TFY4115 Fysikk

Faseoverganger (smelte, fordampe)

Y&F kap.17.6+18.6 (8 sider)

L&H&L Kap. 17.10 (1½ side)

Varme Q tilført et legeme kan:

1) Varme opp stoff: $Q = C \cdot n \cdot \Delta T$

der C = molar varmekapasitet

2) Smelte stoff: $Q = L'_{\mathrm{s}} \cdot \Delta m$

der L'_{s} = spesifikk smeltevarme (J/kg)

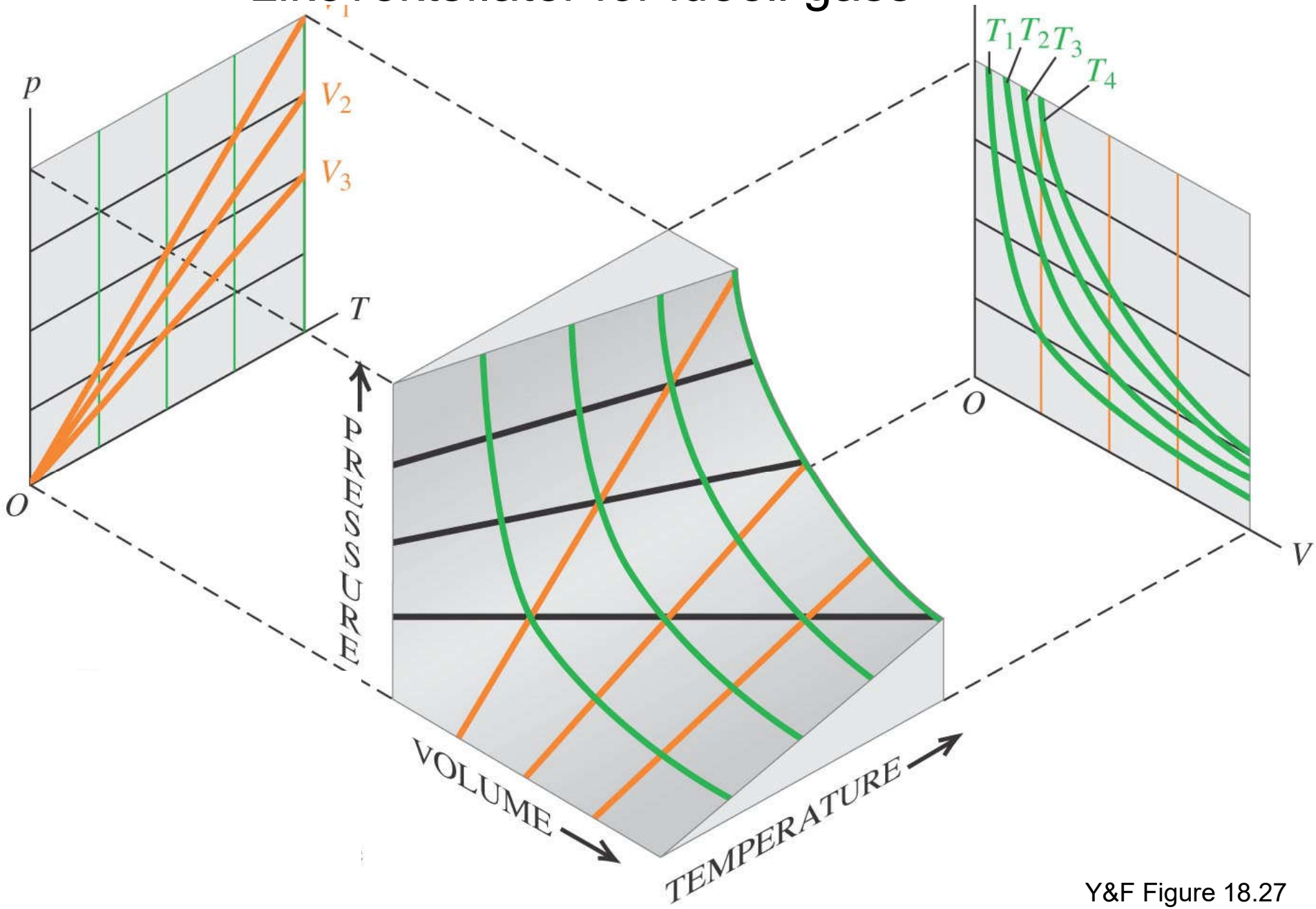
3) Fordampe stoff: $Q = L'_{\mathrm{f}} \cdot \Delta m$

der L'_{f} = spesifikk fordampingsvarme (J/kg)

4) Sublimere stoff: $Q = (L'_{\mathrm{s}} + L'_{\mathrm{f}}) \cdot \Delta m$

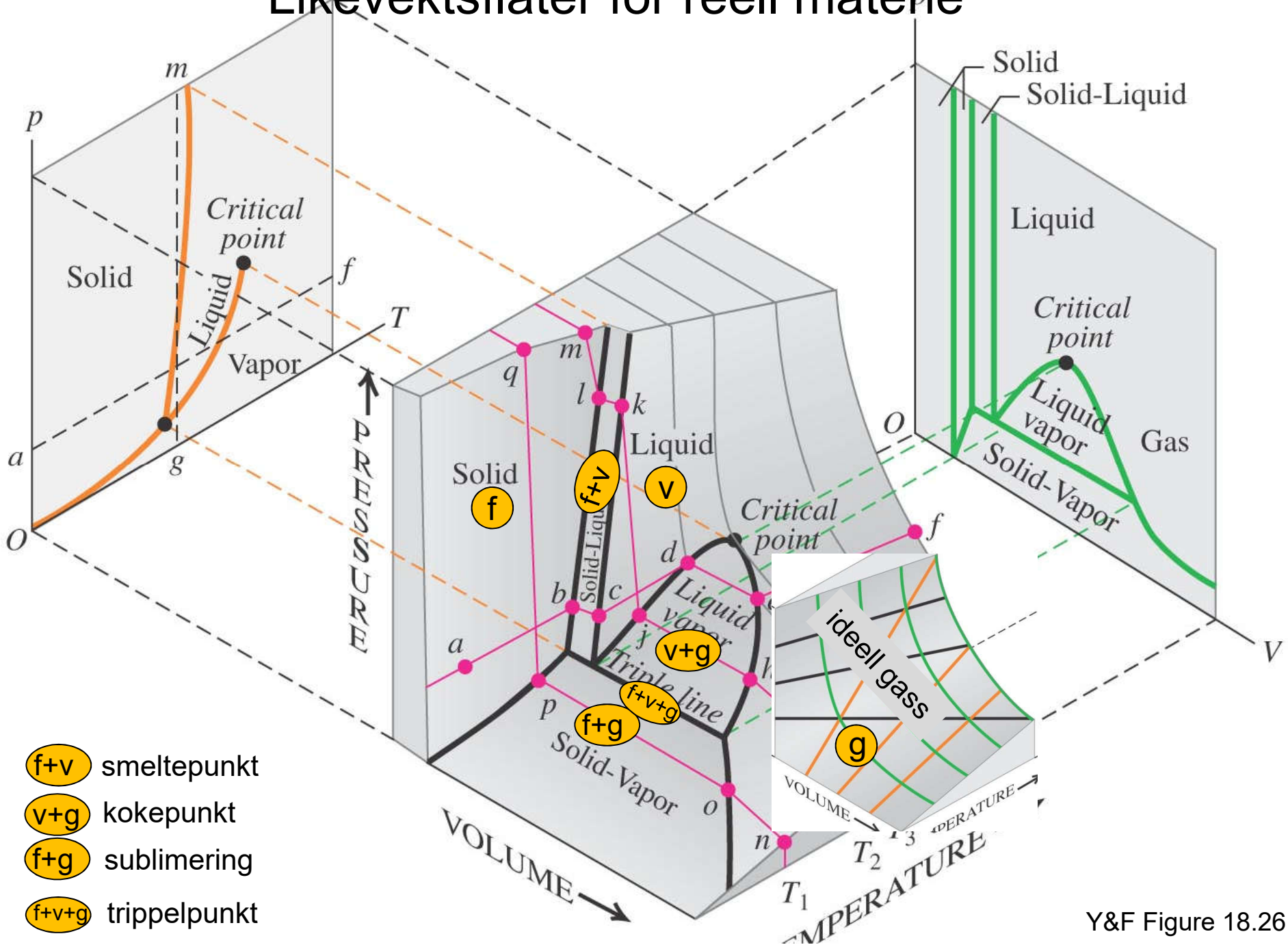
5) Utvide en gass isotermt $Q = W = \int p \, \mathrm{d}V$

