題號： 250　　國立臺灣大學 114 學年度碩士班招生考試試題

科目： 熱力學

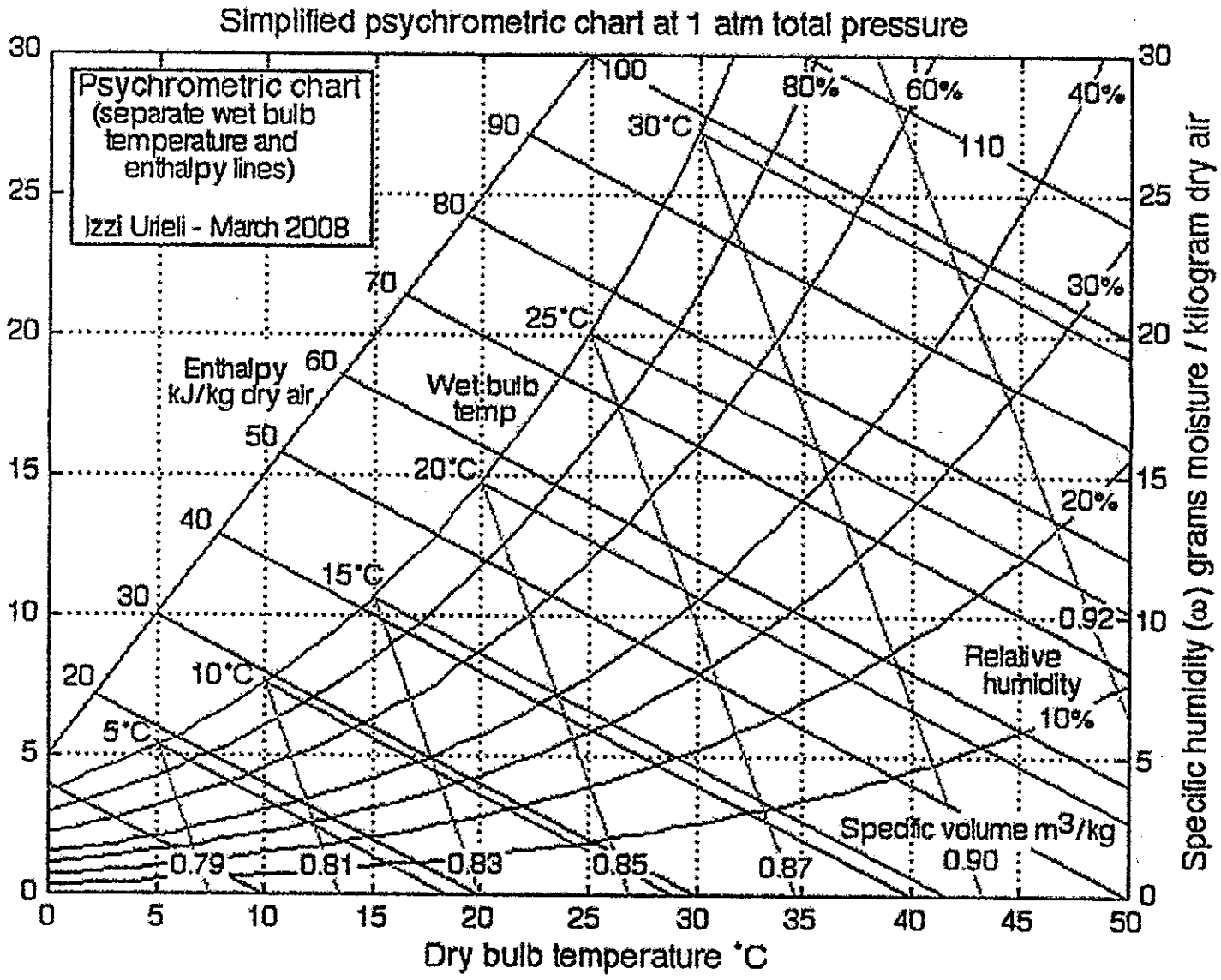
節次： 2

State the conditions you assume, if insufficient

Units have to be included to receive full points.

