UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION 2015

TITLE OF PAPER: INTRODUCTORY PHYSICAL CHEMISTRY

COURSE NUMBER: C202

TIME: 3 HOURS

INSTRUCTIONS: ANSWER ANY FOUR QUESTIONS.

BEGIN THE ANSWER TO EACH QUESTION ON SEPARATE SHEET OF PAPER.

EACH QUESTION IS 25 MARKS

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) Many gases show nearly ideal behaviour at room temperature and low pressures. Using a sketch of either an isotherm or the compressibility factor 'z' for a real gas and that of an ideal gas , briefly explain how they compare at high pressure, moderate pressure, and at low pressure. [15]

b) The equation of state of Dieterici is:

$$P = \frac{nRT}{V - nb} e^{-an/VRT}$$

i) Express the equation in a Virial equation form and find expressions for the second and third Virial coefficients. [5]

useful relations: Virial equation states: $PV_m = RT + B(T)\left(\frac{1}{V_m}\right) + C(T)\left(\frac{1}{V_m}\right)^2 + \ldots$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots \;\&\; \frac{1}{1-x} = 1 + x + x^2 + x^3 + \ldots$$

ii). Calculate the temperature below which O_2 behaves as a real gas. [5]
a=1.748 L^2 atm. mol^{-2} and b=0.0345 $Lmol^{-1}$

QUESTION 2 (25 Marks)

a) Briefly define any three of the following terms: [15]
i). Enthalpy
ii). Internal Energy
iii). Equipartition principle
iv). State function

b). Derive an expression for work in an isothermal reversible expansion of an ideal gas. [5]

Useful relation: $W = -\int_{x_1}^{x_2} F(x)dx$

c). 2.5 mol of Argon is taken from an initial state at P_i=10.0 atm and T=27°C to a final state through the following sequence: [5]

i) isothermal reversible expansion to twice its initial volume.
iii) Isothermal expansion to 3 times its initial volume against a constant external pressure of 1 atm.

Calculate W for each step.

QUESTION 3 (25 Marks)

a).
i). Write short notes on the following: [10]
1) Hess's Law of thermodynamics
2) Kirrchoff's Laws of thermodynamics

ii) Calculate ΔH_m^θ at 298 K for the following reaction: [3]

$$2N_3H(l) + 2NO(g) \longrightarrow H_2O_2(l) + 4N_2(g)$$

	$N_3H(l)$	NO(g)	$H_2O_2(l)$	$N_2(g)$
ΔH_f^θ/kJmol^{-1}	+264	90.25	-187.8	0

ii).Given: $C_3H_6(g) + \frac{9}{2}O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(l)$

ΔH_m^θ(hydrogenation, $C_3H_6(g)$) = -124 kJmol^{-1}

ΔH_m^θ(combustion, $C_3H_8(g)$) = -2220 kJmol^{-1}

ΔH_m^θ(formation, $H_2O(l)$) = -286 kJmol^{-1}

Determine ΔHm^θ(combustion, $C_3H_6(g)$). [2]

b). i).To calibrate a calorimeter a 1.00g sample of $C_6H_{12}(l)$ was burned at constant pressure and it caused the temperature of the calorimeter to rise by 0.160 °C. Then a 1.50 g sample of an unknown liquid was burned in the same calorimeter, causing a temperature rise of 0.249 °C. Is the unknown $C_6H_{12}(l)$ or $C_6H_{14}(l)$?
Explain the basis of your answer. [5]

ii). Using Kirrchoff's Law Calculate ΔH_f at 100°C for the reaction: [5]

$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(l)$$

given:

	$H_2(g)$	$O_2(g)$	$H_2O(l)$
$C_{p,m}/Jmol^{-1}K^{-1}$	28.82	29.36	33.58

QUESTION 4 (25 Marks)

a) Write short notes on the following [10]
   i) Gibbs Free Energy
   ii) HelmHoltz Function

b) The master equation states that:

$$dU = TdS - PdV$$

a). Prove that: $dG = VdP - SdT$ and $-S = \left(\delta G/\delta T\right)_P$ [3]

b). Derive the Gibbs-Helmholtz equation. $\left(\frac{\partial\left(\Delta G/T\right)}{\partial T}\right)_P = -\frac{\Delta H}{T^2}$ [5]

c). The standard enthalpy of the following reaction at 298 K is -92.38 kJ/mol and the standard Gibbs function at the same temperature is -33.26 kJ/mol.

