UNIVERSITY OF SIERRA LEONE

CHEM 221

FOURAH BAY COLLEGE

FIRST EXAMINATION FOR THE DEGREE OF B. Sc. HONOURS

LEVEL I

SECOND SEMESTER EXAMINATION

FRIDAY 21st SEPTEMBER 2018 09.30 – 12.45

CHEM 221 – FURTHER INORGANIC CHEMISTRY

TIME ALLOWED: 3 HOURS PLUS 15 MINUTES READING TIME

INSTRUCTIONS:

- THIS PAPER IS DIVIDED INTO THREE SECTIONS: A, B AND C; ANSWER ALL QUESTIONS IN SECTION A AND A TOTAL OF THREE QUESTIONS FROM SECTIONS B AND C, INCLLUDING AT LEAST ONE QUESTION FROM EACH SECTION

SECTION A (ANSWER ALL QUESTIONS)

SECTION B (ANSWER 1 OR 2 QUESTIONS)

SECTION C (ANSWER 1 OR 2 QUESTIONS)

The Periodic Table of the Elements

1	2											3	4	5	6	7	0
																	(18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)		Key									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4		relative atomic mass **symbol** name atomic (proton) number									10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	96.0 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La * lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac † actinium 89	[267] Rf rutherfordium 104	[268] Db dubnium 105	[271] Sg seaborgium 106	[272] Bh bohrium 107	[270] Hs hassium 108	[276] Mt meitnerium 109	[281] Ds damstadium 110	[280] Rg roentgenium 111	Elements with atomic numbers 112-116 have been reported but not fully authenticated						

140.1 Ce cerium 58	140.9 Pr praseodymium 59	144.2 Nd neodymium 60	[145] Pm promethium 61	150.4 Sm samarium 62	152.0 Eu europium 63	157.3 Gd gadolinium 64	158.9 Tb terbium 65	162.5 Dy dysprosium 66	164.9 Ho holmium 67	167.3 Er erbium 68	168.9 Tm thulium 69	173.1 Yb ytterbium 70	175.0 Lu lutetium 71
232.0 Th thorium 90	231.0 Pa protactinium 91	238.0 U uranium 92	[237] Np neptunium 93	[244] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[247] Bk berkelium 97	[251] Cf californium 98	[252] Es einsteinium 99	[257] Fm fermium 100	[258] Md mendelevium 101	[259] No nobelium 102	[262] Lr lawrencium 103

* **58 – 71** Lanthanides

† **90 – 103** Actinides

Section A

Answer all questions from this section.

A1. Aluminium and Thallium both react with dilute sulphuric acid to form salts.
(a) Write equations for the reactions of aluminium and thallium with sulphuric acid.
(b) State the oxidation number of aluminium and thallium in the salts formed and explain why they are different.

[5]

A2. $SiCl_4$ reacts rapidly with water but CCl_4 does not.
(a) Explain why this is the case.
(b) Write an equation for the reaction of $SiCl_4$ with water and state what you would observe.

[5]

A3. (a) Draw the structure of a molecule of nitrogen and a molecule of phosphorus.
(b) Explain why the structures are different.

[5]

A4. Sulphur forms a large number of stable oxoanions. Draw the structures and give the formulae of any three oxoanions of sulphur. State the oxidation number of the sulphur in each ion.

A5. Hydrogen is sometimes placed in Group 1 of the Periodic Table and sometimes placed in a Group of its own.
(a) Give three arguments for placing hydrogen in Group 1 of the Periodic Table.
(b) Give three arguments against placing hydrogen in Group 1 of the Periodic Table.

[5]

A6. Use VSEPR theory to determine the geometry around the central atom for each of the following molecules:
(a) XeF_4
(b) ICl_3
(c) PCl_5

[5]

A7. State, with an explanation, which of the following in each pair will have the larger bond angle:
(a) SF_6 and XeF_4
(b) SO_2 and CO_2
(c) PCl_3 and PCl_5

[5]

A8. What characteristics distinguish hard and soft acids and bases?

[5]

A9. Classify the following species into hard and soft acids and bases: H^+, BF_3, OH^-, C_6H_6

[5]

A10. Draw the Born-Haber cycle for the formation of magnesium fluoride (MgF_2) from its elements, stating each term used in the transformation process.

[5]

Section B

Answer one or two questions from this section.

B1. This question is about the chemistry of boron and aluminium.

(a) Give two uses of aluminium and describe the properties of aluminium which make it so useful.

(4)

(b) The main source of aluminium is bauxite, an impure form of Al_2O_3. During the extraction of aluminium, the bauxite ore is first purified. Aluminium is then extracted from the pure Al_2O_3 by electrolysis.

(i) Describe the main stages in the purification of Al_2O_3 from bauxite. Use equations to support your answer.

(ii) State the property of Al_2O_3 which allows it to be purified in this way.

(iii) State the main cost in the extraction of aluminium from its ore.

