TFY4115 Fysikk

Faseoverganger (smelte, fordampe)

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

L&H&L Kap. 17.10 (1½ side)

H&S kap 10 (6 sider)

Varme Q tilført et legeme kan:

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

der C = molar varmekapasitet

2) Smelte stoff: $Q = L'_s \; \Delta m$

der L'_s = spesifikk smeltevarme (J/kg)

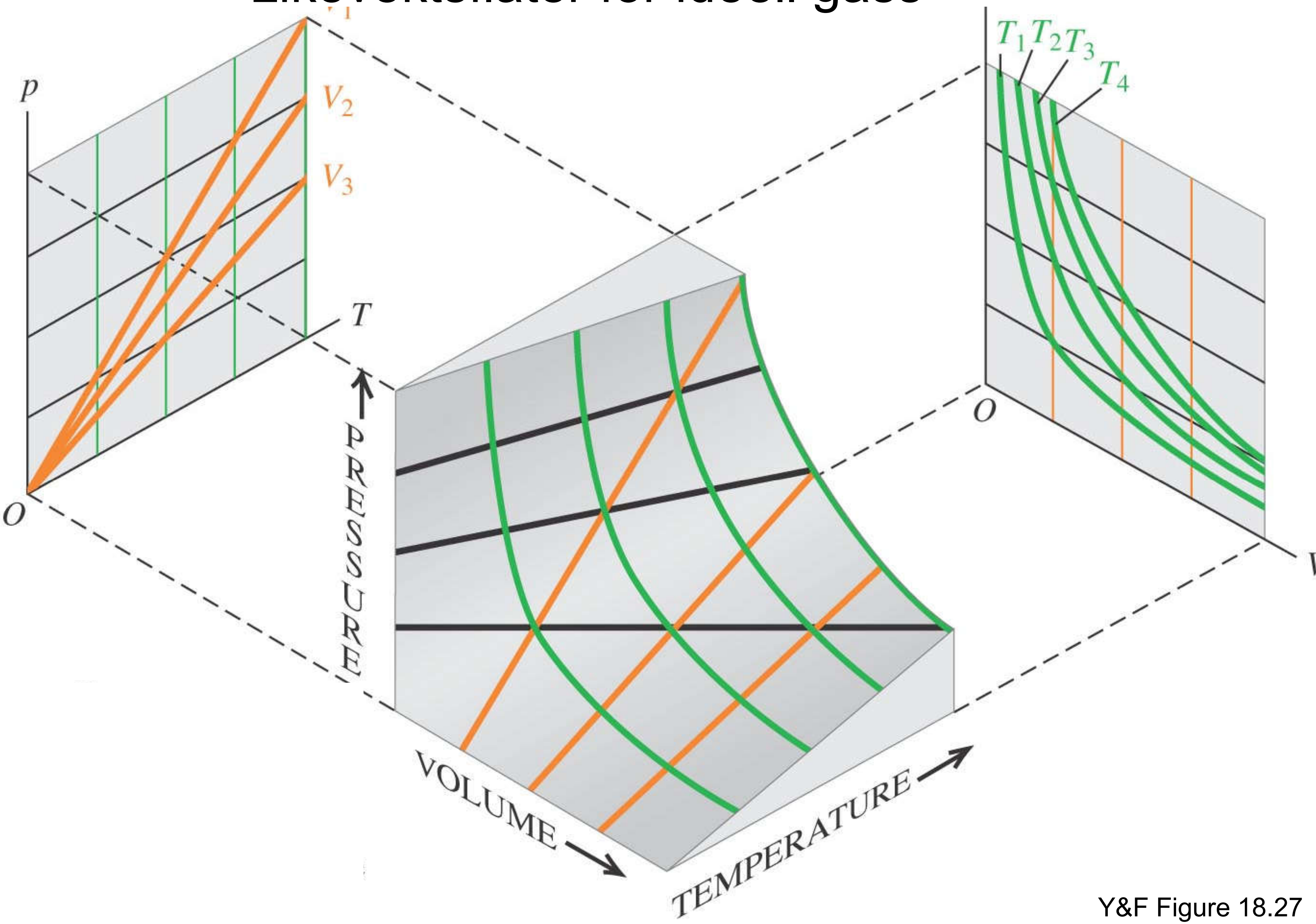
3) Fordampe stoff: $Q = L'_f \; \Delta m$

der L'_f = spesifikk fordampingsvarme (J/kg)

4) Sublimere stoff: $Q = (L'_s + L'_f) \; \Delta m$

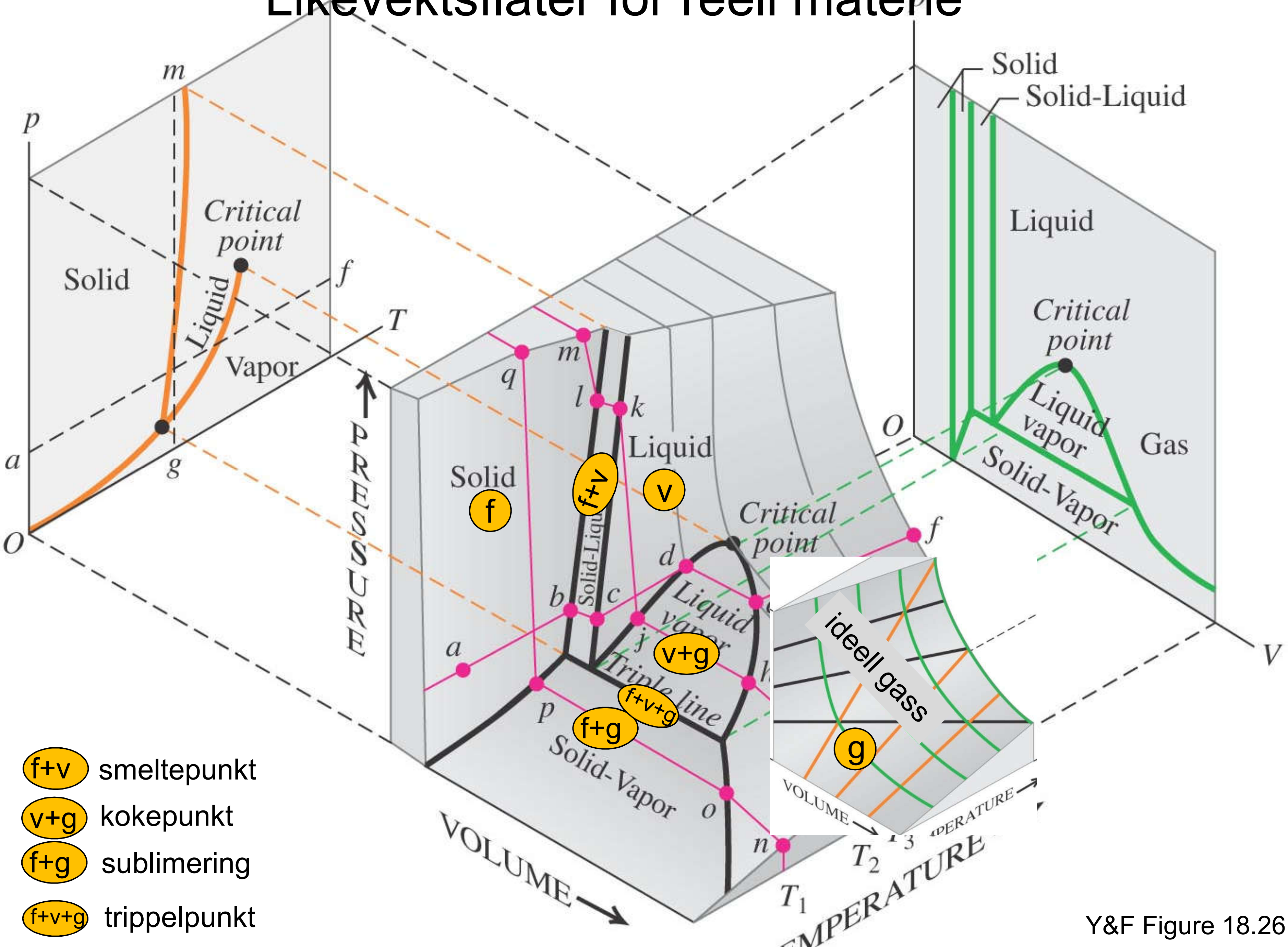
5) Utvide en gass isotermt $Q = \int p \, \mathrm{d}V$

