UNIVERSITY OF SWAZILAND

FINAL EXAMINATION 2005

TITLE OF PAPER:

INTRODUCTORY INORGANIC CHEMISTR

COURSE NUMBER:

C201

TIME:

THREE (3) HOURS

INSTRUCTIONS:

There are six (6) questions each worth 25 marks.

Answer any four (4) questions.

A data sheet and periodic table are attached. Non-programmable calculators may be used.

DO NOT OPEN THIS PAPER UNTIL PERMISSION TO DO SO HAS BEEN GRANTED BY THE CHIEF INVIGILATOR.

(a) On the same diagram, sketch the radial distribution for the 1s, 2s and 2p orbitals. Mention two differences between the 2s and 2p orbitals.

[5]

- (b) Explain the following terms, giving examples where possible to clarify your answers.
 - (i) Lattice Energy
 - (ii) Three centre-two electron bond
 - (iii) Inert pair effect
 - (iv) Diagonal relationship

[8]

(c) The Li²⁺ ion is a one electron system similar to hydrogen. Calculate the frequency of the radiation involved if the electron undergoes a transition from n=3 to n=1 energy levels. Is the radiation absorbed or emitted?

[3]

- (d) (i) Write the electronic configuration of the Cr atom.
 - (ii) Using Slater's rules, calculate the effective nuclear charges on an electron in the 4s and the 3s orbital of the Cr atom.
 - (iii) From which orbital would an electron be removed to form the Cr⁺ ion? [1,3,2]
- (e) Explain why the 1st I.E. of Mg is higher than that of Na, but the 2nd I.E. of Na is higher than that of Mg.

 [3]

(a)	(i)	Draw a clear well labelled molecular orbital diagram of the CN molecule	e. [4]
	(ii)	How does this molecule differ from the CN molecule in bond leng bond strength and magnetic properties.	th
		· · · ·	[4]
(b)	Cons	ider the following molecules	
		XeF_4 , ClF_3 and IF_4^+	
	(i)	Determine the hybridization of the central atom.	
	(ii)	Draw the Lewis structure and predict the shape.	[6]
(c)	Acco	unt for the following observations	
	(i)	SF ₆ is known but OF ₆ does not exist	
	(ii)	CCl ₄ is completely inert towards water whereas SiCl ₄ is immediate hydrolysed on contact with water.	ely
	(iii)	Boron halides are Lewis acids only, but trivalent phosphorus compouncan serve as both Lewis acids and Lewis bases.	
		[[6]
(d)	Expla	in, with examples, the following terms	
	(i) (ii)	n-type semi-conductor hydrogen bonding	
	(11)	, ,	[5]

- (a) The distance between the centres of the positive and negative ions in NaF is 321 pm. Determine:
 - (i) The ionic radii of Na⁺ and F
 - (ii) The coordination number and shape of the NaF crystal lattice.

[5]

- (b) The crystal lattice is usually far from being perfect and different defects may be found in a crystal. Discuss the following defects and state how they help in improving the conductivity of the ionic solid.
 - (i) Metal excess
 - (ii) Frenkel defects
 - (iii) Schottky defects

[9]

(c) Explain the meaning and differences between a metallic conductor, a semiconductor and an insulator

[6]

(d) Arrange the following compounds in order of increase in lattice energy

Mg (OH)₂, MgO, Al₂O₃, NaOH and Al(OH)₃

Justify your order.

[5]

Ouestion 4

(a) (i) Give the names and symbols $\binom{A}{z}X$ of the three isotopes of hydrogen.

 $[1\frac{1}{2}]$

(ii) Describe one method for the industrial production of hydrogen.

[3]

(iii) Mention one use of hydrogen gas.

 $[2\frac{1}{2}]$

(iv) Discuss the similarities and differences between the bonding in B_2H_6 and B_2Cl_6 .

[4]

- (b) When a white substance (A), was treated with dilute HCl(aq) a colourless gas, B, was evolved which turned moist litmus paper red. On bubbling the gas B through lime water, a white precipitate was formed which dissolved to give a clear solution D. On strong heating, A decomposed to give a white precipitate E which turned litmus paper blue. When 1.9735 g of A was heated, it gave 1.5334 g of E. A 25.00 mL portion of the resulting solution required 20.30 mL of a 0.0985 M HCl (aq) for titration to the end point.
 - (i) Identify, with explanations, the compound A to E by name and chemical formulae.
 - (ii) Write balanced equations for all the reactions mentioned.
 - (iii) From the titration data, calculate the molar mass of A.

[14]

(a)	Define the following terms													
	(i)	Isotope												
	(ii)	β decay												
	(iii)	Nuclear fusion.	[6]											
(b)	Write respec	equation showing how $^{238}_{92}U$ and $^{13}_{7}N$ under α decay and β^+ tively.	emission [4]											
(c)	Explai	n or account for the following:												
	(i) The variation in boiling points of the Group VI hydrides whose value, -60, -42 and -2.3 °C for H ₂ O, H ₂ S, H ₂ Se and H ₂ Te respective													
	(ii)	The difference in bond angles of H ₂ O (105°) and F ₂ O(102°)	[5]											
(d)	In each of the following pairs, which is the larger radius													
	(i)	S ² -, Br ⁻												
	(ii)	Fe ²⁺ , Co ³⁺	[4]											

(a)		ewis structures to show the arrangement of valence electrons in borist conjugate base. Write an equation to show how boric acid ionises	
(b)	(i)	Suggest the reasons why Be ²⁺ ion is less than half the size of Mg ²	+ .
	(ii)	Why does Be have the same properties as Al?	
	(iii)	What do you understand by the term hydrolyse?	
	(iv)	Explain why Be salts (e.g. the chloride) readily hydrolyse wherea strontium salts do not.	s
(v)		BeH ₂ and AlCl ₃ are both polymers. Explain why the two compour polymerise and describe the bonding in both.	nds [10]
(c)	Write	balanced equations to show how water reacts with	
	(i)	sodium	
	(ii)	sodium oxide	
	(iii)	sodium hydride	[6]

(d) The hardness of water may be 'temporary' or 'permanent'. What causes each of these conditions and how is each treated?

