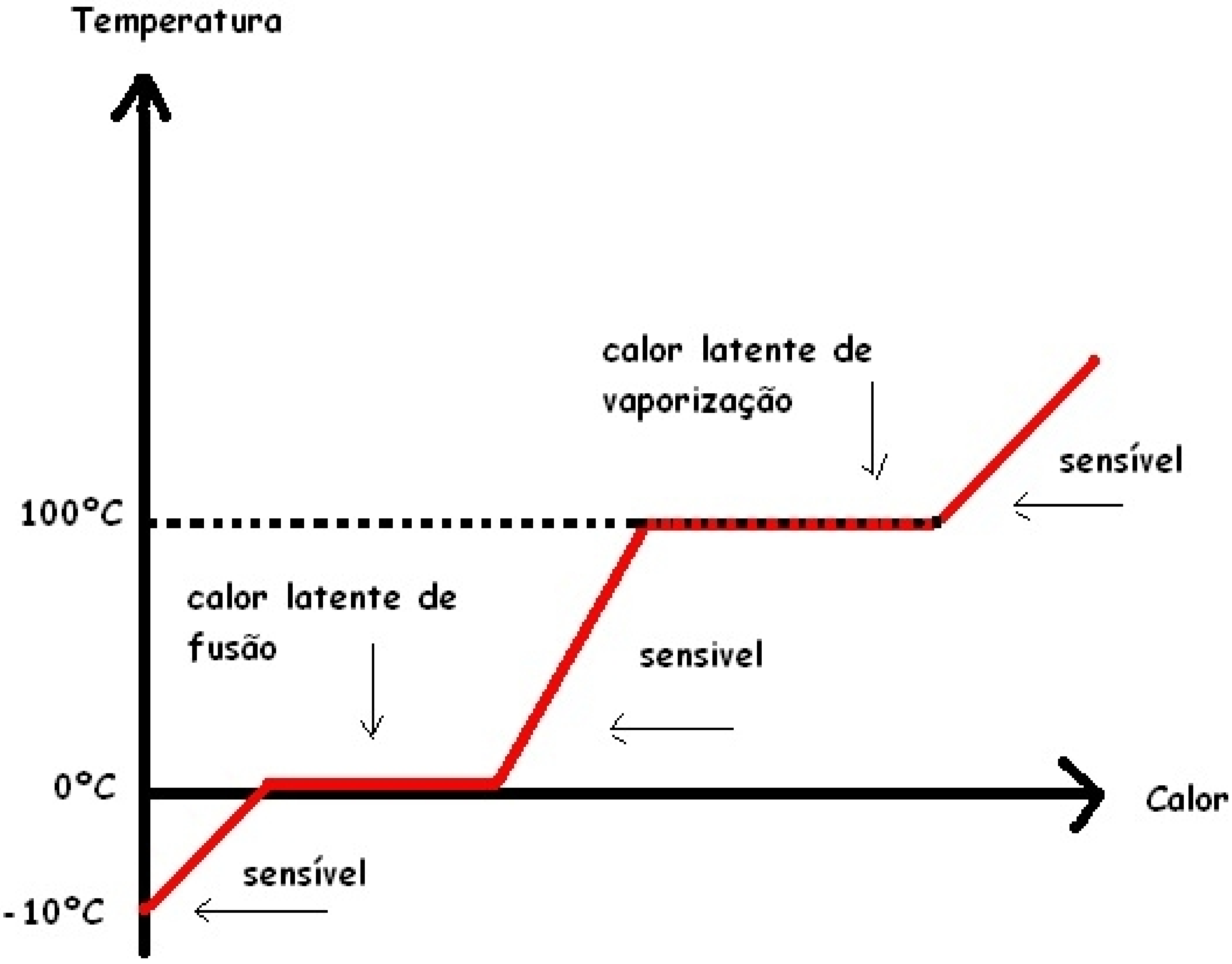
Transições de Fase

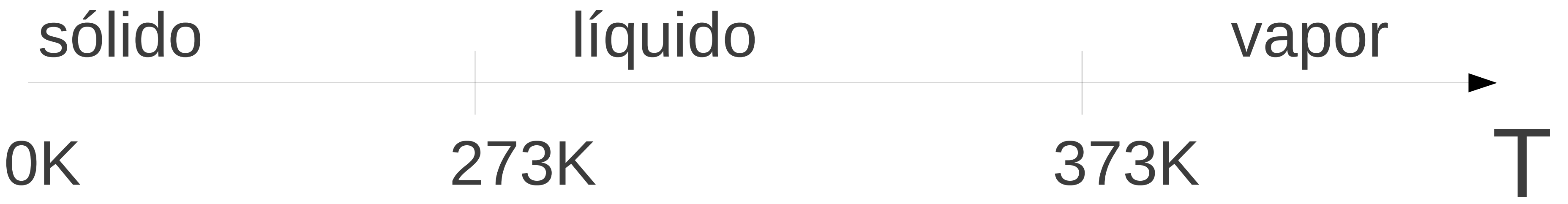
Prof. Fabiano Ribeiro

DEX- UFLA


DESCULPE O
TRANSTORNO,
ESTAMOS MU-
DANDO O PAÍS

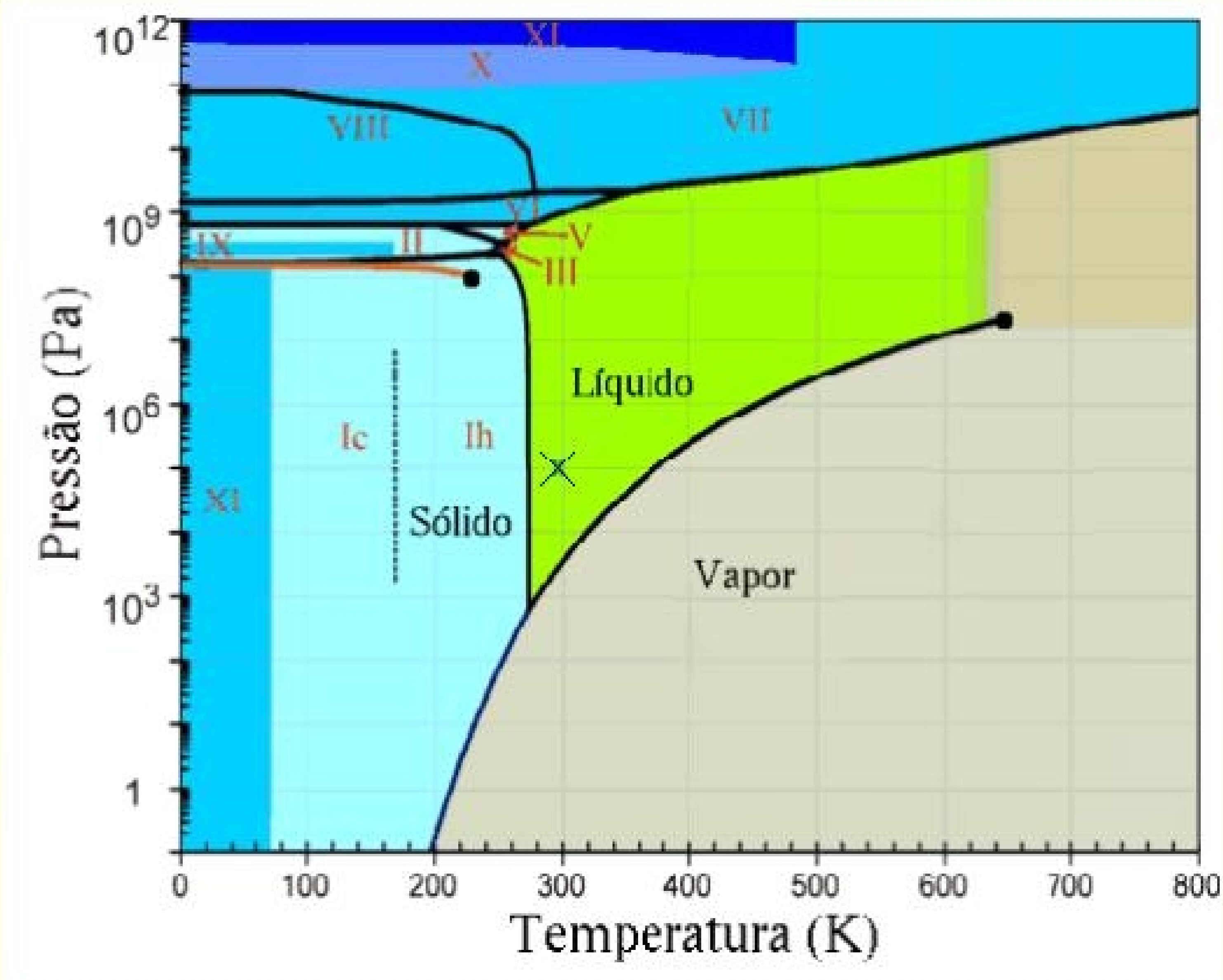

Temperatura
calor latente de vaporização
sensível
100°C
calor latente de fusão
sensivel
0°C
Calor
sensível
-10°C

Fases da Água

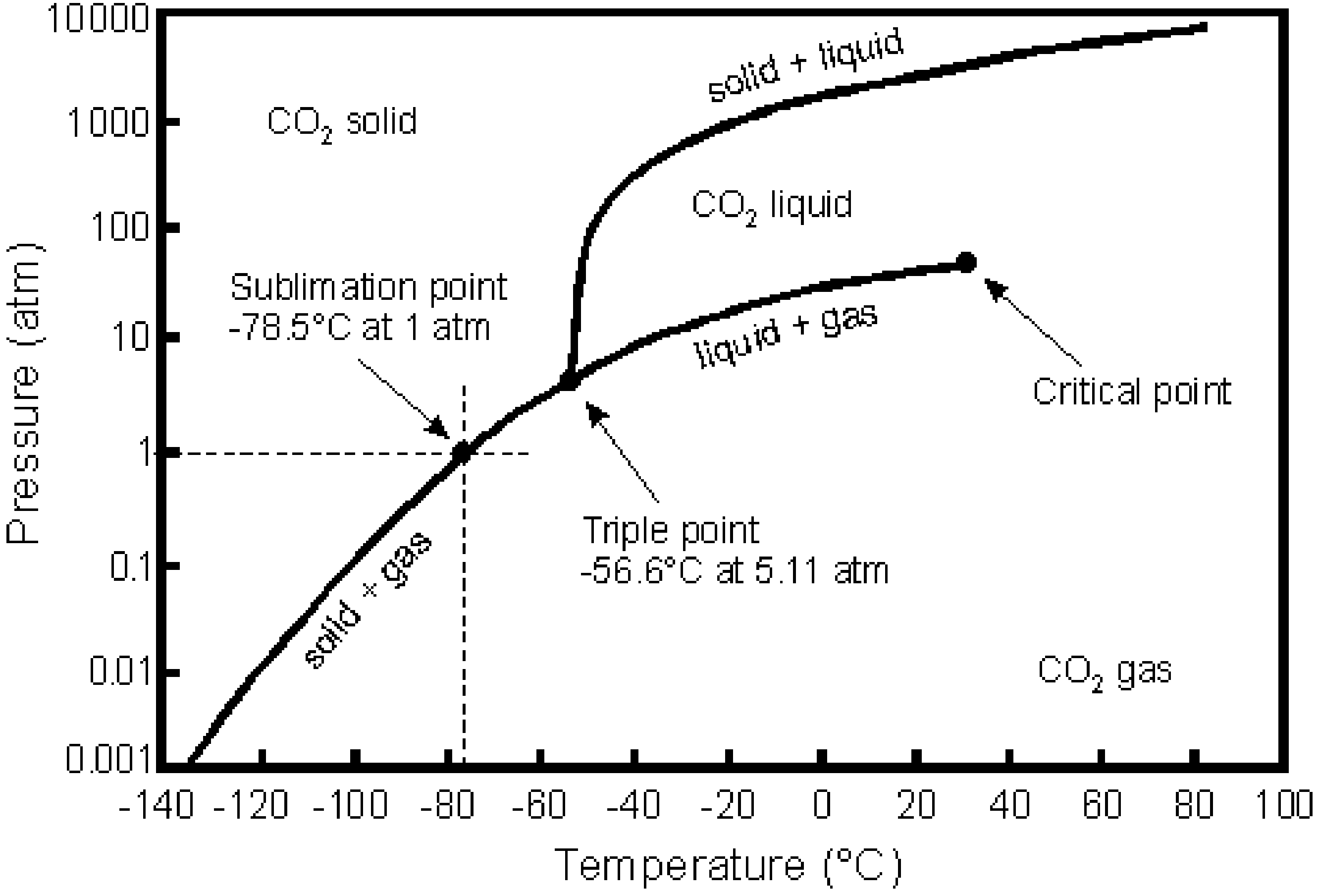


P= 1atm

Diagrama de fases P x V para a água

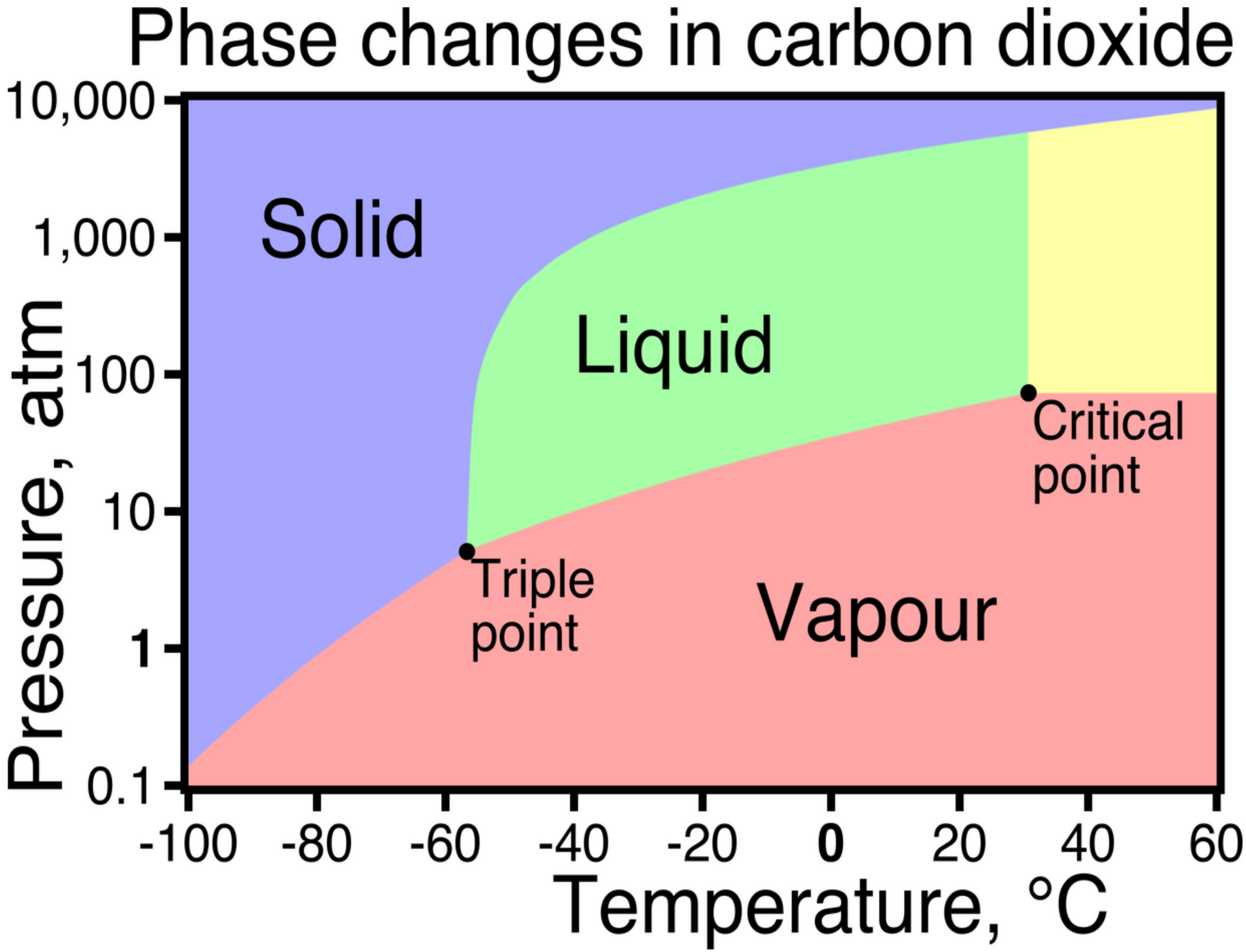


Dioxido de Carbono: CO_2



Pressure-Temperature phase diagram for CO_2.

