

UNIVERSITY OF SWAZILAND
BACHELOR OF SCIENCE

MAIN EXAMINATION 2015

TITLE OF PAPER : INTRODUCTORY PHYSICAL CHEMISTRY

COURSE NUMBER : C202

TIME : 3 HOURS

INSTRUCTIONS : THERE ARE SIX QUESTIONS

: ANSWER ANY FOUR QUESTIONS

: BEGIN THE ANSWER TO EACH QUESTION ON
A SEPARATE SHEET OF PAPER

: DATA SHEETS ARE PROVIDED WITH THIS
EXAMINATION PAPER

DO NOT OPEN THIS PAPER UNTIL THE INVIGILATOR INSTRUCTS YOU TO DO
SO.

Question 1 [25 Marks]

- a) Describe in detail the scientific basis of the van der Waals equation. [10]
- b) A real gas equation of state for a gas is given by:
- $$P = RT(V_m - \beta)^{-1} - (\alpha/T)V_m^{-2} \quad (1)$$
- i) Derive an expression for $V_{m,c}$, T_c and P_c . [6]
ii) Find an expression for the Boyle's temperature, T_B . [4]
iii) Estimate the temperature at which oxygen behaves as an ideal gas, T_B given the constants: $\alpha=1.748 \text{ L}^2\text{atm mol}^{-2}\text{K}$ and $\beta= 0.0345 \text{ L mol}^{-1}$. [2]
iv) Estimate the radii of real gas molecules using equation (1) for real gases given a critical molar volume of $250 \text{ cm}^3\text{mol}^{-1}$ [2]
- c) Using the critical point expressions for $V_{m,c}$, T_c and P_c find an expression or value for compressibility at the critical point, Z_c [1]

Question 2 [25 MARKS]

- a) Using examples and/or diagrams compare and contrast Any Two of the following terms
- i) reversible and irreversible expansion [5]
ii) path and state functions [5]
iii) change in internal energy and change in enthalpy [5]
- b) 4 moles of butane occupies 24 L at 310 K.
- i) Derive an expression for work in a reversible isothermal expansion. [5]
ii) Calculate the work done when the gas expands isothermally against a constant external pressure of 100 torr. [5]
iii) Calculate the work that would be done if the same expansion in b(ii) occurred in a series of equilibrium steps . [5]

[assume butane behaves as an ideal gas]

Question 3 [25 Marks]

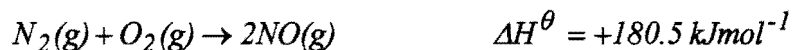
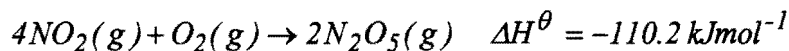
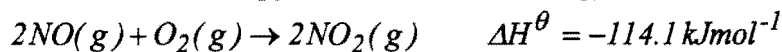
- a) Write short notes on Any Two of the following concepts.
- i) Statistical view of entropy [5]
ii) Clausius inequality [5]
iii) Second law of thermodynamics [5]

For each concept include the origin or a short derivation showing its origin, an example where applicable and the role or implication of each of the concepts in thermodynamics.

- b)
- 1.00 mol of perfect gas at 27°C is expanded isothermally from an initial pressure of 3.00 atm to a final pressure of 1.00 atm . Calculate q , w , ΔS_{sys} , ΔS_{surr} and ΔS_{tot} if the expansion is done:
- (1) reversibly, and [5]
(2) against a constant external pressure of 1.00 atm. [5]
(3) adiabatically against a constant pressure of 1.00 atm. [5]

Question 4 [25 Marks]

- a) (i) Calculate the enthalpy of formation of $N_2O_5(g)$ from the following data: [9]

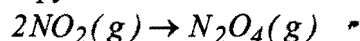


- (ii) Using the enthalpy of formation of $N_2O_5(g)$ obtained from a(i) calculate the change in internal energy for the formation of $N_2O_5(g)$ [6]

- b) (i) Derive Kirrchoff's equation: [4]

$$\Delta H_r(T_2) = \Delta H_r(T_1) + \Delta_r C_p \Delta T$$

- (ii) Predict the standard enthalpy of reaction at 80°C for the reaction: [6]



Refer to table and the data below:

	$C_p \text{ J mol}^{-1}\text{K}^{-1}$	$\Delta H_f^\theta(298 \text{ K}) / \text{kJ/mol}$
$N_2O_4(g)$	77.28	+9.2
$NO_2(g)$	37.20	+33.2

Question 5 [25 Marks]

- a) Write short notes on the following:

(i) Gibbs Free Energy [4]

(ii) Helmholtz Function [4]

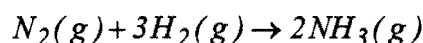
Use equations, examples and Application to clarify your discussion.

