國立清華大學 104 學年度碩士班考試入學試題

系所班組別：工科與系統科學系 乙組

考試科目（代碼）：熱力學 (2602)

 *請在【答案卷】作答

1. Giving following parameters and figure 1:

   $C_{P(\ell)}$: liquid heat capacity at constant pressure, assumed is constant

   $C_{v(\ell)}$: liquid heat capacity st constant volume, assumed is constant

   Liquid volume expansivity: $\alpha_p = \frac{1}{V}(\frac{\partial V}{\partial T})_p$, is a constant value

   Liquid specific volume $V_1=V_2$

   Temperature T_1 and T_2

   (a) Please evaluate the entropy change ΔS_{12} from state 1 to state 2 with function of T_1, T_2, P_1, P_2, V_2, α_p and $C_{P(\ell)}$ (5%)

   (b) Please evaluate the entropy change ΔS_{12} from state 1 to state 2 with function of T_1, T_2, and $C_{v(\ell)}$ (5%)

   (c) The entropy change value derived from (a) should be the same as the value derived from (b), please evaluate the value of $C_{P(\ell)} - C_{v(\ell)}$ with function of (T_1, T_2, P_1, P_2, V_2, α_p) (5%)

   (d) If the state 3 and state 4 following the state equation: P(V-b) = RT, and giving the heat capacity at constant pressure: $C_{p(v)}$, please evaluate the entropy change ΔS_{34} from state 3 to state 4 ($V_3=V_4$) with function of T_4, T_3, P_4, P_3 and $C_{p(v)}$ (5%)

