



MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCE

THIRD YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE IN ANALYTICAL CHEMISTRY

BACHELOR OF EDUCATION (SCIENCE)

BACHELOR OF EDUCATION (SPECIAL NEEDS)

SCH 301: COORDINATION AND ORGANOMETALLIC CHEMISTRY

DATE: 17/3/2022

TIME: 2.00-4.00 PM

INSTRUCTIONS:

1. Question ONE is **COMPULSORY** (Section A) (30 mks)
2. Answer **ANY** other **TWO** questions from **Section B** (each 20 marks)
3. A periodic table is attached at the last page

SECTION A (COMPULSORY)

QUESTION ONE (30 MARKS)

- a) Write the formulas of the following coordination compounds (3 marks)
 - i) Potassium hexacyanoferrate (III)
 - ii) Pentaquathiocyanatoiron (III)sulfate
 - iii) Tetraamineaquachlorocobalt (III)chloride
- b) Explain why Cu ($3d^{10} 4s^1$), Ag ($4d^{10} 5s^1$) and Au ($5d^{10} 6s^1$) are considered transition elements yet they have fully filled d-orbitals. (3 marks)
- c) Discuss two roles of coordination compounds in biological systems (4 marks)
- d) Explain why $[Fe(CN)_6]^{4-}$ and $[Fe(H_2O)_6]^{2+}$ have different colours in dilute solutions (3 marks)
- e) Show whether $HMn(CO)_5$ obeys 18 electron rule given that the neutral atom electron count for constituent atoms are, Mn=7, CO=2 and H=1 (2 marks)

- f) $[Mn(H_2O)_6]^{2+}$ is a low spin complex. Explain using suitable diagrams (4 marks)
- g) Calculate the oxidation number of the transition metal in the following co-ordination compounds
- $[Cr(NH_3)_3Cl_3]$ (1 mark)
 - $K_3[Fe(CN)_6]$ (1 mark)
 - $[CoBr_2(en)_2]^+$ (1 mark)
- h) Draw two geometrical isomers of diaminetetracyanoiron (III) (2 marks)
- i) Explain why $[Cr(NH_3)_6]^{3+}$ is paramagnetic while $[Ni(CN)_4]^{2-}$ is diamagnetic. (4 marks)
- j) Explain why Fe^{3+} is stable given that $Fe=3d^6 4s^2$ (2 marks)

SECTION B: ANSWER ANY TWO QUESTIONS

QUESTION TWO (20 MARKS)

- a) Explain bonding in coordination compounds in terms of Werner's postulates (4 marks)
- b) Define the following terms and give a suitable example for each
- Coordination sphere (2 marks)
 - Ligand (2 marks)
 - Coordination number (2 marks)
- c) A metal complex having composition $[Cr(NH_3)_4Cl_2]Br$ has been isolated in two forms A and B. A reacts with silver nitrate producing a white precipitate which is soluble in dilute ammonia solution. B reacts with silver nitrate producing a pale-yellow precipitate soluble in concentrated ammonia solution. Identify A and B using relevant equations (4 marks)
- Hint: maintain $Cr(NH_3)_4$ as the backbone.*
- d) Hexaaquamanganese (II) ion contains five unpaired electrons, while hexacyanomanganese (II) ion contains only one unpaired electron. Using suitable diagrams, explain this phenomenon using crystal field theory (6 marks)

QUESTION THREE (20 MARKS)

- a) Write the systematic name of following:
- $[Pt(NH_3)_4Cl(NO_2)]SO_4$ (2 marks)
 - $Na_3[FeCl(CN)_5]$ (2 marks)
 - $[Cr(NH_3)_4(H_2O)_2]Cl_3$ (2 marks)
- b) Explain using suitable diagrams why $[Co(NH_3)_6]^{3+}$ is an inner orbital complex whereas $[Ni(NH_3)_6]^{2+}$ is an outer orbital complex (6 marks)

- c) Draw two solvate isomers of chromium (III) chloride hexahydrate and give their systematic names (4 marks)
- d) Discuss the effect of lanthanide contraction on physical and chemical properties of transition metals (4 marks)

QUESTION FOUR (20 MARKS)

- a) Contrast the magnetic nature of $[\text{NiCl}_4]^{2-}$ and $[\text{Ni}(\text{CO})_4]^{2-}$ in their tetrahedral structure (5 marks)
- b) Using a suitable example, show how geometric isomerism can affect the usefulness of a coordination compound. (4 marks)
- c) Using crystal field theory explain why $[\text{Ti}(\text{H}_2\text{O})_6]^{3+}$ is violet octahedral complex (5 marks)
- d) Briefly describe three methods of synthesizing organometallic compounds (6 marks)

QUESTION FIVE (20 MARKS)

- a) Given the coordination compound $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$, use the valence bond theory to;
 - i) Determine the oxidation state of the central metal atom (2 marks)
 - ii) Identify the magnetic nature of the complex (2 marks)
 - iii) Identify the hybridization state of the central atom (2 marks)
 - iv) Identify the geometry of the complex (1 mark)

Hint: Ammonia is a strong field ligand. Use of diagrams is highly encouraged where possible.
- b)
 - i) What is meant by stability of coordination compounds in solution? (1 mark)
 - ii) Discuss three factors that affect stability of coordination complex (6 marks)
- c) Analyse the complex below and identify whether they are coloured or not (6 marks)
 - i) $[\text{Co}(\text{NH}_3)_6]^{3+}$
 - ii) $[\text{Fe}(\text{CN})_6]^{4-}$
 - iii) $[\text{Ni}(\text{CN})_4]^{2-}$

The Periodic Table of the Elements

1 H Hydrogen 1.00794																2 He Helium 4.003																													
3 Li Lithium 6.941	4 Be Beryllium 9.012182																																												
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050																																												
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80																												
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29																												
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)																												
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 (269)	111 (273)	112 (277)	113	114																																
<table><tr><td>58 Ce Cerium 140.116</td><td>59 Pr Praseodymium 140.90765</td><td>60 Nd Neodymium 144.24</td><td>61 Pm Promethium (145)</td><td>62 Sm Samarium 150.36</td><td>63 Eu Europium 151.964</td><td>64 Gd Gadolinium 157.25</td><td>65 Tb Terbium 158.92534</td><td>66 Dy Dysprosium 162.50</td><td>67 Ho Holmium 164.93032</td><td>68 Er Erbium 167.26</td><td>69 Tm Thulium 168.93421</td><td>70 Yb Ytterbium 173.04</td><td>71 Lu Lutetium 174.967</td></tr><tr><td>90 Th Thorium 232.0381</td><td>91 Pa Protactinium 231.03588</td><td>92 U Uranium 238.0289</td><td>93 Np Neptunium (237)</td><td>94 Pu Plutonium (244)</td><td>95 Am Americium (243)</td><td>96 Cm Curium (247)</td><td>97 Bk Berkelium (247)</td><td>98 Cf Californium (251)</td><td>99 Es Einsteinium (252)</td><td>100 Fm Fermium (257)</td><td>101 Md Mendelevium (258)</td><td>102 No Nobelium (259)</td><td>103 Lr Lawrencium (262)</td></tr></table>																		58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967	90 Th Thorium 232.0381	91 Pa Protactinium 231.03588	92 U Uranium 238.0289	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)
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