Dioxido de Carbono: CO_2



Videos

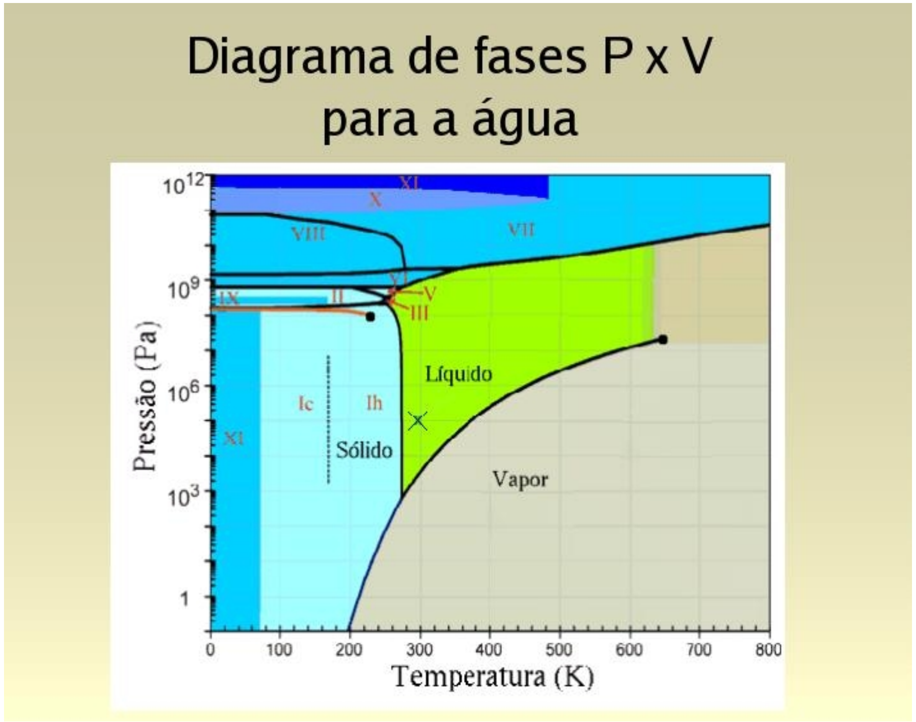


Diagrama de fases P x V
para a água
Pressão (Pa)
Temperatura (K)
Líquido
Sólido
Vapor
Ic
Ih
VIII
VII
X
XI
IX
II
V
III
0
100
200
300
400
500
600
700
800
1

Videos

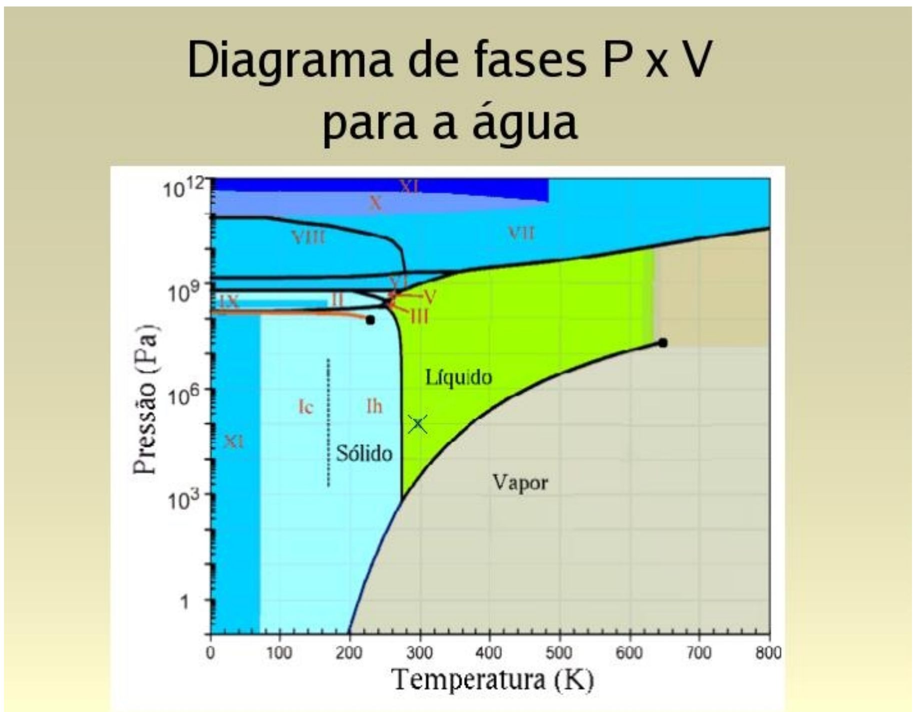
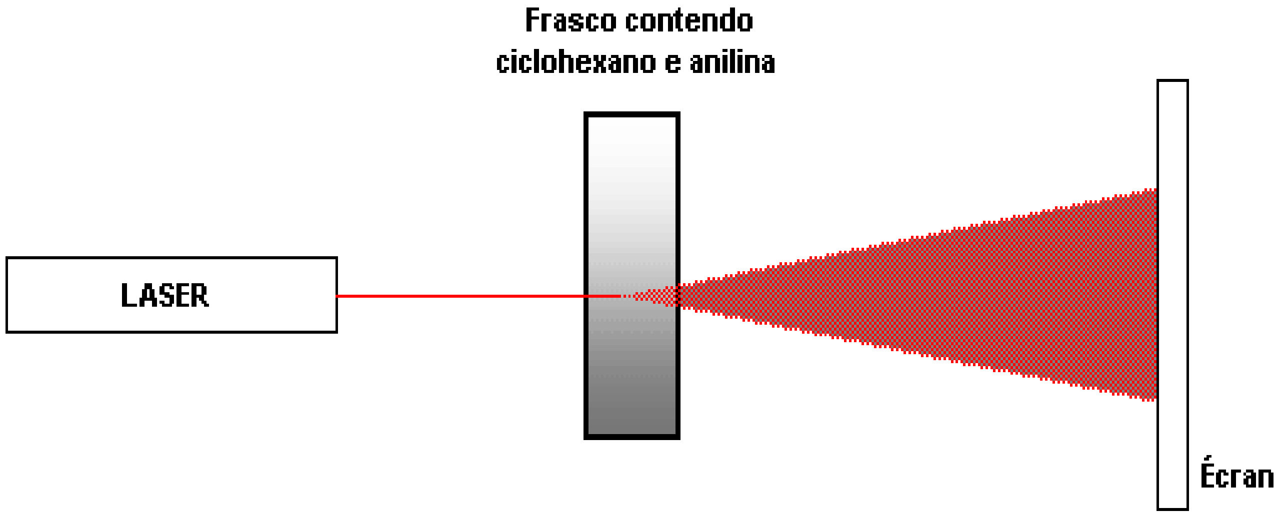
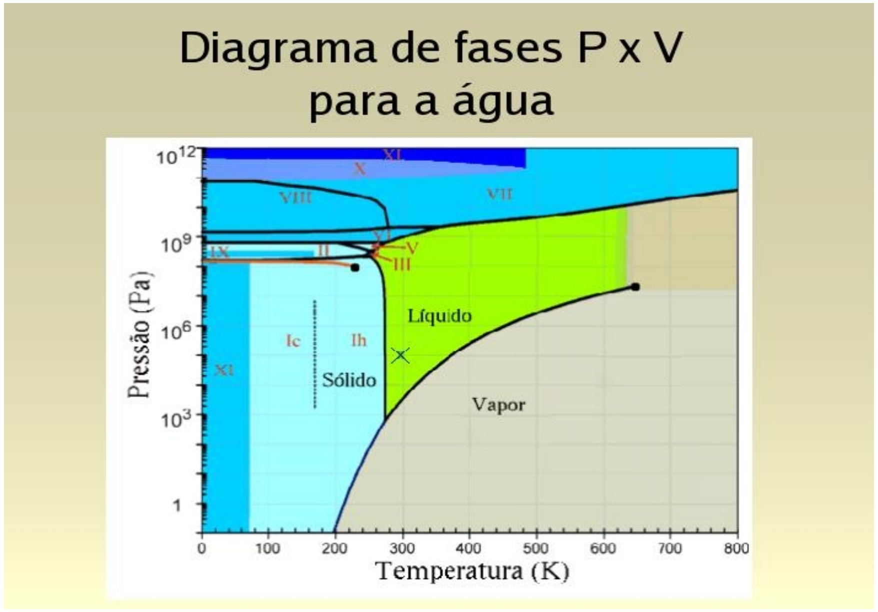


Diagrama de fases P x V
para a água
Pressão (Pa)
Temperatura (K)
Líquido
Sólido
Vapor
Ic
Ih
VIII
VII
IX
II
V
III
XI
X
0
100
200
300
400
500
600
700
800
1
10^3
10^6
10^9
10^{12}