[5]

PERIODIC TABLE OF ELEMENTS

				<u>*</u>			7			ۍ			יע	·	4			ယ			2			•	PERIODS		
	3 .: <u></u>	**Actinide Series		*Lanthanide Series		. 87	Er	223	55	င္တ	132.91	37	ਸੂ ਹ	85.468	19 7	39.098	11	N ₂	22.990	ų.	Σ.	6.941	- <u> </u>	1.008	IA	1	
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General data and fundamental constants

Quantity	Symbol	Value
Speed of light	С	2.997 924 58 X 10 ⁸ m s ⁻¹ ;
Elementary charge	е	1.602 177 X 10 ⁻¹⁹ C
Faraday constant	$F = N_A e$	9.6485 X 10 ⁴ C mol ⁻¹
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		8.205 78 X 10 ⁻² dm³ atm K ⁻¹ mol ⁻¹
		6.2364 X 10 L Torr K ⁻¹ mol ⁻¹
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	$\hbar = h/2\pi$	$1.054\ 57\ X\ 10^{-34}\ J\ s$
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Mass		·
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neutron	m,	1.674 93 X 10 ⁻²⁷ Kg
Vacuum permittivity	$\varepsilon_{\rm o} = 1/c^2 \mu_{\rm o}$	8.854 19 X 10 ⁻¹² J ⁻¹ C ² m ⁻¹
	4πε,	1.112 65 X 10 ⁻¹⁰ J ⁻¹ C ² m ⁻¹
Vacuum permeability	μ_{o}	$4\pi \times 10^{-7} \text{ J s}^2 \text{ C}^{-2} \text{ m}^{-1}$
		$4\pi \times 10^{-7} \text{ T}^2 \text{ J}^{-1} \text{ m}^3$
Magneton		
Bohr	$\mu_{\rm B} = e\hbar/2m_{\rm e}$	9.274 02 X 10 ⁻²⁴ J T ⁻¹
nuclear	$\mu_N = e\hbar/2m_p$	5.050 79 X 10 ⁻²⁷ J T ⁻¹
g value	8e	2.002 32
Bohr radius	$a_o = 4\pi \varepsilon_o \hbar/m_e e^2$	5.291 77 X 10 ⁻¹¹ m
Fine-structure constant	$\alpha = \mu_o e^2 c/2h$	7.297 35 X 10 ⁻³
Rydberg constant	$R_{\infty} = m_e e^4/8h^3c\epsilon_o^2$	1.097 37 X 10 ⁷ m ⁻¹
Standard acceleration		
of free fall	g	9.806 65 m s ⁻²
Gravitational constant	G	6.672 59 X 10 ⁻¹¹ N m ² Kg ⁻²

Conversion factors

1 cal = 1 eV =	4.184 joules 1.602 2 X 10		1 erg 1 eV/r	nolecul	le	= .		l X 10 ^{.7} J 96 485 kJ mol ⁻¹				
Prefixes	f p femto pico 10 ⁻¹⁵ 10 ⁻¹²	nano	μ micro 10 ⁻⁶	milli	centi	deci	k kilo 10³	M mega 10°	G giga 10°			

UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION 2005

TITLE OF PAPER:

INTRODUCTORY INORGANIC CHEMISTR

COURSE NUMBER:

C201

TIME:

THREE (3) HOURS

INSTRUCTIONS:

There are six (6) questions each worth 25 marks.

Answer any four (4) questions.

A data sheet and periodic table are attached. Non-programmable calculators may be used.

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a)	Various quantum numbers are needed to describe the state of an electron in an atom.											
	i.	what are the q	uantum numbe	rs?	(1 mark)							
	ii.	what propertie	es of the electro	ons or atomic orbitals are determined or desc	ribed by							
		these quantum	numbers?		(4 marks)							
	iii. give all the quantum numbers of each of the valence electrons in chlorine. 3 n											
b)	Usi	ing the data bel	low, predict the	crystal structure of MgS.								
			ion	ionic radius (pm)								
			Mg	86								
			S	170	(2 marks)							

c) Describe the type of defects that can occur in the solid state. In each case give at least one example and indicate if any electrical conduction is possible and by what mechanism.

(15 marks)

- a) What postulates did Bohr advance in explaining how electrons are confined to orbitals instead of slowing down or being attracted towards the nucleus? (5 marks)
- b) The transition from the n = 7 to the n = 2 level of hydrogen atom is accompanied by the emission of light slightly beyond the range of human perception. Determine the energy and the wavelength of this light.

 (5 marks)
- c) Draw a clear well-labelled molecular orbital diagram of O₂. Using the diagram, deduce:
 - i. the bond orders of O_2 , O_2 , O_2^2 and O_2^+
 - ii. for each of the above species discuss the magnetic properties. (10 marks)
- d) Arrange the following compounds in order of increase in lattice energy:

Mg(OH)₂, MgO, Al₂O₃, Na₂O, NaOH, Al(OH)₃

Justify your order.