Likevektsflater for ideell gass



Y&F Figure 18.27

Likevektsflater for reell materie



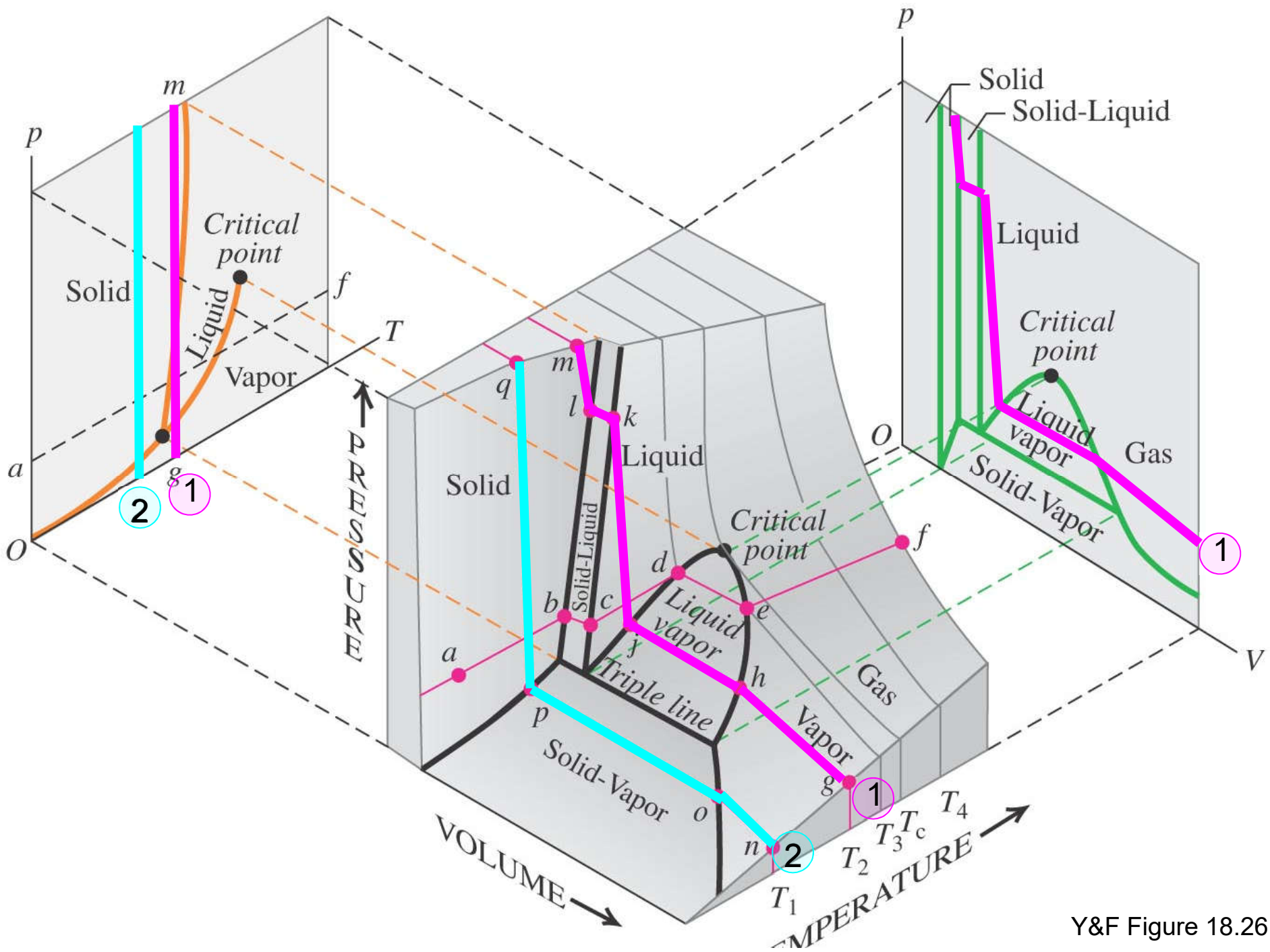
f+v smeltepunkt

v+g kokepunkt

f+g sublimering

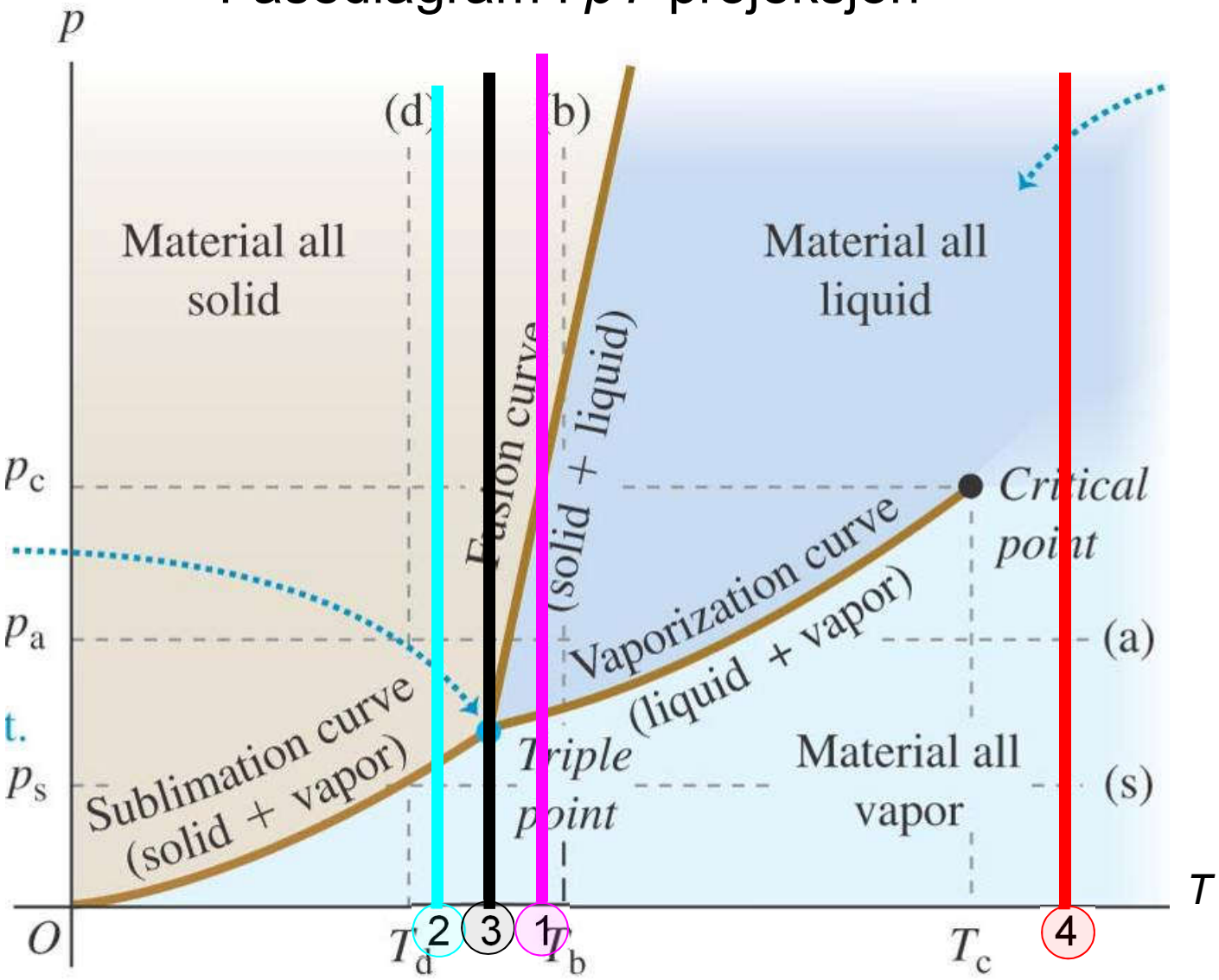
f+v+g trippelpunkt

Y&F Figure 18.26



Y&F Figure 18.26

Fasediagram i *pT*-projeksjon



Y&F Figure 18.24

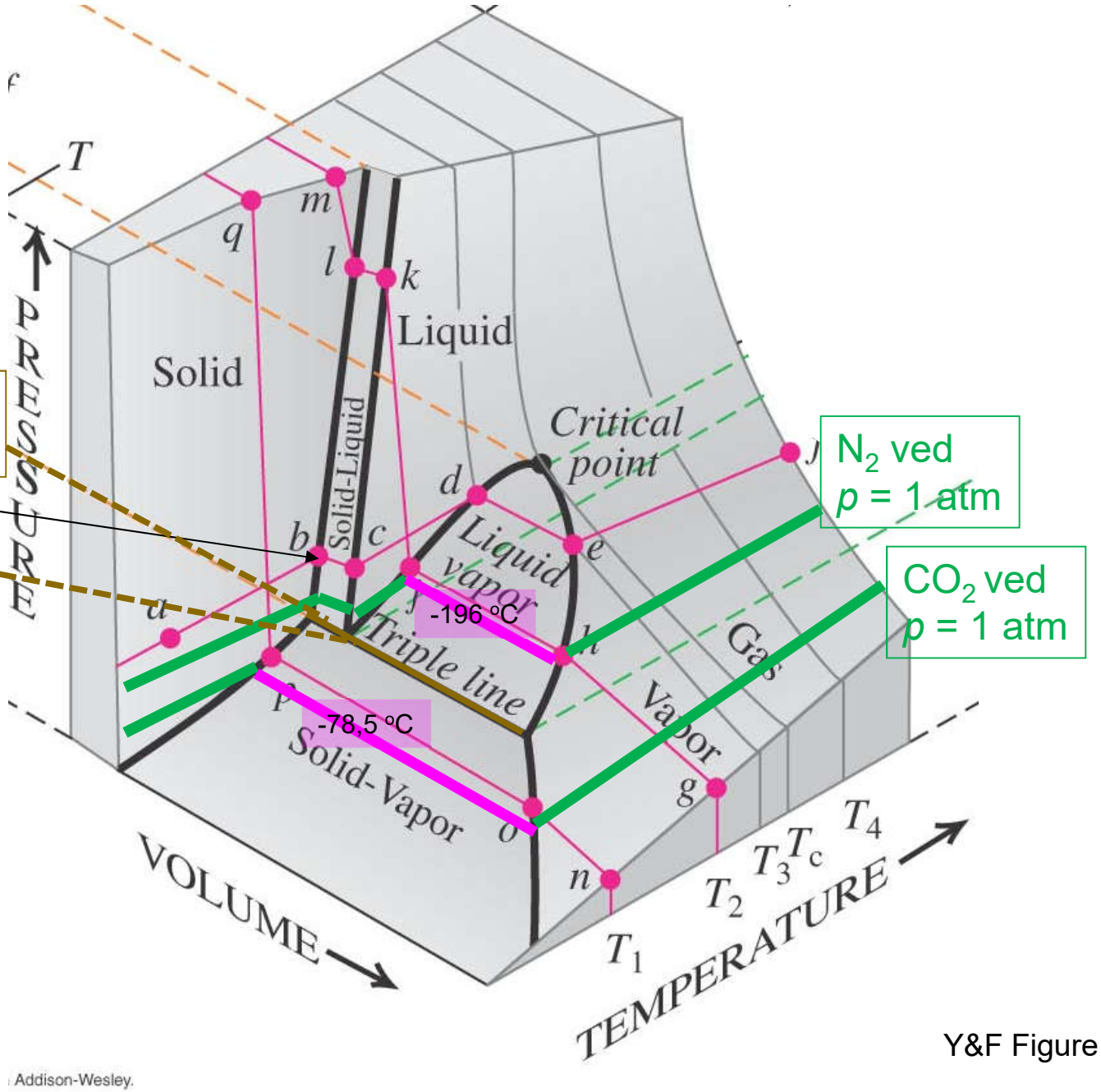
Table 18.3 Triple-Point Data

Substance	Temperature (K)		Pressure (Pa)	
Hydrogen	13.80		0.0704×10^5	
Deuterium	18.63		0.171×10^5	
Neon	24.56		0.432×10^5	
Nitrogen	63.18	= - 210 °C	0.125×10^5	= 0,12 atm
Oxygen	54.36		0.00152×10^5	
Ammonia	195.40		0.0607×10^5	
Carbon dioxide	216.55	= - 56,5 °C	5.17×10^5	= 5,1 atm *)
Sulfur dioxide	197.68		0.00167×10^5	
Water	273.16	= 0,01 °C	0.00610×10^5	= 0,0060 atm

*) ved 1 atm:
sublimerer ved -78,5 °C

Y&F Table 18.3

Likevekt CO_2 og N_2 ved 1 atm



CO_2: p_{triple} = 5,1 atm
T_{triple} = - 56,5 °C

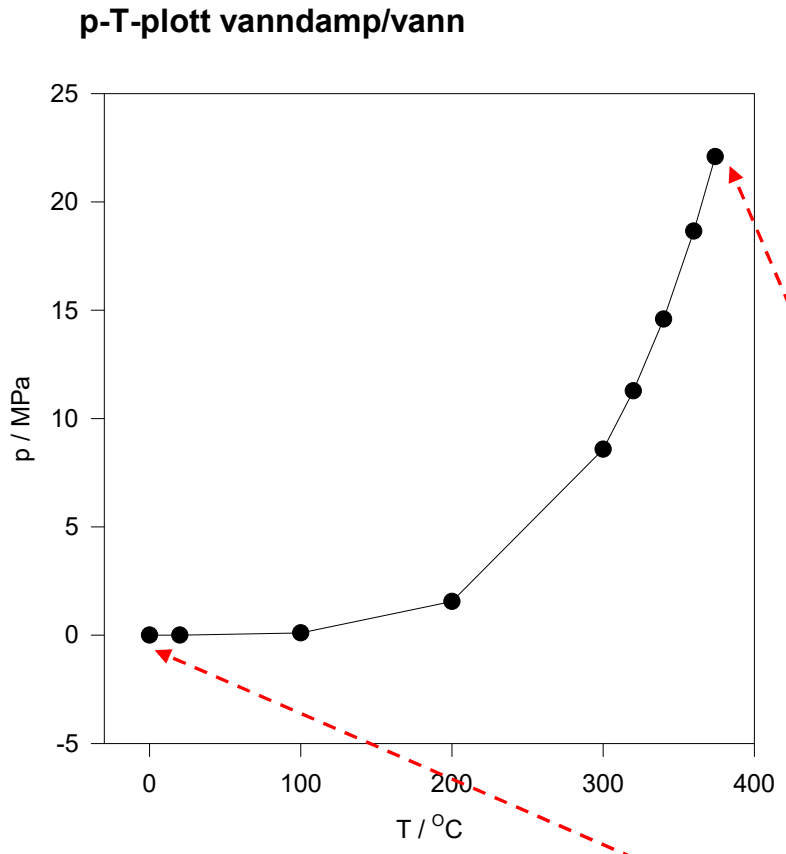
N_2: p_{triple} = 0,12 atm
T_{triple} = - 210 °C

N_2 ved
p = 1 atm

CO_2 ved
p = 1 atm

Y&F Figure 18.

