



Third year

January, 2013

Biochemical Engineering

CH 334

هندسة الكيمياء الحيوية

Time allowed: 180 minutes

الزمن : ١٨٠ دقيقة

Answer all questions

Question (1) (10 marks)

1. Determination of K_m and v_{max} Initial rates of an enzyme catalyzed reaction for various substrate concentration are listed in Table

s, mol/L	4.1×10^{-3}	9.5×10^{-4}	5.2×10^{-4}	1.03×10^{-4}	4.9×10^{-5}	1.06×10^{-5}	5.1×10^{-6}
v, mol/(L.min.) $\times 10^6$	177	173	125	106	80	67	43

- (a) Evaluate v_{max} and K_m by a Lineweaver-Burk plot.
(b) Using an Edie-Hofstee plot, evaluate v_{max} and K_m .
2. Batch enzymic reaction. An enzyme with a K_m of 1×10^{-3} M was assayed using an initial substrate concentration of 3×10^{-5} M. after 2 minutes, 5 percent of the substrate was converted. When will substrate will be converted 80%?

Question (2) (20 marks)

1. Consider a 0.5 L unstirred aerated chemostat with 10 offices mounted in the bottom. If each is 1 mm in diameter and has an airflow rate of 5 mL/min, what specific cell growth rate will be maintained if oxygen is limiting? Neglect breakup and coalescence and assume the medium is sufficiently dilute for it to behave like pure water. Solubility of O_2 at 25°C = 1.26 mmol/l

$$\begin{aligned} \mu_{max} &= 0.5 \text{ h}^{-1} & K_s &= 0.1 \text{ mM} & \sigma &= 72 \frac{\text{g}}{\text{s}^2} & g &= 980 \frac{\text{cm}}{\text{s}^2} \\ \mu_{gas} &= 2 \times 10^{-4} \frac{\text{g}}{\text{cm.s}} & \mathcal{D} &= 0.5 \times 10^{-5} \frac{\text{cm}^2}{\text{s}} & \mu_{liq} &= 10^{-2} \frac{\text{g}}{\text{cm.s}} \\ \rho_{gas} &= 1.4 \text{ g/L} & H_L &= 10 \text{ cm} & Y_{O/X} &= 1 \frac{\text{g cell}}{\text{g } O_2} & x &= 1.0 \text{ g cells/L} \end{aligned}$$

2. Determine k_L for the following

Liquid volume = 10 L
Turbine impeller diameter = 10 cm
Vessel diameter 50 cm
Average bubble diameter = 2 mm
Speed (rpm) = 200
Air-medium binary diffusion coefficient = $0.5 \times 10^{-5} \text{ cm}^2/\text{s}$
Air flowrate = 2 L/min
Medium density = 1.2 g/cm³
Medium viscosity = 0.01 g/(cm.s)

Question (3) (20 marks)

1. Data from an unseeded domestic wastewater BOD Test are 5.0 ml of wastewater in a 300-ml bottle, initial DO of 7.8 mg/L, and five-day DO equal to 4.3 mg/L. Compute
- The BOD, and
 - The ultimate BO, assuming a k-rate of 0.10 per day.
2. A seeded BOD test is to be conducted on meat-processing wastewater. Calculate the BOD value for industrial wastewater if the initial DO in both seed and sample bottle is 8.5 mg/L. and the five-day DO's are 4.5 mg/L. and 3.5 mg/L. for the seed test bottle and seeded wastewater sample respectively, if a sample of 2 ml wastewater is utilized in 300 ml BOD test bottle and 10 ml seeded wastewater containing 1 ml seed.
3. Calculate COD of a sample of water if 20 mL of the sample consumed 1.6 mL of 0.25 N potassium dichromate solution
4. In COD test, 100 ml of FAS was consumed to neutralize a refluxed blank, whereas 25 ml were consumed to neutralize the refluxed sample, if FAS was 0.1 N, calculate the COD of 25 ml sample.