(5 marks)

a)	US	se Stater's rules	to calculate in	e enective nuc	iear cha	rge experienced b	У
	i.	the valence	ce electron in 1	the atom N			
	ü.	the valence	ce 4s electron i	n the atom Zn			
	iii.	a 3d elect	ron in Zn			(2 each = 6 marks)
b)	i.	Define the ter	ms 'ionization	energy' and 'ele	ectroneg	ativity'	(1 mark)
	Ac	count for the f	ollowing obser	vations:			
	ii.	variation in el	lectronegativity	7			
		F	Cl	Br	I		
		4.10	2.83	2.74	2.21		(3 marks)
	iii.	variation in fi	rst ionization e	energies of Gro	up II me	tal (kJ mol ⁻¹)	
		Ве	Mg	Ca	Sr		
		899	737	590	549		(3 marks)
c)	De	fine the follow	ing terms:				
	i.	α-decay					
	ii.	γ-radiation					
	iii.	nuclear fission	n				(6 marks)
d)	If ?	X, Y and Z rep	resent element	s of atomic nur	mber 9,	17 and 55 respec	tively, predict
	the	type of bondir	ng you would e	expect to occur	between	1	
	i.	X and Y	ii.	X and Z		iii. Y and Z	(6 marks)

- a) Account for the following observations:
 - i. There is no reaction between NCl₃ and Cl₂ whereas PCl₃ reacts with Cl₂ to give PCl₅.
 - Ionic compounds usually react rapidly whilst covalent compounds usually react slowly.
 - iii. Methanol CH₃OH has a much higher boiling point than methyl mercaptan,
 CH₃SH. (6 marks)
- b) Write equations for each of the following reactions:
 - i. Hydrolysis of diborane
 - ii. Hydrolysis of SiCl₄
 - iii. Reduction of BF3 with NaH

(6 marks)

- c) The hardness of water may be 'temporary' or 'permanent'. What causes each of these conditions and how is each treated? (8 marks)
- d) On treatment with cold water, an element (A) reacted quickly liberating a colourless odourless gas (B) and a solution (C). When carbon dioxide was bubbled through solution (C) an initial white precipitate (D) was formed, but this re-dissolved forming solution (E) when more carbon dioxide was added. Name the substances (A) to (E).

(5 marks)

(a)	Write the formula of the most common oxide for each of the following													
	i. Na	ì	ii. Al	iii. S										
	Class	sify each of the or	xides as basic, acidic	or amphoteric.										
	iv. F wate		cidic oxides write ba	lanced equations for their	reaction with									
					[8 marks]									
L	: 17-			C										
b)		e the band theor semiconductors.	ry to explain the dir	ference between conducto	rs, insulators [3 marks]									
	ii. St	ate whether the fo	ollowing material is a	nn n-type or a p-type semic	onductor									
		Si doped with	As, Ge dopped with	In	[2 marks]									
c)	Whic	h of the followin	g pairs will have a la	rger bond angle? Explain.										
	i.	CH ₄ , NH ₃												
	ii.	NF ₃ , NH ₃												
					[4 marks]									
d)	i,	Why is diborar	ne called an electron	deficient compound?	[2 marks]									
	iii.	Describe the di	ifference in the struct	tures of (BeH ₂) _n and (BeCl	2)n [6 marks]									

OUESTION 6

- a) Orthoboric acid may be written as H₃BO₃ or B(OH)₃. Is it a strong or a weak acid? How does it ionize in water?

 [1, 2 marks]
- b) Draw a simple well-labeled molecular orbital diagram of CO (carbon monoxide).
 - i. determine the bond order of CO.
 - ii. is it paramagnetic or diamagnetic?
 - iii. how would you prepare CO in the laboratory?
 - iv. give two uses of CO
 - v. explain how CO is quantitatively determined

[3, 1, 1, 2, 2, 2 marks]

- c) Boron halides are Lewis acids only but trivalent phosphorus compounds can serve as both Lewis acids and Lewis bases. Explain this observation. [6 marks]
- d) Explain what is meant by 'inert pair effect'.

[3 marks]

e) The ionization energy of Pb is unexpectedly higher than that of Sn. Why? [2 marks]

PERIODIC TABLE OF ELEMENTS

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	(260) Lr 103	2	174.97 Lu 71	,			85	9.4 1.4	(210)	3	3 -	120.30	מס אבו	Br	79.904	17	Ω	35.453	9	ኳ	18.998				VIIA	17		
se.	_			·			00	kn :	(222)	24	3 &	131.29	31.00	۲ ۲	83.80	18	Ar	39.948	10	Z C	20.180	2	He	4.003	VIIIA	18		

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of free fall	g	9.806 65 m s ⁻²
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		•

Conversion factors

1 cal = 1 eV =	4.184 joules (J)	1 erg	= .	1 X 10 ⁻⁷ J					
	1.602 2 X 10 ⁻¹⁹ J	1 eV/molecule	=	96 485 kJ mol ⁻¹					
Prefixes	femto pico n	μ m o ano micro milli o 0-9 10-6 10-3	centi deci		a				

UNIVERSITY OF SWAZILAND BACHELOR OF SCIENCE

EXAMINATION 2005

TITLE OF PAPER

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) Define the variable, compressibility factor, z. With the aid of Lennard-Jones potential plot and compressibility plots, compare and contrast real and ideal gases.

