NameStudent I.D.	Seat no.
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King Mongkut's University of Technology Thonburi

Final Examination, Second Semester (2/2012)

Course: CHE 242 Thermodynamics II

Chemical Engineering, 2nd year

Date:

Friday 17th May2013

Time: 13.00 - 16.00

Please follow the instructions.

1. There are 4 questions in 5 pages, including the covering page and Tables. Do all problems in the answering book.

2. A calculator and one A4 paper are allowed in the exam.

After you have finished with the examination, raise your hand for permission to leave the examination room,

Students are not allowed to take the examination paper out of the examination room.

If any disallowable material is found in your occupation in the examination room, you will be punished as serious as retirement.

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This exam is evaluated by the committee of the Department of Chemical Engineering

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1) The excess Gibbs energies for liquid argon (Ar) and methane mixtures were measured at several temperatures. The results can be expressed by the following equation.

$$\frac{G^{E}}{RT} = x_{Ar}(1 - x_{Ar}) [A - B(1 - 2x_{Ar})]$$

where A and B are the constant values at a temperature. The values of A and B at temperatures are given below.

T(K)	A	В
109	0.3024	-0.01453
112	0.2929	-0.01169
115	0.2792	0.05115

Determine the following:

- a) The activity coefficients of argon and methane at 112 K and $x_{Ar} = 0.5$ (15 points)
- b) The molar isothermal enthalpy change on producing an $x_{Ar} = 0.5$ at 112 K. (10 points) **Hint:** it is supposed that the interval between temperatures given in the above table is small enough.
- 2) The solubility of ethane in water is very small at 25°C and 1 bar partial pressure. The mole fraction of ethane at this condition is 0.33×10^{-4} . What is the solubility of ethane at 25°C when the partial pressure is 35 bar? At 25°C, the compressibility factor of ethane in the solution is given by the following equation.

$$\bar{Z} = 1 - 7.63 \times 10^{-3} P - 7.22 \times 10^{-5} P^2$$

where P is in bar. At 25°C, the saturation pressure of ethane is 42.07 bar and that of water is 0.0316 bar (assuming gas phase is ideal at 1 bar and the Henry constant is not a function of pressure). (25 points)

3) Estimate the equilibrium conversion, composition of each component at equilibrium and the fraction of acetylene reacts, if there are initially 10 mol of nitrogen and 5 mol of acetylene for the following reaction at 1500K 2 bar. Assume ideal gases.

$$N_2(g) + C_2H_2(g) \rightarrow 2HCN(g)$$
 (25 points)

4) (a) A binary mixture between 25% mol n-butane and 75% mol n-hexane is at the pressure of 200 kPa. Estimate the composition of the liquid phase and/or the vapour phase at the temperature of about 330 K and 360 K. Assume an ideality of all mixtures.

$$lnP* (kPa) = A - \frac{B}{T(K) + C}$$

Data n-butane:

A = 13.6608, B = 2154.7, C = -34.361

n-hexane:

$$A = 13.8193$$
, $B = 2696.04$, $C = -48.833$

(22 points)

(b) Explain the importance of dew point or bubble points in the chemical process industries. (3 points)

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 83.14 \text{ cm}^{3} \text{ bar mol}^{-1} \text{ K}^{-1} = 8,314 \text{ cm}^{3} \text{kPa mol}^{-1} \text{ K}^{-1}$$

Conversion factor table for Pressure

mm Hg	in. Hg	bar	atm	kPa	psia
1	3.937x10 ⁻²	1.333x10 ⁻³	1.316x10 ⁻³	0.1333	1.934x10 ⁻²
25.4	1	3.386x10 ¹	3.342x10 ⁻²	3.386	0.4912
750.06	29.53	1	0.9869	100.0	1.415x10 ⁻³
760.0	29.92	1.013	1	101.3	14.696
75.02	0.2954	$1.000 \text{x} 10^{-2}$	9.872x10 ⁻³	1	0.1451
51.71	2.036	6.893x10 ⁻²	$6.805 \text{x} 10^{-2}$	6.893	1

$$1 \text{ mmHg} = 0.1333 \text{ kPa} = 1.333 \text{x} 10^{-3} \text{ bar} = 1.316 \text{x} 10^{-3} \text{atm} = 1.934 \text{x} 10^{-2} \text{psia}$$

Table C.4: Standard Enthalpies and Gibbs Energies of Formation at 298.15 K[†]