Question (4) (20 marks)

1. Show with the aim of neat sketch

- Typical gram-negative bacterium (E. coli).
- Cell-division cycle of a typical yeast
- Replication of a virulent bacteriophage
- Relationships between input agitation intensity and resultant gas transfer rate

2. Discuss briefly

- Oxygen transport resistance
- Gas transfer through gas-liquid free surfaces plays a major role in oxygen supply and CO₂ removal from animal cell cultures.
- The probability of bubble coalescence depends on the properties of the gas-liquid interface

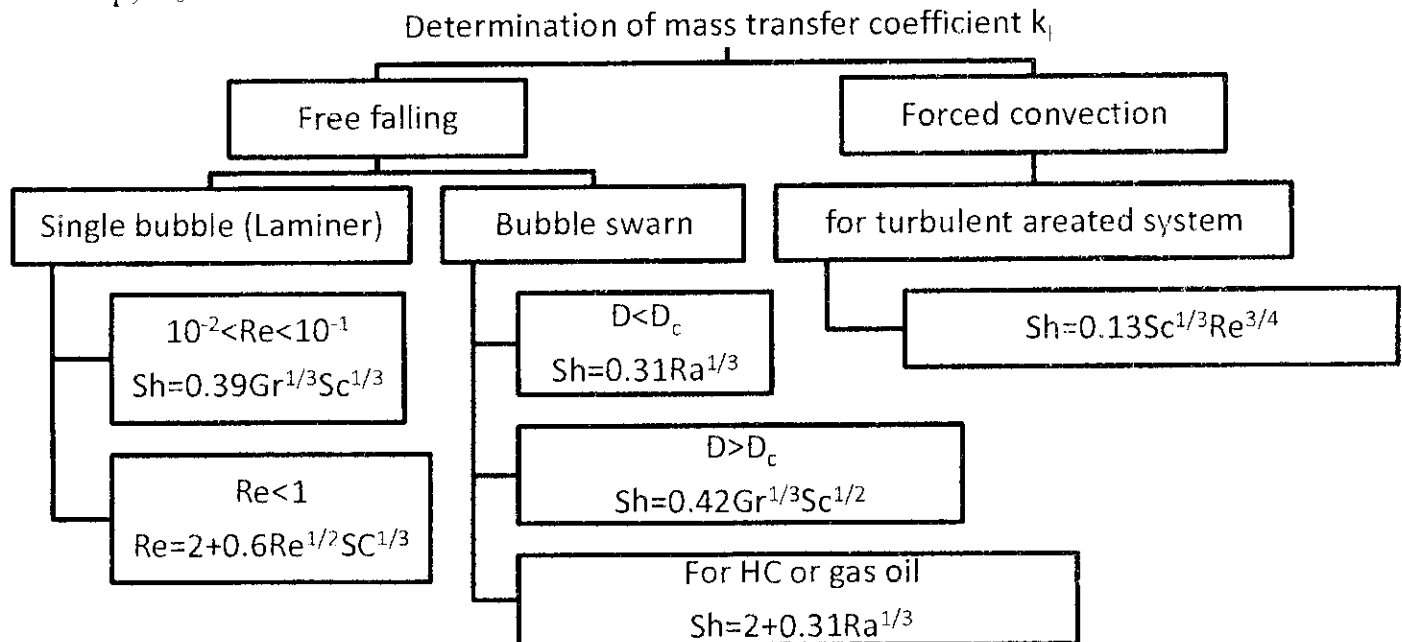
3. What are the factors

- Responsible for the thickness of the mass-transfer resistance zone near bubble and droplet surfaces
- That interact to determine the size of bubbles in bioreactors
- Influencing the total microbial oxygen demand

Supplementary

No break up; $D_0 = \left(\frac{6da}{\Delta \rho g} \right)^{\frac{1}{3}}$

Break up; $D_0 = 4.27d$



$$c_l = c_l^* \left[\frac{Y_{O_2} K_{O_2} k_l a' / X \mu_{max}}{1 - Y_{O_2} c_l^* k_l a' / X \mu_{max}} \right]$$

$$Y_{O_2} k_l a' (c_l^* - c_l) = X \mu_{max} \frac{c_l}{K_{O_2} + c_l}$$

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امتحان الفصل الدراسي الأول يناير 2013

ملاحظات :

- 1- اجب عن جميع الأسئلة التالية.
 - 2- دعم إجابتك بالرسومات الدقيقة للحصول على الدرجة كاملة.
 - 3- للإجابة بطريقة هندسية تقدير خاص عند تقييم الإجابة.
 - 4- عند احتياجك لأي بيانات غير موجودة افرضها بقيمة معقولة وللغرض المعقول تقدير خاص.
 - 5- الامتحان يقع في صفحة واحدة .
- الممتحن الأستاذ الدكتور / إبراهيم أحمد سالم منصور.