Your account should make mention of interactions, equations and any necessary theories to help clarify your discussion. [10]

- b) A mixture of butane (C₄H₁₀) and propene (C₃H₆) occupied 35.5 L at 1.000 bar and 405 K. This mixture reacted completely with 220.6 g of O₂ to produce CO₂ and H₂O.
 - i) What was the composition of the original mixture? Assume ideal gas behaviour. MW $(O_2)=32$ g/mol [9]
 - ii) Calculate the partial pressure, mole fraction of each gas and the total pressure of the final mixture. [6]

Question 2 [25 Marks]

- a) Write short notes on any One of the following: [10]
 - i) Virial equation
 - ii) van der waal's equation

Use diagrams, equations or plots to clarify your notes where necessary.

b) A real gas equation of state for a gas is given by:

$$P = RT(V_m - 3b)^{-1} - (2a/T)V_m^{-2}$$
 (1)

- (i) Derive an expression for V_{m,c}, Tc 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: a=1.748 L²atm mol⁻²K and b= 0.0345 L mol⁻¹. [2]
- (iv) Estimate the radii of real gas molecules using equation (1) given that the critical molar volume is 250 cm³ mol⁻¹ [3]

Question 3 [25 MARKS]

- a) Using examples and/or diagrams compare and contrast <u>Any Two</u> of the following terms
 - i) reversible and irreversible expansion [5]
 - ii) path and state functions [5]
 - iii) work and heat [5]
 - iv) change in internal energy and change in enthalpy [5]
- b) 2 moles of methane occupies 12 L at 310 K.
 - i) Derive an expression for reversible isothermal expansion. [5]
 - ii) Calculate the work done when the gas expands isothermally against a constant external pressure of 200 torr until its volume has tripled. [5]
 - iii) Calculate the work that would be done if the same expansion in b(ii) occurred in a series of equilibrium steps. [5]

Question 4 [25 Marks]

ii)

- a) Write short notes on Any Two of the following concepts:
 - Statistical view of entropy i)
 - [5] Clausius inequality [5]
 - Second law of thermodynamics iii) [5]
 - iv) Third 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) (i) Using an illustration of your choice define fugacity [5]
 - (ii) Using the following chemical potential expression for ideal and real gases

$$\mu_2 = \mu_1^\theta + RT \ln\!\!\left(\frac{p_2}{p_1^\theta}\right) \text{ and } \mu_2 = \mu_1^\theta + RT \ln\!\!\left(\frac{f_2}{f_1^\theta}\right), \text{ respectively}.$$

Derive the fugacity expression

$$f = p \exp \int_{p_1}^{p_2} \left\{ \frac{Z(p, T) - 1}{p} \right\} dp$$
 [5]

(iii) Given that fugacity is given by the expression: [5]

$$f = p \exp \int_{n}^{p_f} \left\{ \frac{Z(p,T) - 1}{p} \right\} dp$$

Evaluate fugacity of O₂ at 200 K given that the compression factor of O₂ is 0.98796 at 4.00000 atm.

Question 5 [25 Marks]

- Calculate the enthalpy of formation of N₂O₅(g) from the following data: [9] a) (i) $2NO(g) + O_2(g) \rightarrow 2NO_2(g) \qquad \Delta H^{\theta} = -114.1 \, kJmol^{-1}$ $4NO_2(g) + O_2(g) \rightarrow 2N_2O_5(g)$ $\Delta H^{\theta} = -110.2 \text{ kJmol}^{-1}$ $N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H^{\theta} = +180.5 \text{ kJmol}^{-1}$
 - (ii) Using the enthalpy of formation of N₂O₅(g) obtained from a(i) calculate the change in internal energy for the formation of N₂O₅(g) [6]
- b) (i) Derive Kirrchoff's equation: [4]

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

(ii) Predict the standard enthalpy of reaction at 100°C for the reaction: [6]

$$2NO_2(g) \rightarrow N_2O_4(g)$$

Refer to table and the data below:

	C _p J mol ⁻¹ K ⁻¹
$N_2O_4(g)$	77.28
$NO_2(g)$	37.20

Question 6 [25 Marks]

- Calculate the change in entropies of the system, ΔS_{sys} , the surroundings, a) ΔS_{surr} and the total change in entropy, ΔS_{tot} , when a sample of nitrogen gas of mass 14 g at 298 K and 1.00 bar doubles its volume in:
 - an isothermal reversible expansion [6]
 - an irreversible isothermal expansion against an external pressure of 0.5 bar. ii)
- What would the change in entropy be if the gas in (a) was compressed to half its b) volume and simultaneously heated to twice its initial temperature? [5]
- c) If 50g water at 80°C is poured into 100g water at 10°C in an insulated vessel given that $C_{p,m}$ =75.5 JK⁻¹mol⁻¹: Calculate: i) final temperature of the mixture [4]

 - the entropy change [6] ii)

THE PERIODIC TABLE OF ELEMENTS

	7			6			S				4			ω			2	,		-	Period		Group
223	Fr	87	132.9	\mathbb{C}^{s}	55	85.47	Rb	37		39.10	K	19	22.99	Za	11	6.94	Li	3	1.008	H	-	IA	-
226.0	Ra	88	137.3	Ba	56	87.62	Sr	38		40.08	Ca	20	24.31	Mg	12	9.01	Be	4				IIA	2
257	Lr	103	174.9	Lu	71	88.91	¥	39	44.96	Sc)	21										IIIB	သ
	Unq	104	178.5	Hf	72	91.22	Zr	40		47.90	Ti	22										IVB	4
	Unp	105	180.9	Ta	73	91.22	Zb	41		50.94	<	23										۷В	5
	Unh	106	183.8	¥	74	95.94	Mo	42		52.01	ဂ ဂ	24		1	, ≤							VIB	6
	Uns	107	186.2	Re	75	98.9	Tc	43		54.9	Mn	25			METALS							VIIB	7
	Uno	108	190.2	S S	76	101.1	Ru	44		55.85	Fe	26								2	z		8
	Une	109	192.2	Ir	77	102.9	Rh	45		58.71	Co	27					METALLOIDS			(N-181	NONLMETALS	VIIIB	9
			195.1	Pt	78	106.4	Pd	46		58.71	Z	28					LOIDS			5	N ≥		10
			196.9	Au	79	107.9	Ag	47		63.54	Cu	29					†			1		ΙΒ	=
			200.6	Hg	80	112.4	Cd	48		65.37	Zn	30										пв	12
			204.4	TI	81	114.8	In	49		69.7	Ga	31	26.9	Al	13	10.81	В	5				IIIA	13
			207.2	Pb	82	118.7	Sn	50		72.59	Ge	32	28.09	S	14	12.01	C	ø.				IVA	14
			208.9	Bi	83	121.8	Sb	51		74.92	As	33	30.97	P	15	14 01	Z	7				VA	15
			210	$\mathbf{P_0}$	84	127.6	Te	52		78.96	Š	34	32.06	Ø	16	16.00	0	8				VIA	16
			210	At	85	126,9	1	53		7991	Br	35	35.45	Ω	17	19 00	F	9				VIIA	17
			222	Ra	88	131.3	Xe	54		83.80	Ŗ	36	36 68	ÀF	81	20.18	Z	-01	4 003	Ŧ	N	VIIIA	18