Likevektsflater for ideell gass



Y&F Figure 18.27

Likevektsflater for reell materie



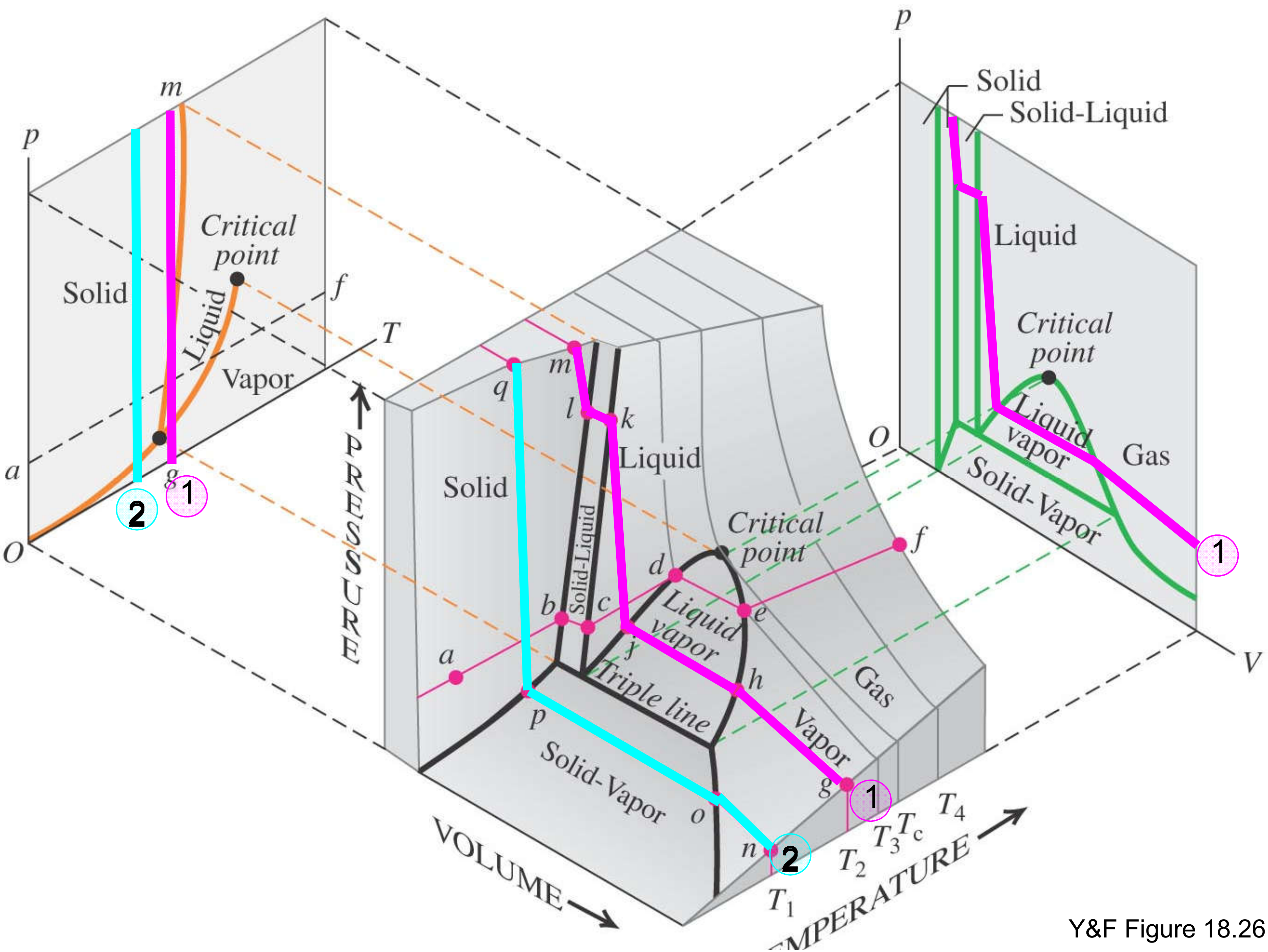
f+v smeltepunkt

v+g kokepunkt

f+g sublimering

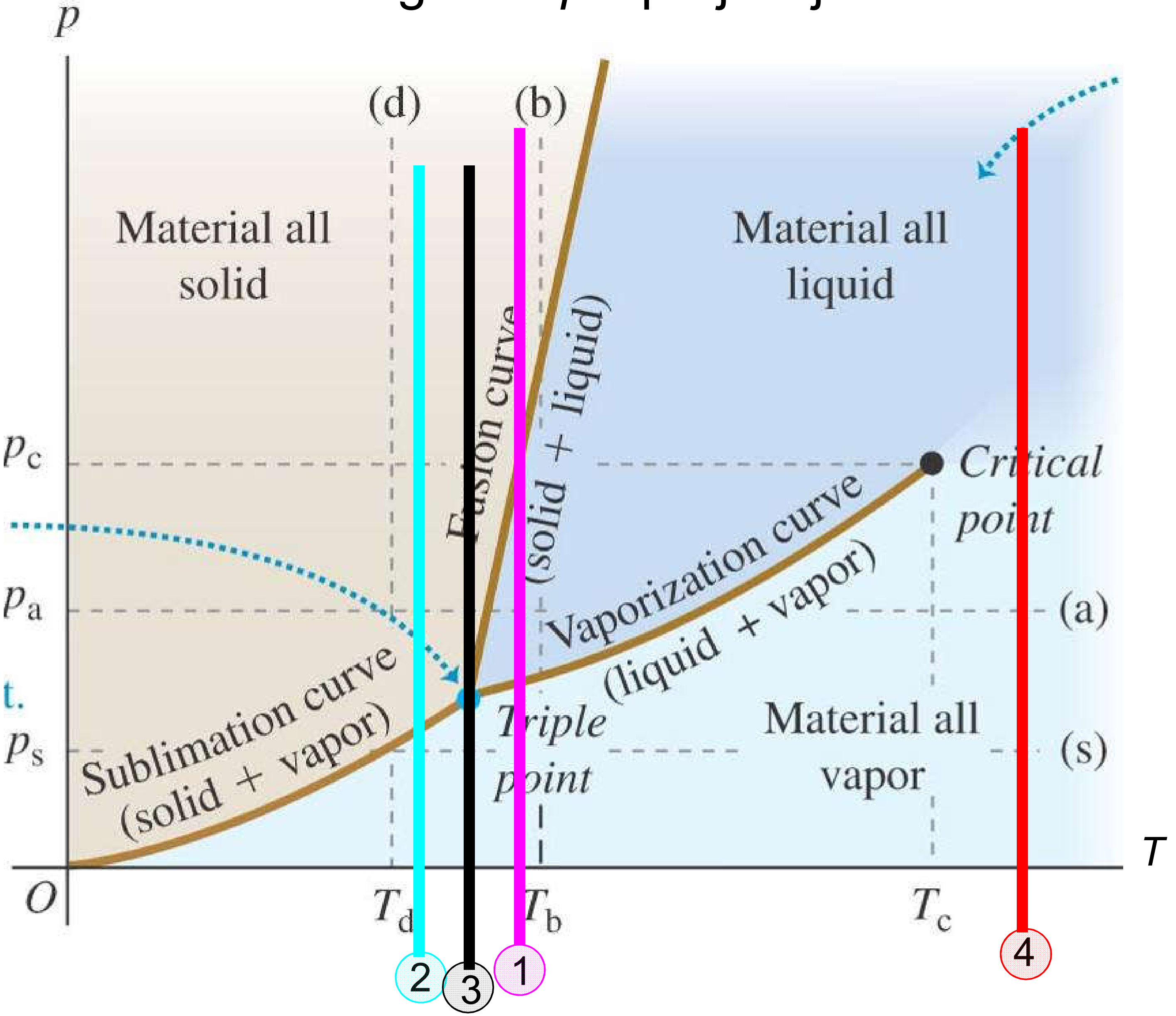
f+v+g trippelpunkt

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 ^{o}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 ^{o}C	5.17×10^5	= 5,1 atm *)
