Ref. No. : Ex/PHARM/T/325/2019

Name of the Examination: B. PHARMACY THIRD YEAR SECOND SEMESTER - 2019

Subject : PHARMACEUTICAL ENGINEERING –I Time: Three hours

Full Marks:100

Answer any five questions taking at least two questions from each group.)

Group A

Q1. (a)(i) Derive the expression of Rate of heat flow by conduction through a metallic cylinder .

(ii) A cylindrical pipe of negligible thickness containing a hot fluid at 150° C and having an outer diameter of 0.4 m is insulated with three layers of each 60 mm thick insulation of thermal conductivities of k_1 =0.02,k_2=0.06 , k_3=0.16 W/mK (starting from inside).The outside surface temperature is 30° C. Determine (i) heat loss by conduction per unit length of pipe and, (ii) interface temperature of insulating layers.

(b) Calculate the overall heat transfer coefficients based on both inside and outside areas for the following cases .

Case (i): water at 10°C flowing in a condenser tube (inside diameter, Di=0.62 inch, thickness of tube =0.065 inch) and saturated steam at 105°C condensing on the outside.

hi=12 kW/m^2 °C, ho= 14 kW/m^2 °C, km=120W/m °C.

Case (ii) Benzene condensing at atmospheric pressure (80 ° C) on the outside wall of a steel pipe (outside diameter, Do=1.315 inch, thickness of tube =0.133 inch) and air at 15°C flowing within the pipe at 6 m/s. hi=20 kW/m^2 °C, ho=1200 kW/m^2 °C

and km=45 W/m °C.

Marks (3+5)+(6+6)

Q2. (a) An aqueous solution of $NaNO_3$ (M.W.85) is fed to a continuous crystallizer at a rate of 5000 kg/hr. The solution is cooled from 90 to 40°C. The cooling agent is water. Loss of water from feed due to evaporation in the crystallizer is 3% of the feed solution. Determine the quantity of heat (kilo watt) that must be withdrawn by the cooling agent.

Data:

Mass fraction of $NaNO_3$ in feed (x_F), mother (x_L) liquor and crystal (x_c) are 0.5763, 0.5111 and 0.5941 respectively.

Heat capacity of feed solution (c_p) = 2469.57 J/kg°K Latent heat (λ) of vaporization of water 2345000 J/kg

Heat of crystallization of $NaNO_3$ (h_c) = 248235.3 J/kg.

Solve by mass balance technique.

(b)A solution containing 23% by mass of sodium phosphate (MW 164) is cooled from 313 to 298 K in a Swenson Walker crystallizer to form crystals of $Na_3PO_4.12H_2O$ .The solubility of Na_3PO_4 at temperature 298 K is 13.42% , and the rate of product formation is 0.063 per second. The mean heat capacity of the solution is 3.2 kJ/kg K and the heat of crystallization is 146.5 kJ/kg of crystal. If cooling water enters and leaves at 288 and 293 K respectively, and the overall heat transfer coefficient is 0.14 kW/m^{2}K. What length of crystallizer is required? Area of heat transfer per one meter is one square meter.

Solve by mass balance technique.

Marks 10+10

Q3. (a) Discuss various effects of system geometry (shape factors)on power number (N_P) or power requirement.

(b) A tank 1.2 m in diameter and 2 m high which is filled to a depth of 1.2 m with a liquid having a viscosity of 11 poise and a density of 800 kg/m^3 .An impellor of diameter 360 mm is installed in the tank 360 mm from the bottom . The agitator rotates at 800 rpm .What are the power requirement for agitating liquid in both **baffled** and **unbaffled** tanks fitted with (i)**propeller** (a=1.7,b=18) and (ii) **turbine** (a=1, b=40) type impellors? Solve by graphical plotting on log-log graph papers.

Data for Propeller impellor							Data for Turbine type impellor				
N_{Re}	250	400	10^3	$2*10^3$	10^4	N_{Re}	200	300	10^3	$3*10^3$	10^4
Unbaffled,Np	0.95	0.9	0.8	0.7	0.6	Unbaffled,Np	3.7	3.8	2.7	1.75	1.4
Baffled, Np	0.95	0.9	0.9	0.9	0.9	Baffled, Np	3.7	3.8	4.5	5.3	6

Marks 4+8*2

Q4.Write short notes on any **four** of the following:

(i)Meirs Supersaturation theory,(ii) caking of crystal during storage,(iii) 1-2 Heat exchanger,

(iv) Vortex in liquid mixing, (v) Ribbon blender, (vi) Turbine impellor system.

Marks 4*5

Ref No. Ex/PHAR/T/325/2019

B. PHARMACEUTICAL TECHNOLOGY THIRD YEAR SECOND SEMESTER -2019

PHARMACEUTICAL ENGINEERING-II TIME: 3 h FULL MARKS: 100

ANSWER ANY FIVE QUESTIONS TAKING ATLEAST TWO FROM EACH GROUP

GROUP-B

(Use graph paper if required)

1. A 6% aqueous solution of a high molecular weight solute has to be concentrated to 35% in a forward-feed double effect evaporator at the rate of 8000 kg.h^{-1}. The feed temperature is 40°C. Saturated steam at 4.5 kg.cm^{-2} is available for heating. A vacuum of 600 mm Hg is maintained in the second effect. Calculate the area requirements, if calandria of equal area are used. The overall heat transfer coefficients are 650 and 470 kcal.h^{-1}m^{-2} °C^{-1} in the first and the last effect respectively. The specific heat of the concentrated liquor is 0.84 kcal.kg^{-1}°C^{-1}. [20 marks]

2.
   a. A material is crushed in a Blake jaw crusher such that the average size of particle is reduced from 40 mm to 10 mm with the consumption of energy of 13.0 kW/(kg/s). What would be the consumption of energy needed to crush the same material of average size 75 mm to an average size of 25 mm:
      a) assuming Rittinger's law applies?
      b) assuming Kick's law applies?