+							atomic m	and of a	mhal indi	and ohe	mhane at	and the m	. 3633EEE.	the atomi	Numbers helow the sumbol indicates the atomic masses; and the numbers about the sampel indicates the atomic numbers
4	255	258.1	257.1	254.1	251.1	249.1	247.1	241.1	239.1	237.1	238.0	231.0	232.0	227.0	
	No	Md	Fm	Es	Cf	Bk	Cm	Am	Ac Th Pa U Np Pu Am Cm	Q N	u	Pa	Th	Ac	Actinides
	102	101	100	66	98	97	96	95	94	93	92	91	90	89	
	173.0	168.9	167.3	164.9	162.5	158.9	157.3	151.3	140.9 144.2 146.9 150.9 151.3 157.3	146.9	144.2	140.9	138.9 140.1	138.9	
	Yb	Tm	Er	Но	Dy	Tb	Gd	Eu	Sm	Pm	Nd	Pr	င့	La	Lanthanides
ليود	70	69	68	67	66	65	64	63	62	61 62	60	59	58	57	

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

			lactic acid (s)						
5+	-694.0	90.079	СН3СН(ОН)СООН						
	-222	342.303	C ₁₂ H ₂₂ O ₁₁ , sucrose (s)	(37.55 at 250.13N)	33.27	331.22	3, 139	173.23	CHION
2645	222	343 303	Cenzzoe, p-D-glocose (s)	737 00 ct 200 teV	36.77	רר לבב	3 450	475.75	2
-2808	-1268	180 159	Cellande B. D. dhippes (s)		30.8	353.25	10.59	278.65	ž.
-2802	-1274	180, 159	C6H12O6, α-D-glucase (s)		14.7	184.55	2.86	89.85	C2H4
-964,4	-537.2	75.068	CH ₂ (NH ₂)CO ₂ H, glycine (s)		8.18	111.66	0.941	90.68	유
-632.2	-333.0	60.056	NH ₂ CO.NH, urea(s)		18.673	212.80	2.377	187.61	H ₂ S
-3393	-31.1	93.129	C6H5NH2 (I)		23,351	239.73	5.652	195.40	NH3
-3054	-165.0	94 114	C ₆ H ₅ OH (s)	(44.016 at 298.15 K)	40.656	373.15	6,008	273.15	F
-2231	-486.6	88.107	CH ₃ COOC ₂ H ₅ (I)		25.23-1	194.64	8.33	217.0	S ₂
-874.5	-484.2	60.053	снасоон (I)	-	98.01	1156	2.601	370.95	Na
-1368	-277.0	46.070	CH3CH2OH (I)		250.63	2436	11.30	1234	Ą
-1193	-166.0	44.054	СН3СНО (g)		59.296	629.73	2.292	234.29	퓬
-726.1	-239.0	32.042	CH3OH (I)		41.80	458.39	15.52	386.75	2
-5157	+78.53	128.175	C ₁₀ H ₈ naphthalene (I)		29.45	332.35	10.573	265.90	Br ₂
-5471	-249.8	114.233	C ₈ H ₁ 8 n-octane (I)		20.410	239.05	6.406	172.12	Cl ₂
-3268	+48.99	78.115	C ₆ H ₆ benzene (I)		6.820	90.18	0.444	54.36	02
-4163	-198.7	86.178	C ₆ H ₁₄ n-hexane (I)		5.586	77.35	0.719	63.15	N ₂
-3920	-156.2	84 163	C ₆ H ₁₂ cyclohexane (I)		0.9163	20.38	0.117	13.96	Н2
-3536	-146.4	72.151	C ₅ H ₁₂ n-pentane(g)		6,506	87.29	1.188	83.61	Ąr
-2877	-126.11	58,124	C4H10 n-butane (g)		0 084	4.22	0.021	3.5	퓬
-2058	20.5	42.081	C ₃ H ₆ (propene(g)						
-2091	53.35	42.081	C ₃ H ₆ cyclopropane(g)		Evaporation	γγ 4 ⊥	Fusion	T _P /K	
-1560	-84.64	30.070	C ₂ H ₆ (g)				desmod		
-1411	+52.30	28.054	C ₂ H ₄ (g)		rature	AH,,/KJ/mol at the transition temperature	∆H _m /KJ/mol at ti	Enthalpies of fusion and evaporation	Enthalpies of f
-1300	+226.8	26.038	C ₂ H ₂ (g)						
	-74,81	16.043	CH4(g)	-127.1	143.323	AgCI(s)	0	Eg. N ₂ , O _{2,} H ₂	DIATOMICS
ΔH _c ⁶ /KJ/mol	ΔH _f ⁹ /KJ/mol	Mr		-178.2	119.975	FeS ₂ (s)	-327.6	166.006	KI(s)
				-100.0	87.91	FeS(s)	-392.2	119.011	KBr(s)
	on at 298.15 K	halpies of formation and combustion at 298.15 K.	Standard molar enthalpies of fo	-910.9	60.085	SiO2(s)	-435.9	74,555	KCI(s)
				-1675.7	101.945	Al ₂ O ₃ (a, s)	-426.7	39.997	NaOH(s)
				-110.5	28.011	CO(g)	-411.0	58.443	NaCl(s)
				-393.5	44 010	(C)-(n)		98.078	H-SO (ac)
6,04	4.11	10.00	S S	136.4 136.4	127 012	CIVEN CIVEN		08.078	H SO (I)
- R.54	477	15.PS	C/S)	7.791-	30.401	HC((aq)	-514.4	274 50	NH4CI(8)
38	25.10 47.86	79.75	NH3	-92.3	36.461	HCl(g)	-114.2	33,030	NH ₂ OH(s)
0	10.29	30.54	H ₂ O	-271.1	20.006	HF(g)	-174.1	63.013	HNO ₃ (I)
-8.62	8.79	44.23	CO ₃	-1209	146.054	SF _s (g)	+294.1	43.028	N ₃ H(g)
-2.85	0.67	37.03	Cl ₂	-20.6	34.080	H ₂ S(g)	+264.1	43,028	N ₃ H(I)
-0.50	3.77	28.58	N ₂	-296.8	64.063	SO ₂ (g)		32.045	N ₂ H ₄ (I)
-1.67	4.18	29.96	O ₂	+9.2	92.012	N-O ₂ (a)		17.031	NH ₃ (g)
0.50	3.26	27.28	H ₂	+33.2	46.006	NO S	187 8	34.015	H ₂ O ₂ (i)
0	0	20 78	Gases (298-2000K)	+142.7	47.998	0,(a)	-241.8	18.015	H ₂ O(g)
c/10 ² J Kmof ⁻¹	b/10 ⁻³ J K ⁻² mol ⁻¹	a/J K 1mof 1		AH, /KJ/moi			ΔΗ _ξ ^γ /KJ/mol		
n	,				Z.		A	×	

