

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular/Backlog), April-May 2018

B. Tech Chemical Engineering, Semester VI

Roll No.....

CH604 : TRANSPORT PHENOMENA

Time: 3 hours

Max. Marks: 100

Instructions to students:

1. Do not write anything other than your roll number on question paper.
2. Assume suitable data wherever required and mention it clearly.
3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.
4. Appendix E is allowed in the examination.

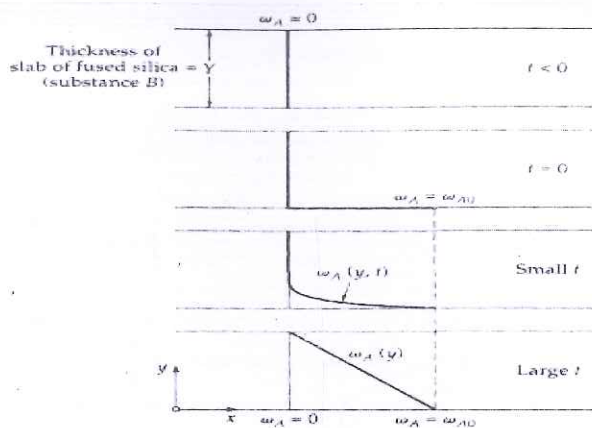
Q.1A Objective type multiple choice questions (10 questions @ 1 mark)

10

- i. The concentration of multi-component mixture in mass transfer process can be represented by:
(a) mass concentration (b) molar concentration (c) molar density (d) all of these
- ii. Fick's law is valid for:
(a) Solids (b) liquids (c) gases (d) all of these
- iii. Viscosity of water in comparison to mercury is:
(a) Higher (b) lower (c) same (d) unpredictable
- iv. The units of dynamic or absolute viscosity is:
(a) m^2/s (b) $\text{kg}\cdot\text{sec}/\text{m}$ (c) $\text{N}\cdot\text{s}/\text{m}^2$ (d) $\text{N}\cdot\text{s}^2/\text{m}$
- v. The units of Stefan - Boltzman constant is:
(a) $\text{W}/\text{cm}^2\cdot\text{K}^4$ (b) $\text{Kcal}/\text{m}^2\cdot\text{hr}\cdot\text{K}^4$ (c) $\text{cal}/\text{cm}^2\cdot\text{sec}\cdot\text{K}^4$ (d) all of these
- vi. With increase in temperature, thermal conductivity of solid metals
(a) Increases (b) decreases (c) remains same (d) depend on other factors
- vii. Lewis number = 1 signifies:
(a) $\text{Pr} = \text{Sc}$ (b) $\text{Pr} = \text{Re}$ (c) $\text{Sc} = \text{Re}$ (d) $\text{Ny} = \text{Sh}$
- viii. Schmidt number is:
(a) $\frac{\mu}{\rho D_{AB}}$ (b) $\text{Re} \cdot \text{Pe}$ (c) $\text{Sh} \times \text{Pe}$ (d) Re/Pe
- ix. Fick's law of diffusion for z-direction is
(a) $J_A = D_{AB} \frac{\partial C_A}{\partial z}$ (d) $J_A = -D_{AB} \frac{\partial^2 C_A}{\partial z^2}$
(B) $J_A = -D_{AB} \frac{\partial C_A}{\partial z}$
(C) $J_A = D_{AB} \frac{\partial^2 C_A}{\partial z^2}$

- x. For a binary diffusivity in gases is depends upon:
 (a) temperature (b) pressure (c) nature of the components (d) all of the these

