NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND SPATIAL SCIENCES

DEPARTMENT OF MINING AND PROCESS ENGNEERING

QUALIFICATION : BACHELOR OF ENGINEERING IN METALLURGY	
QUALIFICATION CODE: 08BEMT	LEVEL: 7
COURSE CODE: HMT 710S	COURSE NAME: HYDROMETALLURGY 314
SESSION: JUNE 2023	PAPER: THEORY
DURATION: 2.5 HOURS	MARKS: 75

FIRST OPPORTUNITY QUESTION PAPER	
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INSTRUCTIONS

1. Answer all questions.
2. Read all the questions carefully before answering.
3. Marks for each question are indicated at the end of each question.
4. Please ensure that your writing is legible, neat and presentable.

PERMISSIBLE MATERIALS

1. Examination paper.

THIS QUESTION PAPER CONSISTS OF 4 PAGES (Including this front page)

Question 1 **[11]**

1.1 Water is an important solvent in hydrometallurgy.

a) Explain why water at normal temperatures is a good solvent for ionic substances. (2)

b) Explain why and how the solvation properties of water changes with an increase in temperature. (2)

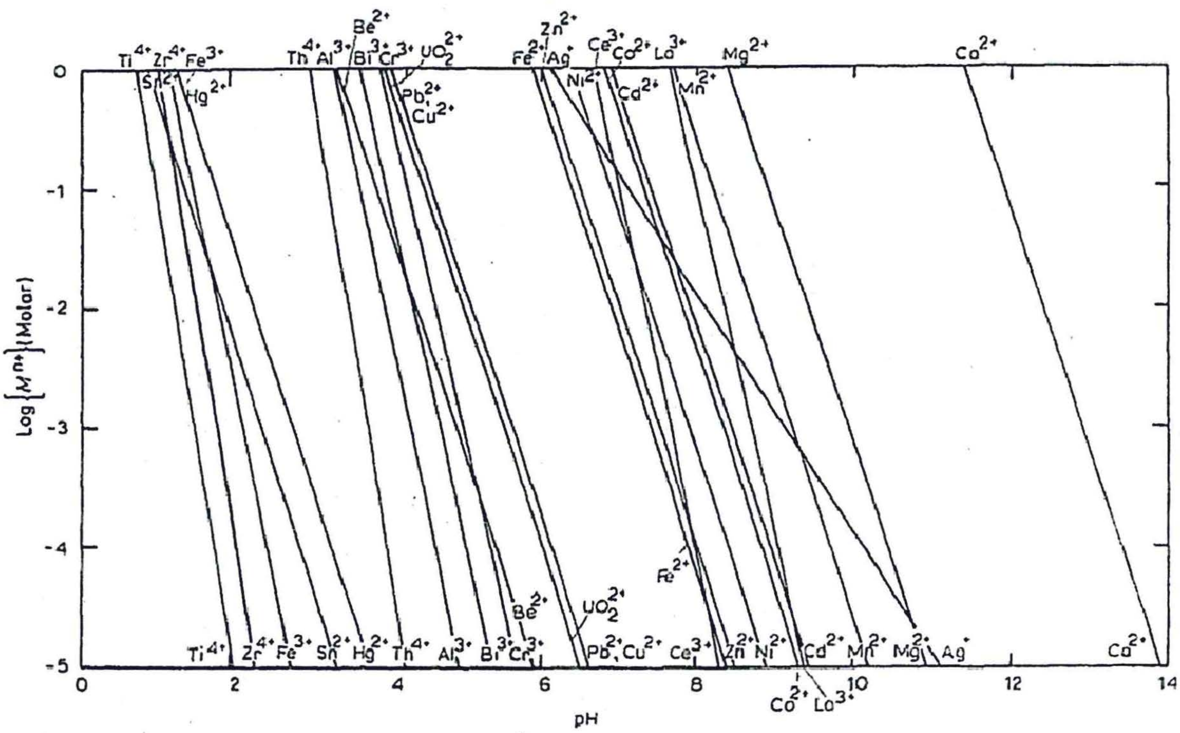
c) Briefly explain the difference between hydration and hydrolysis. (2)

d) Explain how water is different from other chemical liquids. (2)

1.2 The standard process for zinc sulphide extraction follows the 'Roast-leach-electrowinning' route. However, there is an available leaching method that is used in zinc extraction industries today. Briefly describe this leaching procedure. (3)

Question 2 **[8]**

Using the precipitation diagram below, answer the following questions.



a) Discuss how you would separate silver(I) ions from the solution containing magnesium(II) ions. (4)

b) From the diagram, why do the lines for +3 ions have a different gradient than those for +2 ions? (4)

Question 3 **[13]**

A preliminary process design is required for the electrowinning of copper from strip solutions produced by solvent extraction. As shown below, the pregnant strip liquor will be produced at a rate of 100 m^3/h and will contain 63.6 g/dm^3 of copper in a sulphate solution. The composition of the desired spent electrolyte is shown.