Joules per mole of the substance formed

s: CH4 C2H4 C2H4 C3H4 C3H			State	$\Delta H_{f_{200}}^{\circ}$	$\Delta G_{f_{n}}^{2}$
s: CH4 C2H6 (g) -74520 c C2H6 (g) -8320 C3H8 (g) -104680 C4H10 C5H12 C6H14 (g) -125790 C6H14 C6H14 C6H14 C6H14 C6H14 C6H14 C6H14 C6H16 C6H16 C6H16 C6H16 C6H16 C6H16 C6H17 C6H17 C6H17 C6H17 C6H18 C6H18 C6H18 C6H18 C6H18 C6H19 C7H19 C7H18 C	Chemical species		(Note 2)	(Note 1)	(Note 1)
ce CH4 (g) -74520 C2H6 (g) -83820 C2H6 (g) -83820 C3H8 (g) -104680 C4H10 (g) -1125790 c5H12 (g) -166920 C6H14 (g) -166920 c7H16 (g) -166920 c7H16 (g) -166920 c7H16 (g) -166920 c7H1 (g) -126190 c7H1 (g) -126190 c7H2 (g) -126190 c6H2 (g) -126190 c7H4 (g) -123140 c7H4 (g) -235100 c7H4 (g) -235100 c7H4 (g) -235100 c7H4 (g) -235100 c7H4 (g) -23660 c7H4 (g) -23660 c7H4 (g) -23660 c7H4 (g) -1314790 c7H4 (g) -1314790 c7H4 (g) -13180 c7H8 (g) -13180	araffins:				
e C ₂ H ₆ (g) -83 820 C ₃ H ₈ (g) -104 680 C ₄ H ₁₀ (g) -105 790 E C ₄ H ₁₀ (g) -16 920 C ₅ H ₁₂ (g) -16 920 C ₆ H ₁₄ (g) -16 920 C ₇ H ₁₆ (g) -187 780 E C ₇ H ₁₈ (g) -208 750 E C ₇ H ₁₉ (g) -208 750 E C ₇ H ₁ (g) -21 280 E C ₇ H ₁ (g) -21 280 E C ₇ H ₁ (g) -27 480 E C ₇ H ₁ (g) -165 190 E C ₇ H ₁ (g) -21 280 E C ₇ H ₁ (g) -156 190 E C ₇ H ₁ (g) -156 190 E C ₇ H ₁ (g) -156 190 E C ₇ H ₂ (g) -126 190 E C ₇ H ₆ (g) -126 190 E C ₇ H ₆ (g) -123 140 E C ₇ H ₆ (g) -13 140 E C ₇ H ₆ (g) -13 140 E C ₇ H ₆ (g) -13 140 E C ₇ H ₆ (g) -135 190 E C ₇ H ₆ (g) -135 190 E C ₇ H ₆ (g) -235 190 E C ₇ H ₆ (g) -236 69 E C ₇ H ₁ (g) -238 660 E C ₇ H ₁ (g) -190 160 E C ₇ H ₈ (g) -151 180 E C ₇ H ₈ (g) -12 180 E C ₇ H ₈ (g) -12 180	Methane	CH ₄	(8)		-50460
es: C ₂ H ₈ (g) -104 680 Left (g) -125 790 C ₄ H ₁₀ (g) -125 790 C ₅ H ₁₂ (g) -146 760 C ₆ H ₁₄ (g) -166 920 C ₆ H ₁₄ (g) -166 920 C ₇ H ₁₆ (g) -187 780 es: C ₂ H ₄ (g) -208 750 es: C ₂ H ₄ (g) -208 750 es: C ₂ H ₄ (g) -21 280 C ₄ H ₈ (g) -21 280 c ₇ H ₁₄ (g) -21 280 es: C ₂ H ₄ O (g) -165 190 c ₇ H ₁₄ (g) -27 760 estyde C ₂ H ₄ O (g) -165 190 c ₇ H ₁₄ (g) -156 190 c ₇ H ₁₄ (g) -156 190 c ₇ H ₆ (g) -165 190 c ₇ H ₆ (g) -123 140 estyde C ₇ H ₆ (g) -123 140 c ₇ H ₆ (g) -133 140 c ₇ H ₆ O (g) -235 100 c ₇ H ₆ O (g) -108 570 c ₇ H ₈ O (g) -154 70 c ₇ H ₈ O (g) -154 70 c ₇ H ₈ O (g) -154 70 c ₇ H ₈ O (g) -151 180	Ethane	C_2H_6	8	-83820	-31855
nue C_{5H12} (g) -125790 -1 nue C_{5H12} (g) -146760 -1 nue C_{5H14} (g) -146760 -1 es: C_{5H18} (g) -146780 -1 es: C_{5H18} (g) -187780 -1 es: C_{5H18} (g) -208750 1 nue C_{5H19} (g) -2180 7 nue C_{5H10} (g) -2180 7 nue C_{5H10} (g) -2180 7 nue C_{5H10} (g) -2180 7 nue C_{5H12} (g) -48450 -38 nue C_{5H2} (g) -165190 -12 ethyde C_{2H4} (g) -165190 -12 nue C_{2H4} (g) -165190 -12 nue C_{2H4} (g) -165190 -12 ethyde C_{2H4} (g) -165190 -12 nue C_{2H4} (g) -165190 -12 nue C_{2H4} (g) -165190 -12 ethyde C_{2H4} (g) -165190 -12 nuediol C_{2H4} (g) -165190 -12 nuediol C_{2H4} (g) -156190 -12 nuediol C_{2H4} (g) -156190 -12 nuediol C_{2H4} (g) -156190 -12 coxide C_{2H4} (g) -10920 -11 coxide C_{2H4} (g) -10920 -10 coxide C_{2H4} (g) -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -10920 -1092	Propane	C_3H_8	(8)	-104680	-24 290
