國立臺灣科技大學 111 學年度碩士班招生試題
系所組別：化學工程系碩士班
科　　目：化工熱力學與動力學

（總分為 100 分；所有試題務必於答案卷內頁依序作答，否則不予計分）

1. For the elementary gas phase reaction $A \xrightarrow{k} 1/2\,B + C$, $k = 20\ s^{-1}$ with $F_{A0} = 10\ mol\ s^{-1}$ (pure A) and $C_{A0} = 0.1\ mol\ L^{-1}$,

(a) Set up a stoichiometric table. (5%)

(b) Size a plug flow reactor (PFR) with the target conversion of 0.8.

Simpson's rule: $\int_{X0}^{X2} f(X)\ dX = (h/3)\,[f(X_0) + 4f(X_1) + f(X_2)]$,

where $h = (X_2 - X_0)/2$ (10%)

2. For the elementary gas-phase reaction $A \Longleftrightarrow C + 2\,D$ with forward reaction rate constant (k_f) and backward reaction rate constant (k_b) carried out in an isothermal PFR with negligible pressure drop,

(a) Construct a stoichiometric table and then derive expressions for those species involved in the reaction. Note: The feed stock only contains A. (5%)

(b) Derive an expression for sizing the reactor that can achieve the maximum conversion at the exit of PFR. (15%)

3. Assuming that the following irreversible reaction steps are all elementary processes, where H represents the healthy person, I the person infected with COVID 19, and D the victim of COVID 19. Furthermore, the status of I can be regarded as in the pseudo-steady state and k_1, k_2, k_3 and k_4 are the reaction rate constants of the individual step, respectively.

$$
\begin{cases}
H \xrightarrow{k1} I \\
I + H \xrightarrow{k2} 2\,I \\
I \xrightarrow{k3} H \\
I \xrightarrow{k4} D
\end{cases}
$$

(a) Derive an expression for the death rate due to COVID 19. (10%)

(b) What happens to the death rate if the population of H is very small? (5%)

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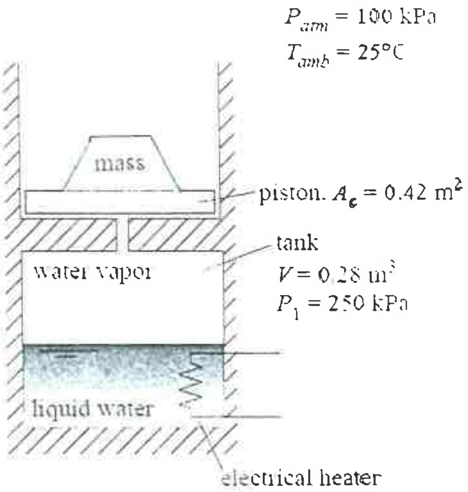
4. Ideal gas is a special case of real gases. Evaluate each of the following operations by first elaborating the governing thermodynamic principle and then discussing how ideal gas may behave differently, if any, comparing to real gas.

(i) Gas liquefaction can be achieved by compressing gas to high pressure following by cooling, and a subsequent Joule-Thomson expansion. (5%)

(ii) The efficiency of a reversible heat engine operated using ideal gas as the working fluid comparing to that using, e.g., steam as the working fluid. (5%)

(iii) When a gas is cooled to below its critical temperature condensed liquid can be obtained coexisting with gas phase. (5%)

5. A simple elevator system is designed utilizing heating of water as shown in the figure. It consists of a well-insulated tank having a volume of $V = 0.28\ \text{m}^3$ containing two phase water at $P_1 = 250$ kPa. At the start of the lifting process, the liquid in the tank occupies 50% of the tank volume, with the remainder being vapor. At the top of the tank is a short pipe that connects the tank to a piston-cylinder device. There is negligible pressure loss when vapor flows through this pipe and the volume of the pipe is negligible. The cross-sectional area of the piston is $A_c = 0.42\ \text{m}^2$. At the start of this process, the piston is floating very near (but not touching) the bottom of the cylinder. Then, the electric heater in the tank is switched on. The piston is observed to rise $z = 2.5$ m in the cylinder, at which time the heater is switched off. Thermal losses may be assumed to be negligible during the lifting process.



