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 ρ_{air} = 1.27 kg/m^3; MW_{air} = 29 g/gmol; the density of water at 4 ^oC is 1000 kg/m^3 and g = 32.174 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 lb_m/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^{o}C/4^{o}C) to lb_m/ft^3
   (o) 15 lb_m/(ft)(s) to kg/(m)(min)
   (p) 4.5 lb_m/ft^3 to kg/m^3
   (q) 1.00 lb_f to N
   (r) 84.5 lb_f/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. 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%.

   (a) Calculate the cubic feet of air necessary for complete combustion per cubic foot of synthetic gas at the same conditions.

   (b) 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 lbmol gas = 359 ft^3 gas at 0 ^oC and 760 mm Hg.

   (c) Calculate the flue gas analysis for parts (a) and (b).

   (20 marks)

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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)

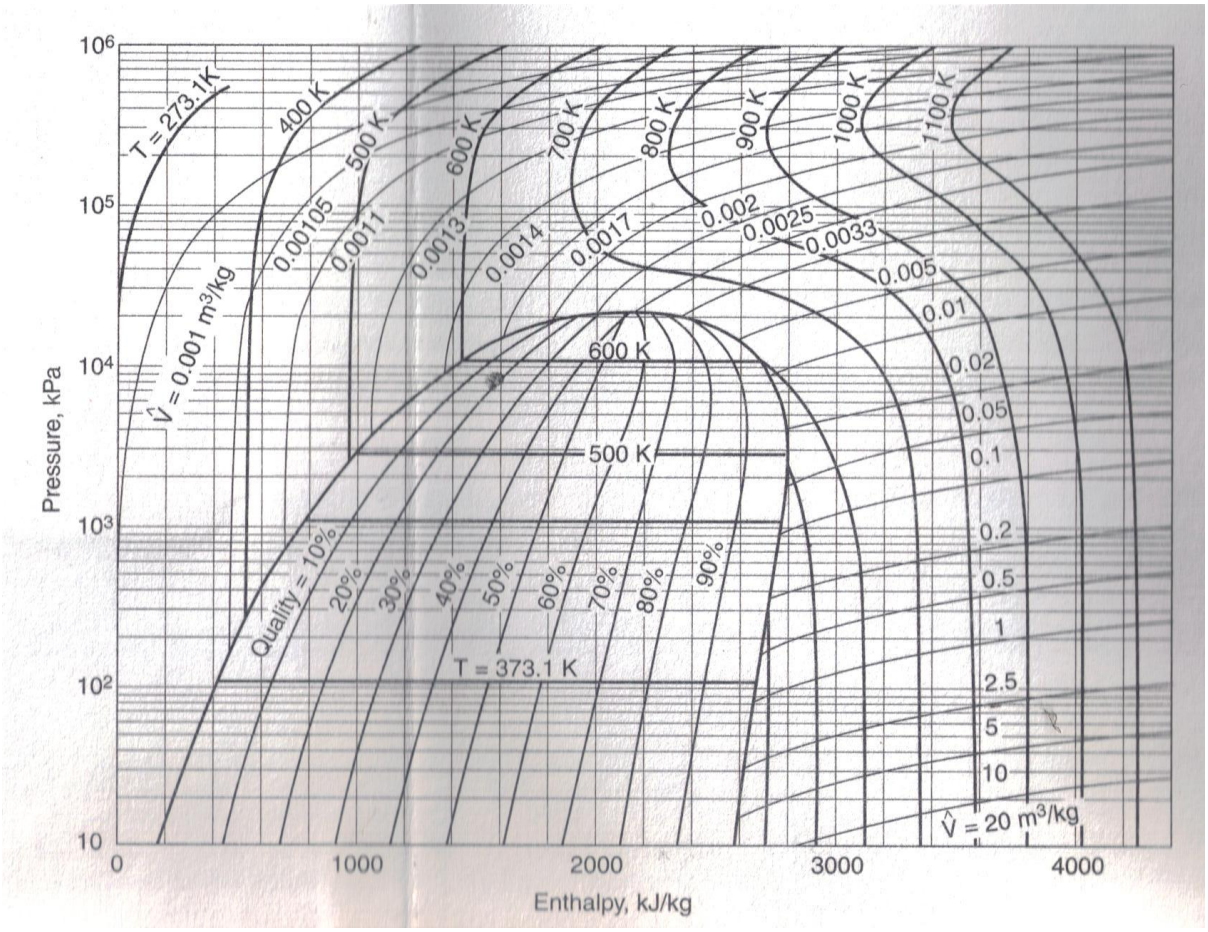


FIGURE 1 Chart of steam properties in SI units

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 ρ_{udara} = 1.27 kg/m^3; MW_{udara} = 29 g/gmol; ketumpatan air pada 4 ^oC ialah 1000 kg/m^3 dan g = 32.174 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 lb$_m$/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^oC/4^oC) to lb$_m$/ft^3
   (o) 15 lb$_m$/(ft)(s) to kg/(m)(min)
   (p) 4.5 lb$_m$/ft^3 to kg/m^3
   (q) 1.00 lb$_f$ to N
   (r) 84.5 lb$_f$/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 ^oF dan 738 mm Hg untuk 1 ft^3 gas sintetik pada keadaan piawai? Diberi 1 lbmol gas = 359 ft^3 pada 0 ^oC dan 760 mm Hg.