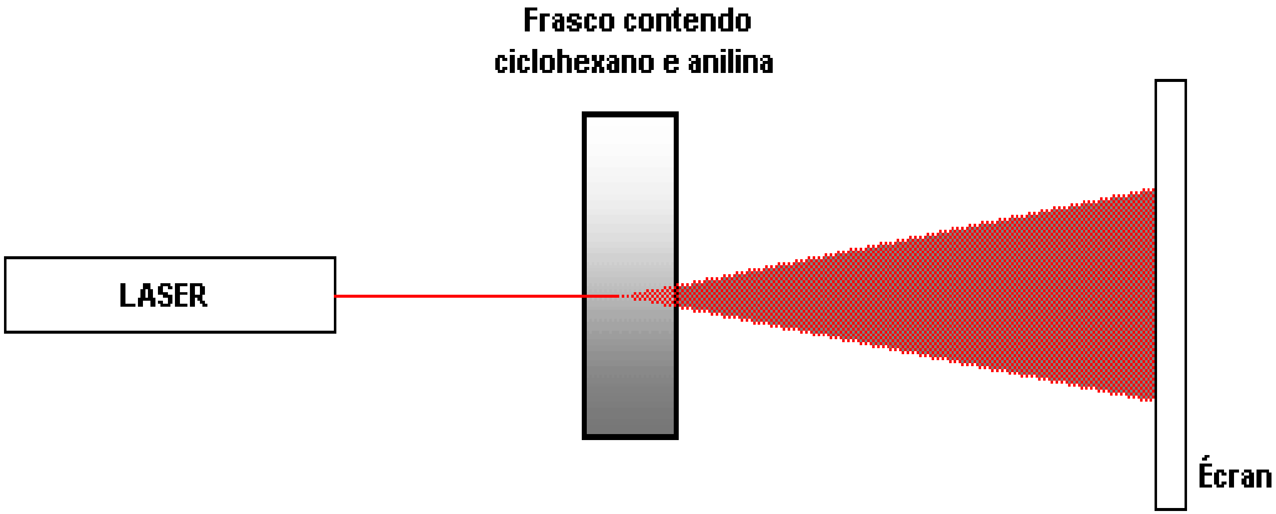
SF_6

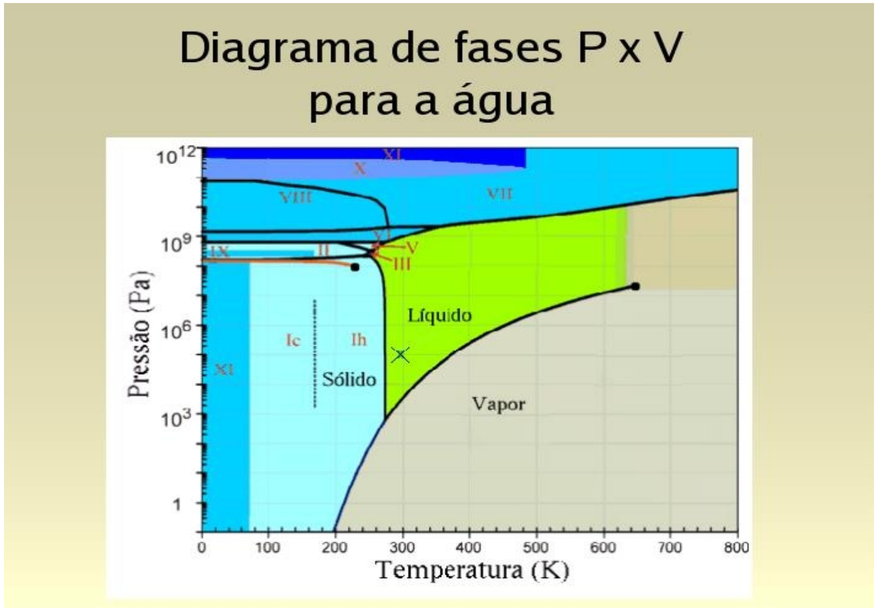
Opalescência Crítica





Opalescência Crítica

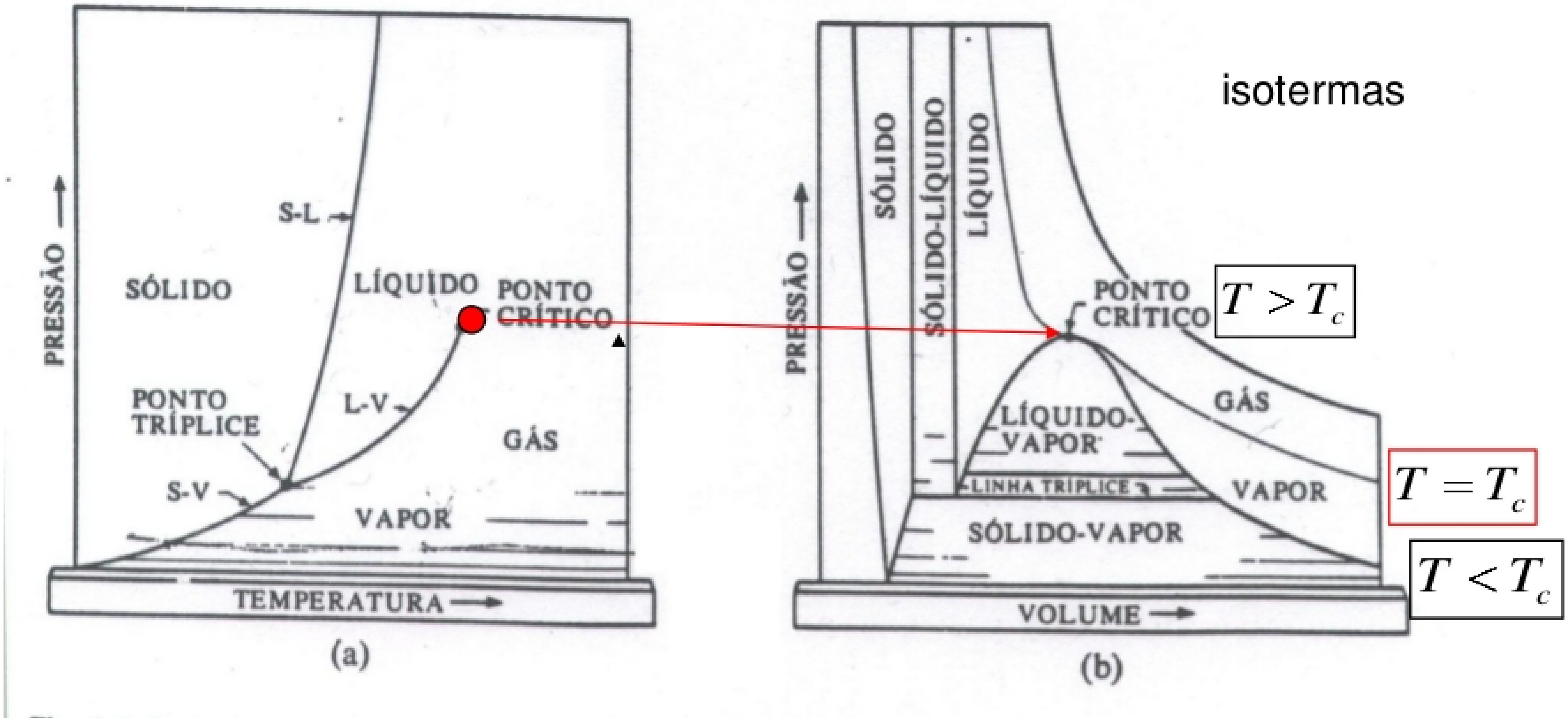




Substânica simples: planos T-p e p-V

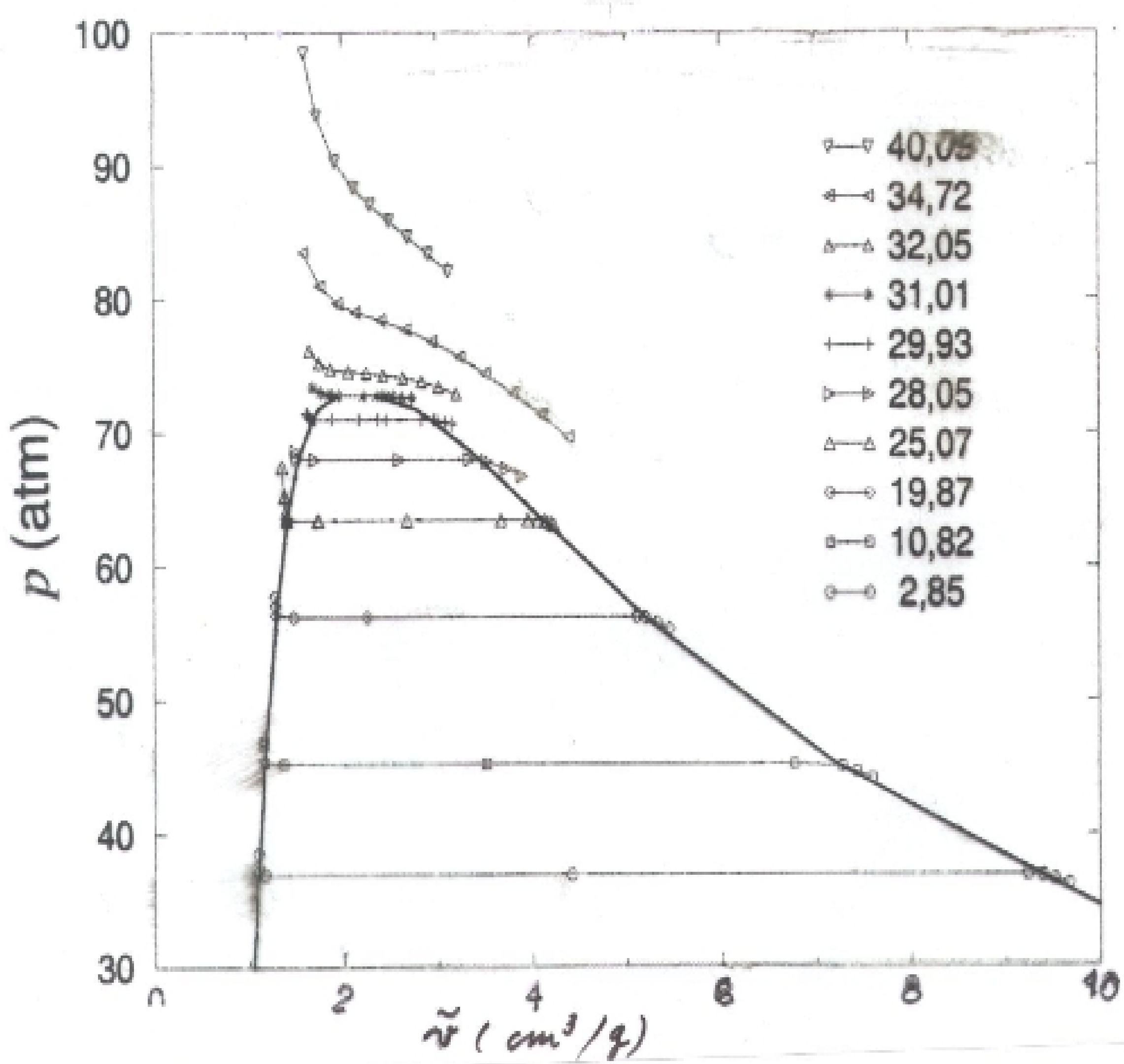
Plano T-p

Plano p-v



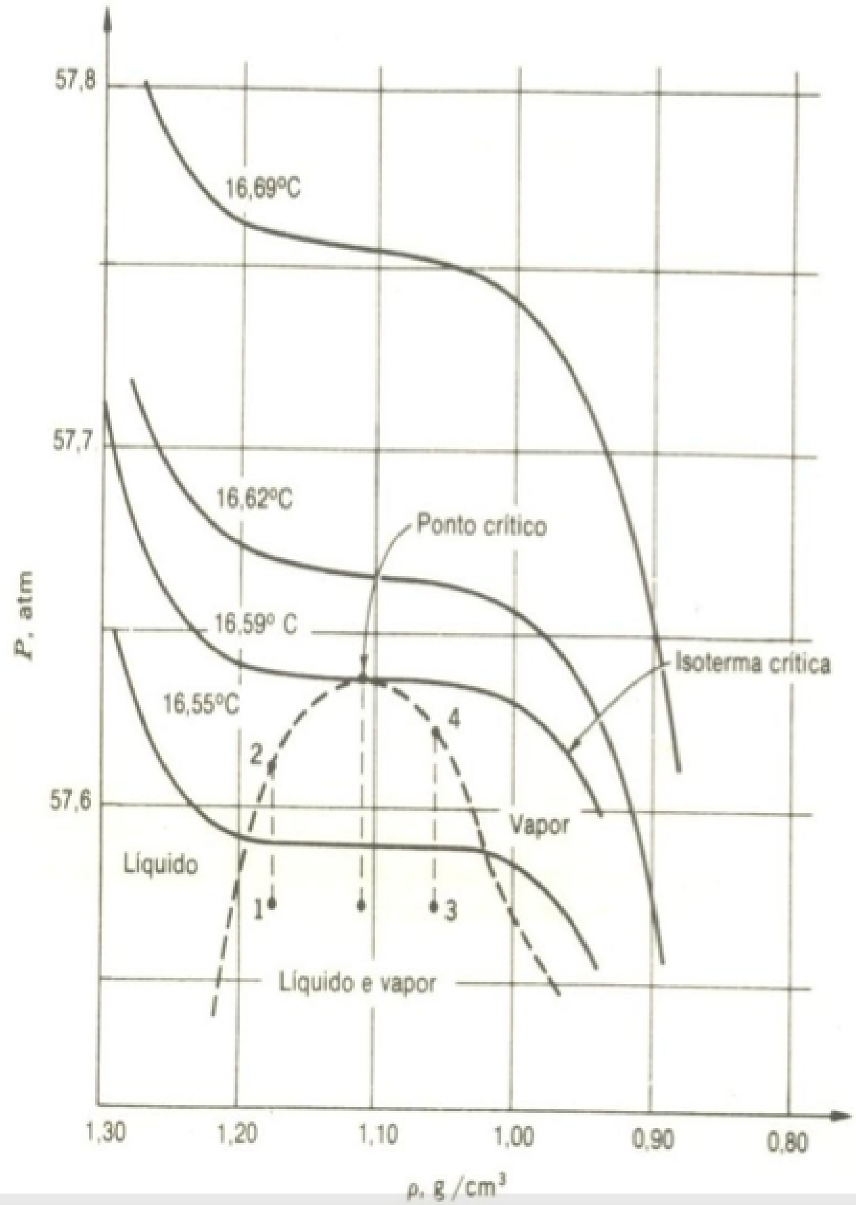
Sears&Salinger, Termodinâmica,
Teoria cinética e Termodinâmica Estatística

Dioxido de Carbono: CO_2



Isotermas
CO2
Michaels (1937)