- b) Derive the integrated Gibbs-Helmholtz equation [5]

$$\frac{\Delta G_2}{T_2} - \frac{\Delta G_1}{T_1} = \Delta H \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

starting from the fundamental thermodynamic equation $dG = VdP - SdT$

- c) Given the reaction:



Calculate the change in Gibbs free energy ΔG^θ

i) at 298K

[5]

ii) at 500K

[5]

iii) Comment on the significance of the values obtained in (i) and (ii). [2]

Question 6 [25 Marks]

a) Draw sketch of the phase diagrams of carbon dioxide and water and explain briefly the differences in slopes and curvature of the liquid-solid and the liquid-gas boundaries, respectively. [15]

b) i) Starting from the Gibbs function $G=H-TS$, .derive the Clausius-Clapeyron equation for evaporation in the form

$$\ln \frac{p_2}{p_1} = -\frac{\overline{\Delta H}_{VAP}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right). \quad [5]$$

ii) The boiling point of methanol is at 64.6°C and 760 mm Hg. Predict the boiling point of benzene at 1.2 atm pressure. [5]

Heat capacities at 25°C

	$C_{v,m}$	$C_{p,m}$
	$\text{JK}^{-1} \text{mol}^{-1}$	$\text{JK}^{-1} \text{mol}^{-1}$
He, Ne, Ar, Kr, Xe	12.47	20.78
H ₂	20.50	28.81
O ₂	21.01	29.33
N ₂	20.83	29.14
CO ₂	28.83	37.14
NH ₃	27.17	35.48
CH ₄	27.43	35.74
N ₂ O ₄		77.28
NO ₂		37.20

F.P Depression, B.P. Elevation

Solvent	F.P °C	K_f °C kg mol ⁻¹	B.P (°C, 101kNm ⁻²)	K_b °C kg mol ⁻¹
Water	0	1.86	100.0	0.52
Benzene	5.51	5.10	80.1	2.60
Acetic Acid	16.6	3.90	118.1	3.10
Cyclohexane	6.5	20.2	81.4	2.79
Camphor	177.7	40.0	205	-
Nitrobenzene	5.7	6.9	210.9	5.24
Ethanol	-177		78.5	1.22
Chloroform	-64		61.3	3.63

Third Law entropies at 25°C, $\text{Sm}^{\ominus}/\text{J K}^{-1} \text{mol}^{-1}$

Solids		Liquids		Gases	
Ag	42.68	Hg	76.02	H ₂	130.6
C(gr)	5.77	Br ₂	152.3	N ₂	192.1
C(d)	2.44			O ₂	205.1
Cu	33.4			Cl ₂	223.0
Zn	41.6	H ₂ O	70.0	CO	197.67
I ₂	116.7			CO ₂	213.7
S(Rh)	31.9	HNO ₃	155.6	HCl	186.8
				H ₂ S	205.6
AgCl	96.2	C ₂ H ₅ OH	161.0	NH ₃	192.5
AgBr	104.6	CH ₃ OH	126.7	CH ₄	186.1
CuSO ₄ ·5H ₂ O	305.4	C ₆ H ₆	49.03	C ₂ H ₆	229.4
HgCl ₂	144	CH ₃ COOH	159.8	CH ₃ CHO	265.7
Sucrose	360.2	C ₆ H ₁₂	298.2		