Q.2	Short answer type questions (4 questions @ 2.5 marks)	10
i	Write down the first law of thermodynamics.	
ii.	Define isolated, closed and open systems.	
iii	Differentiate between mass and molar concentrations.	
iv	Define Newton' law of cooling.	
Q.3A	Define convective mass and molar fluxes.	05
Q.3B	Write down the main axioms of transport phenomena.	05
Q.4A	Explain the theory of diffusion in gases at low density.	05
Q.4B	Write down the limitations of Fick's law of diffusion.	05
Q.5A	A Newtonian fluid is flowing in a narrow slit ($B \ll W \ll L$) formed by two parallel plates, due to the combined effect of both gravity and pressure. Determine the velocity profile, average velocity and mass flow rate for laminar and steady flow.	05
Q.5B	Derive the expressions for equation of motion.	05
Q.6A	Compute the thermal conductivity of Ne at 1 atm and 373.2K.	10
OR		
Q.6A	Estimate maximum temperature rise and average temperature rise in an electrical heat source. Consider an electric wire of circular cross section with radius R, electrical conductivity K_e ohm ⁻¹ cm ⁻¹ . Through this wire there is an electric current density I amp/cm ² .	10
Q.7A	Calculate the steady-state mass flux $j_A y$ of helium for the system in the Fig. at 500K. The partial pressure of helium is 1 atm at $y = 0$ and zero at the upper surface of the plate. The thickness Y of the pyrex plate is 10~2 mm, and its density $\rho(B)$ is 2.6 g/cm ³ . The solubility and diffusivity of helium in pyrex are reported as 0.0084 volumes of gaseous helium per volume of glass, and $D_{AB} = 0.2 \times 10^{-7}$ cm ² /s, respectively. Show that the neglect of the mass average velocity.	05



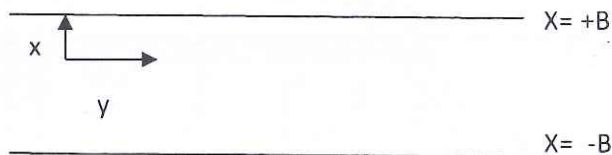
Q.7B A copper wire has a radius of 2 mm and a length of 5 m. For what voltage drop would the temperature rise at the wire axis be 10°C , if the surface temperature of the wire is 20°C ? 05

OR

Q.7B Estimate $c D_{AB}$ for a mixture of 80 mole% CH_4 and 20 mole% C_2H_6 at 136 atm and 313K. It is known that, at 1 atm and 293K, the molar density is $c = 4.17 \times 10^{-5}$ g-mole/ cm^3 and $D_{AB} = 0.163 \text{ cm}^2/\text{s}$. 05

Q.8A A plastic panel of area $A = 1 \text{ ft}^2$ and thickness $Y = 0.252 \text{ in.}$ was found to conduct heat at a rate of 3.0 W at steady state with temperatures $T_0 = 24.00^\circ\text{C}$ and $T_1 = 26.00^\circ\text{C}$ imposed on the two main surfaces. What is the thermal conductivity of the plastic in $\text{cal}/\text{cm} \cdot \text{s} \cdot \text{K}$ at 25°C ? 10

Q.9A Consider a fluid flowing under laminar conditions between two parallel plates which are kept at same temperatures. To as shown in fig the incoming fluid at $z=0$, have the same temperature T_0 assume steady state, determine the increase in temperature of fluid due to the viscous heat dissipation. 10



Q.9B The density of liquid CCl_4 at 20°C and 1 atm is $1.595 \text{ g}/\text{cm}^3$, and its isothermal compressibility $\{1/p\}(\partial p/\partial p)_m$ is $90.7 \times 10^{-6} \text{ atm}^{-1}$. What is its thermal conductivity? 10

OR

Q.9B Predict the thermal conductivity of methane at 110.4 atm and 127°F by the following methods: 10

(a) Use Fig. 9.2-1. Obtain the necessary critical properties from Appendix E.

(b) Use the Eucken formula to get the thermal conductivity at 127°F and low pressure. Then apply a pressure correction by using Fig. 9.2-1. The experimental value is $0.0282 \text{ Btu}/\text{hr} \cdot \text{ft} \cdot \text{F}$.