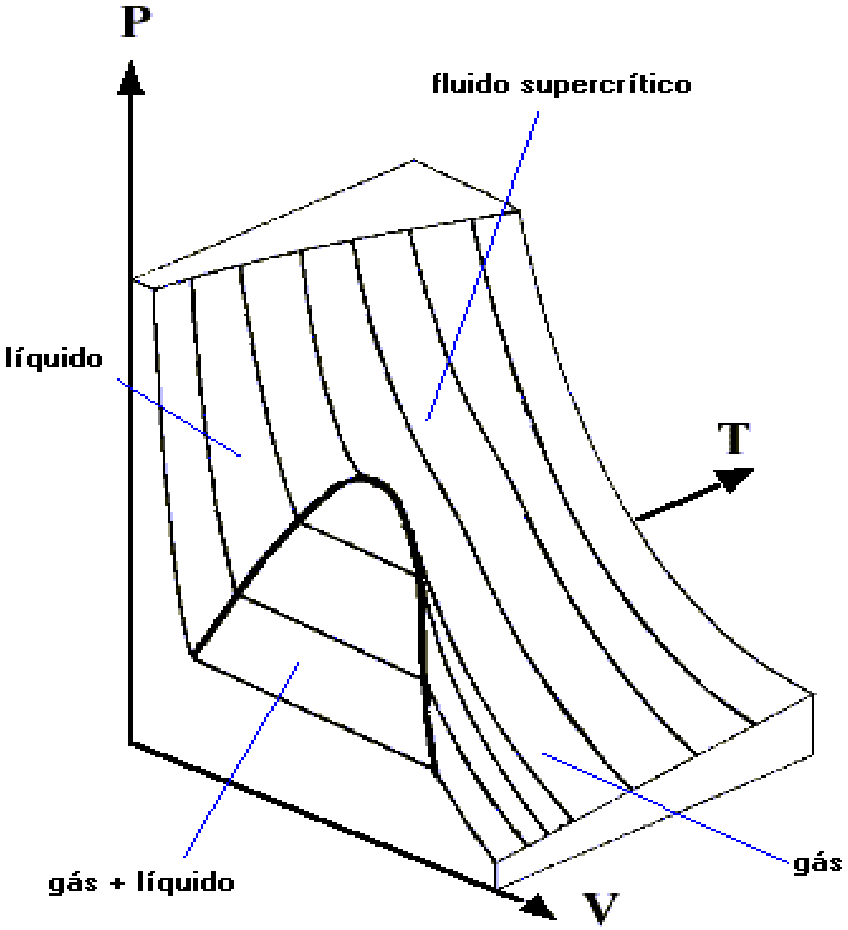
Xenômio

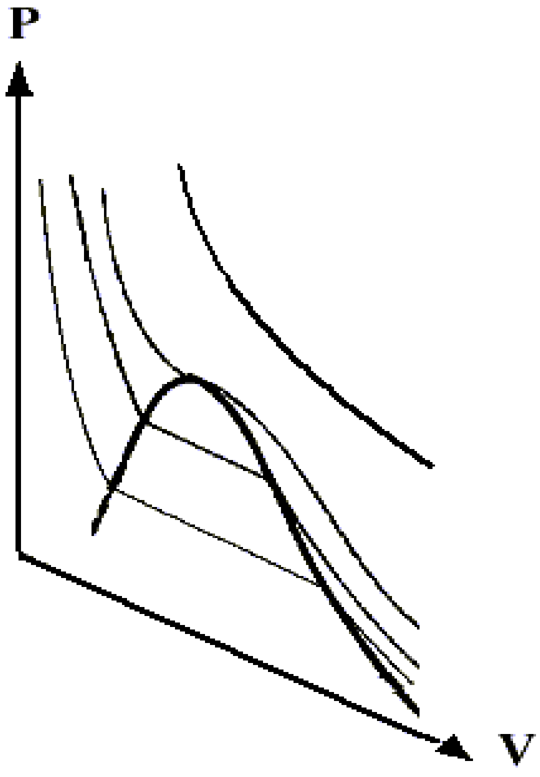


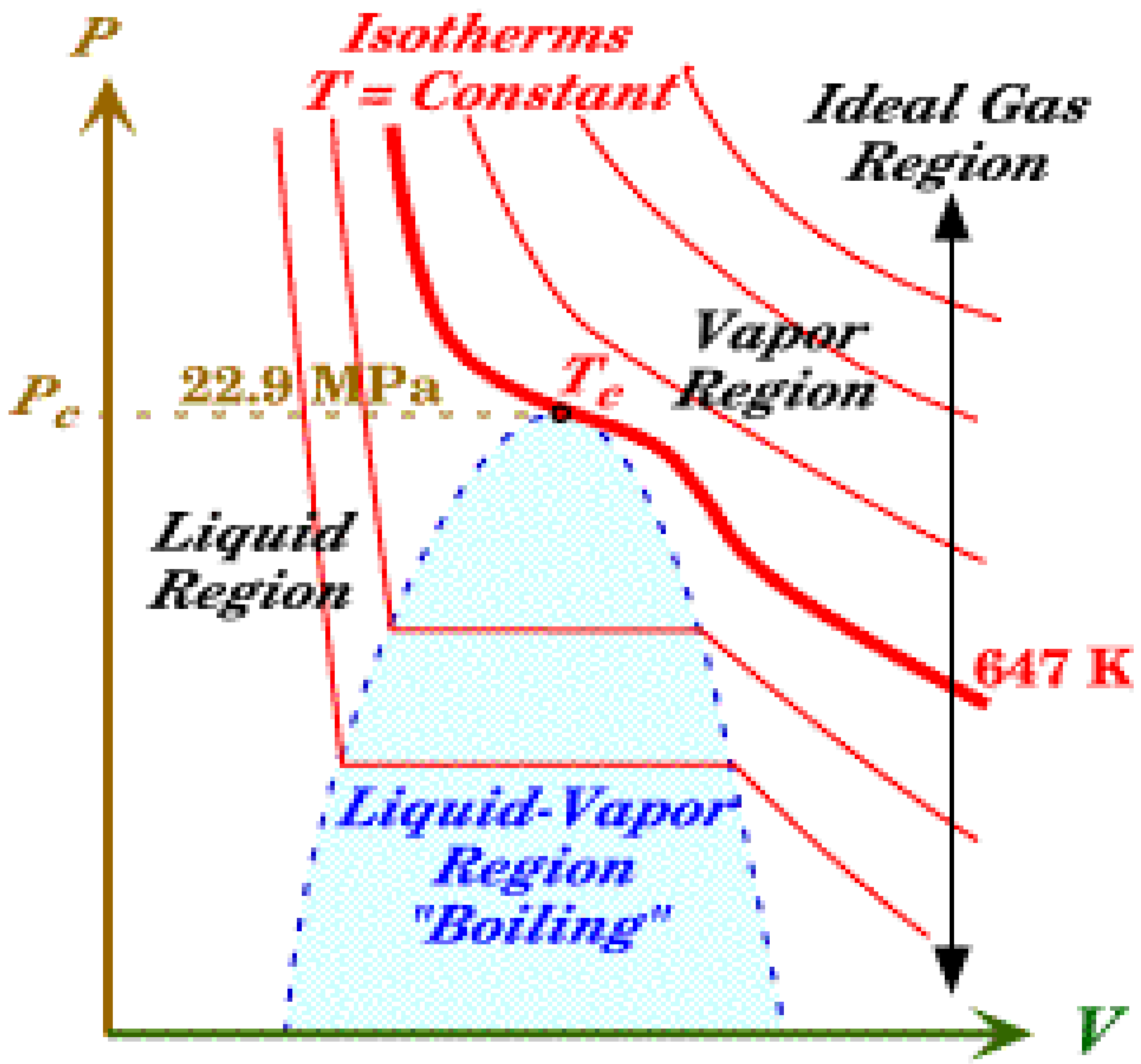
Isotermas do xenônio nas proximidades do ponto crítico Habgood&Scheineider, 1954

Zemansky,
Calor e Termodinâmica, 1978
p. 336.

Diagrama P-V-T







P
Isotherms
T = Constant
Ideal Gas
Region
Vapor
Region
22.9 MPa
P_c
T_c
Liquid
Region
647 K
Liquid-Vapor
Region
"Boiling"
V

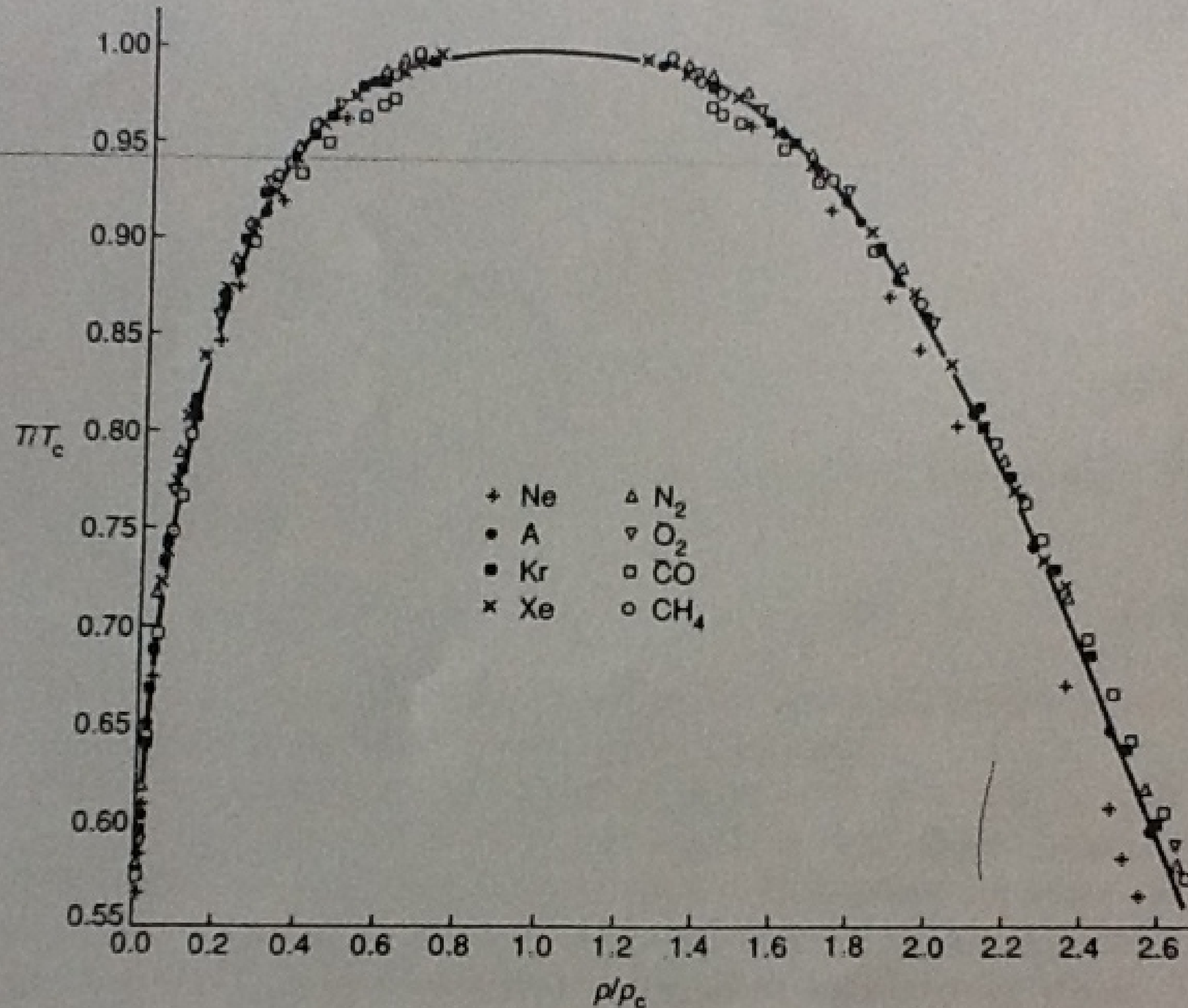
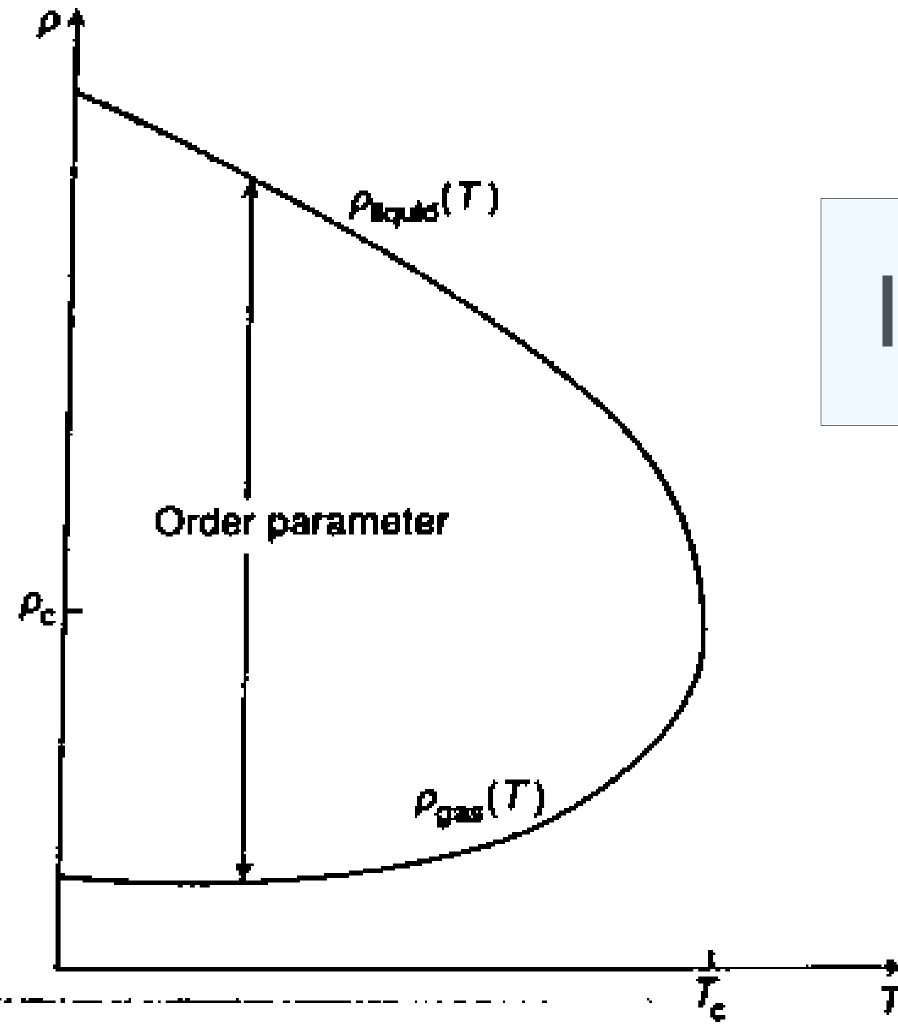


Fig. 2.2. The coexistence curve of eight different fluids plotted in reduced variables. The fit assumes an exponent $\beta = 1/3$. After Guggenheim, E. A. (1945). *Journal of Chemical Physics*, **13**, 253.



$$|\rho_+ - \rho_-| \sim |T - T_c|^{1/3}$$

Fig. 1.2. Values of the densities of the coexisting liquid and gas along the vapour pressure curve. $(\rho_{liquid}(T) - \rho_{gas}(T))$ is the order parameter for the liquid–gas transition.

Propriedades do ponto crítico de algumas substâncias

Subs tan cia	$T_c(K)$	$p_c(N/m^2)$	$v_c(m^3/kmol)$	$p_c v_c/RT_c$	$p(atm)$
Helio4	$5,25$	$2,30 \times 10^5$	$0,0578$	$0,303$	$2,26$
Helio3	$3,34$	$1,15 \times 10^5$	$0,0726$	$0,302$	$1,13$
Hidrogenio	$33,3$	$12,8 \times 10^5$	$0,0650$	$0,300$	$12,6$
Nitrogenio	$126,2$	$33,6 \times 10^5$	$0,0901$	$0,286$	$33,2$
Oxigenio	$154,8$	$50,2 \times 10^5$	$0,078$	$0,304$	$49,5$
Amonia	$405,5$	$111,0 \times 10^5$	0.0725	$0,239$	$109,5$
Diox.Carb.	$304,2$	$73,0 \times 10^5$	$0,094$	$0,271$	$72,0$
Agua	$647,4$	$209,0 \times 10^5$	$0,056$	$0,217$	$206,3$
v.d.Waals	$8a/27Rb$	$a/27b^2$	$3b$	$0,375 = 3/8$	

Expoentes Críticos

- Calor Específico: $C_V \sim |t|^{\alpha}$
- Diferença de densidade: $|\rho_+ - \rho_-| \sim (-t)^{\beta}$
- Compressibilidade: $k_T \sim |t|^{-\gamma}$
- Comprimento Correlação: $\xi \sim |t|^{-\nu}$
- $t \equiv \frac{T-T_c}{T_c}$

Tabela 8.2: Expoentes críticos α, β, γ e δ relativos ao ponto crítico líquido-vapor de diversas substâncias puras.

substância		α	β	γ	δ
hélio-3	^3He	0,11	0,36	1,19	4,1
hélio-4	^4He	0,13	0,36	1,18	
Neônio	Ne		0,33	1,25	
argônio	Ar	0,13	0,34	1,21	
criptônio	Kr		0,36	1,18	
xenônio	Xe	0,11	0,33	1,23	
hidrogênio	H_2		0,33	1,19	
oxigênio	O_2	0,12	0,35	1,25	
nitrogênio	N_2		0,33	1,23	
dióx. carb.	CO_2	0,11	0,32	1,24	
hexafl. enx.	SF_6	0,11	0,32	1,28	
etileno	C_2H_4		0,33	1,18	4,4
etano	C_2H_6	0,12	0,34		