nue C_5H_{12} (g) -146760 — C_6H_{14} (g) -166920 — C_6H_{14} (g) -166920 — C_7H_{16} (g) -16780 — C_7H_{16} (g) -187780 — C_3H_{18} (g) -208750 — C_3H_{18} (g) -208750 — C_3H_{18} (g) -21280 7 C_5H_{10} (g) -21280 7 C_5H_{10} (g) -21280 7 C_7H_{14} (g) -21280 7 C_7H_{14} (g) -21280 7 C_7H_{14} (g) -165190 — C_7H_{14} (g) -156190 — C_7H_{10} (g) -169190 — C_7H_{10} (g) -169190 — C_7H_{10} (g) -169190 — C_7H_{14} (g) -169190 — C_7H_{14} (g) -169190 — C_7H_{14} (g) -190160 — C_7H_{18} (g) — C_7H_{19} (g) — $C_$	n-Butane	C_4H_{10}	(<i>8</i>)	-125790	-16570
ne C ₆ H ₁₄ (g) -166 920 ne C ₇ H ₁₆ (g) -187 780 es: C ₂ H ₄ (g) -208 750 1 es: C ₂ H ₄ (g) -208 750 1 c ₄ H ₈ (g) -21 280 7 c ₅ H ₁₀ (g) -21 280 7 ne C ₅ H ₁₀ (g) -21 280 7 c ₆ H ₁₂ (g) -21 280 7 ne C ₆ H ₁₂ (g) -21 280 7 c ₆ H ₁₂ (g) -21 280 7 ne C ₆ H ₁₂ (g) -165 190 -12 chyde C ₂ H ₄ O ₂ (g) -165 190 -12 chyde C ₂ H ₄ O ₂ (g) -165 190 12 chyde C ₂ H ₆ (g) 109 240 14 e C ₆ H ₁₂ (g) 109 240 14 e C ₆ H ₁₂ (g) 109 240 14 e C ₆ H ₁₂ (g) -156 230 22 coxide C ₆ H ₁₂ (g) -156 230 -15 coxide C ₆ H ₁₀ (g) -23 60 -16 c ₁ H ₂ O ₂ (f) -454 800 -16 c ₂ H ₄ O ₂ (g) -23 60 -16 c ₂ H ₄ O ₃ (g) -23 60 -16 c ₂ H ₄ O ₄ (g) -23 60 -16 c ₄ H ₆ (g) -13 140 2 c ₄ H ₆ (g) -13 140 2 c ₄ H ₆ (g) -13 180 111	n-Pentane	C ₅ H ₁₂	(8)	-146760	-8 650
es: C ₈ H ₁₈ (g) -187780 es: C ₈ H ₁₈ (g) -208750 1 es: C ₂ H ₄ (g) 52 510 6 c ₄ H ₈ (g) -21 280 7 c ₄ H ₁ (g) -21 280 7 c ₆ H ₁₂ (g) -21 280 7 c ₆ H ₁₂ (g) -41 950 8 nneous organics: chyde C ₂ H ₄ O (g) -165 190 -12 chyde C ₂ H ₄ O (g) -165 190 -12 chyde C ₂ H ₄ O (g) -165 190 -12 chyde C ₂ H ₄ O (g) -165 190 -12 chyde C ₂ H ₄ O (g) -155 230 12 chyde C ₄ H ₆ (g) 109 240 14 chyde C ₄ H ₆ (g) 109 240 14 chyde C ₄ H ₆ (g) -156 230 2 chyde C ₄ H ₆ (g) -156 230 12 chyde C ₄ H ₆ (g) -156 230 13 chyde C ₄ H ₆ (g) -235 100 -16 chyde C ₄ H ₆ (g) -235 60 16 chyde C ₄ H ₆ (g) -235 60 16 chyde C ₄ H ₆ (g) -236 60 16 chyde C ₄ H ₆ (g) -238 660 16 chyde C ₄ H ₆ (g) -238 660 16 chyde C ₄ H ₆ (g) -238 660 16 chyde C ₄ H ₆ (g) -238 670 10 chydexane C ₇ H ₄ (g) -238 670 12 chydexane C ₇ H ₄ (g) -238 670 12 chydexane C ₇ H ₄ (g) -131 180 111 chyde C ₇ H ₈ (g) 121 180 111	n-Hexane	C ₆ H ₁₄	8)	-166920	150
es: C2H4 (g) -208 750 ine C3H6 (g) 19 710 ine C4H3 (g) -21 280 C4H3 (g) -21 280 C5H10 (g) -21 280 C5H12 (g) -21 280 C7H14 (g) -21 280 C7H14 (g) -21 280 C1H20 (g) -166 190 C1H20 (g) -166 190 C2H4O2 (g) 829 30 C4H6 (g) 109 240 C4H6 (g) 109 240 C4H6 (g) -156 230 C4H6 (g) -156 230 C4H0 (g) -156 230 C4H0 (g) -156 230 C4H0 (g) -277 690 C1H0 (g) -277 690 C1H10 (g) -116 770 C1H10 (g) -	7-Heptane	C7H16	(8)	-187780	8 260
