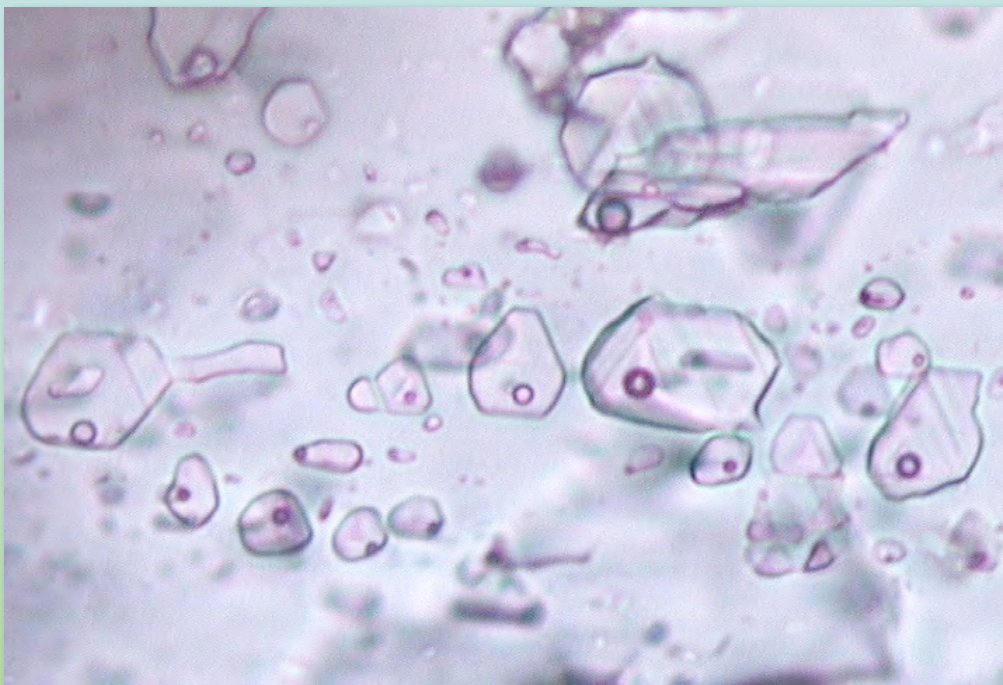


PROPERTIES OF  
RE-EQUILIBRATED HOMOGENEOUS  
FLUID INCLUSION ASSEMBLAGES

*RONALD J. BAKKER*

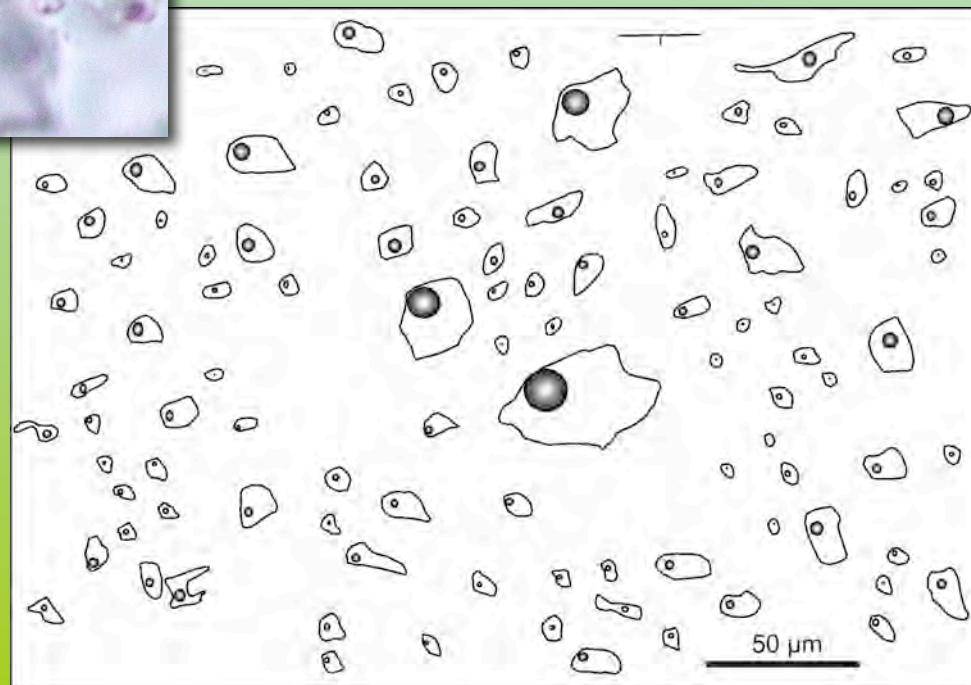
*RESOURCE MINERALOGY  
DEPARTMENT OF APPLIED GEOLOGICAL SCIENCES AND GEOPHYSICS  
UNIVERSITY OF LEOBEN (AUSTRIA)*