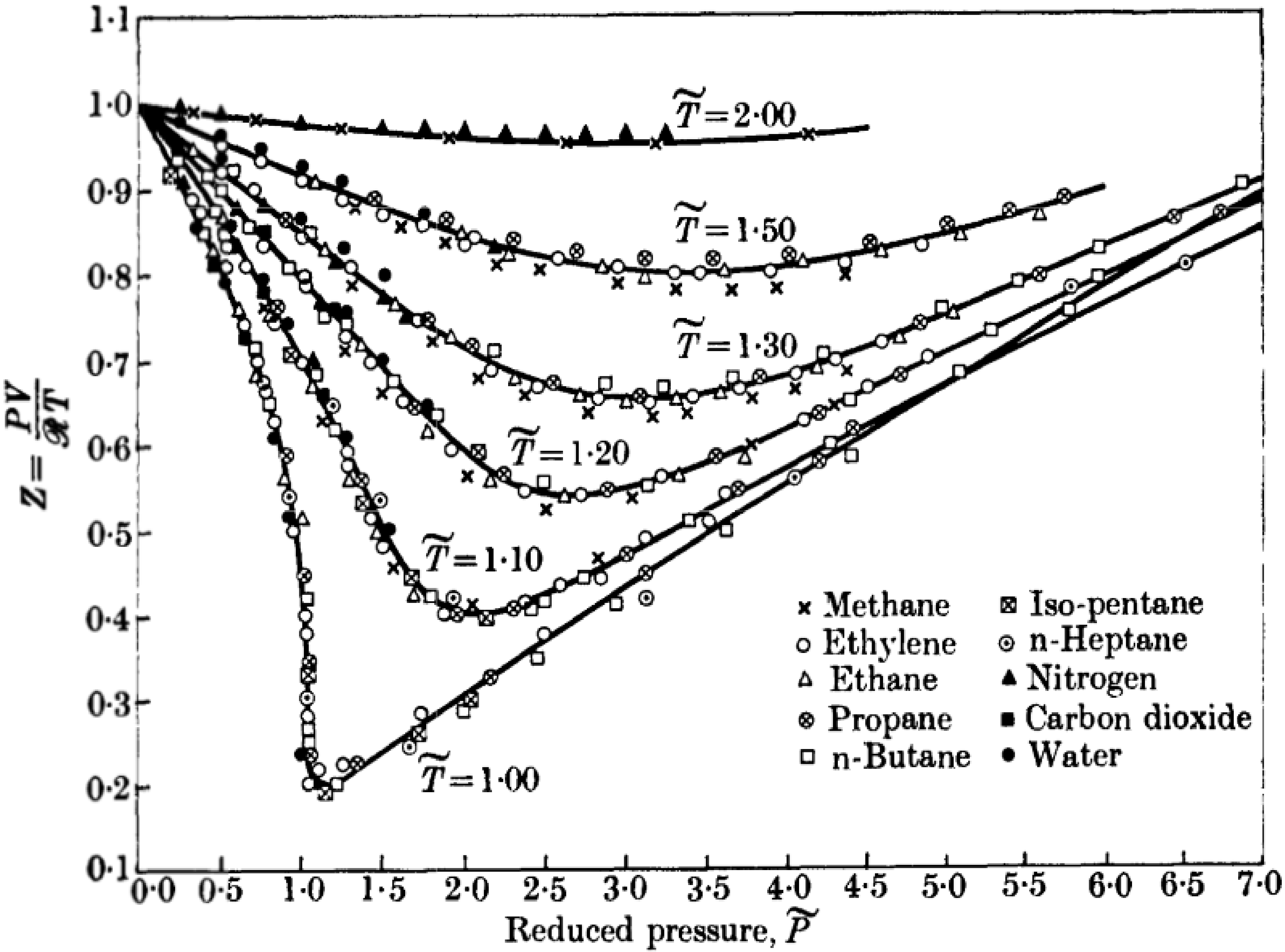
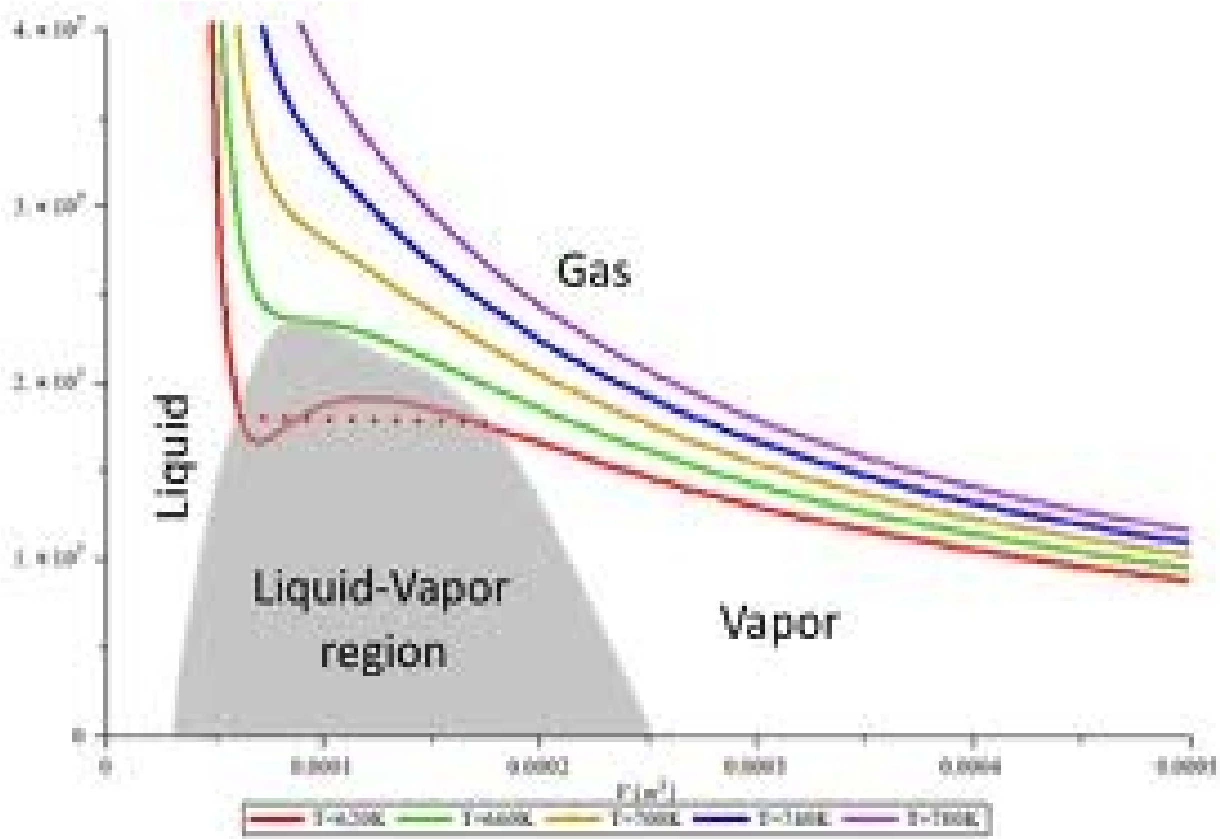


FIG. 5.3. Dependence of the compressibility ratio $Z \equiv PV/\mathscr{R}T$ upon reduced pressure $\tilde{P}$ for different reduced temperatures $\tilde{T}$. The fact that the data for a wide variety of fluids fall on identical curves supports the law of corresponding states. After Su (1946).

O modelo de Van der Waals

$$\left(p + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

The van der Waals equation



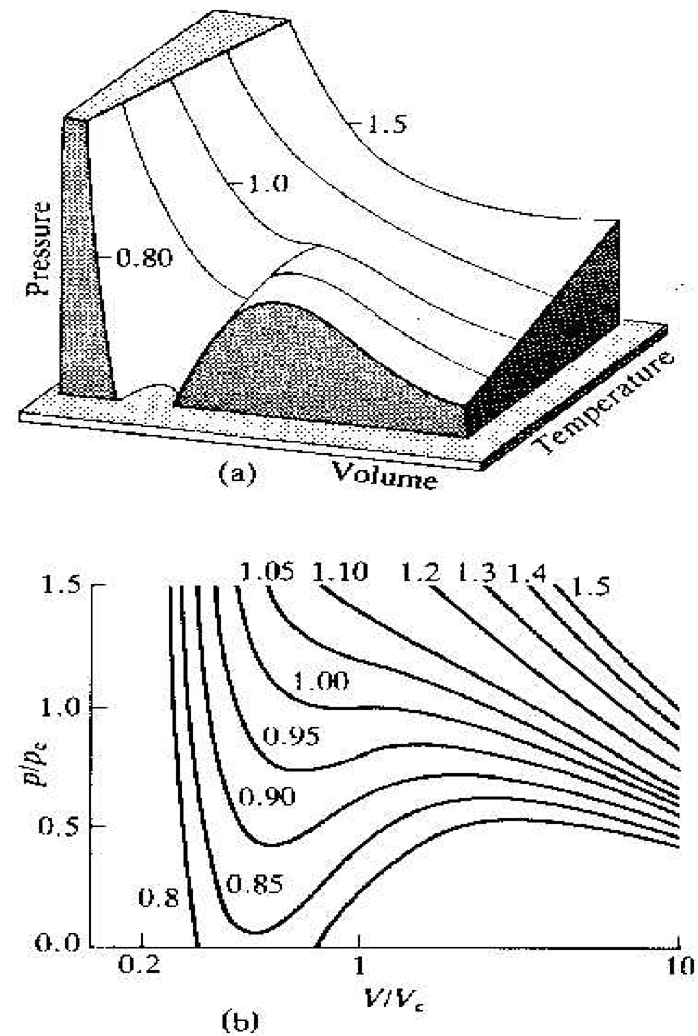
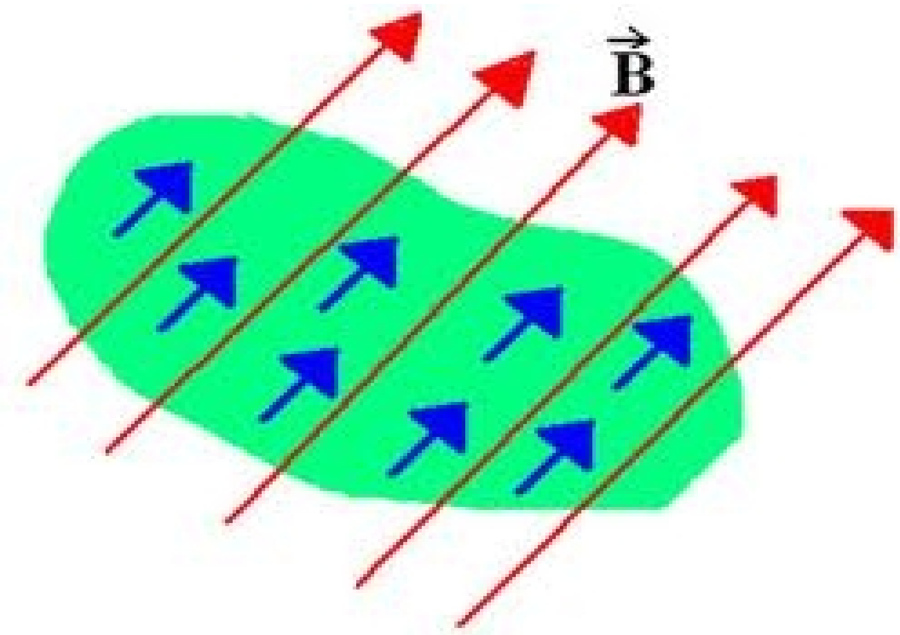
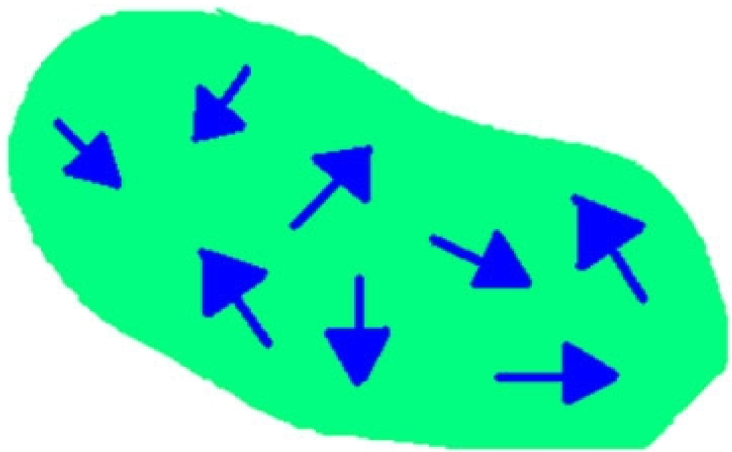


Fig. 1.10 The van der Waals isotherms at several values of T/T_c. (a) The shape of the surface (compare it with the perfect gas surface in Fig. 1.4). (b) A selection of individual isotherms. The van der Waals 'loops' are normally replaced by horizontal straight lines. The critical isotherm is the one at $T/T_c = 1$.

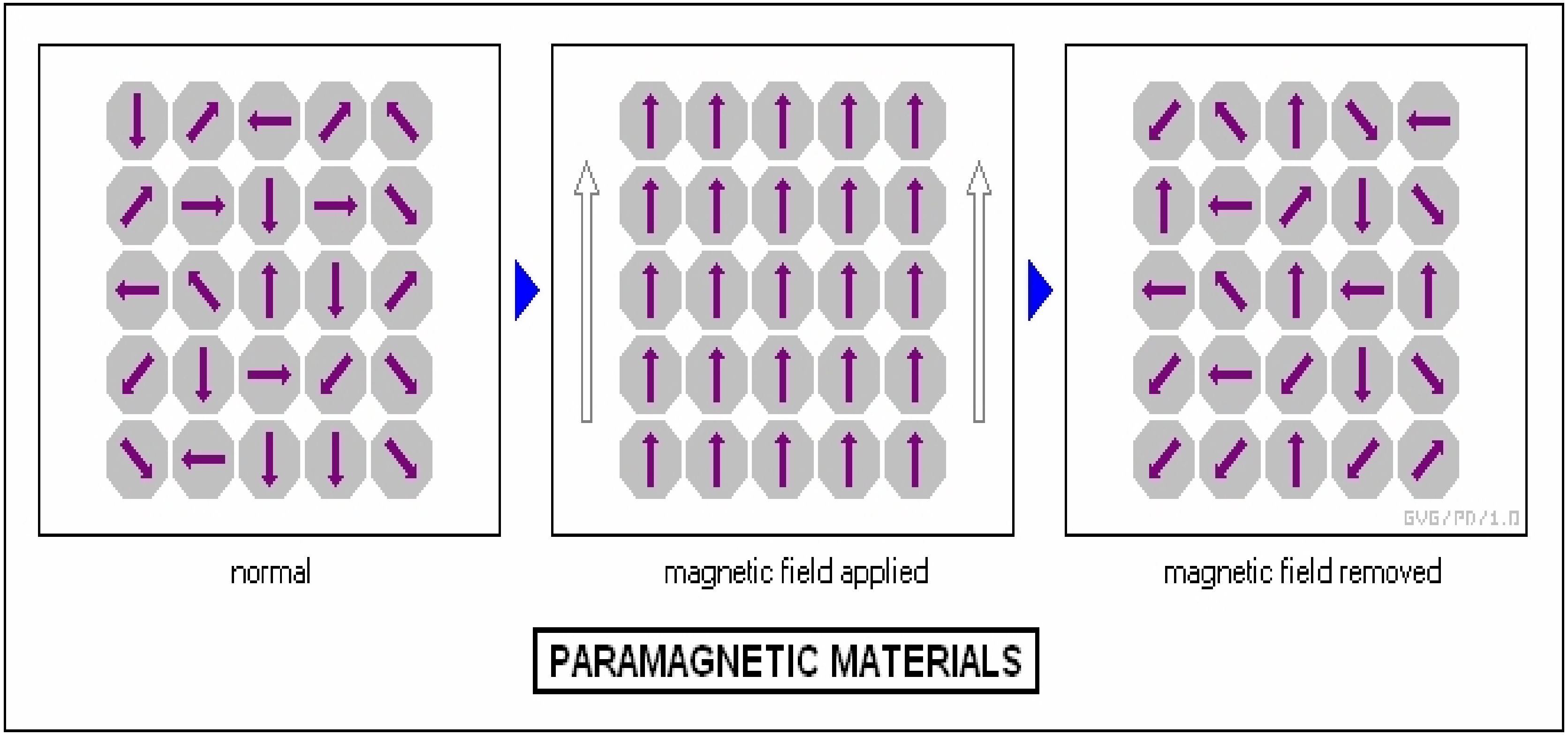
Coeficientes de van der Waals		
Gás	**a** (Pa m³)	**b** (m³/mol)
He	3.46×10^{-3}	23.71×10^{-6}
Ne	2.12×10^{-2}	17.10×10^{-6}
H_2	2.45×10^{-2}	26.61×10^{-6}
CO_2	3.96×10^{-1}	42.69×10^{-6}
H_2O	5.47×10^{-1}	30.52×10^{-6}