Useful Relations				General Data							
$(RT)_{298.15K} = 2.4789 \text{ kJ/mol}$				speed of light	c	$2.997\ 925 \times 10^8 \text{ ms}^{-1}$					
$(RT/F)_{298.15K} = 0.025\ 693 \text{ V}$				charge of proton	e	$1.602\ 19 \times 10^{-19} \text{ C}$					
T/K: 100.15 298.15 500.15 1000.15				Faraday constant	$F = Le$	$9.648\ 46 \times 10^4 \text{ C mol}^{-1}$					
T/Cm ⁻¹ : 69.61 207.22 347.62 695.13				Boltzmann constant	k	$1.380\ 66 \times 10^{-23} \text{ J K}^{-1}$					
1mmHg = 133.222 N m ⁻²				Gas constant	$R = Lk$	$8.314\ 41 \text{ J K}^{-1} \text{ mol}^{-1}$					
$hc/k = 1.438\ 78 \times 10^{-2} \text{ m K}$						$8.205\ 75 \times 10^{-2} \text{ dm}^3 \text{ atm K}^{-1} \text{ mol}^{-1}$					
1atm	1 cal	1 eV	1 cm⁻¹								
$= 1.01325 \times 10^5 \text{ Nm}^{-2}$	$= 4.184 \text{ J}$	$= 1.602\ 189 \times 10^{-19} \text{ J}$	$= 0.124 \times 10^{-3} \text{ eV}$	Planck constant	h	$6.626\ 18 \times 10^{-34} \text{ Js}$					
-760 torr		$= 96.485 \text{ kJ/mol}$	$= 1.9864 \times 10^{-23} \text{ J}$		$\hbar = \frac{h}{2\pi}$	$1.054\ 59 \times 10^{-34} \text{ Js}$					
= 1 bar		$= 8065.5 \text{ cm}^{-1}$		Avogadro constant	$L \text{ or } N_{AV}$	$6.022\ 14 \times 10^{23} \text{ mol}^{-1}$					
SI-units:				Atomis mass unit	u	$1.660\ 54 \times 10^{-27} \text{ kg}$					
$1 \text{ L} = 1000 \text{ ml} = 1000 \text{ cm}^3 = 1 \text{ dm}^3$				Electron mass	m_e	$9.109\ 39 \times 10^{-31} \text{ kg}$					
$1 \text{ dm} = 0.1 \text{ m}$				Proton mass	m_p	$1.672\ 62 \times 10^{-27} \text{ kg}$					
$1 \text{ cal (thermochemical)} = 4.184 \text{ J}$				Neutron mass	m_n	$1.674\ 93 \times 10^{-27} \text{ kg}$					
dipole moment: 1 Debye = $3.335\ 64 \times 10^{-30} \text{ C m}$				Vacuum permittivity	$\epsilon_0 = \mu_0^{-1} c^{-2}$	$8.854\ 188 \times 10^{-12} \text{ J}^{-1} \text{ C}^2 \text{ m}^{-1}$					
force: $1 \text{ N} = 1 \text{ J m}^{-1} = 1 \text{ kgms}^{-2} = 10^5 \text{ dyne}$ pressure: $1 \text{ Pa} = 1 \text{ Nm}^{-2} = 1 \text{ Jm}^{-3}$				Vacuum permeability	μ_0	$4\pi \times 10^{-7} \text{ Js}^2 \text{ C}^{-2} \text{ m}^{-1}$					
$1 \text{ J} = 1 \text{ Nm}$				Bohr magneton	$\mu_B = \frac{e\hbar}{2m_e}$	$9.274\ 02 \times 10^{-24} \text{ JT}^{-1}$					
power: $1 \text{ W} = 1 \text{ J s}^{-1}$ potential: $1 \text{ V} = 1 \text{ J C}^{-1}$				Nuclear magneton	$\mu_N = \frac{e\hbar}{2m_p}$	$5.05079 \times 10^{-27} \text{ JT}^{-1}$					
magnetic flux: $1 \text{ T} = 1 \text{ Vsm}^{-2} = 1 \text{ JCsm}^{-2}$ current: $1 \text{ A} = 1 \text{ Cs}^{-1}$											
Prefixes:				Gravitational constant	G	$6.67259 \times 10^{-11} \text{ Nm}^2 \text{ kg}^{-2}$					
p	n	m	m	c	d	k	M	G	Gravitational acceleration	g	9.80665 ms^{-2}
pico	nano	micro	milli	centi	deci	kilo	mega	giga			
10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^3	10^6	10^9	Bohr radius	a_0	$5.291\ 77 \times 10^{-11} \text{ m}$