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

i) Estimate the Gibbs function at 500 K using the Gibbs-Helmholtz equation. [2]
ii) Using Kirrchoff's Law calculate the Gibbs function. Comment on the magnitude of the Gibbs function. (Assume Cp is dependent on temperature and ΔH^θ independent on temperature). [5]

Substance	ΔH_f^θ/kJ mol^{-1}	S^θ(298 K) J K^{-1}mol^{-1}	C_p JK^{-1}mol^{-1} a	b/10^{-3}	c/10^5
$N_2(g)$	0	192.1	28.58	3.77	-0.50
$H_2(g)$	0	130.6	27.28	3.26	0.50
$NH_3(g)$	-46.11	192.5	29.75	25.10	-1.55

$*C_p = a + bT + cT^2$ in the range 273 to 1500 K

QUESTION 5 (25 Marks)

The Clapeyron equation states that:

$$\frac{dP}{dT} = \frac{\Delta S_m}{\Delta V_m}$$

where P is the vapour pressure of a solid or liquid, ΔS_m and ΔV_m are the changes in molar entropy and molar volume for phase change respectively.

a) Derive the Clausius-Clapeyron equation for evaporation. [15]

$$\ln \frac{P_2}{P_1^*} = \frac{\overline{\Delta H}_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

b). The railway station at Jungfraujoch is the highest in the world, at 3540 m above sea level. The atmospheric pressure there is 0.662 atm. [10]

i) At what temperature does the station-master's kettle boil?
ii). calculate the melting point of ice at the same altitude.

useful information: enthalpy of vaporisation of water is 40.7 kJmol^{-1} at 373.15K and the enthalpy of fusion of water is 6.008 kJmol^{-1} at 273.15 K

useful relation:

$$ln\, \chi_B = \left\{\frac{-\Delta H_{melt,m}}{R}\left(\frac{1}{T} - \frac{1}{T^*}\right)\right\}$$

QUESTION 6 (25 Marks)

a) Write short notes on ***Any Two*** of the following: [10]

i) Upper Consulate Temperature
ii) Eutectic temperature
iii Azeotrope
iii) Zeotrope
iv) Phase reaction

Use example and diagrams to illustrate your points.

b) Write short notes on **Any Three** of the following concepts:

i) Statistical view of entropy [5]
ii) Clausius inequality [5]
iii) Second law of thermodynamics [5]
iv) Third law of thermodynamics [5]

Use example and diagrams to illustrate your points.

Useful Relations

$(RT)_{298.15K}$=2.4789 kJ/mol

$(RT/F)_{298.15K}$=0.025 693 V

T/K:	100.15	298.15	500.15	1000.15
T/Cm^{-1}:	69.61	207.22	347.62	695.13

1mmHg=133.222 N m^{-2}

hc/k=1.438 78x10^{-2} m K

1atm	1 cal	1 eV	1cm^{-1}
1.01325x10^{5} Nm^{-2}	4.184 J	1.602 189x10^{-19} J	0.124x10^{-3} eV
760torr		96.485 kJ/mol 8065.5 cm^{-1}	1.9864x10^{-23}J

SI-units:

1 L = 1000 ml = 1000cm^3 = 1 dm^3

1 dm = 0.1 m

1 cal (thermochemical) = 4.184 J

dipole moment: 1 Debye = 3.335 64x10^{-30} C m

force: ***1N=1J m^{-1}= 1kgms^{-2}***=10^5 dyne pressure: ***1Pa=1Nm^{-2}***=1Jm^{-3}

1J = 1 Nm

power: 1W = 1J s^{-1} potential: 1V =1 J C^{-1}

magnetic flux: 1T=1Vsm^{-2}=1JCsm^{-2} current: 1A=1Cs^{-1}

Prefixes:

p	n	m	m	c	d	k	M	G
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}

General Data

speed of light	c	**2.997 925x10^{8} ms^{-1}**
charge of proton	e	1.602 19x10^{-19} C
Faraday constant	F=Le	9.648 46x10^{4} C mol^{-1}
Boltzmann constant	k	**1.380 66x10^{-23} J K^{-1}**
Gas constant	R=Lk	**8.314 41 J K^{-1} mol^{-1}**
		8.205 75x10^{-2} dm^3 atm K^{-1} mol^{-1}
Planck constant	h	6.626 18x10^{-34} Js
	$\hbar = \frac{h}{2\pi}$	1.054 59x10^{-34} Js
Avogadro constant	L or N_{av}	**6.022 14x10^{23} mol^{-1}**
Atomis mass unit	μ	1.660 54x10^{-27} kg
Electron mass	m_e	**9.109 39x10^{-31} kg**
Proton mass	m_p	1.672 62x10^{-27} kg
Neutron mass	m_n	1.674 93x10^{-27} kg
Vacuum permittivity	$\varepsilon_o = \mu_o^{-1}c^{-2}$	8.854 188x10^{-12} J^{-1} C^2 m^{-1}
Vacuum permeability	μ_o	4πx10^{-7} Js^{2}C^{-2} m^{-1}
Bohr magneton	$\mu_B = e\hbar/2m_e$	9.274 02x10^{-24} JT^{-1}
Nuclear magneton	$\mu_N = e\hbar/2m_p$	5.05079x10^{-27} JT^{-1}
Gravitational constant	G	6.67259x10^{-11} Nm^{2}kg^{-2}
Gravitational acceleration	g	9.80665 ms^{-2}
Bohr radius	a_o	5.291 77x10^{-11} m

Standard molar enthalpies of formation at 298.15 K

	M_r	ΔH_f^θ/KJ/mol		M_r	ΔH_f^θ/KJ/mol
$H_2O(g)$	18.015	-241.8	$O_3(g)$	47.998	+142.7
$H_2O(l)$	18.015	-285.8	NO(g)	30.006	+90.2
$H_2O_2(i)$	34.015	-187.8	$NO_2(g)$	46.006	+33.2
$NH_3(g)$	17.031	-46.1	$N_2O_4(g)$	92.012	+9.2
$N_2H_4(l)$	32.045	+50.6	$SO_2(g)$	64.063	-296.8
$N_3H(l)$	43.028	+264.1	$H_2S(g)$	34.080	-20.6
$N_3H(g)$	43.028	+294.1	$SF_6(g)$	146.054	-1209
$HNO_3(l)$	63.013	-174.1	HF(g)	20.006	-271.1
$NH_2OH(s)$	33.030	-114.2	HCl(g)	36.461	-92.3
$NH_4Cl(s)$	53.492	-314.4	HCl(aq)	36.461	-167.2
$HgCl_2(s)$	271.50	-224.3	HBr(g)	80.917	+36.4
$H_2SO_4(l)$	98.078	-814.0	HI(g)	127.912	+26.5
$H_2SO_4(aq)$	98.078	-909.3	$CO_2(g)$	44.010	-393.5
NaCl(s)	58.443	-411.0	CO(g)	28.011	-110.5
NaOH(s)	39.997	-426.7	$AL_2O_3(\alpha,s)$	101.945	-1675.7
KCl(s)	74.555	-435.9	SiO2(s)	60.085	-910.9
KBr(s)	119.011	-392.2	FeS(s)	87.91	-100.0
KI(s)	166.006	-327.6	$FeS_2(s)$	119.975	-178.2
Diatomics(l,g)		0	AgCl(s)	143.323	-127.1

Enthalpies of fusion and evaporation ΔH_m/KJ/mol at the transition temperature

	T_f/K	Fusion[a]	T_b/K	Evaporation[b]	
He	3.5	0.021	4.22	0 084	
Ar	83.81	1.188	87.29	6.506	
H_2	13.96	0.117	20.38	0.9163	
N_2	63.15	0.719	77.35	5.586	
O_2	54.36	0.444	90.18	6.820	
Cl_2	172.12	6.406	239.05	20.410	
Br_2	265.90	10.573	332.35	29.45	
I_2	386.75	15.52	458.39	41.80	
Hg	234.29	2.292	629.73	59.296	
Ag	1234	11.30	2436	250.63	
Na	370.95	2.601	1156	98.01	
CO_2	217.0	8.33	194.64	25.23⊥	
H_2O	273.15	6.008	373.15	40.656	(44.016 at 298.15 K)
NH_3	195.40	5.652	239.73	23.351	
H_2S	187.61	2.377	212.80	18.673	
CH_4	90.68	0.941	111.66	8.18	
C_2H_6	89.85	2.86	184.55	14.7	
C_6H_6	278.65	10.59	353.25	30.8	
CH_3OH	175.25	3.159	337.22	35.27	(37.99 at 298.15K)