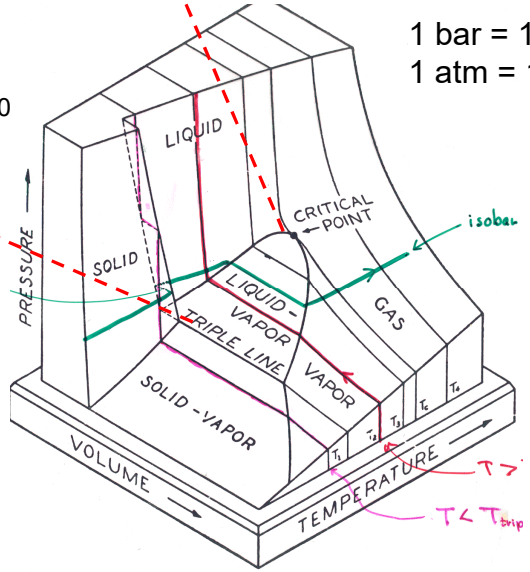
Vanndamptrykk *p* sfa. temp. *T* (kokepunkt)



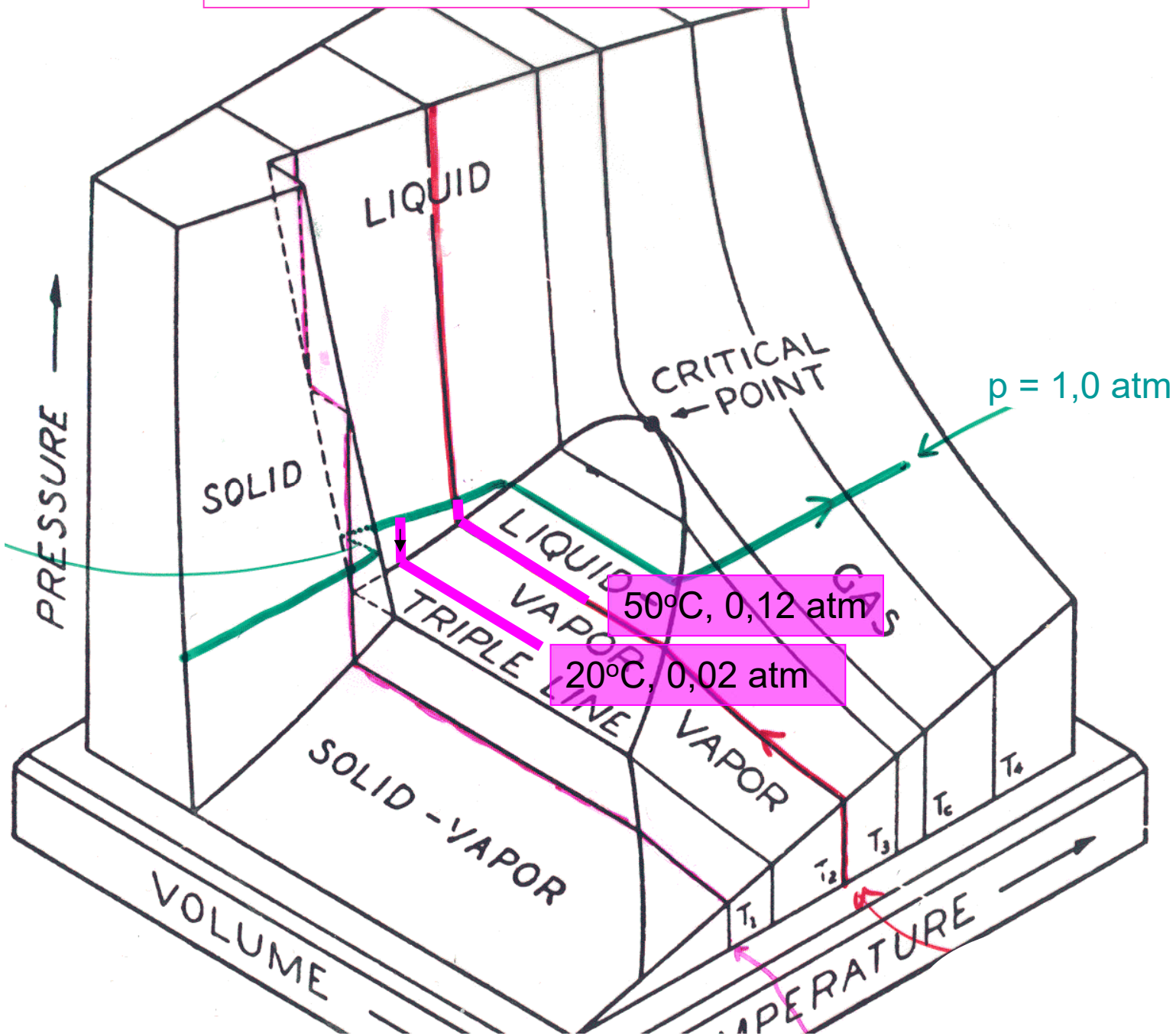
T / °C	*p* / bar
0,01	0,006
20	0,023
50	0,123
100	1,013
200	15,5
300	85,8
320	113
340	146
360	187
374,14	220,9

T / °C	*p* / bar
90	0,701
95	0,846
100	1,013
105	1,22
110	1,43

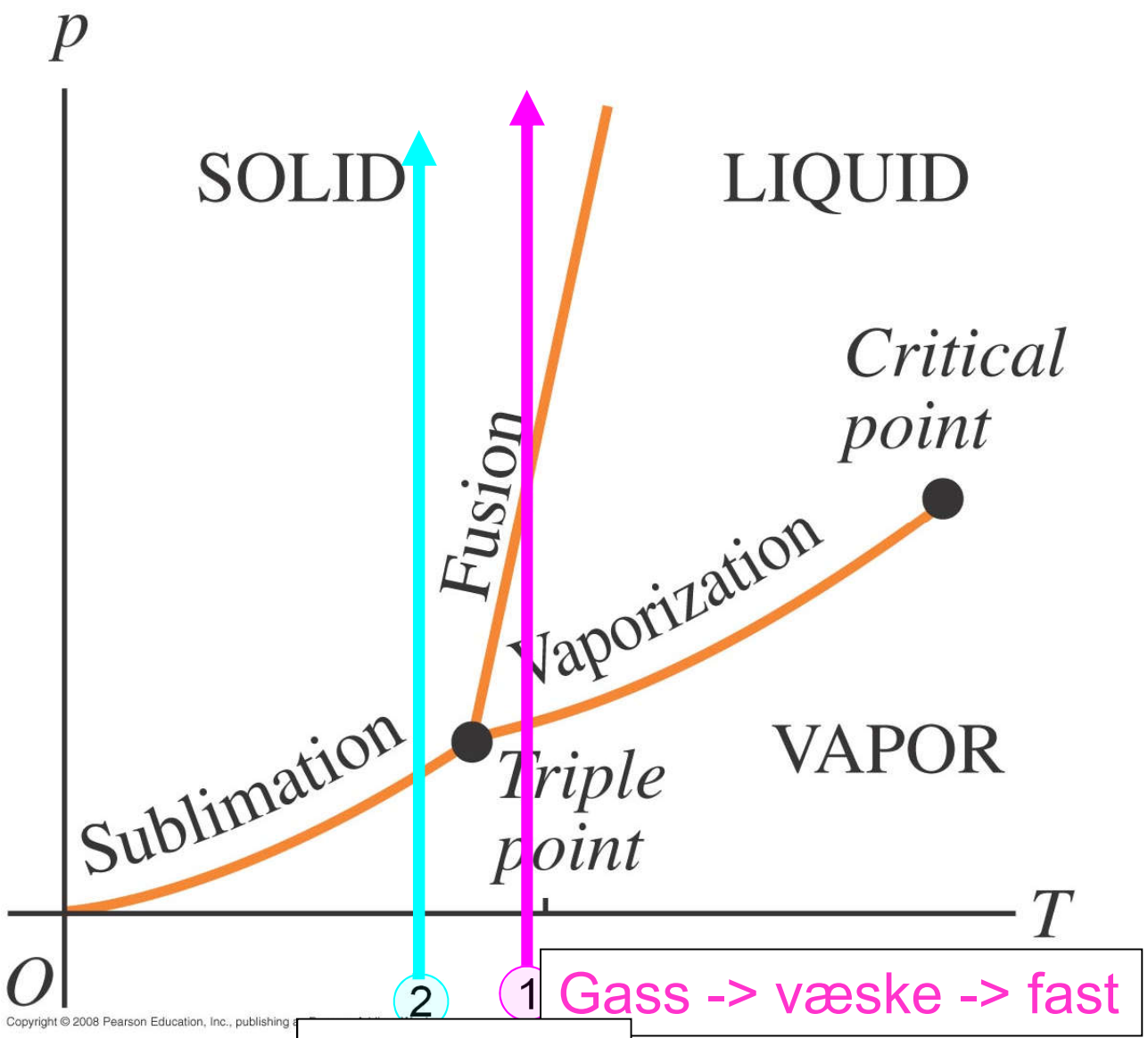
1 bar = 100 kPa = 0,1 MPa
1 atm = 1,013 bar



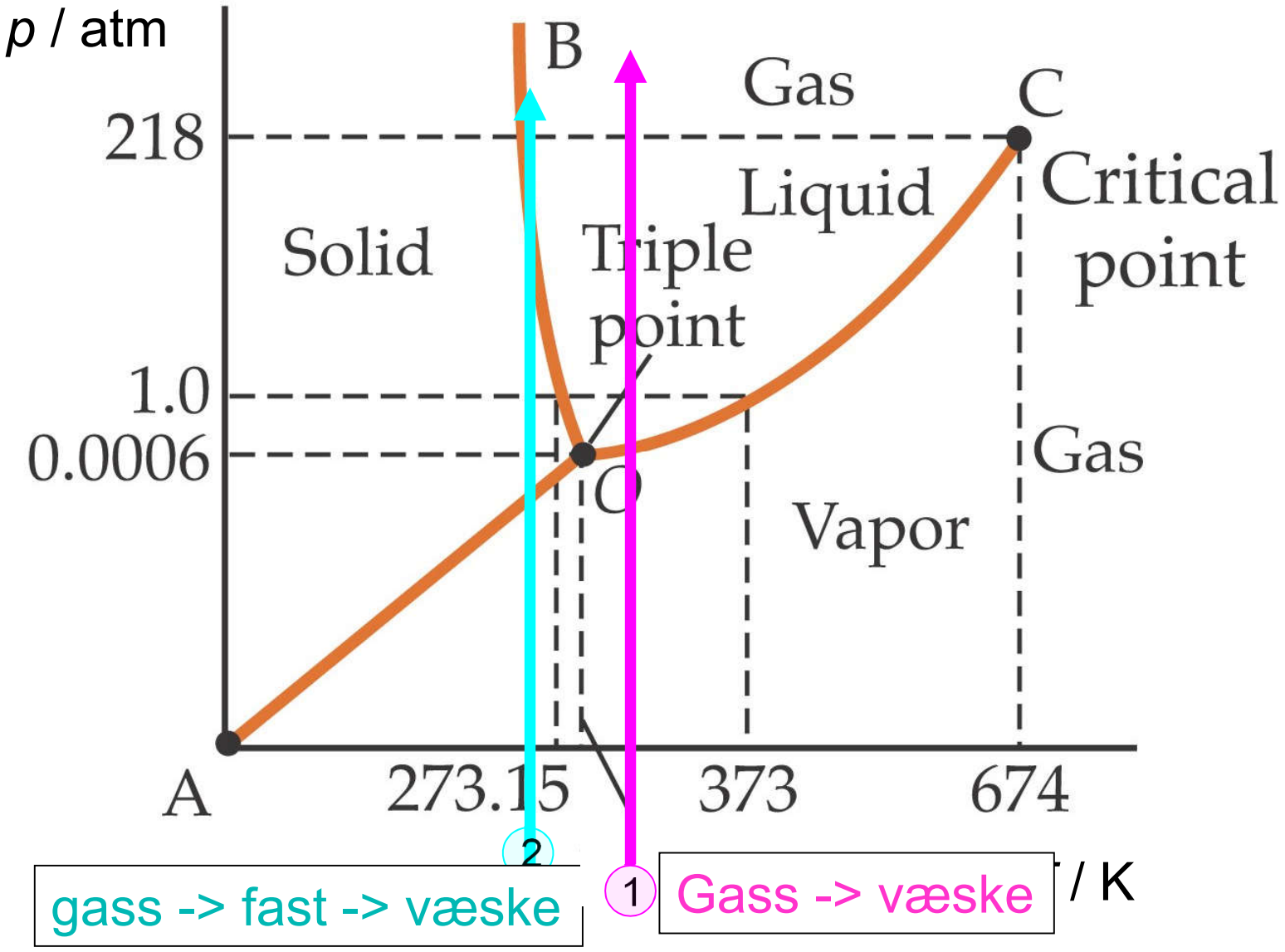
”Håndkokt” vann i sprøyte.