# HOMOGENEOUS FLUID INCLUSION ASSEMBLAGE



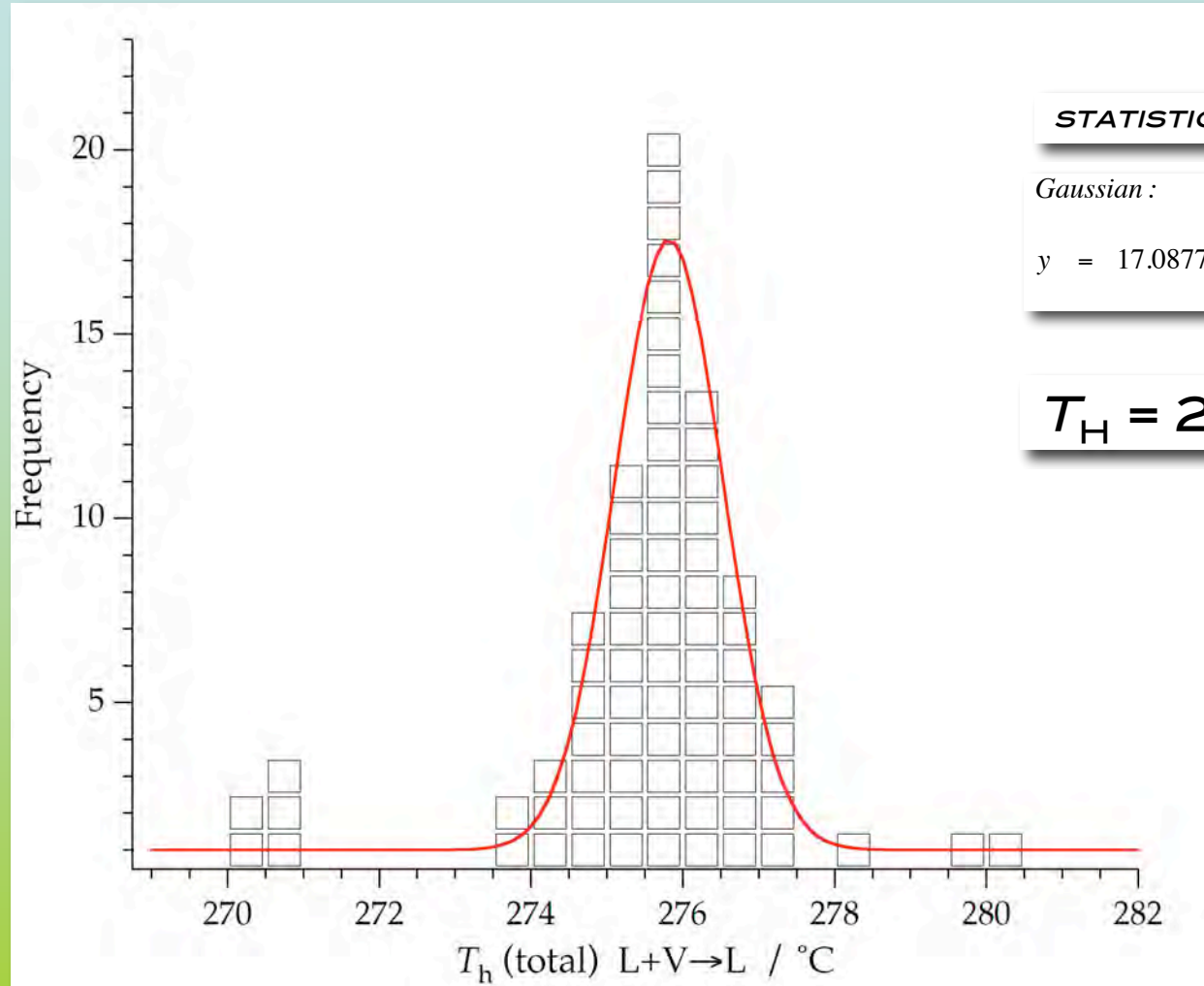
**CALCITE**

**QUARTZ**



# HOMOGENEOUS FLUID INCLUSION ASSEMBLAGE

## EXPECTED HISTOGRAM



### STATISTICAL APPROACH

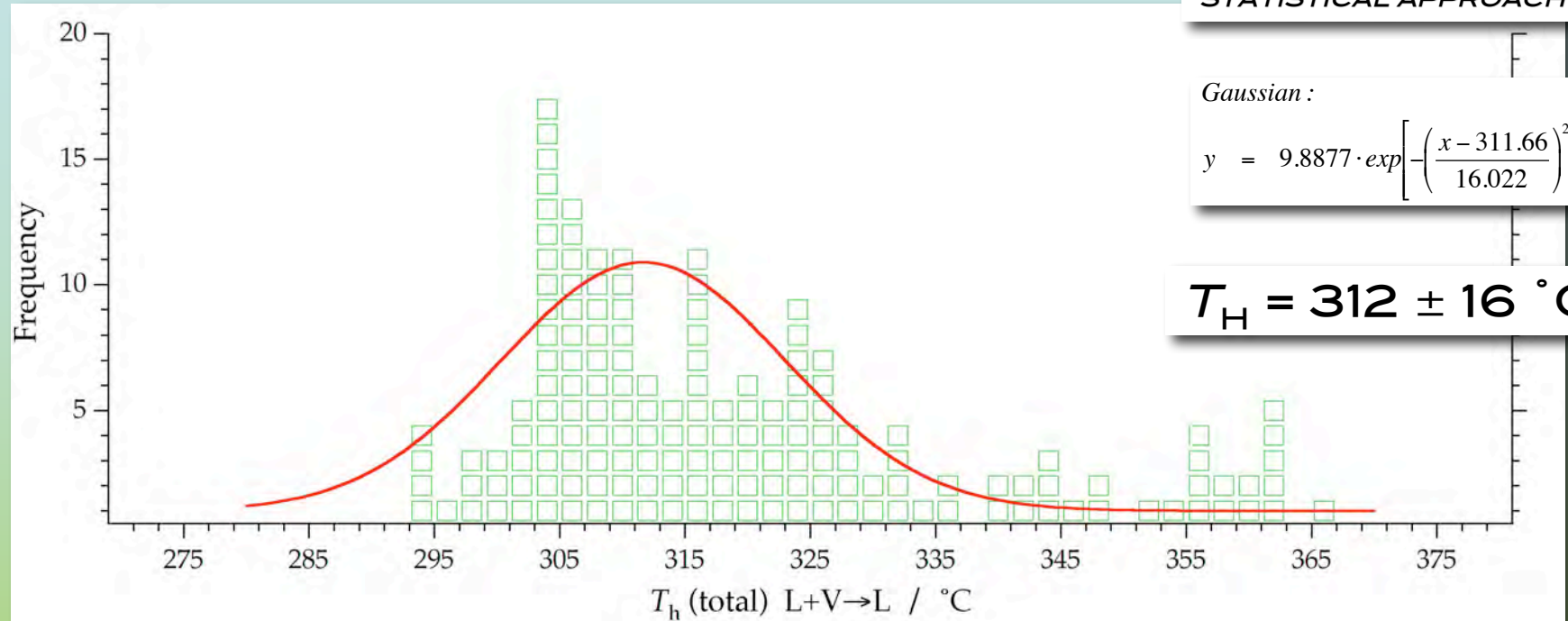
Gaussian :

$$y = 17.0877 \cdot \exp\left[-\left(\frac{x - 275.818}{1.11798}\right)^2\right]$$

$$T_H = 276 \pm 1^\circ \text{C}$$

**SYNTHETIC FLUID INCLUSION ASSEMBLAGE  
NORMAL DISTRIBUTION (GAUSSIAN OR LORENTZIAN)**

# NATURAL SAMPLE



DISTRIBUTION FUNCTIONS ARE NOT APPROPRIATE TO DESCRIBE  $T_H$

- VARIATION:
1. MULTIPLE FIA
  2. VARIATION IN PORE FLUID PROPERTIES
  3. RE-EQUILIBRATION

# RE-EQUILIBRATION PROCESSES

## 1. TOTAL VOLUME CHANGES

MEASURES OF STRAIN:

DILATION =  $\Delta = (V - V_0)/V_0$  (3 DIM)

CONTRACTION = - DILATION

WRONG: STRETCH =  $L/L_0$  (1 DIM)

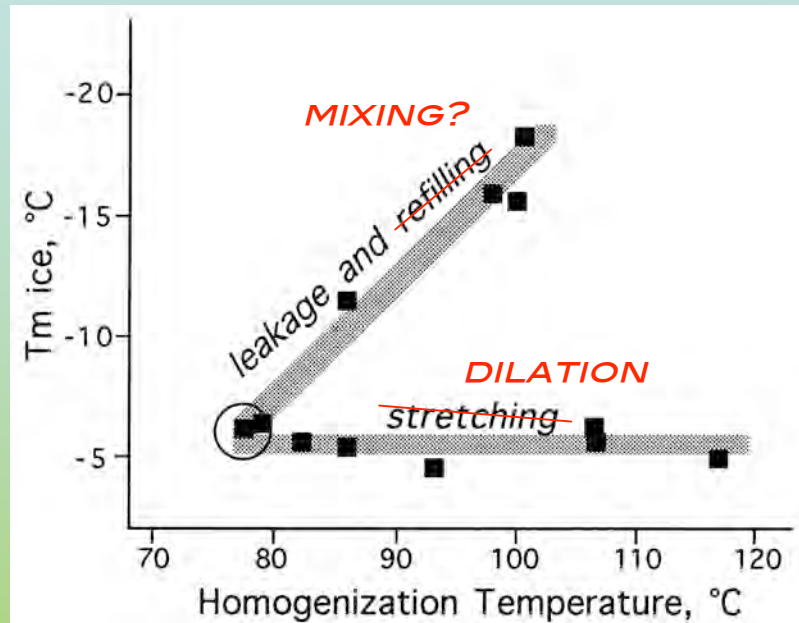
## 2. DIFFUSION OF FLUID COMPONENTS (CHANGES IN AMOUNT OF SUBSTANCE)

## 3. NECKING AFTER PHASE SEPARATION

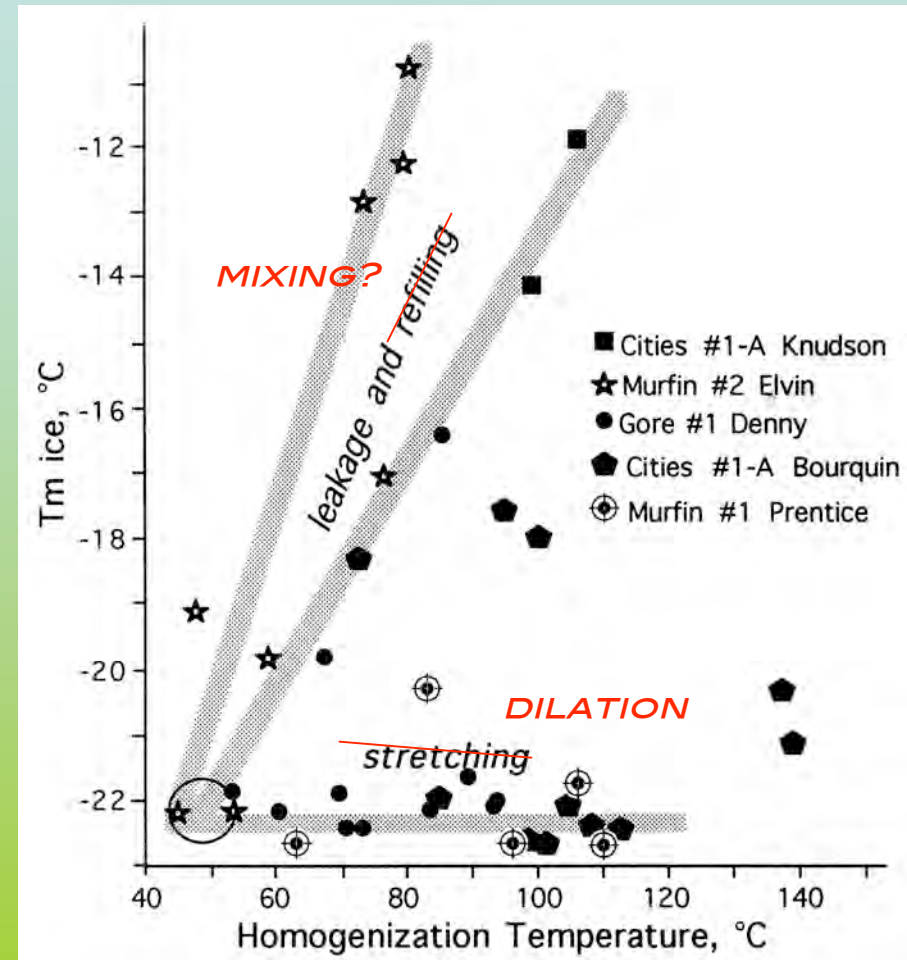
## 4. INCLUSION WALL RECRYSTALLIZATION (CHANGE IN SHAPE, TEXTURE)

# TRENDS MICROTHERMOMETRY FIA

## H<sub>2</sub>O-SALT SYSTEMS



GOLDSTEIN & REYNOLDS (1994)