Materiais Paramagnéticos



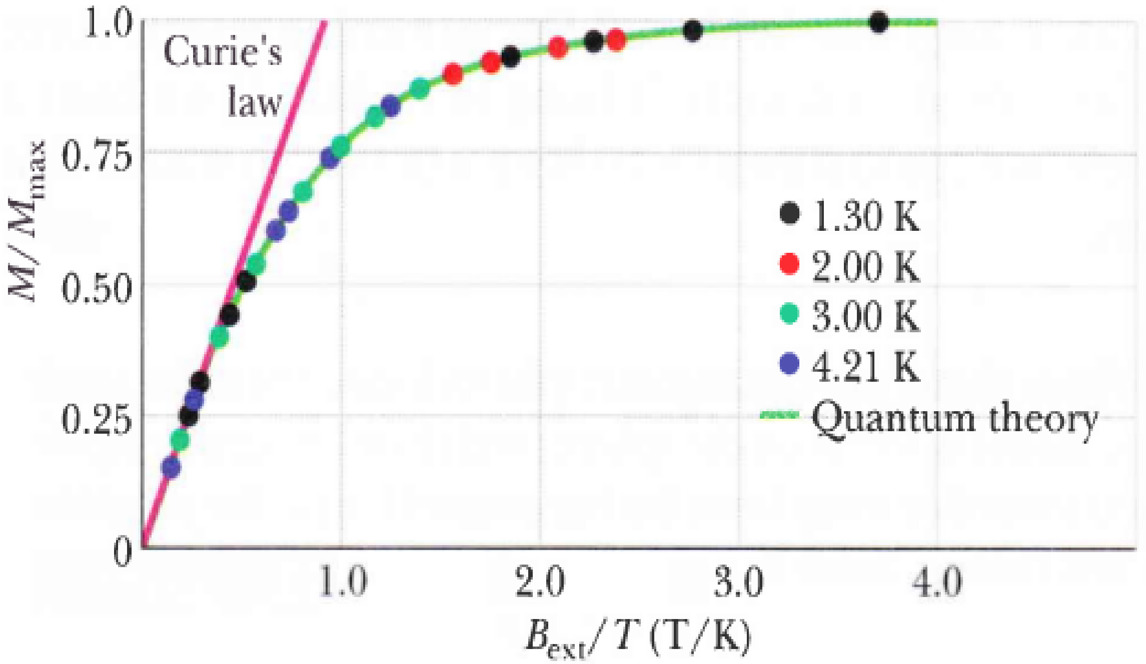


Materiais Paramagnéticos

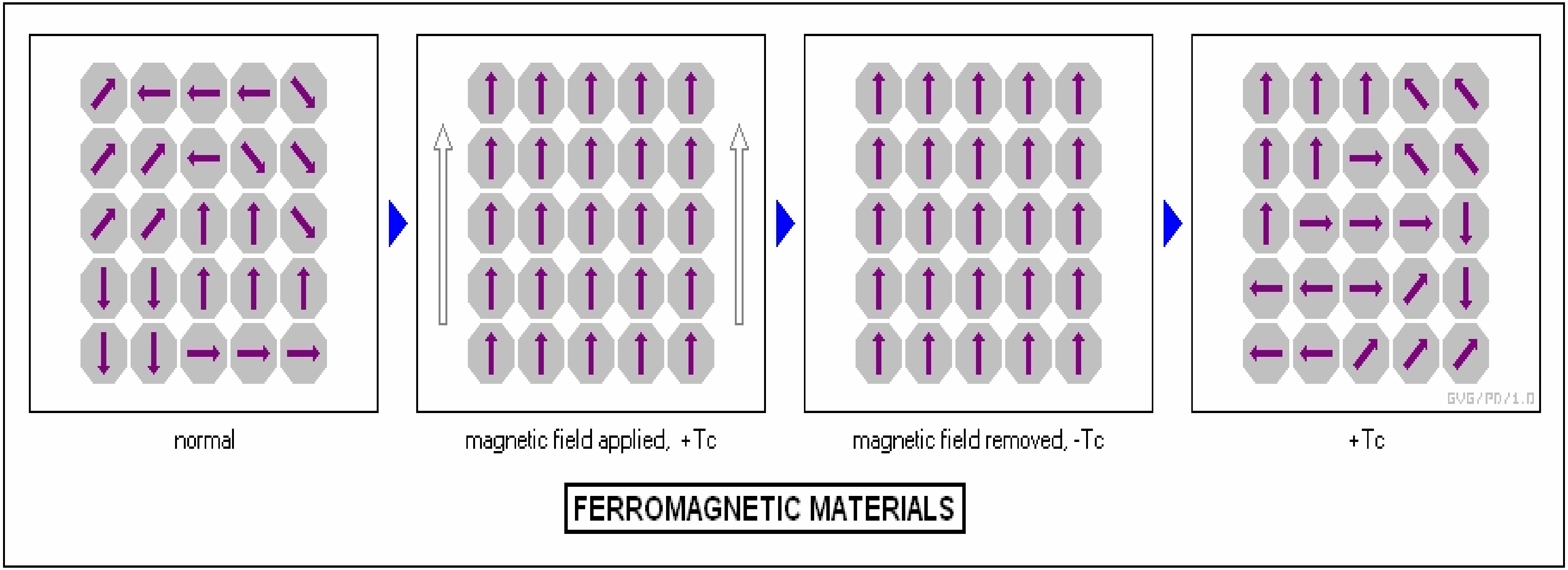


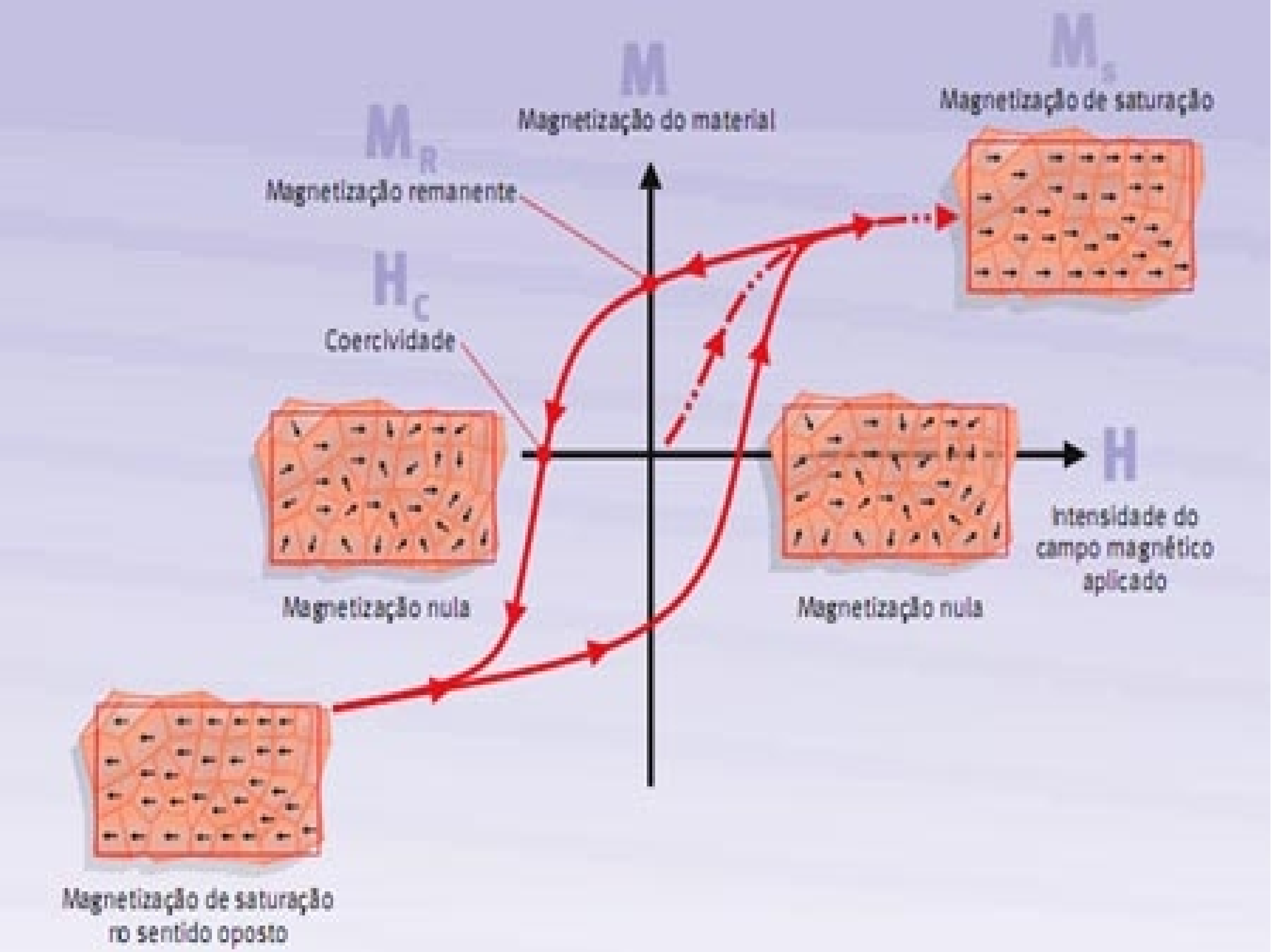
Materiais Paramagnéticos

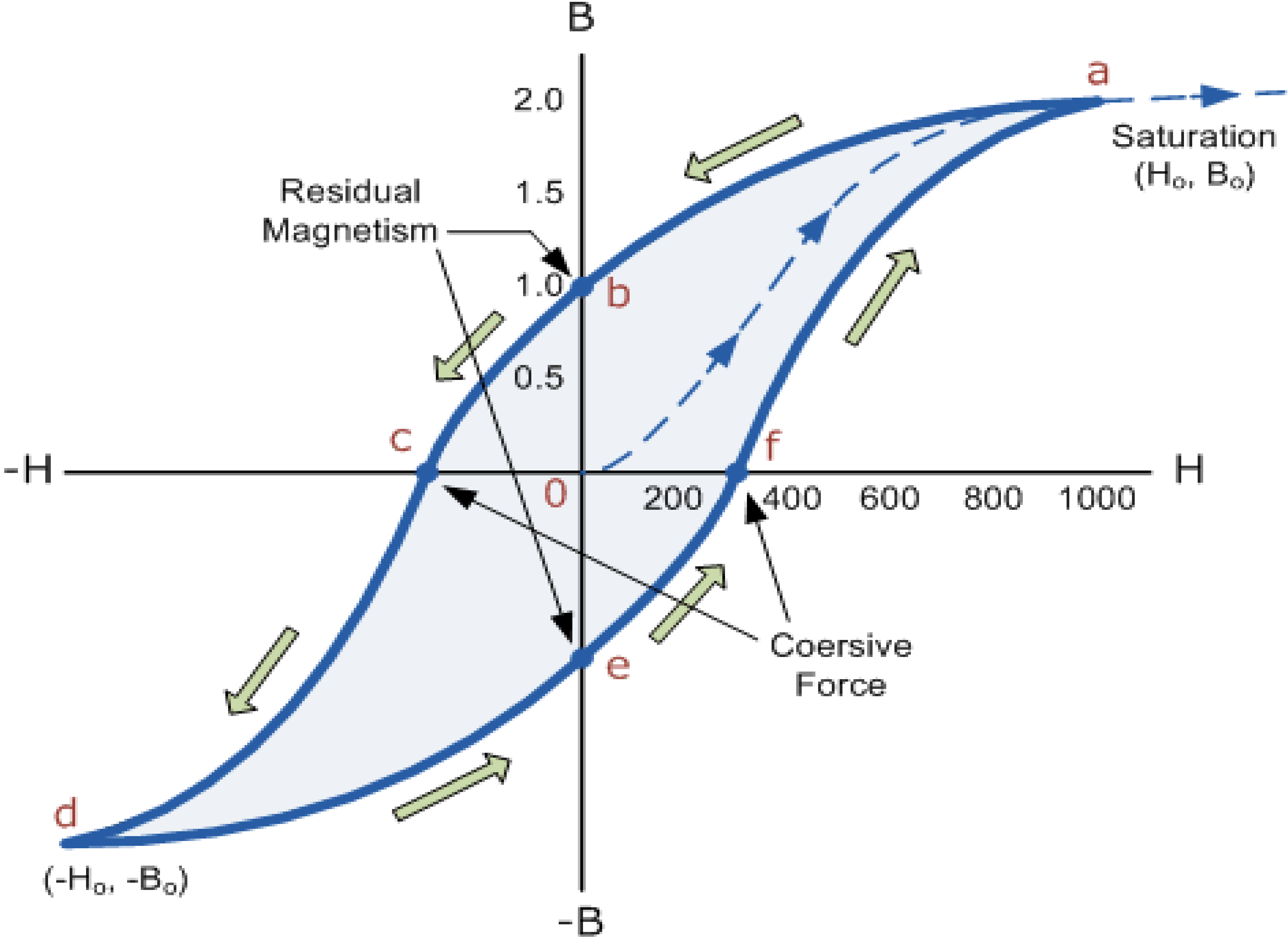
FIG. 32-14 A *magnetization curve* for potassium chromium sulfate, a paramagnetic salt. The ratio of magnetization M of the salt to the maximum possible magnetization M_{max} is plotted versus the ratio of the applied magnetic field magnitude B_{ext} to the temperature T. Curie's law fits the data at the left; quantum theory fits all the data. After W. E. Henry.



