
UNIVERSITI SAINS MALAYSIA

First Semester Examination
2009/2010 Academic Session

November 2009

IEK 101 – Chemical Process Calculations
[Penghitungan Proses Kimia]

Duration: 3 hours
[Masa: 3 jam]

Please check that this examination paper consists of SEVEN pages of printed material before you begin the examination.

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

Instructions: Answer **FIVE** (5) questions. You may answer the questions either in Bahasa Malaysia or in English.

Arahan: Jawab **LIMA** (5) soalan. Anda dibenarkan menjawab soalan sama ada [untuk KBI] dalam Bahasa Malaysia atau Bahasa Inggeris.]

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

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

1. Convert the following to the desired units, given that $\rho_{\text{air}} = 1.27 \text{ kg/m}^3$; $MW_{\text{air}} = 29 \text{ g/gmol}$; the density of water at 4°C is 1000 kg/m^3 and $g = 32.174 \text{ ft/s}^2$:
- 23.3 mi/h to m/s
 - 3.2 N/m^2 to lb_f/ft^2 (at the surface of the earth)
 - 15.2 J to Btu
 - 1.23 kW to J/s
 - 245 g to lb_m
 - 56.7 L to ft^3
 - 12 g/L to lb_m/ft^3
 - $44.4 \text{ lb}_m/\text{in}^2$ to kg/cm^2
 - 788 lbmol NaCl to g
 - 66 gmol NaCl to lbmol
 - 56 lb NaCl to gmol
 - 0.12 g NaCl to lbmol
 - 16.2 ppm NH_3 to mg/L
 - sp. gr. CH_4 (g) = $0.5537(20^\circ\text{C}/4^\circ\text{C})$ to lb_m/ft^3
 - $15 \text{ lb}_m/(\text{ft})(\text{s})$ to $\text{kg}/(\text{m})(\text{min})$
 - $4.5 \text{ lb}_m/\text{ft}^3$ to kg/m^3
 - 1.00 lb_f to N
 - $84.5 \text{ lb}_f/\text{ft}^2$ to Pa (at the surface of the earth)
 - $72 \text{ U.S.gal}/\text{in}^2$ to mL/mm^2
 - 1.0 N to lb_f

(20 marks)

2. A solution composed of 50% ethanol, 10% methanol, and 40% water is fed at the rate of 100 kg/h into a separator that produces one stream at the rate of 60 kg/h with the composition of 80% ethanol, 15% methanol, and 5% water, and a second stream of unknown composition. Calculate the composition (in %) of the three compounds in the unknown stream and its flowrate in kg/h.

(20 marks)

3. A synthetic gas generated from coal has the following composition: CO_2 , 7.2%; CO , 24.3%; H_2 , 14.1%; CH_4 , 3.5%; N_2 , 50.9%. Assume that air has a composition as follows: N_2 , 79%; O_2 , 21%.

- Calculate the cubic feet of air necessary for complete combustion per cubic foot of synthetic gas at the same conditions.
- If 38% excess air were used for combustion, what volume of flue gas at 750°F and 738 mm Hg would be produced per cubic foot of synthetic gas at standard conditions? Given $1 \text{ lbmol gas} = 359 \text{ ft}^3 \text{ gas at } 0^\circ\text{C and } 760 \text{ mm Hg}$.
- Calculate the flue gas analysis for parts (a) and (b).

(20 marks)

4. Determine Q , W , ΔU and ΔH for the isothermal expansion of 1.31 mol of an ideal gas against a constant external pressure of 1.05 atm. The initial conditions are: $T = 276$ K and $P_1 = 4.62$ atm; the final pressure is $P_2 = 2.21$ atm for the gas.
- (20 marks)
5. Use FIGURE 1 and/or the steam tables to answer the following questions.
- (a) What is the enthalpy change needed to change 1 kg of a water-steam mixture of 60% quality to one of 80% quality if the mixture is at 400 K?
- (b) Calculate the ΔH value for an isobaric (constant pressure) change of steam from 800 kPa and 500 K to saturated liquid.
- (c) Do the same for an isothermal change to saturated liquid.
- (d) Does an enthalpy change from saturated vapor, from 500 K to 370 K and 50 kPa, represent an enthalpy increase or decrease? The volume would increase or decrease?
- (e) In what state is water,
- (i) at 280 kPa and 400 K?
- (ii) at 480 kPa and 425 K?