      Which of these results would be regarded as being more reliable and why?
   b. The screen analysis shown in the table-1 below, applies to a sample of crushed quartz. The density of the particle is 3000 kg/m^3, and the shape factor are a=1.5, and Φ_s=0.6. for the material between 4-mesh and 200 mesh in particle size, calculate a) Aw, and Nw b) $\overline{D_V}$ c) v $\overline{D_s}$ d) $\overline{D_W}$ e) $\overline{N_i}$ for the 150/200 mesh increment. f) What fraction of the total number of particles is in the 150/200-mesh increment?
   c. Write short on any three: a. Ball Mill, b. Roller Mill, c. Hammer Mill, d. Fluid Energy Mill.
   d. If crushing rolls, 1m in diameter, are set so that the crushing surfaces are 12.5mm apart and the angle of nip is 31°, what is the maximum size of particle which should be fed to the rolls? If the actual capacity of the machine is 20 per cent of the theoretical, calculate the throughout in kg/s when running at 3.0 Hz if the working face of the rolls is 0.4 m long and the bulk density of the feed is 2500 kg/m^3. [5+10+3+2=20 marks]

3.
   a. Answer any three

      Explain the advantages and disadvantages of the following:
      i. Cyclone Separator
      ii. Dynamic Scrubbers
      iii. Short-Tube Vertical Evaporator
      iv. Gasketed Plate Evaporator
   b. Derive the design equation of filtration. Using Sperry correlation derive the condition at constant pressure and incompressible sludge. Drive the filtration time cycle.

c. A quartz mixture having the screen analysis shown in the table-2 below is screened through a standard 10-mesh screen. The cumulative screen analysis of the overflow and underflow are also provided. Calculate the mass ratios of the overflow and underflow to feed and the overall effectiveness of the screen.

[4×3=12 +4+4 =20 marks]

4.

a. An evaporator is used to concentrate 5000 kg/h of a 15% solution of NaOH in water entering at 65°C to a product of 55% solids. The pressure of the saturated steam used is 25 psia and the pressure in the vapour space of the evaporator is 12 kPa. The overall heat transfer coefficient is 1600 $W/m^2.K$. Calculate the steam used, the steam economy in kg vaporized/kg steam used, and the heating surface area in km^2.

b. Design a liquid-liquid gravity separator which can handle a two phase liquid stream of 0.5 m^3/min. The feed contains 45% by volume of light phase and 55% by volume of a heavy phase. Densities of light (ρ_l) and heavy phase (ρ_h) are 900 and 1150 kg/m^3 respectively. Required settling time of light phase is 5 min while the settling time for heavy phase is 4 min. [10+10=20 marks]

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Supplementary Data

Table-1

Mesh	Screen opening D_{pi}, mm	Mass fraction retained, x_i	Average particle diameter in increment, $\bar{D}_{pi}$, mm	Cumulative fraction smaller than D_{pi}
4	4.699	0.0000	—	1.0000
6	3.327	0.0251	4.013	0.9749
8	2.362	0.1250	2.845	0.8499
10	1.651	0.3207	2.007	0.5292
14	1.168	0.2570	1.409	0.2722
20	0.833	0.1590	1.001	0.1132
28	0.589	0.0538	0.711	0.0594
35	0.417	0.0210	0.503	0.0384
48	0.295	0.0102	0.356	0.0282
65	0.208	0.0077	0.252	0.0205
100	0.147	0.0058	0.178	0.0147
150	0.104	0.0041	0.126	0.0106
200	0.074	0.0031	0.089	0.0075
Pan	—	0.0075	0.037	0.0000

Table-2

		Cumulative fraction smaller than D_p		
Mesh	D_p, mm	Feed	Overflow	Underflow
4	4.699	0	0	
6	3.327	0.025	0.071	
8	2.362	0.15	0.43	0
10	1.651	0.47	0.85	0.195
14	1.168	0.73	0.97	0.58
20	0.833	0.885	0.99	0.83
28	0.589	0.94	1.00	0.91
35	0.417	0.96		0.94
65	0.208	0.98		0.975
Pan		1.00		1.00

Table 3 Saturation Temperature Table for Steam in SI Units

T C	P_{sat} kPa	v_f m3/kg	v_g m3/kg	v_{fg} m3/kg	h_f kJ/kg	h_g kJ/kg	h_{fg} kJ/kg	u_f kJ/kg	u_g kJ/kg	u_{fg} kJ/kg	s_f kJ/kg K	s_g kJ/kg K	s_{fg} kJ/kg K
0	0.6119	0.000995	205.94	205.93	0.9007	2500.02	2499.12	0.9001	2374.02	2373.12	-0.0013	9.1582	9.1595
2	0.7066	0.000995	179.63	179.63	9.2488	2504.40	2495.15	9.2481	2377.48	2368.24	0.0297	9.1052	9.0755
4	0.8140	0.000996	157.04	157.04	17.5909	2508.60	2491.01	17.5901	2380.76	2363.17	0.0604	9.0531	8.9928
6	0.9357	0.000996	137.59	137.59	25.9279	2512.64	2486.72	25.9269	2383.90	2357.97	0.0908	9.0020	8.9113
8	1.0732	0.000997	120.82	120.82	34.2606	2516.58	2482.31	34.2595	2386.91	2352.66	0.1209	8.9519	8.8309
10	1.2282	0.000997	106.31	106.31	42.5897	2520.42	2477.83	42.5885	2389.84	2347.25	0.1508	8.9026	8.7518
12	1.4026	0.000998	93.74	93.74	50.9160	2524.19	2473.27	50.9146	2392.70	2341.79	0.1804	8.8542	8.6738
14	1.5985	0.000999	82.83	82.83	59.2401	2527.90	2468.66	59.2385	2395.51	2336.27	0.2098	8.8066	8.5969
16	1.8180	0.000999	73.33	73.33	67.5625	2531.58	2464.02	67.5607	2398.27	2330.71	0.2389	8.7599	8.5211
18	2.0635	0.001000	65.04	65.04	75.8837	2535.23	2459.34	75.8817	2401.01	2325.13	0.2678	8.7141	8.4463
20	2.3376	0.001000	57.80	57.80	84.2043	2538.85	2454.65	84.2020	2403.73	2319.53	0.2964	8.6690	8.3725
22	2.6431	0.001001	51.47	51.46	92.5247	2542.46	2449.94	92.5220	2406.43	2313.91	0.3249	8.6247	8.2998
24	2.9830	0.001002	45.90	45.90	100.845	2546.06	2445.21	100.842	2409.12	2308.28	0.3531	8.5811	8.2280
26	3.3604	0.001002	41.02	41.02	109.166	2549.65	2440.48	109.163	2411.81	2302.65	0.3811	8.5384	8.1572
28	3.7789	0.001003	36.72	36.71	117.488	2553.23	2435.74	117.484	2414.49	2297.01	0.4090	8.4963	8.0874
30	4.2420	0.001004	32.92	32.92	125.811	2556.81	2431.00	125.807	2417.17	2291.36	0.4366	8.4550	8.0184
32	4.7536	0.001005	29.57	29.56	134.136	2560.39	2426.25	134.131	2419.84	2285.71	0.4640	8.4143	7.9503
34	5.3181	0.001005	26.60	26.60	142.462	2563.96	2421.50	142.456	2422.52	2280.06	0.4913	8.3744	7.8831
36	5.9398	0.001006	23.96	23.96	150.790	2567.53	2416.74	150.784	2425.19	2274.40	0.5183	8.3351	7.8168
38	6.6235	0.001007	21.62	21.62	159.120	2571.09	2411.97	159.113	2427.86	2268.74	0.5452	8.2964	7.7512
40	7.3743	0.001008	19.54	19.54	167.452	2574.65	2407.20	167.444	2430.52	2263.08	0.5719	8.2584	7.6865
42	8.1975	0.001009	17.69	17.69	175.786	2578.20	2402.41	175.778	2433.18	2257.41	0.5985	8.2210	7.6226
44	9.0987	0.001009	16.04	16.03	184.123	2581.75	2397.63	184.114	2435.84	2251.73	0.6248	8.1843	7.5594
46	10.084	0.001010	14.56	14.56	192.463	2585.29	2392.83	192.452	2438.50	2246.04	0.6510	8.1481	7.4970
48	11.160	0.001011	13.23	13.23	200.805	2588.82	2388.02	200.794	2441.14	2240.35	0.6771	8.1125	7.4354
50	12.333	0.001012	12.05	12.04	209.150	2592.34	2383.19	209.137	2443.78	2234.65	0.7030	8.0775	7.3745
52	13.610	0.001013	10.98	10.98	217.498	2595.86	2378.36	217.484	2446.42	2228.93	0.7287	8.0430	7.3143