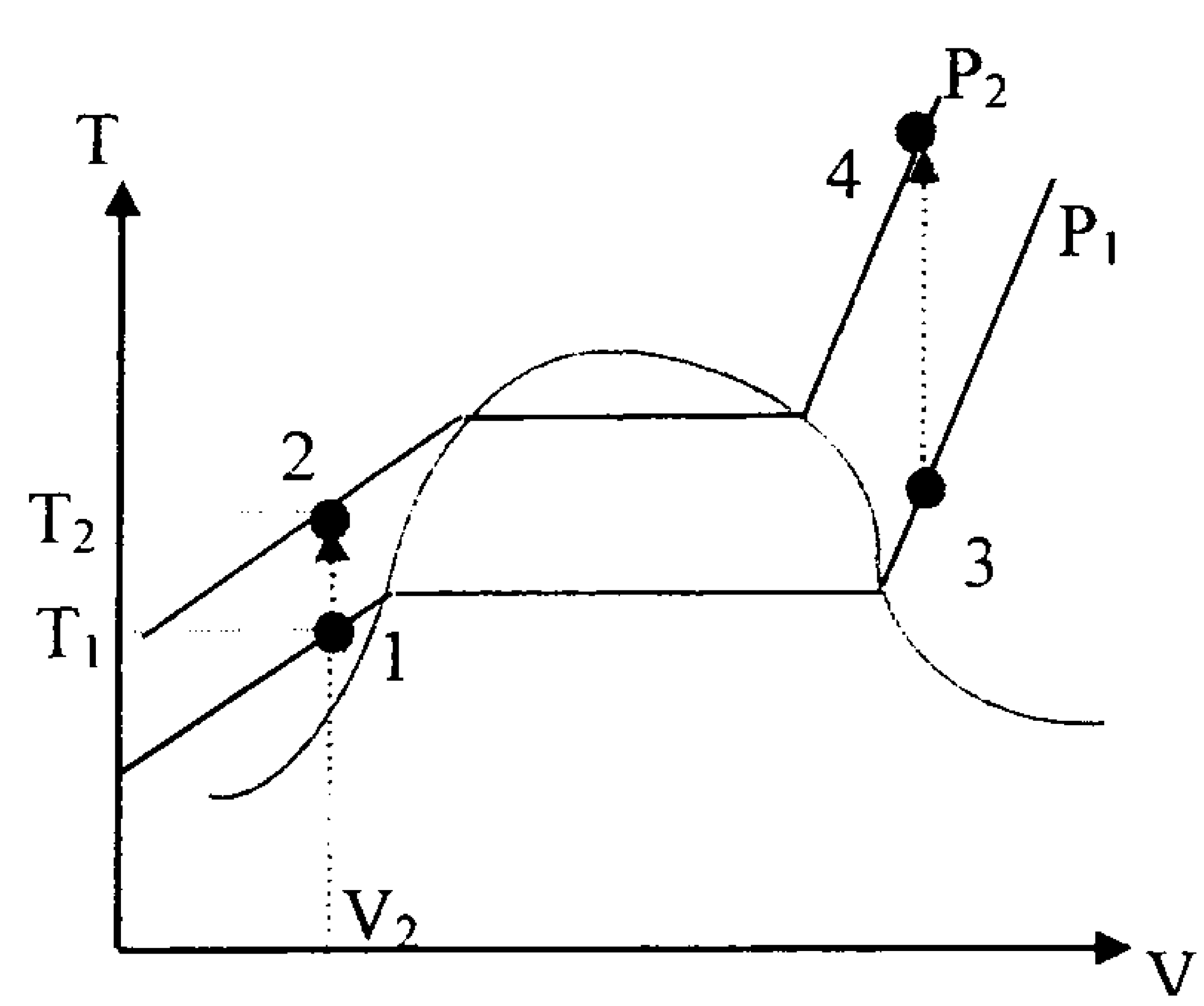

Figure 1

2. True/False questions: **(please answer: ○ or ╳)**
Considering the descriptions of Clausius inequality:
(1) For all kinds of thermodynamics cycles: $\oint(\frac{\delta Q}{T})_b \geq 0$ (1%)
(2) For a Carnot cycle: $\oint(\frac{\delta Q}{T})_b = 0$ (1%)
A simple power cycle is operating between two reservoirs, the hot and cold reservoirs, with heat transfer of Q_H and Q_C and temperature of T_H and T_C,:
(3) If this power cycle is reversible, the cycle efficiency can be determined by:$h = 1 - \frac{Q_C}{Q_H}$ (1%)
(4) If this power cycle is irreversible, the cycle efficiency can be determined by: $h = 1 - \frac{T_C}{T_H}$ (1%)
A refrigeration cycle is operating between two reservoirs with Q_H, Q_C, T_H and T_C:
(5) The C.O.P. (coefficient of performance) of this refrigeration cycle can be determined by: $b = \frac{Q_C}{Q_{H-Q_C}}$ (1%)
(6) If this refrigeration cycle is reversible, the C.O.P. of this cycle can be $b > \frac{T_C}{T_{H-T_C}}$ (1%)
(7) If the cycle is used as a heat pump and the system friction cannot be ignored, the C.O.P. of this cycle is: $g < \frac{T_H}{T_{H-T_C}}$ (1%)
(8) The differential entropy change can be expressed as: $dS = (\frac{\delta Q}{T})_{rev}$ (1%)
(9) Entropy is a state function only under a reversible process, and therefore for an irreversible process, entropy becomes a path function. (1%)
(10) Entropy cannot increase if there is no heat transfer across the system boundary. (1%)
(11) A system with uniform temperature is called mechanical equilibrium. (1%)
(12) Energy can transfer across the boundary of an isolated system. (1%)
(13) For an open system, mass and energy can flow in/out freely. (1%)
(14) For a closed system, both heat and work can transfer out. (1%)
(15) During an adiabatic process, temperature is constant. (1%)
(16) During an isobaric process, pressure is constant. (1%)
(17) During an isochoric process, volume is constant. (1%)
(18) During an isothermal process, there is no heat and work transfer. (1%)
(19) Work and heat are state function. (1%)
(20) A thermodynamic state of a system can be fixed by two extensive properties. (1%)

3. Steam at a pressure of 15bar and a temperature of 320^0C is contained in a large vessel. Connected to the vessel through a valve is a turbine followed by a small initially tank water vapor at 1bar, 100 ^{0}C with a volume of 0.6m^3. When emergency power is required, the valve is opened and the tank fills with steam until the pressure is 15bar. The temperature in the tank is then 400^0C. The filling process takes place adiabatically and kinetic and potential energy effects are negligible. Determine (a) how much vapor mass is charged into the tank in Kg (2%) (b) The internal energy of the tank at initial state in KJ (3%) (c) The internal energy of the tank at final state in KJ (5%) (d) Amount of work developed by the turbine, in KJ. (5%) (e) Assume turbine power is 0.5KW, how much time it takes to final state in minutes (5%)