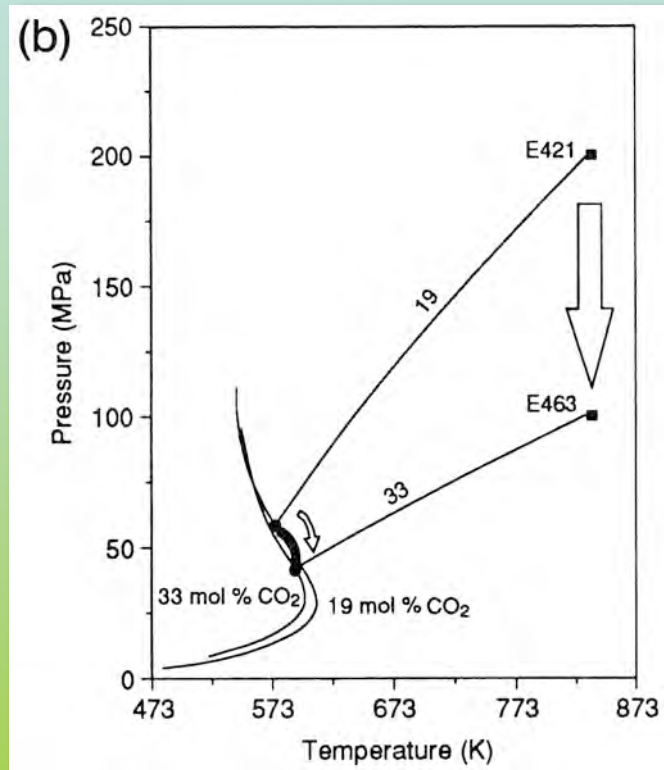
TRENDS:  
NUMBER OF MEASUREMENT



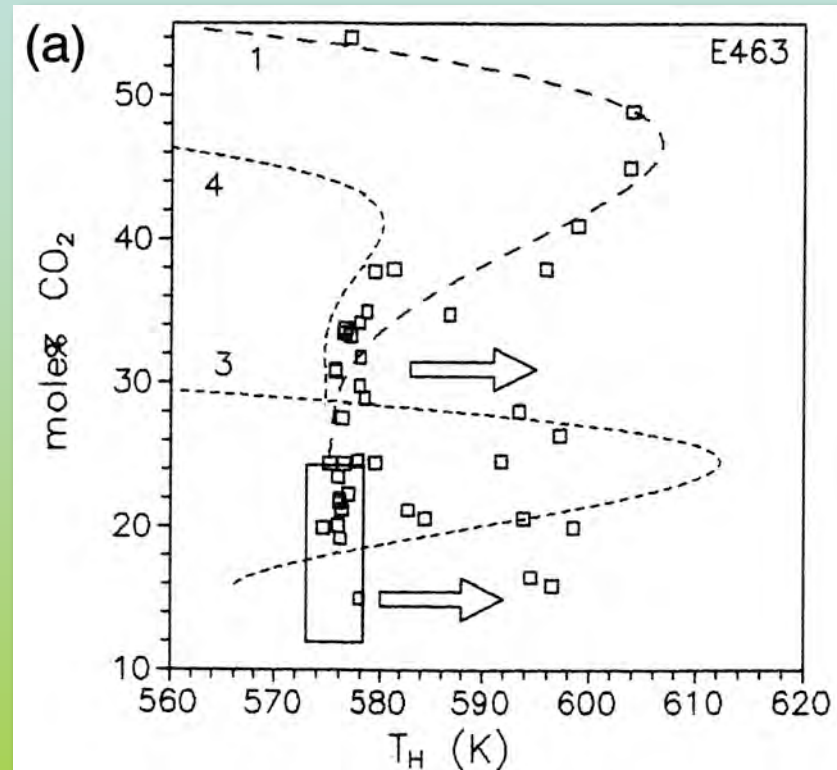
# TRENDS MICROTHERMOMETRY FIA

## H<sub>2</sub>O-CO<sub>2</sub> SYSTEMS

### APPROXIMATE MODELLING (GRAPHICAL INTERPR. OF PHASE DIAGRAMS)



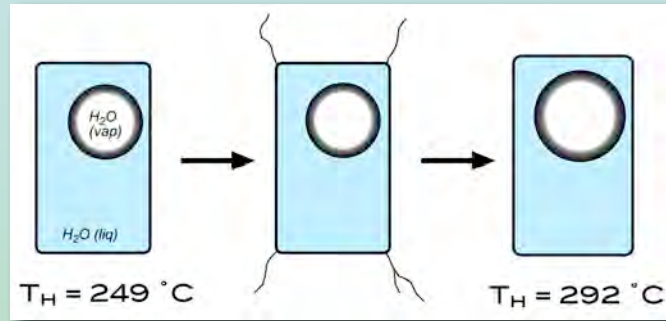
BAKKER & JANSEN (1991)



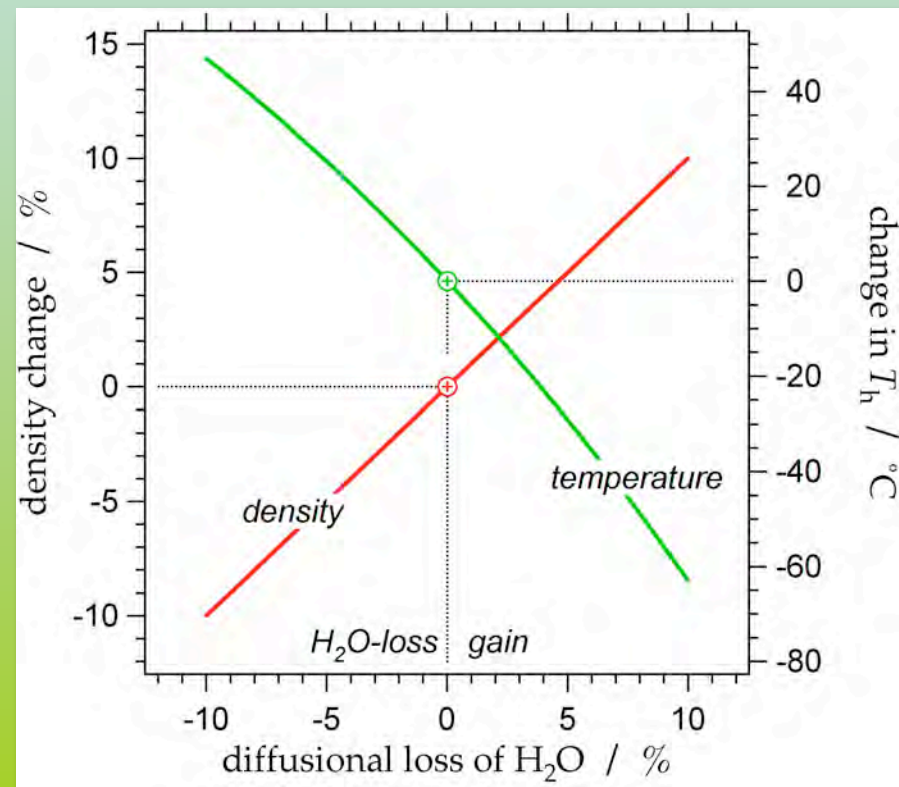
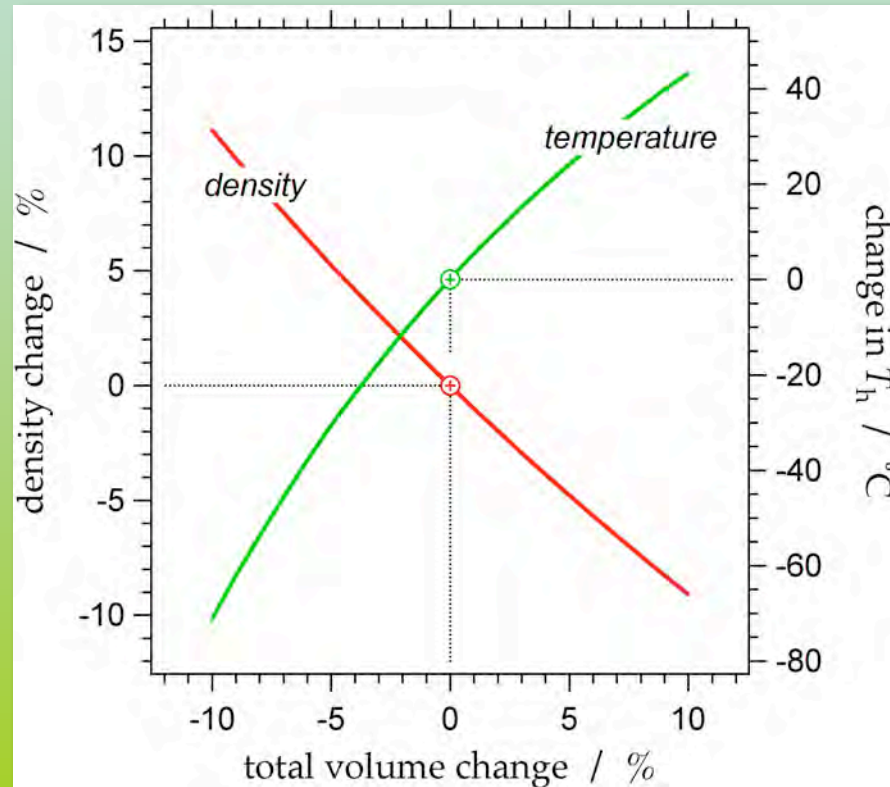
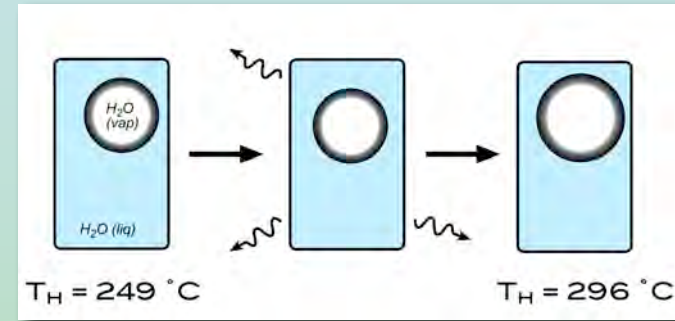
- 1. BEST FIT THROUGH LOWEST  $T_H$  VALUES
- 3, 4. PREFERENTIAL LEAKAGE H<sub>2</sub>O
- HOR. ARROWS = DILATION