⊥ Sublimation: [a]various pressures: [b]at 1atm

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

	$a/J\,K^{-1}mol^{-1}$	$b/10^{-3}J\,K^{-2}mol^{-1}$	$c/10^5 J\,Kmol^{-1}$
Gases (298-2000K)			
He, Ne, Ar, Kr, Xe	20.78	0	0
H_2	27.28	3.26	0.50
O_2	29.96	4.18	-1.67
N_2	28.58	3.77	-0.50
Cl_2	37.03	0.67	-2.85
CO_2	44.23	8.79	-8.62
H_2O	30.54	10.29	0
NH_3	29.75	25.10	-1.55
CH_4	23.64	47.86	-1.92

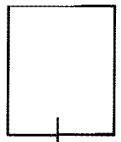
Standard molar enthalpies of formation and combustion at 298.15 K.

	M_r	ΔH_f^θ/KJ/mol	ΔH_c^θ/KJ/mol
$CH_4(g)$	16.043	-74.81	
$C_2H_2(g)$	26.038	+226.8	1300
$C_2H_4(g)$	28.054	+52.30	1411
$C_2H_6(g)$	30.070	-84.64	1560
C_3H_6 cyclopropane(g)	42.081	53.35	2091
C_3H_6 (propene(g)	42.081	20.5	2058
C_4H_{10} n-butane (g)	58.124	-126.11	2877
C_5H_{12} n-pentane(g)	72.151	-146.4	3536
C_6H_{12} cyclohexane (l)	84.163	-156.2	3920
C_6H_{14} n-hexane (l)	86.178	-198.7	4163
C_6H_6 benzene (l)	78.115	+48.99	3268
C_8H_{18} n-octane (l)	114.233	-249.8	5471
$C_{10}H_8$ naphthalene (l)	128.175	+78.53	5157
CH_3OH (l)	32.042	-239.0	726.1
CH_3CHO (g)	44.054	-166.0	1193
CH_3CH_2OH (l)	46.070	-277.0	1368
CH_3COOH (l)	60.053	-484.2	874.5
$CH_3COOC_2H_5$ (l)	88.107	-486.6	2231
C_6H_5OH (s)	94.114	-165.0	3054
$C_6H_5NH_2$ (l)	93.129	-31.1	3393
$NH_2CO.NH$, urea(s)	60.056	-333.0	632.2
$CH_2(NH_2)CO_2H$, glycine (s)	75.068	-537.2	964.4
$C_6H_{12}O_6$, α-D-glucose (s)	180.159	-1274	2802
$C_6H_{22}O_6$, β-D-glucose (s)	180.159	-1268	2803
$C_{12}H_{22}O_{11}$, sucrose (s)	342.303	-2222	5645
$CH_3CH(OH)COOH$ lactic acid (s)	90.079	-694.0	1344

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

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	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
Period 1	1 **H** 1.008																	2 He 4.003
2	3 **Li** 6.94	4 **Be** 9.01											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											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.

Useful Relations

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=760torr		=96.485 kJ/mol	=1.9864x10^{-23}J
=1 bar		= 8065.5 cm^{-1}	

SI-units:

1 L = 1000 ml = 1000cm^3 = 1 dm^3

1 dm = 0.1 m

1 cal (thermochemical) = 4.184 J

dipole moment: 1 Debye = 3.335 64x10^{-30} C m

force: ***1N=1J m^{-1}= 1kgms^{-2}***=10^5 dyne pressure: ***1Pa=1Nm^{-2}***=1Jm^{-3}

1J = 1 Nm

power: 1W = 1J s^{-1} potential: 1V =1 J C^{-1}

magnetic flux: 1T=1Vsm^{-2}=1JCsm^{-2} current: 1A=1Cs^{-1}

Prefixes:

p	n	m	m	c	d	k	M	G
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}

General Data

speed of light	**c**	**2.997 925x10^{8} ms^{-1}**
charge of proton	*e*	1.602 19x10^{-19} C
Faraday constant	F=L*e*	9.648 46x10^{4} C mol^{-1}
Boltzmann constant	**k**	**1.380 66x10^{-23} J K^{-1}**
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$H_2SO_4(l)$)	98.078	-814.0	HI(g)	127.912	+26.5
$H_2SO_4(aq)$	98.078	-909.3	$CO_2(g)$	44.010	-393.5
NaCl(s)	58.443	-411.0	CO(g)	28.011	-110.5
NaOH(s)	39.997	-426.7	$Al_2O_3(\alpha,s)$	101.945	-1675.7
KCl(s)	74.555	-435.9	SiO2(s)	60.085	-910.9
KBr(s)	119.011	-392.2	FeS(s)	87.91	-100.0
KI(s)	166.006	-327.6	$FeS_2(s)$	119.975	-178.2
DIATOMICS	**Eg. N_2, O_2, H_2**	**0**	AgCl(s)	143.323	-127.1