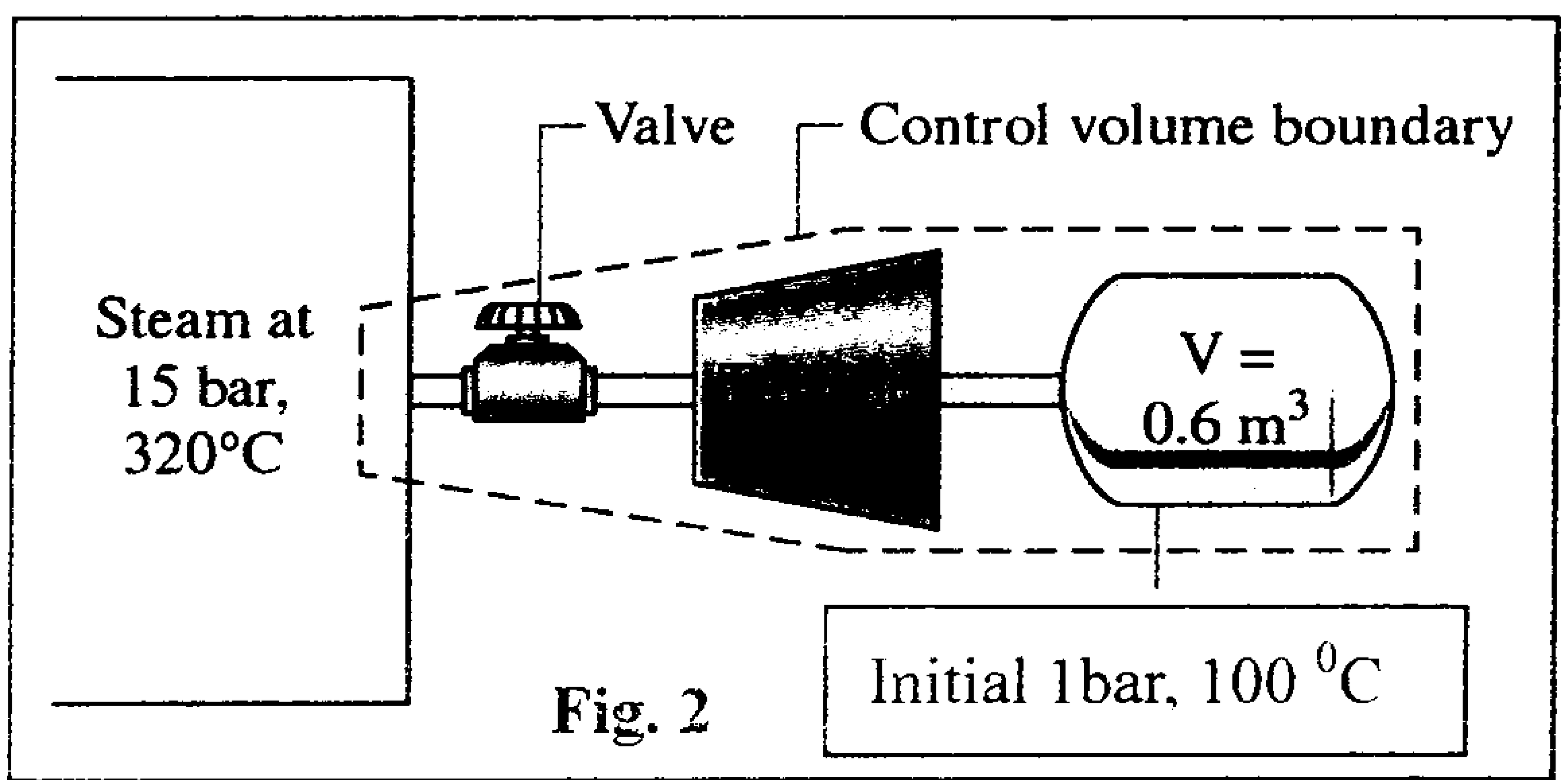

Fig. 2

4. In the following figure 3, shows a gas separated from vacuum by a membrane (state 1: V_1, T_1). The tank is fully isolated with fiber glass. Then let membrane rupture and the gas fill the entire volume, (state 2: V_2), all the friction loss can be neglected, gas can be assumed to be an ideal gas:
   (a) Is there any mechanical work? If there is work, write down the work equation as function of (T, V_1, V_2), if there is no mechanical work, explain why? (2%)
   (b) What is the internal energy change? (3%)
   (c) What is the temperature T_2 at state 2? And why (5%)
   (d) If $V_2 = 2\ V_1$, what is the entropy change? Assume the gas heat capacity at constant volume C_v is constant (5%)
   (e) Draw the P-V diagram from state 1 to state 2 (5%)

