UNIVERSITY OF SIERRA LEONE

CHEM 122

FOURAH BAY COLLEGE

FIRST EXAMINATION FOR THE DEGREE OF B. Sc. HONOURS

LEVEL I

SECOND SEMESTER EXAMINATION

MONDAY 10th SEPTEMBER 2018 13.30 – 16.45

CHEM 122 – GROUP CHEMISTRY AND INTRODUCTORY NUCLEAR 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. $BeCl_2$ is a covalent compound but BeF_2 and $MgCl_2$ are ionic compounds.

(a) Use ideas about electronegativity to explain why $MgCl_2$ is ionic but $BeCl_2$ is covalent.

(b) Use ideas about polarizability to explain why BeF_2 is ionic but $BeCl_2$ is covalent.

[5]

A2. As you go down a group of the Periodic Table, there is a gradual change in the physical properties of the elements.

(a) State and explain how the melting points of the alkali metals changes down the group.

(b) State and explain how the melting points of the halogens changes down the group.

[5]

A3. Sodium and magnesium differ significantly in the way in which they react with water.

(a) Write equations to show how sodium and magnesium both react with water. State the conditions required for these reactions to take place.

(b) Explain the difference in the reactivities of sodium and magnesium with water.

[5]

A4. A student added bromine water separately to solutions of sodium chloride and sodium iodide.

(a) State what she would observe in each case.

(b) Write equations for any reactions occurring and explain any differences.

[5]

A5. Chromium can form a number of stable ions, including both Cr^{2+} and Cr^{3+}.

(a) Give the full electronic configurations of Cr, Cr^{2+} and Cr^{3+}.

(b) Explain why chromium can form more than one stable ion.

[5]

A6. (a) What is radioactivity?

(b) The first two steps in the conversion of $^{234}_{91}\mathrm{Pa}$ to $^{208}_{82}\mathrm{Pb}$ are β-emission followed by α-emission. Write a balanced nuclear equation for each step.

[5]

A7. (a) Give the composition of each of the following:

(i) alpha particle (ii) beta particle (iii) positron (iv) gamma ray

(b) Explain why the penetrating power of alpha radiation is less than that of beta and gamma radiations.

[5]

A8. Explain what happens to the nucleus of a carbon-14 atom during:

(a) beta-emission

(b) alpha-decay

(c) electron capture

[5]

A9. Balance the following nuclear reactions by supplying values for r, s, t, q, y and m:

$$^{27}_{13}\mathrm{Pa} + {}^{r}_{s}\mathrm{n} \rightarrow {}^{24}_{t}\mathrm{Na} + {}^{q}_{2}\mathrm{He}$$

$$^{56}_{y}\mathrm{Fe} + {}^{m}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\alpha + {}^{54}_{25}\mathrm{Mn}$$

[5]

A10. The most abundant isotope of helium is $^4_2\mathrm{He}$, which has a nuclear mass of 6.6447 x 10^{-27} kg.
The mass of a proton is 1.6726 x 10^{-27} kg. The mass of a neutron is 1.6779 x 10^{-27} kg. The speed of light c is 3.00 x 10^8 ms^{-1}. 1 eV = 1.6 x 10^{-19} J. Einstein's equation is $E = mc^2$.
Calculate:

(a) The mass defect of $^4_2\mathrm{He}$

(b) (i) The binding energy of $^4_2\mathrm{He}$ in J

(b) (ii) The binding energy of $^4_2\mathrm{He}$ in eV

[5]

Section B

Answer one question from this section.

B1. This question is about the anomalous behaviour of lithium and beryllium compared with other elements in their respective groups.

(a) Lithium and sodium react differently with oxygen. Write equations to show how lithium and sodium react with oxygen and explain the differences in the two oxides formed.

(5)

(b) Lithium and sodium also react differently with nitrogen. Describe, using equations as appropriate, how lithium and sodium react with nitrogen.

(3)

(c) Beryllium and calcium react differently with carbon. Write equations to show how beryllium and calcium react with carbon and explain the differences in the two carbides formed.

(5)

(d) Beryllium oxide and calcium oxide react differently with alkalis. Describe, using equations as appropriate, how beryllium oxide and calcium oxide react with alkalis.

(3)

(e) In aqueous solution, lithium ions and beryllium ions both form hydrated complex ions with the formulae $[Li(H_2O)_4]^+$ and $[Be(H_2O)_4]^{2+}$ respectively.

(i) Explain why the other elements in Group 1 do not form complex ions analogous to $[Li(H_2O)_4]^+$.

(ii) Explain why the other elements in Group 2 do not form complex ions analogous to $[Be(H_2O)_4]^{2+}$.

(5)

(f) Explain why the chemical properties of lithium and beryllium are so different from the other elements in their respective groups.

(2)

Total 25 marks

B2. This question is about the chemical properties of the halides.