T C	P_{sat} kPa	v_f m3/kg	v_g m3/kg	v_{fg} m3/kg	h_f kJ/kg	h_g kJ/kg	h_{fg} kJ/kg	u_f kJ/kg	u_g kJ/kg	u_{fg} kJ/kg	s_f kJ/kg K	s_g kJ/kg K	s_{fg} kJ/kg K
54	14.999	0.001014	10.02	10.02	225.848	2599.36	2373.51	225.833	2449.04	2223.21	0.7543	8.0091	7.2547
56	16.507	0.001015	9.159	9.158	234.202	2602.85	2368.65	234.185	2451.66	2217.48	0.7798	7.9757	7.1959
58	18.143	0.001016	8.381	8.380	242.558	2606.34	2363.78	242.540	2454.27	2211.73	0.8051	7.9428	7.1377
60	19.916	0.001017	7.679	7.678	250.918	2609.80	2358.89	250.898	2456.87	2205.97	0.8302	7.9104	7.0802
62	21.834	0.001018	7.044	7.043	259.281	2613.26	2353.98	259.259	2459.46	2200.20	0.8552	7.8786	7.0234
64	23.906	0.001019	6.470	6.469	267.647	2616.70	2349.05	267.623	2462.04	2194.41	0.8801	7.8472	6.9671
66	26.144	0.001020	5.949	5.948	276.016	2620.13	2344.11	275.990	2464.61	2188.62	0.9048	7.8163	6.9115
68	28.557	0.001021	5.476	5.475	284.389	2623.54	2339.15	284.360	2467.16	2182.80	0.9294	7.7859	6.8564
70	31.156	0.001023	5.047	5.046	292.765	2626.94	2334.18	292.733	2469.71	2176.97	0.9539	7.7559	6.8020
72	33.952	0.001024	4.656	4.655	301.144	2630.32	2329.18	301.109	2472.24	2171.13	0.9782	7.7263	6.7481
74	36.957	0.001025	4.300	4.299	309.527	2633.69	2324.16	309.489	2474.76	2165.27	1.0024	7.6972	6.6948
76	40.184	0.001026	3.976	3.975	317.913	2637.04	2319.13	317.872	2477.27	2159.40	1.0265	7.6686	6.6421
78	43.645	0.001028	3.680	3.679	326.303	2640.37	2314.07	326.258	2479.76	2153.51	1.0505	7.6403	6.5899
80	47.353	0.001029	3.409	3.408	334.696	2643.69	2308.99	334.648	2482.25	2147.60	1.0743	7.6125	6.5382
82	51.322	0.001030	3.162	3.161	343.093	2646.99	2303.90	343.040	2484.72	2141.68	1.0980	7.5850	6.4870
84	55.567	0.001032	2.935	2.934	351.494	2650.27	2298.78	351.437	2487.17	2135.74	1.1216	7.5579	6.4364
86	60.102	0.001033	2.727	2.726	359.899	2653.53	2293.64	359.837	2489.62	2129.78	1.1450	7.5313	6.3862
88	64.942	0.001034	2.537	2.536	368.308	2656.78	2288.47	368.240	2492.04	2123.80	1.1684	7.5050	6.3366
90	70.104	0.001036	2.361	2.360	376.720	2660.01	2283.29	376.648	2494.46	2117.81	1.1916	7.4790	6.2874
92	75.603	0.001037	2.200	2.199	385.137	2663.21	2278.08	385.059	2496.86	2111.80	1.2147	7.4534	6.2387
94	81.457	0.001039	2.052	2.051	393.558	2666.40	2272.84	393.474	2499.25	2105.77	1.2377	7.4282	6.1905
96	87.683	0.001040	1.915	1.914	401.984	2669.57	2267.58	401.893	2501.62	2099.73	1.2606	7.4033	6.1427
98	94.299	0.001042	1.789	1.788	410.414	2672.72	2262.30	410.316	2503.98	2093.66	1.2833	7.3787	6.0954
100	101.325	0.001043	1.673	1.672	418.849	2675.84	2256.99	418.743	2506.32	2087.57	1.3060	7.3545	6.0485
102	108.778	0.001045	1.566	1.565	427.289	2678.95	2251.66	427.175	2508.64	2081.47	1.3285	7.3306	6.0020
104	116.678	0.001046	1.466	1.465	435.733	2682.03	2246.30	435.611	2510.95	2075.34	1.3510	7.3070	5.9560
106	125.047	0.001048	1.374	1.373	444.183	2685.09	2240.91	444.052	2513.25	2069.19	1.3733	7.2837	5.9103
108	133.905	0.001050	1.289	1.288	452.638	2688.13	2235.49	452.498	2515.52	2063.03	1.3955	7.2606	5.8651
110	143.273	0.001051	1.210	1.209	461.099	2691.14	2230.04	460.948	2517.78	2056.83	1.4177	7.2379	5.8203

