Name of the Examination: B. PHARMACY THIRD YEAR SECOND SEMESTER - 2018

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.(i)Write on the principle ,construction, operation, advantages and disadvantages of Krystal crystallizer or Draft tube baffle crystallizer.

(ii) A Swenson Walker crystallizer is to be used to produce 1 ton /hr of $FeSO_4,7H_2O$(M.W. 278) crystals by the cooling of a saturated solution (33.23%)which enters the crystallizer at T_F=125°F and the slurry leaves at T_L=75°F.After product formation, concentration of mother liquor at T_L is 22.51%.Cooling water enters counter currently the crystallizer jacket at 60°F and leaves at 70°F.Average specific heat of feed solution is 0.7 BTU/lb/°F and heat of crystallization is 28.49 BTU/lb. The overall heat transfer coefficient is 35 BTU/(hr)(sq ft)(°F).There are 3 sq ft of cooling surface per foot of crystallizer length.

(a)Estimate the cooling water requirement in litre/hr. (b) Determine number of crystallizer sections.

Marks 10+10

Q2.(i) Write on propeller and paddle type impellers. Mention different types of dimensionless groups involved in mixing of liquid system. Explain vortex formation in a liquid and how can it be prevented?

(ii) 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 20 poise and a density of 900 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 .

Calculate power requirement in horse power for agitating liquid in both **baffled** and **unbaffled** tanks with (i)**propeller** (a=1.7,b=18) and (ii) **turbine** (a=1, b=40) type impellors? Choose a rpm when baffled tank is not necessary. Plot each of following coordinates on log-log paper and solve the problem.

Propeller type						Turbine type				
N_{Re} Unbaffled,Np	250 0.95	400 0.9	10^3 0.8	$2*10^3$ 0.7	10^4 0.6	N_{Re} Unbaffled,Np	200 3.7	300 3.8	10^3 2.7	$3*10^3$ 1.75	10^4 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 10+10

Q3.(i) Derive the expression for steady state heat flow through a cylinder, and(ii) Derive the expression for overall heat transfer coefficient .(iii) Give a description of 2-4 shell and tube heat exchanger with neat diagram.

(iv) A flat furnace wall is constructed of a 114mm layer of Sil-o-cel brick, with a thermal conductivity of 0.138 W/m.°C backed by a 229 mm layer of common brick, of thermal conductivity of 1.38 W/m.°C . The temperature of the inner face of the wall is 765°C and that of the outer face is 77°C. (a)What is the heat loss through the wall? (b) What is the temperature of the interface between the two bricks layers? (c) supposing the contact the two bricks layers is very poor and a contact resistance of 0.09° C.m^2/W is present, What would be the heat loss?

Marks (4+4+4)+8

B. PHARMACY THIRD YEAR SECOND SEMESTER - 2018

PHARMACEUTICAL ENGINEERING - I   TIME: 3 h   FULL MARKS: 100
ANSWER ANY FIVE QUESTIONS TAKING ATLEAST TWO FROM EACH GROUP

GROUP-B

(Use graph paper if required)

[Use steam table as required]

1. A 6% aqueous solution of high molecular weight solute has to be concentrated to 40% in a forward feed double effect evaporator at the rate of 12000 kg/h. The feed temperature is 40°C. Saturated steam at 4.5 kg/cm² is available for heating. A vacuum of 600 mm Hg is maintained in the second effect. Calculate the area requirements, if the calandria of equal area are used. The overall heat transfer coefficients are 550 and 370 kcal/hm² °C in the first effect and the last effect respectively. The specific heat of the concentrated liquor is 0.87kcal/kg °C.   [20]

2.

   a. An evaporator is used to concentrate 4536 kg/h of a 20% solution of NaOH in water entering at 65°C to a product of 50% solid. The pressure of the saturated steam used is 170.6 kPa and the pressure in the vapor space of the evaporator is 11.75 kPa. The overall heat-transfer coefficient is 2000 W/m²K. Calculate the steam used, the steam economy in kg vaporized/kg steam used, and the heating surface area in m².