السؤال الأول:

مادة عضوية يتم انتاجها بالنظام الدفعي، حيث لا يتم الحصول على أى منتج حتى تتم الدورة تماما. وكل دورة تتألف من الزمن اللازم لاتمام التفاعل، إضافة إلى زمن مقداره (1.4) ساعة لتفريغ النواتج. أما زمن التشغيل لكل دورة فيرتبط بحجم الانتاج وفقا للتعبير التالي $(1.5P_b)^{0.25}$ ساعة. حيث (P_b) هي عدد الباوندات من المنتج النهائي الذى يتم انتاجه فى الدفعة الواحدة. فإذا كانت تكاليف التشغيل للمفاعل أثناء فترة التشغيل هي عشرون دولار للساعة التشغيلية الواحدة. أما تكاليف التفريغ فهي خمسة عشر دولارا لكل ساعة من ساعات التفريغ. وأما التكاليف الثابتة فهي بدورها تتوقف على حجم الدفعة وتساوى $(340)(P_b)^{0.8}$ دولار للدفعة الواحدة. وعند الضرورة يمكن تشغيل المصنع أربعة وعشرين ساعة كل يوم لمدة (300) يوم فى السنة الواحدة فيبلغ الانتاج السنوى مليون باوند من المنتج النهائي وعند معدل الانتاج هذا فإن باقى المصاريف الخاصة بالمواد الخام وبعض المصاريف الأخرى والتي لم يرد ذكرها فيما سبق تبلغ (260000) دولار، أحسب زمن الدورة الواحدة لأقل تكلفة سنوية.

السؤال الثانى:

المعادلة التالية تبين تأثير المتغيرين (y, x) على التكاليف الكلية لعملية صناعية ما.

$$C_T = 2.33x + \frac{11900}{xy} + 1.86y + 10$$

احسب قيم كل من (y, x) التى تعطى أقل تكلفة كلية.

السؤال الثالث:

مبادل حرارى تم تصميمه لاستخدامه فى إحدى العمليات الكيميائية وهو مبادل من النوع القياسى ثمنه (1000) دولار ويعمر لمدة ست سنوات وهناك أيضا مبادل حرارى مكافئ للمبادل الأول من حيث التصميم والإداء يتكلف (1500) دولار ولكنه يعمر لفترة مقدارها عشر سنوات وقيمة أنقاضه فى نهاية عمره التشغيلى هي (200) دولار فإذا كانت انقاص المبادل الأول تساوى صفر وان المال يستثمر بمعدل فائدة مقداره (5%) -احسب أى المبادلين أفضل على ضوء مبدأ رسالة التكاليف.

السؤال الرابع:

التكاليف الإبتدائية لبرج تقطير هي (24000) دولار وتقدر فترة حياته التشغيلية بـ (8) سنوات وسوف تستخدم طريقة الرصيد الموظف في حساب تكاليف التهلاك السنوية ومعدل الفائدة المؤثر لأرصدة التهلاك يساوى (4%) سنويا فإذا كانت قيمة انقراض برج التقطير هي (4000) دولار. احسب قيمة هذا البرج بعد خمس سنوات من بدء تشغيله.

السؤال الخامس:

شركة تنتج صابون يحتوى على (30%) من وزنه ماء بسعر مقداره (10) دولار أمريكى لكل مائة باوند من الصابون وتكاليف النقل تقع على عاتق المشتري (FOB) وهذا يعنى أن المغاسل المستهلكة لهذا الصابون يجب أن تدفع تكلفة النقل ولقد وجدت الشركة المنتجة لهذا الصابون أنه من الأفضل إنتاج صابون مكافئ للصابون السابق ولكنه يحتوى فقط على (5%) من وزنه ماء ويدهى أن الماء ليس ذى أهمية ما للمغاسل وسوف تقبل هذه المغاسل الصابون الذى يحتوى على (5%) ماء إذا كانت الكلفة فى النهاية تكافئ تكلفة الصابون فى النوع الآخر فإذا كانت التكلفة هي (0.7) دولار أمريكى لكل مائة (100) باوند فيكم يجب أن تبيع الشركة المنتجة كل (100) باوند من الصابون الجديد إذا ما أريد للمغاسل ألا تتحمل أى اعباء إضافية.

السؤال السادس:

ثمن شراء الأجهزة والمعدات لمصنع يصنع مواد صلبة هو (500,000) دولار أمريكى فإذا كان هذا الخط الإنتاجى سيقام كعملية توسيع لمصنع موجود فعلاً. أحسب رؤوس الأموال الكلية اللازمة للاستثمار وكذلك رؤوس الأموال الثابتة. أيضاً أحسب النسبة المئوية التى تمثلها كل من تكلفة الأرض وفئة التعاقد.