es: c C ₂ H ₄ (g) 52 510 ne C ₃ H ₆ (g) 19710 c C ₄ H ₈ (g) -540 c C ₅ H ₁₀ (g) -21 280 c C ₆ H ₁₂ (g) -21 280 c C ₇ H ₁₄ (g) -21 280 c C ₇ H ₁₄ (g) -166 190 -1 c C ₂ H ₄ O (g) -166 190 -1 c C ₆ H ₆ (g) 82 930 11 c C ₆ H ₆ (g) 82 930 11 c C ₆ H ₆ (g) 109 240 11 c C ₆ H ₆ (g) 109 240 11 c C ₆ H ₆ (g) 109 240 11 c C ₆ H ₆ (g) 227 480 -136 29 c C ₆ H ₆ (g) -123 140 c C ₆ H ₆ (g) -123 140 c C ₆ H ₆ O (f) -156 230 -1 c c c c c c c c c c c c c c c c c c c	1-Octane	C_8H_{18}	8)	-208 750	16 260
rine C ₂ H ₄ (g) 52.510 rine C ₃ H ₆ (g) 19710 C ₄ H ₈ (g) -21.280 C ₅ H ₁₀ (g) -21.280 C ₆ H ₁₂ (g) -41.950 Innous organics: c ₆ H ₁₂ (g) -166.190 -1. chyde C ₂ H ₄ O ₂ (l) -448.500 -3. cid C ₂ H ₄ O ₂ (l) -49.800 1. c ₆ H ₆ (g) 82.930 1. c ₆ H ₆ (g) 109.240 1. c ₆ H ₆ (g) 109.240 1. c ₆ H ₁₀ (g) -1.56.230 -1. c ₆ H ₆ (g) 227.480 2. c ₇ H ₆ (g) 227.480 1. c ₇ H ₆ (g) 227.480 1. c ₇ H ₆ (g) 29.20 1. c ₇ H ₆ O (l) -277.690 -1. c ₇ H ₆ O (l) -277.690 -1. c ₇ H ₆ O (g) -23.660 -1. c ₇ H ₆ O (g) -23.660 -1. c ₇ H ₁ O (g) -277.690 -1. c ₇ H ₁ O (g) -23.860 -1. c ₇ H ₁ O (g) -23.860 -1. c ₇ H ₁ O (g) -23.860 -1. c ₇ H ₁ O (g) -1.09.770 2. c ₇ H ₈ (g) 20.10 1. c ₇ H ₈ (g) 1.12.180 1.1	-Alkenes:				
rue C ₃ H ₆ (g) 19710 rue C ₄ H ₈ (g) -540 C ₅ H ₁₀ (g) -21280 C ₆ H ₁₂ (g) -41950 Ince C ₆ H ₁₂ (g) -41950 c ₇ H ₁₄ (g) -62760 ethyde C ₂ H ₄ O ₂ (g) -165190 -1 cid C ₂ H ₄ O ₂ (g) -165190 -1 cid C ₂ H ₄ O ₂ (g) -165190 -1 cid C ₂ H ₄ O ₂ (g) -165190 -1 cid C ₂ H ₄ O ₂ (g) -165190 -1 cid C ₂ H ₄ O ₂ (g) -156290 11 e C ₆ H ₆ (g) 82 930 11 e C ₆ H ₆ (g) 109 240 11 e C ₆ H ₁₂ (g) -135 140 c C ₆ H ₆ (g) -135 140 c C ₆ H ₆ O ₂ (g) -135 140 c C ₇ H ₆ O ₃ (g) -235 100 -11 c c oxide C ₇ H ₆ O (g) -235 100 -11 c c oxide C ₇ H ₆ O (g) -235 100 -11 c c oxide C ₇ H ₆ O (g) -237 690 -11 c oxide C ₇ H ₆ O (g) -237 690 -11 cyclohexane C ₇ H ₁₄ (g) -238 660 -11 cyclohexane C ₇ H ₁₄ (g) -190 160 c ₇ H ₈ (g) -101 12 180 11	Ethylene	C_2H_4	(8)	52 510	68 460
ne C ₅ H ₁₀ (g) -540 ne C ₅ H ₁₀ (g) -21280 C ₆ H ₁₂ (g) -21280 C ₇ H ₁₄ (g) -21280 c ₇ H ₁₄ (g) -62760 ehyde C ₂ H ₄ O ₂ (g) -165 190 -1 cid C ₂ H ₄ O ₂ (g) -165 190 -3 cid C ₂ H ₄ O ₂ (g) -165 190 -3 cid C ₄ H ₆ (g) 277 480 -3 e C ₆ H ₆ (g) 82 930 11 e C ₆ H ₆ (g) 109 240 11 exame C ₆ H ₁₂ (g) -155 290 11 e C ₆ H ₆ (g) 109 240 11 e C ₆ H ₆ (g) -155 30 -1 c C ₇ H ₆ O ₂ (g) -155 30 -1 c Sance C ₆ H ₁₀ (g) -235 100 -1 c Subsequence C ₇ H ₁ O (g) -237 690 11 e soxide C ₇ H ₆ O (g) -237 690 11 e soxide C ₇ H ₆ O (g) -237 690 11 c Subsequence C ₇ H ₁ O (g) -238 660 -11 c Subsequence C ₇ H ₁ O (g) -238 660 -11 c Syclohexane C ₇ H ₁ O (g) -238 660 -11 c Syclohexane C ₇ H ₁ O (g) -109 150 150 c C ₇ H ₈ (g) -112 180 11 c C ₇ H ₈ (g) 12 180 11	Propylene	C_3H_6	(8)	19 710	62 205