(i) Determine the temperature and the quality of the water before and at the completion of the lifting process. (10%)

(ii) Evaluate the mass of piton plus the loaded weight. How much work is done and how much heat is needed for the lifting process? What is the efficiency of this operation. (10%)

6. Separating air to enriched oxygen and enriched nitrogen streams has great market applications. One company claims an invented process that operates continuously by first compressing air to 2 bar and 25 °C, and then isothermally expanding to 1 bar through a secret device that has no moving parts and resulting in two streams. The first stream contains 95 % oxygen while the other contains only 5 % oxygen. Evaluate if such a claim can be trusted. You need to elaborate the assumption(s) you make for your analysis. (15%)

===================== Some Useful Equations ============================

$$d\underline{S} = \frac{C_V}{T}dT + \left(\frac{\partial P}{\partial T}\right)_{\underline{V}} d\underline{V}$$

$$\underline{H}(T,P) - \underline{H}^{IG}(T,P) = RT(Z-1) + \int_{\underline{V}=\infty}^{\underline{V}(T,P)} \left[T\left(\frac{\partial P}{\partial T}\right)_{\underline{V}} - P\right] d\underline{V}$$

$$d\underline{S} = \frac{C_P}{T}dT - \left(\frac{\partial \underline{V}}{\partial T}\right)_P dP$$

$$\underline{S}(T,P) - \underline{S}^{IG}(T,P) = R\ln Z + \int_{\underline{V}=\infty}^{\underline{V}(T,P)} \left[\left(\frac{\partial P}{\partial T}\right)_{\underline{V}} - \frac{R}{\underline{V}}\right] d\underline{V}$$

$$d\underline{U} = C_V dT + \left[T\left(\frac{\partial P}{\partial T}\right)_{\underline{V}} - P\right] d\underline{V}$$

$$\underline{H}(T,P) - \underline{H}^{IG}(T,P) = RT(Z-1) + \frac{T\left(\frac{da}{dT}\right) - a}{2\sqrt{2}b} \ln\frac{Z + (1+\sqrt{2})B}{Z + (1-\sqrt{2})B}$$

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$$d\underline{H} = C_P dT + \left[\underline{V} - T\left(\frac{\partial \underline{V}}{\partial T}\right)_P\right] dP$$

$$\ln\phi = \ln\frac{f}{P} = \frac{1}{RT}\int_{\underline{V}\to\infty}^{\underline{V}}\left(\frac{RT}{\underline{V}} - P\right) d\underline{V} - \ln Z + (Z-1)$$

$$f^L(T,P) = P^{sat}\left(\frac{f}{P}\right)_{sat,T}\exp\left(\frac{1}{RT}\int_{P^{sat}}^{P}\underline{V}^L dP\right)$$

$$\overline{\theta}_1(T,P,\underline{x}) - \underline{\theta}_1(T,P,\underline{x}) = \Delta_{mix}\underline{\theta}(T,P,\underline{x}) - x_2\left.\frac{\partial\Delta_{mix}\underline{\theta}}{\partial x_2}\right|_{T,P}$$

$$\overline{\theta}_2(T,P,\underline{x}) - \underline{\theta}_2(T,P,\underline{x}) = \Delta_{mix}\underline{\theta}(T,P,\underline{x}) - x_1\left.\frac{\partial\Delta_{mix}\underline{\theta}}{\partial x_1}\right|_{T,P}$$

$$\left(\frac{dP}{dT}\right)_{\underline{G}'=\underline{G}''} = \frac{\Delta\underline{S}}{\Delta\underline{V}} = \frac{\Delta\underline{H}}{T\Delta\underline{V}}$$

$$\underline{S}(T,P) - \underline{S}^{IG}(T,P) = R\ln(Z-B) + \frac{\frac{da}{dT}}{2\sqrt{2}b}\ln\frac{Z+(1+\sqrt{2})B}{Z+(1-\sqrt{2})B}$$

