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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.

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Question 1

(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 Li^{2+} 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]

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Question 2

(a) (i) Draw a clear well labelled molecular orbital diagram of the CN molecule. [4]

(ii) How does this molecule differ from the CN^- molecule in bond length, bond strength and magnetic properties. [4]

(b) Consider 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) Account 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 immediately hydrolysed on contact with water.

(iii) Boron halides are Lewis acids only, but trivalent phosphorus compounds can serve as both Lewis acids and Lewis bases. [6]

(d) Explain, with examples, the following terms

(i) n-type semi-conductor
(ii) hydrogen bonding

[5]

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Question 3

(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 semi-conductor and an insulator

[6]

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

$Mg(OH)_2$, MgO, Al_2O_3, $NaOH$ and $Al(OH)_3$

Justify your order.

[5]

Question 4

(a) (i) Give the names and symbols ($^{A}_{Z}X$) of the three isotopes of hydrogen. [1½]

(ii) Describe one method for the industrial production of hydrogen. [3]

(iii) Mention one use of hydrogen gas. [2½]

(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]

Question 5

(a) Define the following terms

(i) Isotope

(ii) β decay

(iii) Nuclear fusion.

[6]

(b) Write equation showing how $^{238}_{92}U$ and $^{13}_{7}N$ under α decay and β^+ emission respectively.

[4]

(c) Explain or account for the following:

(i) The variation in boiling points of the Group VI hydrides whose values are 100, -60, -42 and -2.3 °C for H_2O, H_2S, H_2Se and H_2Te respectively.

[6]

(ii) The difference in bond angles of H_2O (105°) and F_2O(102°)

[5]

(d) In each of the following pairs, which is the larger radius

(i) S^{2-}, Br^-

(ii) Fe^{2+}, Co^{3+}

[4]

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QUESTION 6

(a) Draw Lewis structures to show the arrangement of valence electrons in boric acid and in its conjugate base. Write an equation to show how boric acid ionises in water. [4]

(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 whereas strontium salts do not.

(v) BeH_2 and $AlCl_3$ are both polymers. Explain why the two compounds polymerise and describe the bonding in both. [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

	GROUPS																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PERIODS	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.008 H 1																	4.003 He 2
2	6.941 Li 3	9.012 Be 4										Atomic mass → Symbol → Atomic No. →	10.811 B 5	12.011 C 6	14.007 N 7	15.999 O 8	18.998 F 9	20.180 Ne 10
3	22.990 Na 11	24.305 Mg 12				TRANSITION ELEMENTS							26.982 Al 13	28.086 Si 14	30.974 P 15	32.06 S 16	35.453 Cl 17	39.948 Ar 18
4	39.098 K 19	40.078 Ca 20	44.956 Sc 21	47.88 Ti 22	50.942 V 23	51.996 Cr 24	54.938 Mn 25	55.847 Fe 26	58.933 Co 27	58.69 Ni 28	63.546 Cu 29	65.39 Zn 30	69.723 Ga 31	72.61 Ge 32	74.922 As 33	78.96 Se 34	79.904 Br 35	83.80 Kr 36
5	85.468 Rb 37	87.62 Sr 38	88.906 Y 39	91.224 Zr 40	92.906 Nb 41	95.94 Mo 42	98.907 Tc 43	101.07 Ru 44	102.91 Rh 45	106.42 Pd 46	107.87 Ag 47	112.41 Cd 48	114.82 In 49	118.71 Sn 50	121.75 Sb 51	127.60 Te 52	126.90 I 53	131.29 Xe 54
6	132.91 Cs 55	137.33 Ba 56	138.91 *La 57	178.49 Hf 72	180.95 Ta 73	183.85 W 74	186.21 Re 75	190.2 Os 76	192.22 Ir 77	195.08 Pt 78	196.97 Au 79	200.59 Hg 80	204.38 Tl 81	207.2 Pb 82	208.98 Bi 83	(209) Po 84	(210) At 85	(222) Rn 86
7	223 Fr 87	226.03 Ra 88	(227) **Ac 89	(261) Rf 104	(262) Ha 105	(263) Unh 106	(262) Uns 107	(265) Uno 108	(266) Une 109	(267) Uun 110								

*Lanthanide Series	140.12 Ce 58	140.91 Pr 59	144.24 Nd 60	(145) Pm 61	150.36 Sm 62	151.96 Eu 63	157.25 Gd 64	158.93 Tb 65	162.50 Dy 66	164.93 Ho 67	167.26 Er 68	168.93 Tm 69	173.04 Yb 70	174.97 Lu 71
**Actinide Series	232.04 Th 90	231.04 Pa 91	238.03 U 92	237.05 Np 93	(244) Pu 94	(243) Am 95	(247) Cm 96	(247) Bk 97	(251) Cf 98	(252) Es 99	(257) Fm 100	(258) Md 101	(259) No 102	(260) Lr 103

( ) indicates the mass number of the isotope with the longest half-life.