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

C12(g) Br2(g) Br2(l)	Cl2(g) Br2(g	Cl2(g)	(3\g)	22	O2(g)	N2(g)	H2(g)	Ar(g)	Hc(g)			KI(s)	KBr(s)	KCl(s)	NaOH	NaCl(H2SO	H2S0	7LPG11	NH4C	NH20	HNO3	N3H(N3H(1	N2H4	3)EHN	H2O2	H2O(1	H2O(8	
													_	,	(s)	(i	4(aq)	٥	(9)	I(s)	H(s)	9			(1)	ນ [<u>)</u>)	ت 	
159.82		159.82	70.91	47.998	31.999	28.013	2.016	39.95	4.003			166.006	119.011	74.555	39.997	58.443	98.078	98.078	271.50	53.492	33.030	63.013	43.028	43.028	32.045	17.031	34.015	18.015	18.015	М
	0	3.110	0	163.2	0	0	0	0	0			-324.89	-380.66	409.14	-379.49	-384.14	-744.53	-690.00	-178.6	-202.87		-80.71	328.1	327.3	149.43	-16,45	-120.35	-120.35	-228.57	ΔG _f ^θ /KJ/mol
	152.23	245.46	223.07	238.93	205.138	191.61	130.684	154.84	126.15			106.32	95.90	82.59	64.46	72.13	20.1	156.90	146.0	94.6		155.60	238.97	140.6	121.21	192.45	109.6	109.6	188.83	S ^θ /J K ⁻¹ mol ⁻¹
				Na(s)	Na(g)	Ag(s)	Ag(g)	Hg(l)	Hg(g)		AgCl(s)	FeS2(s)	FeS(s)	SiO2	AL2O3(□,s)	CO(g)	CO2(g)	HI(g)	HBr(g)	HCl(aq)	HCl(g)	HF(g)	SF6(g)	H ₂ S(g)	SO2(g)	N2O4(g)	NO2(g)	NO(g)	O3(g)	
				22.99	370.95	107.87	107.87	200.59	200.59		143.323	119,975	87.91	60.09	101.945	28.011	44.010	127.912	80.917	36.461	36.461	20.006	146.054	34.080	64.063	92.012	46.006	30.006	47.998	ΜŢ
				0	76.76	0	245.65	0	31.82		-109.79	-166.9	-100.4	-856.64	-1582.3	-137.17	-394.36	1.70	-53.45	-131.23	-95.30	-273.2	-1105.3	-33.56	-300.19	97.89	51.31	86.55	163.2	∆G _F ^θ /KJ/mol
				51.21	153.71	42.55	173.00	76.02	174.96		96.2	52.93	60.29	41.84	50.92	197.67	213.74	206.59	198.70	56.5	186.91	173.78	291.82	205.79	248.22	304.29	240.06	210.76	238.93	S ⁰ /J K ⁻¹ mol ⁻¹
	17(a) 253.81 19.33 260.69	159.82 0 253.81 19.33	159.82 3.110 159.82 0 253.81 19.33	70.91 0 223.07 159.82 3.110 245.46 159.82 0 152.23 253.81 19.33 260.69	47.998 163.2 238.93 Na(s) 22.99 0 70.91 0 223.07 223.07 159.82 3.110 245.46 245.46 159.82 0 152.23 253.81 19.33 260.69	31.999 0 205.138 Na(g) 370.95 76.76 47.998 163.2 238.93 Na(s) 22.99 0 70.91 0 223.07 21.99 0 159.82 3.110 245.46 159.82 0 152.23 253.81 19.33 260.69	28.013 0 191.61 Ag(s) 107.87 0 31.999 0 205.138 Na(g) 370.95 76.76 47.998 163.2 238.93 Na(g) 22.99 0 70.91 0 223.07 23.07 22.99 0 159.82 3.110 245.46 3.110 245.46 253.81 19.33 260.69 269.69	2.016 0 130.684 Ag(g) 107.87 245.65 28.013 0 191.61 Ag(s) 107.87 0 31.999 0 205.138 Na(g) 370.95 76.76 47.998 163.2 238.93 Na(s) 22.99 0 70.91 0 223.07 225.07 245.46 25.381 159.82 3.110 245.46 3.22.99 0 3.22.99 0 3.22.99 0 0 3.22.99 0	39.95 0 154.84 Hg(J) 200.59 0	4.003 0 126.15 Hg(g) 200.59 31.82 39.95 0 154.84 Hg(l) 200.59 0 2.016 0 130.684 Ag(g) 107.87 245.65 28.013 0 191.61 Ag(s) 107.87 0 31.999 0 205.138 Na(g) 370.95 76.76 47.998 163.2 238.93 Na(s) 22.99 0 70.91 0 223.07 Na(s) 22.99 0 159.82 3.110 245.46 152.23 3.10 260.69	4.003 0 126.15 Hg(g) 200.59 31.82 39.95 0 154.84 Hg(l) 200.59 0 2.016 0 130.684 Ag(g) 107.87 245.65 28.013 0 191.61 Ag(s) 107.87 0 31.999 0 205.138 Na(g) 370.95 76.76 47.998 163.2 238.93 Na(s) 22.99 0 70.91 0 223.07 S2.39 3 Na(s) 22.99 0 159.82 3.110 245.46 159.82 19.33 260.69	AgCl(s) 143.323 -109.79 4.003 0 126.15 Hg(g) 200.59 31.82 39.95 0 154.84 Hg(l) 200.59 0 2.016 0 130.684 Ag(g) 107.87 245.65 28.013 0 191.61 Ag(g) 107.87 0 31.999 0 205.138 Na(g) 370.95 76.76 47.998 163.2 238.93 Na(g) 22.99 0 159.82 0 152.23 Na(g) 22.99 0 159.82 0 152.23	166,006) 119.011 -380.66 95.90 FeS(s) 87.91 -100.4 166.006 -324.89 106.32 FeS2(s) 119.975 -166.9 166.006 -324.89 106.32 FeS2(s) 119.975 -166.9 109.79 140.323 -109.79 140.323 -109.79 140.323 -109.79 140.323 -109.79 140.323 -109.79 140.323 -109.79 140.323 -109.79 140.323 -109.79 140.323 182 110.84 14g(l) 200.59 0 110.87 245.65 120.13 0 191.61 Ag(s) 107.87 0 100.131.999 0 205.138 Na(g) 370.95 76.76 147.998 163.2 23.893 Na(g) 370.95 76.76 159.82 0 152.23 Na(s) 22.99 0 159.82 0 