Fasediagram i *pT*-projeksjon **for alle andre stoff enn H_2O**

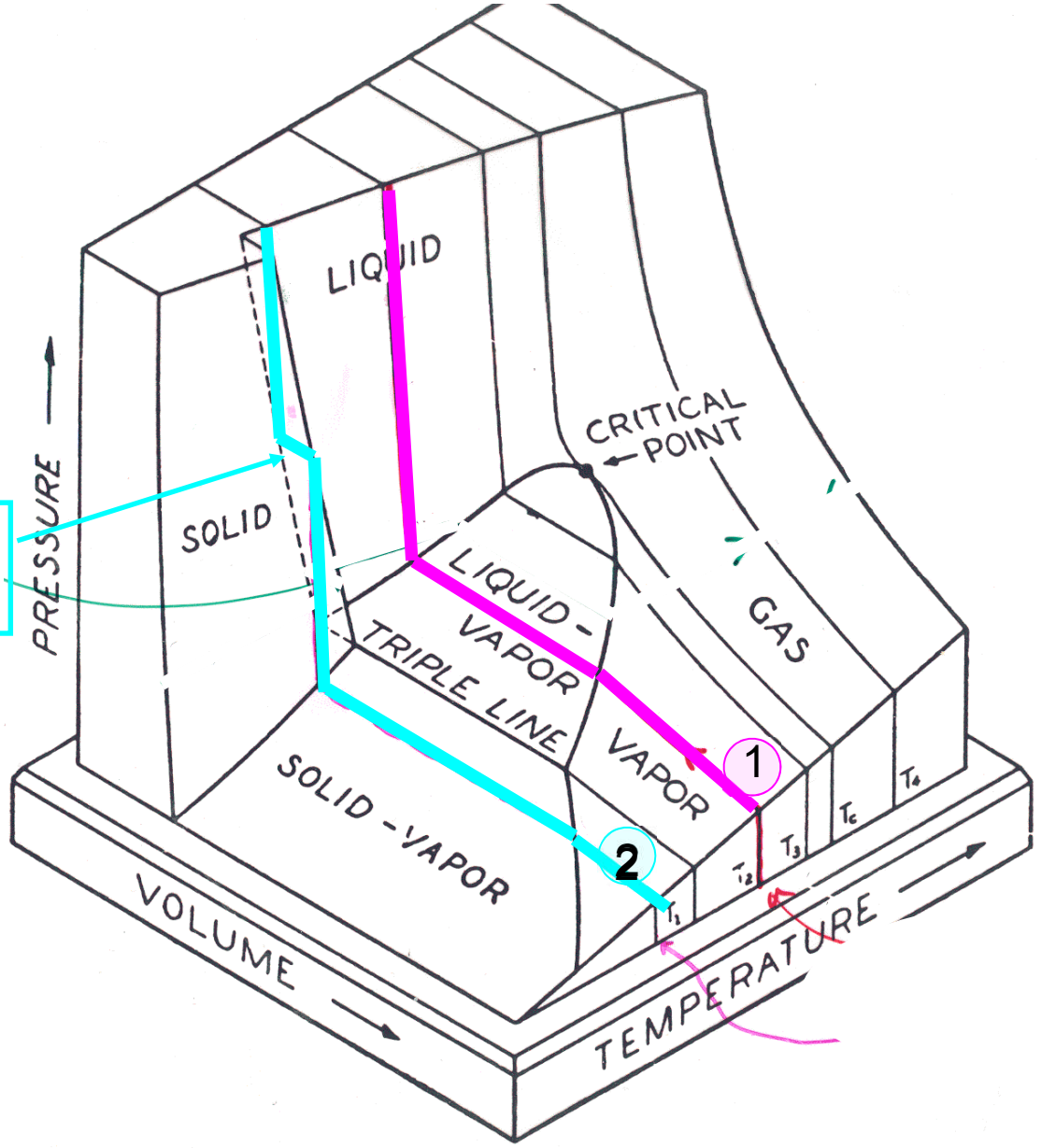


Fasediagram i *pT*-projeksjon for H_2O

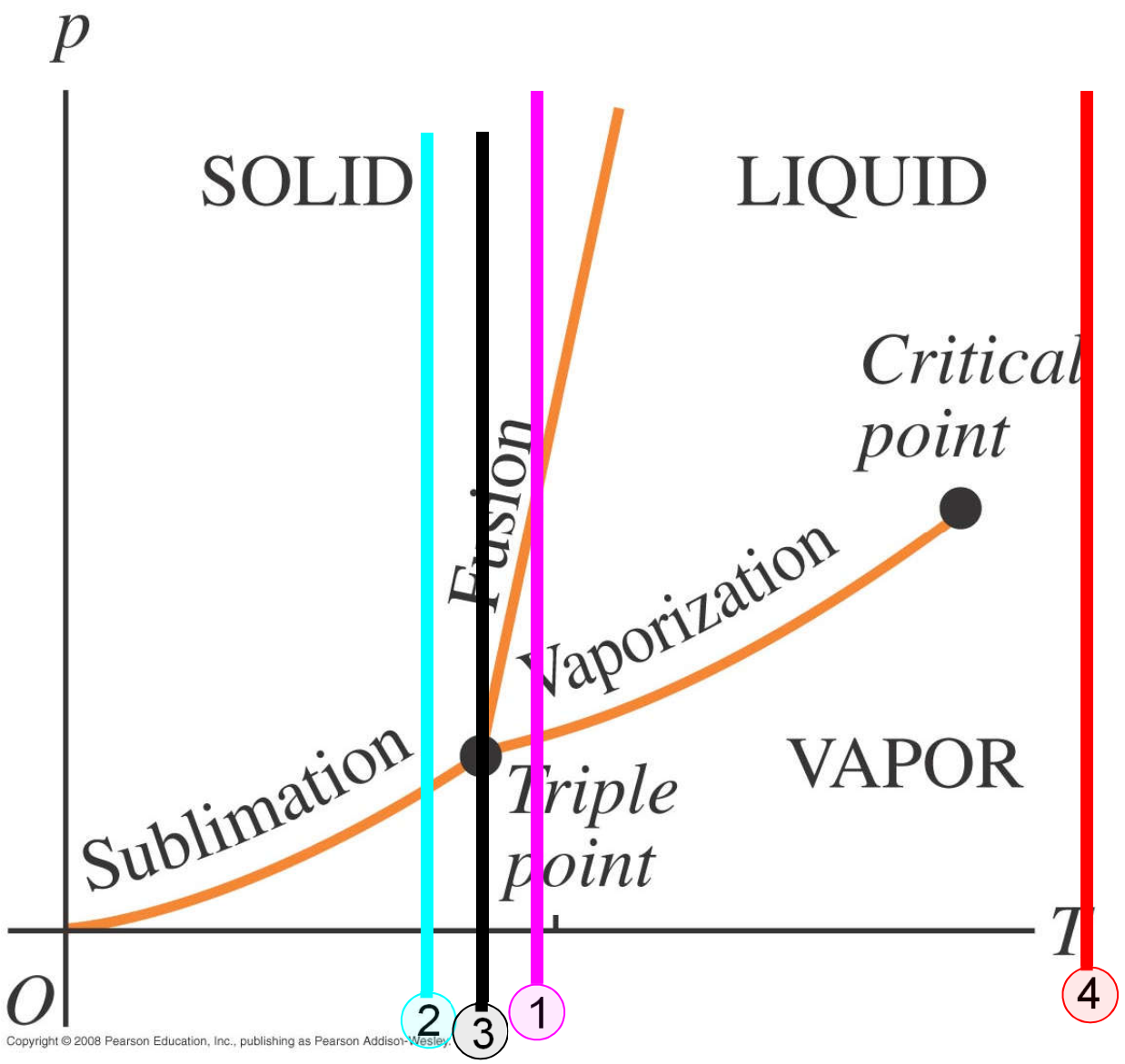


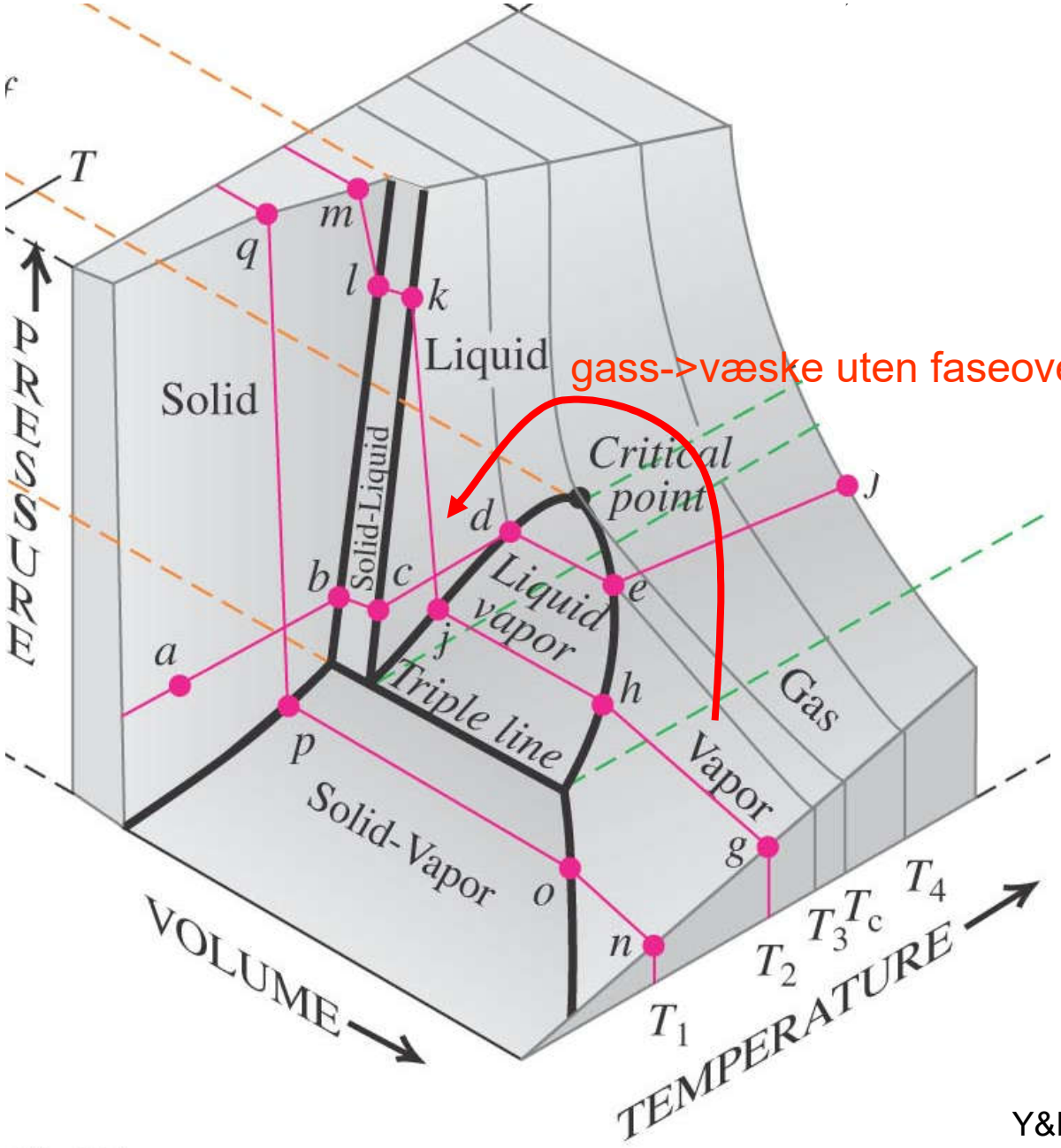
Fasediagram H_2O

is -> vann:
volum avtar



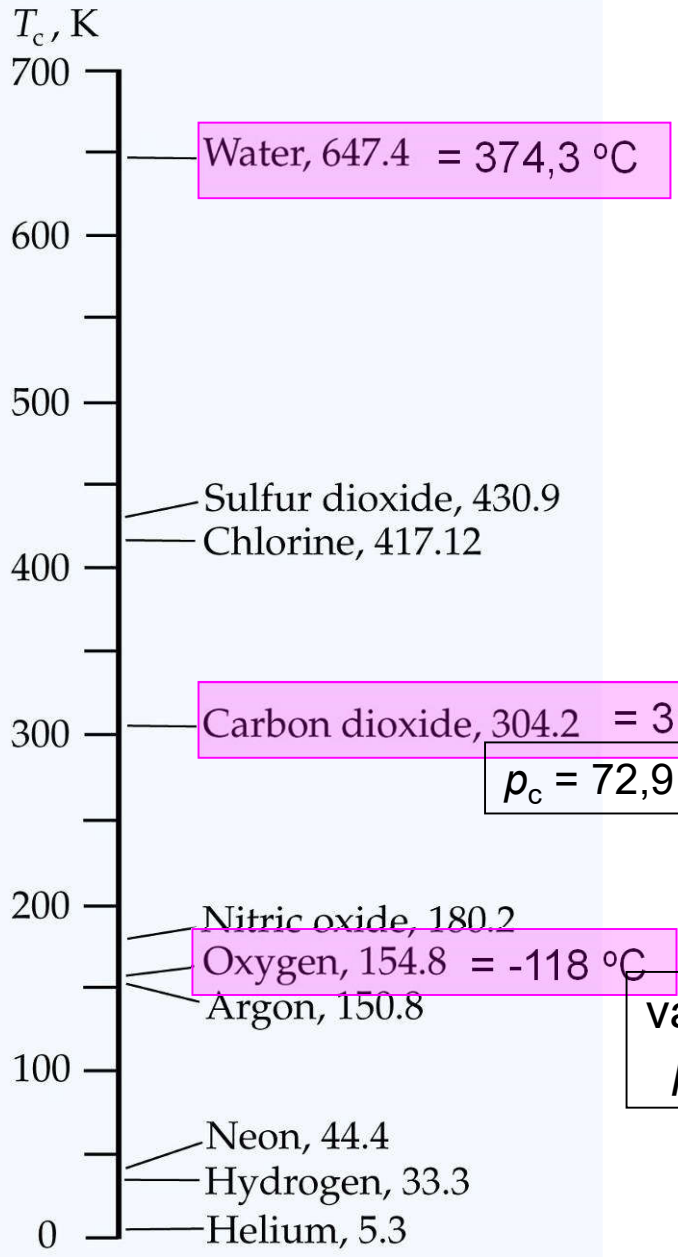
Fasediagram i *pT*-projeksjon



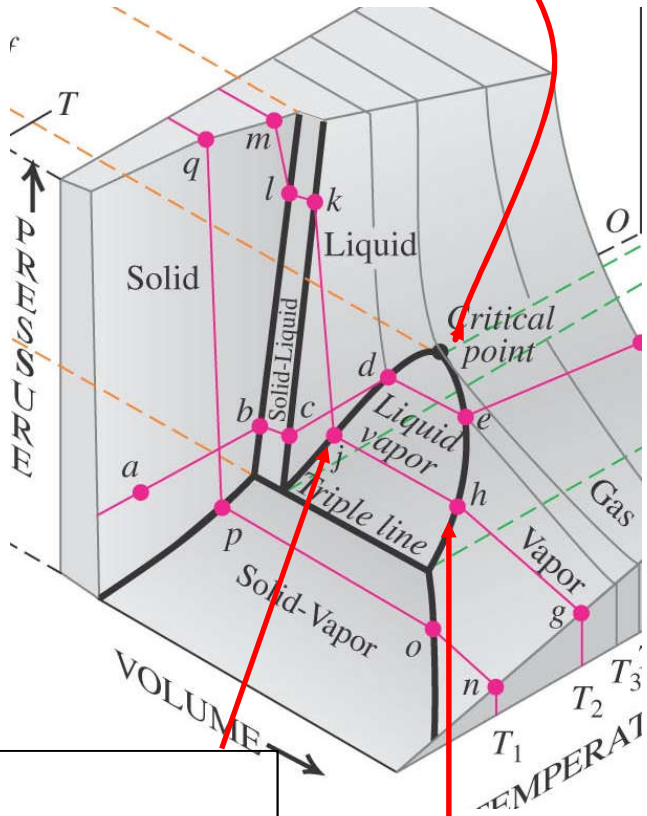


Y&F Figure 18.26

Critical Temperatures T_c for Various Substances



p_c = 218 atm v_c = 3,16 l/kg

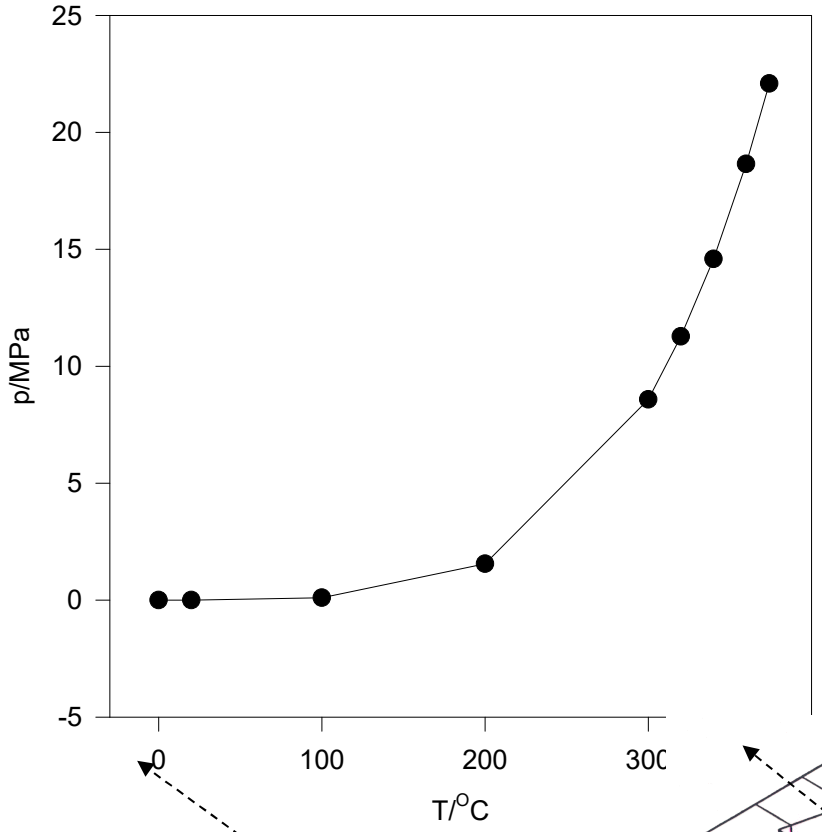


p_c = 72,9 atm

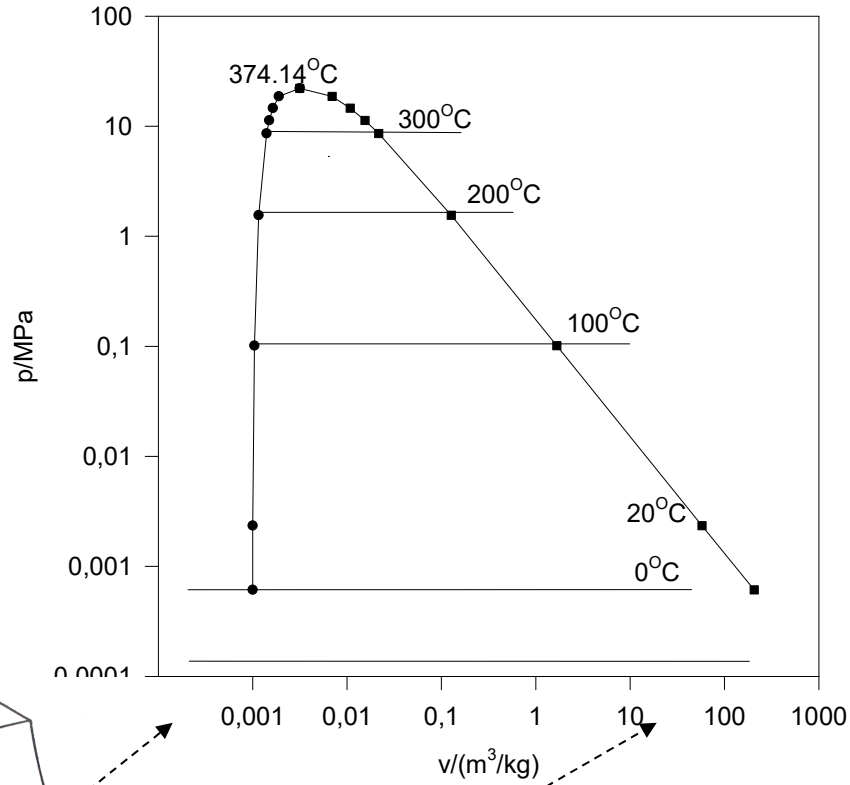
vann 100 °C:
p = 1,0 atm v = 1,04 l/kg

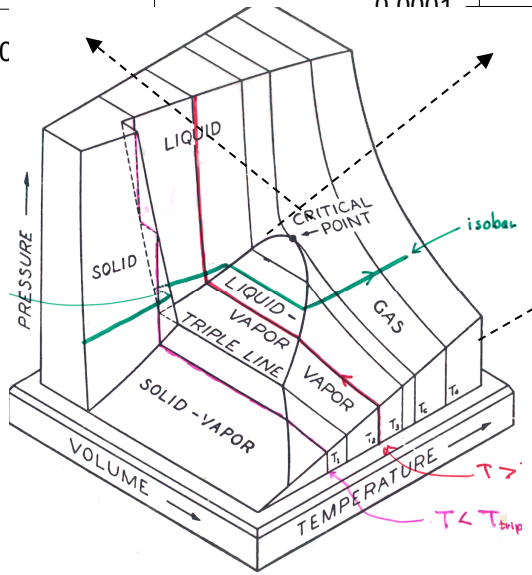
damp 100 °C:
p = 1,0 atm v = 1700 l/kg

p-T-plott vanndamp/vann



p-v-plott vanndamp/vann





Data vanndamp og vann 0°C til 374°C

T/°C	p/MPa	v_v/(m³/kg)	v_g/(m³/kg)	L_f/(kJ/kg)	"R"
0,01	0,0006	0,001000	206,1	2501	8,31
20	0,0023	0,001002	57,8	2454	8,31
50	0,0123	0,001012	12,0	2383	8,23
100	0,1013	0,001044	1,67	2257	8,18
200	1,55	0,001157	0,127	1941	7,53
300	8,58	0,001404	0,0217	1405	5,84
320	11,27	0,001499	0,0155	1239	5,30
340	14,58	0,001638	0,0108	1028	4,62
360	18,65	0,001893	0,00695	721,0	3,66
374,14	22,09	0,003155	0,003155	0,0	1,97