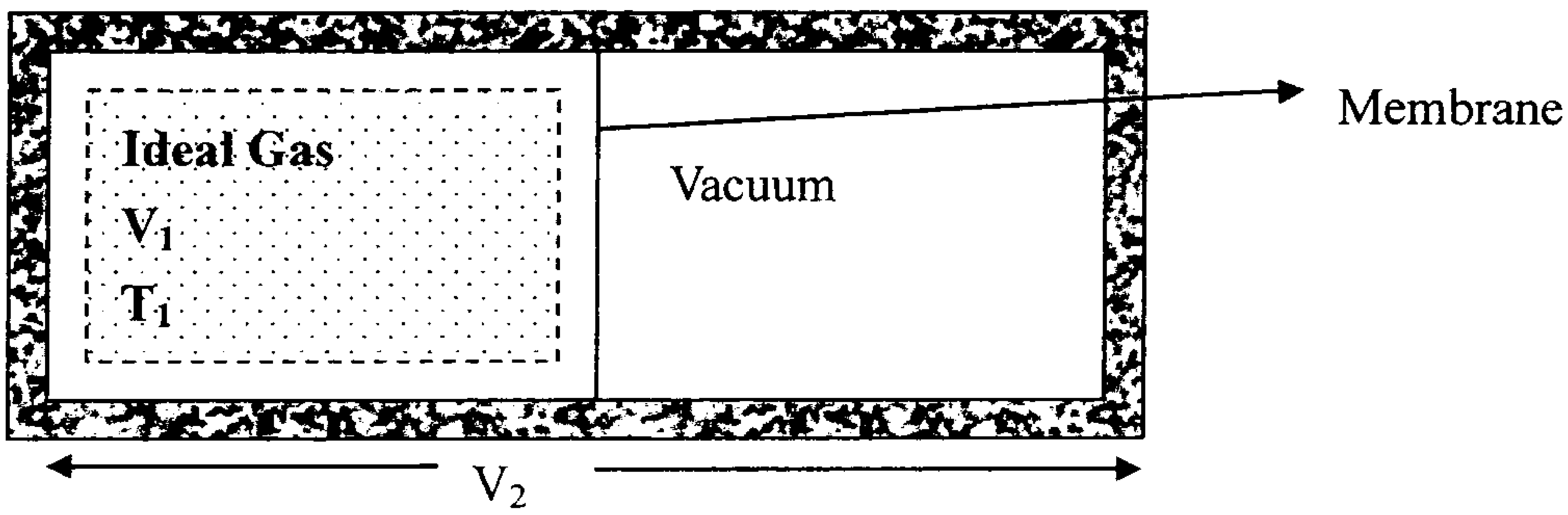

Fig. 3

5. A steam turbine operates at steady state with inlet conditions of P_1=5 bar, T_1=320°C. Steam leaves the turbine at pressure of 1 bar. There is no significant heat transfer between the turbine and its surroundings, and kinetic and potential energy changes between inlet and exit are negligible. If the isentropic turbine efficiency is 75%, (a) Determine the actual work $W_{act,t}$ developed per unit mass of steam flowing through the turbine, in kJ/kg. (5%) (b) Determine the isentropic work $W_{s,t}$ developed per unit mass of steam flowing through the turbine, in kJ/kg. (2%) (c) Please draw the T-S diagram from state 1 to state 2 (3%) and state 1 to state 2s, where 2s is the state following the isentropic process from state 1 (2%) (d) What is the enthalpy h_2 at state 2, in KJ/Kg. (3%) (e) What is the temperature $T_{2,act}$ at state 2 (3%) and T_{2s} at state 2s (2%).