Sulfur dioxide	197.68		0.00167×10^5	
Water	273.16	= 0,01 ^{o}C	0.00610×10^5	= 0,0060 atm

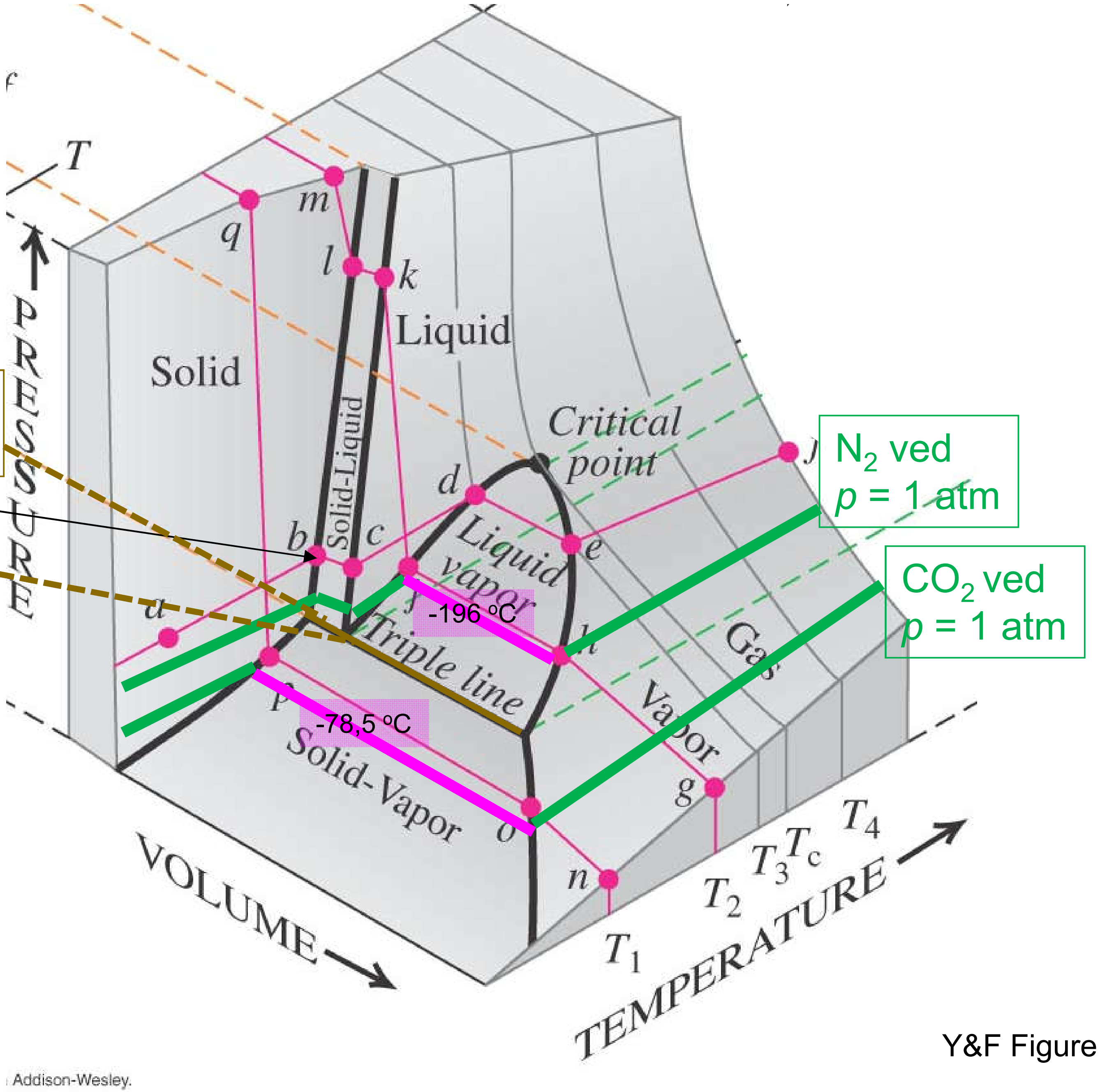
*) ved 1 atm:
sublimerer ved -78,5 ^{o}C

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

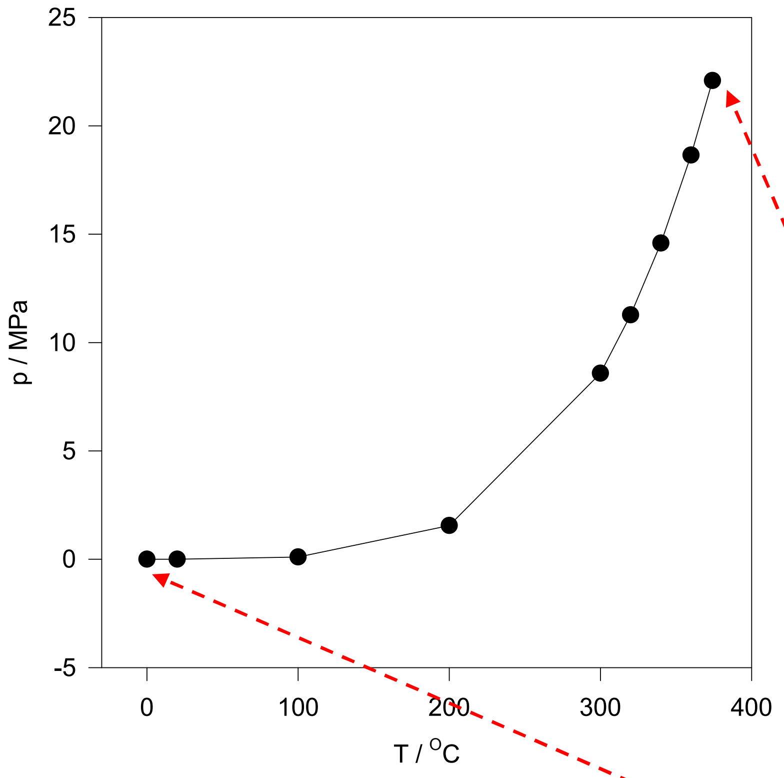
N_2: p_{triple} = 0,12 atm
T_{triple} = - 210 °C



Y&F Figure 18.