p-*T*-plott

p = vanndampens metningstrykk

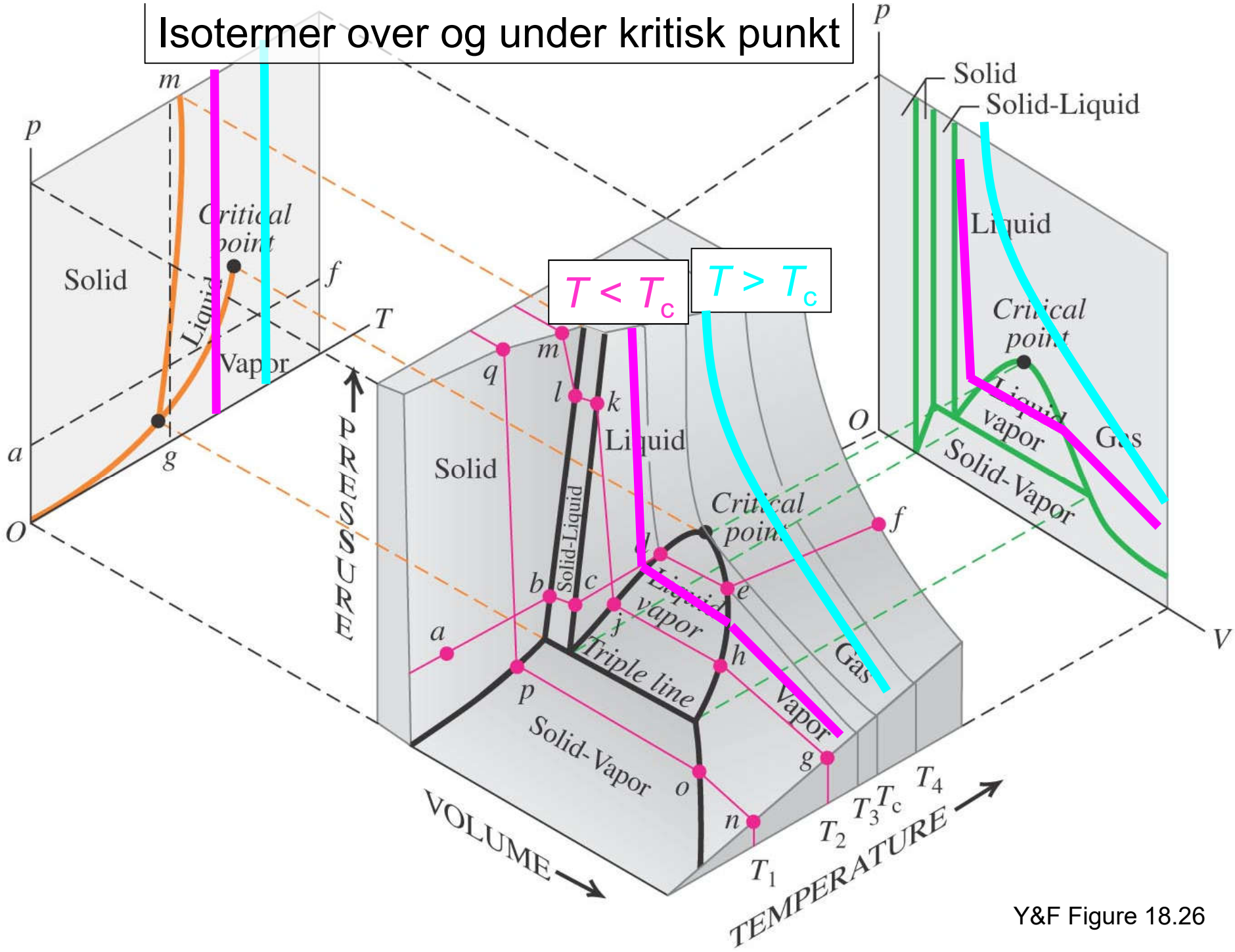
v_v = vannets spesifikke volum

v_g = vanndampens spesifikke volum

l_f = spesifikk fordampningsvarme

"R" = $p\,v_g/T$ (= R = 8,31 J/(K mol) hvis ideell gass)