Calculate,

a) The daily rate of production of copper. (3)

b) The required acid concentration in the pregnant strip liquor. What assumptions have you made in these calculations? (10)

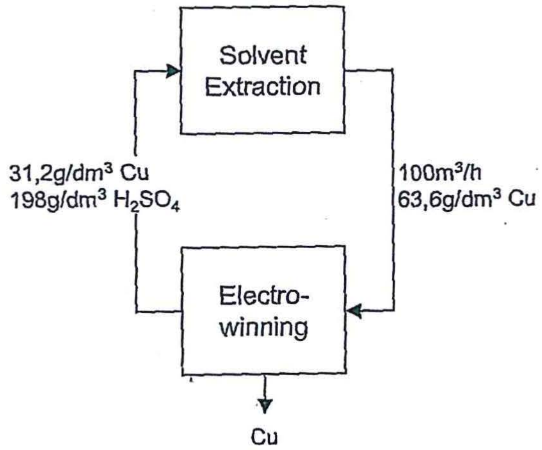


Figure 1. The solvent extraction and electrowinning circuit

Question 4 **[12]**

Skorpion Zinc (SZ) is one of the mines in Namibia that processes zinc and since its start till about 2019, SZ processed the orebody as explored. Answer the following questions on zinc extraction at SZ.

a) Skorpion zinc ore is a unique orebody and could not be processed using traditional zinc extraction routes. Explain why. (4)

b) What is SZ ore deposit? (1)

c) Given the SZ unique orebody, how would you effectively and efficiently leach such ore deposit? (5)

d) Write the balanced equation of leaching zinc silicate ore with sulphuric acid. (2)

Question 5 [9]

5.1 Discuss the advantages of roasting copper sulphide ores followed by acid leaching of the calcine. (5)

5.2 The technologies of copper hydrometallurgy for treating copper oxide and sulphide ore and concentrates are continuously developing and expanding. Briefly discuss the key drivers for this development around SX-EW route of copper processing. (4)

Question 6 [10]

You are given a project to leach a copper sulphide ore from a newly explored mine site. The mine stakeholders are unclear of the importance of doing mineralogical analysis before leaching begins as they want the leaching process to commence immediately. Briefly discuss the importance of mineralogy to present to the stakeholders.

Question 7 [12]

In an electrolysis device, an external direct – current supply is connected to two platinum electrodes immersed in a 1.0 M $CuSO_{4\ (aq)}$ solution at 25^{0}C. As the cell runs, copper metal is deposited onto one electrode and $O_{2(g)}$ is produced at the other electrode.

a) Sketch this cell and label the anode and cathode electrodes, also the direction of the flow of electrons. (4)

b) Write the balanced net ionic equation of the overall electrolysis reaction that occurs in the cell. (2)

c) Determine the Gibbs free energy for this reaction. (3)

d) An electric current of 1.50 amps passes through the cell for 40 Minutes. Calculate the mass in grams of the $Cu_{(s)}$ that is deposited on the electrode. (3)

Table 1: Standard reduction potential

Reduction Half-Reaction	Standard Reduction Potential (V)
$F_2(g)+2e^- \rightarrow 2F^-(aq)$	+2.87
$S_2O_8^{2-}(aq)+2e^- \rightarrow 2SO_4^{2-}(aq)$	+2.01
$O_2(g)+4H^+(aq)+4e^- \rightarrow 2H_2O(l)$	+1.23
$Br_2(l)+2e^- \rightarrow 2Br^-(aq)$	+1.09
$Ag^+(aq)+e^- \rightarrow Ag(s)$	+0.80
$Fe^{3+}(aq)+e^- \rightarrow Fe^{2+}(aq)$	+0.77
$I_2(l)+2e^- \rightarrow 2I^-(aq)$	+0.54
$Cu^{2+}(aq)+2e^- \rightarrow Cu(s)$	+0.34
$Sn^{4+}(aq)+2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$S(s)+2H^+(aq)+2e^- \rightarrow H_2S(g)$	+0.14
$2H^+(aq)+2e^- \rightarrow H_2(g)$	**0.00**
$Sn^{2+}(aq)+2e^- \rightarrow Sn(g)$	-0.14
$V^{3+}(aq)+e^- \rightarrow V^{2+}(aq)$	-0.26
$Fe^{2+}(aq)+2e^- \rightarrow Fe(s)$	-0.44
$Cr^{3+}(aq)+3e^- \rightarrow Cr(s)$	-0.74
$Zn^{2+}(aq)+2e^- \rightarrow Zn(s)$	-0.76
$Mn^{2+}(aq)+2e^- \rightarrow Mn(s)$	-1.18
$Na^+(aq)+e^- \rightarrow Na(s)$	-2.71
$Li^+(aq)+e^- \rightarrow Li(s)$	-3.04

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											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
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 (272)	112 (277)	113	114				

58 **Ce** Cerium 140.116	59 **Pr** Prascodymium 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)

1995 IUPAC masses and Approved Names from http://www.chem.qmw.ac.uk/iupac/AtWt/
masses for 107-111 from C&EN, March 13, 1995, p. 35
112 from http://www.gsi.de/z112e.html