THE PERIODIC TABLE OF ELEMENTS

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	IA	IIA	IIIB	IVB	VB	VIB	VII B	VIII B			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
Period 1	1 H 1.008	NON-METALS ←															2 He 4.003	
2	3 Li 6.94	4 Be 9.01	METALLOIDS ←										5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31	METALS →										13 Al 26.9	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.01	25 Mn 54.9	26 Fe 55.85	27 Co 58.71	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.7	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 91.22	42 Mo 95.94	43 Tc 98.9	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	71 Lu 174.9	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 196.9	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 208.9	84 Po 210	85 At 210	86 Rn 222
7	87 Fr 223	88 Ra 226.0	103 Lr 257	104 Unq	105 Unp	106 Unh	107 Uns	108 Uno	109 Une									

Lanthanides	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm 146.9	62 Sm 150.9	63 Eu 151.3	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0
Actinides	89 Ac 227.0	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np 237.1	94 Pu 239.1	95 Am 241.1	96 Cm 247.1	97 Bk 249.1	98 Cf 251.1	99 Es 254.1	100 Fm 257.1	101 Md 258.1	102 No 255

Numbers below the symbol indicates the **atomic masses**; and the numbers above the symbol indicates the **atomic numbers**.

SOURCE: International Union of Pure and Applied Chemistry, I mills, ed., *Quantities, Units, and symbols in Physical Chemistry*, Blackwell Scientific publications, Boston, 1988, pp 86-98.

Standard molar enthalpies of formation at 298.15 K

Temperature dependence of heat capacities, $C_{p,m} = a + bT + cT^{-2}$

M_f	$\Delta H_f^\ominus/\text{KJ/mol}$	M_f	$\Delta H_f^\ominus/\text{KJ/mol}$	a/J K ⁻¹ mol ⁻¹	b/10 ⁻³ J K ⁻² mol ⁻¹	c/10 ⁵ J K mol ⁻¹
H ₂ O(g)	18.015	O ₃ (g)	47.998	Gases (298-2000K)		
H ₂ O(l)	-285.8	NO(g)	30.006	He, Ne, Ar, Kr, Xe	20.78	0
H ₂ O ₂ (l)	-187.8	NO ₂ (g)	46.006	H ₂	27.28	3.26
NH ₃ (g)	17.031	N ₂ O ₄ (g)	92.012	O ₂	29.96	4.18
N ₂ H ₄ (l)	32.045	SO ₂ (g)	64.063	N ₂	28.58	3.77
N ₂ H(l)	43.028	H ₂ S(g)	34.080	Cl ₂	37.03	0.67
N ₃ H(g)	43.028	SF ₆ (g)	146.054	CO ₂	44.23	8.79
HNO ₃ (l)	63.013	HF(g)	20.006	H ₂ O	30.54	10.29
NH ₂ OH(s)	33.030	HCl(g)	36.461	NH ₃	29.75	25.10
NH ₄ Cl(s)	53.492	HCl(aq)	36.461	CH ₄	23.64	47.86
HgCl ₂ (s)	271.50	HBr(g)	80.917			
H ₂ SO ₄ (l)	98.078	HI(g)	127.912			
H ₂ SO ₄ (aq)	98.078	CO ₂ (g)	44.010			
NaCl(s)	58.443	CO(g)	28.011			
NaOH(s)	39.997	AL ₂ O ₃ (α,s)	101.945			
KCl(s)	74.555	SiO ₂ (s)	60.085			
KBr(s)	119.011	FeS(s)	87.91			
KI(s)	166.006	FeS ₂ (s)	119.975			
Diatomics(g)	0	AgCl(s)	143.323			

Standard molar enthalpies of formation and combustion at 298.15 K.