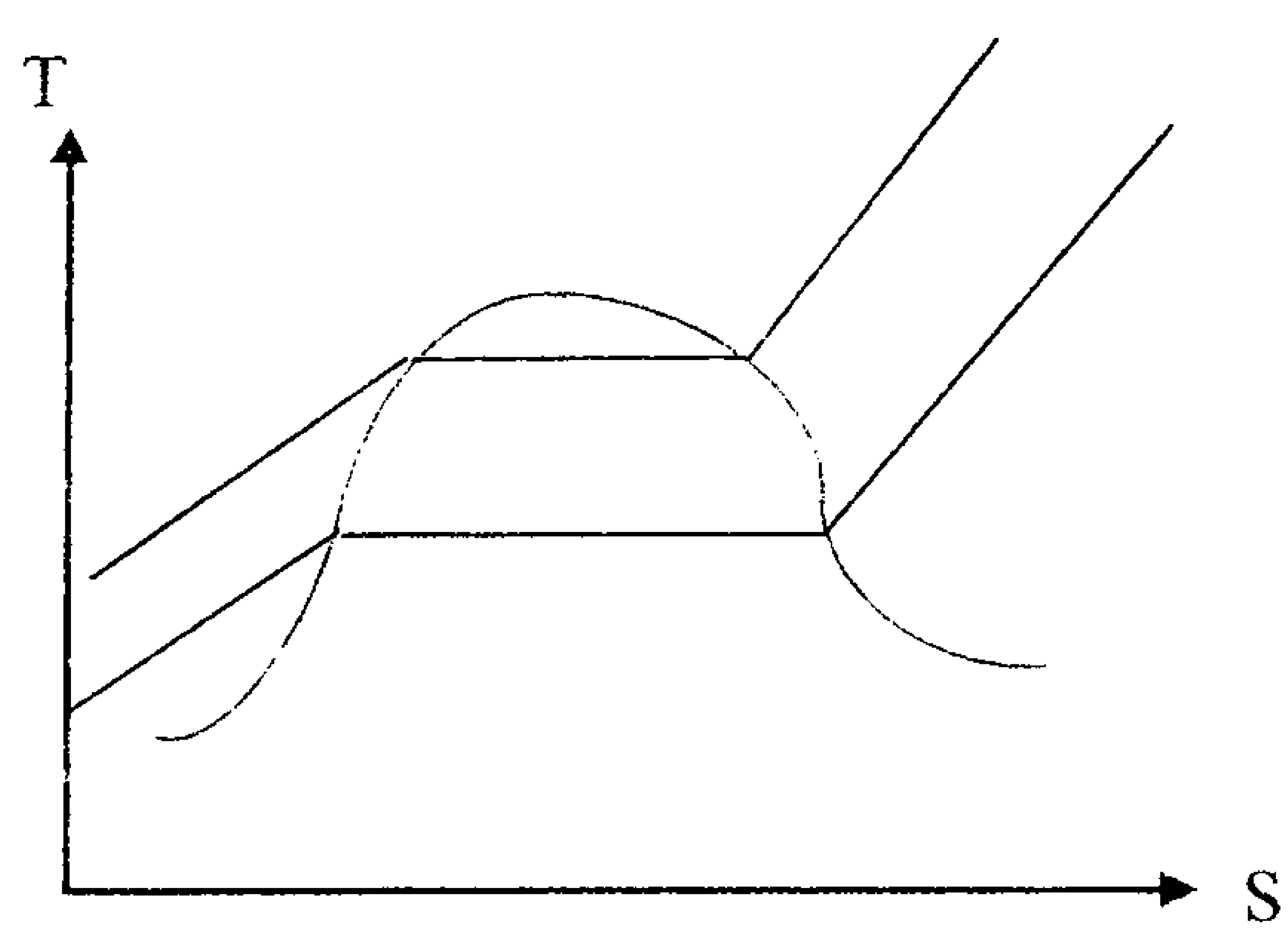

Fig. 4

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TABLE A-2 (*Continued*)

