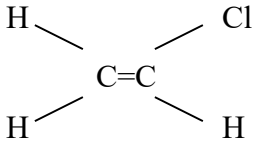
UNIVERSITY OF LAGOS
DEPARTMENT OF CHEMICAL AND PETROLEUM ENGINEERING
2024/2025 SESSION
CHG 432: PRINCIPLES OF PLANT DESIGN I
ASSIGNMENTS

1. In the generation of possible designs, the design exercise is the identification of the various ways of meeting the design objective, analysing and evaluating them for the selection step. It is desired to produce vinyl chloride,



a monomer intermediate for the production of polyvinyl chloride. Some reaction paths have been identified as follows:

(i) $C_2H_4 + Cl_2 \longrightarrow C_2H_3Cl + HCl$

(ii) $C_2H_2 + HCl \longrightarrow C_2H_3Cl$

(iii) $C_2H_4 + Cl_2 \longrightarrow C_2H_4Cl_2$

$C_2H_4Cl_2 \longrightarrow C_2H_3Cl + HCl$

$C_2H_4 + Cl_2 \longrightarrow C_2H_3Cl + HCl$

(iv) $C_2H_4 + 2HCl + \frac{1}{2}O_2 \longrightarrow C_2H_4Cl_2 + H_2O$

$C_2H_4Cl_2 \longrightarrow C_2H_3Cl + HCl$

$C_2H_4 + HCl + \frac{1}{2}O_2 \longrightarrow C_2H_3Cl + H_2O$

(v) $C_2H_4 + Cl_2 \longrightarrow C_2H_4Cl_2$

$C_2H_4 + 2HCl + \frac{1}{2}O_2 \longrightarrow C_2H_4Cl_2 + H_2O$

$2C_2H_4Cl_2 \longrightarrow 2C_2H_3Cl + 2HCl$

$2C_2H_4 + Cl_2 + \frac{1}{2}O_2 \longrightarrow 2C_2H_3Cl + H_2O$

The costs of all the chemicals involved are given below:

CHEMICAL	COST (=N=/KG)
Ethylene	400.00
Acetylene	900.00
Chlorine	300.00
Vinyl chloride	600.00
Hydrogen chloride	400.00
Water	10.00
Oxygen (air)	0.00
Dichloroethane	500.00

(a) By estimating the gross profit in =N=/Kg of vinyl chloride based on the purchase and sales of materials and products respectively, which of the reaction path(s) could be given further consideration in obtaining a final design?

(b) Estimate the quantity of chemicals and products for each promising reaction path on a daily basis, as well as the gross profit per day. Assume a basis of 5,000Kg/hr of vinyl chloride.

(c) Which of the reaction path(s) will you consider as the best or the worst? Explain.

(d) What category of design problem is this? Outline the design sequential steps that are to be followed in order to arrive at a final design.

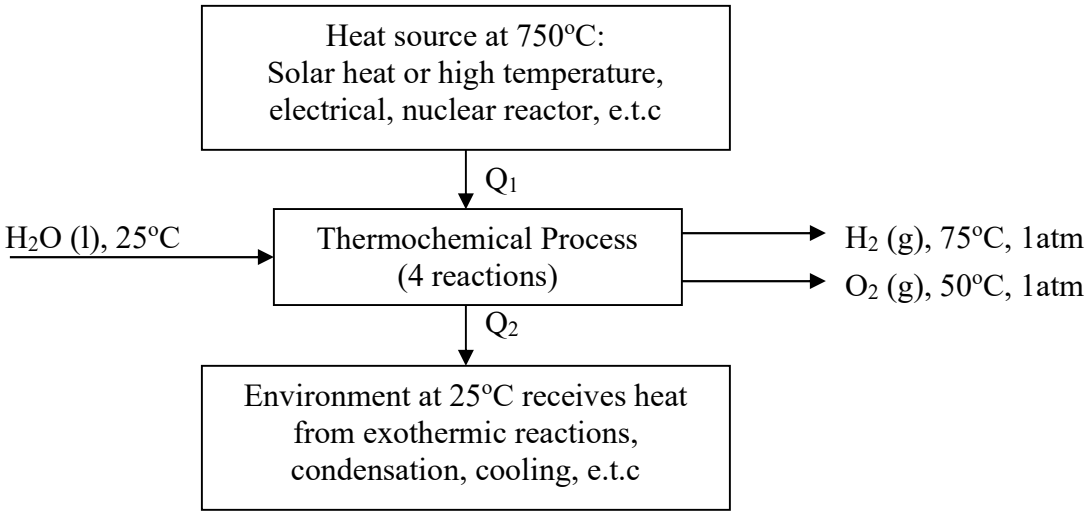
2. Two researchers have proposed a process for the thermochemical production of hydrogen from water according to the following set of reactions:

$$CaBr_2 + 2H_2O = Ca(OH)_2 + 2HBr$$
$$HgO = Hg + \tfrac{1}{2} O_2$$
$$2HBr + Hg = HgBr_2 + H_2$$
$$HgBr_2 + Ca(OH)_2 = CaBr_2 + HgO + H_2O$$