   b. Write short notes on any three: a) Basket Type Vertical Evaporator, b) Falling Film Evaporators, C) Gasketed Plate Evaporator, d) Parallel Feed.

   c.

   i. .... tube vertical evaporator is commonly used for handling solutions that tend to foam
      a. Short
      b. Long
      c. Either (i) or (ii)
      d. None of these.

   ii. Euler number

      e.
      $$\frac{Inertial\ effects}{pressure\ effects}$$

      f.
      $$\frac{pressure\ effects}{inertial\ effects}$$

      g.
      $$\frac{inertial\ effects}{gravitational\ effect}$$

      d.
      $$\frac{viscous\ effects}{gravitational\ effects}$$

   iii. Reynolds number

      a.
      $$\frac{inertial\ effects}{gravitational\ effect}$$

      b.
      $$\frac{inertial\ effects}{viscous\ effects}$$

      c.
      None of these

      d.
      $$\frac{viscous\ effects}{gravitational\ effects}$$

[8+9+3=20]

3.

   a. The screen analysis shown in the table-1 below, applies to a sample of crushed quartz. The density of the particle is 3000 kg/m³, 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) A_w, and N_w b)

$\overline{D_V}$ c) $\overline{D_s}$ 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?

b. 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.

c. The following relation between specific resistance and pressure drop has been determined:

$$\alpha = 8.8*10^{10}[1+3.36*10^{-4}(\Delta p \ in \ lb/ft^2)^{0.86}]$$

This relation is valid over a pressure range of 0-1000 lbf/sq.in. A slurry of this material yielding 3 lb of cake solid per cubic filtrate is to be filtered at a constant pressure drop of 70 lbf/sq.in and 70°F. The resistance of filter-medium $R_m=0.65*10^{10}$per ft. Determine square feet of the filter surface area required to give 1400 gal of filtrate in a 1-h filtration?

[8+7+5=20]

4.

I.

a. The weak liquor to be fed to the evaporator is composed of a non-volatile .... and a ...... solvent.
   i.   Solute, volatile
   ii.   Solute, solute
   iii.   Volatile, volatile
   iv.   None of these

b. In the .... feed system, vapor and liquor flow in counter current fashion.
   ii.   Backward
   iii.   Forward
   iv.   Mixed
   v.   Parallel

II. Compare forward feed arrangement with backward feed arrangement in case of a multiple effect evaporation system.

III. A certain set of crushing rolls has rolls of 100 cm diameter by 38 cm width face. They are set so that crushing surfaces are 1.25 cm apart at the narrowest point. The manufacture recommends that they may run at 50 to 100 rpm. They are to crush a rock having a specific gravity of 2.35 and the angle of nip is 30°. What are the maximum permissible size of feed and maximum actual capacity in tonnes per hour, if the actual capacity is 12% of the theoretical.?

IV. A certain set of crushing rolls has rolls of 1000 mm diameter by 375 mm width of face. They are set so that the crushing surfaces are 12 mm apart at the narrowest point. What is the maximum permissible size of feed? Given: Angle of nip = 30°.

V. A material is crushed in a Blake jaw crusher such that the average size of particle is reduced from 50 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?

[2+4+6+4+4=20]

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_p
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