T C	P_{sat} kPa	v_f m3/kg	v_g m3/kg	v_{fg} m3/kg	h_f kJ/kg	h_g kJ/kg	h_{fg} kJ/kg	u_f kJ/kg	u_g kJ/kg	u_{fg} kJ/kg	s_f kJ/kg K	s_g kJ/kg K	s_{fg} kJ/kg K
112	153.173	0.001053	1.137	1.136	469.565	2694.13	2224.57	469.404	2520.03	2050.62	1.4397	7.2155	5.7758
114	163.628	0.001055	1.069	1.068	478.038	2697.10	2219.06	477.865	2522.25	2044.38	1.4616	7.1933	5.7318
116	174.662	0.001057	1.005	1.004	486.516	2700.04	2213.52	486.332	2524.46	2038.12	1.4834	7.1715	5.6880
118	186.297	0.001058	0.946389	0.945331	495.001	2702.95	2207.95	494.804	2526.64	2031.84	1.5051	7.1498	5.6447
120	198.559	0.001060	0.891572	0.890512	503.493	2705.84	2202.35	503.282	2528.81	2025.53	1.5267	7.1285	5.6017
122	211.472	0.001062	0.840500	0.839438	511.991	2708.70	2196.71	511.766	2530.96	2019.19	1.5483	7.1074	5.5591
124	225.062	0.001064	0.792881	0.791817	520.496	2711.53	2191.04	520.257	2533.09	2012.83	1.5697	7.0865	5.5168
126	239.354	0.001066	0.748448	0.747382	529.009	2714.34	2185.33	528.754	2535.19	2006.44	1.5910	7.0659	5.4749
128	254.377	0.001068	0.706958	0.705890	537.530	2717.11	2179.58	537.258	2537.28	2000.02	1.6123	7.0455	5.4332
130	270.156	0.001070	0.668188	0.667118	546.058	2719.86	2173.80	545.769	2539.34	1993.57	1.6334	7.0254	5.3919
132	286.720	0.001072	0.631933	0.630861	554.595	2722.57	2167.98	554.287	2541.38	1987.09	1.6545	7.0054	5.3510
134	304.097	0.001074	0.598007	0.596933	563.140	2725.25	2162.11	562.813	2543.40	1980.59	1.6754	6.9857	5.3103
136	322.317	0.001076	0.566238	0.565162	571.693	2727.90	2156.21	571.347	2545.39	1974.05	1.6963	6.9662	5.2699
138	341.408	0.001078	0.536469	0.535391	580.256	2730.52	2150.26	579.888	2547.36	1967.47	1.7171	6.9469	5.2298
140	361.402	0.001080	0.508556	0.507476	588.828	2733.10	2144.27	588.438	2549.31	1960.87	1.7378	6.9279	5.1900
142	382.328	0.001082	0.482365	0.481283	597.410	2735.65	2138.24	596.996	2551.23	1954.23	1.7585	6.9090	5.1505
144	404.219	0.001084	0.457774	0.456690	606.002	2738.16	2132.16	605.564	2553.12	1947.55	1.7790	6.8903	5.1113
146	427.106	0.001086	0.434672	0.433585	614.604	2740.64	2126.03	614.140	2554.98	1940.84	1.7995	6.8718	5.0723
148	451.022	0.001089	0.412954	0.411865	623.217	2743.07	2119.86	622.726	2556.82	1934.10	1.8199	6.8535	5.0336
150	476.000	0.001091	0.392524	0.391433	631.841	2745.47	2113.63	631.322	2558.63	1927.31	1.8402	6.8353	4.9952
152	502.073	0.001093	0.373295	0.372202	640.477	2747.84	2107.36	639.928	2560.41	1920.49	1.8604	6.8174	4.9570
154	529.277	0.001095	0.355186	0.354090	649.124	2750.16	2101.04	648.544	2562.17	1913.62	1.8806	6.7996	4.9190
156	557.644	0.001098	0.338120	0.337023	657.783	2752.44	2094.66	657.170	2563.89	1906.72	1.9006	6.7819	4.8813
158	587.212	0.001100	0.322029	0.320930	666.454	2754.68	2088.23	665.808	2565.58	1899.77	1.9206	6.7645	4.8438
160	618.016	0.001102	0.306849	0.305747	675.138	2756.88	2081.74	674.457	2567.24	1892.79	1.9406	6.7472	4.8066
162	650.092	0.001105	0.292519	0.291414	683.836	2759.04	2075.20	683.117	2568.87	1885.75	1.9604	6.7300	4.7696
164	683.477	0.001107	0.278985	0.277878	692.546	2761.15	2068.60	691.790	2570.47	1878.68	1.9802	6.7130	4.7328
166	718.210	0.001110	0.266195	0.265085	701.271	2763.22	2061.95	700.474	2572.03	1871.56	2.0000	6.6961	4.6962
168	754.328	0.001112	0.254102	0.252990	710.010	2765.24	2055.23	709.171	2573.56	1864.39	2.0196	6.6794	4.6598