The first two reactions are to be run at high temperature (600 – 730 ºC) and the last two reactions are carried out at lower temperature (200 – 500 ºC). The sum of these four reactions is simply the splitting of water as follows:

$$H_2O = H_2 + \tfrac{1}{2} O_2$$

All the other compounds [$CaBr_2$, $Ca(OH)_2$, HBr, $HgBr_2$, HgO, Hg] are separated and recycled so that the overall process is as shown below:



The purpose of this process is the manufacture of hydrogen to be used as a non-polluting, multipurpose fuel. According to one design of the process, heat rejected to the environment (Q_2) is 2.602 x 10^5 J/Kgmol of water.

(a) What is the heating requirement (Q_1), expressed in KW-hr/Kg of H_2.

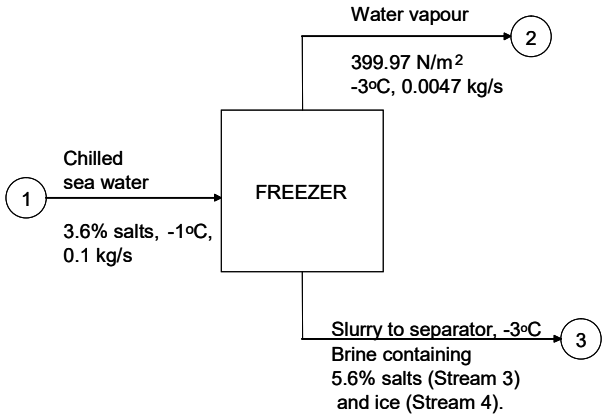
(b) If turbines in a hydroelectric plant are fed by water falling from a height of 30 meters, estimate the Kilogram of water in one hour needed to sustain the power for the thermochemical plant.

Hint: Neglect turbine inefficiency.

Standard heats of formation at 25°C:
H_2O (l) = -68,320 cal
H_2 (g) = 0
O_2 (g) = 0

Average specific heat capacity from 25°C to 75°C:
H_2 (g) = 6.90 cal/mole °K
O_2 (g) = 7.06 cal/mole °K

3. (a) The freezer unit of a vacuum freezing-vapour compression process for the desalination of sea water operates under conditions at steady state. By identifying important process variables and possible constraints, calculate unknown flow rates and rate of absorption of heat from the environment. The freezer unit is shown below.



Hint:

(i) Salt is complex mixture and can be treated as a single substance since its composition does not change.

(ii) The enthalpy change of the salts is small compared to that of water and can be neglected.

Data:

Specific enthalpy of water vapour at $0^oC = 2.50 \times 10^6$ J/kg

Specific enthalpy of ice at $0^oC = -3.33 \times 10^5$ J/kg

Specific enthalpy of liquid water at $0^oC = 0$

Mean specific heat capacity of water vapour from 0^oC to $-3^oC = 1.83 \times 10^3$ J/kg^oC

Mean specific heat capacity of ice from 0^oC to $-3^oC = 2.10 \times 10^3$ J/kg^oC

Mean specific heat capacity of liquid water from 0^oC to $-1^oC = 4.184 \times 10^3$ J/kg^oC

Mean specific heat capacity of liquid water from 0^oC to $-3^oC = 4.184 \times 10^3$ J/kg^oC

4. Present a viability cash flow table for a chemical plant that purchased equipments with $20million through a loan at a bank interest rate of 12%. The project life is expected to be 5years for a 1year moratorium. Company tax and excise duty are 20% and 5% respectively. Sales at the end of the first year is $9million while the expenditure is 1/5 of the sales. It is expected that the income will increase 15% yearly, while the expenditure will increase 10% yearly. Calculate the discounted cash flow rate of return of the plant. Write a simple computer program on how to estimate the DCFR showing every necessary step to achieve this.