M_f	$\Delta H_f^\ominus/\text{KJ/mol}$	$\Delta H_c^\ominus/\text{KJ/mol}$
CH ₄ (g)	16.043	-74.81
C ₂ H ₂ (g)	26.038	+226.8
C ₂ H ₄ (g)	28.054	+52.30
C ₂ H ₆ (g)	30.070	-84.64
C ₃ H ₆ cyclopropane(g)	42.081	53.35
C ₃ H ₆ (propene)(g)	42.081	20.5
C ₄ H ₁₀ n-butane (g)	58.124	-126.11
C ₅ H ₁₂ n-pentane(g)	72.151	-148.4
C ₆ H ₁₂ cyclohexane (l)	84.163	-158.2
C ₆ H ₁₄ n-hexane (l)	86.178	-198.7
C ₆ H ₆ benzene (l)	78.115	+48.99
C ₈ H ₁₈ n-octane (l)	114.233	-249.8
C ₁₀ H ₈ naphthalene (l)	128.175	+78.53
CH ₃ OH (l)	32.042	-239.0
CH ₃ CHO (g)	44.054	-166.0
CH ₃ CH ₂ OH (l)	46.070	-277.0
CH ₃ COOH (l)	60.053	-484.2
CH ₃ COOC ₂ H ₅ (l)	88.107	-486.6
C ₆ H ₅ OH (s)	94.114	-165.0
C ₆ H ₅ NH ₂ (l)	93.129	-31.1
NH ₂ CO.NH, urea(s)	60.056	-333.0
CH ₂ (NH ₂)CO ₂ H, glycine (s)	75.088	-537.2
C ₆ H ₁₂ O ₆ , α-D-glucose (s)	180.159	-1274
C ₆ H ₁₂ O ₆ , β-D-glucose (s)	180.159	-1268
C ₁₂ H ₂₂ O ₁₁ , sucrose (s)	342.303	-2222
CH ₃ CH(OH)COOH lactic acid (s)	90.079	-694.0

Enthalpies of fusion and evaporation $\Delta H_{tr}/\text{KJ/mol}$ at the transition temperature

T_f/K	Fusion ^a	T_b/K	Evaporation ^b
He	3.5	4.22	0.084
Ar	83.81	87.29	6.506
H ₂	13.96	20.38	0.9163
N ₂	63.15	77.35	5.586
O ₂	54.36	90.18	6.820
Cl ₂	172.12	239.05	20.410
Br ₂	265.90	332.35	29.45
I ₂	386.75	458.39	41.80
Hg	234.29	629.73	59.296
Ag	1234	2436	250.63
Na	370.95	1156	98.01
CO ₂	217.0	194.84	25.23 [†]
H ₂ O	273.15	373.15	40.656 (44.016 at 298.15 K)
NH ₃	195.40	239.73	23.351
H ₂ S	187.61	212.80	18.673
CH ₄	90.88	111.66	8.18
C ₂ H ₆	89.85	184.55	14.7
C ₆ H ₆	278.65	353.25	30.8
CH ₃ OH	175.25	337.22	35.27 (37.99 at 298.15K)