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

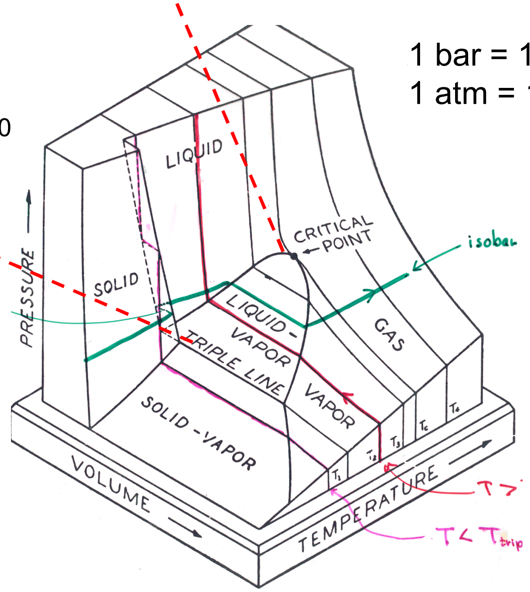
p-T-plott vanndamp/vann



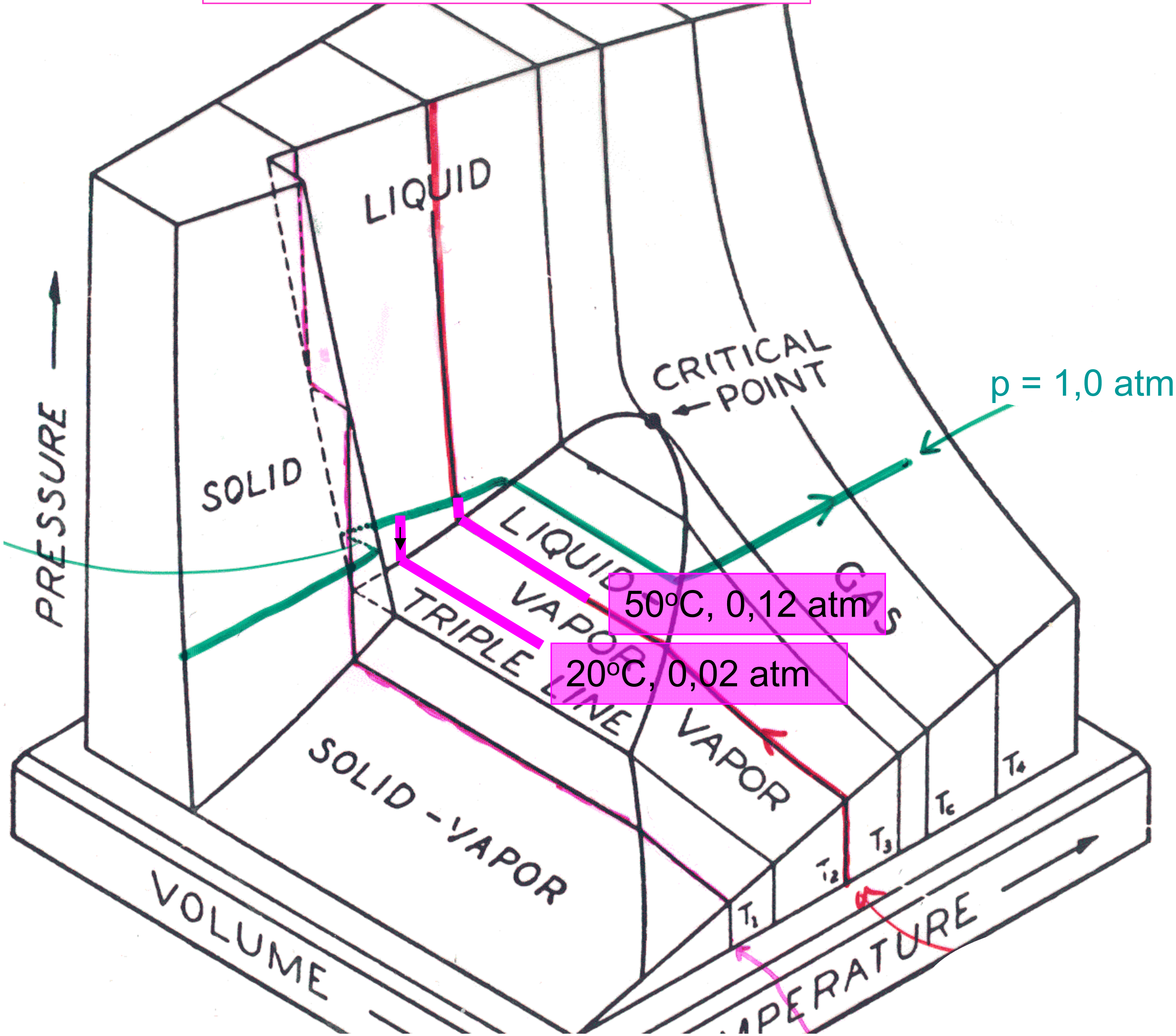
T / ^{o}C	p / bar
0,01	0,006
20	0,023
50	0,123
100	1,013
200	15,5
300	85,8
320	113
340	146
360	187
374,14	220,9

T / ^{o}C	p / bar
90	0,701
95	0,846
100	1,013
105	1,22
110	1,43

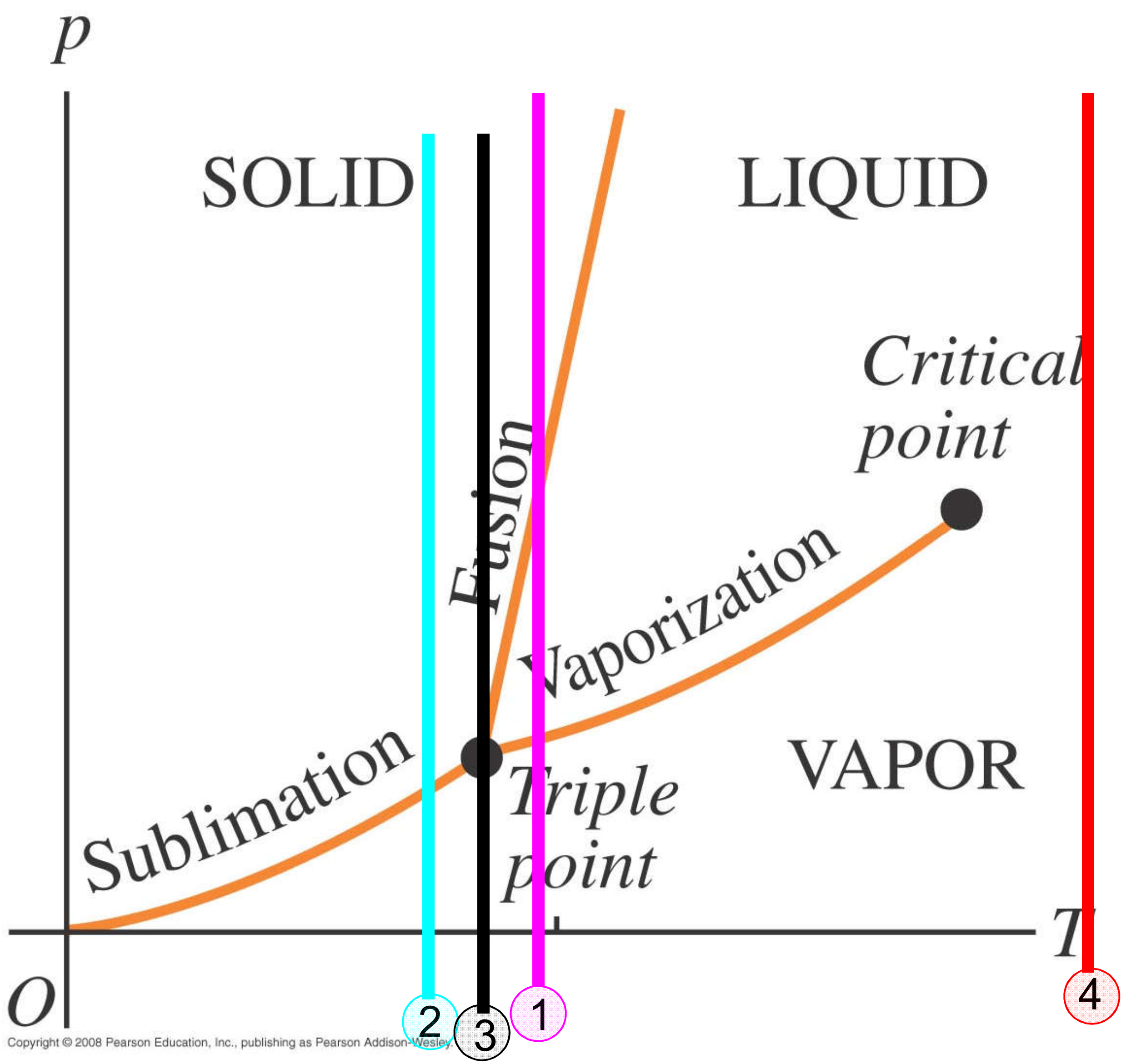
1 bar = 100 kPa = 0,1 MPa
1 atm = 1,013 bar