ne C ₅ H ₁₀ (g) -21 280 ne C ₆ H ₁₂ (g) -41 950 C ₇ H ₁₄ (g) -62 760 choose organics: choose C ₇ H ₂ O (g) -166 190 -1 chyde C ₂ H ₄ O (g) -166 190 -1 cid C ₂ H ₄ O (g) -166 190 -1 cid C ₂ H ₄ O (g) -166 190 -1 code C ₆ H ₆ (g) 82 930 -1 code C ₆ H ₆ (g) 82 930 -1 code C ₆ H ₁ O (g) -123 140 code C ₆ H ₁ O (g) -123 140 code C ₆ H ₁ O (g) -123 140 code C ₆ H ₁ O (g) -123 140 code C ₇ H ₆ O (g) -235 100 -1 code C ₇ H ₆ O (g) -237 690 -1 code C ₇ H ₆ O (g) -237 690 -1 code C ₇ H ₆ O (g) -237 690 -1 code C ₇ H ₆ O (g) -237 690 -1 code C ₇ H ₆ O (g) -237 690 -1 code C ₇ H ₆ O (g) -237 690 -1 code C ₇ H ₁ O (g) -238 660 -1 code C ₇ H ₁ O (g) -238 660 -1 code C ₇ H ₁ O (g) -238 660 -1 code C ₇ H ₁ O (g) -238 660 -1 code C ₇ H ₁ O (g) -238 660 -1 code C ₇ H ₁ O (g) -238 660 -1 code C ₇ H ₁ O (g) -154 770 code C ₇ H ₈ O (g) -124 180 11 code C ₇ H ₈ O (g) -124 180 11	-Butene	C_4H_8	(8)	-540	70 340
ne C ₆ H ₁₂ (g) -41950 C ₇ H ₁₄ (g) -62 760 C ₇ H ₁₄ (g) -62 760 Inneous organics: c ₂ H ₄ O (g) -166 190 -1 c ₂ H ₄ O (g) -166 190 -1 c ₄ H ₆ (g) 2274 480 -2 c ₆ H ₆ (g) 82 930 11 c ₆ H ₆ (g) 82 930 11 c ₆ H ₆ (g) 109 240 11 c ₇ H ₆ (g) 109 240 11 c ₇ H ₆ (g) 109 240 11 c ₇ H ₆ (g) -123 140 C ₇ H ₆ (g) -123 140 C ₇ H ₆ O (f) -156 230 C ₇ H ₆ O (f) -156 230 C ₇ H ₆ O (f) -277 690 -17 c ₇ H ₈ O (g) -277 690 -17 c ₇ H ₈ O (g) -278 600 -16 c ₇ H ₁ O (g) -277 690 -17 c ₇ H ₈ O (g) -108 570 -10 c ₇ H ₈ O (g) -108 170 C ₇ H ₈ O (g) -109 160 C ₇ H ₈ O (g) -109 160 C ₇ H ₈ O (g) -1154 770 C ₇ H ₈ O (g) -1154 180 11	-Pentene	C5H10	(8)	-21280	78 410
chyde C ₂ H ₄ O (g) -166 190 -1 chyde C ₂ H ₄ O (g) -166 190 -1 cid C ₂ H ₄ O ₂ (f) -484 500 -3 cid C ₂ H ₄ O ₂ (f) -484 500 -3 cid C ₂ H ₄ O ₂ (g) -227 480 2 c ₄ H ₆ (g) 82 930 11 c ₄ H ₆ (g) 109 240 11 c ₄ H ₆ (g) 109 240 11 c ₄ H ₆ (g) -156 230 c ₄ H ₆ O ₂ (f) -454 800 -3 c ₄ H ₆ O ₂ (f) -156 230 c ₄ H ₆ O ₂ (f) -156 230 c ₄ H ₆ O ₂ (f) -156 230 c ₄ H ₆ O ₂ (f) -235 100 -1 c ₄ H ₆ O (g) -235 100 -1 c ₄ H ₆ O (g) -235 100 -1 c ₄ H ₆ O (g) -235 100 -1 c ₄ H ₆ O (g) -235 100 -1 c ₄ H ₆ O (g) -236 660 -1 c ₄ Olohexane C ₄ H ₁ O (g) -238 660 -1 c ₄ Olohexane C ₇ H ₁ O (g) -154 770 c ₄ C ₄ O (g) -154 770 c ₄ C ₄ O (g) -154 770 c ₇ H ₈ (g) -151 80 11	-Hexene	C ₆ H ₁₂	(8)	-41950	86 830
ehyde C ₂ H ₄ O (g) -166 190 -1 cid C ₂ H ₄ O (l) -484 500 -3 ne C ₂ H ₄ O (l) -484 500 -3 e C ₆ H ₆ (g) 227 480 -3 c G ₆ H ₆ (g) 82 930 1 c G ₆ H ₁ (g) 109 240 1 c G ₆ H ₁ (g) 109 240 1 c G ₆ H ₁ (g) -156 230 c G ₇ H ₆ (g) -131 140 c G ₇ H ₆ O (l) -156 230 c G ₇ H ₆ O (l) -275 690 -1 c oxide C ₂ H ₆ O (l) -275 690 -1 c oxide C ₂ H ₆ O (g) -235 100 -1 c oxide C ₂ H ₆ O (g) -235 100 -1 c oxide C ₁ H ₂ O (g) -235 600 -1 c oxide C ₁ H ₂ O (g) -236 660 -1 c oxide C ₁ H ₂ O (g) -236 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -238 660 -1 c oxide C ₁ H ₁ O (g) -154 770 c oxide C ₁ H ₁ O (g) -154 770 c oxide C ₁ H ₁ O (g) -154 770 c oxide C ₁ H ₁ O (g) -154 770 c oxide C ₁ H ₁ O (g) -154 730 c oxide C ₁ H ₁ O (g) -154 730 c oxide C ₁ H ₈ O (g) -124 730	-Heptene	C7H14		-62 760	