[†] Sublimation: ^a various pressures: ^b at 1 atm

Source: American Institute of Physics handbook, McGraw-Hill

Standard molar Gibbs free energy and molar entropy of formation at 298.15 K

	M_r	$\Delta G_f^\theta/\text{KJ/mol}$	$S^\theta/\text{J K}^{-1} \text{mol}^{-1}$		M_r	$\Delta G_f^\theta/\text{KJ/mol}$	$S^\theta/\text{J K}^{-1} \text{mol}^{-1}$
H ₂ O(g)	18.015	-228.57	188.83	O ₂ (g)	47.998	163.2	238.93
H ₂ O(l)	18.015	-120.35	109.6	NO(g)	30.006	86.55	210.76
H ₂ O ₂ (l)	34.015	-120.35	109.6	NO ₂ (g)	46.006	51.31	240.06
NH ₃ (g)	17.031	-16.45	192.45	N ₂ O ₄ (g)	92.012	97.89	304.29
N ₂ H ₄ (l)	32.045	149.43	121.21	SO ₂ (g)	64.063	-300.19	248.22
N ₂ H(l)	43.028	327.3	140.6	H ₂ S(g)	34.080	-33.56	205.79
N ₂ H(g)	43.028	328.1	238.97	SF ₆ (g)	146.054	-1105.3	291.82
HNO ₃ (l)	63.013	-80.71	155.60	HF(g)	20.006	-273.2	173.78
NH ₄ OH(s)	33.030			HCl(g)	36.461	-95.30	186.91
NH ₄ Cl(s)	53.492	-202.87	94.6	HCl(aq)	36.461	-131.23	56.5
HgCl ₂ (s)	271.50	-178.6	146.0	HBr(g)	80.917	-53.45	198.70
H ₂ SO ₄ (l)	98.078	-690.00	156.90	HI(g)	127.912	1.70	206.59
H ₂ SO ₄ (aq)	98.078	-744.53	20.1	CO ₂ (g)	44.010	-394.36	213.74
NaCl(s)	58.443	-384.14	72.13	CO(g)	28.011	-137.17	197.67
NaOH(s)	39.997	-379.49	64.46	Al ₂ O ₃ (□,s)	101.945	-1582.3	50.92
KCl(s)	74.555	-409.14	82.59	SiO ₂	60.09	-856.64	41.84
KBr(s)	119.011	-380.66	95.90	FeS(s)	87.91	-100.4	60.29
KI(s)	166.006	-324.89	106.32	FeS ₂ (s)	119.975	-166.9	52.93
				AgCl(s)	143.323	-109.79	96.2
He(g)	4.003	0	126.15	Hg(g)	200.59	31.82	174.96
Ar(g)	39.95	0	154.84	Hg(l)	200.59	0	76.02
H ₂ (g)	2.016	0	130.684	Ag(g)	107.87	245.65	173.00
N ₂ (g)	28.013	0	191.61	Ag(s)	107.87	0	42.55
O ₂ (g)	31.999	0	205.138	Na(g)	370.95	76.76	153.71
O ₃ (g)	47.998	163.2	238.93	Na(s)	22.99	0	51.21
Cl ₂ (g)	70.91	0	223.07				
Br ₂ (g)	159.82	3.110	245.46				
Br ₂ (l)	159.82	0	152.23				
I ₂ (g)	253.81	19.33	260.69				
I ₂ (s)	253.81	0	116.135				

	M_r	$\Delta G_f^\theta/\text{KJ/mol}$	$S^\theta/\text{J K}^{-1} \text{mol}^{-1}$
organic compounds			
CH ₄ (g) methane	16.043	-50.72	186.26
C ₂ H ₂ (g) ethyne	26.038	209.20	200.94
C ₂ H ₄ (g) ethene	28.05	68.15	219.56
C ₂ H ₆ (g) ethane	30.070	-32.82	229.60
C ₃ H ₆ cyclopropane(g)	42.081	104.45	237.55
C ₃ H ₆ propene(g)	42.081	62.78	267.05
C ₄ H ₁₀ n-butane (g)	58.124	-17.03	310.23
C ₅ H ₁₂ n-pentane(g)	72.151	-8.20	348.40
C ₆ H ₁₂ cyclohexane (l)	84.163	26.8	
C ₆ H ₁₄ n-hexane (l)	86.178		204.3
C ₆ H ₆ benzene (l)	78.115	124.3	173.3
C ₆ H ₆ benzene (g)	78.115	129.72	269.31
C ₈ H ₁₈ n-octane (l)	114.233	6.4	361.1
C ₁₀ H ₈ naphthalene (l)	128.175		
CH ₃ OH (g)	32.042	-161.96	239.81
CH ₃ OH (l)	32.042	-166.27	126.8
CH ₃ CHO (g)	44.054	-128.86	250.3
CH ₃ CH ₂ OH (l)	46.07	-174.78	160.7
CH ₃ COOH (l)	60.053	-389.9	159.8
CH ₃ COOC ₂ H ₅ (l)	88.107	-332.7	259.4
C ₆ H ₅ OH (s)	94.114	-50.9	146.0
C ₆ H ₅ NH ₂ (l)	93.129		
CH ₂ (NH ₂)CO ₂ H, glycine (s)	75.068	-373.4	103.5
C ₆ H ₁₂ O ₆ , □-D-glucose (s)	180.159		
C ₆ H ₁₂ O ₆ , □-D-glucose (s)	180.159	-910	212
C ₁₂ H ₂₂ O ₁₁ , sucrose (s)	342.303	-1543	360.2
CH ₃ CH(OH)COOH	90.079		
lactic acid (s)			

Source: American Institute of Physics handbook, McGraw-Hill.