where $Z = PV/RT$ and $B = Pb/RT$

$$\ln\frac{f}{P} = \frac{\underline{G}(T,P) - \underline{G}^{IG}(T,P)}{RT} = \frac{1}{RT}\int_0^P\left(\underline{V} - \frac{RT}{P}\right) dP$$

$$f^S(T,P) = P^{sat}\left(\frac{f}{P}\right)_{sat,T}\exp\left(\frac{1}{RT}\sum_{J=1}\int_{P^J}^{P^{J+1}}\underline{V}^J dP\right)$$

$$\overline{G}_j = \underline{G}_j + RT\ln y_j \; + \int_{P^*}^{P}(\overline{V}_j - \underline{V}_j)dP$$

$$\text{and}\quad \underline{G} = \sum_{j=1}^{n} y_j\underline{G}_j + RT\sum_{j=1}^{n} y_j\ln y_j + \int_{P^*}^{P}(\underline{V} - \sum_{j=1}^{n} y_j\underline{V}_j)dP$$

$$d\underline{H} = Td\underline{S} + \underline{V}dP = C_P dT + \left[\underline{V} - T\left(\frac{\partial \underline{V}}{\partial T}\right)_P\right] dP$$

PROPERTIES OF SATURATED WATER IN SI UNITS BY PRESSURE

Press. kPa	T K	Volume, m³/kg V_l	V_g	Enthalpy, kJ/kg H_l	H_{lg}	H_g	Internal Energy, kJ/kg U_l	U_{lg}	U_g
0.80	276.92	0.001000	159.7	15.4	2492.4	2507.8	15.4	2364.4	2379.8
1.0	280.13	0.001000	129.2	28.6	2485.1	2513.7	28.6	2355.1	2383.7
1.2	282.81	0.001000	108.7	39.7	2479.0	2518.7	39.7	2348.0	2387.7
1.4	285.13	0.001001	93.92	49.3	2473.6	2522.9	49.3	2341.6	2390.9
1.6	287.17	0.001001	82.76	57.8	2468.9	2526.7	57.8	2335.9	2393.7
1.8	288.99	0.001001	74.03	65.5	2464.5	2530.0	65.5	2331.5	2397.0
2.0	290.65	0.001002	67.00	72.4	2460.6	2533.0	72.4	2326.6	2399.0
2.5	294.23	0.001002	54.25	87.5	2452.1	2539.6	87.5	2317.1	2404.6
3.0	297.23	0.001003	45.67	100.1	2445.0	2545.1	100.1	2308.0	2408.1
4.0	302.12	0.001004	34.80	120.7	2433.2	2553.9	120.7	2294.4	2415.1
5.0	306.03	0.001005	28.19	137.2	2423.8	2561.0	137.2	2282.8	2420.0
6.0	309.31	0.001007	23.74	151.0	2415.9	2566.9	151.0	2272.9	2423.9
8.0	314.66	0.001009	18.10	173.7	2402.8	2576.5	173.7	2257.8	2431.5
10	318.96	0.001010	14.67	191.8	2392.4	2584.2	191.8	2245.4	2437.2
12	322.57	0.001012	12.36	207.1	2383.5	2590.6	207.1	2235.5	2442.6
14	325.70	0.001013	10.69	220.3	2375.8	2596.1	220.3	2225.8	2446.1
16	328.47	0.001015	9.433	231.9	2369.1	2601.0	231.9	2218.1	2450.0
18	330.96	0.001016	8.445	242.4	2362.9	2605.3	242.4	2210.9	2453.3
20	333.22	0.001017	7.649	251.9	2357.4	2609.3	251.9	2204.4	2456.3
25	338.12	0.001020	6.204	272.6	2345.1	2617.7	272.5	2190.2	2462.7
30	342.26	0.001022	5.229	289.9	2334.9	2624.8	289.8	2178.0	2467.8
40	349.02	0.001026	3.993	318.3	2318.0	2636.3	318.3	2158.0	2476.3
50	354.48	0.001030	3.240	341.3	2304.1	2645.4	341.3	2142.1	2483.4
60	359.09	0.001033	2.732	360.6	2292.4	2653.0	360.4	2128.6	2489.0