السؤال السابع:

- أ. قارن بين الأداء اللغوى والأداء المستمر فى الوحدات الصناعية الكيميائية.
- ب. ما هى أهم العوامل التى يجب أن تؤخذ فى الاعتبار عن اختيار موقع مصنع.
- ج. ما هو المقصود بالتكاليف الثابتة والتكاليف العام

ك. الحوي

Answer the following 5 questions:-

1. It is required to dissolve copper scrap in 5 M H_2SO_4 containing 0.001 M CuSO_4 to produce CuSO_4 :
- (i) Prove that copper can not be dissolved in deaerated acid (without dissolved O_2) but can be dissolved in aerated acid (containing dissolved oxygen) with O_2 reduction ($\frac{1}{2}\text{O}_2 + 2\text{H}^+ + 2\text{e}^- = \text{H}_2\text{O}$)
- (ii) if the corrosion current density is 0.01 A/cm^2 , Calculate the daily rate of CuSO_4 production if the active area of the copper scrap is 5000 cm^2 , Show how i_{corr} can be determined experimentally.
- (iii) Suggest two different methods for increasing the rate of CuSO_4 production in the reactor.
- Data: $(e_0)_{\text{ox}}$ of $\text{Cu}/\text{Cu}^{++} = -0.38 \text{ V}$; $(e_0)_{\text{ox}}$ of $\text{O}_2/\text{H}_2\text{O} = -1.23 \text{ V}$
At. wt. of copper = 63

2. Give reasons for the following:-

- (i) in some environments sacrificial cathodic protection can not protect immersed steel structures and impressed current cathodic protection should be used to protect the structure.
- (ii) substances such as ZnCl_2 , NaNO_2 and Na_3PO_4 inhibit corrosion.
- (iii) Although metals such as Ni and Zn lie above H_2 in the e.m.s they can be deposited from aqueous solutions.
- (iv) Salts such as FeCl_3 and CuCl_2 are highly corrosive.

3. In a process of Zn plating of a Steel sheet (area = 250 cm^2) from a solution containing 0.25 M ZnSO_4 ($\text{pH} = 5$) using a soluble Zn anode a current density of 0.05 A/cm^2 was used:
- (i) if it is required to deposit a Zn layer of thickness 0.1 mm calculate the required time.
- (ii) calculate the energy consumption in K.W.h/Kg.

(iii) Show how to improve the energy efficiency of the Process.

Data: density of zinc = 7.14 g/cm^3 ; current efficiency of Zn deposition = 75% ; At. wt. of Zn = 65 ; $\eta_{\text{anode}} = 0.15 \text{ V}$, $\eta_{\text{cathode}} = 0.12 \text{ V}$; IR drop = 0.25 V . $(E_0)_{\text{ox of Zn} | \text{Zn}^{2+}} = 0.76 \text{ V}$

4. For a buried steel pipeline carrying fresh water:

(i) Write the cells responsible for internal and external corrosion and write the cell reactions.

(ii) Show how the pipeline can be protected against corrosion both internally and externally.

(iii) if the mass transfer coefficient of dissolved O_2 diffusion from the solution bulk to the internal wall is $5 \times 10^{-3} \text{ cm/s}$ Calculate the rate of corrosion of the inner wall in mm/y and Calculate the corrosion allowance if the lifetime of the Pipeline is 20 year.

data: Solubility of dissolved O_2 in water = 8 ppm at 25°C .

Steel density = 7.9 g/cm^3 .

At. wts: Fe = 56 ; O = 16

5. Write short notes on:-

(i) erosion-corrosion and how to avoid it.

(ii) crevice corrosion and how to avoid it.

(iii) electrochemical Passivity and its use in protecting metallic structures against corrosion.

(iv) Painting as a tool for corrosion prevention.

N.B: Assume reasonably any missing data

Ajay

Answer all questions.