# UNARY SYSTEM $\text{H}_2\text{O}$

## VOLUME (DILATION)



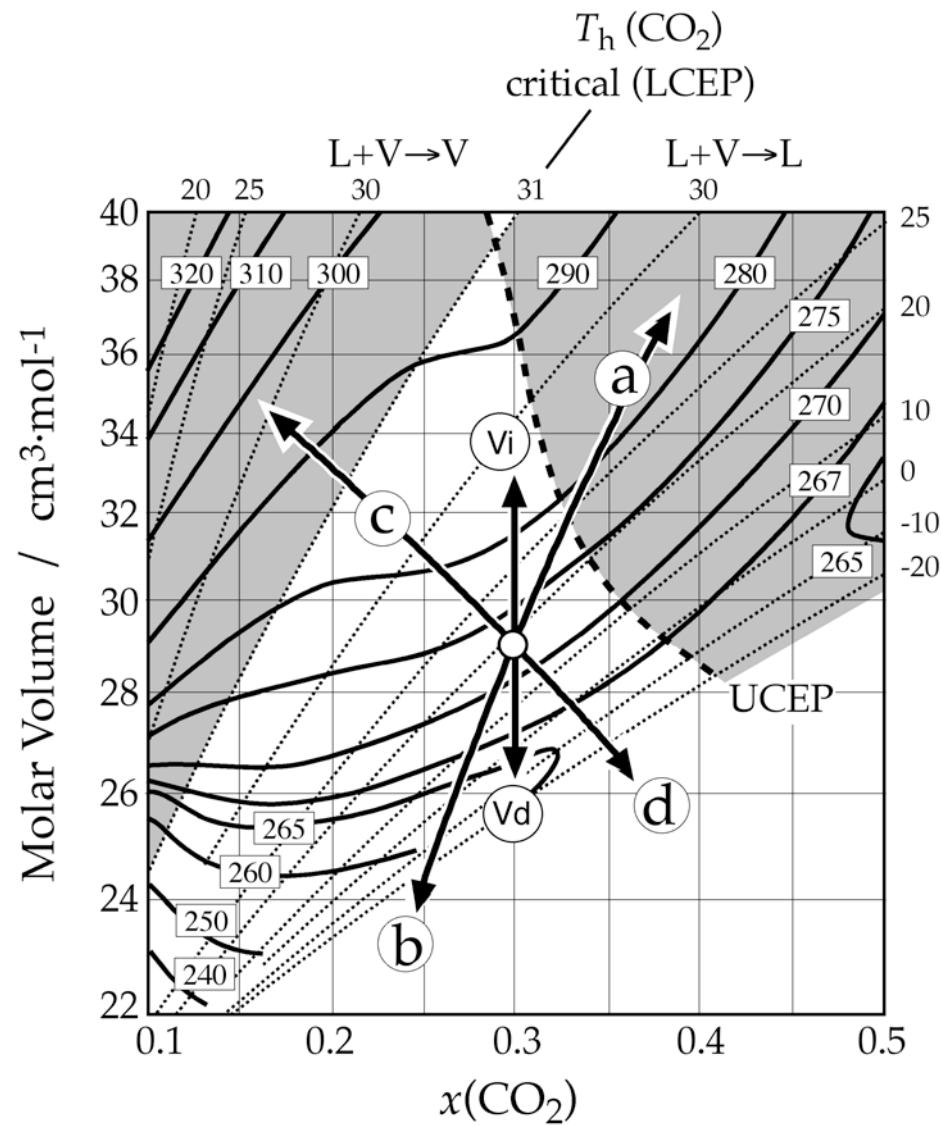
## DIFFUSION (LOSS $\text{H}_2\text{O}$ )



CALCULATED WITH SOFTWARE PACKAGE „FLUIDS“: PROGRAM „LONER HGK“ OR „LONER 14“ (BAKKER, 2003)



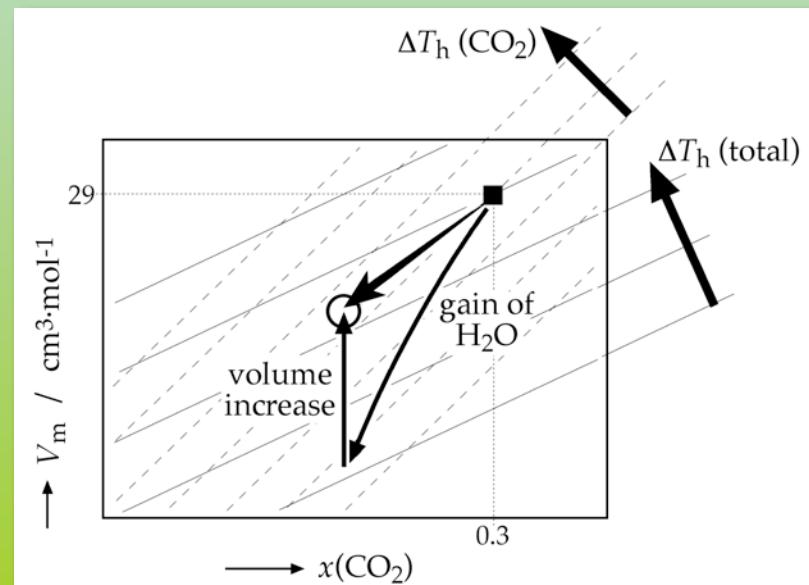
# BINARY SYSTEM $\text{H}_2\text{O}-\text{CO}_2$