80	366.65	0.001038	2.087	392.3	2273.0	2665.3	392.2	2106.1	2498.3
100	372.78	0.001043	1.694	418.0	2257.0	2675.0	418.0	2088.0	2506.0
101.325	373.14	0.001043	1.673	419.5	2256.1	2675.6	419.5	2086.1	2505.6
120	377.96	0.001047	1.428	439.7	2243.4	2683.1	439.5	2072.6	2512.1
140	382.46	0.001051	1.237	458.6	2231.4	2690.0	458.5	2058.5	2517.0
160	386.47	0.001054	1.091	475.5	2220.5	2696.0	475.3	2045.7	2521.0
180	390.09	0.001058	0.9775	490.8	2210.6	2701.4	490.6	2034.8	2525.4
200	393.38	0.001061	0.8857	504.7	2201.5	2706.2	504.5	2024.7	2529.2
250	400.59	0.001067	0.7187	535.2	2181.3	2716.5	535.0	2002.5	2537.5
300	406.70	0.001073	0.6058	561.2	2163.7	2724.9	560.9	1982.0	2542.9
400	416.78	0.001084	0.4625	604.3	2133.8	2738.1	603.8	1949.3	2558.1
500	425.01	0.001093	0.3749	639.8	2108.4	2748.2	639.3	1921.8	2561.1
600	432.00	0.001101	0.3157	670.1	2086.3	2756.4	669.6	1897.8	2567.4
800	443.59	0.001115	0.2404	720.7	2048.0	2768.7	719.8	1856.9	2576.7
1000	453.06	0.001127	0.1944	762.5	2015.1	2777.6	761.6	1822.0	2583.6
1200	461.14	0.001139	0.1633	798.5	1985.9	2784.4	797.2	1791.2	2588.4
1400	468.22	0.001149	0.1408	830.2	1959.4	2789.6	828.6	1764.0	2592.6
1600	474.56	0.001159	0.1238	858.8	1934.8	2793.6	856.9	1738.7	2595.6
1800	480.30	0.001168	0.1104	884.9	1911.8	2796.7	884.8	1742.9	2597.7
2000	485.57	0.001176	0.09963	908.9	1890.2	2799.1	906.5	1693.6	2600.1
2500	497.15	0.001197	0.07998	962.4	1840.2	2802.6	959.4	1643.2	2602.6
3000	507.05	0.001216	0.06668	1008.7	1795.0	2803.7	1005.7	1598.0	2603.7
4000	523.55	0.001252	0.4978	1087.6	1713.4	2801.0	1082.6	1519.4	2602.0
5000	537.14	0.001286	0.03944	1154.5	1639.4	2793.9	1147.5	1449.4	2596.9
6000	548.79	0.001319	0.03244	1213.7	1570.2	2783.9	1205.7	1383.2	2588.9
7000	559.03	0.001352	0.02737	1267.4	1504.3	2771.7	1267.3	1312.4	2579.7
8000	568.22	0.001385	0.02352	1317.0	1440.5	2757.5	1306.0	1262.5	2568.5
10,000	584.22	0.001453	0.01803	1407.9	1316.4	2724.3	1393.9	1150.4	2544.3
11,000	591.30	0.001489	0.01599	1450.2	1255.0	2705.2	1434.2	1095.0	2529.2
12,000	597.90	0.001527	0.01426	1491.2	1193.2	2684.4	1473.1	1040.3	2513.4
13,000	604.09	0.001567	0.01278	1531.1	1130.7	2661.8	1509.0	986.8	2495.8
14,000	609.90	0.001610	0.01149	1570.4	1066.8	2637.2	1542.4	933.8	2476.2
16,000	620.59	0.001710	0.009307	1648.9	931.3	2580.2	1615.9	815.3	2431.2
18,000	630.22	0.001840	0.007492	1731.4	777.4	2508.8	1689.4	685.4	2374.8
20,000	638.96	0.002041	0.005836	1828.5	581.0	2409.5	1786.5	506.0	2292.5
22,089	647.29	0.003155	0.003155	2098.8	0.0	2098.8	2091.8	0	2091.8