I. Put true or false:

- i) Water is an almost universal solvent.
- ii) H_2O indicates that it is the combination of two volumes of oxygen and one volume of hydrogen.
- iii) Water purification satisfactory for municipal uses is frequently wholly suited for many industrial processes.
- iv) Modern combined units for clarification provide all steps in one unit.
- v) The pure alum contains 15.3% Al_2O_3 .
- vi) Ferric chloride is widely employed for sewage treatment.
- vii) Ferric sulfate coagulant does not require the addition of hydrated lime to complete the reaction.
- viii) Sodium aluminate has an acid character.
- ix) When granular beds of carbon are employed for dechlorination, regeneration process is required.
- x) Lime/Soda softening is applied to water containing non-carbonate hardness.
- xi) The solubility of $CaCO_3$ increases with increase of temperature.
- xii) In lime softening, presence of magnesium bicarbonate or sodium bicarbonate results in the reduction of the solubility of $CaCO_3$.
- xiii) In hot lime softening, the precipitated calcium and magnesium have higher solubilities.
- xiv) In hot lime softening, significant silica reduction can be achieved.
- xv) In ion exchange softening, the ions are removed in equivalent amounts.
- xvi) Regeneration of ion exchange materials by sea water is practical for small installations.

II. Complete the following statements:

- i) Hard water is obtained from areas where or is abundant.
- ii) Carbonate hardness (at one time identified as Hardness) represents bicarbonates of and.....
- iii) Caustic soda is known to attack steel resulting in the characteristic cracking known as
- iv) Jar testing can provide data on and
- v) The rate of settling of solid particles in water depends upon and
- vi) $\text{Al}_2(\text{SO}_4)_3 + 3 \text{Ca}(\text{HCO}_3)_2 \rightarrow \dots\dots\dots$
- vii) $2 \text{NaAlO}_2 + \text{CO}_2 + 3 \text{H}_2\text{O} \rightarrow \dots\dots\dots$
- viii) As the temperature is lowered, the dosage of chemical for coagulation must be
- ix) Powdered activated carbon is used when In this process the efficiency is And the capital cost is
- x) $\text{Mg}(\text{HCO}_3)_2 + 2 \text{Ca}(\text{OH})_2 \rightarrow \dots\dots\dots$
- xi) $\text{MgCl}_2 + \text{Na}_2\text{R} \rightarrow \dots\dots\dots$
- xii) Sodium chloride and not potassium chloride is used in regeneration of cation exchange materials because and
- xiii) The items which influence the salt consumed in regeneration of ion exchange materials depend upon and
- xiv) Backwashing of ion exchange materials is done to also to

III. Write short notes on the following:

- a) Sodium sulfide as an oxygen scavenger in steam generation systems.
- b) Neutralizing inhibitors to control after boiler section corrosion
- c) Chemistry of deposit formation in steam generating systems.

IV.

- a) For the removal of calcium hardness by lime softening, what lime dosage (purity : 77% CaO) is required to treat water containing 80 mg/L calcium?
- b) Water with alkalinity of 22 mg / L as CaCO_3 will be treated with the lime-alum coagulation. Alum dosage is 99 mg / L. Determine the lime dosage needed to react with alum.

V. Write briefly on the following:

- a) EDTA as antiscalant in steam generating systems.
- b) Effect of carbon dioxide, hydrogen sulfide and chlorine on the degree of corrosion of steel in cooling water systems.
- c) Effect of temperature on the extent of corrosion in cooling water systems.

H : 1 , O : 16 , Al : 27 , S : 32 , Ca : 40



Modeling and Simulation in Chemical Engineering [CH 311]
النمذجة و المحاكاة في الهندسة الكيميائية

Time Allowed: 3 hours.
زمن الامتحان : 3 ساعات

Answer the following questions:

1-Consider a liquid flow system consisting of a sealed tank with noncondensable gas above the liquid as shown in Fig.1. Derive an unsteady-state model relating the liquid level h to the input flow rate q_1 . You may make the following assumptions:

- (i) The operation of the system is independent of the ambient pressure P_a .
- (ii) The gas obeys the ideal gas law. A constant amount of moles of gas are present in the tank.
- (iii) The operation is isothermal.
- (iv) The flow through the valve is given by: $q = C_v \sqrt{P_g + \frac{\rho g h}{g_c} - P_a}$