Mesh	D_p, mm	Cumulative fraction smaller than D_p		
		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
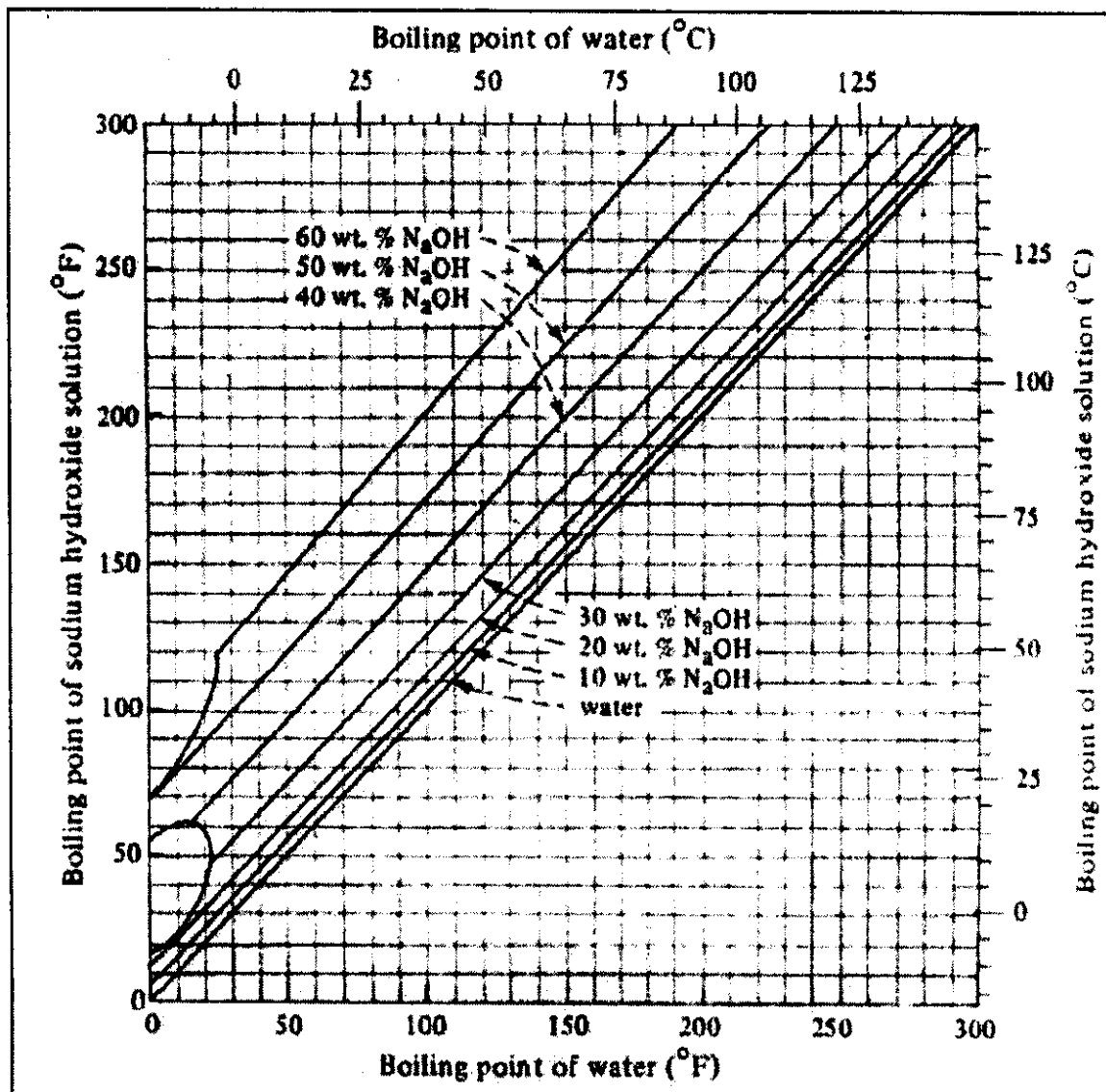