(20 marks)

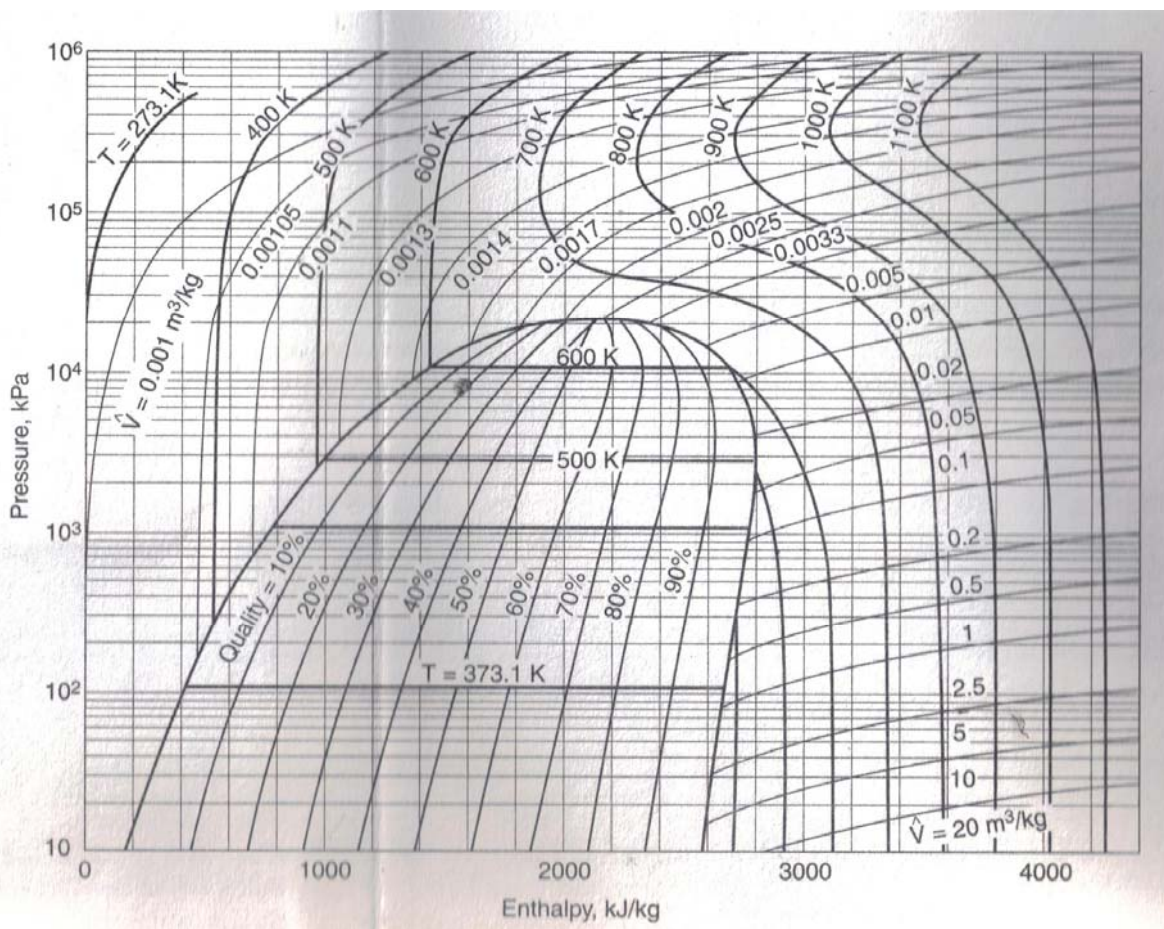


FIGURE 1 Chart of steam properties in SI units

6. You are asked to measure the rate at which waste gases are being discharged from a stack. The gases entering contain 2.1% carbon dioxide. Pure carbon dioxide is introduced into the bottom of the stack at a measured rate of 4.0 lb_m per minute. You measure the discharge of gases leaving the stack, and find the concentration of carbon dioxide is 3.2%. Calculate the rate of flow, in lbmol/min, of the entering waste gases.