T C	P_{sat} kPa	v_f m3/kg	v_g m3/kg	v_{fg} m3/kg	h_f kJ/kg	h_g kJ/kg	h_{fg} kJ/kg	u_f kJ/kg	u_g kJ/kg	u_{fg} kJ/kg	s_f kJ/kg K	s_g kJ/kg K	s_{fg} kJ/kg K
170	791.870	0.001115	0.242662	0.241547	718.764	2767.22	2048.45	717.881	2575.06	1857.18	2.0392	6.6628	4.6236
172	830.875	0.001117	0.231834	0.230717	727.532	2769.15	2041.62	726.604	2576.52	1849.92	2.0588	6.6464	4.5876
174	871.384	0.001120	0.221580	0.220461	736.316	2771.03	2034.71	735.340	2577.95	1842.61	2.0782	6.6301	4.5518
176	913.436	0.001122	0.211865	0.210743	745.116	2772.87	2027.75	744.091	2579.34	1835.25	2.0976	6.6139	4.5162
178	957.072	0.001125	0.202656	0.201531	753.931	2774.65	2020.72	752.855	2580.69	1827.84	2.1170	6.5978	4.4808
180	1002.34	0.001128	0.193922	0.192794	762.764	2776.39	2013.62	761.634	2582.01	1820.38	2.1363	6.5818	4.4456
182	1049.27	0.001130	0.185635	0.184504	771.613	2778.07	2006.46	770.427	2583.29	1812.87	2.1555	6.5660	4.4105
184	1097.91	0.001133	0.177767	0.176634	780.480	2779.71	1999.23	779.236	2584.54	1805.30	2.1747	6.5502	4.3756
186	1148.30	0.001136	0.170295	0.169159	789.364	2781.29	1991.93	788.060	2585.74	1797.68	2.1938	6.5346	4.3408
188	1200.50	0.001139	0.163195	0.162057	798.266	2782.82	1984.56	796.899	2586.91	1790.01	2.2129	6.5191	4.3062
190	1254.53	0.001141	0.156446	0.155304	807.187	2784.30	1977.11	805.755	2588.03	1782.28	2.2319	6.5037	4.2718
192	1310.45	0.001144	0.150027	0.148882	816.127	2785.72	1969.60	814.627	2589.12	1774.49	2.2508	6.4883	4.2375
194	1368.30	0.001147	0.143919	0.142772	825.086	2787.09	1962.01	823.516	2590.17	1766.65	2.2697	6.4731	4.2033
196	1428.14	0.001150	0.138105	0.136955	834.064	2788.41	1954.34	832.422	2591.18	1758.75	2.2886	6.4579	4.1693
198	1489.99	0.001153	0.132568	0.131415	843.063	2789.67	1946.61	841.345	2592.14	1750.80	2.3074	6.4428	4.1354
200	1553.92	0.001156	0.127293	0.126137	852.082	2790.87	1938.79	850.286	2593.07	1742.78	2.3262	6.4279	4.1017
202	1619.96	0.001159	0.122266	0.121106	861.123	2792.02	1930.89	859.244	2593.95	1734.71	2.3449	6.4129	4.0681
204	1688.17	0.001163	0.117472	0.116309	870.184	2793.11	1922.92	868.222	2594.79	1726.57	2.3635	6.3981	4.0346
206	1758.60	0.001166	0.112899	0.111733	879.268	2794.14	1914.87	877.217	2595.59	1718.38	2.3822	6.3833	4.0012
208	1831.29	0.001169	0.108535	0.107366	888.373	2795.11	1906.74	886.232	2596.35	1710.12	2.4007	6.3686	3.9679
210	1906.30	0.001172	0.104369	0.103196	897.501	2796.02	1898.52	895.267	2597.06	1701.80	2.4193	6.3540	3.9347
212	1983.67	0.001176	0.100390	0.099214	906.653	2796.88	1890.22	904.321	2597.74	1693.41	2.4377	6.3394	3.9017
214	2063.46	0.001179	0.096588	0.095409	915.828	2797.67	1881.84	913.395	2598.36	1684.97	2.4562	6.3249	3.8687
216	2145.71	0.001182	0.092955	0.091773	925.026	2798.40	1873.38	922.489	2598.95	1676.46	2.4746	6.3104	3.8358
218	2230.49	0.001186	0.089481	0.088295	934.250	2799.07	1864.82	931.605	2599.49	1667.88	2.4929	6.2960	3.8031
220	2317.83	0.001189	0.086158	0.084969	943.498	2799.68	1856.19	940.741	2599.98	1659.24	2.5113	6.2817	3.7704
222	2407.80	0.001193	0.082979	0.081785	952.772	2800.23	1847.46	949.899	2600.44	1650.54	2.5295	6.2673	3.7378
224	2500.45	0.001197	0.079935	0.078738	962.071	2800.72	1838.65	959.079	2600.84	1641.77	2.5478	6.2530	3.7053
226	2595.84	0.001200	0.077021	0.075820	971.397	2801.14	1829.74	968.281	2601.21	1632.93	2.5660	6.2388	3.6728