Duhring lines for aqueous solutions of sodium hydroxide.
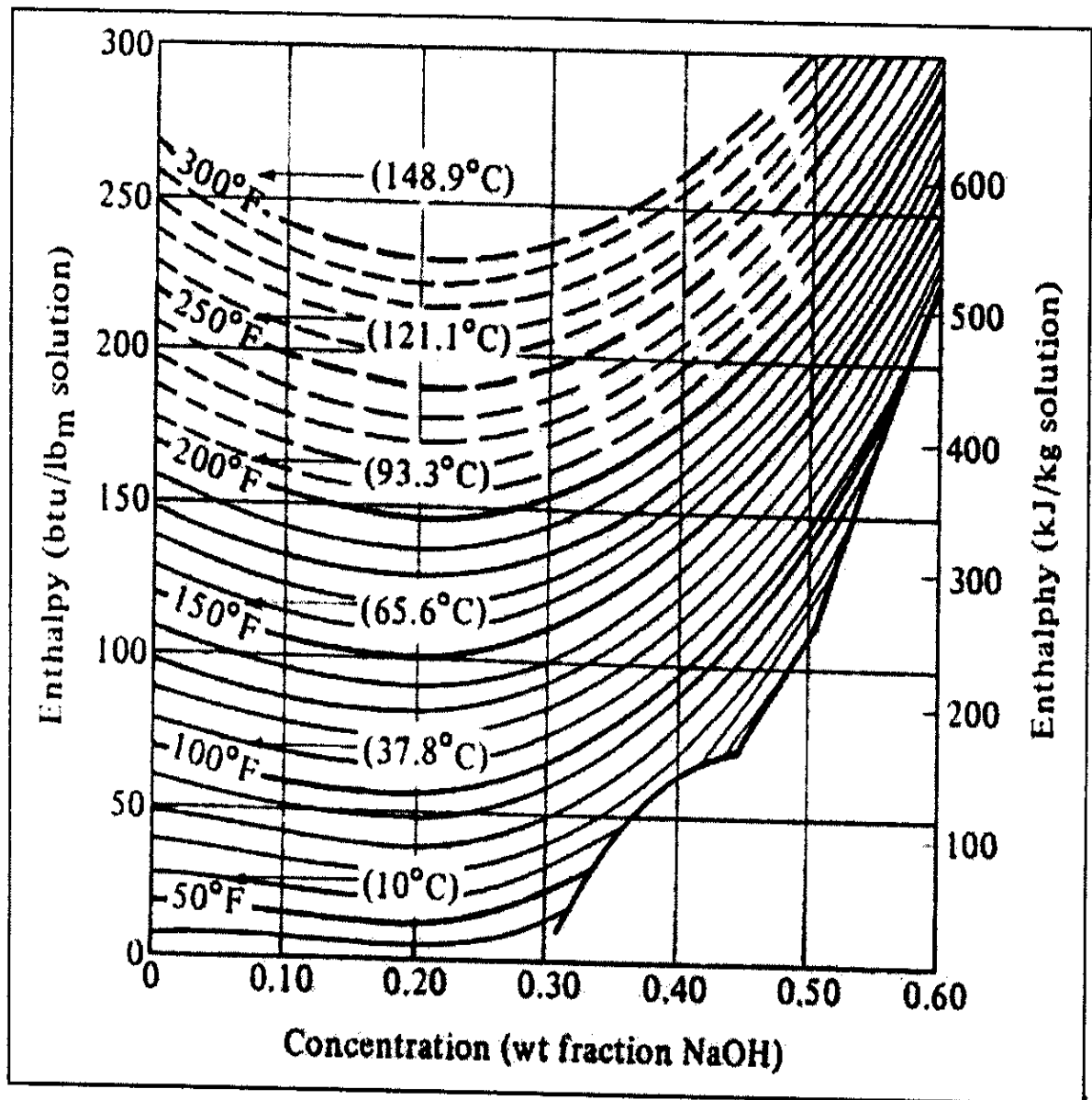
Enthalpy concentration chart for the system NaOH water.