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Superheated Vapor‡

T°C	P = 0.010 MPa (45.81)				P = 0.050 MPa (81.33)				P = 0.10 MPa (99.63)			
	$\hat{V}$	$\hat{U}$	$\hat{H}$	$\hat{S}$	$\hat{V}$	$\hat{U}$	$\hat{H}$	$\hat{S}$	$\hat{V}$	$\hat{U}$	$\hat{H}$	$\hat{S}$
Sat.	14.674	2437.9	2584.7	8.1502	3.240	2483.9	2645.9	7.5939	1.6940	2506.1	2675.5	7.3594
50	14.869	2443.9	2592.6	8.1749	—	—	—	—	—	—	—	—
100	17.196	2515.5	2687.5	8.4479	3.418	2511.6	2682.5	7.6947	1.6958	2506.7	2676.2	7.3614
150	19.512	2587.9	2783.0	8.6882	3.889	2585.6	2780.1	7.9401	1.9364	2582.8	2776.4	7.6134
200	21.825	2661.3	2879.5	8.9038	4.356	2659.9	2877.7	8.1580	2.172	2658.1	2875.3	7.8343
250	24.136	2736.0	2977.3	9.1002	4.820	2735.0	2976.0	8.3556	2.406	2733.7	2974.3	8.0333
300	26.445	2812.1	3076.5	9.2813	5.284	2811.3	3075.5	8.5373	2.639	2810.4	3074.3	8.2158
400	31.063	2968.9	3279.6	9.6077	6.209	2968.5	3278.9	8.8642	3.103	2967.9	3278.2	8.5435
500	35.679	3132.3	3489.1	9.8978	7.134	3132.0	3488.7	9.1546	3.565	3131.6	3488.1	8.8342
600	40.295	3302.5	3705.4	10.1608	8.057	3302.2	3705.1	9.4178	4.028	3301.9	3704.7	9.0976
700	44.911	3479.6	3928.7	10.4028	8.981	3479.4	3928.5	9.6599	4.490	3479.2	3928.2	9.3398
800	49.526	3663.8	4159.0	10.6281	9.904	3663.6	4158.9	9.8852	4.952	3663.5	4158.6	9.5652
900	54.141	3855.0	4396.4	10.8396	10.828	3854.9	4396.3	10.0967	5.414	3854.8	4396.1	9.7767
1000	58.757	4053.0	4640.6	11.0393	11.751	4052.9	4640.5	10.2964	5.875	4052.8	4640.3	9.9764
1100	63.372	4257.5	4891.2	11.2287	12.674	4257.4	4891.1	10.4859	6.337	4257.3	4891.0	10.1659
1200	67.987	4467.9	5147.8	11.4091	13.597	4467.8	5147.7	10.6662	6.799	4467.7	5147.6	10.3463
1300	72.602	4683.7	5409.7	11.5811	14.521	4683.6	5409.6	10.8382	7.260	4683.5	5409.5	10.5183

