to the atmosphere in the indicated compounds; for example, 8700 metric tons of carbon ($8.7 \times 10^6$ kg C) was released in carbon dioxide. Determine:

*Nombor di lajur tengah menunjukkan kuantiti tahunan karbon yang terlepaskan ke atmosfera di dalam sebatian yang ditunjukkan; sebagai contoh, 8700 tan metrik karbon ($8.7 \times 10^6$ kg C) telah terlepaskan dari karbon dioksida. Tentukan:*

[i] the combined annual release (in metric tons) of all three species resulting from biomass combustion.

*gabungan pelepasan tahunan (dalam tan metrik) daripada ketiga-tiga spesis yang terhasil daripada pembakaran biojisim.*

[ii] the average molecular weight of the combined gases of all three species resulting from biomass combustion.

*berat molekul purata gas gabungan ketiga-tiga spesis yang terhasil daripada pembakaran biojisim.*

*[12 marks/markah]*

3.

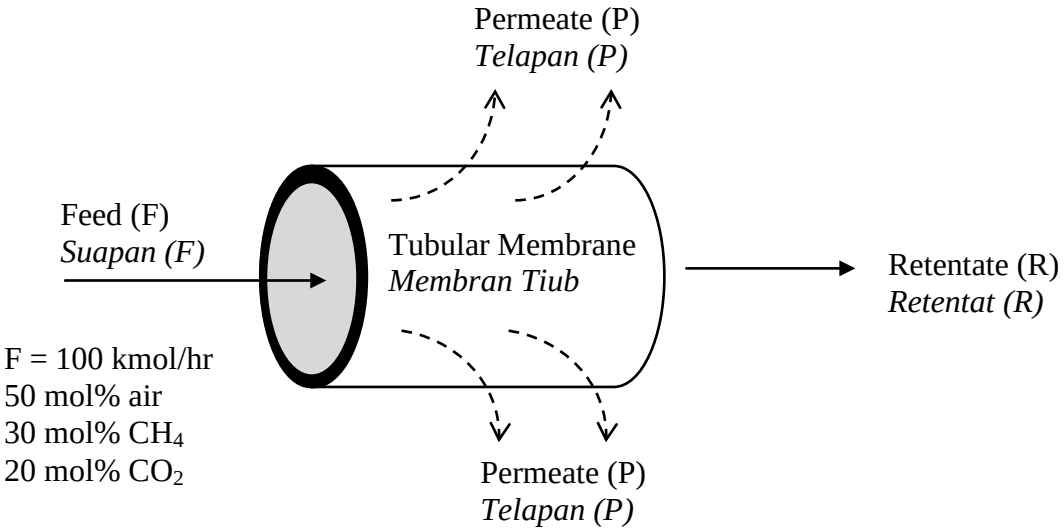


Figure Q.3.
*Rajah S.3.*

Figure Q.3. shows a tubular membrane used to separate $CO_2$ from a natural gas mixtures ($CO_2$, air and $CH_4$). The feed stream (F) enter the tubular membrane and goes out at the other end as the retentate stream (R). The gases being separated across the membrane goes out as the permeate stream (P). The membrane shall allow only $CO_2$ to diffuse across the membrane. However due to the molecule size of $O_2$ which very close to $CO_2$, it has been found out that some $O_2$ is also diffused across the membrane. Both the retentate and permeate streams is analysed and the data shows that 90% $CO_2$ and 20% $O_2$ diffuse across the membrane into the permeate stream. Calculate the gas composition in mole% and mass % in both retentate and permeate streams.

*Rajah S.3. menunjukkan satu membran tiub yang diguna untuk memisahkan $CO_2$ daripada campuran gas asli ($CO_2$, udara dan $CH_4$). Aliran suapan (F) memasuki membran tiub tersebut dan keluar pada sebelah hujung membran sebagai aliran retentat (R). Gas-gas yang dipisahkan merentasi membran tersebut dan keluar sebagai aliran telapan (P). Membran tersebut sepatutnya membenarkan $CO_2$ sahaja telap merentasinya.*

*Walaubagaimanapun, disebabkan saiz molekul $O_2$ dan $CO_2$ yang hampir sama, maka didapati terdapat sebahagian $O_2$ juga turut telap merentasi membran tersebut. Kedua-dua aliran telapan dan aliran retentan dianalisa dan data menunjukkan bahawa 90% $CO_2$ dan 20% $O_2$ telap merentasi membran ke aliran resapan. Kirakan komposisi dalam % mol dan % jisim bagi kedua-dua retentan dan aliran telapan.*