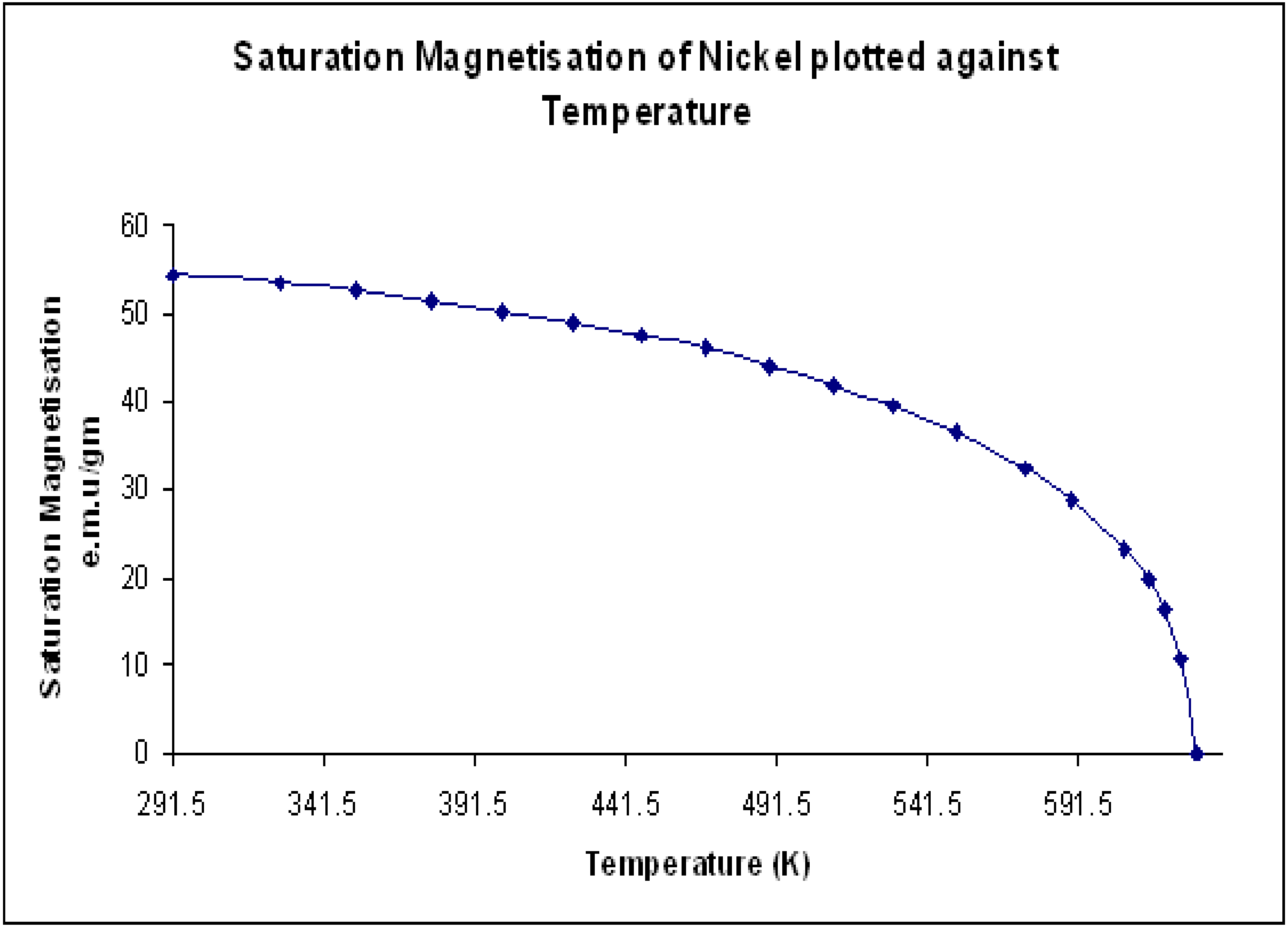
Materiais Ferromagnéticos

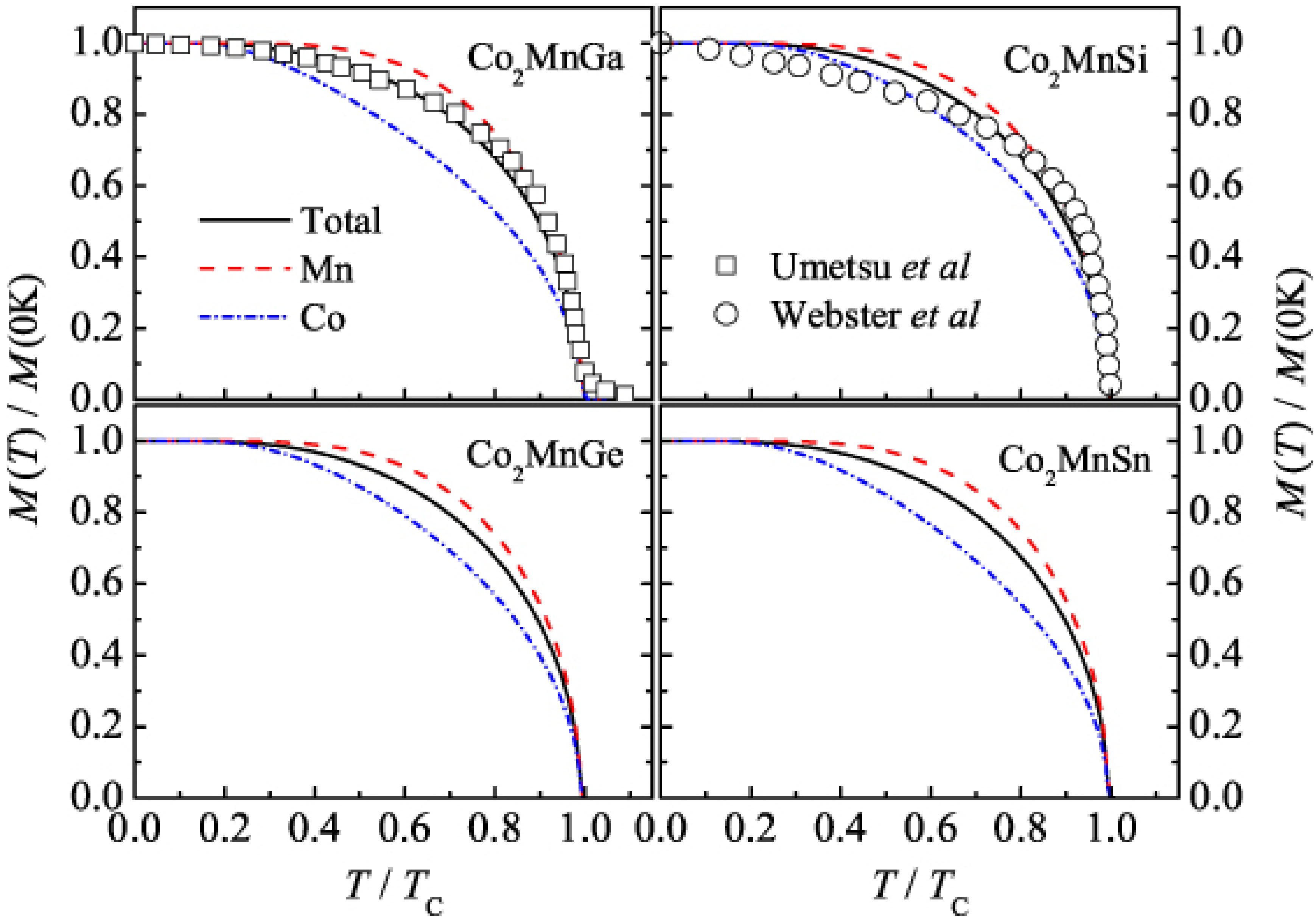



M
Magnetização do material
M_s
Magnetização de saturação
M_R
Magnetização remanente
H_C
Coercividade
H
Intensidade do campo magnético aplicado
Magnetização nula
Magnetização nula
Magnetização de saturação no sentido oposto

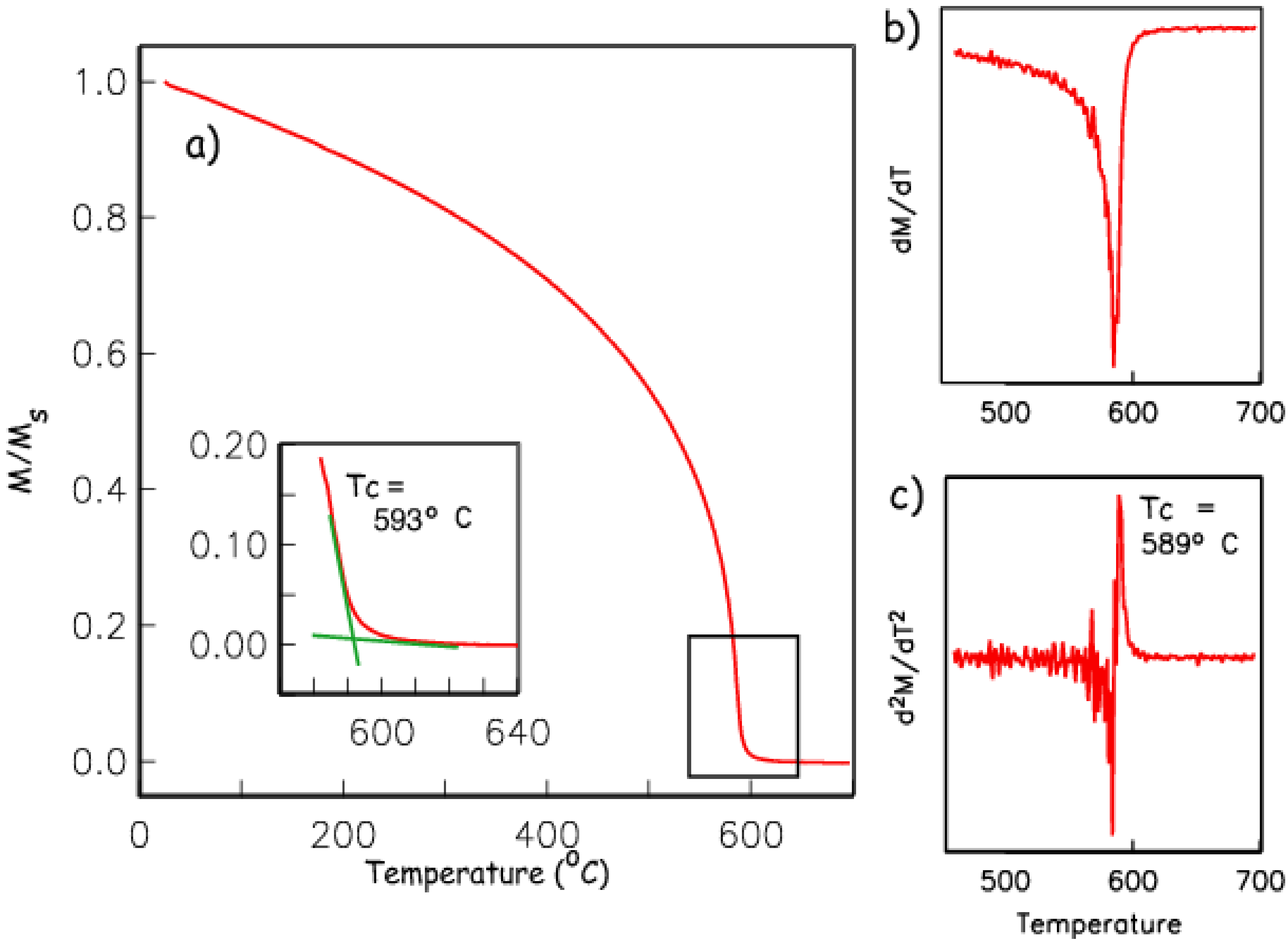


B
2.0
1.5
1.0
0.5
a
Saturation
(H$_o$, B$_o$)
Residual
Magnetism
b
c
f
-H
H
0
200
400
600
800
1000
Coersive
Force
e
d
(-H$_o$, -B$_o$)
-B


Saturation Magnetisation of Nickel plotted against Temperature
Saturation Magnetisation e.m.u/gm
60
50
40
30
20
10
0
291.5
341.5
391.5
441.5
491.5
541.5
591.5
Temperature (K)



Co2MnGa
Co2MnSi
Co2MnGe
Co2MnSn
Total
Mn
Co
Umetsu et al
Webster et al
M(T) / M(0K)
T / TC
0.0
0.2
0.4
0.6
0.8
1.0


a)
M/Ms
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
Temperature (°C)
0.20
0.10
0.00
600
640
Tc =
593° C
b)
dM/dT
500
600
700
c)
d2M/dT2
Tc =
589° C
500
600
700
Temperature

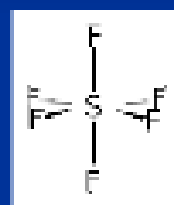
1. Critical point and phase transition

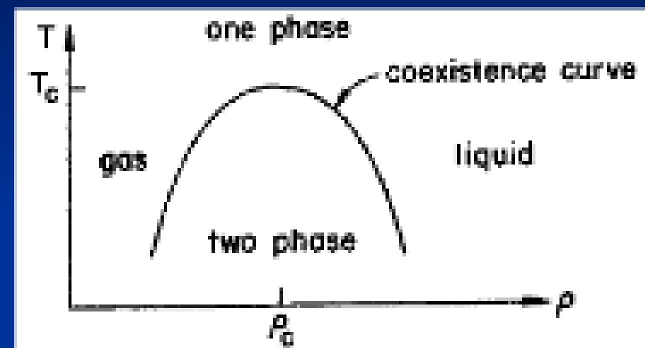
Critical point of fluid (p=const)

1. temp dependence

- Phases for SF_6 the curve is

$$|\rho_+ - \rho_-| \propto |T - T_c|^{0.327 \pm 0.006}$$





rho = density

T_c = critical temp

Fig 1: phase diagram of fluid at p=const

- Magnetization for DyAlO3

$$M \propto (T_c - T)^{0.311 \pm 0.005}$$

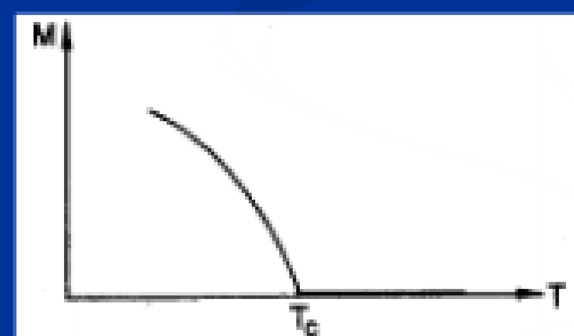


Fig 2: Onset of magnetization in ferromagnet

Diagrama de Fases

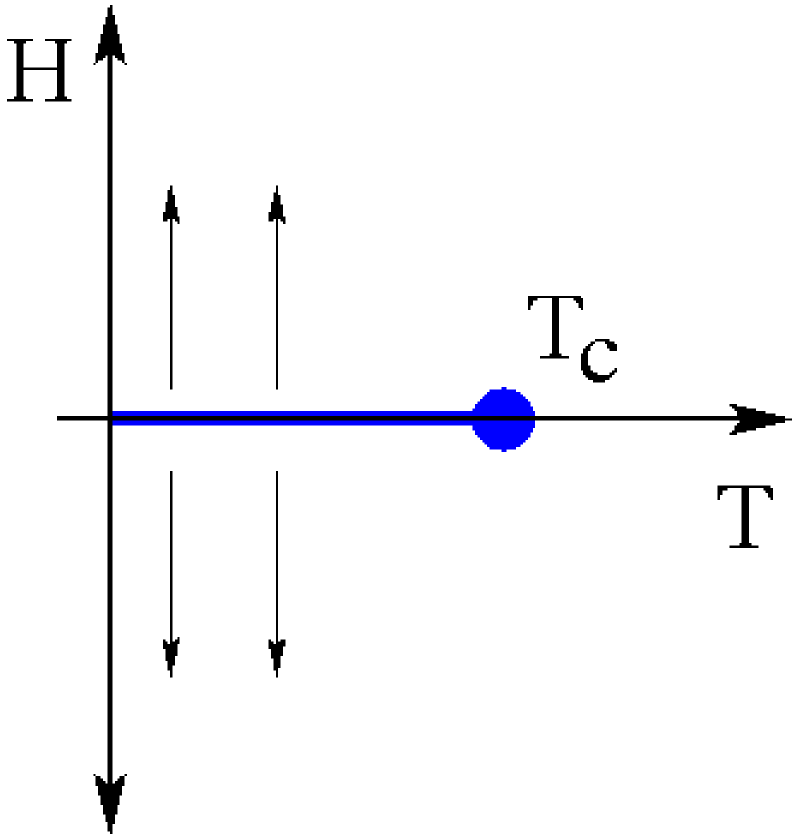
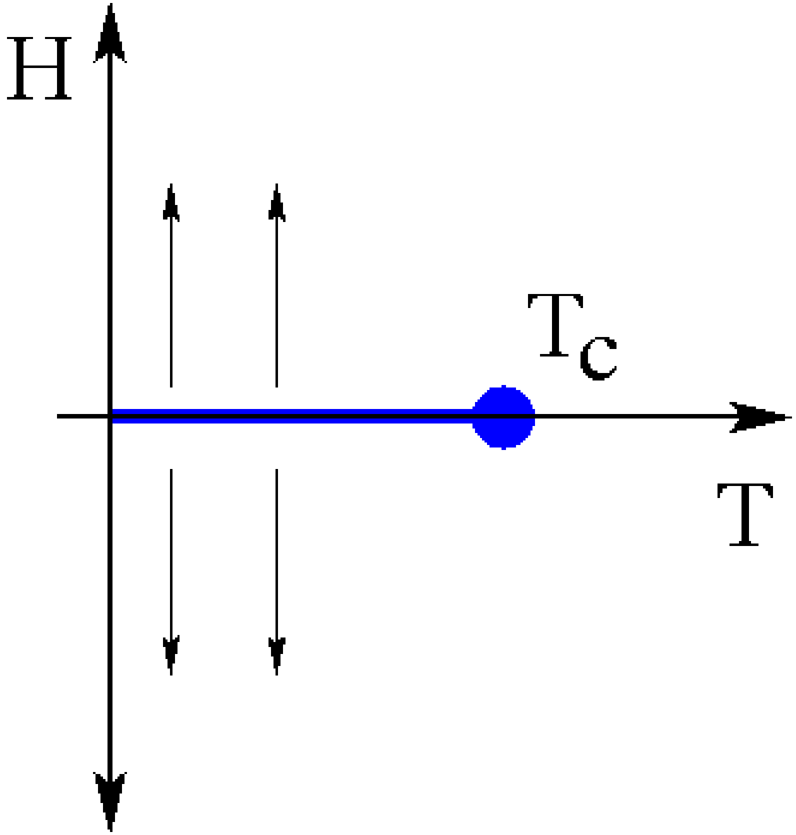