	P = 0.20 MPa (120.23)				P = 0.30 MPa (133.55)				P = 0.40 MPa (143.63)			
Sat.	0.8857	2529.5	2706.7	7.1272	0.6058	2543.6	2725.3	6.9919	0.4625	2553.6	2738.6	6.8959
150	0.9596	2576.9	2768.8	7.2795	0.6339	2570.8	2761.0	7.0778	0.4708	2564.5	2752.8	6.9299
200	1.0803	2654.4	2870.5	7.5066	0.7163	2650.7	2865.6	7.3115	0.5342	2646.8	2860.5	7.1706
250	1.1988	2731.2	2971.0	7.7086	0.7964	2728.7	2967.6	7.5166	0.5951	2726.1	2964.2	7.3789
300	1.3162	2808.6	3071.8	7.8926	0.8753	2806.7	3069.3	7.7022	0.6548	2804.8	3066.8	7.5662
400	1.5493	2966.7	3276.6	8.2218	1.0315	2965.6	3275.0	8.0330	0.7726	2964.4	3273.4	7.8985
500	1.7814	3130.8	3487.1	8.5133	1.1867	3130.0	3486.0	8.3251	0.8893	3129.2	3484.9	8.1913
600	2.013	3301.4	3704.0	8.7770	1.3414	3300.8	3703.2	8.5892	1.0055	3300.2	3702.4	8.4558
700	2.244	3478.8	3927.6	9.0194	1.4957	3478.1	3927.1	8.8319	1.1215	3477.9	3926.5	8.6987
800	2.475	3663.1	4158.2	9.2449	1.6499	3662.9	4157.8	9.0576	1.2372	3662.4	4157.3	8.9244
900	2.706	3854.5	4395.8	9.4566	1.8041	3854.2	4395.4	9.2692	1.3529	3853.9	4395.1	9.1362
1000	2.937	4052.5	4640.0	9.6563	1.9581	4052.3	4639.7	9.4690	1.4685	4052.0	4639.4	9.3360
1100	3.168	4257.0	4890.7	9.8458	2.1121	4256.8	4890.4	9.6585	1.5840	4256.5	4890.2	9.5256
1200	3.399	4467.5	5147.3	10.0262	2.2661	4467.2	5147.1	9.8389	1.6996	4467.0	5146.8	9.7060
1300	3.630	4683.2	5409.3	10.1982	2.4201	4683.0	5409.0	10.0110	1.8151	4682.8	5408.8	9.8780

	P = 0.50 MPa (151.86)				P = 0.60 MPa (158.85)				P = 0.80 MPa (170.43)			
Sat.	0.3749	2561.2	2748.7	6.8213	0.3157	2567.4	2756.8	6.7600	0.2404	2576.8	2769.1	6.6628
200	0.4249	2642.9	2855.4	7.0592	0.3520	2638.9	2850.1	6.9665	0.2608	2630.6	2839.3	6.8158
250	0.4744	2723.5	2960.7	7.2709	0.3938	2720.9	2957.2	7.1816	0.2931	2715.5	2950.0	7.0384
300	0.5226	2802.9	3064.2	7.4599	0.4344	2801.0	3061.6	7.3724	0.3241	2797.2	3056.5	7.2328
350	0.5701	2882.6	3167.7	7.6329	0.4742	2881.2	3165.7	7.5464	0.3544	2878.2	3161.7	7.4089
400	0.6173	2963.2	3271.9	7.7938	0.5137	2962.1	3270.3	7.7079	0.3843	2959.7	3267.1	7.5716
500	0.7109	3128.4	3483.9	8.0873	0.5920	3127.6	3482.8	8.0021	0.4433	3126.0	3480.6	7.8673
600	0.8041	3299.6	3701.7	8.3522	0.6697	3299.1	3700.9	8.2674	0.5018	3297.9	3699.4	8.1333
700	0.8969	3477.5	3925.9	8.5952	0.7472	3477.0	3925.3	8.5107	0.5601	3476.2	3924.2	8.3770
800	0.9896	3662.1	4156.9	8.8211	0.8245	3661.8	4156.5	8.7367	0.6181	3661.1	4155.6	8.6033
900	1.0822	3853.6	4394.7	9.0329	0.9017	3853.4	4394.4	8.9486	0.6761	3852.8	4393.7	8.8153
1000	1.1747	4051.8	4639.1	9.2328	0.9788	4051.5	4638.8	9.1485	0.7340	4051.0	4638.2	9.0153
1100	1.2672	4256.3	4889.9	9.4224	1.0559	4256.1	4889.6	9.3381	0.7919	4255.6	4889.1	9.2050
1200	1.3596	4466.8	5146.6	9.6029	1.1330	4466.5	5146.3	9.5185	0.8497	4466.1	5145.9	9.3855
1300	1.4521	4682.5	5408.6	9.7749	1.2101	4682.3	5408.3	9.6906	0.9076	4681.8	5407.9	9.5575

‡*Note:* Number in parenthesis is temperature of saturated steam at the specified pressure.

