KATHMANDU UNIVERSITY
End Semester Examination
August, 2018

Marks scored:

Level : B.E.
Year : III
Course : CHEG 313
Semester: II

Exam Roll No. :
Time: 30 mins.
F. M. : 10

Registration No.:
Date AUG 19 2018

SECTION "A"

[20 Q × 0.5 = 10 marks]

Select the most appropriate answer

1. The use of activated carbon to remove pollutants from aqueous wastes is an example of
   a. Leaching b. Extraction c. Adsorption d. Absorption

2. The most common packing used in industrial operations is
   a. Raschig rings b. Lessing rings
   c. Single spiral rings d. Cross-partition rings

3. What is the reflux ratio at total reflux?
   a. Zero b. Unity c. Infinity d. One

4. The adsorption isotherm for a favorable isotherm is
   a. Linear b. Horizontal c. Convex upward d. Concave upward

5. When the feed to a distillation column is a saturated vapor, the slope of the feed line is
   a. Zero b. Unity c. Infinity d. Negative

6. To increase the absorption factor (V = gas flow rate, L = liquid flow rate)
   a. Increase both L and V b. Increase L and decrease V
   c. Decrease L and increase V d. Decrease both L and V

7. Relative humidity is the ratio of
   a. Partial pressure of the vapor to the vapor pressure of the liquid at room temperature
   b. Partial pressure of the vapor to the vapor pressure of the liquid at gas temperature
   c. Actual humidity to saturation humidity
   d. Partial pressure of the vapor to the partial pressure of vapor free gas

8. The term "cooling range" in a cooling tower refers to the difference in the temperature of
   a. Hot water entering the tower and cooled water leaving the tower
   b. Hot water entering the tower and the wet bulb temperature of the air
   c. Cold water entering the tower and the wet bulb temperature of the air
   d. None of these

9. Fenske equation determines the
   a. Height of the distillation column
   b. Maximum number of theoretical plates
   c. Minimum number of theoretical plates
   d. Minimum number of ideal plates

10. For equimolal diffusion in a stagnant film, what is the value of the mass transfer coefficient if the thickness of a stagnant layer is 5 mm and the molecular diffusivity is given to be 10^{-5} cm^2/s?
a. 2×10^{-5} b. 5×10^{-6} c. 5×10^{-5} d. 1×10^{-6}

11. A gas stream containing 5 percent of solute A is to be passed through a packed bed to remove 99 percent of A by absorption in water. If the gas and water flow rates are 10 $mol/h.ft^2$ and 50 $mol/h.ft^2$, what is the mole fraction of the solute in the exiting water?
a. 0.0059 b. 0.0099 c. 0.060 d. 0.089

12. The diffusivity of carbon dioxide through a 250 micron thick wall is given to be 2×10^{-5} cm^2/s. The concentration of the gas inside the wall is 5 mol/cm^3. If the concentration profile of the gas inside the bottle decreases linearly to zero at the outer surface of the bottle, what is the flux of the carbon dioxide diffusion neglecting convection contribution?
a. 5×10^{-5} $mol/cm^2.s$ b. 4×10^{-3} $mol/cm^2.s$
c. 2×10^{-4} $mol/cm^2.s$ d. 1×10^{-3} $mol/cm^2.s$

13. Under conditions of flooding in packed tower, the gas pressure drop is
a. Maximum b. Minimum c. Constant d. Increases rapidly

14. Which of the following parameter remains constant during chemical dehumidification?
a. Partial pressure of the vapour b. Dry bulb temperature
c. Wet bulb temperature d. None of these

15. Molecular diffusivity of a liquid
a. Increases with temperature
b. Decreases with temperature
c. Is independent of temperature
d. May increase or decrease with temperature

16. Dry bulb temperature of the gas is _____ than wet bulb temperature
a. Less than b. Equal to
c. More than d. May be less or more

17. Flash distillation is suitable for separating the constituents of a binary system which
a. Form minimum boiling azeotrope b. Have very wide boiling points
c. Have very close boiling points d. Form constant boiling azeotrope

18. If the overall efficiency and murphee plate efficiency are equal, then both the equilibrium and operating lines are
a. Straight b. Parallel c. Both a and b d. Neither a or b

19. Wet bulb and dry bulb temperature become identical at ___ percent saturation curves
a. 50 b. 75 c. 100 d. None

20. Which of the following provides maximum contact surface area for a liquid vapor system?
a. Sieve- plate column b. Wetted wall column
c. Packed tower d. Bubble-cap plate column

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SECTION "B"

Attempt *any FOUR* questions.