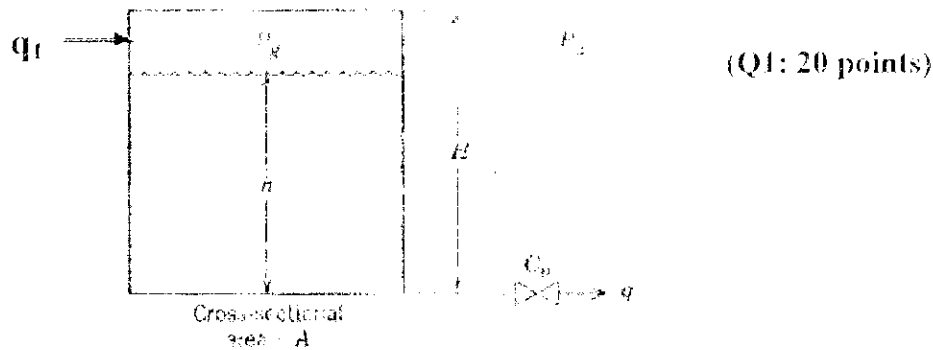


Figure 1: The sealed tank in Problem 1

- 2- A gravity-flow tank system is shown in Figure2. Let L be the length of the exit line and its cross-sectional area be A_{pipe} . The vertical, cylindrical tank has a cross-sectional area of A_{tank} . Assuming turbulent flow conditions, write a model to describe how the level of the tank varies with time. For turbulent flow conditions, the frictional force will be proportional to the square of the velocity and the length of the pipe (Frictional force = $K_F L v^2$).

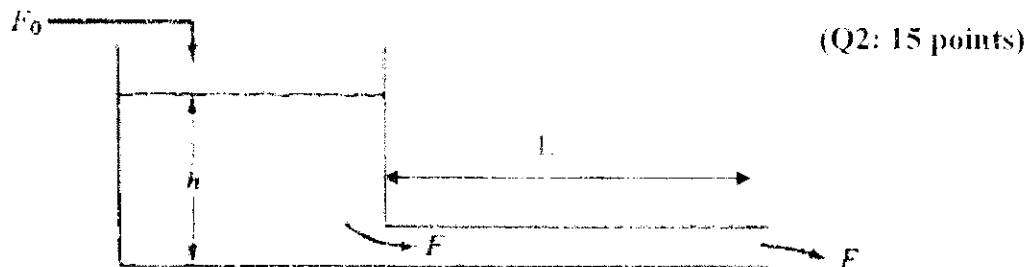
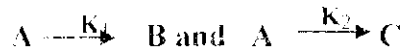


Figure 2: Gravity-Flow tank in Problem 2

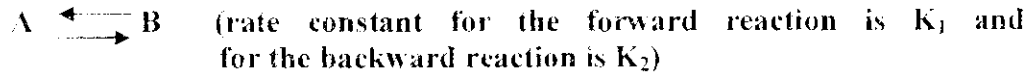
3- Write the component continuity equations for a perfectly mixed batch reactor (NO INFLOW OR OUTFLOW) with first-order isothermal reactions in the two cases outlined below:

(i) Simultaneous reactions

(Q3: 20 points)



(ii) Reversible reaction



STATE all assumptions.

4- Starting with the interval $[a_0, b_0]$ given below, use the bisection method to find AN INTERVAL OF WIDTH 0.05 that contains a solution of the given equation.

$$\exp(x) - 2 - x = 0 \quad [-2.4, -1.6]$$

(Q4: 20 points)

5- The equation given below results from an energy balance in a slab with heat generation (q).

$$-k \frac{d^2 T}{dx^2} = q$$

(Q5: 20 points)

(a) What do you need to do to be able to solve this second order equation using Euler's method?

YOU ARE REQUIRED TO GIVE A SHORT ANSWER DESCRIBING THE STEPS

(b) Use Euler's method ($h=0.1$) to find x_1, y_1 and x_2, y_2 to the system of differential equations:

$$\frac{dx}{dt} = 3x - y$$

$$\frac{dy}{dt} = 4x - y$$

$$\text{with } x_0=2 \text{ and } y_0=3$$

6- The Redlich-Kwong equation of state is given by:

$$P = \frac{RT}{(V-b)} - \frac{a}{V(V+b)\sqrt{T}}$$

(Q6: 10 points)

It is required to find the molar volume of a gas using this equation at a defined pressure P and temperature T .

(a and b are known constants.)

(a) Explain briefly how you can solve this equation numerically. Choose one (only one) method.

YOU ARE NOT REQUIRED TO SOLVE THE EQUATION!

Just propose a method and give a short and CLEAR answer.

(c) Propose a method to determine your initial guess.

(d) When will you end your iteration.

Separation Processes I
Time allowed: 3 hour

عمليات الفصل I
الزمن: ثلاث ساعات

Answer the Following Questions:

Question -1.