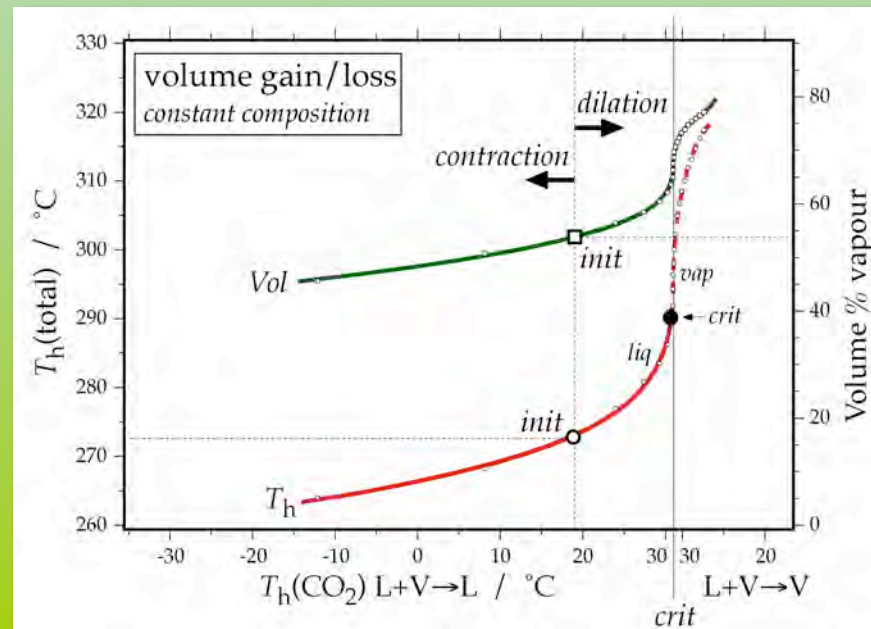
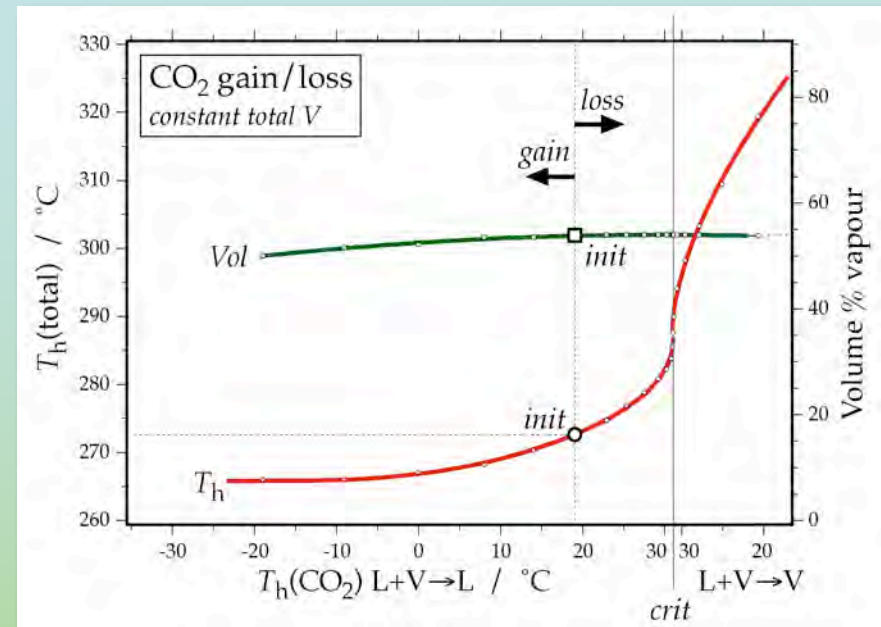
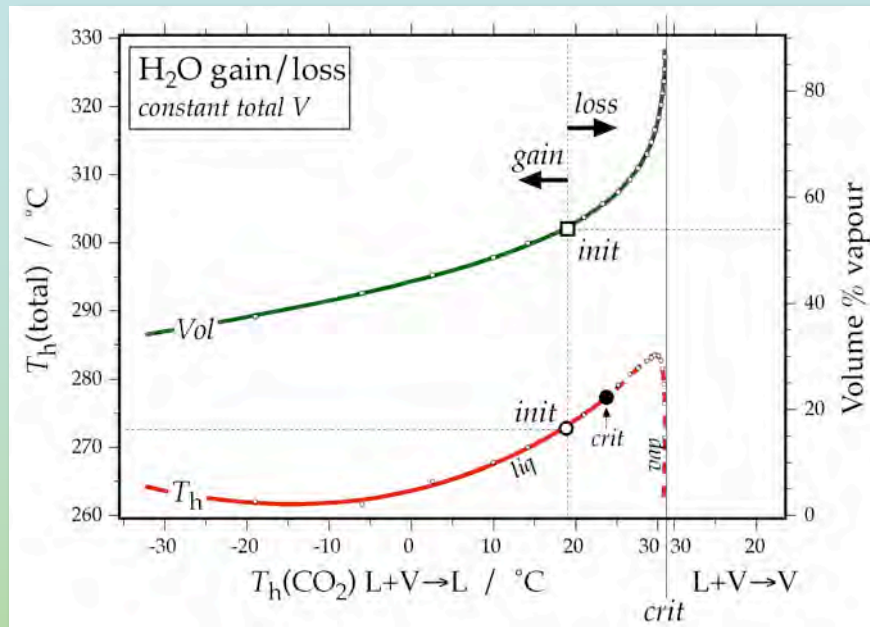
VX DIAGRAM AFTER BAKKER & DIAMOND (2000)

- A. PREF. LOSS  $\text{H}_2\text{O}$
- B. PREF. GAIN  $\text{H}_2\text{O}$
- C. PREF. LOSS  $\text{CO}_2$
- D. PREF. GAIN  $\text{CO}_2$
- VI DILATION
- VD CONTRACTION

## COMBINATION OF PROCESSES

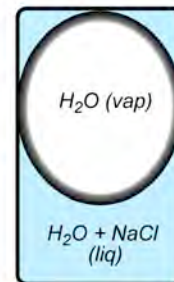
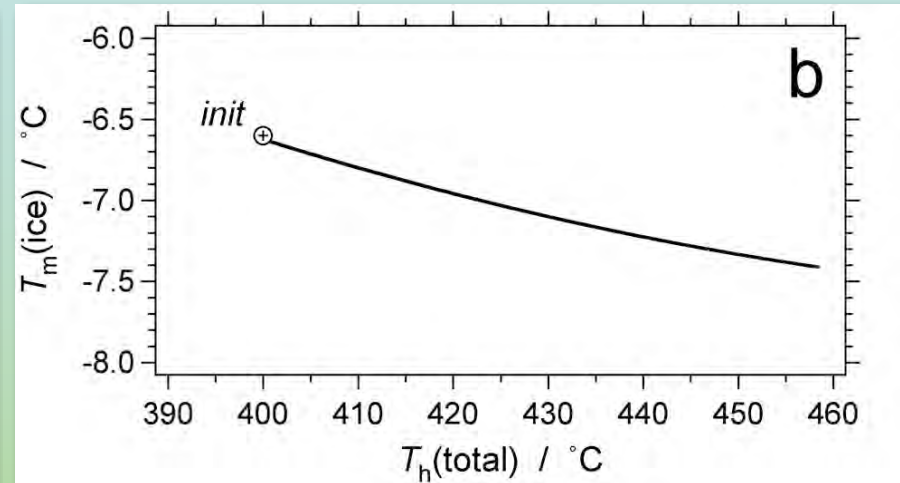
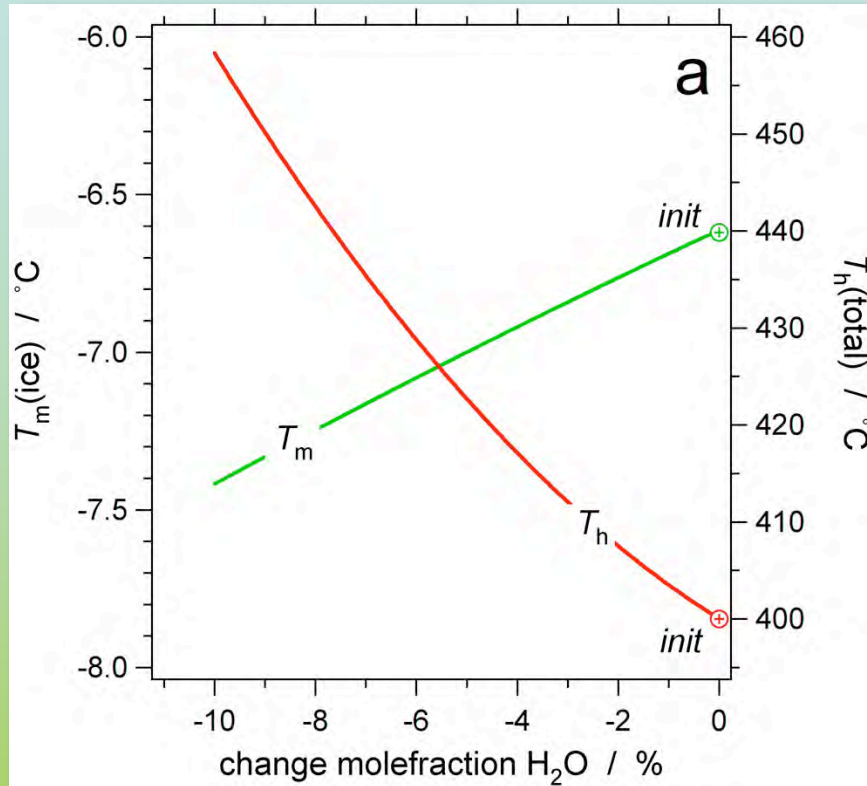