Temp. °C	Press. bar	Specific Volume m³/kg Sat. Liquid $v_f \times 10^3$	Sat. Vapor v_g	Internal Energy kJ/kg Sat. Liquid u_f	Sat. Vapor u_g	Enthalpy kJ/kg Sat. Liquid h_f	Evap. h_{fg}	Sat. Vapor h_g	Entropy kJ/kg · K Sat. Liquid s_f	Sat. Vapor s_g	Temp. °C
50	.1235	1.0121	12.032	209.32	2443.5	209.33	2382.7	2592.1	.7038	8.0763	50
55	.1576	1.0146	9.568	230.21	2450.1	230.23	2370.7	2600.9	.7679	7.9913	55
60	.1994	1.0172	7.671	251.11	2456.6	251.13	2358.5	2609.6	.8312	7.9096	60
65	.2503	1.0199	6.197	272.02	2463.1	272.06	2346.2	2618.3	.8935	7.8310	65
70	.3119	1.0228	5.042	292.95	2469.6	292.98	2333.8	2626.8	.9549	7.7553	70
75	.3858	1.0259	4.131	313.90	2475.9	313.93	2321.4	2635.3	1.0155	7.6824	75
80	.4739	1.0291	3.407	334.86	2482.2	334.91	2308.8	2643.7	1.0753	7.6122	80
85	.5783	1.0325	2.828	355.84	2488.4	355.90	2296.0	2651.9	1.1343	7.5445	85
90	.7014	1.0360	2.361	376.85	2494.5	376.92	2283.2	2660.1	1.1925	7.4791	90
95	.8455	1.0397	1.982	397.88	2500.6	397.96	2270.2	2668.1	1.2500	7.4159	95
100	1.014	1.0435	1.673	418.94	2506.5	419.04	2257.0	2676.1	1.3069	7.3549	100
110	1.433	1.0516	1.210	461.14	2518.1	461.30	2230.2	2691.5	1.4185	7.2387	110
120	1.985	1.0603	0.8919	503.50	2529.3	503.71	2202.6	2706.3	1.5276	7.1296	120
130	2.701	1.0697	0.6685	546.02	2539.9	546.31	2174.2	2720.5	1.6344	7.0269	130
140	3.613	1.0797	0.5089	588.74	2550.0	589.13	2144.7	2733.9	1.7391	6.9299	140
150	4.758	1.0905	0.3928	631.68	2559.5	632.20	2114.3	2746.5	1.8418	6.8379	150
160	6.178	1.1020	0.3071	674.86	2568.4	675.55	2082.6	2758.1	1.9427	6.7502	160
170	7.917	1.1143	0.2428	718.33	2576.5	719.21	2049.5	2768.7	2.0419	6.6663	170
180	10.02	1.1274	0.1941	762.09	2583.7	763.22	2015.0	2778.2	2.1396	6.5857	180
190	12.54	1.1414	0.1565	806.19	2590.0	807.62	1978.8	2786.4	2.2359	6.5079	190
200	15.54	1.1565	0.1274	850.65	2595.3	852.45	1940.7	2793.2	2.3309	6.4323	200
210	19.06	1.1726	0.1044	895.53	2599.5	897.76	1900.7	2798.5	2.4248	6.3585	210
220	23.18	1.1900	0.08619	940.87	2602.4	943.62	1858.5	2802.1	2.5178	6.2861	220
230	27.95	1.2088	0.07158	986.74	2603.9	990.12	1813.8	2804.0	2.6099	6.2146	230
240	33.44	1.2291	0.05976	1033.2	2604.0	1037.3	1766.5	2803.8	2.7015	6.1437	240
250	39.73	1.2512	0.05013	1080.4	2602.4	1085.4	1716.2	2801.5	2.7927	6.0730	250
260	46.88	1.2755	0.04221	1128.4	2599.0	1134.4	1662.5	2796.6	2.8838	6.0019	260
270	54.99	1.3023	0.03564	1177.4	2593.7	1184.5	1605.2	2789.7	2.9751	5.9301	270
280	64.12	1.3321	0.03017	1227.5	2586.1	1236.0	1543.6	2779.6	3.0668	5.8571	280
290	74.36	1.3656	0.02557	1278.9	2576.0	1289.1	1477.1	2766.2	3.1594	5.7821	290
300	85.81	1.4036	0.02167	1332.0	2563.0	1344.0	1404.9	2749.0	3.2534	5.7045	300
320	112.7	1.4988	0.01549	1444.6	2525.5	1461.5	1238.6	2700.1	3.4480	5.5362	320
340	145.9	1.6379	0.01080	1570.3	2464.6	1594.2	1027.9	2622.0	3.6594	5.3357	340
360	186.5	1.8925	0.006945	1725.2	2351.5	1760.5	720.5	2481.0	3.9147	5.0526	360
374.14	220.9	3.155	0.003155	2029.6	2029.6	2099.3	0	2099.3	4.4298	4.4298	374.14

Source: Tables A-2 through A-5 are extracted from J. H. Keenan, F. G. Keyes, P. G. Hill, and J. G. Moore, *Steam Tables*, Wiley, New York, 1969.

