

ORDRE DES INGÉNIEURS DU QUÉBEC

MAY 2012 SESSION

Open-book examination
Calculators : only authorized models
Duration : 3 hours

04-Chim-A3 MASS TRANSFER OF RATIONS

QUESTION # 1 - Distillation

By distillation at atmospheric pressure ethanol has to be recovered from its aqueous 20 mol% solution. The solution is fed at a flow rate of 236 kg/h to the column at the bubble point. The distillate must not contain more than 20 mol% water and the residue must not contain more than 5 mol% ethanol. The column is equipped with a total condenser and a partial reboiler. For the distillation the reflux ratio $R = 3R_{min}$ has to be used.

Determine by the method McCabe-Thiele:

- (12 pts) a) The number of theoretical stages needed to achieve desired separation.
(2 pts) b) The optimal position for the column feed.

The equilibrium data are given at the end of the exam.

QUESTION # 2 - Distillation

By distillation at atmospheric pressure 80% of the amount of ethanol present in an aqueous solution having 20 mol% ethanol has to be recovered. The feed of 10kmol/h is introduced to the column at bubble point. The flow rate of the distillate must be 2kmol/h. The column is equipped with a total condenser and a partial reboiler. For the distillation the reflux ratio $R = 3R_{min}$ has to be used.

Determine:

- (2 pts) a) The flow rate and the composition (in mol fraction) of the residue.
- (12 pts) b) By using the method FUG (Fenske – Underwood - Gilliland) the number of theoretical stages of the column.

The equilibrium data are given at the end of the exam.

