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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]

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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]

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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

PERIODS	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 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	$F = N_A e$	9.6485×10^{4} C mol^{-1}
Boltzmann constant	k	$1.380\ 66 \times 10^{-23}$ J K^{-1}
Gas constant	$R = N_A k$	$8.314\ 51$ 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	$a_o = 4\pi\varepsilon_o\hbar/m_e e^2$	$5.291\ 77 \times 10^{-11}$ m
Fine-structure constant	$\alpha = \mu_o e^2 c/2h$	$7.297\ 35 \times 10^{-3}$
Rydberg constant	$R_\infty = m_e e^4/8h^3 c\varepsilon_o^2$	$1.097\ 37 \times 10^{7}$ 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}