※ 注意：請於試卷內之「非選擇題作答區」依序作答，並應註明作答之大題及小題題號。

1. For a micro-environment where dry-bulb temperature= 25°C, and dew point = 15 °C, please determine:
   (a) (5%) The specific humidity in g/kg dry air of the air in the space
   (b) (5%) The relative humidity in % of the air in the space
   (c) (5%) When the direct evaporative cooling is applied in the space, how many degrees of the maximum temperature drop can be achieved?



見背面

2. A refrigerator uses refrigerant-134a as the working fluid, and operates on an ideal vapor-compression refrigeration cycle between 4 °C and 42 °C. The refrigerant enters the compressor as a saturated vapor and leaves at 1200 kPa. The outlet of the condenser is at the saturated liquid line. The outlet of the evaporator is at the saturated vapor line.
   (a) (5%) the compressor outlet temperature if the compression is isentropic.
   (b) (9%) the change in enthalpy during the compression process. (kJ/kg).
   (c) (9%) the enthalpy at the inlet of the evaporator if the throttling process is isentropic.
   (d) (7%) the actual COP using the result from (b) and (c).
   (e) (5%) the theoretical maximum COP.

TABLE A–11

Saturated refrigerant-134a—Temperature table

		Specific volume, m^3/kg		*Internal energy,* kJ/kg			*Enthalpy,* kJ/kg			*Entropy,* kJ/kg·K		
Temp., T °C	Sat. press., P_{sat} kPa	Sat. liquid, v_f	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g	Sat. liquid, s_f	Evap., s_{fg}	Sat. vapor, s_g
0	293.01	0.0007722	0.069335	51.61	178.58	230.18	51.83	198.67	250.50	0.20432	0.72726	0.93158
2	314.84	0.0007761	0.064690	54.28	177.01	231.30	54.53	197.14	251.66	0.21408	0.71641	0.93050
4	337.90	0.0007802	0.060412	56.97	175.44	232.40	57.23	195.58	252.82	0.22381	0.70565	0.92946
6	362.23	0.0007843	0.056469	59.66	173.84	233.51	59.95	194.01	253.96	0.23351	0.69496	0.92847
8	387.88	0.0007886	0.052829	62.37	172.23	234.60	62.68	192.42	255.09	0.24318	0.68435	0.92752
10	414.89	0.0007929	0.049466	65.09	170.61	235.69	65.42	190.80	256.22	0.25282	0.67380	0.92661
12	443.31	0.0007973	0.046354	67.82	168.96	236.78	68.17	189.16	257.33	0.26243	0.66331	0.92574
14	473.19	0.0008018	0.043471	70.56	167.30	237.86	70.94	187.49	258.43	0.27201	0.65289	0.92490
16	504.58	0.0008064	0.040798	73.31	165.62	238.93	73.72	185.80	259.51	0.28157	0.64252	0.92409
18	537.52	0.0008112	0.038317	76.07	163.92	239.99	76.51	184.08	260.59	0.29111	0.63219	0.92330
20	572.07	0.0008160	0.036012	78.85	162.19	241.04	79.32	182.33	261.64	0.30062	0.62192	0.92254
22	608.27	0.0008209	0.033867	81.64	160.45	242.09	82.14	180.55	262.69	0.31012	0.61168	0.92180
24	646.18	0.0008260	0.031869	84.44	158.68	243.13	84.98	178.74	263.72	0.31959	0.60148	0.92107
26	685.84	0.0008312	0.030008	87.26	156.89	244.15	87.83	176.90	264.73	0.32905	0.59131	0.92036
28	727.31	0.0008366	0.028271	90.09	155.08	245.17	90.70	175.03	265.73	0.33849	0.58117	0.91967
30	770.64	0.0008421	0.026648	92.93	153.24	246.17	93.58	173.13	266.71	0.34792	0.57105	0.91897
32	815.89	0.0008477	0.025131	95.79	151.37	247.17	96.49	171.19	267.67	0.35734	0.56095	0.91829
34	863.11	0.0008535	0.023712	98.67	149.48	248.15	99.41	169.21	268.61	0.36675	0.55086	0.91760
36	912.35	0.0008595	0.022383	101.56	147.55	249.11	102.34	167.19	269.53	0.37615	0.54077	0.91692
38	963.68	0.0008657	0.021137	104.47	145.60	250.07	105.30	165.13	270.44	0.38554	0.53068	0.91622
40	1017.1	0.0008720	0.019968	107.39	143.61	251.00	108.28	163.03	271.31	0.39493	0.52059	0.91552
42	1072.8	0.0008786	0.018870	110.34	141.59	251.92	111.28	160.89	272.17	0.40432	0.51048	0.91480
44	1130.7	0.0008854	0.017837	113.30	139.53	252.83	114.30	158.70	273.00	0.41371	0.50036	0.91407