TABLE A-4 (*Continued*)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 10.0 bar = 1.0 MPa (T_{sat} = 179.91°C)				p = 15.0 bar = 1.5 MPa (T_{sat} = 198.32°C)			
Sat.	0.1944	2583.6	2778.1	6.5865	0.1318	2594.5	2792.2	6.4448
200	0.2060	2621.9	2827.9	6.6940	0.1325	2598.1	2796.8	6.4546
240	0.2275	2692.9	2920.4	6.8817	0.1483	2676.9	2899.3	6.6628
280	0.2480	2760.2	3008.2	7.0465	0.1627	2748.6	2992.7	6.8381
320	0.2678	2826.1	3093.9	7.1962	0.1765	2817.1	3081.9	6.9938
360	0.2873	2891.6	3178.9	7.3349	0.1899	2884.4	3169.2	7.1363
400	0.3066	2957.3	3263.9	7.4651	0.2030	2951.3	3255.8	7.2690
440	0.3257	3023.6	3349.3	7.5883	0.2160	3018.5	3342.5	7.3940
500	0.3541	3124.4	3478.5	7.7622	0.2352	3120.3	3473.1	7.5698
540	0.3729	3192.6	3565.6	7.8720	0.2478	3189.1	3560.9	7.6805
600	0.4011	3296.8	3697.9	8.0290	0.2668	3293.9	3694.0	7.8385
640	0.4198	3367.4	3787.2	8.1290	0.2793	3364.8	3783.8	7.9391

TABLE A-4 (*Continued*)

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg · K
	p = 5.0 bar = 0.50 MPa (T_{sat} = 151.86°C)				p = 7.0 bar = 0.70 MPa (T_{sat} = 164.97°C)			
Sat.	0.3749	2561.2	2748.7	6.8213	0.2729	2572.5	2763.5	6.7080
180	0.4045	2609.7	2812.0	6.9656	0.2847	2599.8	2799.1	6.7880
200	0.4249	2642.9	2855.4	7.0592	0.2999	2634.8	2844.8	6.8865
240	0.4646	2707.6	2939.9	7.2307	0.3292	2701.8	2932.2	7.0641
280	0.5034	2771.2	3022.9	7.3865	0.3574	2766.9	3017.1	7.2233
320	0.5416	2834.7	3105.6	7.5308	0.3852	2831.3	3100.9	7.3697
360	0.5796	2898.7	3188.4	7.6660	0.4126	2895.8	3184.7	7.5063
400	0.6173	2963.2	3271.9	7.7938	0.4397	2960.9	3268.7	7.6350
440	0.6548	3028.6	3356.0	7.9152	0.4667	3026.6	3353.3	7.7571
500	0.7109	3128.4	3483.9	8.0873	0.5070	3126.8	3481.7	7.9299
600	0.8041	3299.6	3701.7	8.3522	0.5738	3298.5	3700.2	8.1956
700	0.8969	3477.5	3925.9	8.5952	0.6403	3476.6	3924.8	8.4391

H_2O

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TABLE A-4 Properties of Superheated Water Vapor

T °C	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K	v m³/kg	u kJ/kg	h kJ/kg	s kJ/kg·K
	p = 0.70 bar = 0.07 MPa (T_{sat} = 89.95°C)				p = 1.0 bar = 0.10 MPa (T_{sat} = 99.63°C)			
Sat.	2.365	2494.5	2660.0	7.4797	1.694	2506.1	2675.5	7.3594
100	2.434	2509.7	2680.0	7.5341	1.696	2506.7	2676.2	7.3614
120	2.571	2539.7	2719.6	7.6375	1.793	2537.3	2716.6	7.4668
160	2.841	2599.4	2798.2	7.8279	1.984	2597.8	2796.2	7.6597
200	3.108	2659.1	2876.7	8.0012	2.172	2658.1	2875.3	7.8343
240	3.374	2719.3	2955.5	8.1611	2.359	2718.5	2954.5	7.9949
280	3.640	2780.2	3035.0	8.3162	2.546	2779.6	3034.2	8.1445
320	3.905	2842.0	3115.3	8.4504	2.732	2841.5	3114.6	8.2849
360	4.170	2904.6	3196.5	8.5828	2.917	2904.2	3195.9	8.4175
400	4.434	2968.2	3278.6	8.7086	3.103	2967.9	3278.2	8.5435
440	4.698	3032.9	3361.8	8.8286	3.288	3032.6	3361.4	8.6636
500	5.095	3131.8	3488.5	8.9991	3.565	3131.6	3488.1	8.8342