$\hat{V}$ [=] m³/kg;　$\hat{U}$, $\hat{H}$ [=] J/g = kJ/kg;　$\hat{S}$ [=] kJ/kg K

Superheated Vapor (*Continued*)

T°C	P = 1.00 MPa (179.91)				P = 1.20 MPa (187.99)				P = 1.40 MPa (195.07)			
	$\hat{V}$	$\hat{U}$	$\hat{H}$	$\hat{S}$	$\hat{V}$	$\hat{U}$	$\hat{H}$	$\hat{S}$	$\hat{V}$	$\hat{U}$	$\hat{H}$	$\hat{S}$
Sat.	0.194 44	2583.6	2778.1	6.5865	0.163 33	2588.8	2784.8	6.5233	0.140 84	2592.8	2790.0	6.4693
200	0.2060	2621.9	2827.9	6.6940	0.169 30	2612.8	2815.9	6.5898	0.143 02	2603.1	2803.3	6.4975
250	0.2327	2709.9	2942.6	6.9247	0.192 34	2704.2	2935.0	6.8294	0.163 50	2698.3	2927.2	6.7467
300	0.2579	2793.2	3051.2	7.1229	0.2138	2789.2	3045.8	7.0317	0.182 28	2785.2	3040.4	6.9534
350	0.2825	2875.2	3157.7	7.3011	0.2345	2872.2	3153.6	7.2121	0.2003	2869.2	3149.5	7.1360
400	0.3066	2957.3	3263.9	7.4651	0.2548	2954.9	3260.7	7.3774	0.2178	2952.5	3257.5	7.3026
500	0.3541	3124.4	3478.5	7.7622	0.2946	3122.8	3476.3	7.6759	0.2521	3121.1	3474.1	7.6027
600	0.4011	3296.8	3697.9	8.0290	0.3339	3295.6	3696.3	7.9435	0.2860	3294.4	3694.8	7.8710
700	0.4478	3475.3	3923.1	8.2731	0.3729	3474.4	3922.0	8.1881	0.3195	3473.6	3920.8	8.1160
800	0.4943	3660.4	4154.7	8.4996	0.4118	3659.7	4153.8	8.4148	0.3528	3659.0	4153.0	8.3431
900	0.5407	3852.2	4392.9	8.7118	0.4505	3851.6	4392.2	8.6272	0.3861	3851.1	4391.5	8.5556
1000	0.5871	4050.5	4637.6	8.9119	0.4892	4050.0	4637.0	8.8274	0.4192	4049.5	4636.4	8.7559
1100	0.6335	4255.1	4888.6	9.1017	0.5278	4254.6	4888.0	9.0172	0.4524	4254.1	4887.5	8.9457
1200	0.6798	4465.6	5145.4	9.2822	0.5665	4465.1	5144.9	9.1977	0.4855	4464.7	5144.4	9.1262
1300	0.7261	4681.3	5407.4	9.4543	0.6051	4680.9	5407.0	9.3698	0.5186	4680.4	5406.5	9.2984

	P = 1.60 MPa (201.41)				P = 1.80 MPa (207.15)				P = 2.00 MPa (212.42)			
Sat.	0.123 80	2596.0	2794.0	6.4218	0.110 42	2598.4	2797.1	6.3794	0.099 63	2600.3	2799.5	6.3409
225	0.132 87	2644.7	2857.3	6.5518	0.116 73	2636.6	2846.7	6.4808	0.103 77	2628.3	2835.8	6.4147
250	0.141 84	2692.3	2919.2	6.6732	0.124 97	2686.0	2911.0	6.6066	0.111 44	2679.6	2902.5	6.5453
300	0.158 62	2781.1	3034.8	6.8844	0.140 21	2776.9	3029.2	6.8226	0.125 47	2772.6	3023.5	6.7664
350	0.174 56	2866.1	3145.4	7.0694	0.154 57	2863.0	3141.2	7.0100	0.138 57	2859.8	3137.0	6.9563
400	0.190 05	2950.1	3254.2	7.2374	0.168 47	2947.7	3250.9	7.1794	0.151 20	2945.2	3247.6	7.1271
500	0.2203	3119.5	3472.0	7.5390	0.195 50	3117.9	3469.8	7.4825	0.175 68	3116.2	3467.6	7.4317
600	0.2500	3293.3	3693.2	7.8080	0.2220	3292.1	3691.7	7.7523	0.199 60	3290.9	3690.1	7.7024
700	0.2794	3472.7	3919.7	8.0535	0.2482	3471.8	3918.5	7.9983	0.2232	3470.9	3917.4	7.9487
800	0.3086	3658.3	4152.1	8.2808	0.2742	3657.6	4151.2	8.2258	0.2467	3657.0	4150.3	8.1765
900	0.3377	3850.5	4390.8	8.4935	0.3001	3849.9	4390.1	8.4386	0.2700	3849.3	4389.4	8.3895
1000	0.3668	4049.0	4635.8	8.6938	0.3260	4048.5	4635.2	8.6391	0.2933	4048.0	4634.6	8.5901
1100	0.3958	4253.7	4887.0	8.8837	0.3518	4253.2	4886.4	8.8290	0.3166	4252.7	4885.9	8.7800
1200	0.4248	4464.2	5143.9	9.0643	0.3776	4463.7	5143.4	9.0096	0.3398	4463.3	5142.9	8.9607
1300	0.4538	4679.9	5406.0	9.2364	0.4034	4679.5	5405.6	9.1818	0.3631	4679.0	5405.1	9.1329