A benzene-toluene mixture at its bubble point containing 50 mol % benzene is to be continuously rectified at atmospheric pressure to produce a distillate containing 95 % benzene. Ninety five percent of the benzene in the feed must be recovered, with a partial re-boiler and total condenser, calculate:

- Minimum reflux ratio.
- The moles of bottom product (B) and its composition (X_B), using a reflux ratio of twice the minimum.
- The number of the actual plates if the overall efficiency is 60 %
- The minimum number of plates.
- The composition of vapor leaving the third plate from the top

Equilibrium data in mole fraction benzene at 101.3 kPa

x	0.21	0.37	0.51	0.64	0.72	0.79	0.86	0.91	0.96	0.98
y	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95

Question -2

A forward feed double effect evaporator is fed with 2.5 kg /s of a liquor containing 15 % solid to be concentrate to 55 % solid. The operating pressure in the second effect is 18 kN/m². The boiling point rise of the concentrated liquor in the second effect is 6 K. The overall heat transfer coefficients in the first and second effects are 1.8 and 0.63 kW/m².K, Determine:

- The boiling point of the solution in the first and the second effect.
- Steam consumption if it is assumed to loss only its latent heat
- The rate of evaporation in the first and the second effect
- The concentration of the liquor from the first effect
- The overall steam economy
- The heat transfer area in each effect

Given:

- The saturation temperature of water (boiling point) at 18 kN/m² is 331 K
- Steam temperature is 412 K
- Specific heat capacity for all solutions is 4.2 kJ/kg.K
- Feed temperature is 300 K
- The latent heat of vaporization in the first and the second effect are 2280 and 2320 kJ/kg respectively while for steam its latent heat may be taken as 2200 kJ/kg.

Question -3

1000 kg/h of 26 wt % ethylene glycol (A) in – water (C) solution is to be extracted at 25 °C in a two countercurrent stages with pure furfural (S) to obtain a raffinate containing 5 wt % ethylene glycol. Using the equilibrium diagram shown in Figure 1, determine:

- The minimum flow rate of solvent (S^{\min}).
 - The flow rates and the compositions of the extract leaving the first stage (E_1) and the raffinate leaving the final stage (R_n) if $S^{\text{actual}} = 2.26 S^{\min}$.
 - The number of ideal stages in the column
-

Question -4

State whether the following statements are true or false

1. The number of theoretical stages in liquid-liquid extraction increases as the solute concentration in the final raffinate decreases.
2. The capital cost of the backward feed multi-effect evaporators is higher than that of forward feed units.
3. For distillation of a cold liquid feed, the number of plates in the rectifying section is lower than that in the stripping section
4. The number of stages in liquid-liquid extraction increases as the solute concentration in the final raffinate increases.
5. In multi-effect evaporators, the pressure in the last effect is higher than that in the first effect.
6. In the distillation operation, the slope of the q-line for saturated liquid is positive value while for sub-cooled liquid is negative value.
7. In the liquid-liquid extraction process, each phase consists of three components if the carrier and the extractive solvent is partially miscible.
8. The composition of vapor leaving the top of the distillation column equals the composition of the reflux stream if complete condensation takes place in the top condenser.
9. The minimum number of plates in a binary system distillation is highly affected by the thermal conditions of the feed.
10. The slope of the top operating line is at its minimum value at the condition of maximum reflux.

Question -5

- Explain the different factors that affect steam consumption in evaporators
- State the main factors affecting evaporator selection and the main problems arising during evaporation
- State the conditions under which liquid-liquid extraction is used and give three applications to the process
- With the aid of simple sketch, compare between forward and backward feed multi-effect evaporator unit