cid C ₂ H ₄ O (g) -166 190 -1 cid C ₂ H ₄ O (f) -484 500 -3 ne C ₂ H ₂ O (f) -484 500 -3 c C ₆ H ₆ (g) 227 480 2 c C ₆ H ₆ (g) 82 930 1 c C ₆ H ₆ (g) 82 930 1 c C ₆ H ₇ (g) 109 240 1 c C ₆ H ₁ (g) 109 240 1 c C ₆ H ₁ (g) -123 140 c C ₆ H ₁ (g) -123 140 c C ₇ H ₆ O (g) -235 100 -1 c C ₇ H ₆ O (g) -235 100 -1 c c xide C ₇ H ₆ O (g) -235 100 -1 c xide C ₇ H ₆ O (g) -235 100 -1 c xide C ₇ H ₆ O (g) -235 100 -1 c xide C ₇ H ₆ O (g) -235 100 -1 c xide C ₇ H ₁ O (g) -25 630 -1 c xide C ₇ H ₁ O (g) -25 630 -1 c xide C ₇ H ₁ O (g) -238 660 -1 c xide C ₇ H ₁ O (g) -238 660 -1 c xide C ₇ H ₁ O (g) -154 770 c xide C ₇ H ₁ O (g)	fiscellaneous organics				
cid C ₂ H ₄ O ₂ (1) -484 500 -3 ne C ₂ H ₂ (2) 227 480 2 e C ₆ H ₆ (3) 82 930 1 c C ₆ H ₆ (1) 49 080 1 c C ₆ H ₆ (1) 109 240 1 c c c c c c c c c c c c c c c c c c	Acetaldehyde	C_2H_4O	(8)	-166 190	-128 860
ne C ₂ H ₂ (g) 227 480 2 C ₆ H ₆ (g) 82 930 1 C ₆ H ₆ (g) 82 930 1 C ₆ H ₆ (g) 109 240 1 C ₆ H ₁ (g) -123 140 109 240 1 C ₆ H ₁₂ (g) -123 140 109 240 1 C ₇ H ₆ O (g) -124 54 800 -3 C ₇ H ₆ O (g) -235 100 -1 C ₇ H ₆ O (g) -235 100 -1 C ₇ H ₆ O (g) -235 100 -1 C ₇ H ₇ O (g) -277 690 1 C ₁ C ₁ O (g) -277 690 1 C ₁ C ₂ O (g) -275 630 -1 C ₁ C ₂ O (g) -275 630 -1 C ₁ C ₂ O (g) -277 690 1 C ₁ C ₂ O (g) -277 690 1 C ₁ C ₂ O (g) -278 660 -1 C ₁ O (g) -288 660 -1 C ₁ O (g) -154 770 1 yclohexane C ₇ H ₁₄ (g) -154 770 1 yclohexane C ₇ H ₁₄ (g) -154 770 1 C ₇ H ₈ (g) 12 180 1	Acetic acid	C2H4O2	3	-484 500	-389900
C6H6 (g) 82 930 1 C6H6 (g) 82 930 1 C6H6 (g) 109 240 1 C3H6 (g) 109 240 1 C6H12 (g) -123 140 C6H12 (g) -123 140 C2H6O (l) -454 800 -3 C2H6O (g) -235 100 -1 CH4O (g) -25 630 -1 CH4O (g) -20 660 -1 CH4O (g) -154 700 Syclohexane C7H14 (g) -154 770 Syclohexane C7H14 (g) -154 770 CH8 (g) 20 106 C7H8 (g) 12 180 1	Acetylene	C_2H_2	8		209 970
c C ₆ H ₆ (1) 49 080 1 adiene C ₄ H ₆ (g) 109 240 1 cxane C ₆ H ₁₂ (g) -123 140 cxane C ₆ H ₁₂ (f) -156 230 nucdiol C ₂ H ₆ O ₂ (f) -454 800 -3 c ₂ H ₆ O (g) -235 100 -3 c ₂ H ₆ O (g) -235 100 -1 c ₂ H ₆ O (g) -235 100 -1 cxane C ₈ H ₁₀ (g) 29 920 1 cxane C ₈ H ₁₀ (g) -25 630 -1 chyde CH ₂ O (g) -108 570 -1 chyde CH ₂ O (g) -108 570 -1 chyde CH ₄ O (g) -238 660 -1 yclohexane C ₇ H ₁₄ (g) -154 770 yclohexane C ₇ H ₁₄ (g) -154 770 c ₈ H ₈ (g) -154 770 c ₇ H ₈ (g) 12 180 1	Senzene	C_6H_6	8)	82 930	129 665