1. An open pan of diameter 0.2 m and height 80 mm (above water at 27 °C) is exposed to ambient air at 27 °C (Pressure = 1 atm) and 25% relative humidity. Determine
   a. The evaporation rate assuming only mass diffusion occurs. [5]
   b. The evaporation rate considering both diffusion and the bulk motion. [5]

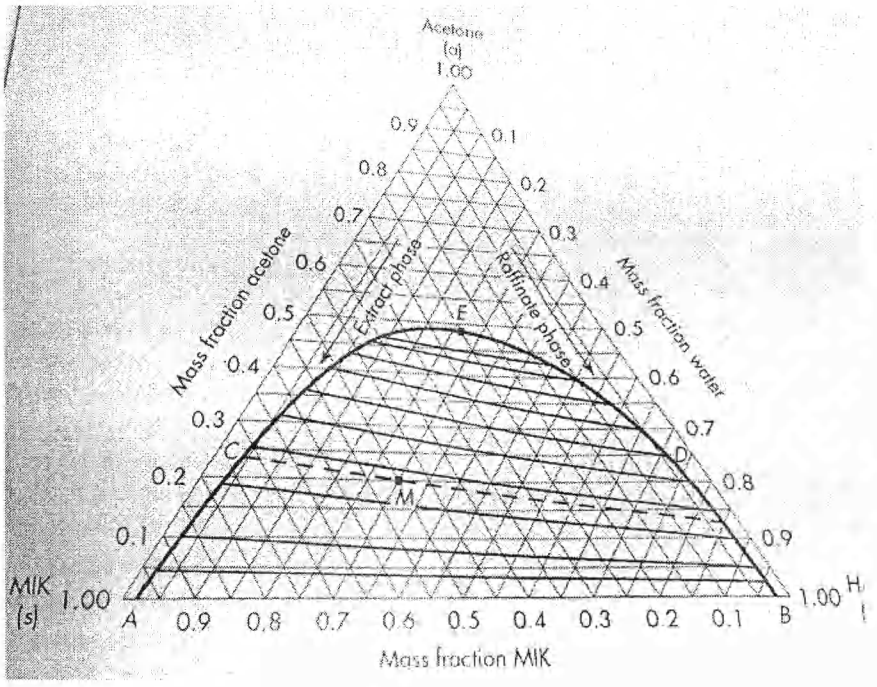
2. An absorber is to remove 99 percent of solute A from a gas stream containing 4 mol percent A. Solutions of A in the solvent follows Henry's law, and the temperature of the liquid can be neglected. Calculate
   a. N_{Oy} for operation at 1 atm using solute free liquid at a rate of 1.5 times the minimum value. [5]
   b. For the same liquid rate, calculate N_{Oy} for operation at 2 atm and at 4 atm. [5]

3. Fresh halibut livers containing 25.7% (weight percent) oil are to be extracted with pure ethyl ether to remove 95% of the oil in a countercurrent multistage leaching process. The feed rate is 1000 kg of the fresh liver per hour. The final exit overflow solution is to contain 70% by mass oil. The molar flow varies as follows.

Kg solution / kg inert solid	Kg oil / kg solution
0.205	0
0.286	0.2
0.405	0.4
0.599	0.6
0.719	0.81

Calculate the amount and compositions of the exit stream and the total number of theoretical stages. [10]

4. A mixture containing 40 weight percent acetone and 60 weight percent water is contacted with an equal amount of MIK.
   a. What fraction of the acetone can be extracted in a single stage process? [4]
   b. What fraction of the acetone could be extracted if the fresh solvent were divided into two parts and two successive extractions were used? [6]