# BINARY SYSTEM $\text{H}_2\text{O}-\text{CO}_2$



# BINARY SYSTEM H<sub>2</sub>O-NACL

## PREFERENTIAL LOSS OF H<sub>2</sub>O



10 MASS% NACL

$$V_M = 31.89 \text{ CM}^3 \cdot \text{MOL}^{-1}$$

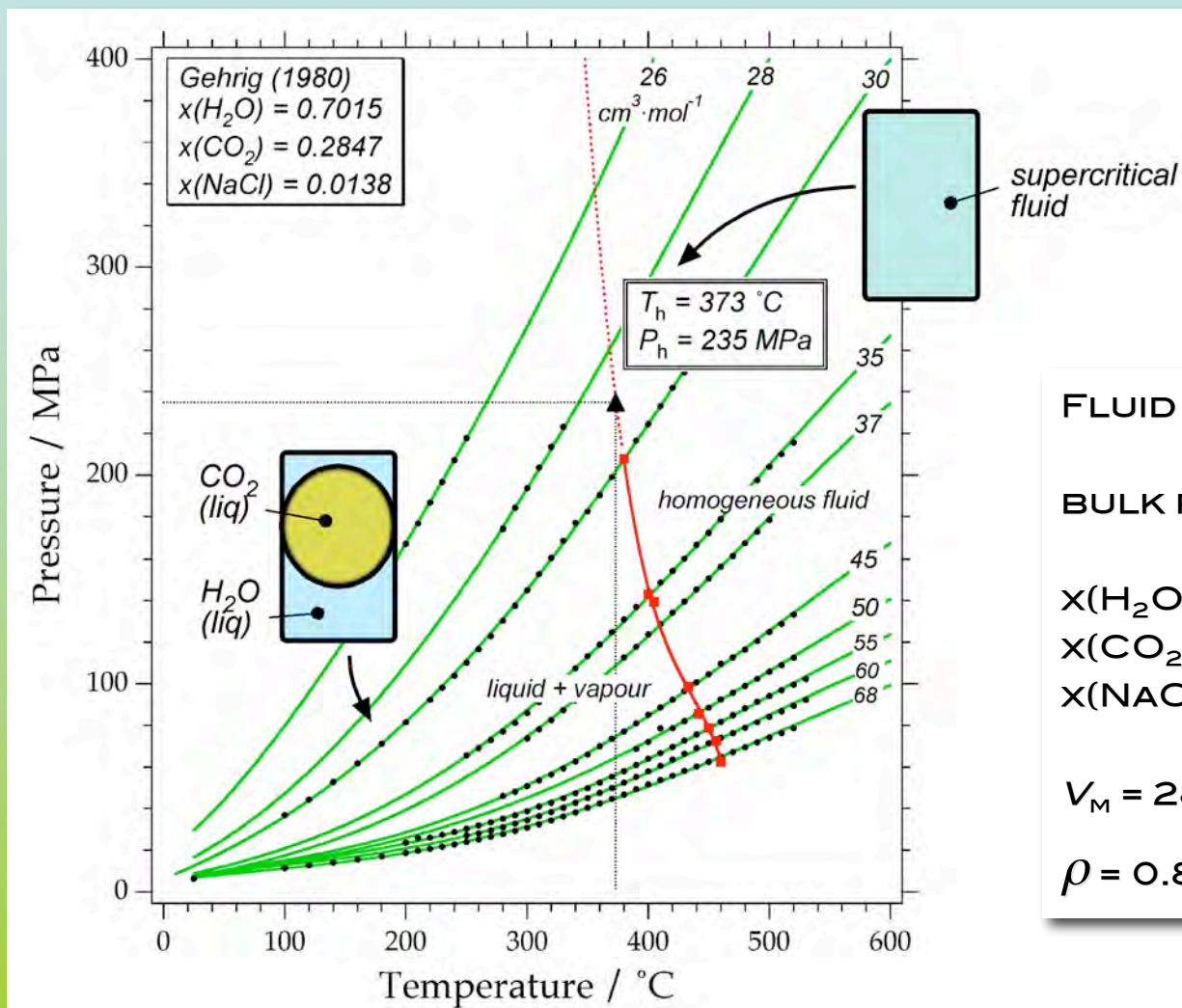
$$T_M (\text{ICE}) = -6.6 ^\circ\text{C}$$

$$T_H (\text{LV} \rightarrow \text{L}) = 400 ^\circ\text{C}$$

CALCULATED WITH SOFTWARE PACKAGE „FLUIDS“: PROGRAM „LONER AP“ AND „AQSO WNK“ (BAKKER, 2012)

# TERNARY SYSTEM H<sub>2</sub>O-CO<sub>2</sub>-NaCl

## HIGH TEMPERATURE PHASE CHANGE



### FLUID INCLUSION:

#### BULK PROPERTIES

$$x(\text{H}_2\text{O}) = 0.7297$$

$$x(\text{CO}_2) = 0.2571$$

$$x(\text{NaCl}) = 0.0132$$

$$V_M = 28.77\text{ cm}^3\cdot\text{mol}^{-1}$$

$$\rho = 0.8496\text{ g}\cdot\text{cm}^{-3}$$



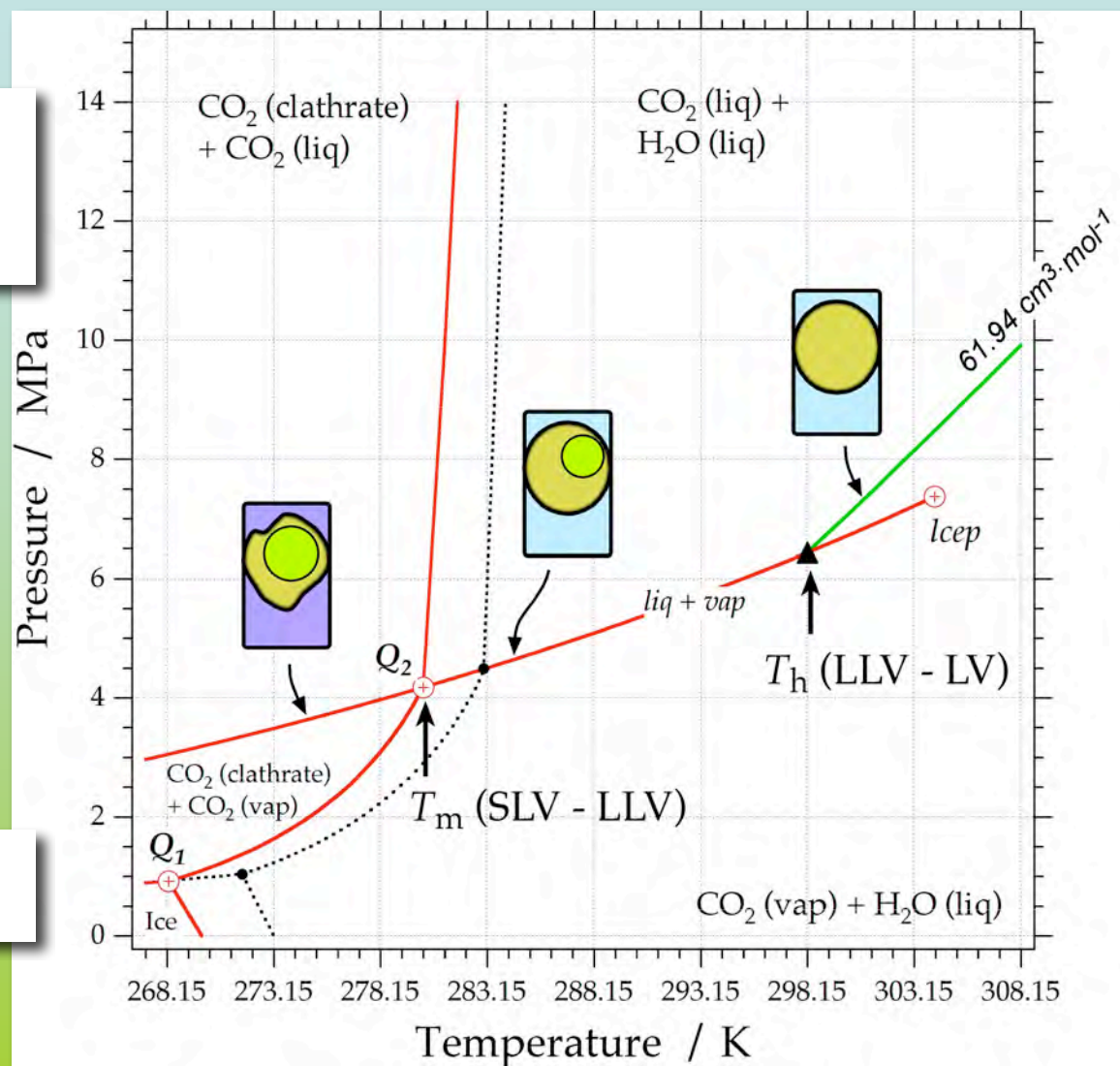
# TERNARY SYSTEM $\text{H}_2\text{O}-\text{CO}_2-\text{NaCl}$

## LOW TEMPERATURE PHASE CHANGES

$T_M (\text{CLA}) = 7.0^\circ \text{C}$   
 $T_H (\text{CO}_2) = 25.0^\circ \text{C}$   
 $\varphi (\text{AQ.}) = 50\%$

PARTIAL PROPERTIES:

$V_M (\text{CO}_2) = 61.94 \text{ cm}^3 \cdot \text{mol}^{-1}$

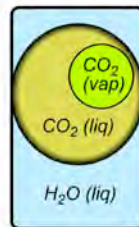


CALCULATED WITH SOFTWARE PACKAGE „CLATHRATES“: PROGRAMS „Q2“ AND „CURVES“ (BAKKER, 1997)



