NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

DEPARTMENT OF CIVIL, MINING AND PROCESS ENGINEERING

QUALIFICATION: BACHELOR OF ENGINEERING IN METALLURGY	
QUALIFICATION CODE: 08BMET	LEVEL: 8
COURSE CODE: HMY720S	COURSE NAME: HYDROMETALLURGY 324
SESSION: NOVEMBER 2022	PAPER: 1
DURATION: 90 MINUTES	MARKS: 50

SECOND OPPORTUNITY QUESTION PAPER	
EXAMINER(S)	Prof D Groot
MODERATOR:	Dr T Coetsee, University of Pretoria

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

PERMISSIBLE MATERIALS

1. Examination paper.
2. Scientific calculator, non-programmable

THIS QUESTION PAPER CONSISTS OF 5 PAGES (Including this front page)

Question 1

Consider a Sherritt-type cobalt refinery as shown below.

(a) Explain the chemical principles used to separate nickel from cobalt in this flowsheet, and why it is necessary as the hydrogen reduction step is selective. [5]

(b) Draw a modified flowsheet to recover the cobalt as cathode. [3]

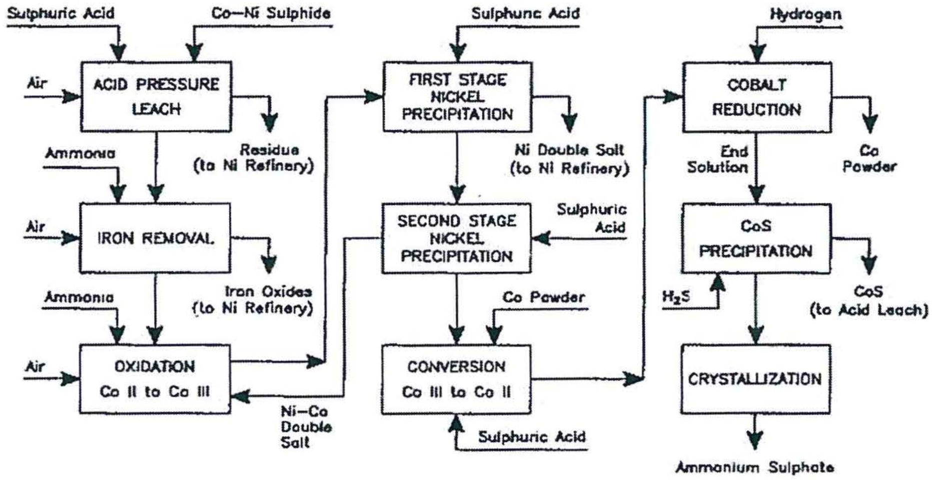

Figure 10. Sherritt Cobalt Refinery Flowsheet

Question 2

The 4f (lanthanides) and 5f (actinides) elements differ considerably in their chemistries. The chemistry of both periods of elements also differs much from the transition metals.

(a) Discuss how the 4f and 5f elements generally differ in terms of their coordination chemistry. [3]

(b) Discuss how the ability of the 5f elements to form unusual complex ions (as compared to transition metals) is used in the extraction of uranium from its ores. [5]

Question 3

Discuss the factors that affect the morphology (i.e. what the deposit looks like) of copper electrodeposits. [8]

Question 4

Nickel ores are found as sulfides and as laterites.

(a) Describe the operation of the Moa Bay process for laterite ores. [5]

(b) Briefly discuss how the environmental impact of this plant could be reduced. [2]

Question 5

Consider a typical hydrometallurgical plant.

(a) Explain why a series of stirred tank reactors are used, instead of a single, large reactor with the same retention time. [3]

(b) Would a number of parallel stirred tank reactors (same number, same retention time) have the efficiency as a series? Explain your answer. [2]

(c) Explain how a stirred tank reactor on a plant differs from a CSTR. [3]

(d) Discuss how the difference in performance between a real reactor and a CSTR can be dealt with during plant design. [6]

Question 6

You wish to model the dissolution kinetics of calcium oxide particles in a 0.01 mol/l solution of hydrochloric acid. The particles are +10 -72 micron. A number of experiments are done at various temperatures and stirring rates. It is found that the measured rate is fairly insensitive to the temperature, but varies greatly with stirring.

Calculate the expected time for the dissolution of all particles. [5]

Given: density of calcium oxide: 3.34 g/cm^3; diffusion coefficient: 7.93 x 10^{-4} cm^2/s at 20 deg; solubility of the reaction product is 74.5 g/100 ml (20 °C).

Given information

See following pages (2).

Table 25.1 Conversion-Time Expressions for Various Shapes of Particles, Shrinking-Core Model

		Film Diffusion Controls	Ash Diffusion Controls	Reaction Controls
Constant Size Particles	**Flat plate** $X_B = 1 - \frac{1}{L}$ L = half thickness	$\frac{t}{\tau} = X_B$ $\tau = \frac{\rho_B L}{b k_g C_{Ag}}$	$\frac{t}{\tau} = X_B^2$ $\tau = \frac{\rho_B L^2}{2b \mathscr{D}_e C_{Ag}}$	$\frac{t}{\tau} = X_B$ $\tau = \frac{\rho_B L}{b k'' C_{Ag}}$
	Cylinder $X_B = 1 - \left(\frac{r_c}{R}\right)^2$	$\frac{t}{\tau} = X_B$ $\tau = \frac{\rho_B R}{2b k_g C_{Ag}}$	$\frac{t}{\tau} = X_B + (1 - X_B)\ln(1 - X_B)$ $\tau = \frac{\rho_B R^2}{4b \mathscr{D}_e C_{Ag}}$	$\frac{t}{\tau} = 1 - (1 - X_B)^{1/2}$ $\tau = \frac{\rho_B R}{b k'' C_{Ag}}$
	Sphere $X_B = 1 - \left(\frac{r_c}{R}\right)^3$	$\frac{t}{\tau} = X_B$ **(11)** $\tau = \frac{\rho_B R}{3b k_g C_{Ag}}$ **(10)**	$\frac{t}{\tau} = 1 - 3(1 - X_B)^{2/3} + 2(1 - X_B)$ **(18)** $\tau = \frac{\rho_B R^2}{6b \mathscr{D}_e C_{Ag}}$ **(17)**	$\frac{t}{\tau} = 1 - (1 - X_B)^{1/3}$ **(23)** $\tau = \frac{\rho_B R}{b k'' C_{Ag}}$ **(22)**
Shrinking Sphere	**Small particle** Stokes regime	$\frac{t}{\tau} = 1 - (1 - X_B)^{2/3}$ **(30)** $\tau = \frac{\rho_B R_0^2}{2b \mathscr{D} C_{Ag}}$ **(29)**	Not applicable	$\frac{t}{\tau} = 1 - (1 - X_B)^{1/3}$ $\tau = \frac{\rho_B R_0}{b k'' C_{Ag}}$
	Large particle (u = constant)	$\frac{t}{\tau} = 1 - (1 - X_B)^{1/2}$ **(31)** $\tau = (\text{const}) \frac{R_0^{3/2}}{C_{Ag}}$	Not applicable	$\frac{t}{\tau} = 1 - (1 - X_B)^{1/3}$ $\tau = \frac{\rho_B R}{b k'' C_{Ag}}$

Periodic Table of the Elements

Atomic Number
Symbol
Name
Atomic Mass

1 IA 1A	2 IIA 2A	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8	9 VIII 8	10	11 IB 1B	12 IIB 2B	13 IIIA 3A	14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 84.798
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [278]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]

Lanthanide Series	57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
Actinide Series	89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]