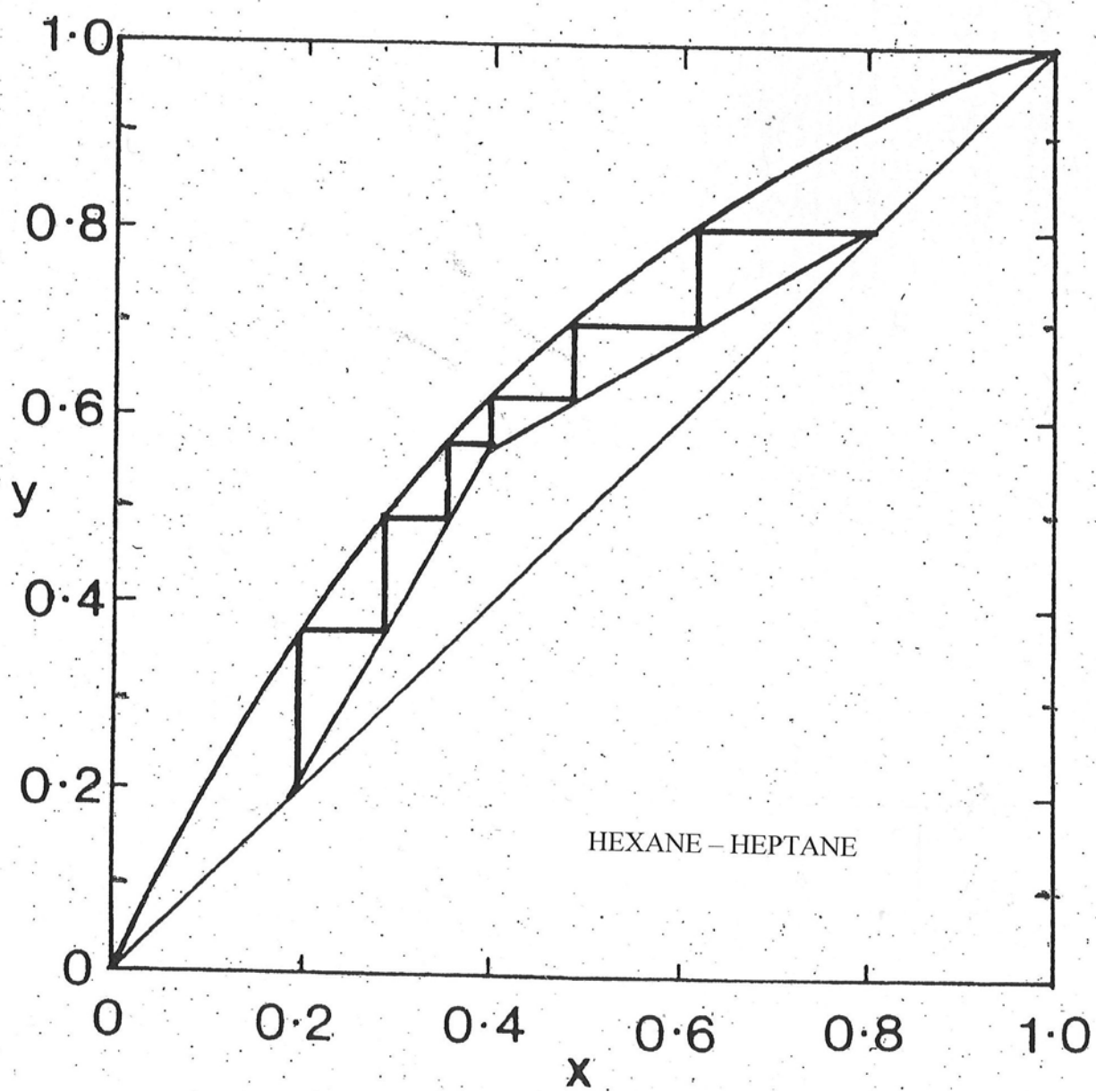
QUESTION # 3 - Equilibrium

The attached Figure represents the results for the distillation at 1 atm of a binary mixture hexane-heptane. The column has to be equipped with a total condenser and a partial reboiler.

Determine:

- (5 pts) a) The temperature of the vapour entering the total condenser;
- (5 pts) b) The temperature in the partial reboiler;
- (2 pts) c) The number of theoretical stages required **for the column**.

The chart of K_i can be found at the end of the exam.



QUESTION # 4 - Absorption

The air containing 1.4mol% of SO₂ is contacted in the packing filled absorption column with water that already contains 0.005mol% SO₂. The total flow rate of the gas (air with the SO₂) is 50mol/s. The air at the exit of the absorption column has to contain only 0.4mol% of SO₂. The equilibrium curve is represented by $y=40x$.

Determine:

- (5 pts) a) The minimum flow rate of water, L_{min} ;
- (6 pts) b) The number of transfer units NOG for a water flow rate: $L = 1.4L_{min}$;
- (5 pts) c) The number of theoretical stages by using the group method (method of Kremser) for the same water flow rate: $L = 1.4L_{min}$.

QUESTION # 5 - Diffusion

Before buying outdoor pool it is reasonable to estimate the cost of water loss by evaporation. For the conditions of a hot day estimation is needed of the water loss from a circular pool having 5m diameter. The average water temperature is 20°C. The average air temperature is 25°C and humidity corresponds to a dew point of 10°C. Assuming that the stagnating gas layer above water is 2 cm and remains constant,

Determine:

- (10 pts) a) The molar flux due to evaporation;
- (2 pts) a) The water loss in litres during 24 h (one day);

Note: $D_{H_2O-air} = 0.256 \text{ cm}^2/\text{s}$.

QUESTION #6 – Liquid-Liquid Extraction

Acetic acid has to be recovered from its mixture with isopropyl ether by extraction with water. The mixture contains 50 wt% of acetic acid.

In the first extraction, 36 kg of mixture is contacted with 50 kg of water.

Determine by using the ternary diagram:

- (8 pts) a) The amounts and compositions of extract and of raffinate.

In the second extraction the raffinate from the first extraction is contacted with 10 kg of water.

Determine by using the ternary diagram :

- (8 pts) b) The acid concentration in the new raffinate.