Table 3   Saturation Temperature Table for Steam in SI Units

T °C	P_sat kPa	v_f m³/kg	v_g m³/kg	u_f kJ/kg	u_fg kJ/kg	u_g kJ/kg	h_f kJ/kg	h_fg kJ/kg	h_g kJ/kg	s_f kJ/kg·K	s_fg kJ/kg·K	s_g kJ/kg·K
0	0.6112	0.000999	205.94	0.0007	2500.93	2500.93	0.0001	2374.02	2374.12	-0.0013	9.1582	9.1595
2	0.7055	0.000999	179.63	9.348	2504.40	2495.15	9.348	2377.48	2368.24	0.0297	9.1052	9.0755
4	0.8140	0.000999	157.04	17.809	2508.90	2491.01	17.809	2380.74	2363.17	0.0604	9.0531	8.9928
6	0.9357	0.000999	137.99	25.9279	2513.64	2486.72	25.911	2383.99	2357.97	0.0908	9.0020	8.9113
8	1.0722	0.000997	120.82	34.2606	2516.18	2482.31	34.299	2386.91	2352.64	0.1209	8.9518	8.8309
10	1.2282	0.000997	106.31	42.5897	2520.42	2477.83	42.585	2390.24	2347.25	0.1508	8.9026	8.7518
12	1.4028	0.000998	93.74	50.9160	2523.82	2472.27	50.9166	2392.79	2341.79	0.1804	8.8542	8.6738
14	1.5985	0.000999	82.83	59.2401	2527.90	2468.66	59.2365	2395.51	2336.27	0.2098	8.8068	8.5969
16	1.8180	0.000999	73.33	67.5605	2531.58	2464.02	67.5607	2398.27	2330.71	0.2389	8.7599	8.5211
18	2.0635	0.001000	65.04	75.8837	2535.23	2459.34	75.8817	2401.01	2325.13	0.2678	8.7141	8.4463
20	2.3374	0.001000	57.80	84.2043	2538.85	2454.65	84.2009	2403.73	2319.53	0.2964	8.6690	8.3725
22	2.6431	0.001001	51.46	92.5247	2542.44	2449.94	92.9208	2406.43	2313.91	0.3249	8.6247	8.2998
24	2.9830	0.001002	45.90	100.845	2546.06	2445.21	100.843	2409.13	2308.23	0.3531	8.5811	8.2280
26	3.3604	0.001003	41.02	109.166	2549.65	2440.48	109.163	2411.81	2302.65	0.3811	8.5384	8.1572
28	3.7789	0.001004	36.71	117.488	2553.23	2435.74	117.484	2414.49	2297.01	0.4090	8.4963	8.0874
30	4.2430	0.001004	32.92	125.811	2556.81	2431.00	125.807	2417.17	2291.34	0.4366	8.4550	8.0184
32	4.7536	0.001005	29.57	134.136	2560.39	2426.25	134.131	2419.84	2285.71	0.4640	8.4143	7.9503
34	5.3181	0.001006	26.60	142.462	2563.94	2421.50	142.456	2422.52	2280.06	0.4913	8.3744	7.8831
36	5.9388	0.001006	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	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	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	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	184.122	2581.75	2397.03	184.114	2435.84	2251.73	0.6248	8.1843	7.5594
46	10.084	0.001010	14.56	192.461	2585.29	2392.83	192.452	2438.50	2246.04	0.6510	8.1481	7.4970
48	11.160	0.001011	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	12.04	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	217.458	2595.85	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_g 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	4.290	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 kPa	v_f m³/kg	v m³/kg	v_g 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	6.8029
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	4.7694
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_{fg} m³/kg	v_g 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