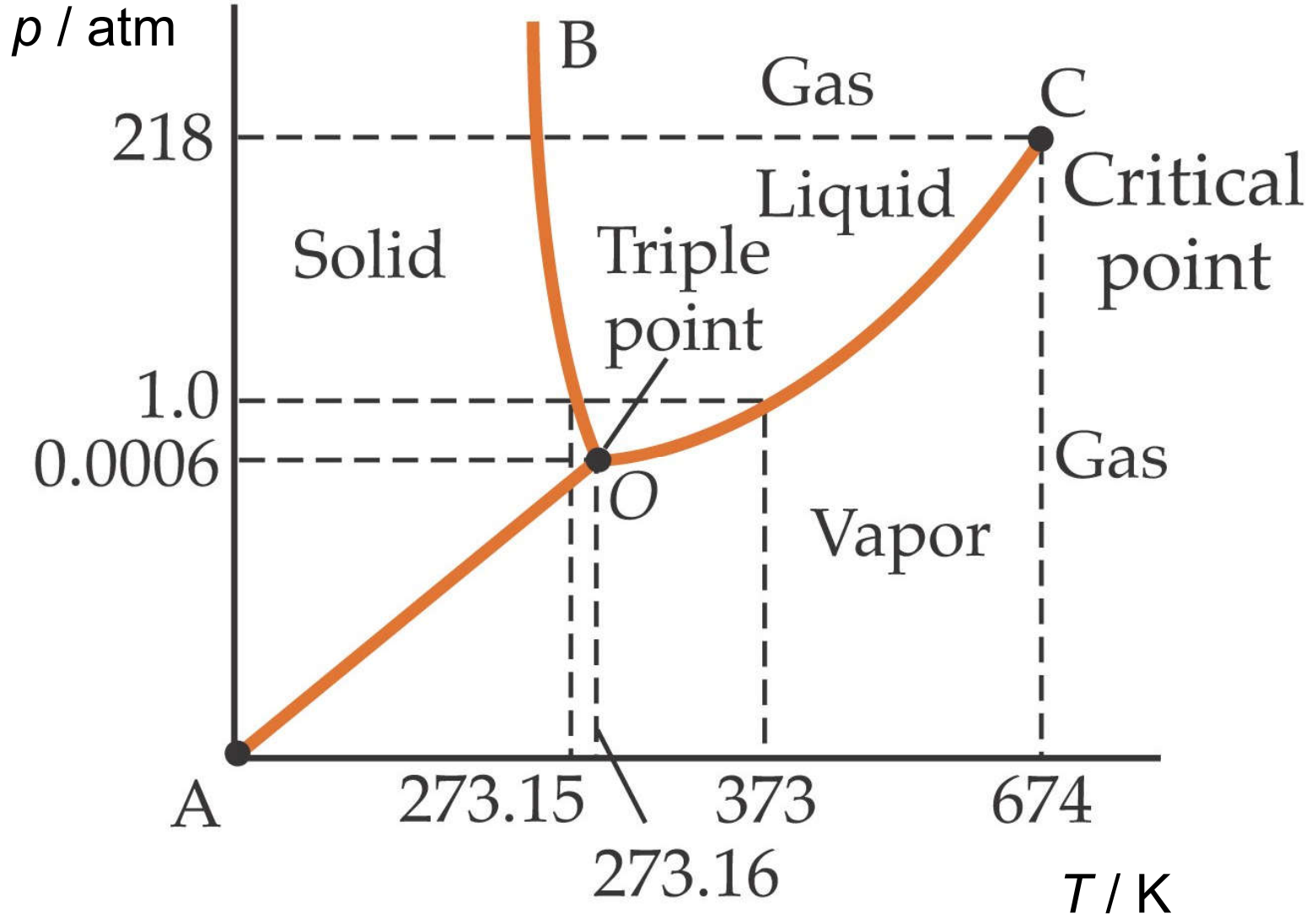
Isotermer over og under kritisk punkt



Y&F Figure 18.26

Fasediagram i pT-projeksjon for H_2O

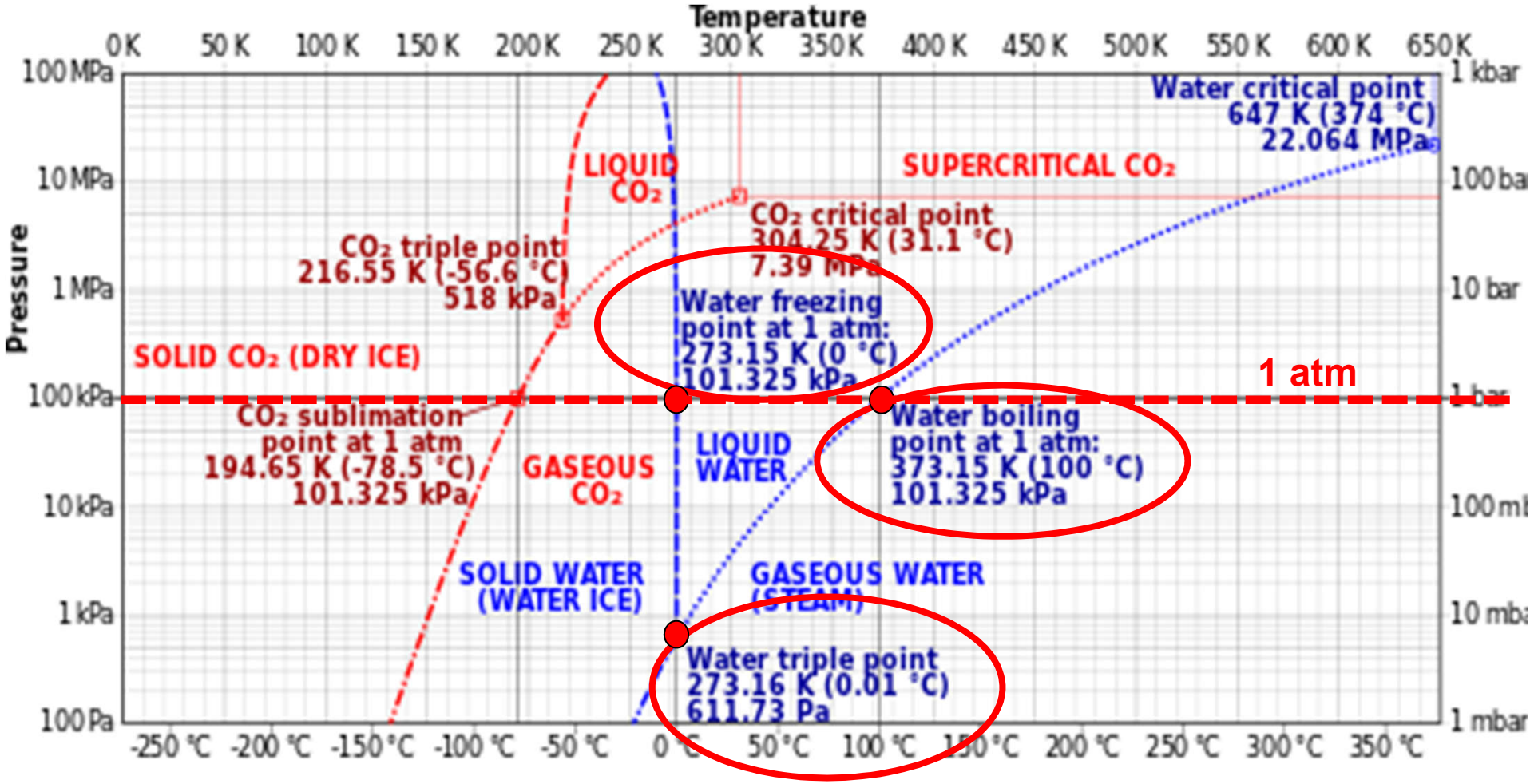
Forenklet



pT-fasediagram for CO_2 og H_2O

Fra: http://en.wikipedia.org/wiki/Dry_ice

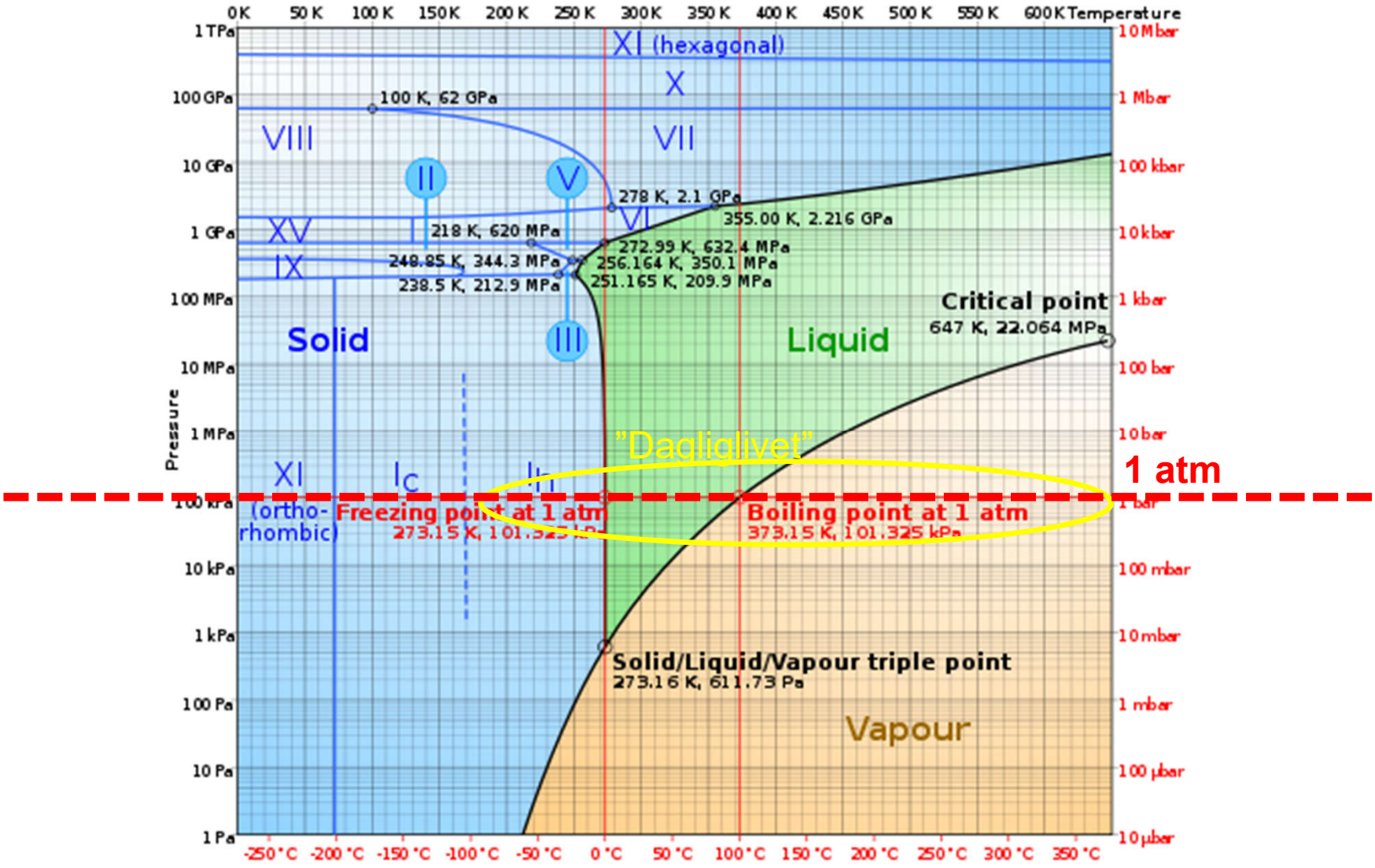
Forenklet



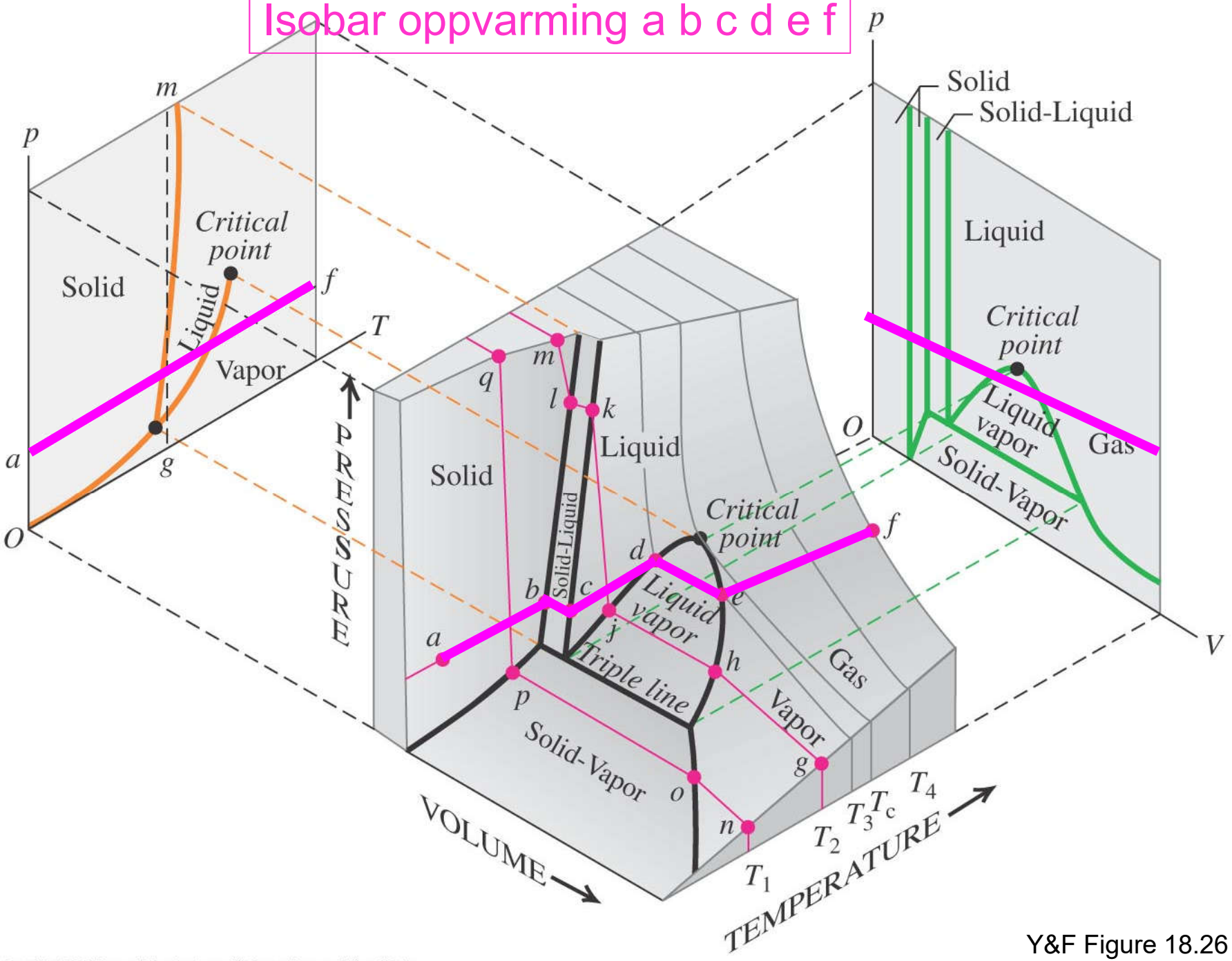
Fasediagram i log(*p*)-*T*-projeksjon for H_2O

Is har 15 ulike krystallfaser

(fra en.wikipedia.org)