152.23 Na(s) 22.99 0 159.82 0 152.23) 74.555 409.14 82.59 SiO2 60.09 456.64) 119.011 -380.66 95.90 FeS(s) 87.91 -100.4 166.006 -324.89 106.32 FeS2(s) 119.975 -166.9 4.003 0 126.15 Hg(g) 200.59 31.82 39.95 0 154.84 Hg(l) 200.59 0 28.013 0 191.61 Ag(g) 107.87 245.65 27.99 0 205.138 Na(g) 107.87 0 47.998 163.2 238.93 Na(g) 370.95 76.76 159.82 0 152.23 Na(s) 22.99 0 159.82 0 152.23 Na(s) 22.99 0	((s) 39.997 -379.49 64.46 AL ₂ O ₃ (□ ₃ s) 101.945 -1582.3 2) 74.555 409.14 82.59 SiO ₂ 60.09 -856.64 119.011 -380.66 95.90 FeS(s) 87.91 -100.4 166.006 -324.89 106.32 FeS ₂ (s) 119.975 -166.9 4.003 0 126.15 Hg(g) 200.59 31.82 39.95 0 154.84 Hg(l) 200.59 0 2.016 0 130.684 Ag(g) 107.87 245.65 28.013 0 191.61 Ag(g) 107.87 0 70.91 0 205.138 Ng(g) 370.95 76.76 159.82 3.110 245.46 159.82 3.110 245.46	s) 58.443 -384.14 72.13 CO(g) 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72.1.50 -178.6 146.0 HCl(aq) 36.461 -95.30 72.1.50 -178.6 146.0 HBr(g) 127.912 1.70 98.078 -744.53 20.1 COg(g) 44.010 -394.36 58.443 -344.4 72.13 COg(g) 28.011 -137.17 39.997 379.49 64.46 AL ₂ O ₃ (□ _x) 101.945 -1582.3 119.011 -380.66 95.90 FeS(g) 87.91 -100.4 119.011 -380.66 95.90 FeS(g) 87.91 -100.4 129.012 39.95 0 126.15 Hg(g) 200.59 31.82 28.013 0 126.15 Hg(g) 200.59 0 28.013 0 126.15 Hg(g) 200.59 0 28.013 0 126.15 Hg(g) 200.59 0 29.015 0 238.93 Na(g) 370.95 76.76 159.82 0 152.36 Na(g) 22.99 0 253.81 19.33 260.69 152.23 159.85 10.33 159.85 253.81 19.33 260.69 150.69 150.69 150.69 253.81 19.33 260.69 150.69 160.69 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 253.81 19.33 260.69 260.69 260.69 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 20.01 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-202.87 94.6 HCI(g) 20.006 -273.2 g(g) 271.50 -178.6 146.0 HBr(g) 36.461 -95.30 g(g) 271.50 -178.6 146.0 HBr(g) 36.461 -95.30 g(g) 271.50 -178.6 146.0 HBr(g) 36.461 -95.30 g(g) 271.50 -178.6 146.0 HBr(g) 36.461 -131.23 g(g) 28.078 -590.00 156.90 HI(g) 127.912 1.70 4(1) 98.078 -744.53 20.1 CO2(g) 28.011 -137.17 4(g	34.015 -120.35 109.6 NO2(g) 46.006 51.31 17.031 -16.45 192.45 N2O4(g) 92.012 97.89 32.045 149.43 121.21 SC2(g) 64.063 -300.19 43.028 328.1 238.97 SF6(g) 34.080 -33.56 43.028 328.1 238.97 SF6(g) 34.080 -33.56 43.028 328.1 238.97 SF6(g) 34.080 -33.56 43.028 328.1 193.3 260.69 50.02 140.5 H2S(g) 36.461 -105.3 43.028 328.1 193.3 260.69 50.02 146.00 HF(g) 36.461 -131.23 44.02 -178.6 146.0 HBr(g) 80.917 -53.45 45.02 -178.6 146.0 HBr(g) 127.912 1.70 46.03 -178.6 146.0 HBr(g) 127.912 1.70 47.04 -178.6 146.0 HBr(g) 127.912 1.70 48.41 -72.13 CCQ(g) 44.010 -394.36 49.97 -379.49 64.46 A1 ₂ C3(C) 101.945 -1582.3 40.03 -324.89 106.32 FeS2(s) 119.975 -166.9 40.03 0 126.15 Hg(g) 200.59 31.82 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	¥	ΔG _ε ^θ /KJ/mol	Sθ/J K-1 mol-1
organic compounds		ļ,	
CH4(g) methane	16,043	-50.72	186.26
C2H2(g) ethyne	26.038	209.20	200.94
C2H4(g) ethene	28.05	68.15	219.56
C2H6(g) ethane	30.070	-32.82	229.60
C3H6 cyclopropane(g)	42.081	104.45	237.55
C3H6 propene(g)	42.081	62.78	267.05
C4H10 n-butane (g)	58.124	-17.03	310.23
C5H12 n-pentane(g)	72.151	-8.20	348.40
C6H12 cyclohexane (l)	84.163	26.8	
C6H14 n-hexane (l)	86.178		204.3
C6H6 benzene (I)	78.115	124.3	173.3
C6H6 benzene (g)	78.115	129.72	269.31
C8H18 n-octane (l)	114.233	6.4	361.1
C10H8 naphthalene (1)	128.175		
CH3OH (g)	32.042	-161.96	239.81
CH3OH (I)	32.042	-166.27	126.8
СН3СНО (g)	44.054	-128.86	250.3
СH3CH2OH (I)	46.07	-174.78	160.7
CH3COOH (I)	60.053	-389.9	159.8
CH3COOC2H5 (I)	88.107	-332.7	259.4
C6H5OH (s)	94.114	-50.9	146.0
C6H5NH2 (I)	93.129		
CH2(NH2)CO2H, glycine (s)	75.068	-373.4	103.5
C6H12O6, □-D-glucose (s)	180.159		
C6H22O6, D-D-glucose (s)	180.159	-910	212
C12H22O11, sucrose (s)	342.303	-1543	360.2
CH3CH(OH)COOII	90.079		
lactic acid (s)			