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Superheated refrigerant-134a (*Concluded*)

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 = 0.80 MPa (T_{sat} = 31.31°C)				P = 0.90 MPa (T_{sat} = 35.51°C)			
Sat.	0.025645	246.82	267.34	0.9185	0.022686	248.82	269.25	0.9169
40	0.027035	254.84	276.46	0.9481	0.023375	253.15	274.19	0.9328
50	0.028547	263.87	286.71	0.9803	0.024809	262.46	284.79	0.9661
60	0.029973	272.85	296.82	1.0111	0.026146	271.62	295.15	0.9977
70	0.031340	281.83	306.90	1.0409	0.027413	280.74	305.41	1.0280
80	0.032659	290.86	316.99	1.0699	0.028630	289.88	315.65	1.0574
90	0.033941	299.97	327.12	1.0982	0.029806	299.08	325.90	1.0861
100	0.035193	309.17	337.32	1.1259	0.030951	308.35	336.21	1.1141
110	0.036420	318.47	347.61	1.1531	0.032068	317.72	346.58	1.1415
120	0.037625	327.89	357.99	1.1798	0.033164	327.19	357.04	1.1684
130	0.038813	337.42	368.47	1.2062	0.034241	336.78	367.59	1.1949
140	0.039985	347.08	379.07	1.2321	0.035302	346.48	378.25	1.2211
150	0.041143	356.86	389.78	1.2577	0.036349	356.30	389.01	1.2468
160	0.042290	366.78	400.61	1.2830	0.037384	366.25	399.89	1.2722
170	0.043427	376.83	411.57	1.3081	0.038408	376.33	410.89	1.2973
180	0.044554	387.01	422.65	1.3328	0.039423	386.54	422.02	1.3221
	P = 1.20 MPa (T_{sat} = 46.29°C)				P = 1.40 MPa (T_{sat} = 52.40°C)			
Sat.	0.016728	253.84	273.92	0.9132	0.014119	256.40	276.17	0.9107
50	0.017201	257.64	278.28	0.9268				
60	0.018404	267.57	289.66	0.9615	0.015005	264.46	285.47	0.9389
70	0.019502	277.23	300.63	0.9939	0.016060	274.62	297.10	0.9733
80	0.020529	286.77	311.40	1.0249	0.017023	284.51	308.34	1.0056
90	0.021506	296.28	322.09	1.0547	0.017923	294.28	319.37	1.0364
100	0.022442	305.81	332.74	1.0836	0.018778	304.01	330.30	1.0661
110	0.023348	315.40	343.41	1.1119	0.019597	313.76	341.19	1.0949
120	0.024228	325.05	354.12	1.1395	0.020388	323.55	352.09	1.1230
130	0.025086	334.79	364.90	1.1665	0.021155	333.41	363.02	1.1504
140	0.025927	344.63	375.74	1.1931	0.021904	343.34	374.01	1.1773

見背面

3. A lead-acid battery is an energy storage device that is commonly used in cars and motorcycles for the start-up purpose. A single lead-acid cell when discharged runs on the following reaction:

$$Pb_{(s)} + PbO_{2(s)} + 4H^{+}_{(aq)} + 2SO^{2-}_{4\ (aq)} \rightarrow 2PbSO_{4(s)} + 2H_2O_{(l)}$$

Please answer the following questions.