	P = 2.50 MPa (223.99)				P = 3.00 MPa (233.90)				P = 3.50 MPa (242.60)			
Sat.	0.079 98	2603.1	2803.1	6.2575	0.066 68	2604.1	2804.2	6.1869	0.057 07	2603.7	2803.4	6.1253
225	0.080 27	2605.6	2806.3	6.2639	—	—	—	—	—	—	—	—
250	0.087 00	2662.6	2880.1	6.4085	0.070 58	2644.0	2855.8	6.2872	0.058 72	2623.7	2829.2	6.1749
300	0.098 90	2761.6	3008.8	6.6438	0.081 14	2750.1	2993.5	6.5390	0.068 42	2738.0	2977.5	6.4461
350	0.109 76	2851.9	3126.3	6.8403	0.090 53	2843.7	3115.3	6.7428	0.076 78	2835.3	3104.0	6.6579
400	0.120 10	2939.1	3239.3	7.0148	0.099 36	2932.8	3230.9	6.9212	0.084 53	2926.4	3222.3	6.8405
450	0.130 14	3025.5	3350.8	7.1746	0.107 87	3020.4	3344.0	7.0834	0.091 96	3015.3	3337.2	7.0052
500	0.139 98	3112.1	3462.1	7.3234	0.116 19	3108.0	3456.5	7.2338	0.099 18	3103.0	3450.9	7.1572
600	0.159 30	3288.0	3686.3	7.5960	0.132 43	3285.0	3682.3	7.5085	0.113 24	3282.1	3678.4	7.4339
700	0.178 32	3468.7	3914.5	7.8435	0.148 38	3466.5	3911.7	7.7571	0.126 99	3464.3	3908.8	7.6837
800	0.197 16	3655.3	4148.2	8.0720	0.164 14	3653.5	4145.9	7.9862	0.140 56	3651.8	4143.7	7.9134
900	0.215 90	3847.9	4387.6	8.2853	0.179 80	3846.5	4385.9	8.1999	0.154 02	3845.0	4384.1	8.1276
1000	0.2346	4046.7	4633.1	8.4861	0.195 41	4045.4	4631.6	8.4009	0.167 43	4044.1	4630.1	8.3288
1100	0.2532	4251.5	4884.6	8.6762	0.210 98	4250.3	4883.3	8.5912	0.180 80	4249.2	4881.9	8.5192
1200	0.2718	4462.1	5141.7	8.8569	0.226 52	4460.9	5140.5	8.7720	0.194 15	4459.8	5139.3	8.7000
1300	0.2905	4677.8	5404.0	9.0291	0.242 06	4676.6	5402.8	8.9442	0.207 49	4675.5	5401.7	8.8723

$\hat{V}$ [=] m³/kg;　$\hat{U}$, $\hat{H}$ [=] J/g = kJ/kg;　$\hat{S}$ [=] kJ/kg K