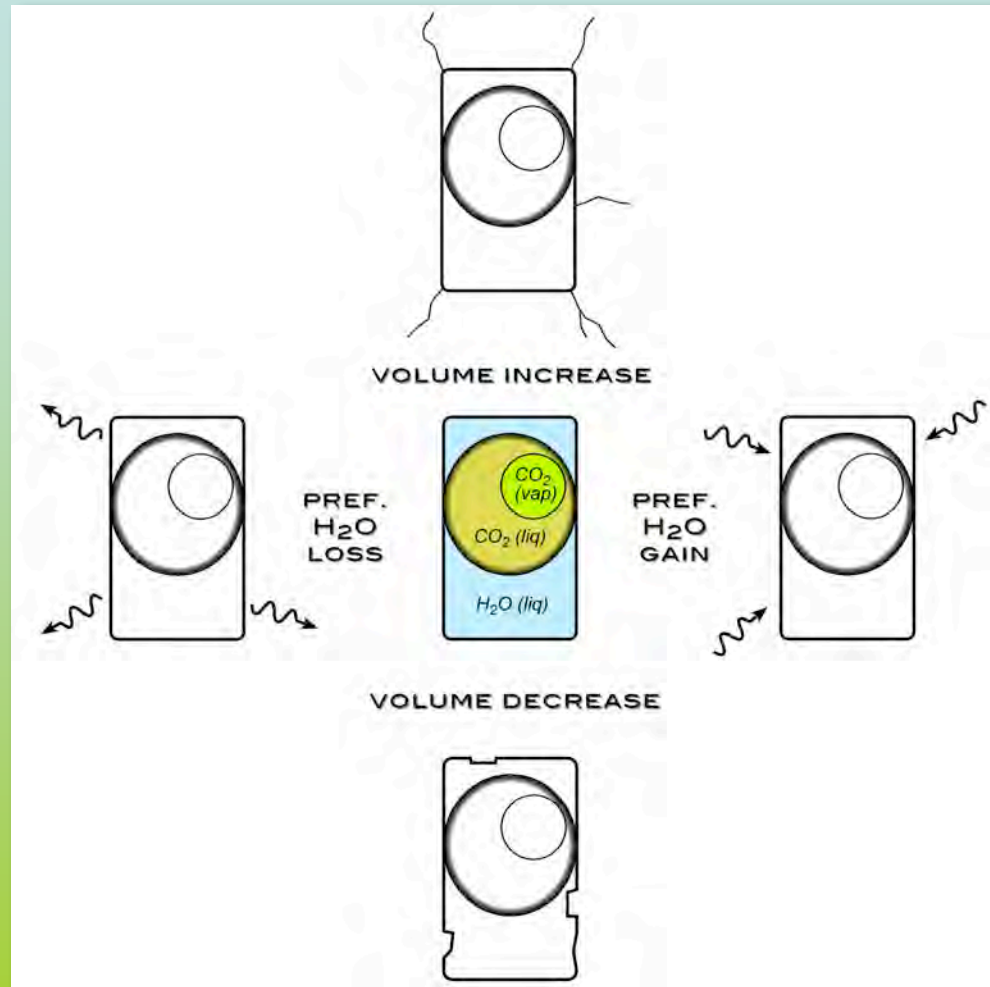
# TERNARY $\text{H}_2\text{O}-\text{CO}_2\text{-NaCl}$ FIA

## RE-EQUILIBRATION PROCESSES



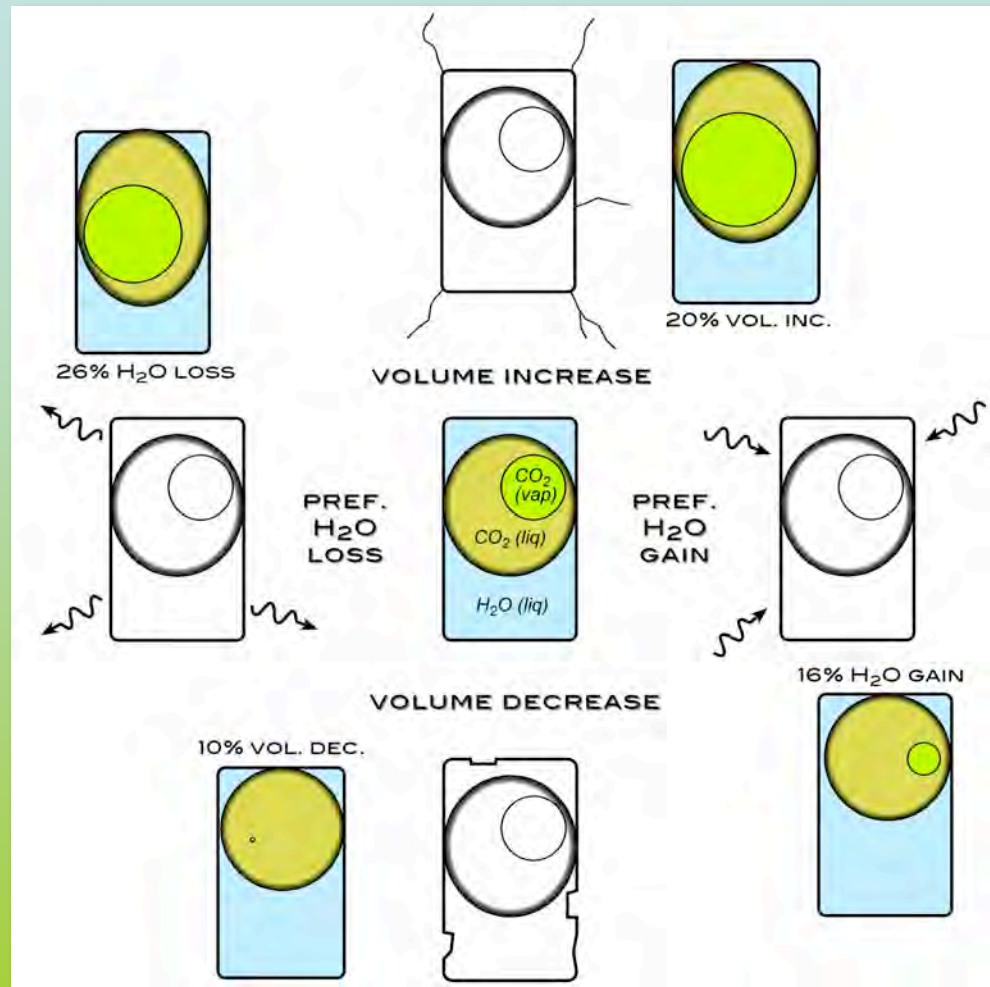
# TERNARY $\text{H}_2\text{O}$ - $\text{CO}_2$ - $\text{NaCl}$ FIA

## RE-EQUILIBRATION PROCESSES



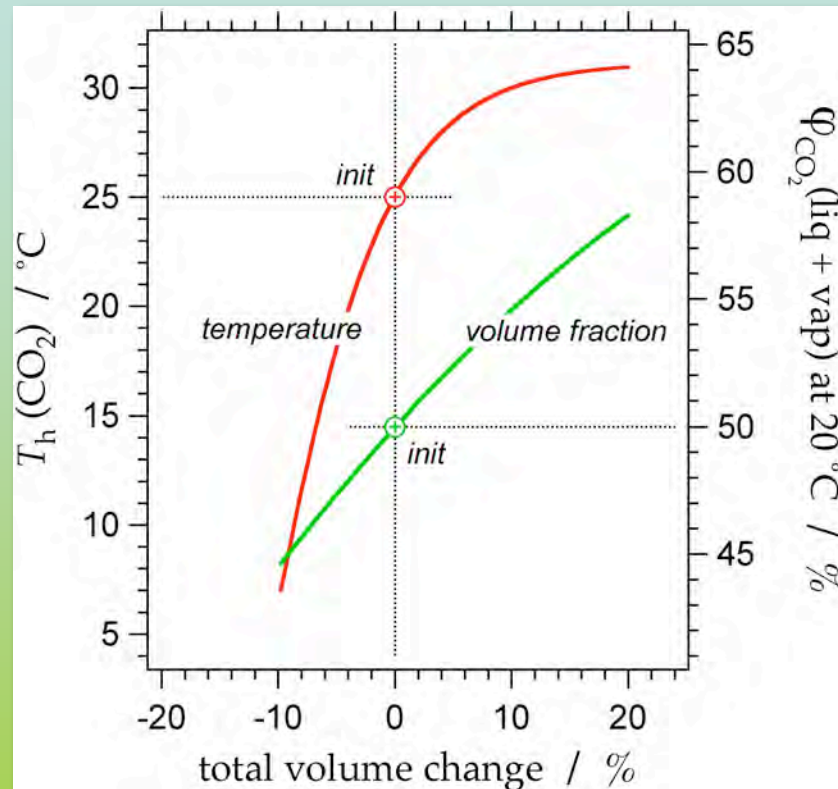
# TERNARY $\text{H}_2\text{O}$ - $\text{CO}_2$ - $\text{NaCl}$ FIA