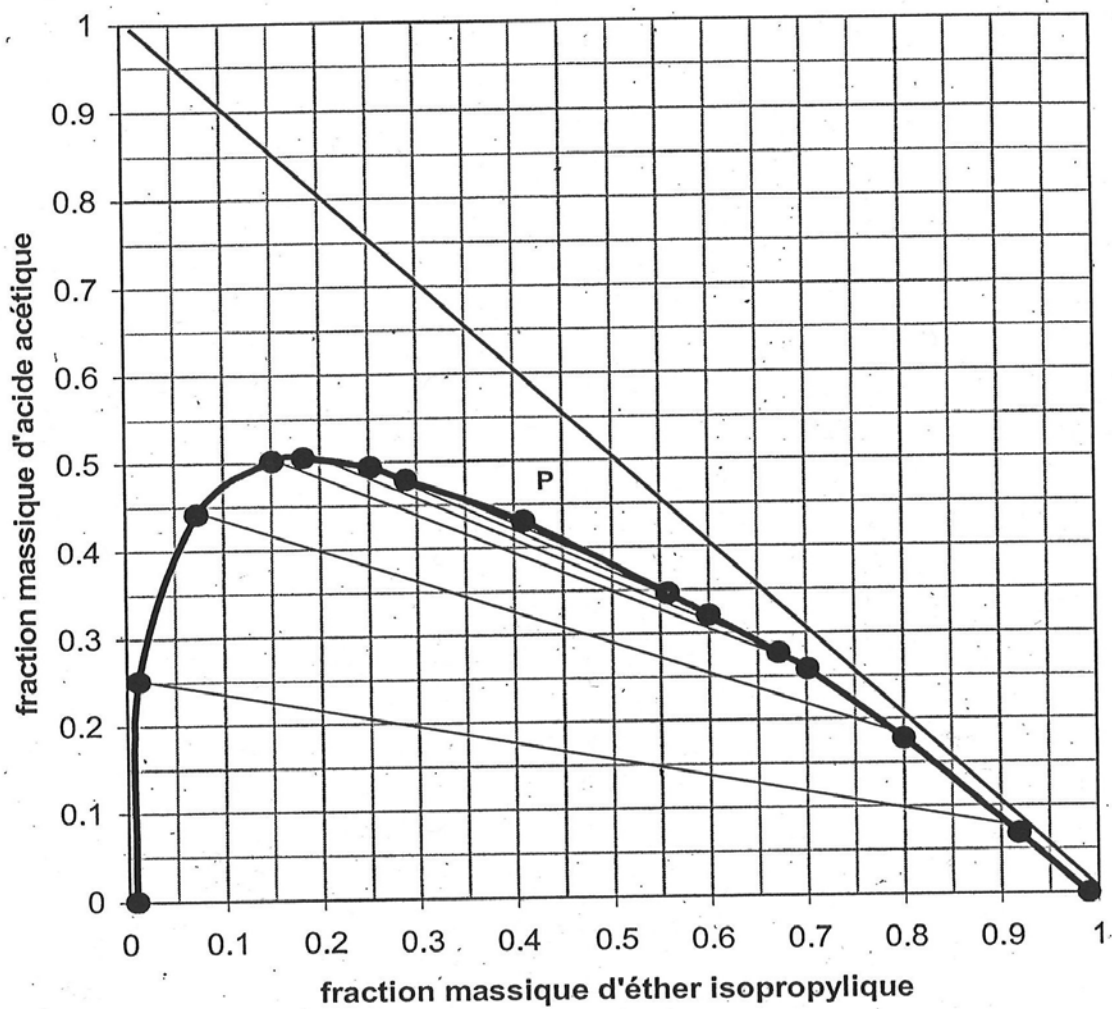


Diagramme ternaire pour le système éther isopropylique- eau- acide acétique à 25 °C et 1 atm