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

Heat capacities at 25°C

F.P Depression, B.P. Elevation

NO ₂	N ₂ O ₄	CH4	NH ₃	CO ₂	N ₂	02	H ₂	He, Ne, Ar, Kr, Xe		
		27.43	27.17	28.83	20.83	21.01	20.50	12.47	JK ⁻¹ mol ⁻¹	C _{v,m}
37 70	77.28	35.74	35.48	37.14	29.14	29.33	28.81	20.78	JK ⁻¹ mol ⁻¹	$C_{p,m}$
	Chloroform					Acetic Acid	Benzene	Water		Solvent
	Chloroform	Ethanol	Nitrobenzene	Camphor	Cyclohexane	bid	Benzene 5.51			Solvent F.P

80.1 118.1 81.4 205 210.9 78.5

3.10 2.79 2.60 0.52

5.24 1.22

61.3

100.0

B.P K_b (°C, 101kNm⁻²) °C kg mol⁻¹

Third Law entropies at 25°C, Sm⁹/J K⁻¹ mol⁻¹

		7.00.7	C6H12	360.2	Sucrose
265.7	CH ₃ CHO	159.8	СН,СООН	144	HgCl ₂
229.4	C ₂ H ₆		C ₆ H ₆	305.4	CuSO ₄ 5H ₂ O
186.1	CH ₄		СН ₃ ОН	104.6	AgBr
192.5	NH ₃		C ₂ H ₅ OH	96.2	AgCl
205.6	H ₂ S				
186.8	HCl	155.6	HNO ₃	31.9	S(Rh)
213.7	CO_2			116.7	I_2
		70.0	H ₂ O	41.6	Zn
223.0	Cl ₂			33.4	Cu
205.1	O_2			2.44	C(d)
192.1	Z ₂	152.3	Br ₂	5.77	C(gr)
130.6	H_2	76.02	Hg	42.68	Ag
Gases	0	Liquids		Solids	