Diagrama de Fases



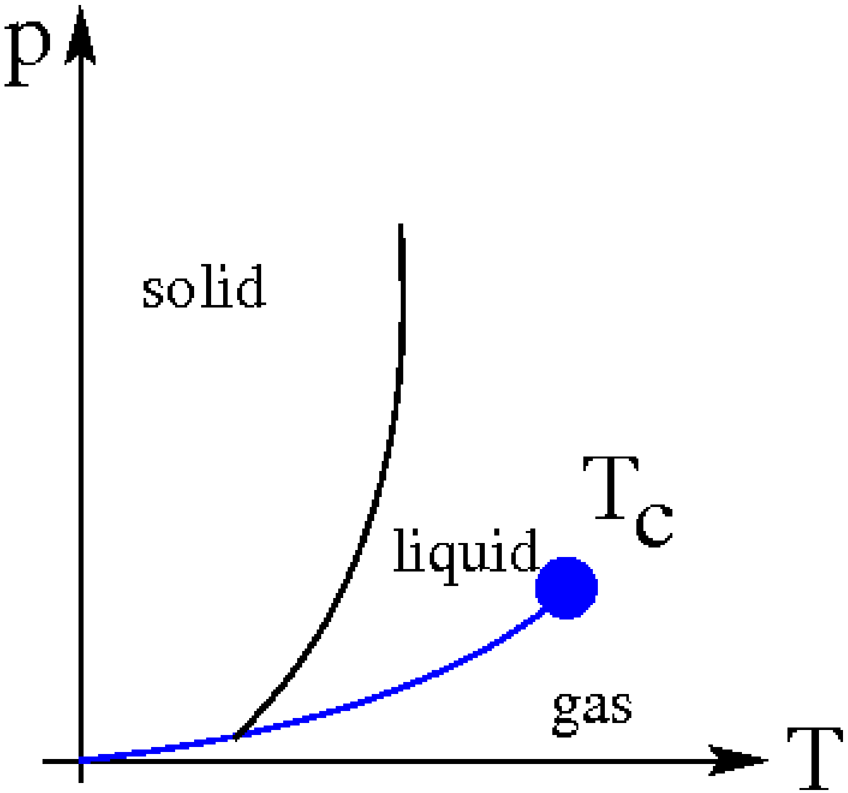
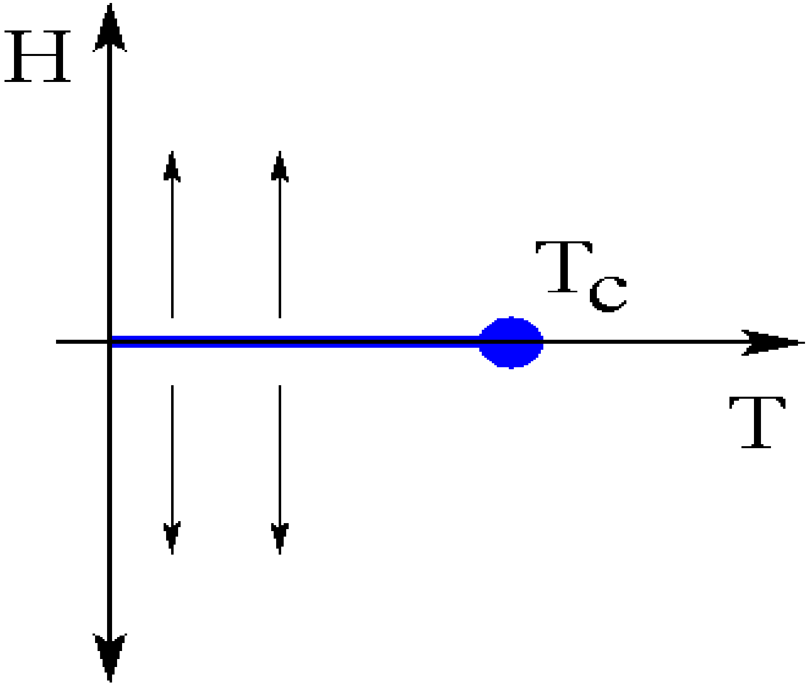
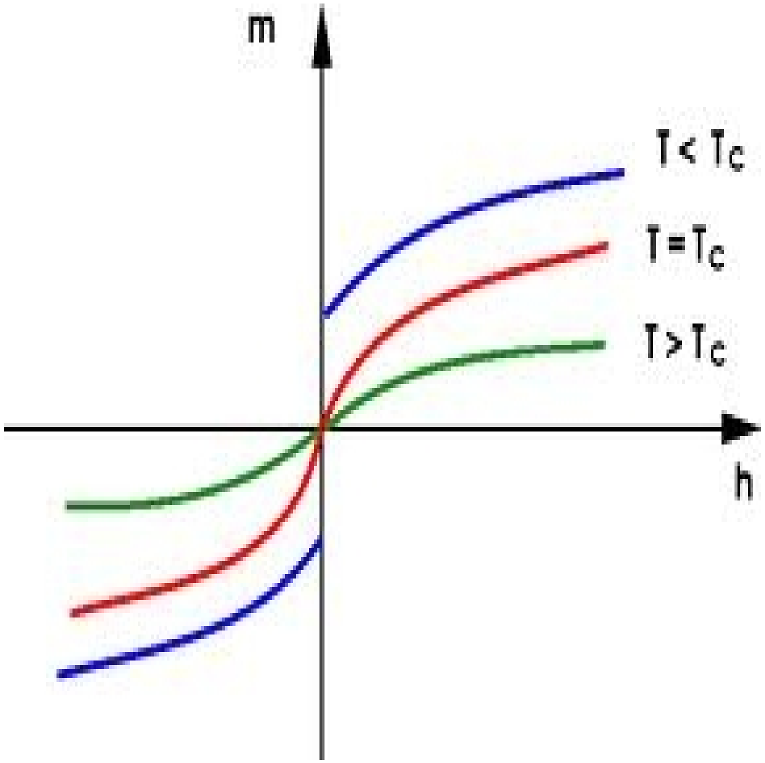


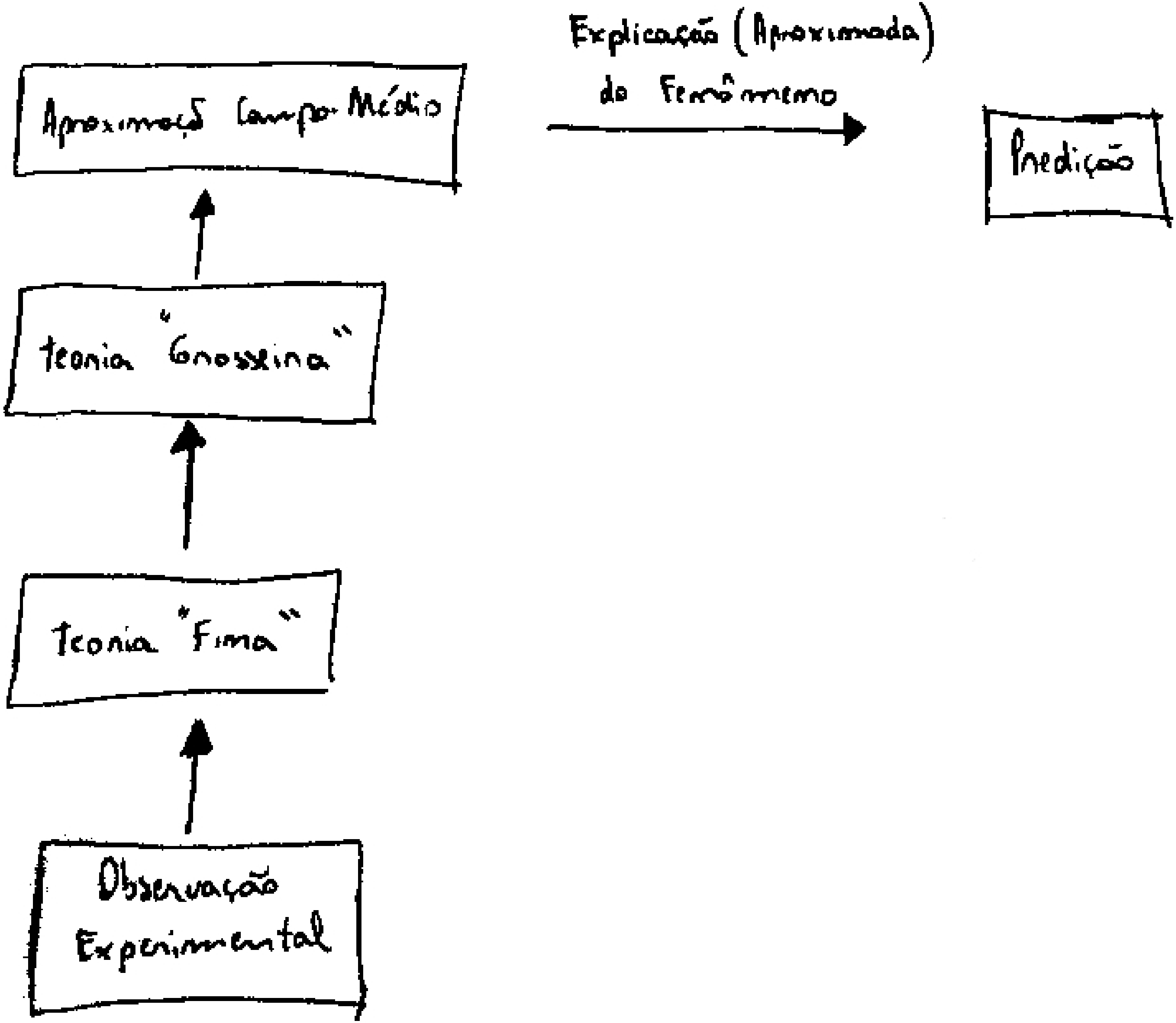
Diagrama de Fases

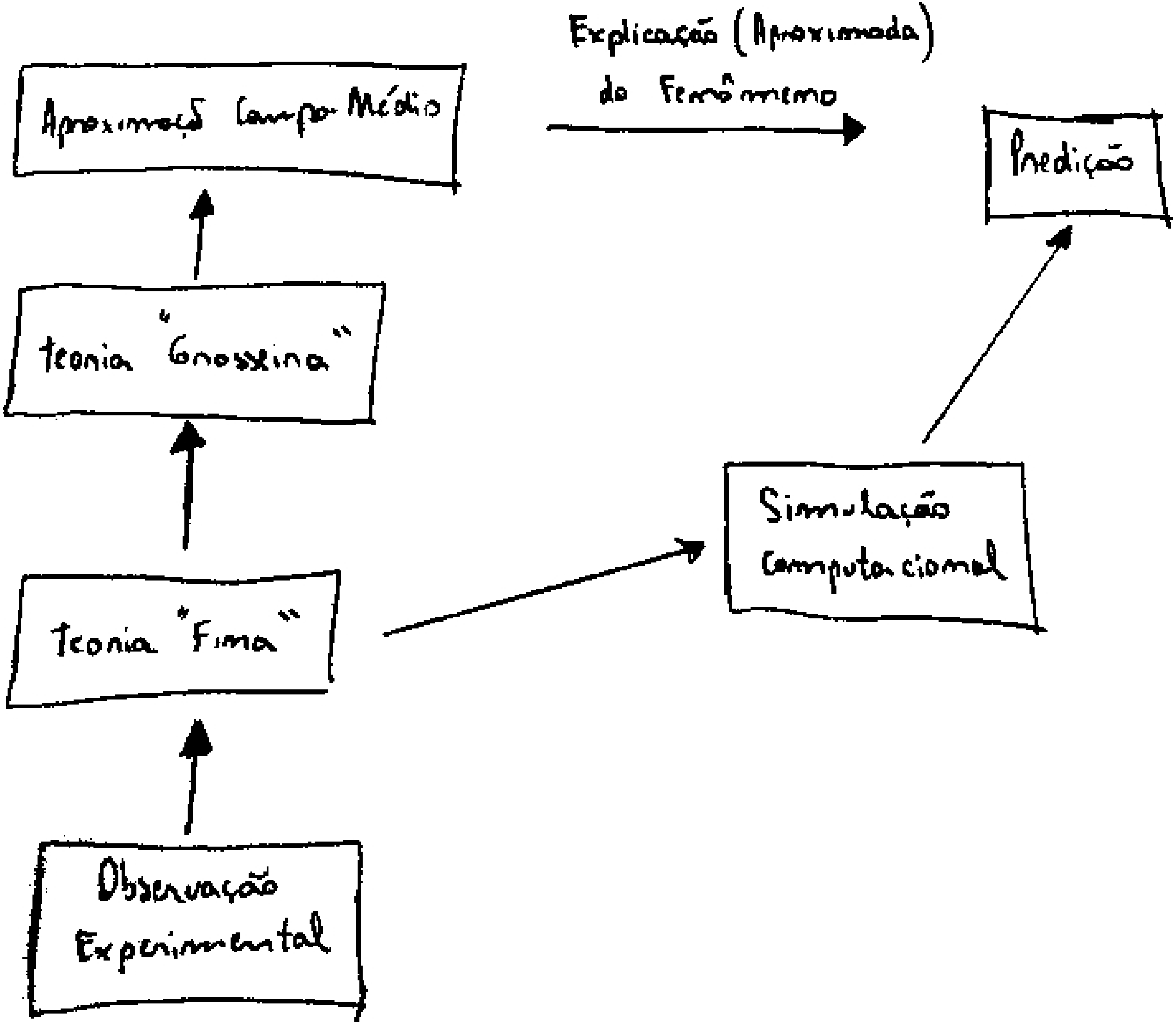




Expoentes Críticos

	α	β	γ	$\alpha + 2\beta + \gamma$	δ	ν	η
Experimentos para qualquer fluido	$\approx 0,11$	$\approx 1/3$	$1,2 - 1,4$	$\approx 2,03$	$\approx 4,1 - 4,4$	-	-
Experimentos com Materiais Ferromagnéticos	≈ 0	$\approx 1/3$	$5/4$	$\approx 2,3$	-	-	-


Aproximaçõ Campo Médio
Explicação (Aproximada) do Fenômemo
Predição
teoria "Grosseira"
teoria "Fina"
Observação Experimental



Explicação (Aproximada) do Fenômeno
Aproximação Campo Médio
Predição
teoria "Grosseira"
Simulação computacional
teoria "Fina"
Observação Experimental