(20 marks)

1. Tukar unit-unit di bawah ke unit yang dikehendaki. Diberi bahawa $\rho_{\text{udara}} = 1.27 \text{ kg/m}^3$; $MW_{\text{udara}} = 29 \text{ g/gmol}$; ketumpatan air pada 4°C ialah 1000 kg/m^3 dan $g = 32.174 \text{ ft/s}^2$:

- (a) 23.3 mi/h to m/s
- (b) 3.2 N/m^2 to lb_f/ft^2 (at the surface of the earth)
- (c) 15.2 J to Btu
- (d) 1.23 kW to J/s
- (e) 245 g to lb_m
- (f) 56.7 L to ft^3
- (g) 12 g/L to lb_m/ft^3
- (h) $44.4 \text{ lb}_m/\text{in}^2$ to kg/cm^2
- (i) 788 lbmol NaCl to g
- (j) 66 gmol NaCl to lbmol
- (k) 56 lb NaCl to gmol
- (l) 0.12 g NaCl to lbmol
- (m) 16.2 ppm NH_3 to mg/L
- (n) sp. gr. CH_4 (g) = $0.5537(20^\circ\text{C}/4^\circ\text{C})$ to lb_m/ft^3
- (o) $15 \text{ lb}_m/(\text{ft})(\text{s})$ to $\text{kg}/(\text{m})(\text{min})$
- (p) $4.5 \text{ lb}_m/\text{ft}^3$ to kg/m^3
- (q) 1.00 lb_f to N
- (r) $84.5 \text{ lb}_f/\text{ft}^2$ to Pa (at the surface of the earth)
- (s) 72 U.S.gal/ in^2 to mL/mm^2
- (t) 1.0 N to lb_f

(20 marks)

2. Satu larutan yang terdiri daripada 50% etanol, 10% metanol dan 40% air dimasukkan pada kadar 100 kg/h ke dalam suatu pemisah dengan dua aliran keluar. Aliran pertama keluar pada kadar 60 kg/h dengan komposisi 80% etanol, 15% metanol dan 5% air. Komposisi aliran keluar yang kedua tidak diketahui. Kira komposisi (dalam %) ketiga-tiga komponen dan kadar alir (dalam unit kg/h) aliran kedua.

(20 markah)

3. Satu gas sintetik yang terhasil daripada arang mempunyai komposisi yang berikut: CO_2 , 7.2%; CO, 24.3%; H_2 , 14.1%; CH_4 , 3.5%; N_2 , 50.9%. Anggap udara mempunyai komposisi seperti berikut: N_2 , 79%; O_2 , 21%.

- (a) Hitung isipadu udara (ft^3) diperlukan untuk pembakaran yang lengkap untuk 1 ft^3 gas sintetik pada keadaan yang sama.
- (b) Jika sebanyak 38% udara lebihan telah digunakan dalam pembakaran, apakah isipadu gas yang terhasil pada 750°F dan 738 mm Hg untuk 1 ft^3 gas sintetik pada keadaan piawai? Diberi 1 lbmol gas = 359 ft^3 pada 0°C dan 760 mm Hg.
- (c) Hitung komposisi gas yang terhasil daripada pembakaran untuk bahagian (a) dan (b).

(20 markah)