(a) Describe a simple chemical test which you could use to identify chloride ions, bromide ions and iodide ions in aqueous solution. State clearly what you would observe in each case and write ionic equations for any reactions taking place.

(8)

(b) The reducing power of the halides changes down Group 7. This can be illustrated in the very different ways in which chloride, bromide and iodide ions react with concentred sulphuric acid (H_2SO_4).

(i) State and explain how the reducing power of the halides changes down Group 7.

(ii) State the oxidation number of sulphur in H_2SO_4.

(iii) Write an equation to show how H_2SO_4 reacts with chloride ions and state the final oxidation number of the sulphur.

(iv) Write an equation to show how H_2SO_4 reacts with bromide ions and state the final oxidation number of the sulphur. Your answer should be different to your equation in (ii)

(v) Write an equation to show how H_2SO_4 reacts with iodide ions and state the final oxidation number of the sulphur. Your answer should be different to your equations in (ii) and (iii)

(12)

(c) Iodide ions react with persulphate ions according to the following equation: $S_2O_8^{2-} + 2I^- \rightarrow 2SO_4^{2-} + I_2$
This reaction is normally slow at room temperature but is effectively catalyzed by Fe^{2+} ions.

(i) Explain why this reaction is slow in the absence of a catalyst.

(ii) Write two equations to show how this reaction is catalysed by Fe^{2+} ions

(iii) What property of Fe and its compounds makes them effective catalysts?

(5)

Total 25 marks

B3. This question is about complex ions containing iron and zinc.

(a) Write the electronic configurations of Fe^{3+} and Zn^{2+}

(2)

(b) Fe^{3+} and Zn^{2+} can both form a number of different complex ions:

(i) Write the formula of the complex ion formed when water is added to Zn^{2+} ions. Draw the ion, showing its shape and structure clearly. State the coordination number of the complex ion.

(ii) Write the formula of the complex ion formed when an excess of HCl is added to Fe^{3+} ions. Draw the ion, showing its shape and structure clearly. State the coordination number of the complex ion.

(iii) Write the formula of the complex ion formed when an excess of 1,2-diaminoethane ($H_2NCH_2CH_2NH_2$) is added to Fe^{3+} ions. Draw both isomers of this complex ion, showing their shape and structure clearly. State the type of isomerism shown by this complex ion.

(13)

(c) Explain why the complex ion in (b) (iii) is more stable than the complex ions in (b) (i) or (b) (ii).

(2)

(d) Explain why complex ions containing Fe^{3+} are usually coloured but complex ions containing Zn^{2+} are usually not coloured.

(5)

Question B3 continues overleaf

(e) Aqueous solutions of Fe^{2+} and Zn^{2+} are both acidic, although aqueous solutions of Fe^{3+} are usually more acidic than aqueous solutions of Zn^{2+}. Explain these observations.

(5)

Maximum 25 marks

Section C

Answer one or two questions from this section.

C1. Nuclear reactions are first-order processes governed by the following equation: $\log_{10}\frac{N_0}{N} = \frac{kt}{2.303}$

(a) Identify the variable N_0, N, k and t

(b) Define the term half-life ($t_{\frac{1}{2}}$) of a radio-nuclide and hence use the equation above to deduce an expression for $t_{\frac{1}{2}}$.

(c) The half-life of caesium-137 is 30 years.
- (i) How much of a 100 g sample of caesium-137 will remain after 300 years?
- (ii) How long does it take for three-fourths of a caesium-137 sample to decay?
- (ii) What is the driving force for the decay of caesium-137?

Total 25 marks

C2. (a) Distinguish between
- (i) nuclides and nucleons
- (ii) protons and positrons
- (iii) nuclear fission and nuclear fusion
- (iv) binding energy and mass defect
- (v) nuclear reactions and chemical reactions

(b) The uranium decay series starts with $^{238}_{92}U$ and finishes with $^{206}_{82}Pb$. Each step involves the loss of either an α-particle or a β-particle. Deduce how many α-particles and β-particles are given off.

(c) Account for the following observations:
- (i) $^{238}_{92}U$ and $^{238}_{92}U^{2+}$ behave in the same way during nuclear reactions.
- (ii) $^{235}_{92}U$ and $^{236}_{92}U$ have identical chemical properties.

Total 25 marks

C3. (a) Write notes on nuclear stability with particular reference to:
- (i) The proton to neutron ratio
- (ii) The odd and even rule
- (iii) Other factors affecting nuclear stability.

(b)
- (i) How is carbon-14 made and how does carbon dating work?
- (ii) Explain the use of nuclear reactions in energy production.

(c) A fossil bone contains one sixteenth (1/16) as much carbon-14 as a living organism. Given that the $t_{\frac{1}{2}}$ for carbon-14 is 5715 years, how old is the fossil?

Total 25 marks

END OF QUESTION PAPER