(a) Use data in **Table 1** to determine the values of ΔH, ΔS and ΔG for this discharge reaction occurred in a lead-acid cell (for one mole of Pb). Assume that the reaction occurs at ambient temperature (298 K) and pressure (1 bar). (*9%*)

(b) Based on (a), show that the thermodynamic identity $\Delta G=\Delta H - T\Delta S$ is valid. (*6%*)

(c) In a lead-acid cell, the sulfate ions will first combine with protons through the reaction $2SO^{2-}_{4(aq)} + 2H^{+}_{(aq)} \rightarrow 2HSO^{-}_{4(aq)}$

Then, half reactions for a lead-acid cell are

at (-) electrode: $Pb_{(s)} + HSO^{2-}_{4\ (aq)} \rightarrow PbSO_{4(s)} + H^{+}_{(aq)} + 2e^{-}$

at (+) electrode: $PbO_{2(s)} + 3H^{+}_{(aq)} + HSO^{-}_{4(aq)} + 2e^{-} \rightarrow PbSO_{4(s)} + 2H_2O_{(l)}$

Use the identity $\Delta G = -nFV$, where n is the charge number, F the Faraday constant, to calculate the voltage V of a lead-acid cell. (*5%*)

(d) Following (c), the work generated from a lead-acid cell (for each mole of Pb used) is ΔG. Explain why it is not ΔH. (*5%*)

(e) The electrolyte of a lead-acid battery is usually composed of 6 M sulfuric acid instead of 1 M. Is the actual cell voltage higher or lower than the result in (c)? Explain how you reach your conclusion. (*5%*)

(f) A lead-acid battery is a secondary battery, which means it can be charged; i.e., the aforementioned full-cell reaction will be running backward during charging. But this means cell entropy decreases during charging. How could this be possible? (*5%*)

Table 1. Thermodynamics Properties of Selected Substances

Substance (form)	$\Delta_f H$ (kJ)	$\Delta_f G$ (kJ)	S (J/K)	C_P (J/K)	V (cm^3)
H_2 (g)	0	0	130.68	28.82	
H (g)	217.97	203.25	114.71	20.78	
H^+ (aq)	0	0	0	0	
H_2O (l)	−285.83	−237.13	69.91	75.29	18.068
H_2O (g)	−241.82	−228.57	188.83	33.58	
O_2 (g)	0	0	205.14	29.38	
O_2 (aq)	−11.7	16.4	110.9		
OH^- (aq)	−229.99	−157.24	−10.75	−148.5	
Pb (s)	0	0	64.81	26.44	18.3
PbO_2 (s)	−277.4	−217.33	68.6	64.64	
$PbSO_4$ (s)	−920.0	−813.0	148.5	103.2	
SO^{2-}_4 (aq)	−909.27	−744.53	20.1	−293	
HSO^-_4 (aq)	−887.34	−755.91	131.8	−84	

All of the values in this table are for one mole of material at 298 K and 1 bar. The form of the substance, either solid (s), liquid (l), gas (g) or aqueous solution (aq), is denoted after the chemical formula. Data for aqueous solutions are at a standard concentration of 1 mole per kilogram water. The enthalpy and Gibbs free energy of formation, $\Delta_f H$ and $\Delta_f G$, represent the changes in H and G upon forming one more of the material starting with elements in their most stable pure states (e.g., O_2 (g), etc.).

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※ 本大題請於試卷內之「非選擇題作答區」標明題號依序作答。

4. Multiple choice (Please select the most appropriate answer, 5% each)

(a) Which of the following statement regarding heat and work is NOT true?
(1) heat and work are path dependent
(2) work can be completely converted to heat
(3) heat can be completely converted to work
(4) entropy always flows along with heat

(b) What is the most important reason that makes a fuel cell usually much more efficient than a heat engine?
(1) use different fuels
(2) operate at different temperatures
(3) produce different amount of waste heat
(4) built with different materials

(c) Which of the following statement regarding dilute solutions is false?
(1) solute interacts with solvent
(2) solute interacts with solute
(3) solvent interacts with solvent
(4) solvent and solute homogeneously mixed

試題隨卷繳回