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: 3 HOURS	MARKS: 100

FIRST 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 6 PAGES (Including this front page)

Question 1

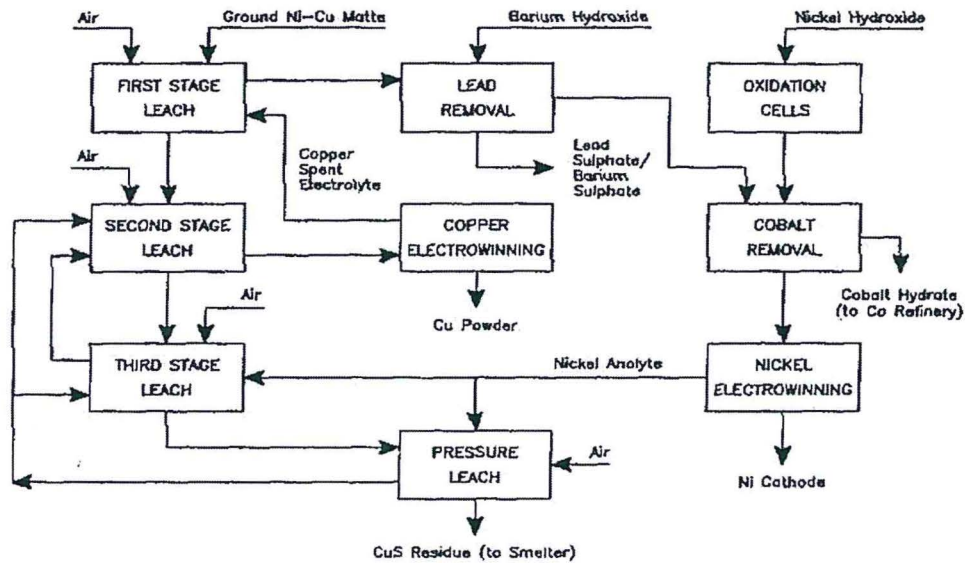Consider the Outokumpu nickel refinery flowsheet.

Figure 4. Outokumpu Harjavalta Nickel Refinery Flowsheet

(a) Comment on the suitability of the Outokumpu nickel refinery flowsheet for processing the feed composition shown in the table below. This feed composition is close to the standard base metal matte feed.   [6]

(b) What changes would you make to the standard Outokumpu flowsheet to produce better quality copper? Be specific about the proposed changes and state reasons for your changes.
                                                                          [3]

(c) Write a balanced chemical reaction for the Cobalt Removal stage.   [2]

(d) Focussing on the main issues, write brief notes on the Safety, Health and Environmental aspects of your modified flowsheet.   [5]

(e) Electrowinning is done using a specific current density at the cathodes. Briefly discuss the advantages and disadvantages of using a lower than normal current density, and a higher than normal current density.   [4]

(f) If you wished to model the leaching kinetics, would you use a shrinking particle or a shrinking core model? Explain your answer.   [4]

PGM	5%
Ni	55 – 70%
Cu	25 – 30%
Co	0.6%
Fe	0.3%
S	6%

Question 2

The 4f elements play an important role in modern electrical motors and generators, while some 5f elements are important in power generation.

(a) Give an outline of how the individual 4f elements are produced from a mineral concentrate such as monazite. [8]

(b) What Safety, Health and Environmental precautions would have to be taken in the process outlined in (b)? See a typical elemental analysis in the table: [5]

	Monazite concentrate, %
P_2O_5	24-29
Ln_2O_3	55-65
ThO_2	5-10
U_3O_8	0.2-0.4
SiO_2	1-3
CaO	0.2-0.8
Fe_2O_3	1-2
Al_2O_3	0.1-0.8
ZrO_2	0.7

(c) Discuss the roles that iron and acid play in the acid leaching process of uraninite. Write suitable, balanced chemical reactions to supplement your discussion. [5]

Question 3

The typical pyrometallurgical production of copper results in impure (blister) copper. Anodes are cast from the blister copper, and these are electrorefined to produce marketable copper.

(a) Discuss the effects of mass transfer at the electrodes. [8]

(b) Discuss the role of electrolyte additives. [7]

(c) Discuss the typical methods used in the tankhouse to prevent the build-up of nickel in the copper electrolyte. [4]

Question 4

The chemistries of nickel and cobalt are very similar, yet their electrowinning processes generally differ.

(a) Discuss why nickel is generally electrowon in divided electrochemical cells, yet cobalt is normally electrowon in undivided cells. [2]

(b) Describe the operation of a nickel divided cell. [6]

(c) What are the disadvantages of using divided cells? [2]

Question 5

Various types of reactors are used in the metallurgical industry: leach and CIP reactors, flotation cells, autoclaves, etc.

(a) Explain how laboratory testwork can be used to estimate the retention time for a series of equally sized CSTR's on a plant. [5]

(b) A leaching plant needs to be designed to process a cobalt ore. In a laboratory test a sample of the milled ore was stirred in a beaker with the required reagents. It was found that after an hour, 91% of the ore had been leached. However, at least 97% leach efficiency is desired. What retention time would be needed for a series of three stirred tank reactors? State your assumptions. [6]

(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

A sample of xenotime ore was reacted with a hot, concentrated solution of NaOH. The leach resulted in a solution containing sodium phosphate and a slurry containing the lanthanide values.