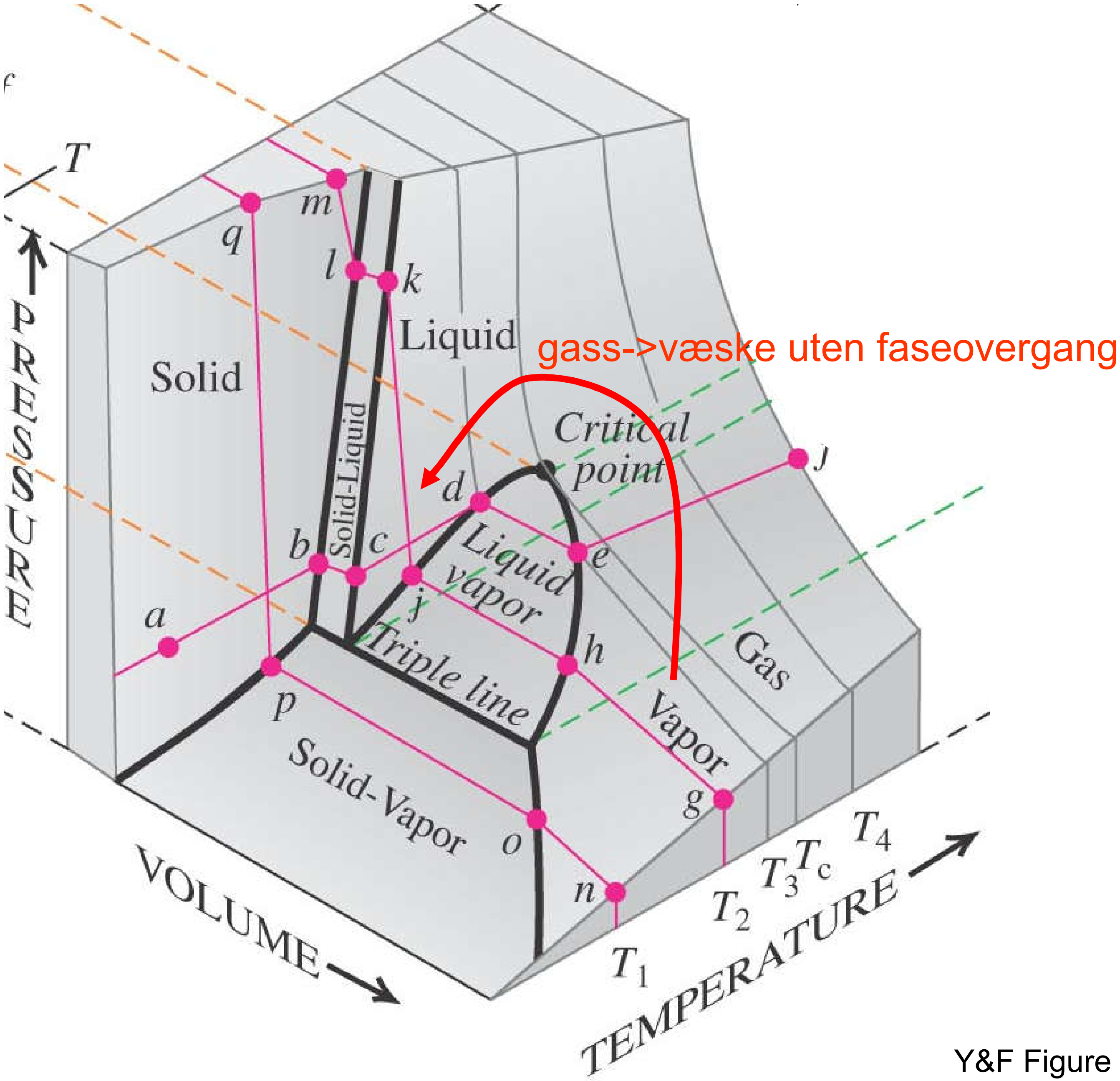


”Håndkokt” vann i sprøyte.