Given data :
*Diberi data:*

| | Molecular weight *Berat molekul* (kg/kmol) | Molecular size *Saiz molekul* (Å) |
|---|---|---|
| $O_2$ | 32 | 3.4 |
| $N_2$ | 28 | 3.6 |
| $CO_2$ | 44.01 | 3.3 |
| $CH_4$ | 16.04 | 3.8 |

*[15 marks/markah]*

4. Methane and oxygen react in the presence of a catalyst to form formaldehyde. In a parallel reactions, methane is oxidized to carbon dioxide and water as shown in the following reactions:

*Dengan adanya pemangkin, metana dan oksigen bertindak balas untuk membentuk formaldehid. Dalam tindak balas-tindak balas serentak, metana juga teroksida untuk menghasilkan karbon dioksida dan air seperti yang ditunjukkan oleh tindak balas-tindak balas berikut:*

$$CH_4 + O_2 \rightarrow HCHO + H_2O$$

$$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$$

The feed to the reactor contains equimolar amounts of methane and oxygen. The fractional conversion of methane is 0.9 and the fractional yield of formaldehyde is 0.855.

*Suapan yang memasuki reaktor mengandungi kandungan molar yang sama di antara metana dan oksigen. Pecahan penukaran metana ialah 0.9 dan pecahan hasil formaldehid ialan 0.855.*

[a] Draw and label a flowchart for the process.
*Lukis dan labelkan carta aliran bagi proses tersebut.* *[3 marks/markah]*

[b] Use a degree-of-freedom analysis based on extents of reactions to determine how many process values must be specified for the remaining variables values to be calculated.

*Dengan menggunakan analisa "degree-of-freedom", berdasarkan tindak balas-tindak balas lanjutan, tentukan berapa bilangan nilai-nilai proses yang mesti ditentukan bagi mengira pembolehubah-pembolehubah yang selebihnya.*
*[5 marks/markah]*

…6/-

[c] Calculate the molar composition of the reaction output streams and the selectivity of formaldehyde production relative to carbon dioxide production.

*Kirakan komposisi molar bagi aliran-aliran hasil tindak balas dan kememilihan bagi penghasilan formaldehid berbanding dengan penghasilan karbon dioksida.*

Hint: Take the basis of feed to be 100 mol/s.
*Petunjuk: Gunakan 100 mol/s sebagai asas suapan.*

*[12 marks/markah]*

5. [a] What is an equation of state? At what conditions does the ideal gas equation provide the most accurate estimates?

*Apakah itu persamaan keadaan? Pada keadaan apakah persamaan gas unggul memberikan anggaran yang paling tepat? [3 marks/markah]*

[b] A process stream flowing at 35 kmol/h contains 15 mole% hydrogen and the remainder 1-butene. The stream pressure is 10.0 atm absolute, the temperature is 50°C, and the velocity is 150 m/min. Determine the diameter (in cm) of the pipe transporting this stream using Kay's rule.

*Suatu aliran proses yang mengalir pada 35 kmol/j mengandungi 15 mol% hidrogen dan bakinya 1-butena. Tekanan aliran tersebut ialah 10.0 atm mutlak, suhu ialah 50 °C, dan halaju ialah 150 m/min. Tentukan diameter (dalam sm) paip yang mengangkut aliran ini dengan menggunakan kaedah Kay. [12 marks/markah]*

[c] A quantity of liquid chloroform is placed in an open, transparent three liter flask and boiled long enough to purge all air from the vapor space. The flask is then sealed and allowed to equilibrate at 30 °C, at which chloroform has a vapor pressure of 243 mm Hg. Visual inspection shows 10 mL of liquid chloroform present. You may assume ideal gas behavior for the vapor in your calculation.

*Suatu kuantiti klorofom cecair dimasukkan ke dalam kelalang tiga liter yang lutsinar serta terbuka, dan dididih sehingga kesemua udara terkeluar dari ruang wap. Seterusnya, kelalang tersebut ditutup dan dibiarkan untuk mencapai keseimbangan pada 30 °C, di mana klorofom mempunyai tekanan wap sebanyak 243 mm Hg. Pemerhatian menunjukkan 10 mL klorofom cecair terdapat di dalam kelalang tersebut. Anggap wap bersifat gas unggul dalam pengiraan.*

[i] What is the pressure in the flask at equilibrium? Explain your answer.
*Apakah tekanan di dalam kelalang tersebut pada keadaan keseimbangan? Jelaskan jawapan anda.*

[ii] What is the total mass (in grams) of chloroform in the flask?
*Berapakah jumlah jisim klorofom (dalam gram) di dalam kelalang tersebut?*

[iii] What fraction of the mass is in the vapor phase at equilibrium?
*Apakah pecahan jisim yang hadir dalam fasa wap pada keadaan keseimbangan?* *[10 marks/markah]*

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