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

	a/J $K^{-1}mol^{-1}$	b/10^{-3}J $K^{-2}mol^{-1}$	c/10^5J $Kmol^{-1}$
Gases (298-2000K)			
He, Ne, Ar, Kr, Xe	20.78	0	0
H_2	27.28	3.26	0.50
O_2	29.96	4.18	-1.67
N_2	28.58	3.77	-0.50
Cl_2	37.03	0.67	-2.85
CO_2	44.23	8.79	-8.62
H_2O	30.54	10.29	0
NH_3	29.75	25.10	-1.55
CH_4	23.64	47.86	-1.92
C(S)	16.86	4.77	-8.54

Enthalpies of fusion and evaporation ΔH_m/KJ/mol at the transition temperature

	T_f/K	Fusion[a]	T_b/K	Evaporation[b]	
He	3.5	0.021	4.22	0 084	
Ar	83.81	1.188	87.29	6.506	
H_2	13.96	0.117	20.38	0.9163	
N_2	63.15	0.719	77.35	5.586	
O_2	54.36	0.444	90.18	6.820	
Cl_2	172.12	6.406	239.05	20.410	
Br_2	265.90	10.573	332.35	29.45	
I_2	386.75	15.52	458.39	41.80	
Hg	234.29	2.292	629.73	59.296	
Ag	1234	11.30	2436	250.63	
Na	370.95	2.601	1156	98.01	
CO_2	217.0	8.33	194.64	25.23⊥	
H_2O	273.15	6.008	373.15	40.656	(44.016 at 298.15 K)
NH_3	195.40	5.652	239.73	23.351	
H_2S	187.61	2.377	212.80	18.673	
CH_4	90.68	0.941	111.66	8.18	
C_2H_6	89.85	2.86	184.55	14.7	
C_6H_6	278.65	10.59	353.25	30.8	
CH_3OH	175.25	3.159	337.22	35.27	(37.99 at 298.15K)

Standard molar enthalpies of formation and combustion at 298.15 K.

	M_r	ΔH_f^θ/KJ/mol	ΔH_c^θ/KJ/mol
$CH_4(g)$	16.043	-74.81	
$C_2H_2(g)$	26.038	+226.8	-1300
$C_2H_4(g)$	28.054	+52.30	-1411
$C_2H_6(g)$	30.070	-84.64	-1560
C_3H_6 cyclopropane(g)	42.081	53.35	-2091
C_3H_6 (propene(g)	42.081	20.5	-2058
C_4H_{10} n-butane (g)	58.124	-126.11	-2877
C_5H_{12} n-pentane(g)	72.151	-146.4	-3536
C_6H_{12} cyclohexane (l)	84.163	-156.2	-3920
C_6H_{14} n-hexane (l)	86.178	-198.7	-4163
C_6H_6 benzene (l)	78.115	+48.99	-3268
C_8H_{18} n-octane (l)	114.233	-249.8	-5471
$C_{10}H_8$ naphthalene (l)	128.175	+78.53	-5157
CH_3OH (l)	32.042	-239.0	-726.1
CH_3CHO (g)	44.054	-166.0	-1193
CH_3CH_2OH (l)	46.070	-277.0	-1368
CH_3COOH (l)	60.053	-484.2	-874.5
$CH_3COOC_2H_5$ (l)	88.107	-486.6	-2231
C_6H_5OH (s)	94.114	-165.0	-3054
$C_6H_5NH_2$ (l)	93.129	-31.1	-3393
$NH_2CO.NH_2$ urea(s)	60.056	-333.0	-632.2
$CH_2(NH_2)CO_2H$, glycine (s)	75.068	-537.2	-964.4
$C_6H_{12}O_6$, α-D-glucose (s)	180.159	-1274	-2802
$C_6H_{22}O_6$, β-D-glucose (s)	180.159	-1268	-2808
$C_{12}H_{22}O_{11}$, sucrose (s)	342.303	-2222	-5645
$CH_3CH(OH)COOH$ lactic acid (s)	90.079	-694.0	-1344