QUESTION #7 - Humidity

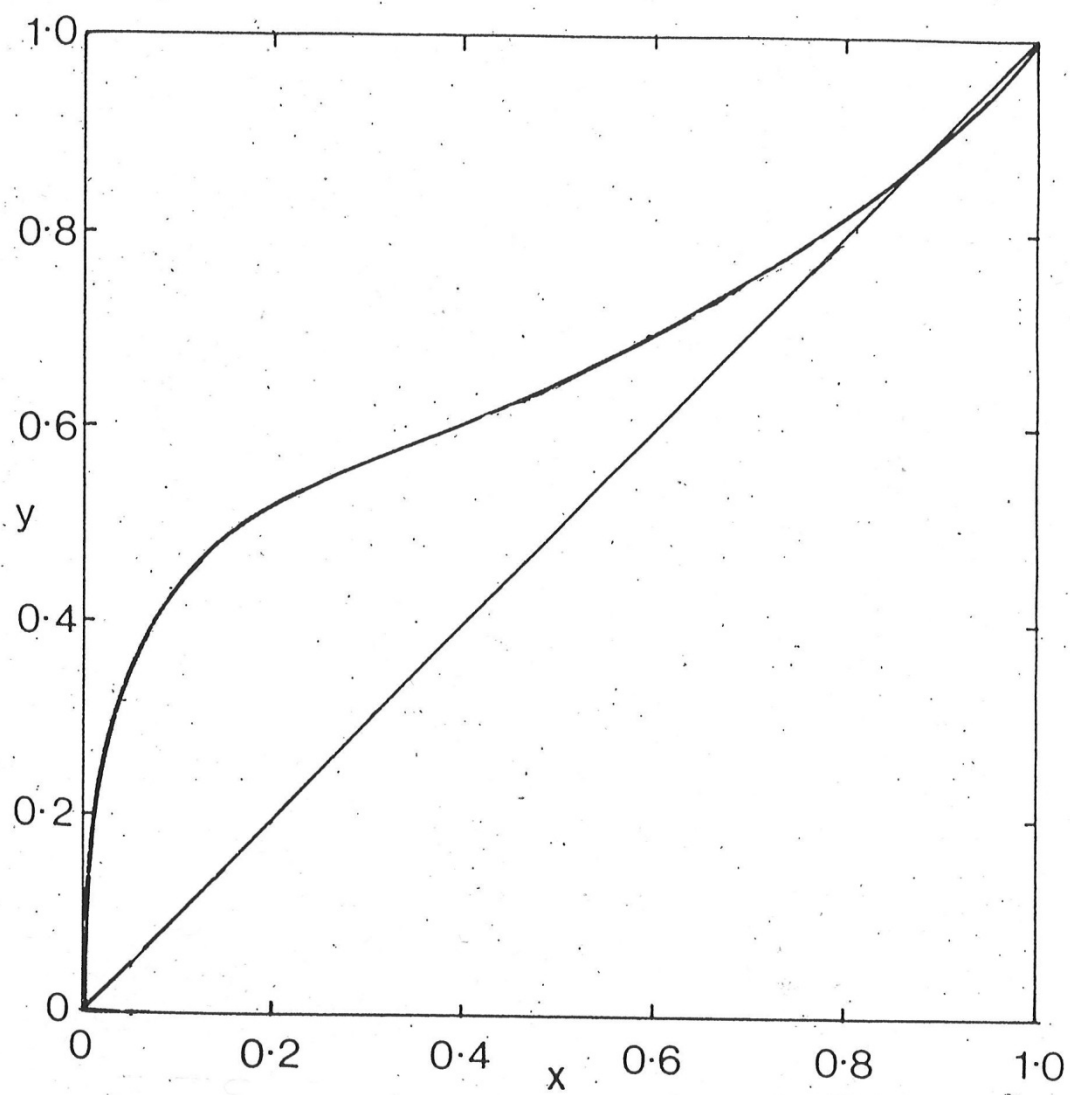
A system has to be designed to remove humidity from air by adsorption on CaSO_4 . The completely dried air is needed for a room housing scientific apparatus. The characteristics of the humid air to be dried are:

- Dry –bulb temperature: 36°C
- Wet-bulb temperature: 21°C

Determine:

- (4 pts)** a) The absolute humidity of the air before the treatment;
- (2 pts)** a) The percentage humidity of the air before the treatment;
- (4 pts)** a) The humid volume of the air before the treatment;
- (6 pts)** a) The amount of solid CaSO_4 needed to adsorb the humidity during 24h if the solid CaSO_4 converts to $\text{CaSO}_4 \cdot 4\text{H}_2\text{O}$ and if the quantity of dry air to be produced is $1 \text{ m}^3(\text{NTP})/\text{min}$.