   (c) Hitung komposisi gas yang terhasil daripada pembakaran untuk bahagian (a) dan (b).

   (20 markah)

…6/-

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 K dan P_1 = 4.62 atm; tekanan akhir gas tersebut ialah P_2 = 2.21 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).*

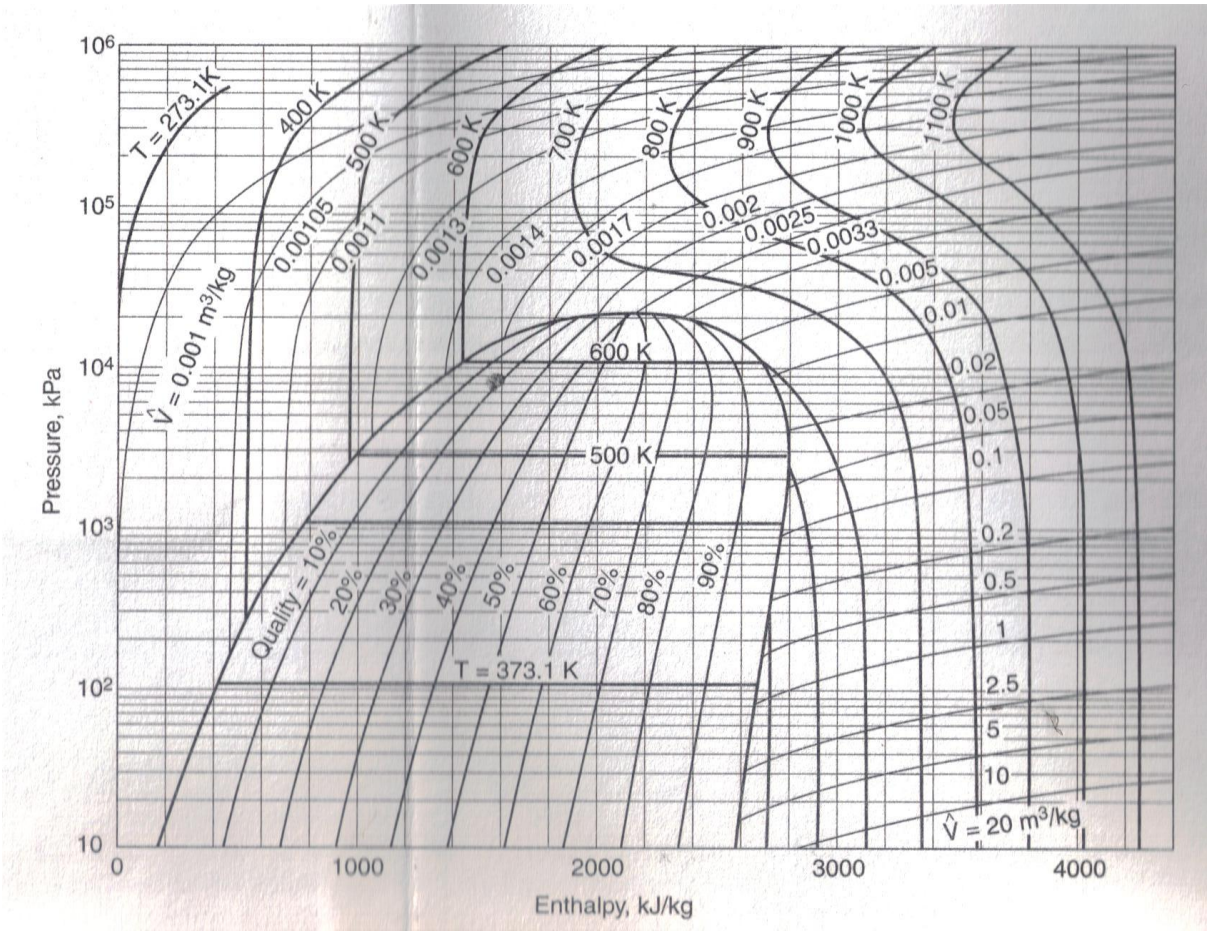
   (c) *Laku yang sama seperti bahagian (b) pada keadaan isoterma.*

   (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)

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