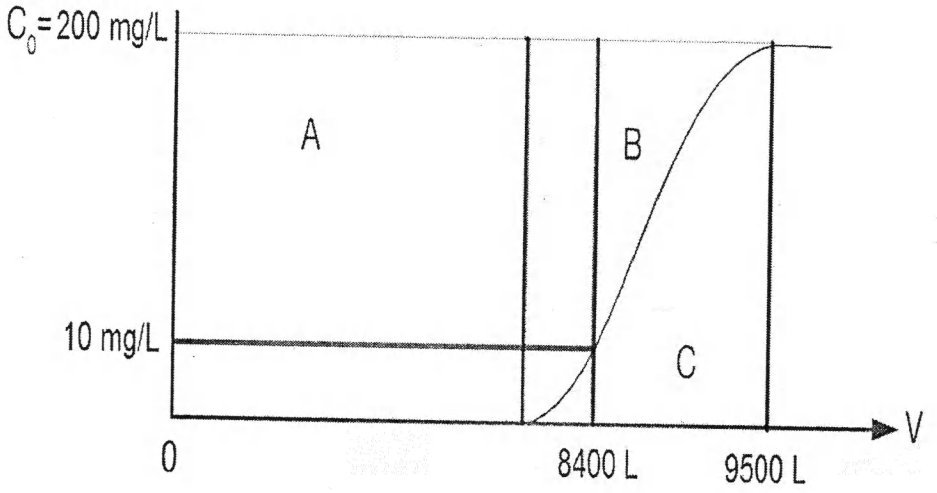
5. A continuous rectifying column handles a mixture consisting of 40 percent of benzene by mass and 60 percent of toluene by mass at the rate of 4 kg/s, and separates it into a product containing 97 percent of benzene by mass and a liquid containing 98 percent toluene by mass. The feed is liquid at its boiling point.

   a. Calculate the mass flow of distillate and waste liquor. [2]
   b. If a reflux ratio of 3.5 is employed, how many plates are required for the column? [2]
   c. What would be the minimum number of stages? [2]
   d. What would be the minimum reflux ratio? [2]
   e. If cooling water enters the condenser at 25 °C and 40 °C, how much cooling water is required in kg/hour? Given the latent heat of benzene and toluene is 7360 and 7960 cal/g mol respectively. [2]
   Molecular weight of benzene and toluene are 78 and 92 respectively. Show all the work on the equilibrium curve provided. The specific heat capacity of water is 1 cal/g mol.°C.

6. Packed adsorption columns are designed based on the scale up approach from the laboratory or pilot scale column. Usually a breakthrough curve is obtained from the laboratory experiment which is then used for scaling up.
An industrial wastewater having a TOC of 200 mg/L will be treated by GAC for a flow rate of 150 m^3/day. Allowable TOC in the effluent is 10 mg/L.

Pilot Plant Data:

Q = 50 L/hr
Column diameter = 9.5 cm
Column depth (packed bed) = 175 cm
Packed bed carbon density = 400 kg/m^3
$V_{breakthrough}$ = 8400 L
$V_{exhaustion}$ = 9500 L (Exhaustion is saturation)