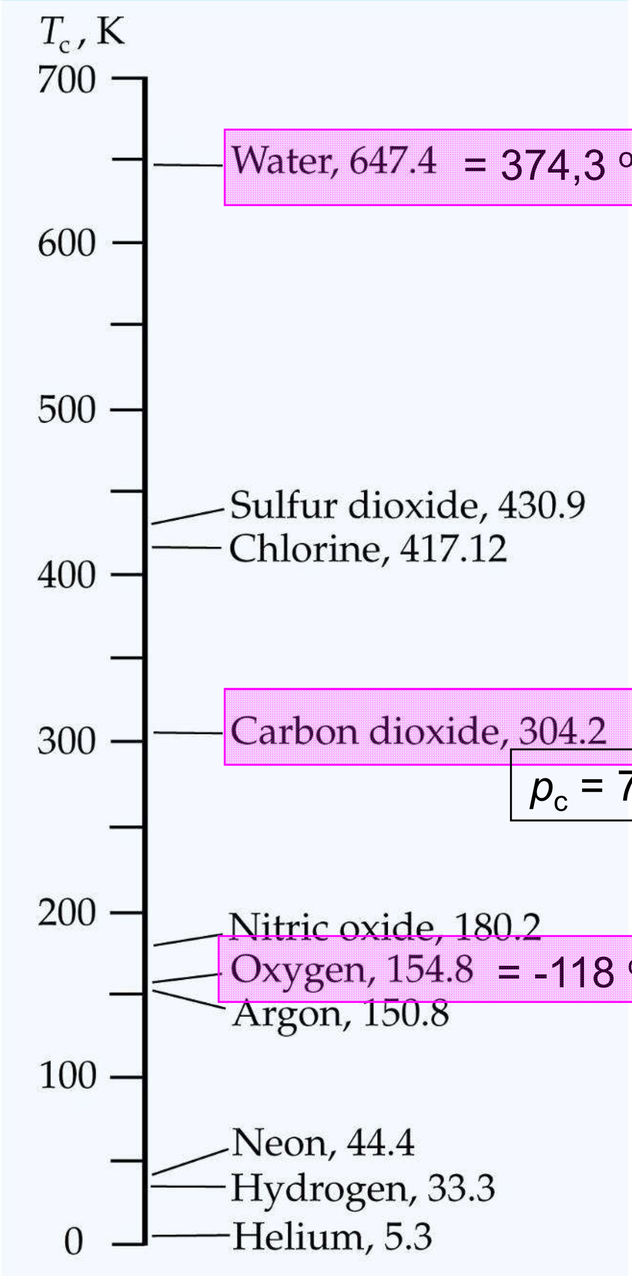
Fasediagram i *pT*-projeksjon





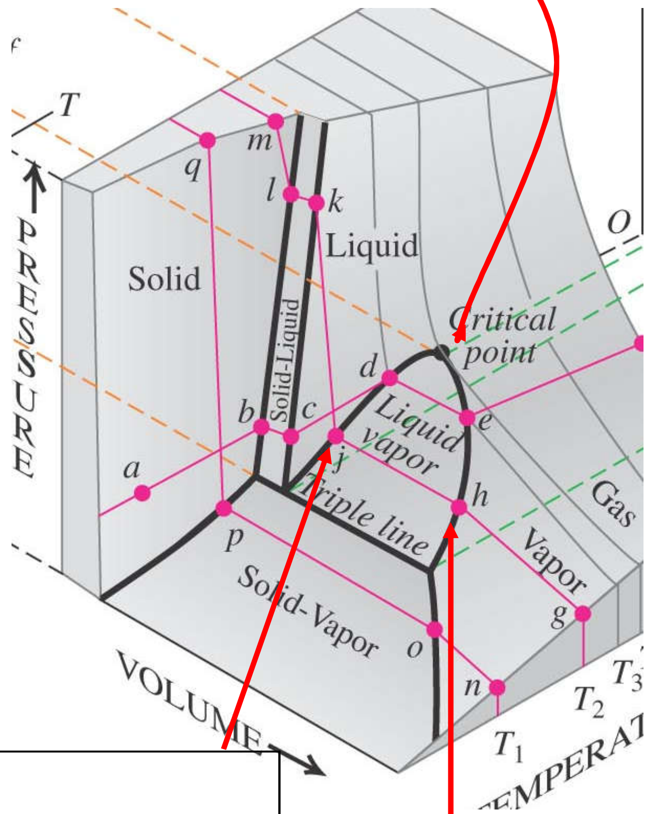
Y&F Figure 18.26

Critical Temperatures T_c for Various Substances



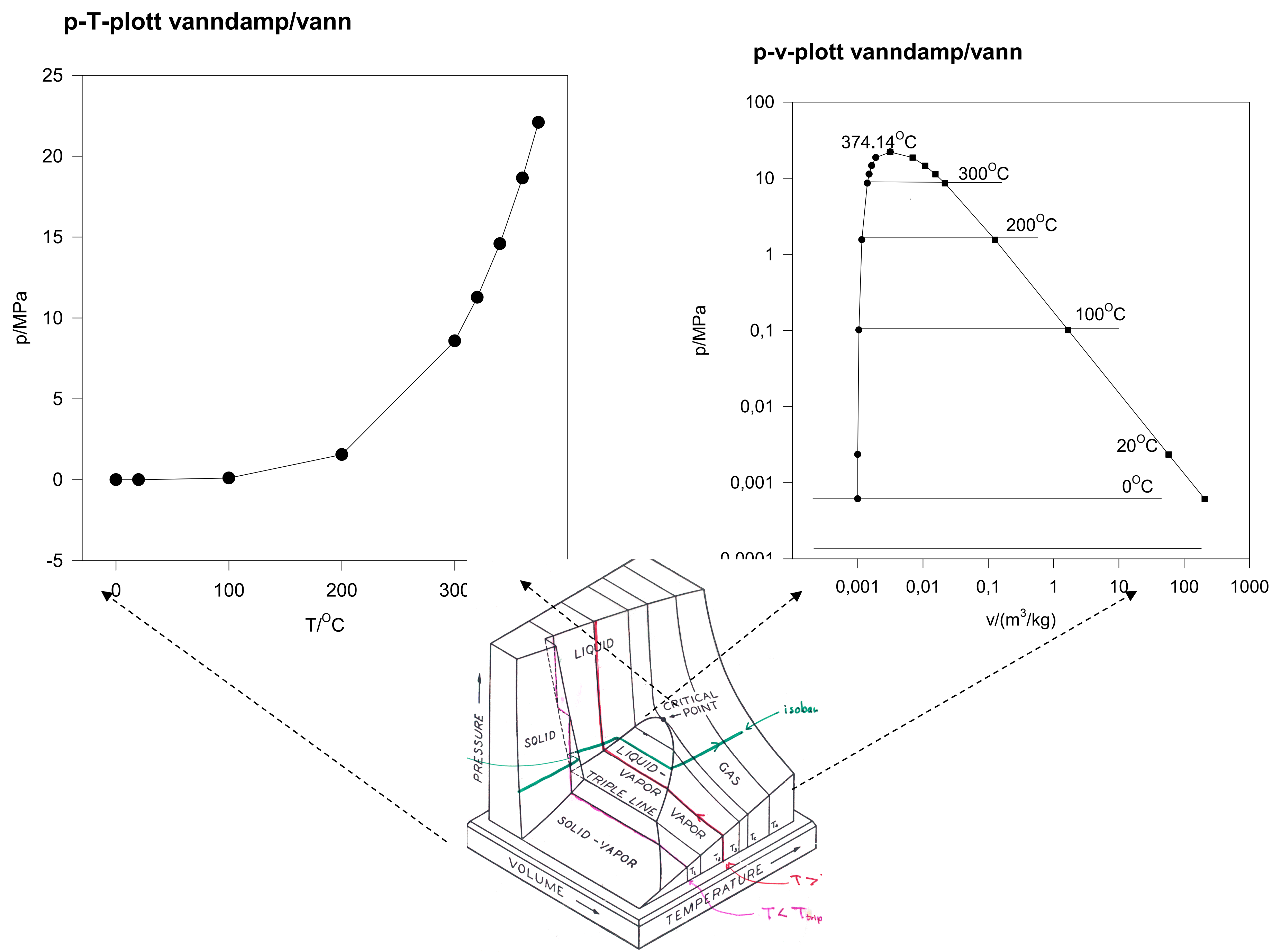
p_c = 72,9 atm

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

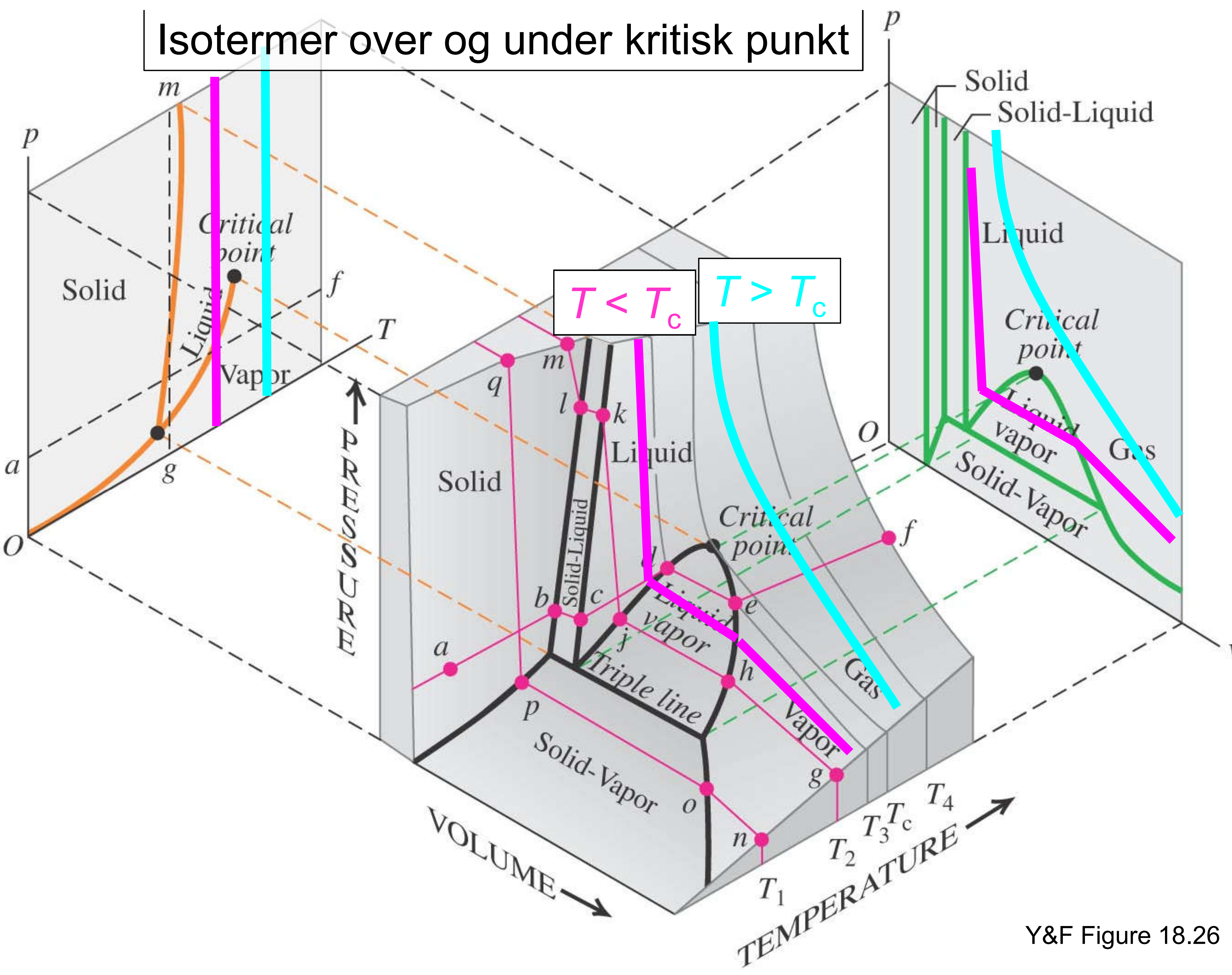


vann 100 °C:
p = 1,0 atm v = 1,04 l/kg