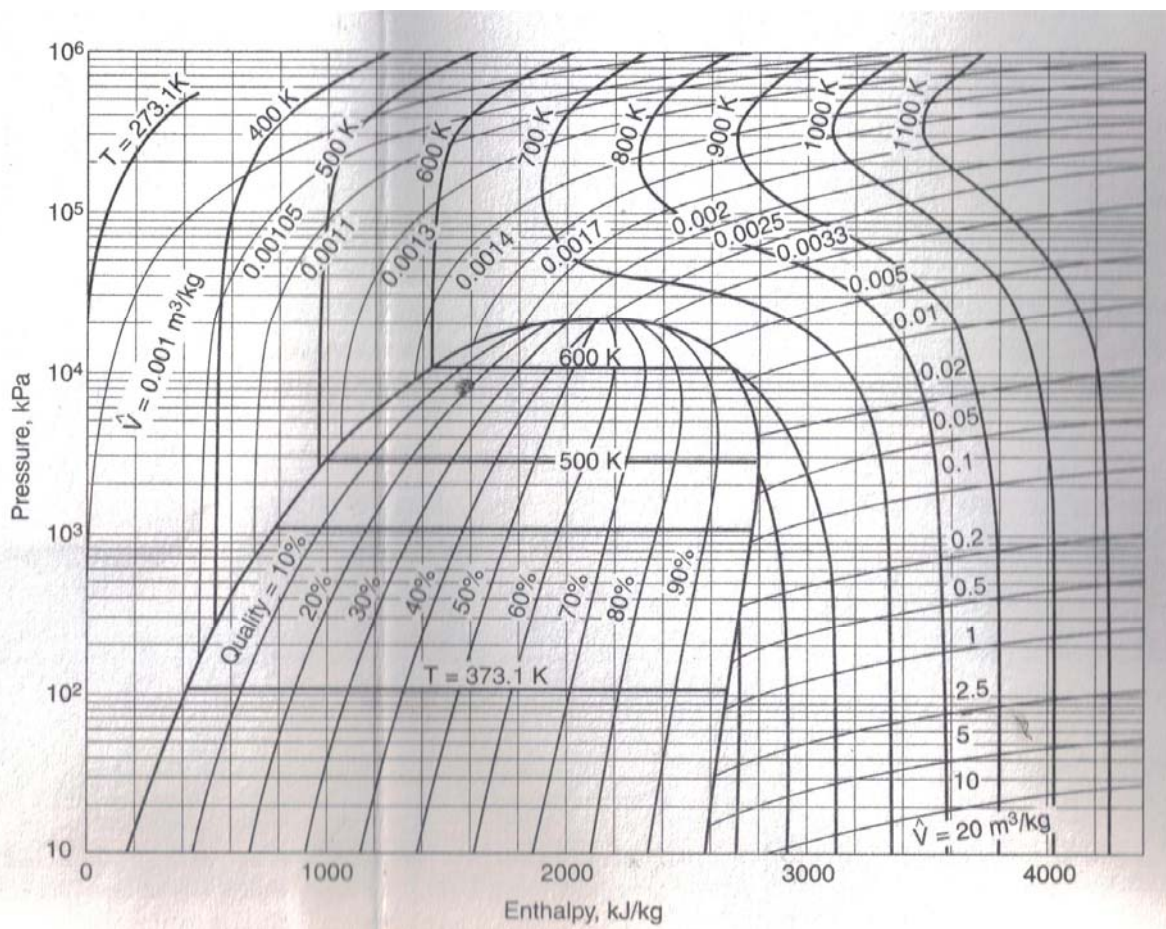
4. Tentukan Q , W , ΔU dan ΔH untuk pengembangan isoterma 1.31 mol suatu gas unggul yang dikenakan tekanan yang malar sebanyak 1.05 atm. Keadaan awal gas tersebut ialah: $T = 276\text{ K}$ dan $P_1 = 4.62\text{ atm}$; tekanan akhir gas tersebut ialah $P_2 = 2.21\text{ atm}$.

(20 markah)

5. Guna RAJAH 1 dan/atau jadual stim untuk menjawab soalan-soalan di bawah.

- (a) Apakah perubahan entalpi yang diperlukan untuk menukar 1 kg campuran air-stim pada kualiti 60% ke 80% jika campuran tersebut bersuhu 400 K?
- (b) Kira nilai ΔH apabila stim, pada 800 kPa dan 500 K, bertukar ke cecair tepu pada keadaan isobarik (tekanan malar).
- (c) Laku yang sama seperti bahagian (b) pada keadaan isoterma.
- (d) Adakah perubahan entalpi gas tepu, daripada 500 K ke 370 K dan 50 kPa, menaik atau menurun? Adakah isipadunya naik atau turun?
- (e) Pada keadaan apakah air,
- (i) pada 280 kPa dan 400 K?
- (ii) pada 480 kPa dan 425 K?

(20 markah)



RAJAH 1 Carta ciri-ciri stim dalam unit SI

6. Anda diminta memantau kadar gas sisa dikeluarkan dari suatu cerobong. Gas yang memasuki proses tersebut mengandungi 2.1% karbon dioksida. Karbon dioksida yang tulen dialirkan masuk di bawah cerobong tersebut pada kadar 4.0 lb_m setiap minit. Apabila anda mengukur gas sisa yang keluar tersebut, anda mendapati bahawa kepekatan karbon dioksida ialah 3.2%. Hitung kadar alir dalam lbmol/min gas sisa yang masuk.

(20 markah)