adiene C ₄ H ₆ (g) 109 240 1 exame C ₆ H ₁₂ (g) -123 140 exame C ₆ H ₁₂ (f) -156 230 C ₂ H ₆ O ₂ (f) -454 800 -3 C ₂ H ₆ O (g) -235 100 -1 C ₂ H ₆ O (g) -235 100 -1 ce oxide C ₂ H ₄ O (g) -277 690 1 et oxide C ₄ H ₀ O (g) -52 630 -1 fethyde CH ₂ O (g) -52 630 -1 exide CH ₂ O (g) -108 570 -1 oil CH ₄ O (g) -238 660 -1 oil CH ₄ O (f) -238 660 -1 oil CH ₄ O (f) -238 660 -1 cyclohexane C ₇ H ₁₄ (g) -154 770 cyclohexane C ₇ H ₁₄ (g) -190 160 cyth ₈ (g) 50 170 cyth ₈ (g) 50 170 cyth ₈ (g) 12 180 1	Benzene	C_6H_6	9	49 080	124 520
xane	,3-Butadiene	C_4H_6	(8)	109 240	149 795
xane	Cyclohexane	C_6H_{12}	(8)	-123140	31 920
unediol C ₂ H ₆ O ₂ (<i>t</i>) -454 800 -3 C ₂ H ₆ O (<i>g</i>) -235 100 -1 C ₂ H ₆ O (<i>t</i>) -277 690 -1 mage C ₃ H ₁₀ (<i>g</i>) 29 920 1 evide C ₄ H ₂ O (<i>g</i>) -52 630 -5 lehyde CH ₂ O (<i>g</i>) -52 630 -1 CH ₄ O (<i>g</i>) -108 570 -1 order CH ₄ O (<i>g</i>) -200 660 -1 order CH ₄ O (<i>t</i>) -238 660 -1 order CH ₄ O (<i>t</i>) -238 660 -1 order CH ₄ O (<i>t</i>) -190 160 CH ₄ O (<i>t</i>) -190 160 CH ₈ (<i>g</i>) 147 360 CH ₈ (<i>g</i>) 12 180 1	Cyclohexane	C_6H_{12}	S	-156230	26 850
C2H ₆ O (g) -235 100 -1 C2H ₆ O (l) -277 690 -1 C2H ₆ O (l) -277 690 -1 c oxide C ₃ H ₁ O (g) 29 920 1 c exide C ₄ H ₂ O (g) -52 630 -2 c oxide CH ₂ O (g) -108 570 -1 c CH ₄ O (g) -200 660 -1 c CH ₄ O (l) -238 660 -1 c CH ₄ O (l) -238 660 -1 c CH ₄ O (l) -190 100 c C ₄ H ₄ (g) 147 360 c C ₇ H ₈ (g) 50 170 1 c C ₇ H ₈ (g) 12 180 1	.2-Ethanediol	$C_2H_6O_2$	9	-454 800	-323080
C2H6O (1) -277 690 -1	Sthanol	C_2H_6O	(8)	-235100	168 490
a coxide C ₈ H ₁₀ (g) 29 920 1 2 coxide C ₂ H ₄ O (g) -52 630 -61 61 61 61 61 61 61 61 61 61 61 61 61 6	thanol	C_2H_6O	(2)	-277690	-174780
e oxide C ₂ H ₄ O (g) -52 630 -61 61 61 62 0 (g) -52 630 -72 630 -73 630 0 (g) -108 570 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	thylbenzene	C_8H_{10}	(8)	29 920	130 890
lehyde CH ₂ O (g) -108 570 -1 CH ₄ O (g) -200 660 -1 CH ₄ O (f) -238 660 -1 yclohexane C ₇ H ₁₄ (g) -154 770 yclohexane C ₇ H ₁₄ (l) -190 160 C ₈ H ₈ (g) 147 360 C ₇ H ₈ (g) 12 180 1	thylene oxide	C ₂ H ₄ O	8	-52630	-13010
Ol CH4O (g) -200 660 -1 Ol CH4O (f) -238 660 -1 yclohexane C ₇ H ₁₄ (g) -154 770 yclohexane C ₇ H ₁₄ (l) -190 160 C ₈ H ₈ (g) 147 360 C ₇ H ₈ (g) 50 170 C ₇ H ₈ (g) 12 180	ormaldehyde	CH_2O	8)	-108570	-102530
yclohexane C ₇ H ₁₄ (g) -238 660 -1 yclohexane C ₇ H ₁₄ (g) -154 770 C ₈ H ₈ (g) -190 160 C ₇ H ₈ (g) 147 360 2 C ₇ H ₈ (g) 50 170 1 C ₇ H ₈ (g) 50 170 1	dethanol	CH_4O	8)	-200 660	~161 960
yclohexane C ₇ H ₁₄ (g) -154 770 yclohexane C ₇ H ₁₄ (l) -190 160 C ₈ H ₈ (g) 147 360 2 C ₇ H ₈ (g) 50 170 1 C ₇ H ₈ (l) 12 180 1	Aethanol	$CH_{4}O$	(2)	-238 660	-166270
yclohexane C ₇ H ₁₄ (1) -190 160 C ₈ H ₈ (g) 147 360 2 C ₇ H ₈ (g) 50 170 1 C ₇ H ₈ (l) 12 180 1	dethylcyclohexane	C7H14	(8)	-154770	27 480
C ₈ H ₈ (g) 147 360 C ₇ H ₈ (g) 50 170 C ₇ H ₈ (t) 12 180	dethylcyclohexane	C7H14	(2)	-190 160	20 560
C ₇ H ₈ (g) 50 170 C ₇ H ₈ (l) 12 180	tyrene	C_8H_8	8		213 900
C ₇ H ₈ (I) 12 180 113	oluene	C_7H_8	8)	50 170	122 050
	Toluene	C_7H_8	(2)		113 630