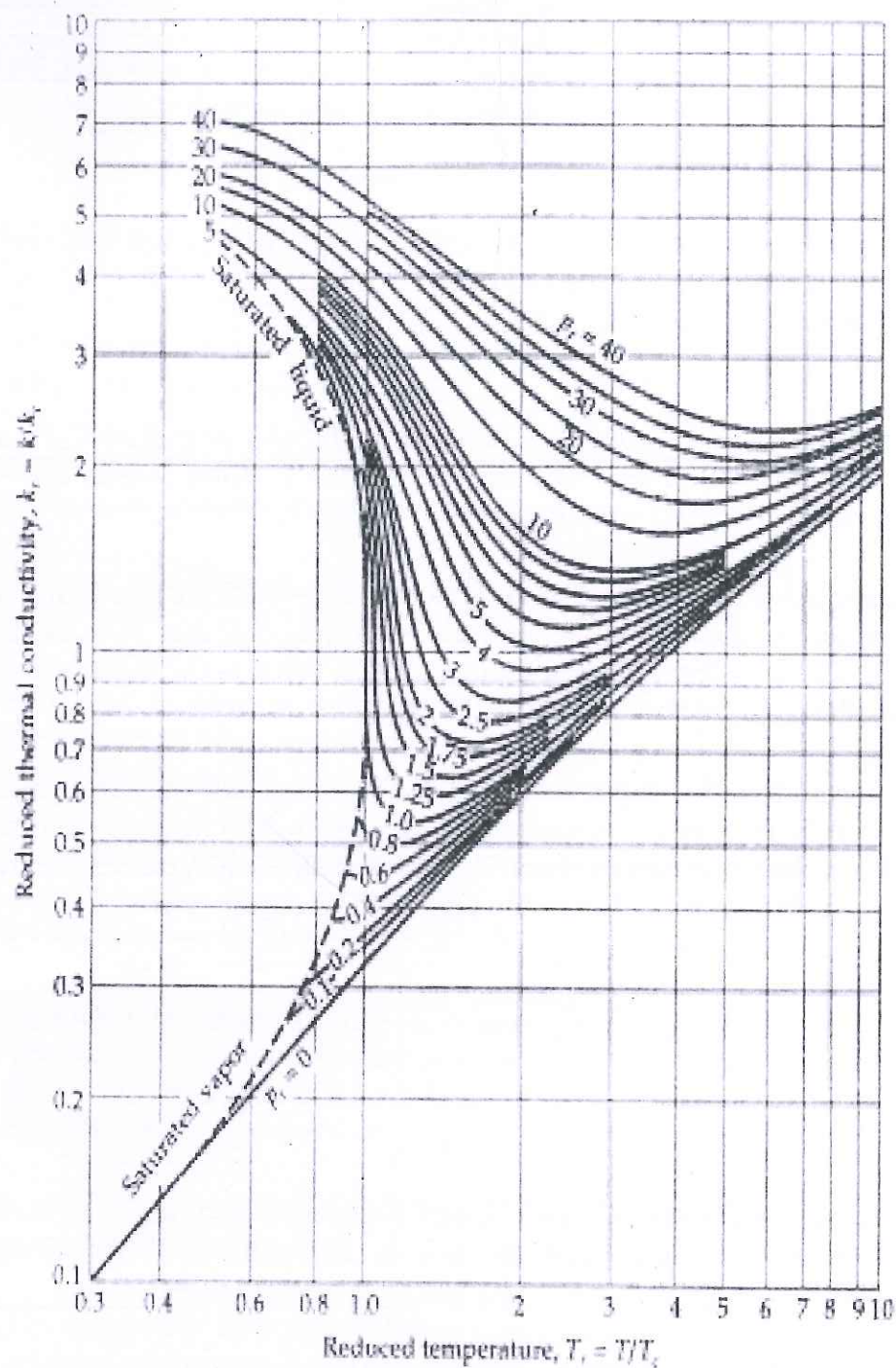


Fig. 9.2-1. Reduced thermal conductivity for monatomic substances as a function of the reduced temperature and pressure [E. J. Owens and G. Thodos, *AIChE Journal*, 3, 454-461 (1957)]. A large-scale version of this chart may be found in O. A. Hougen, K. M. Watson, and R. A. Ragatz, *Chemical Process Principles Charts*, 2nd edition, Wiley, New York (1960).