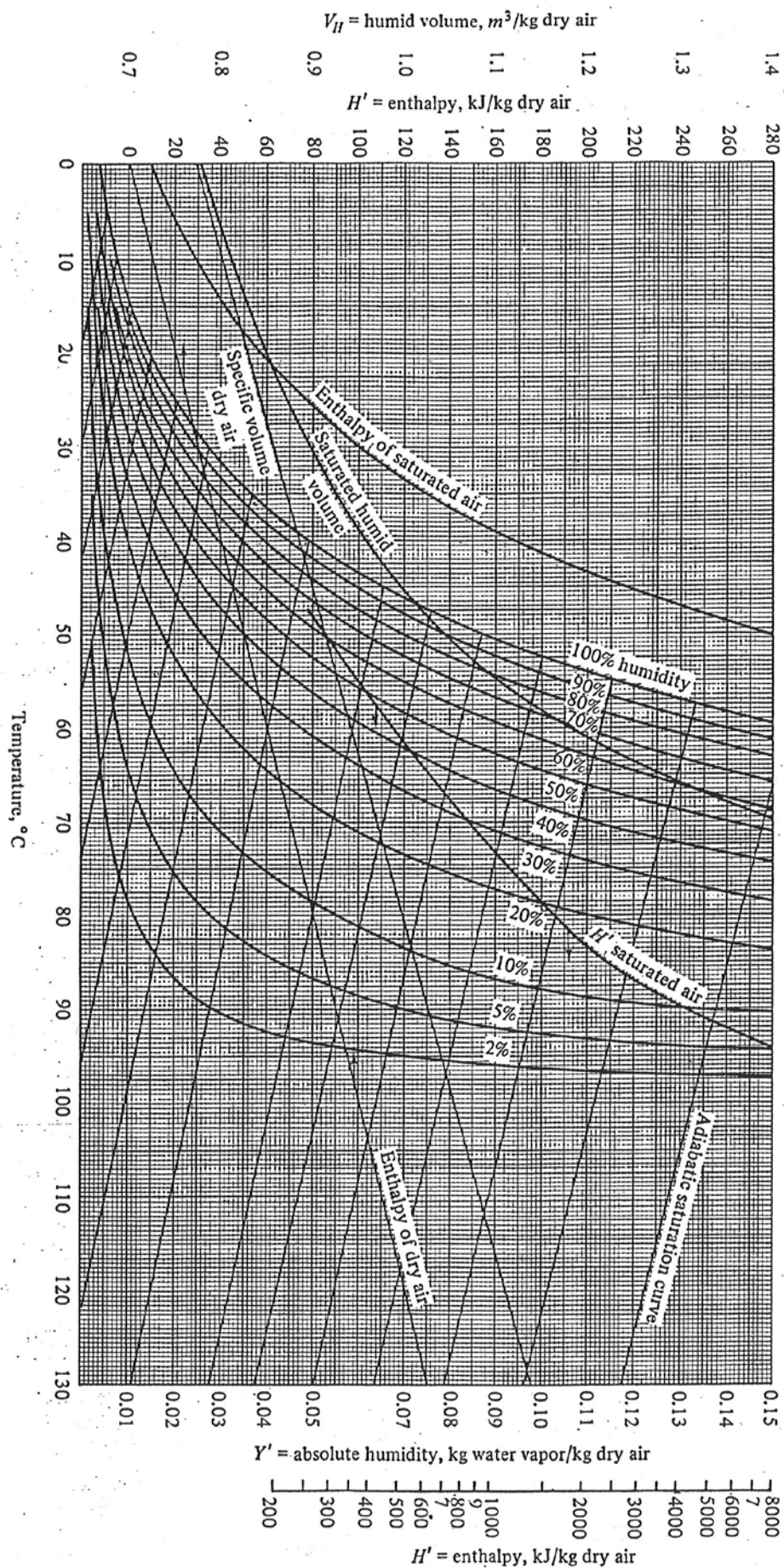
The psychrometric chart is at the end of the exam.