General data and fundamental constants

Quantity	Symbol	Value
Speed of light	c	$2.997\ 924\ 58 \times 10^{8}$ m s^{-1}
Elementary charge	e	$1.602\ 177 \times 10^{-19}$ C
Faraday constant	$F = N_Ae$	9.6485×10^{4} C mol^{-1}
Boltzmann constant	k	$1.380\ 66 \times 10^{-23}$ J K^{-1}
Gas constant	$R = N_Ak$	$8.314\ 51$ J K^{-1} mol^{-1}
		$8.205\ 78 \times 10^{-2}$ dm^{3} atm K^{-1} mol^{-1}
		6.2364×10 L Torr K^{-1} mol^{-1}
Planck constant	h	$6.626\ 08 \times 10^{-34}$ J s
	$\hbar = h/2\pi$	$1.054\ 57 \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\ 14 \times 10^{23}$ mol^{-1}
Atomic mass unit	u	$1.660\ 54 \times 10^{-27}$ Kg
Mass		
electron	m_e	$9.109\ 39 \times 10^{-31}$ Kg
proton	m_p	$1.672\ 62 \times 10^{-27}$ Kg
neutron	m_n	$1.674\ 93 \times 10^{-27}$ Kg
Vacuum permittivity	$\varepsilon_o = 1/c^2\mu_o$	$8.854\ 19 \times 10^{-12}$ J^{-1} C^{2} m^{-1}
	$4\pi\varepsilon_o$	$1.112\ 65 \times 10^{-10}$ J^{-1} C^{2} m^{-1}
Vacuum permeability	μ_o	$4\pi \times 10^{-7}$ J s^{2} C^{-2} m^{-1}
		$4\pi \times 10^{-7}$ T^{2} J^{-1} m^{3}
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\ 02 \times 10^{-24}$ J T^{-1}
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\ 79 \times 10^{-27}$ J T^{-1}
g value	g_e	2.002 32
Bohr radius	$a_o = 4\pi\varepsilon_o\hbar/m_ee^2$	$5.291\ 77 \times 10^{-11}$ m
Fine-structure constant	$\alpha = \mu_oe^2c/2h$	$7.297\ 35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_ee^4/8h^3c\varepsilon_o^2$	$1.097\ 37 \times 10^{7}$ m^{-1}
Standard acceleration of free fall	g	$9.806\ 65$ m s^{-2}
Gravitational constant	G	$6.672\ 59 \times 10^{-11}$ N m^{2} Kg^{-2}

Conversion factors

1 cal	=	4.184 joules (J)	1 erg	=	1×10^{-7} J
1 eV	=	$1.602\ 2 \times 10^{-19}$ J	1 eV/molecule	=	96 485 kJ mol^{-1}

Prefixes

f	p	n	μ	m	c	d	k	M	G
femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}

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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QUESTION 1

a) Various quantum numbers are needed to describe the state of an electron in an atom.

i. what are the quantum numbers? *(1 mark)*

ii. what properties of the electrons or atomic orbitals are determined or described by these quantum numbers? *(4 marks)*

iii. give all the quantum numbers of each of the valence electrons in chlorine. *(3 marks)*

b) Using the data below, 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)*

QUESTION 2

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 O_2. 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, Al_2O_3, Na_2O, $NaOH$, $Al(OH)_3$

Justify your order. *(5 marks)*

QUESTION 3

a) Use Slater's rules to calculate the effective nuclear charge experienced by

i. the valence electron in the atom N

ii. the valence 4s electron in the atom Zn

iii. a 3d electron in Zn . *(2 each = 6 marks)*

b) i. Define the terms 'ionization energy' and 'electronegativity' *(1 mark)*

Account for the following observations:

ii. variation in electronegativity

F	Cl	Br	I
4.10	2.83	2.74	2.21

(3 marks)

iii. variation in first ionization energies of Group II metal (kJ mol^{-1})

Be	Mg	Ca	Sr
899	737	590	549

(3 marks)

c) Define the following terms:

i. α-decay

ii. γ-radiation

iii. nuclear fission *(6 marks)*

d) If X, Y and Z represent elements of atomic number 9, 17 and 55 respectively, predict the type of bonding you would expect to occur between

i. X and Y ii. X and Z iii. Y and Z *(6 marks)*

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QUESTION 4

a) Account for the following observations:

i. There is no reaction between NCl_3 and Cl_2 whereas PCl_3 reacts with Cl_2 to give PCl_5.

ii. Ionic compounds usually react rapidly whilst covalent compounds usually react slowly.

iii. Methanol CH_3OH has a much higher boiling point than methyl mercaptan, CH_3SH. *(6 marks)*

b) Write equations for each of the following reactions:

i. Hydrolysis of diborane

ii. Hydrolysis of $SiCl_4$

iii. Reduction of BF_3 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)

QUESTION 5

(a) Write the formula of the most common oxide for each of the following

i. Na   ii. Al   iii. S

Classify each of the oxides as basic, acidic or amphoteric.

iv. For the basic or acidic oxides write balanced equations for their reaction with water.