T C	P_{sat} kPa	v_f m3/kg	v_g m3/kg	v_{fg} m3/kg	h_f kJ/kg	h_g kJ/kg	h_{fg} kJ/kg	u_f kJ/kg	u_g kJ/kg	u_{fg} kJ/kg	s_f kJ/kg K	s_g kJ/kg K	s_{fg} kJ/kg K
228	2694.01	0.001204	0.074229	0.073025	980.750	2801.50	1820.75	977.506	2601.53	1624.02	2.5841	6.2246	3.6404
230	2795.02	0.001208	0.071555	0.070346	990.131	2801.80	1811.67	986.754	2601.80	1615.05	2.6023	6.2104	3.6081
232	2898.94	0.001212	0.068991	0.067779	999.539	2802.03	1802.49	996.025	2602.03	1606.00	2.6204	6.1963	3.5759
234	3005.81	0.001216	0.066532	0.065316	1008.98	2802.19	1793.22	1005.32	2602.21	1596.89	2.6384	6.1821	3.5437
236	3115.69	0.001220	0.064174	0.062954	1018.44	2802.30	1783.85	1014.64	2602.35	1587.71	2.6564	6.1680	3.5116
238	3228.65	0.001224	0.061911	0.060687	1027.94	2802.33	1774.39	1023.99	2602.44	1578.46	2.6744	6.1539	3.4795
240	3344.74	0.001228	0.059739	0.058511	1037.46	2802.30	1764.84	1033.36	2602.49	1569.13	2.6923	6.1398	3.4475
242	3464.02	0.001233	0.057654	0.056421	1047.02	2802.21	1755.19	1042.75	2602.49	1559.74	2.7102	6.1258	3.4155
244	3586.55	0.001237	0.055651	0.054414	1056.61	2802.05	1745.43	1052.17	2602.45	1550.28	2.7281	6.1117	3.3836
246	3712.39	0.001242	0.053727	0.052486	1066.23	2801.82	1735.58	1061.62	2602.36	1540.74	2.7460	6.0977	3.3517
248	3841.61	0.001246	0.051878	0.050632	1075.89	2801.52	1725.63	1071.10	2602.23	1531.13	2.7638	6.0836	3.3199
250	3974.26	0.001251	0.050100	0.048850	1085.58	2801.16	1715.58	1080.60	2602.05	1521.44	2.7815	6.0696	3.2880
252	4110.40	0.001256	0.048391	0.047135	1095.30	2800.73	1705.43	1090.14	2601.82	1511.68	2.7993	6.0555	3.2562
254	4250.11	0.001260	0.046747	0.045486	1105.06	2800.23	1695.17	1099.70	2601.55	1501.85	2.8170	6.0414	3.2245
256	4393.44	0.001265	0.045164	0.043899	1114.85	2799.66	1684.81	1109.29	2601.23	1491.94	2.8346	6.0273	3.1927
258	4540.47	0.001270	0.043641	0.042371	1124.69	2799.02	1674.34	1118.92	2600.87	1481.95	2.8523	6.0132	3.1610
260	4691.25	0.001275	0.042175	0.040900	1134.56	2798.32	1663.76	1128.57	2600.46	1471.89	2.8699	5.9991	3.1293
262	4845.85	0.001281	0.040763	0.039483	1144.47	2797.54	1653.08	1138.26	2600.01	1461.75	2.8874	5.9850	3.0976
264	5004.33	0.001286	0.039403	0.038117	1154.42	2796.70	1642.28	1147.98	2599.51	1451.53	2.9050	5.9708	3.0659
266	5166.78	0.001291	0.038093	0.036801	1164.41	2795.79	1631.38	1157.74	2598.97	1441.23	2.9225	5.9566	3.0342
268	5333.25	0.001297	0.036829	0.035532	1174.44	2794.80	1620.36	1167.53	2598.38	1430.86	2.9399	5.9424	3.0025
270	5503.82	0.001303	0.035612	0.034309	1184.52	2793.75	1609.23	1177.35	2597.75	1420.40	2.9574	5.9282	2.9708
272	5678.56	0.001309	0.034437	0.033129	1194.64	2792.62	1597.98	1187.21	2597.07	1409.86	2.9748	5.9139	2.9391
274	5857.53	0.001315	0.033304	0.031990	1204.81	2791.43	1586.62	1197.11	2596.35	1399.23	2.9921	5.8995	2.9074
276	6040.80	0.001321	0.032211	0.030891	1215.03	2790.16	1575.13	1207.05	2595.58	1388.53	3.0094	5.8852	2.8757
278	6228.47	0.001327	0.031157	0.029830	1225.29	2788.82	1563.53	1217.03	2594.76	1377.73	3.0267	5.8707	2.8440
280	6420.58	0.001333	0.030138	0.028805	1235.61	2787.41	1551.80	1227.05	2593.91	1366.86	3.0440	5.8562	2.8123
282	6617.23	0.001340	0.029155	0.027816	1245.98	2785.93	1539.95	1237.12	2593.01	1355.89	3.0612	5.8417	2.7805
284	6818.48	0.001346	0.028206	0.026859	1256.40	2784.38	1527.98	1247.22	2592.06	1344.84	3.0784	5.8271	2.7488

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286	7024.42	0.001353	0.027288	0.025935	1266.88	2782.75	1515.87	1257.38	2591.07	1333.69	3.0955	5.8125	2.7170
288	7235.11	0.001360	0.026402	0.025042	1277.42	2781.06	1503.64	1267.58	2590.03	1322.46	3.1126	5.7977	2.6852
290	7450.65	0.001367	0.025545	0.024178	1288.01	2779.29	1491.27	1277.83	2588.96	1311.13	3.1296	5.7830	2.6533
292	7671.10	0.001374	0.024717	0.023343	1298.67	2777.44	1478.77	1288.13	2587.83	1299.71	3.1466	5.7681	2.6215
294	7896.54	0.001382	0.023917	0.022535	1309.39	2775.53	1466.14	1298.48	2586.67	1288.19	3.1635	5.7532	2.5896
296	8127.07	0.001389	0.023142	0.021753	1320.18	2773.54	1453.36	1308.89	2585.46	1276.57	3.1804	5.7382	2.5578
298	8362.76	0.001397	0.022393	0.020996	1331.03	2771.47	1440.44	1319.35	2584.20	1264.85	3.1972	5.7231	2.5259
300	8603.69	0.001405	0.021669	0.020263	1341.96	2769.34	1427.38	1329.87	2582.91	1253.04	3.2139	5.7079	2.4940
302	8849.96	0.001413	0.020967	0.019554	1352.96	2767.13	1414.16	1340.45	2581.57	1241.11	3.2306	5.6927	2.4621
304	9101.63	0.001421	0.020288	0.018867	1364.04	2764.84	1400.80	1351.10	2580.18	1229.08	3.2472	5.6773	2.4302
306	9358.81	0.001430	0.019631	0.018201	1375.19	2762.48	1387.29	1361.81	2578.76	1216.95	3.2636	5.6619	2.3982
308	9621.58	0.001439	0.018995	0.017556	1386.43	2760.05	1373.62	1372.59	2577.29	1204.70	3.2800	5.6463	2.3664
310	9890.03	0.001448	0.018379	0.016931	1397.76	2757.54	1359.78	1383.44	2575.77	1192.34	3.2962	5.6307	2.3345
312	10164.24	0.001457	0.017782	0.016325	1409.17	2754.96	1345.79	1394.36	2574.22	1179.86	3.3123	5.6150	2.3027
314	10444.32	0.001466	0.017203	0.015737	1420.68	2752.30	1331.62	1405.36	2572.62	1167.26	3.3282	5.5991	2.2709
316	10730.34	0.001476	0.016643	0.015167	1432.28	2749.56	1317.28	1416.44	2570.98	1154.54	3.3439	5.5832	2.2393
318	11022.41	0.001486	0.016100	0.014614	1443.98	2746.75	1302.77	1427.61	2569.30	1141.69	3.3594	5.5671	2.2077
320	11320.63	0.001496	0.015573	0.014078	1455.79	2743.87	1288.08	1438.86	2567.57	1128.71	3.3746	5.5510	2.1764
322	11625.08	0.001506	0.015063	0.013557	1467.71	2740.91	1273.20	1450.20	2565.80	1115.60	3.3895	5.5347	2.1452
324	11935.86	0.001517	0.014568	0.013052	1479.74	2737.87	1258.13	1461.64	2563.99	1102.35	3.4041	5.5183	2.1142
326	12253.07	0.001527	0.014088	0.012561	1491.88	2734.76	1242.87	1473.17	2562.13	1088.96	3.4182	5.5018	2.0836
328	12576.82	0.001538	0.013623	0.012084	1504.15	2731.57	1227.41	1484.81	2560.24	1075.43	3.4318	5.4851	2.0533
330	12907.21	0.001550	0.013171	0.011622	1516.55	2728.30	1211.75	1496.55	2558.29	1061.74	3.4448	5.4684	2.0235
332	13244.33	0.001561	0.012733	0.011172	1529.09	2724.96	1195.87	1508.41	2556.31	1047.90	3.4571	5.4515	1.9944
334	13588.29	0.001573	0.012308	0.010735	1541.76	2721.54	1179.78	1520.38	2554.28	1033.90	3.4685	5.4344	1.9659
336	13939.20	0.001585	0.011896	0.010311	1554.57	2718.04	1163.46	1532.48	2552.21	1019.74	3.4788	5.4173	1.9384
338	14297.16	0.001598	0.011496	0.009898	1567.54	2714.46	1146.92	1544.70	2550.10	1005.40	3.4879	5.4000	1.9121
340	14662.29	0.001611	0.011108	0.009497	1580.67	2710.81	1130.14	1557.05	2547.94	990.89	3.4953	5.3825	1.8872
342	15034.68	0.001624	0.010731	0.009107	1593.96	2707.08	1113.11	1569.55	2545.74	976.19	3.5009	5.3649	1.8641