(8)

(c) Boron is also found naturally as B_2O_3. Explain why boron is not extracted from B_2O_3 by electrolysis and suggest a suitable method for the extraction of boron from its oxide. Use an equation to support your answer.

(3)

(d) Boron fluoride and aluminium chloride both form simple molecules in the gas phase. The two molecules, however, have different structures.

(i) Using diagrams to support your answer, draw the structures of boron fluoride and aluminium chloride in the gas phase.

(ii) Explain why the two molecules have different structures.

(7)

(e) $LiAlH_4$ and $NaBH_4$ are both useful reducing agents in organic chemistry. Explain why.

(3)

Total 25 marks

B**2.** This question is about the chemistry of carbon, silicon, tin and lead.

(a) Pure carbon exists in the form of two stable allotropes – diamond and graphite. Pure silicon exists only as a structure analogous to diamond.

(i) Briefly describe the structures of diamond and graphite.

(ii) Explain why silicon does not form a structure similar to graphite.

(7)

(b) Carbon dioxide is a gas at room temperature. Silicon dioxide is a solid at room temperature with a high melting point. Carbon also forms a stable monoxide but silicon does not.

(i) Describe the structures of carbon dioxide and silicon dioxide and explain why the melting points of the two substances are so different.

(ii) Explain why carbon dioxide and silicon dioxide have different structures.

(iii) Explain why silicon does not form a stable monoxide.

(8)

Question B2 continues on the next page

(c) Tin (IV) oxide and lead (IV) oxide react differently with concentrated hydrochloric acid.

(i) Write equations for the reactions of tin (IV) oxide and lead (IV) oxide with concentrated hydrochloric acid.

(ii) State the type of reaction occurring in each case.

(iii) Explain why tin (IV) oxide and lead (IV) oxide react differently with concentrated hydrochloric acid.

(7)

(d) Write equations to show the half-reactions taking place in a lead-acid battery. Explain what these half-reactions show about the chemistry of lead.

(3)

Total 25 marks

B3. This question is about the chemistry of nitrogen, phosphorus and the halogens

(a) Explain why phosphorus forms a stable pentachloride (PCl_5) but nitrogen does not.

(3)

(b) Phosphorus forms two stable oxides. Nitrogen forms a large number of oxides.

(i) Draw the structures of, and give the molecular formulae of, the two stable oxides of phosphorus.

(ii) Draw the structures of, and give the molecular formulae of, any two oxides of nitrogen.

(iii) Explain why the oxides of phosphorus and nitrogen have completely different structures.

(iv) Explain why nitrogen forms a large number of oxides.

(12)

(b) The following table shows some data on the halogens:

Halogen	First electron affinity ($kJmol^{-1}$)	X-X bond dissociation enthalpy ($kJmol^{-1}$)	H-X bond dissociation enthalpy ($kJmol^{-1}$)
Fluorine	-328	158	568
Chlorine	-349	243	432
Bromine	-325	193	366
Iodine	-295	151	298

(i) Explain the trends in the first electron affinities, X-X bond dissociation enthalpies and H-X bond dissociation enthalpies of the halogens.

(ii) Explain why, in water, HCl is a strong acid but HF is a weak acid.

(10)

Total 25 marks

Section C

Answer one or two questions from this section.

C1. (a) Write short notes on the following:

(i) Energy changes in ionic bond formation

(ii) The Born-Haber cycles for the formation of sodium chloride (NaCl(s)) from its elements

(iii) Properties of ionic salts.

(b) Use the cycle in B1(a)(ii) to calculate the lattice enthalpy of NaCl given the following data:
Atomisation of Na: $\Delta H^o = +108$ kJmol^{-1}
Atomisation of Cl: $\Delta H^o = +122$ kJmol^{-1}
First ionisation of Na: $\Delta H^o = +495$ kJmol^{-1}
First electron addition of Cl: $\Delta H^o = -360$ kJmol^{-1}
Standard enthalpy of formation of NaCl(s): $\Delta H^o = -411$ kJmol^{-1}

(c) Explain why $CaCl_2$ exists but CaCl and $CaCl_3$ do not.

Total 25 marks

C2. Simple molecules have simple formulae and shapes through, in certain cases, no obvious relationship exists between the two parameters. Scientists have, however, designed an easy theory for predicting simple molecular shapes. Fully discuss this statement using carbon dioxide (CO_2), boron trifluoride (BCl_3), ammonia (NH_3), water (H_2O) and sulphur hexafluoride (SF_6).

Total 25 marks

C3. Discuss the theory of hard and soft acids and bases (HSAB) under the following headings:

(i) Definitions of Lewis acid-base theory

(ii) Recognition of acids and bases

(iii) Interpretation of reactions in terms of Lewis theory

(iv) HSAB principle

(v) Refinements to the HSAB theory

(vi) Application of the HSAB principle

Total 25 marks

END OF QUESTION PAPER