T °C	P kPa	v_f m³/kg	v_{fg} m³/kg	v_g m³/kg	u_f kJ/kg	u_{fg} kJ/kg	u_g kJ/kg	h_f kJ/kg	h_{fg} kJ/kg	h_g kJ/kg	s_f kJ/kg K	s_{fg} kJ/kg K	s_g kJ/kg K
286	7024.42	0.001353	0.025935	0.027288	1257.38	1333.69	2591.07	1266.88	1515.87	2782.75	3.0955	2.7170	5.8125
288	7235.11	0.001360	0.025042	0.026402	1267.54	1322.46	2590.03	1277.42	1503.64	2781.06	3.1126	2.6852	5.7977
290	7450.65	0.001367	0.024178	0.025545	1277.83	1311.13	2588.96	1288.01	1491.27	2779.29	3.1296	2.6533	5.7830
292	7671.10	0.001374	0.023343	0.024717	1288.13	1299.71	2587.83	1298.67	1478.77	2777.44	3.1466	2.6215	5.7681
294	7896.54	0.001382	0.022535	0.023917	1298.48	1288.19	2586.67	1309.39	1466.14	2775.53	3.1635	2.5896	5.7532
296	8127.07	0.001389	0.021753	0.023142	1308.89	1276.57	2585.46	1320.18	1453.36	2773.54	3.1804	2.5578	5.7382
298	8362.76	0.001397	0.020996	0.022393	1319.35	1264.85	2584.20	1331.03	1440.44	2771.47	3.1972	2.5259	5.7231
300	8603.69	0.001405	0.020263	0.021669	1329.87	1253.04	2582.91	1341.96	1427.38	2769.34	3.2139	2.4940	5.7079
302	8849.96	0.001413	0.019554	0.020967	1340.45	1241.11	2581.57	1352.96	1414.16	2767.13	3.2306	2.4621	5.6927
304	9101.63	0.001421	0.018867	0.020288	1351.10	1229.08	2580.18	1364.04	1400.80	2764.84	3.2472	2.4302	5.6773
306	9358.81	0.001430	0.018201	0.019631	1361.81	1216.95	2578.76	1375.19	1387.29	2762.48	3.2636	2.3982	5.6619
308	9621.58	0.001439	0.017556	0.018995	1372.59	1204.70	2577.29	1386.43	1373.62	2760.05	3.2800	2.3664	5.6463
310	9890.03	0.001448	0.016931	0.018379	1383.44	1192.34	2575.77	1397.76	1359.78	2757.54	3.2962	2.3345	5.6307
312	10164.24	0.001457	0.016325	0.017782	1394.36	1179.86	2574.22	1409.17	1345.79	2754.96	3.3123	2.3027	5.6150
314	10444.32	0.001466	0.015737	0.017203	1405.36	1167.26	2572.62	1420.68	1331.62	2752.30	3.3282	2.2709	5.5991
316	10730.34	0.001476	0.015167	0.016643	1416.44	1154.54	2570.98	1432.28	1317.28	2749.56	3.3439	2.2393	5.5832
318	11022.41	0.001486	0.014614	0.016100	1427.61	1141.69	2569.30	1443.98	1302.77	2746.75	3.3594	2.2077	5.5671
320	11320.63	0.001496	0.014078	0.015573	1438.86	1128.71	2567.57	1455.79	1288.08	2743.87	3.3746	2.1764	5.5510
322	11625.08	0.001506	0.013557	0.015063	1450.20	1115.60	2565.80	1467.71	1273.20	2740.91	3.3895	2.1452	5.5347
324	11935.86	0.001517	0.013052	0.014568	1461.64	1102.35	2563.99	1479.74	1258.13	2737.87	3.4041	2.1142	5.5183
326	12253.07	0.001527	0.012561	0.014088	1473.17	1088.96	2562.13	1491.88	1242.87	2734.76	3.4182	2.0836	5.5018
328	12576.82	0.001538	0.012084	0.013623	1484.81	1075.43	2560.24	1504.15	1227.41	2731.57	3.4318	2.0533	5.4851
330	12907.21	0.001550	0.011622	0.013171	1496.55	1061.74	2558.29	1516.55	1211.75	2728.30	3.4448	2.0235	5.4684
332	13244.33	0.001561	0.011172	0.012733	1508.41	1047.90	2556.31	1529.09	1195.87	2724.96	3.4571	1.9944	5.4515
334	13588.29	0.001573	0.010735	0.012308	1520.38	1033.90	2554.28	1541.76	1179.78	2721.54	3.4685	1.9659	5.4344
336	13939.20	0.001585	0.010311	0.011896	1532.48	1019.74	2552.21	1554.57	1163.46	2718.04	3.4788	1.9384	5.4173
338	14297.16	0.001598	0.009898	0.011496	1544.70	1005.40	2550.10	1567.54	1146.92	2714.46	3.4879	1.9121	5.4000
340	14662.29	0.001611	0.009497	0.011108	1557.05	990.89	2547.94	1580.67	1130.14	2710.81	3.4953	1.8872	5.3825
342	15034.68	0.001624	0.009107	0.010731	1569.55	976.19	2545.74	1593.96	1113.11	2707.08	3.5009	1.8641	5.3649

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
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	3.4940	5.3294	1.8354
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	3.0469	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