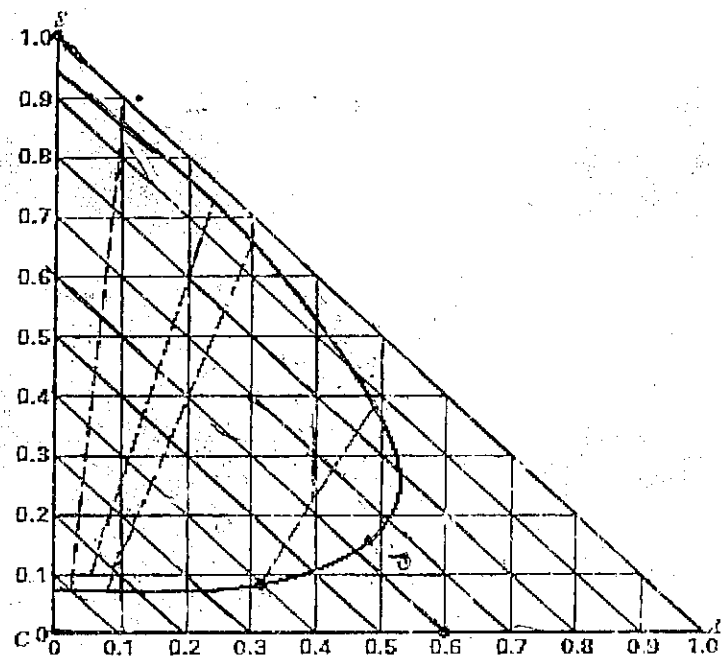
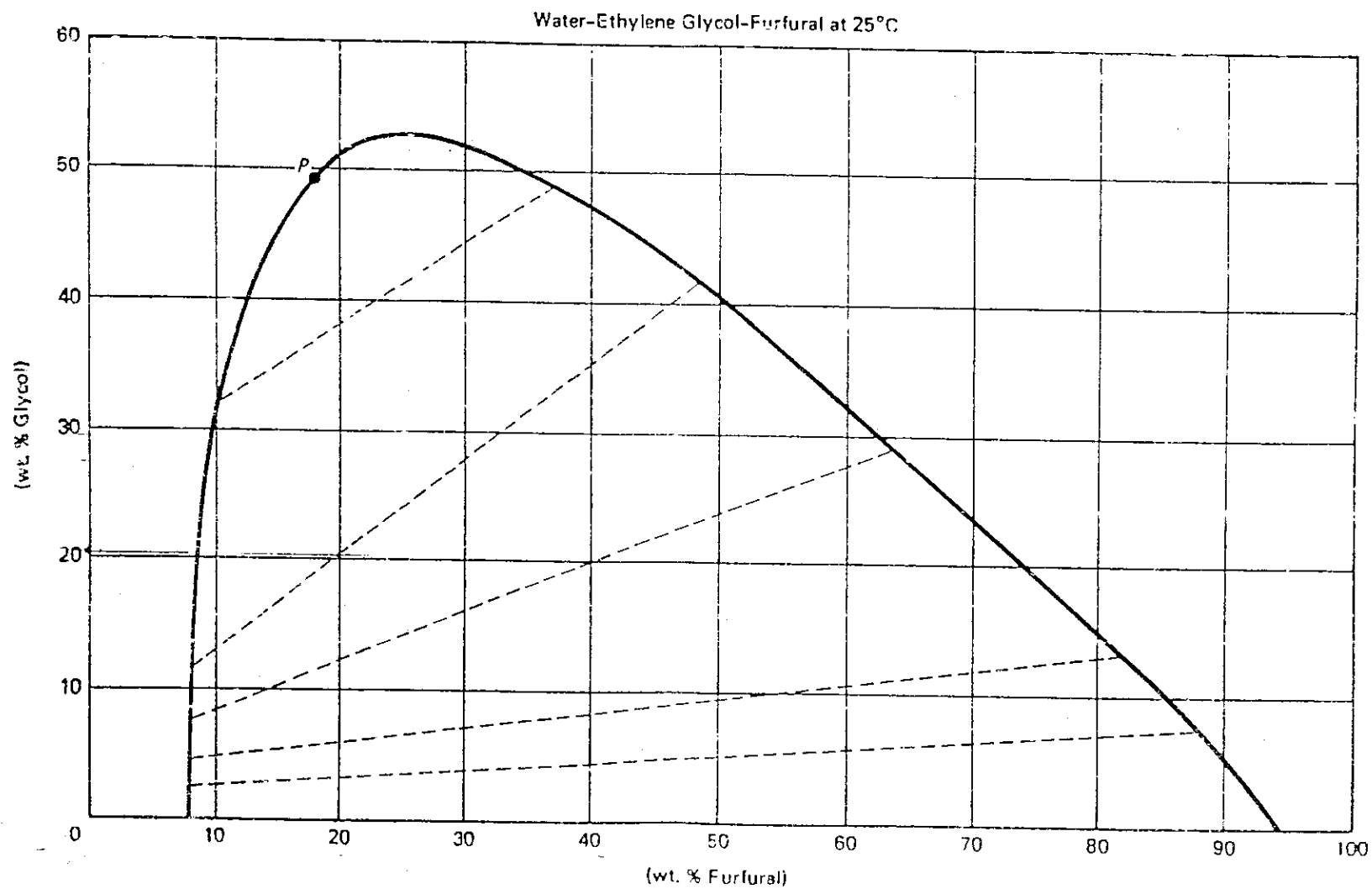


Fig. 1



Liquid-liquid equilibrium phase diagram for the water-ethylene glycol-furfural system at 25°C.