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344	15414.47	0.001637	0.010365	0.008728	1607.42	2703.26	1095.84	1582.19	2543.50	961.31	3.5040	5.3472	1.8433
346	15801.74	0.001651	0.010009	0.008359	1621.07	2699.38	1078.31	1594.98	2541.21	946.23	3.5040	5.3294	1.8254
348	16196.63	0.001665	0.009664	0.008000	1634.90	2695.41	1060.51	1607.93	2538.88	930.94	3.5002	5.3114	1.8111
350	16599.25	0.001679	0.009330	0.007650	1648.92	2691.36	1042.44	1621.05	2536.50	915.45	3.4915	5.2932	1.8017
352	17009.71	0.001694	0.009004	0.007311	1663.15	2687.24	1024.08	1634.34	2534.07	899.73	3.4764	5.2749	1.7985
354	17428.13	0.001709	0.008689	0.006980	1677.60	2683.03	1005.43	1647.81	2531.60	883.79	3.4528	5.2565	1.8036
356	17854.64	0.001724	0.008382	0.006658	1692.26	2678.75	986.48	1661.47	2529.09	867.61	3.4179	5.2378	1.8199
358	18289.36	0.001740	0.008084	0.006344	1707.16	2674.38	967.22	1675.33	2526.52	851.19	3.3676	5.2191	1.8515
360	18732.41	0.001756	0.007795	0.006039	1722.30	2669.94	947.64	1689.40	2523.91	834.51	3.2954	5.2002	1.9047
362	19183.91	0.001773	0.007514	0.005741	1737.69	2665.41	927.72	1703.68	2521.26	817.57	3.1918	5.1811	1.9893
364	19644.00	0.001790	0.007242	0.005452	1753.35	2660.81	907.45	1718.19	2518.55	800.36	3.0409	5.1619	2.1210
366	20112.81	0.001807	0.006977	0.005170	1769.28	2656.12	886.84	1732.93	2515.79	782.86	2.8150	5.1425	2.3276
368	20590.46	0.001825	0.006720	0.004895	1785.50	2651.35	865.85	1747.93	2512.99	765.06	2.4610	5.1230	2.6620
370	21077.08	0.001843	0.006470	0.004627	1802.03	2646.50	844.48	1763.17	2510.13	746.95	1.8582	5.1033	3.2451
372	21572.82	0.001862	0.006228	0.004366	1818.86	2641.57	822.71	1778.69	2507.22	728.53	0.5970	5.0835	4.4864
374	22077.81	0.001881	0.005993	0.004111	1836.02	2636.56	800.54	1794.49	2504.26	709.77	-19.7443	5.0635	24.8077