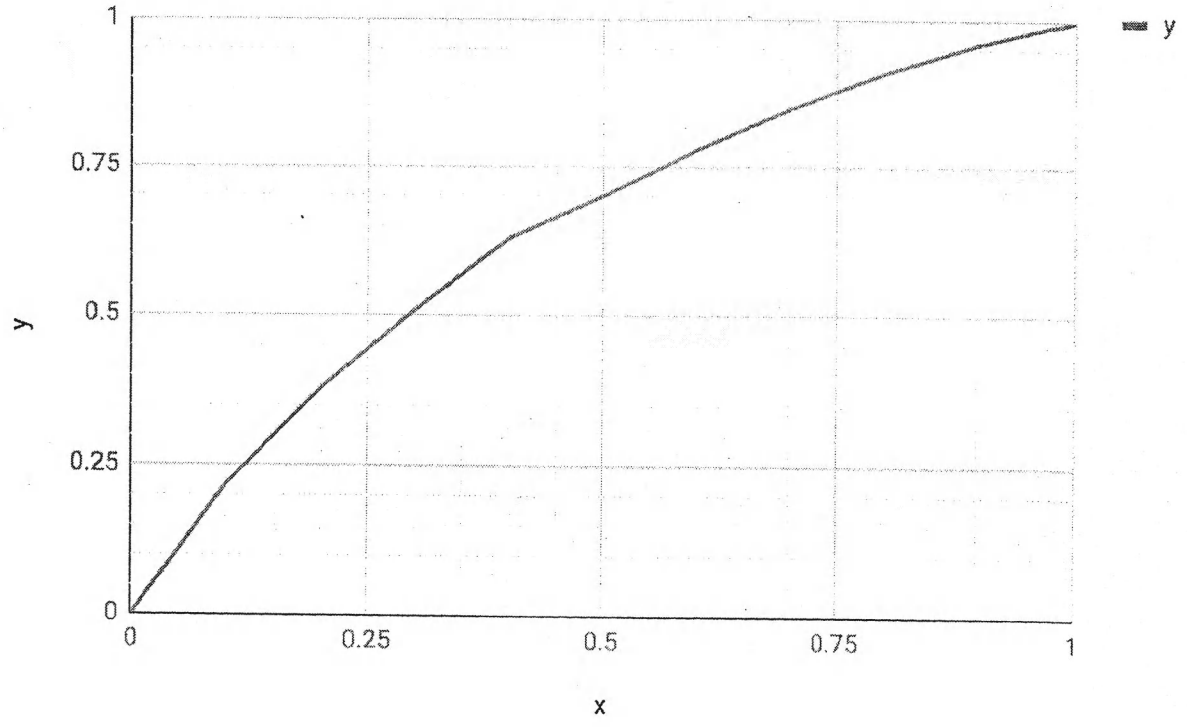


Breakthrough Curve of the Pilot Plant

Based on the above data,

a. What is the filtration rate of the pilot plant? [1]
b. What would be the diameter of the packed column? Remember, both pilot and the scale up will have the same filtration rate. [1]
c. If the height of the packed column is the same as that of the pilot plant, what is the mass of carbon required for the packed column? [1]
d. For the pilot plant, what is the amount of TOC removed per gram of carbon at exhaustion? This value would be the same for the packed column. [1]
e. What fraction of the capacity is left unused for the pilot plant? [2]
f. Calculate the breakthrough time of the packed column. What volume of wastewater is treated before breakthrough? [4]

For problem 5 (To be turned in with the answer sheet):



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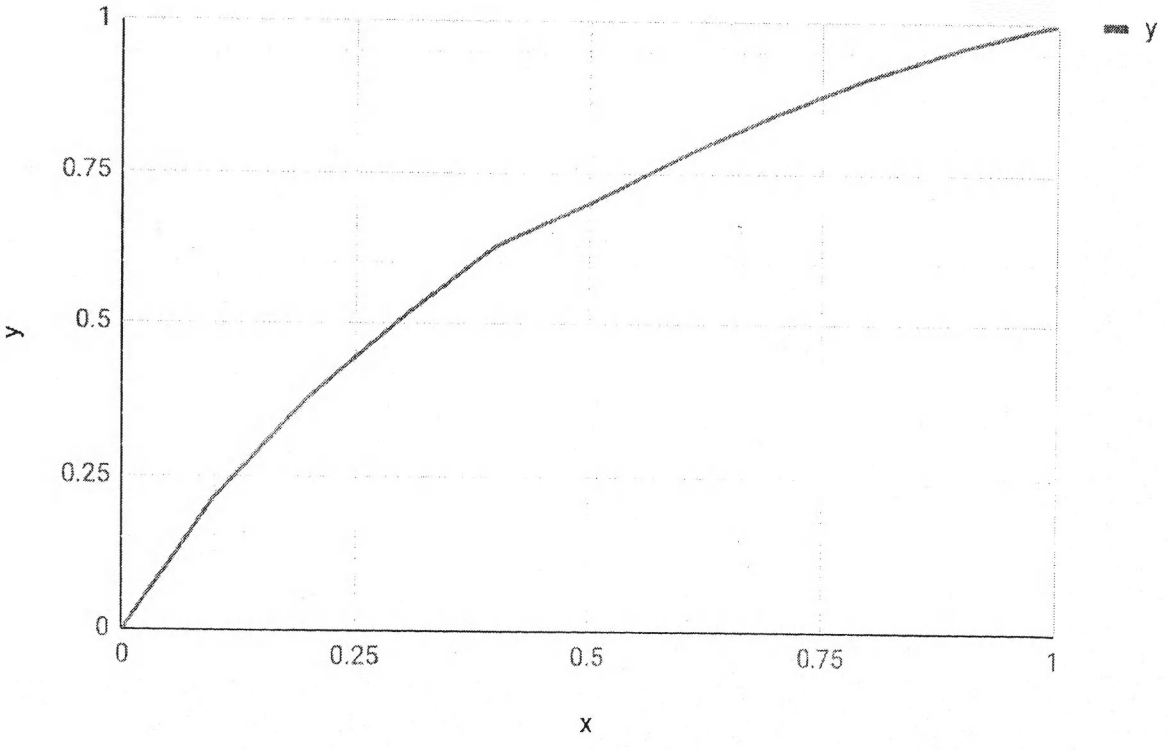