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

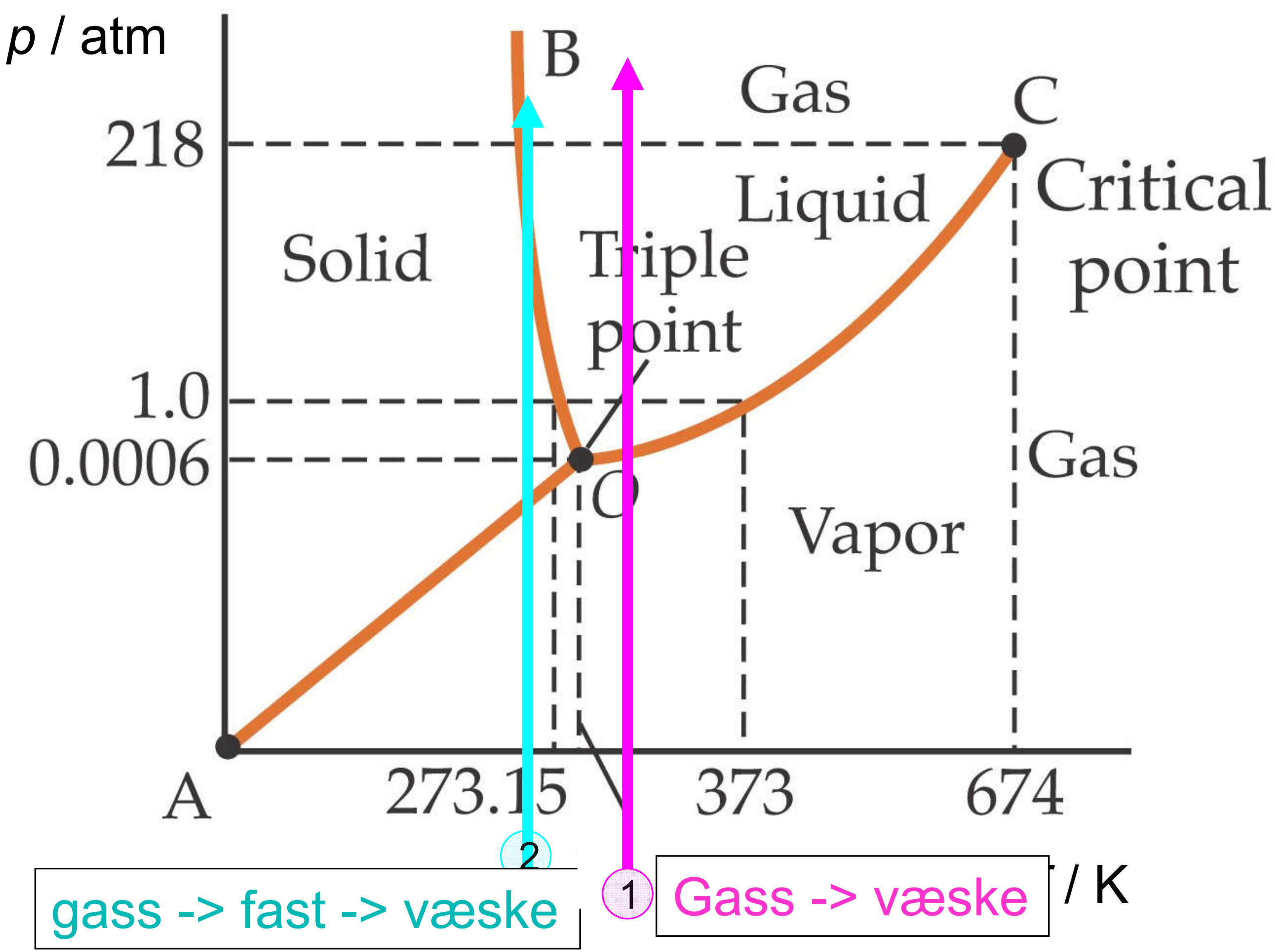

p-T-plott vanndamp/vann
p/MPa
T/°C
25
20
15
10
5
0
-5
0
100
200
300
p-v-plott vanndamp/vann
p/MPa
v/(m³/kg)
100
10
1
0,1
0,01
0,001
0,0001
0,001
0,01
0,1
1
10
100
1000
374.14°C
300°C
200°C
100°C
20°C
0°C
LIQUID
SOLID
CRITICAL POINT
isobar
LIQUID - VAPOR
TRIPLE LINE
GAS
VAPOR
SOLID - VAPOR
PRESSURE
VOLUME
TEMPERATURE
T >
T < T_trip