## RE-EQUILIBRATION PROCESSES

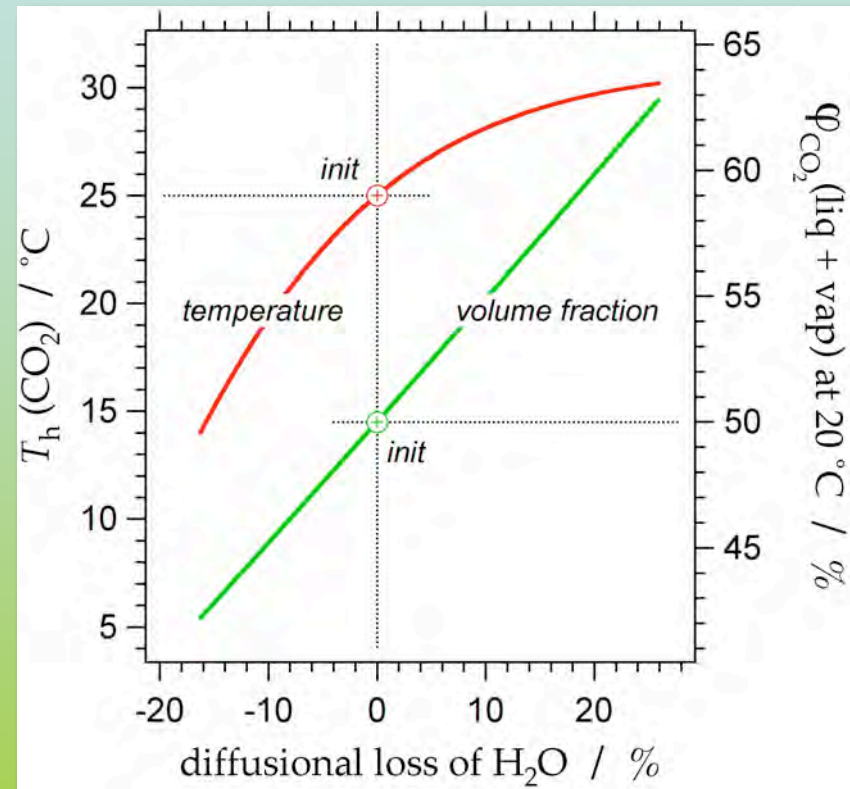


# TERNARY $\text{H}_2\text{O}-\text{CO}_2-\text{NaCl}$ FIA

## DILATION-CONTRACTION



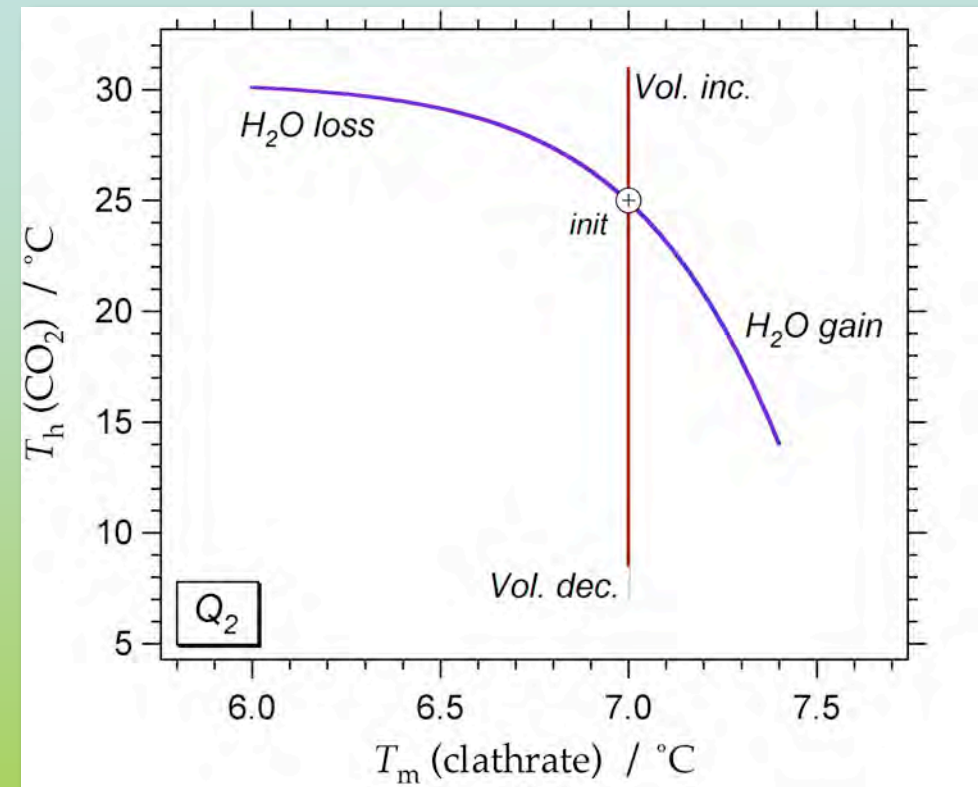
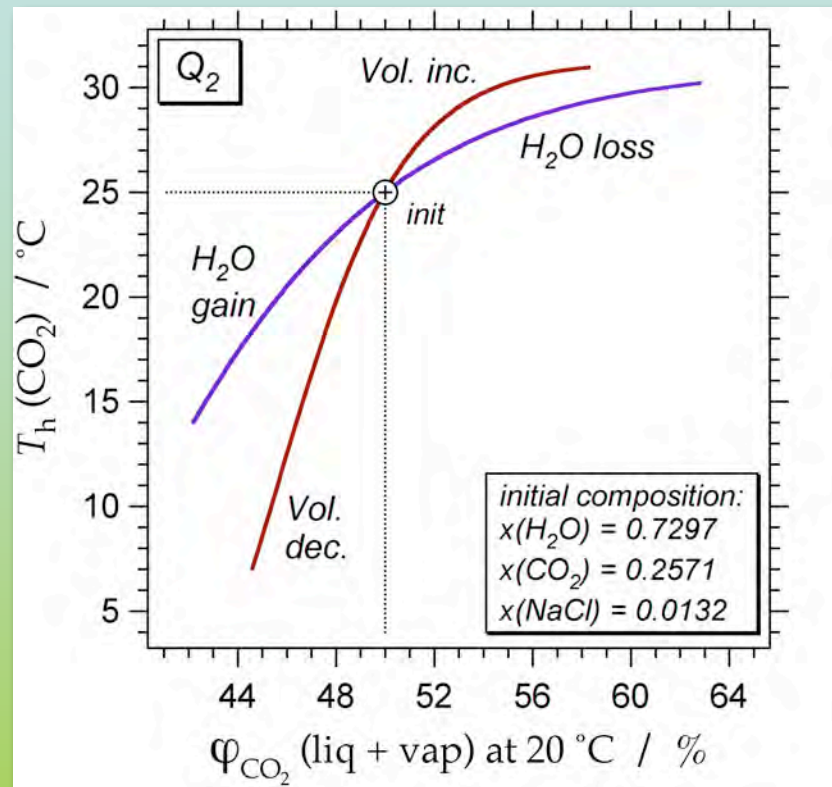
## DIFFUSION



CALCULATED WITH SOFTWARE PACKAGE „CLATHRATES“: PROGRAMS „Q2“ (BAKKER, 1997) AND „FLUIDS“: PROGRAM „BULK“ (BAKKER, 2003)

# TERNARY $\text{H}_2\text{O}-\text{CO}_2-\text{NaCl}$ FIA

## RE-EQUILIBRATION TRENDS



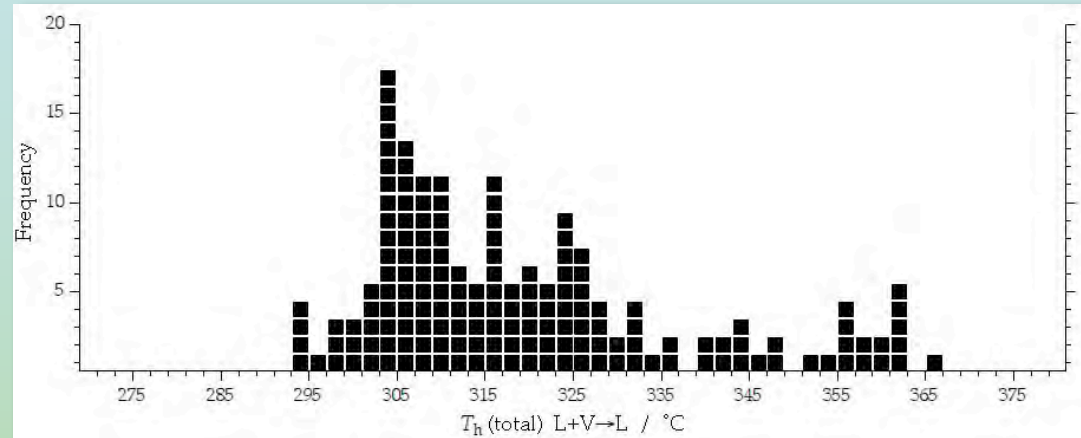
CALCULATED WITH SOFTWARE PACKAGE „CLATHRATES“: PROGRAMS „Q2“ (BAKKER, 1997) AND „FLUIDS“: PROGRAM „BULK“ (BAKKER, 2003)



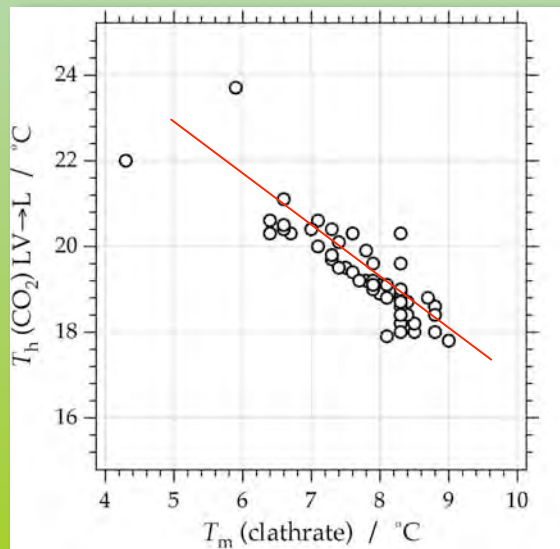
# CONCLUSIONS

## HISTOGRAMS

?



## COMBINED TRENDS IN $T_H$ , $T_M$ , $\varphi_{VAP}$



## THERMODYNAMIC MODELLING:

1. RECONSTRUCTION POSSIBILITIES
2. PROCESS IDENTIFICATIONS