TABLE A.6 Thermophysical Properties of Saturated Water[a]

Temperature, T (K)	Pressure, p (bars)[b]	Specific Volume (m^3/kg)		Heat of Vaporization, h_{fg} (kJ/kg)	Specific Heat (kJ/kg · K)		Viscosity ($N \cdot s/m^2$)		Thermal Conductivity (W/m · K)		Prandtl Number		Surface Tension, $\sigma_f \cdot 10^3$ (N/m)
		$v_f \cdot 10^3$	v_g		$c_{p,f}$	$c_{p,g}$	$\mu_f \cdot 10^6$	$\mu_g \cdot 10^6$	$k_f \cdot 10^3$	$k_g \cdot 10^3$	Pr_f	Pr_g	
273.15	0.00611	1.000	206.3	2502	4.217	1.854	1750	8.02	569	18.2	12.99	0.815	75.5
275	0.00697	1.000	181.7	2497	4.211	1.855	1652	8.09	574	18.3	12.22	0.817	75.3
280	0.00990	1.000	130.4	2485	4.198	1.858	1422	8.29	582	18.6	10.26	0.825	74.8
285	0.01387	1.000	99.4	2473	4.189	1.861	1225	8.49	590	18.9	8.81	0.833	74.3
290	0.01917	1.001	69.7	2461	4.184	1.864	1080	8.69	598	19.3	7.56	0.841	73.7
295	0.02617	1.002	51.94	2449	4.181	1.868	959	8.89	606	19.5	6.62	0.849	72.7
300	0.03531	1.003	39.13	2438	4.179	1.872	855	9.09	613	19.6	5.83	0.857	71.7
305	0.04712	1.005	29.74	2426	4.178	1.877	769	9.29	620	20.1	5.20	0.865	70.9
310	0.06221	1.007	22.93	2414	4.178	1.882	695	9.49	628	20.4	4.62	0.873	70.0
315	0.08132	1.009	17.82	2402	4.179	1.888	631	9.69	634	20.7	4.16	0.883	69.2
320	0.1053	1.011	13.98	2390	4.180	1.895	577	9.89	640	21.0	3.77	0.894	68.3
325	0.1351	1.013	11.06	2378	4.182	1.903	528	10.09	645	21.3	3.42	0.901	67.5
330	0.1719	1.016	8.82	2366	4.184	1.911	489	10.29	650	21.7	3.15	0.908	66.6
335	0.2167	1.018	7.09	2354	4.186	1.920	453	10.49	656	22.0	2.88	0.916	65.8
340	0.2713	1.021	5.74	2342	4.188	1.930	420	10.69	660	22.3	2.66	0.925	64.9
345	0.3372	1.024	4.683	2329	4.191	1.941	389	10.89	668	22.6	2.45	0.933	64.1
350	0.4163	1.027	3.846	2317	4.195	1.954	365	11.09	668	23.0	2.29	0.942	63.2
355	0.5100	1.030	3.180	2304	4.199	1.968	343	11.29	671	23.3	2.14	0.951	62.3
360	0.6209	1.034	2.645	2291	4.203	1.983	324	11.49	674	23.7	2.02	0.960	61.4
365	0.7514	1.038	2.212	2278	4.209	1.999	306	11.69	677	24.1	1.91	0.969	60.5
370	0.9040	1.041	1.861	2265	4.214	2.017	289	11.89	679	24.5	1.80	0.978	59.5
373.15	1.0133	1.044	1.679	2257	4.217	2.029	279	12.02	680	24.8	1.76	0.984	58.9
375	1.0815	1.045	1.574	2252	4.220	2.036	274	12.09	681	24.9	1.70	0.987	58.6
380	1.2869	1.049	1.337	2239	4.226	2.057	260	12.29	683	25.4	1.61	0.999	57.6
385	1.5233	1.053	1.142	2225	4.232	2.080	248	12.49	685	25.8	1.53	1.004	56.6
390	1.794	1.058	0.980	2212	4.239	2.104	237	12.69	686	26.3	1.47	1.013	55.6
400	2.455	1.067	0.731	2183	4.256	2.158	217	13.05	688	27.2	1.34	1.033	53.6
410	3.302	1.077	0.553	2153	4.278	2.221	200	13.42	688	28.2	1.24	1.054	51.5
420	4.370	1.088	0.425	2123	4.302	2.291	185	13.79	688	29.8	1.16	1.075	49.4
430	5.699	1.099	0.331	2091	4.331	2.369	173	14.14	685	30.4	1.09	1.10	47.2