Table C.4 (Continued)

[†]From TRC Thermodynamic Tables—Hydrocarbons, Thermodynamics Research Center, Texas A & M Univ. System, College Station, TX; "The NBS Tables of Chemical Thermodynamic Properties," J. Phys. and Chem. Reference Data, vol. 11, supp. 2, 1982.

1. The standard property changes of formation ΔH_{fog}^2 and ΔG_{fog}^2 are the changes occurring when 1 mol of the listed compound is formed from its elements with each substance in its standard state at 25°C (298.15 K).

Standard states: (a) Gases (g): pure ideal gas at 1 bar and 25°C (298.15 K).
 Liquids (l) and solids (s): pure substance at 1 bar and 25°C (298.15 K).
 Solutes in aqueous solution (aa): Hypothetical ideal 1-molal solution of solute in water at 1 bar and 25°C (298.15 K).

Table C.1: Heat Capacities of Gases in the Ideal-Gas State[†]

Constants in equation $C_P^{ig}/R = A + BT + CT^2 + DT^{-2}$ T (kelvins) from 298.15 K to Tmax Chemical species $10^{3} B$ 10⁶ C $10^{-5} D$ Tmax A Paraffins: Methane CH₄ 1500 4.217 1.702 9.081 -2.164Ethane C_2H_6 1500 6.369 1.131 19.225 -5.5611500 Propane C_3H_8 9.011 28.785 --8.824 1.213 1500 n-Butane 11.928 1.935 36.915 C4H10 -11.402iso-Butane C4H10 1500 11.901 1.677 37.853 -11.945C5H12 n-Pentane 1500 14.731 2.464 45.351 -14.111n-Hexane C_6H_{14} 1500 17.550 3.025 53.722 -16.791C7H16 n-Heptane 1500 20.361 3.570 62.127 -19.4861500 n-Octane C₈H₁₈ 23.174 4.108 70.567 -22.2081-Alkenes: 1500 1.424 Ethylene C_2H_4 5.325 14.394 -4.3921500 7.792 Propylene C_3H_6 1.637 22.706 -6.9151500 10.520 1.967 31.630 1-Butene C_4H_8 -9.8731-Pentene 1500 C₅H₁₀ 13.437 2.691 39.753 -12.4471-Hexene 1500 16.240 3.220 C_6H_{12} 48.189 -15.1571-Heptene C7H14 1500 19.053 3.768 56.588 -17.8471500 1-Octene C₈H₁₆ 21.868 4.324 64.960 -20.521Miscellaneous organics: Acetaldehyde C_2H_4O 1000 6.506 1.693 17.978 -6.158Acetylene C_2H_2 1500 5.253 6.132 1.952 -1.299-13.301 C_6H_6 1500 Benzene 10.259 -0.20639.064 1,3-Butadiene C_4H_6 1500 10.720 2.734 26.786 -8.882Cyclohexane C_6H_{12} 1500 -3.87663.249 -20.92813.121 Ethanol C_2H_6O 1500 8.948 3.518 20.001 -6.002Ethylbenzene 1500 15.993 1.124 55,380 -18.476 C_8H_{10} Ethylene oxide C_2H_4O 1000 5.784 -0.38523.463 -9.296Formaldehyde CH₂O 1500 4.191 2.264 7.022 -1.877Methanol CH₄O 1500 5.547 2.211 12.216 -3.450Styrene 1500 15.534 2.050 C₈H₈ 50.192 -16.662Toluene 1500 12.922 0.290 47.052 -15.716 C₇H₈ Miscellaneous inorganics: 2000 3.509 3.355 0.575 Air -0.016. Ammonia NH_3 1800 4.269 3.578 3.020 -0.1863000 4.493 Bromine Br_2 4.337 0.056 -0.154Carbon monoxide ,co 2500 3.507 3.376 0.557 -0.031CO2 Carbon dioxide 2000 4.467 5.457 1.045 -1.157Carbon disulfide CS_2 1800 5.532 6.311 0.805 -0.906Chlorine 3000 4.082 Cl_2 4.442 0.089 -0.344Hydrogen 3000 3.468 3.249 H_2 0.422 0.083 Hydrogen sulfide H_2S 2300 4.114 3.931 1.490 -0.232Hydrogen chloride HC1 2000 3.512 3.156 0.623 0.151 Hydrogen cyanide 2500 **HCN** 4.326 1.359 4.736 -0.725Nitrogen N_2 2000 3.502 3.280 0.593 0.040 Nitrous oxide N_2O 2000 5.328 4.646 1.214 -0.928. Nitric oxide. NO. 2000 3.590 3.387 0.629 0.014 Nitrogen dioxide NO₂ 2000 4.447 4.982 1.195 -0.792Dinitrogen tetroxide N_2O_4 2000 9.198 11.660 2.257 -2.7872000 Oxygen O_2 3.535 3.639 0.506 -0.227Sulfur dioxide 2000 -4.796 ${\mathfrak S}{\mathfrak O}_2$ 5.699 0.801 -1.015Sulfur trioxide SO_3 2000 6.094 8.060 1.056 -2.028 Water H₂O 2000 4.038 3.470 1.450 0.121

[†] Selected from H. M. Spencer, Ind. Eng. Chem., vol. 40, pp. 2152–2154, 1948; K. K. Kelley, U.S. Bur. Mines. Rull. 584, 1960: 1 R. Pankratz, ILS Rur. Mines. Rull. 672, 1982