Isobar oppvarming a b c d e f

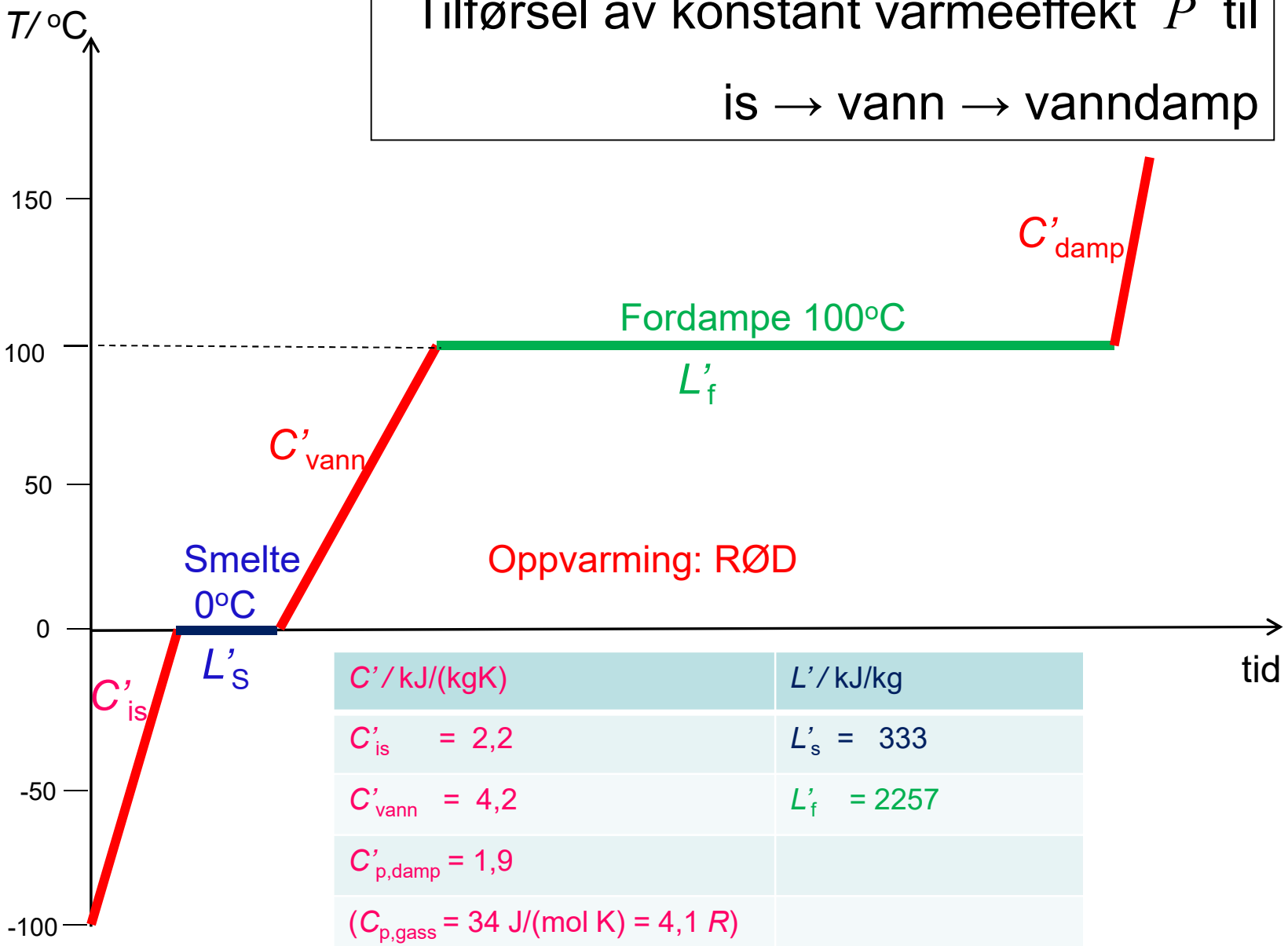


Y&F Figure 18.26

Isobar oppvarming (smelting og fordamping)

Tilførsel av konstant varmeeffekt P til

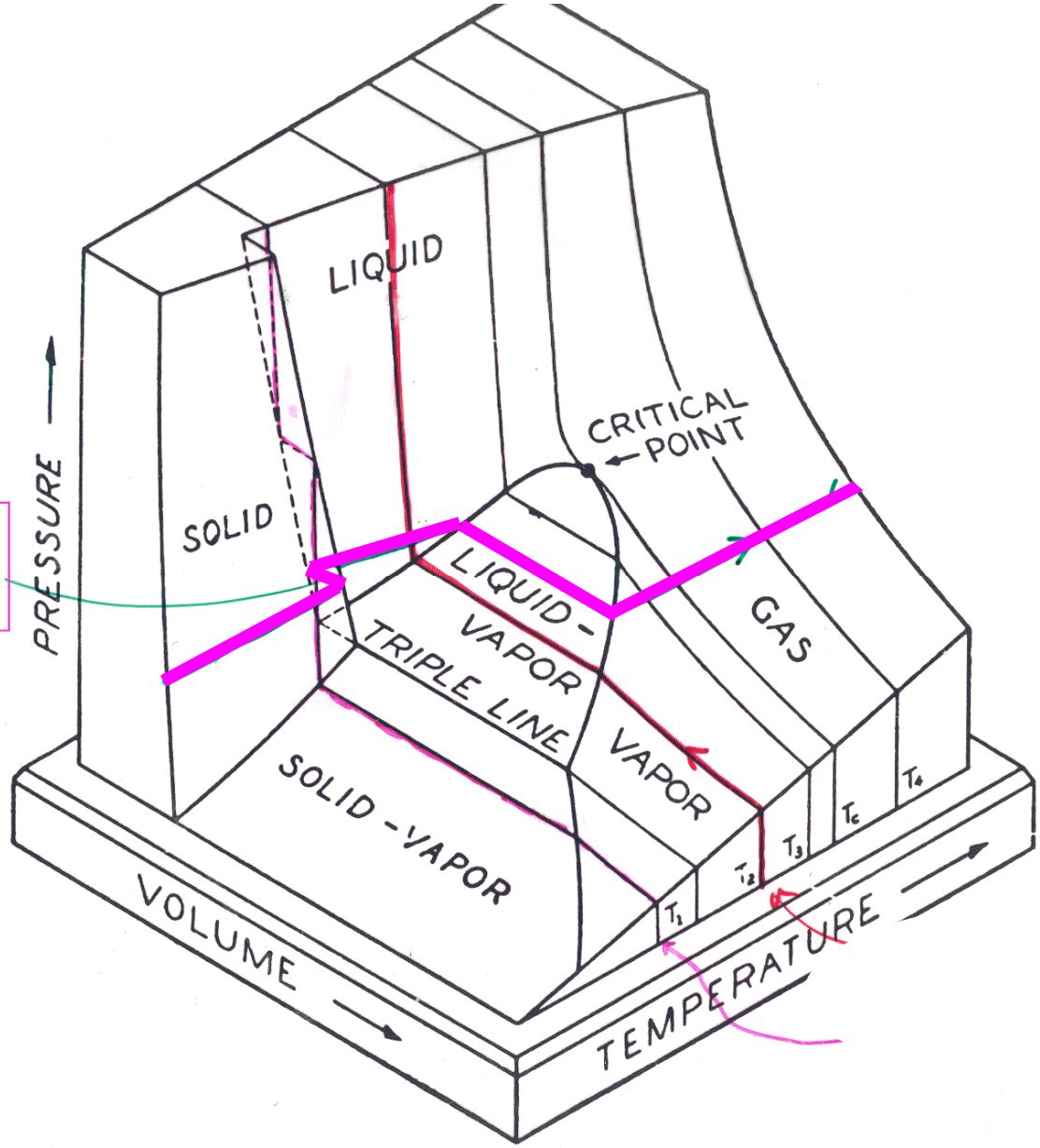
is → vann → vanndamp



C' / kJ/(kgK)	L' / kJ/kg
C'_{is} = 2,2	L'_s = 333
C'_{vann} = 4,2	L'_f = 2257
$C'_{p,damp}$ = 1,9	
($C_{p,gass}$ = 34 J/(mol K) = 4,1 R)	

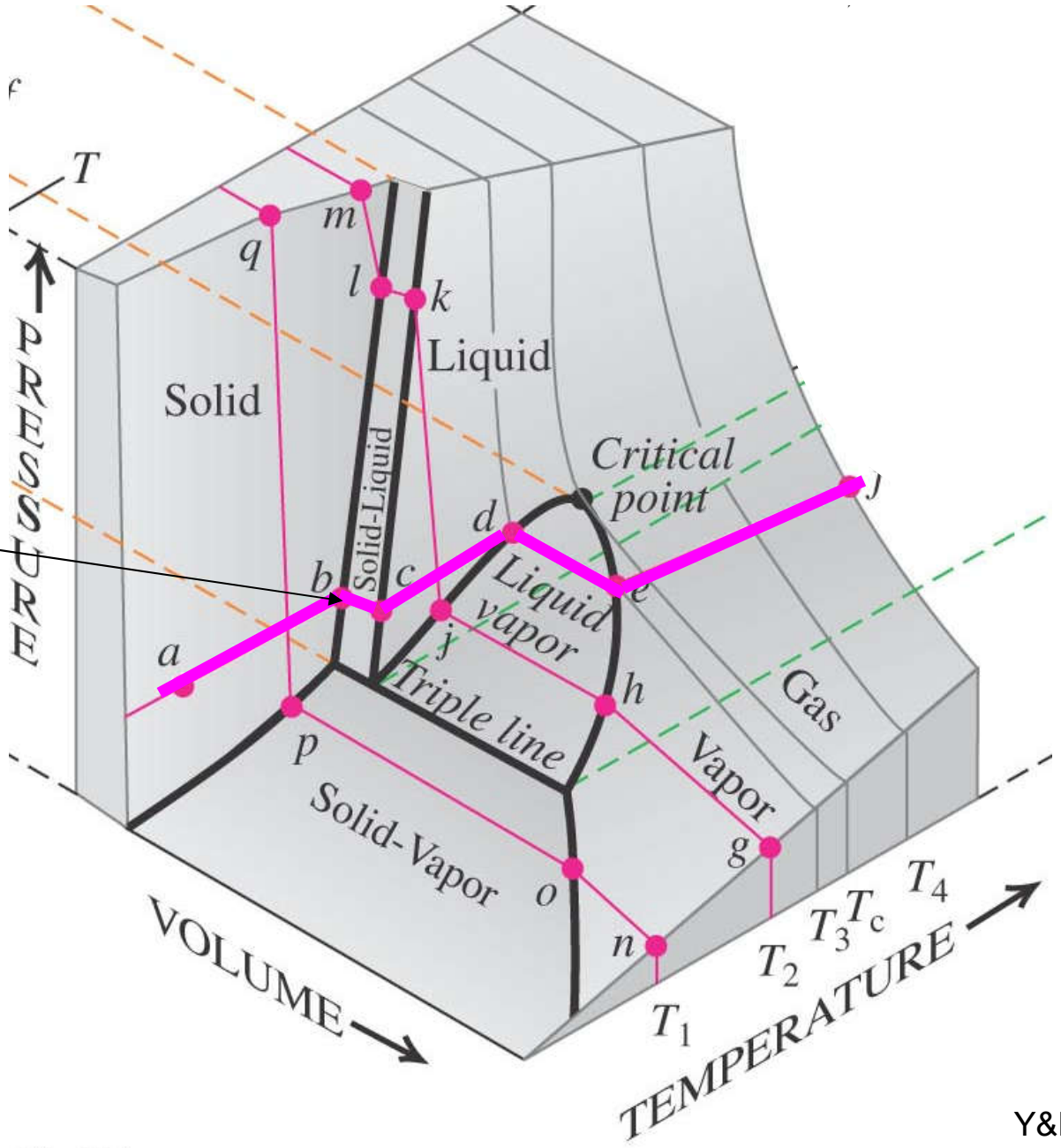
Isobar oppvarming VANN

is -> vann:
volum avtar



Isobar oppvarming STOFFER ≠ VANN

volum øker

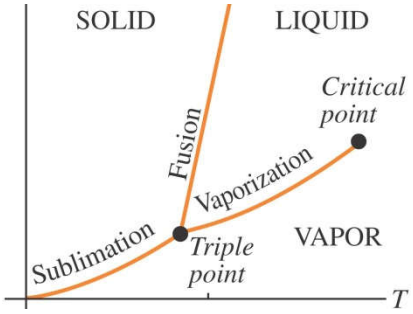


Addison-Wesley.

Y&F Figure 18.26

Faseoverganger. Oppsummering

- Fasediagram i pVT-rommet viser hvilke områder de tre faser fast, væske, gass kan eksistere hver for seg og sammen. Gjelder for reine faser (én type stoff).
- I fasediagram i pT-projeksjon er sameksistensflatene kurver. Fasediagram i pV-projeksjon også ofte brukes.
- Smelting (fast -> væske): L'_s = spesifikk smeltevarme (J/kg)
- Fordamping (væske -> gass) : L'_f = spesifikk fordampingsvarme (J/kg)
- I pT-plott har sameksistenskurve væske/gass $\mathrm{d}p/\mathrm{d}T > 0$.
- I pT-plott har sameksistenskurve fast/væske $\mathrm{d}p/\mathrm{d}T > 0$, **unntatt H_2O** fordi is har større volum enn vann.



- Sameksistenskurve væske/gass har et maksimalt (kritisk) punkt (p_{krit}, T_{krit}). For $p>p_{krit}$ og/eller $T > T_{krit}$ har væske og gass samme egenskaper.