⊥ Sublimation: [a]various pressures: [b]at 1atm

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

Heat capacities at 25°C

	$C_{v,m}$ / $JK^{-1}\ mol^{-1}$	$C_{p,m}$ / $JK^{-1}\ mol^{-1}$
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_2O_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
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, Sm^{θ}/J K^{-1} 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_2O	70.0		
I_2	116.7			CO_2	213.7
S(Rh)	31.9	HNO_3	155.6	HCl	186.8
				H_2S	205.6
AgCl	96.2	C_2H_5OH	161.0	NH_3	192.5
AgBr	104.6	CH_3OH	126.7	CH_4	186.1
$CuSO_45H_2O$	305.4	C_6H_6	49.03	C_2H_6	229.4
$HgCl_2$	144	CH_3COOH	159.8	CH_3CHO	265.7
Sucrose	360.2	C_6H_{12}	298.2		

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

	M_r	ΔG_f^θ/KJ/mol	S^θ/J K^{-1} mol^{-1}		M_r	ΔG_f^θ/KJ/mol	S^θ/J K^{-1} mol^{-1}
$H_2O(g)$	18.015	-228.57	188.83	$O_3(g)$	47.998	163.2	238.93
$H_2O(l)$	18.015	-120.35	109.6	NO(g)	30.006	86.55	210.76
$H_2O_2(l)$	34.015	-120.35	109.6	$NO_2(g)$	46.006	51.31	240.06
$NH_3(g)$	17.031	-16.45	192.45	$N_2O_4(g)$	92.012	97.89	304.29
$N_2H_4(l)$	32.045	149.43	121.21	$SO_2(g)$	64.063	-300.19	248.22
$N_3H(l)$	43.028	327.3	140.6	$H_2S(g)$	34.080	-33.56	205.79
$N_3H(g)$	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
$NH_2OH(s)$	33.030			HCl(g)	36.461	-95.30	186.91
$NH_4Cl(s)$	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
$H_2SO_4(l)$)	98.078	-690.00	156.90	HI(g)	127.912	1.70	206.59
$H_2SO_4(aq)$	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_2O_3(□,s)	101.945	-1582.3	50.92
KCl(s)	74.555	-409.14	82.59	SiO2	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	ΔG_f^θ/KJ/mol	S^θ/J K^{-1} mol^{-1}
organic compounds			
$CH_4(g)$ methane	16.043	-50.72	186.26
$C_2H_2(g)$ ethyne	26.038	209.20	200.94
$C_2H_4(g)$ ethene	28.05	68.15	219.56
$C_2H_6(g)$ ethane	30.070	-32.82	229.60
C_3H_6 cyclopropane(g)	42.081	104.45	237.55
C_3H_6 propene(g)	42.081	62.78	267.05
C_4H_{10} n-butane (g)	58.124	-17.03	310.23
C_5H_{12} n-pentane(g)	72.151	-8.20	348.40
C_6H_{12} cyclohexane (l)	84.163	26.8	
C_6H_{14} n-hexane (l)	86.178		204.3
C_6H_6 benzene (l)	78.115	124.3	173.3
C_6H_6 benzene (g)	78.115	129.72	269.31
C_8H_{18} n-octane (l)	114.233	6.4	361.1
$C_{10}H_8$ naphthalene (l)	128.175		
CH_3OH (g)	32.042	-161.96	239.81
CH_3OH (l)	32.042	-166.27	126.8
CH_3CHO (g)	44.054	-128.86	250.3
CH_3CH_2OH (l)	46.07	-174.78	160.7
CH_3COOH (l)	60.053	-389.9	159.8
$CH_3COOC_2H_5$ (l)	88.107	-332.7	259.4
C_6H_5OH (s)	94.114	-50.9	146.0
$C_6H_5NH_2$ (l)	93.129		
$CH_2(NH_2)CO_2H$, glycine (s)	75.068	-373.4	103.5
$C_6H_{12}O_6$, α-D-glucose (s)	180.159		
$C_6H_{22}O_6$, β-D-glucose (s)	180.159	-910	212
$C_{12}H_{22}O_{11}$, sucrose (s)	342.303	-1543	360.2
$CH_3CH(OH)COOH$	90.079		
lactic acid (s)			

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