(a) For the same leaching efficiency, how much longer would you expect the leaching time to be if the particle size was doubled? State your assumptions. [5]

(b) Could the leaching time be shortened by using a higher temperature or increasing the stirring rate? Explain your answer and state your assumptions. [4]

Given information

See following pages (2).

$$k\tau = N[\{\frac{1}{1-XA}\}^{1/N} - 1]$$

$$X_A = 1 - \{\frac{1}{(1+k\tau/N)^N}\}$$

First-order reaction

$$1 - X_A = \frac{C_A}{C_{A0}}$$

$$\frac{(C_{A0}V/F_{A0})_{N\ reactors}}{(C_{A0}V/F_{A0})_{plug}} = \frac{\tau}{\tau_{N=\infty}} = \frac{\tau_p}{N_\tau}$$

$k\tau = 50$

$k\tau = 1$

$N = 1$

$N = 2$

$N = 3$
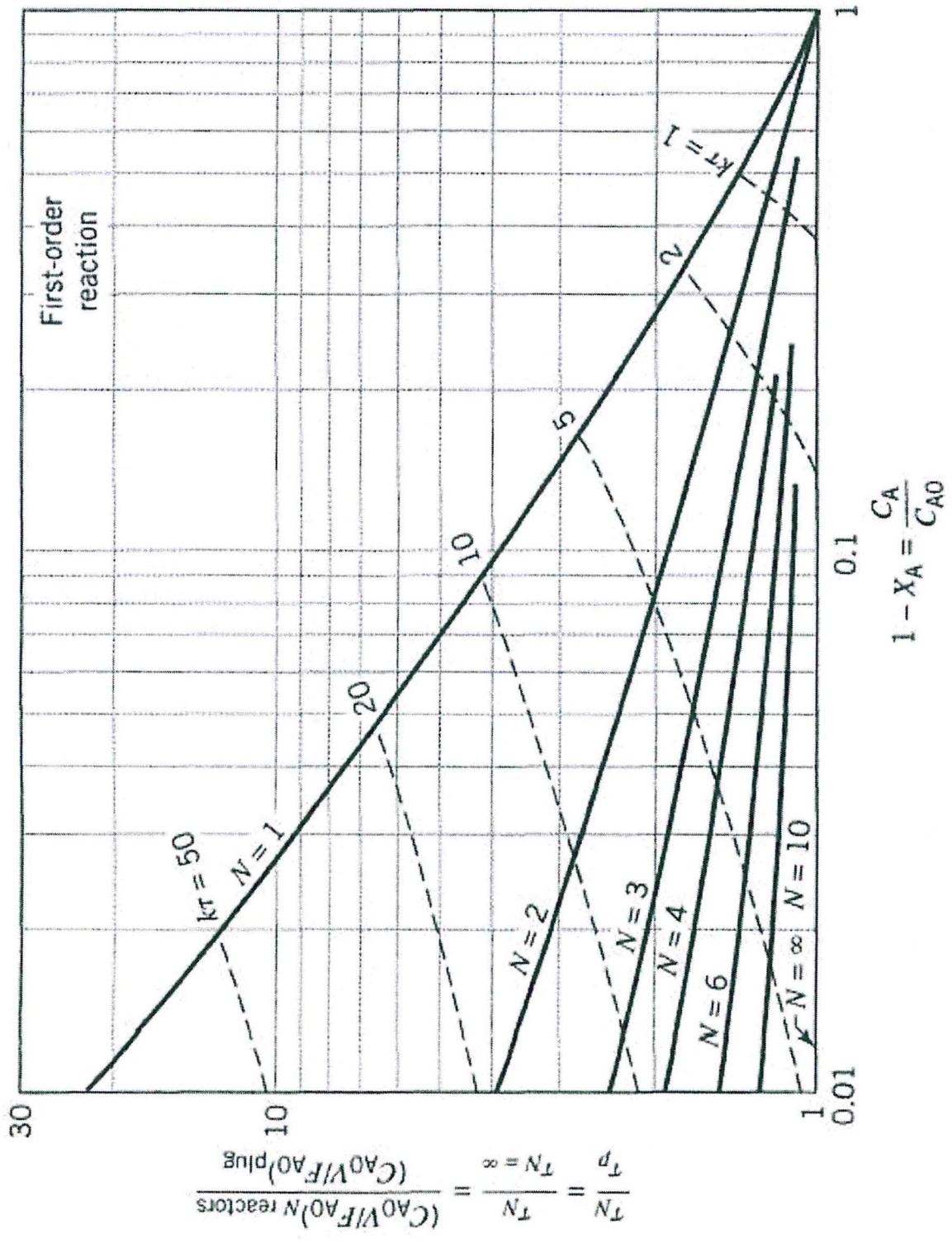
$N = 4$

$N = 6$

$N = 10$

$N = \infty$

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