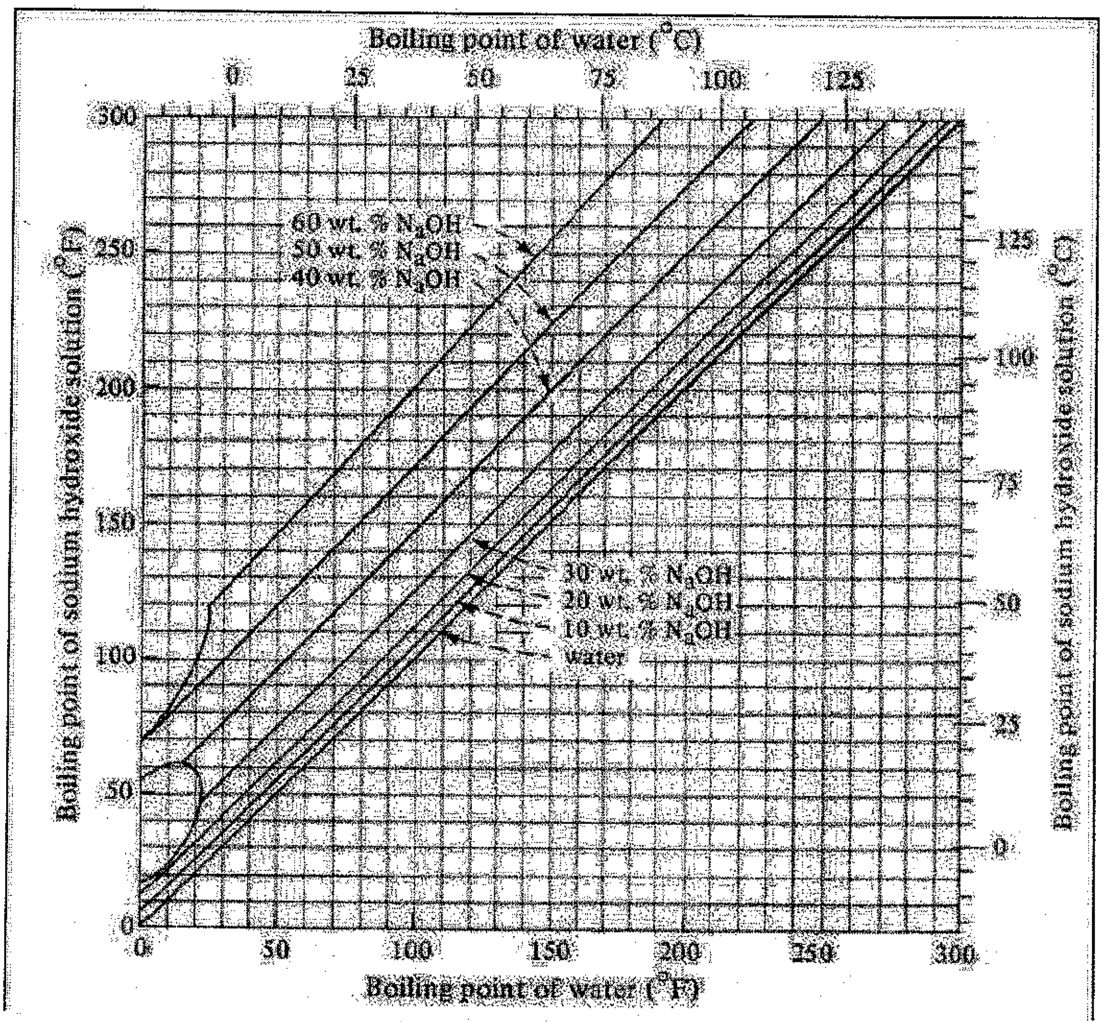

Figure. 1 Duhring lines for aqueous solutions of sodium hydroxide.

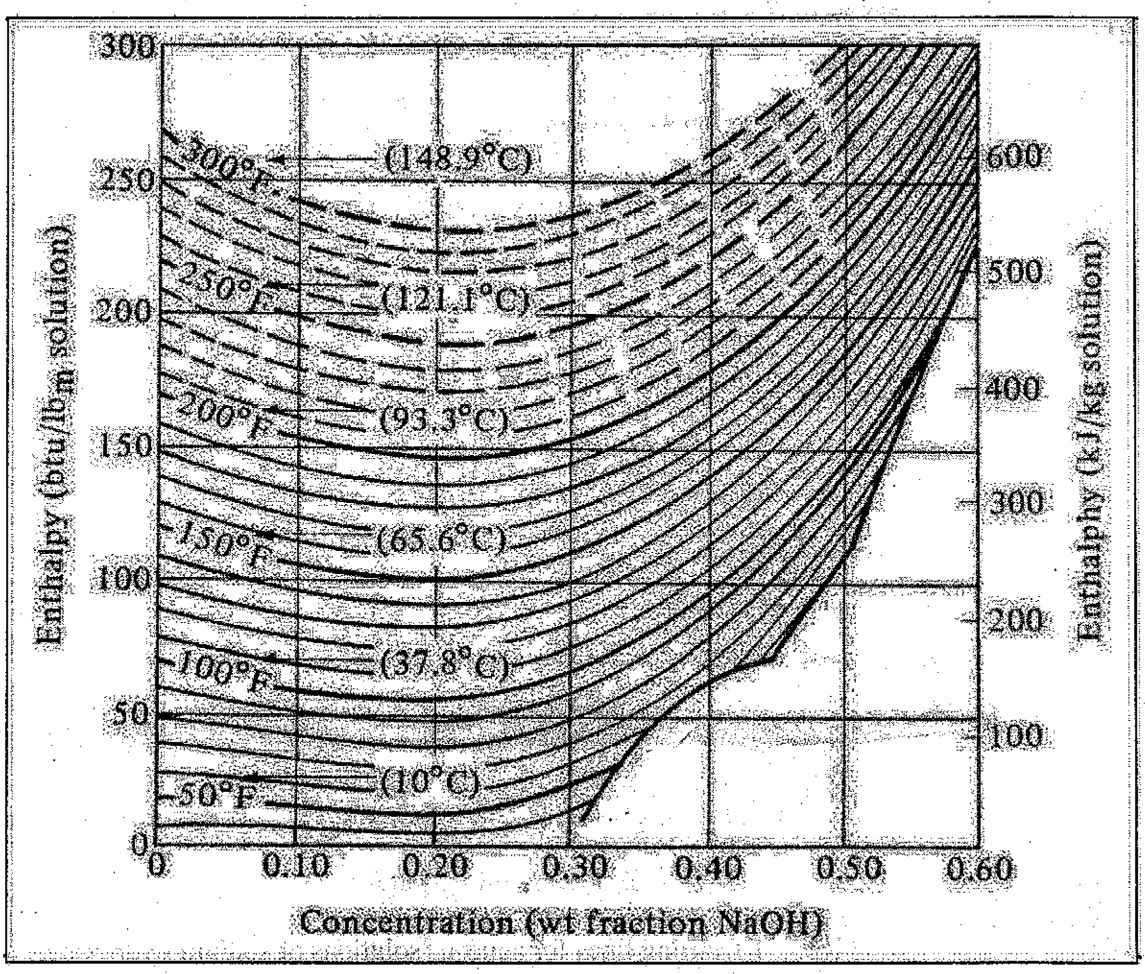

Figure.2 Enthalpy concentration chart for the system NaOH water.