Table E.1 Lennard-Jones (6-12) Potential Parameters and Critical Properties

		Lennard-Jones parameters			Critical properties ^a				
Substance	Molecular Weight M	σ (Å)	ϵ/k (K)	Ref.	T_c (K)	P_c (atm)	$\hat{V}_c$ (cm ³ /g-mole)	ρ_c (g/cm ³ × 10 ³)	λ_c (cal/cm ³ × K × 10 ³)
Light elements:									
H ₂	2.016	2.915	38.0	a	33.3	12.80	65.0	34.7	—
He	4.003	2.576	10.2	a	5.26	2.26	57.8	25.4	—
Noble gases:									
Ne	20.183	2.789	35.7	a	44.5	26.9	41.7	156	79.2
Ar	39.948	3.432	122.4	b	150.7	48.0	75.2	264	71.0
Kr	83.80	3.675	170.0	b	209.4	54.3	92.2	306	49.4
Xe	131.30	4.009	234.7	b	289.8	58.0	118.8	490	40.2
Simple polyatomic gases:									
Air	28.97	3.617	97.0	a	132	36.4	86.6	193	90.8
N ₂	28.01	3.667	99.8	b	126.2	33.5	90.1	180	86.8
O ₂	32.00	3.433	113	a	154.4	49.7	74.4	250	106.3
CO	28.01	3.590	110	a	132.9	34.5	93.1	190	86.5
CO ₂	44.01	3.996	190	a	304.2	72.8	94.1	343	122
NO	30.01	3.470	119	a	180	64	57	258	118.2
N ₂ O	44.01	3.879	220	a	309.7	71.7	96.3	332	131
SO ₂	64.06	4.026	363	c	430.7	77.8	122	411	98.6
F ₂	38.00	3.653	112	a	—	—	—	—	—
Cl ₂	70.91	4.115	357	a	417	76.1	124	420	97.0
Br ₂	159.82	4.268	520	a	584	102	144	—	—
I ₂	253.81	4.982	550	a	800	—	—	—	—
Hydrocarbons:									
CH ₄	16.04	3.780	154	b	191.1	45.8	98.7	159	158
CH ₂ =CH ₂	26.04	4.114	212	d	308.7	61.6	112.9	232	—
CH ₃ —CH ₃	28.05	4.228	216	b	282.4	50.0	124	215	—
C ₂ H ₂	30.07	4.388	232	b	305.4	48.2	148	210	203
CH ₃ C≡CH	40.06	4.742	261	d	394.8	—	—	—	—
CH ₃ CH=CH ₂	42.08	4.766	275	b	365.0	45.5	181	233	—
C ₃ H ₈	44.10	4.934	273	b	369.8	41.9	200	228	—
n—C ₄ H ₁₀	58.12	5.604	304	b	425.2	37.5	255	239	—

$i\text{-C}_4\text{H}_{10}$	58.12	5.393	295.	b	408.1	36.0	263.	239.
$n\text{-C}_5\text{H}_{12}$	72.15	5.850	326.	b	469.5	33.2	311.	238.
$i\text{-C}_5\text{H}_{12}$	72.15	5.812	327.	b	460.4	33.7	306.	—
$\text{C}(\text{CH}_3)_4$	72.15	5.759	312.	b	433.8	31.6	303.	—
$n\text{-C}_6\text{H}_{14}$	86.18	6.264	342.	b	507.3	29.7	370.	248.
$n\text{-C}_7\text{H}_{16}$	100.20	6.663	352.	b	540.1	27.0	432.	254.
$n\text{-C}_8\text{H}_{18}$	114.23	7.035	361.	b	568.7	24.5	492.	259.
$n\text{-C}_9\text{H}_{20}$	128.26	7.463	351.	b	594.6	22.6	548.	265.
Cyclohexane	84.16	6.143	313.	d	553.	40.0	308.	284.
Benzene	78.11	5.443	387.	b	562.6	48.6	260.	312.
Other organic compounds:								
CH_4	16.04	3.780	154.	b	191.1	45.8	98.7	159.
CH_3Cl	50.49	4.151	355.	c	416.3	65.9	143.	338.
CH_2Cl_2	84.93	4.748	398.	c	510.	60.	—	—
CHCl_3	119.38	5.389	340.	e	536.6	54.	240.	410.
CCl_4	153.82	5.947	323.	e	556.4	45.0	276.	413.
C_2N_2	52.04	4.361	349.	e	400.	59.	—	—
COS	60.07	4.130	336.	e	378.	61.	—	—
CS_2	76.14	4.483	467.	e	552.	78.	170.	404.
CCl_2F_2	120.92	5.116	280.	b	384.7	39.6	218.	—