[8 marks]

b) i. Use the band theory to explain the difference between conductors, insulators and semiconductors. *[3 marks]*

ii. State whether the following material is an n-type or a p-type semiconductor

Si doped with As, Ge dopped with In *[2 marks]*

c) Which of the following pairs will have a larger bond angle? Explain.

i. CH_4, NH_3

ii. NF_3, NH_3

[4 marks]

d) i. Why is diborane called an electron deficient compound? *[2 marks]*

iii. Describe the difference in the structures of $(BeH_2)_n$ and $(BeCl_2)_n$ *[6 marks]*

QUESTION 6

a) Orthoboric acid may be written as H_3BO_3 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]*

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() indicates the mass number of the isotope with the longest half-life.

General data and fundamental constants

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	$\hbar = h/2\pi$	$1.054\,57 \times 10^{-34}$ J s
Avogadro constant	N_A	$6.022\,14 \times 10^{23}$ mol^{-1}
Atomic mass unit	u	$1.660\,54 \times 10^{-27}$ Kg
Mass		
electron	m_e	$9.109\,39 \times 10^{-31}$ Kg
proton	m_p	$1.672\,62 \times 10^{-27}$ Kg
neutron	m_n	$1.674\,93 \times 10^{-27}$ Kg
Vacuum permittivity	$\varepsilon_o = 1/c^2\mu_o$	$8.854\,19 \times 10^{-12}$ J^{-1} C^2 m^{-1}
	$4\pi\varepsilon_o$	$1.112\,65 \times 10^{-10}$ J^{-1} C^2 m^{-1}
Vacuum permeability	μ_o	$4\pi \times 10^{-7}$ J s^2 C^{-2} m^{-1}
		$4\pi \times 10^{-7}$ T^2 J^{-1} m^3
Magneton		
Bohr	$\mu_B = e\hbar/2m_e$	$9.274\,02 \times 10^{-24}$ J T^{-1}
nuclear	$\mu_N = e\hbar/2m_p$	$5.050\,79 \times 10^{-27}$ J T^{-1}
g value	g_e	2.002 32
Bohr radius	$a_o = 4\pi\varepsilon_o\hbar/m_e e^2$	$5.291\,77 \times 10^{-11}$ m
Fine-structure constant	$\alpha = \mu_o e^2 c/2h$	$7.297\,35 \times 10^{-3}$
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Standard acceleration of free fall	g	$9.806\,65$ m s^{-2}
Gravitational constant	G	$6.672\,59 \times 10^{-11}$ N m^2 Kg^{-2}

Conversion factors

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1 eV	=	$1.602\,2 \times 10^{-19}$ J	1 eV/molecule	=	96 485 kJ mol^{-1}

Prefixes

f	p	n	μ	m	c	d	k	M	G
femto	pico	nano	micro	milli	centi	deci	kilo	mega	giga
10^{-15}	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}

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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 (C_4H_{10}) and propene (C_3H_6) occupied 35.5 L at 1.000 bar and 405 K. This mixture reacted completely with 220.6 g of O_2 to produce CO_2 and H_2O.

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:

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

(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 L^2atm mol^{-2}K 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 $cm^3 mol^{-1}$ [3]

Question 3 [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) 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]

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]
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

[5]

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

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

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

Evaluate fugacity of O_2 at 200 K given that the compression factor of O_2 is 0.98796 at 4.00000 atm.

Question 5 [25 Marks]

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

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g) \qquad \Delta H^\theta = -114.1\,kJmol^{-1}$$

$$4NO_2(g) + O_2(g) \rightarrow 2N_2O_5(g) \qquad \Delta H^\theta = -110.2\,kJmol^{-1}$$

$$N_2(g) + O_2(g) \rightarrow 2NO(g) \qquad \Delta H^\theta = +180.5\,kJmol^{-1}$$

(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 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]

a) Calculate the change in entropies of the system, $\Delta S_{sys,}$ the surroundings, $\Delta S_{surr,}$ and the total change in entropy, $\Delta S_{tot,}$, when a sample of nitrogen gas of mass 14 g at 298 K and 1.00 bar doubles its volume in:

i) an isothermal reversible expansion [6]

ii) an irreversible isothermal expansion against an external pressure of 0.5 bar. [4]

b) What would the change in entropy be if the gas in (a) was compressed to half its 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 $JK^{-1}mol^{-1}$: Calculate:

i) final temperature of the mixture [4]

ii) the entropy change [6]

THE PERIODIC TABLE OF ELEMENTS

NON-METALS ←
METALLOIDS ←
METALS

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.*

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
$H_2O_2(l)$	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	**Eg. N_2, O_2, H_2**	**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/10^5J $Kmol^{-1}$
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

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	-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

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

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	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	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
$C_6H_{12}O_6$, □-D-glucose (s)	180.159		
$C_6H_{22}O_6$, □-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.

Heat capacities at 25°C

	$C_{v,m}$	$C_{p,m}$
	JK^{-1} mol^{-1}	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^{-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, S_m^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		