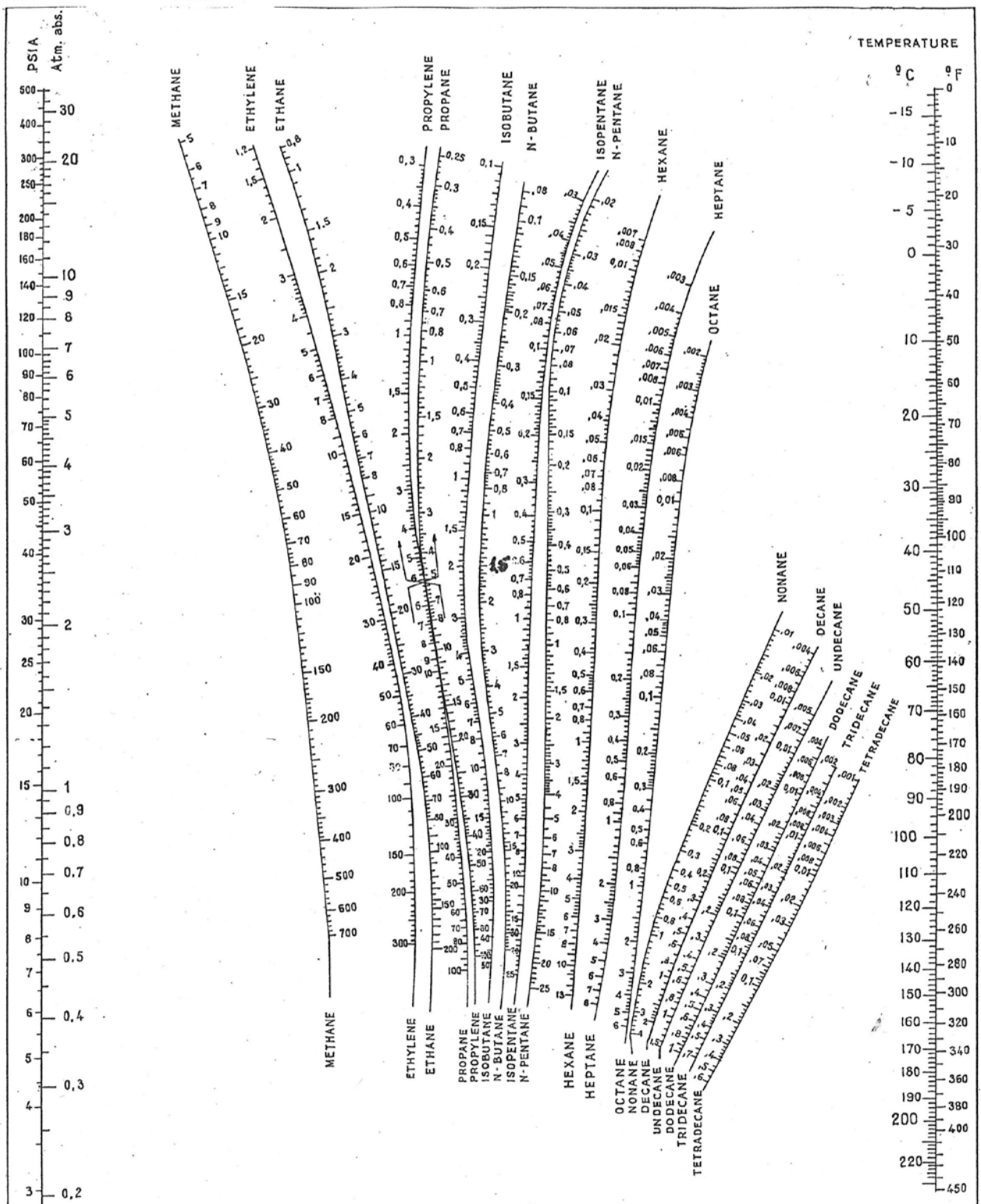


Ethanol – Water ; $P = 101.3 \text{ kPa}$

Psychrometric chart for air-water vapor, 1 std atm abs, in SI units.

(a)





COEFFICIENTS D'EQUILIBRE DES HYDROCARBURES
(Scheibel & Jenny)