Table E.2 Collision Integrals for Use with the Lennard-Jones (6-12) Potential for the Prediction of Transport Properties of Gases at Low Densities^{a,b}

kT/ϵ or kT/ϵ_{AB}	$\Omega_{\mu} = \Omega_{\lambda}$ (for viscosity and thermal conductivity)	$\Omega_{T,AB}$ (for diffusivity)	kT/ϵ or kT/ϵ_{AB}	$\Omega_{\mu} = \Omega_{\lambda}$ (for viscosity and thermal conductivity)	$\Omega_{T,AB}$ (for diffusivity)
0.30	2.840	2.649	2.7	1.0691	0.9782
0.35	2.676	2.468	2.8	1.0583	0.9682
0.40	2.531	2.314	2.9	1.0482	0.9588
0.45	2.401	2.182	3.0	1.0388	0.9500
0.50	2.284	2.066	3.1	1.0300	0.9418
0.55	2.178	1.965	3.2	1.0217	0.9340
0.60	2.084	1.877	3.3	1.0139	0.9267
0.65	1.999	1.799	3.4	1.0066	0.9197
0.70	1.922	1.729	3.5	0.9996	0.9131
0.75	1.853	1.667	3.6	0.9931	0.9068
0.80	1.790	1.612	3.7	0.9868	0.9008
0.85	1.734	1.562	3.8	0.9809	0.8952
0.90	1.682	1.517	3.9	0.9753	0.8897
0.95	1.636	1.477	4.0	0.9699	0.8845
1.00	1.593	1.440	4.1	0.9647	0.8796
1.05	1.554	1.406	4.2	0.9598	0.8748
1.10	1.518	1.375	4.3	0.9551	0.8703
1.15	1.485	1.347	4.4	0.9506	0.8659
1.20	1.455	1.320	4.5	0.9462	0.8617
1.25	1.427	1.296	4.6	0.9420	0.8576
1.30	1.401	1.274	4.7	0.9380	0.8537
1.35	1.377	1.253	4.8	0.9341	0.8499
1.40	1.355	1.234	4.9	0.9304	0.8463
1.45	1.334	1.216	5.0	0.9268	0.8428
1.50	1.315	1.199	6.0	0.8963	0.8129
1.55	1.297	1.183	7.0	0.8727	0.7898
1.60	1.280	1.168	8.0	0.8538	0.7711
1.65	1.264	1.154	9.0	0.8380	0.7555
1.70	1.249	1.141	10.0	0.8244	0.7422
1.75	1.235	1.128	12.0	0.8018	0.7202
1.80	1.222	1.117	14.0	0.7836	0.7025
1.85	1.209	1.105	16.0	0.7683	0.6878
1.90	1.198	1.095	18.0	0.7552	0.6751
1.95	1.186	1.085	20.0	0.7436	0.6640
2.00	1.176	1.075	25.0	0.7198	0.6414
2.10	1.156	1.058	30.0	0.7010	0.6235
2.20	1.138	1.042	35.0	0.6854	0.6088
2.30	1.122	1.027	40.0	0.6723	0.5964
2.40	1.107	1.013	50.0	0.6510	0.5763
2.50	1.0933	1.0006	75.0	0.6140	0.5415
2.60	1.0807	0.9890	100.0	0.5887	0.5180

^a The values in this table, applicable for the Lennard-Jones (6-12) potential, are interpolated from the results of L. Monchick and E. A. Mason, *J. Chem. Phys.*, **35**, 1676-1697 (1961). The Monchick-Mason table is believed to be slightly better than the earlier table by J. O. Hirschfelder, R. B. Bird, and E. L. Spotz, *J. Chem. Phys.*, **16**, 968-981 (1948).

^b This table has been extended to lower temperatures by C. F. Curtiss, *J. Chem. Phys.*, **97**, 7679-7686 (1992). Curtiss showed that at low temperatures, the Boltzmann equation needs to be modified to take into account "cebiting pairs" of molecules. Only by making this modification is it possible to get a smooth transition from quantum to classical behavior. The deviations are appreciable below dimensionless temperatures of 0.30.