TABLE A.8 Binary Diffusion Coefficients at One Atmosphere[a,b]

Substance A	Substance B	T (K)	D_{AB} (m^2/s)
Gases			
NH_3	Air	298	0.28×10^{-4}
H_2O	Air	298	0.26×10^{-4}
CO_2	Air	298	0.16×10^{-4}
H_2	Air	298	0.41×10^{-4}
O_2	Air	298	0.21×10^{-4}
Acetone	Air	273	0.11×10^{-4}
Benzene	Air	298	0.88×10^{-5}
Naphthalene	Air	300	0.62×10^{-5}
Ar	N_2	293	0.19×10^{-4}
H_2	O_2	273	0.70×10^{-4}
H_2	N_2	273	0.68×10^{-4}
H_2	CO_2	273	0.55×10^{-4}
CO_2	N_2	293	0.16×10^{-4}
CO_2	O_2	273	0.14×10^{-4}
O_2	N_2	273	0.18×10^{-4}
Dilute Solutions			
Caffeine	H_2O	298	0.63×10^{-9}
Ethanol	H_2O	298	0.12×10^{-8}
Glucose	H_2O	298	0.69×10^{-9}
Glycerol	H_2O	298	0.94×10^{-9}
Acetone	H_2O	298	0.13×10^{-8}
CO_2	H_2O	298	0.20×10^{-8}
O_2	H_2O	298	0.24×10^{-8}
H_2	H_2O	298	0.63×10^{-8}
N_2	H_2O	298	0.26×10^{-8}
Solids			
O_2	Rubber	298	0.21×10^{-9}
N_2	Rubber	298	0.15×10^{-9}
CO_2	Rubber	298	0.11×10^{-9}
He	SiO_2	293	0.4×10^{-13}
H_2	Fe	293	0.26×10^{-12}
Cd	Cu	293	0.27×10^{-18}
Al	Cu	293	0.13×10^{-33}

[a]Adapted with permission from References 24, 25, and 26.

[b]Assuming ideal gas behavior, the pressure and temperature dependence of the diffusion coefficient for a binary mixture of gases may be estimated from the relation

$$D_{AB} \propto p^{-1} T^{3/2}$$

Relevant Equations:

$$D \propto P^{-1}T^{1.75}$$

$$N_{Oy} = \frac{y_b - y_a}{\overline{\Delta y_L}}$$

$$N_{Ox} = \frac{x_b - x_a}{\overline{\Delta x_L}}$$

$$N_A = y_A(N_A + N_B) - D_{AB}\rho_M \frac{dy_A}{db}$$

$$\overline{\Delta y_L} = \frac{(y_b - y_b^*) - (y_a - y_a^*)}{\ln \frac{(y_b - y_b^*)}{(y_a - y_a^*)}}$$

$$\overline{\Delta x_L} = \frac{(x_b^* - x_b) - (x_a^* - x_a)}{\ln \frac{(x_b^* - x_b)}{(x_a^* - x_a)}}$$

$$H_{Oy} = H_y + m\frac{G}{L}H_x$$

$$H_{Ox} = H_x + \frac{L}{mG}H_y$$

$$E = \frac{K_D V}{L}$$

$$A = \frac{L}{mV} = \frac{1}{E}$$

$$N = \frac{\ln[(y_b - y_b^*)/(y_a - y_a^*)]}{\ln A}$$

$$N = \frac{\ln[(x_a - x_a^*)/(x_b - x_b^*)]}{\ln S}$$