Isotermer over og under kritisk punkt

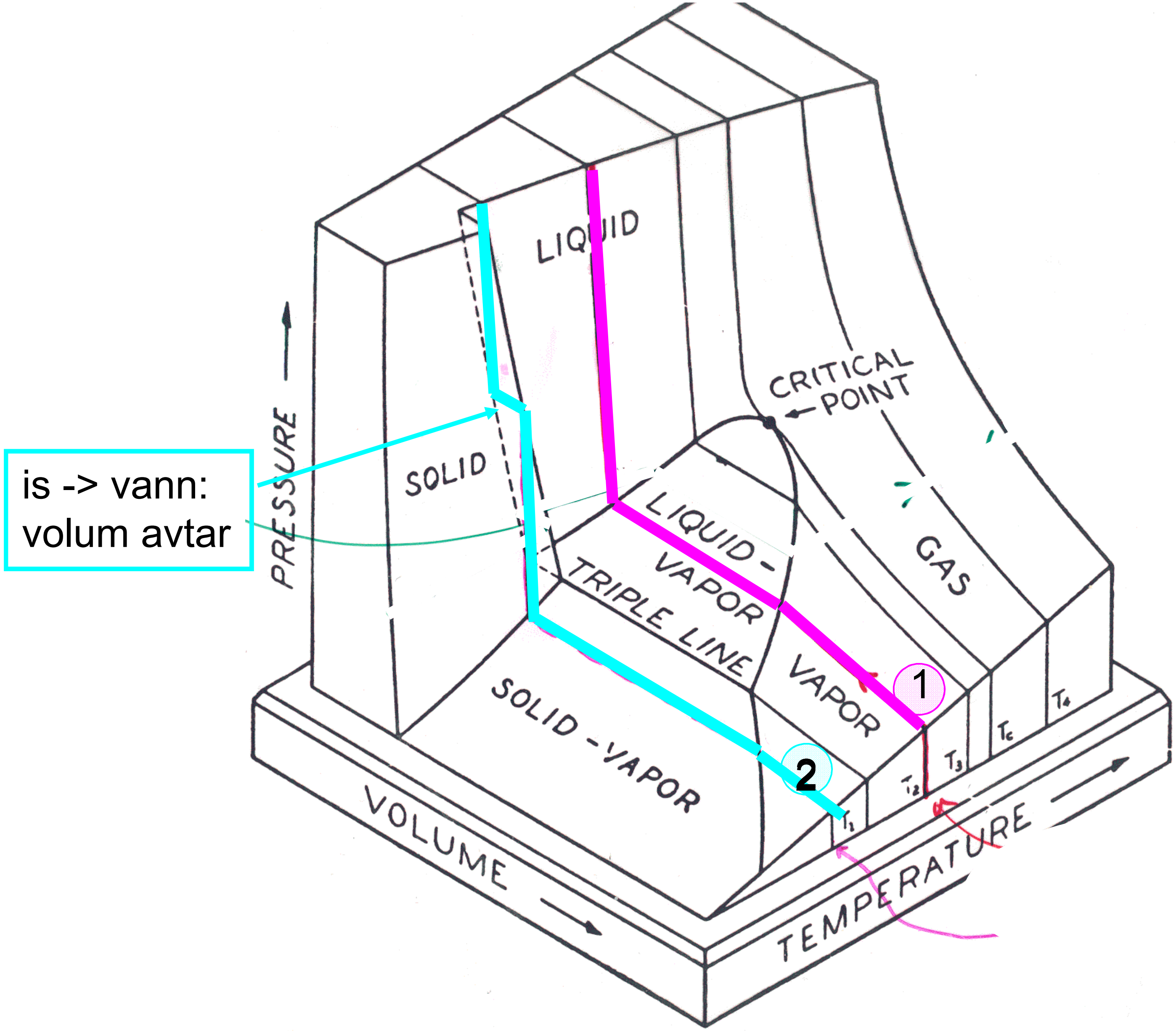


Y&F Figure 18.26

Fasediagram i *pT*-projeksjon **for H_2O**

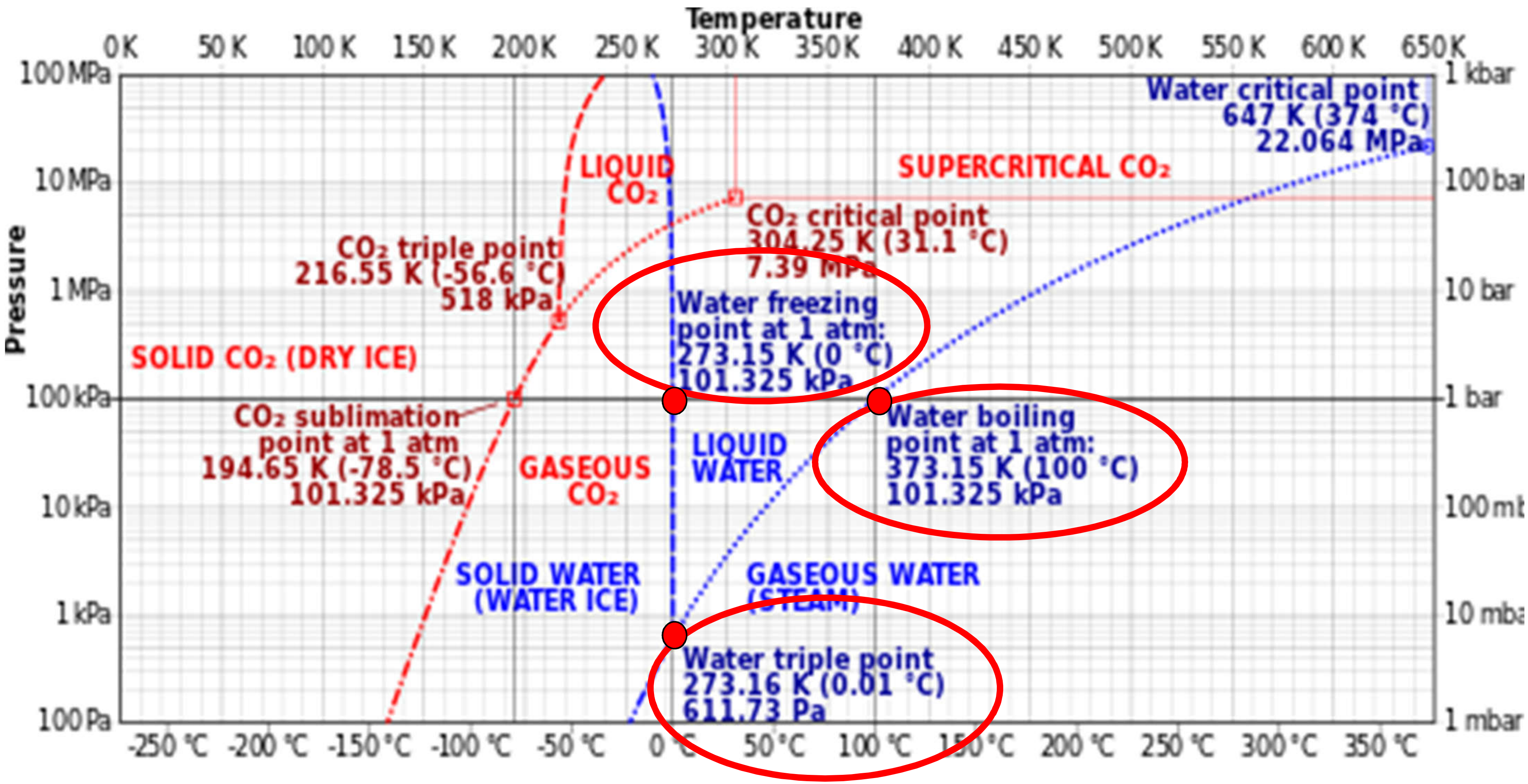


Fasediagram H_2O



pT-fasediagram for CO_2 og H_2O

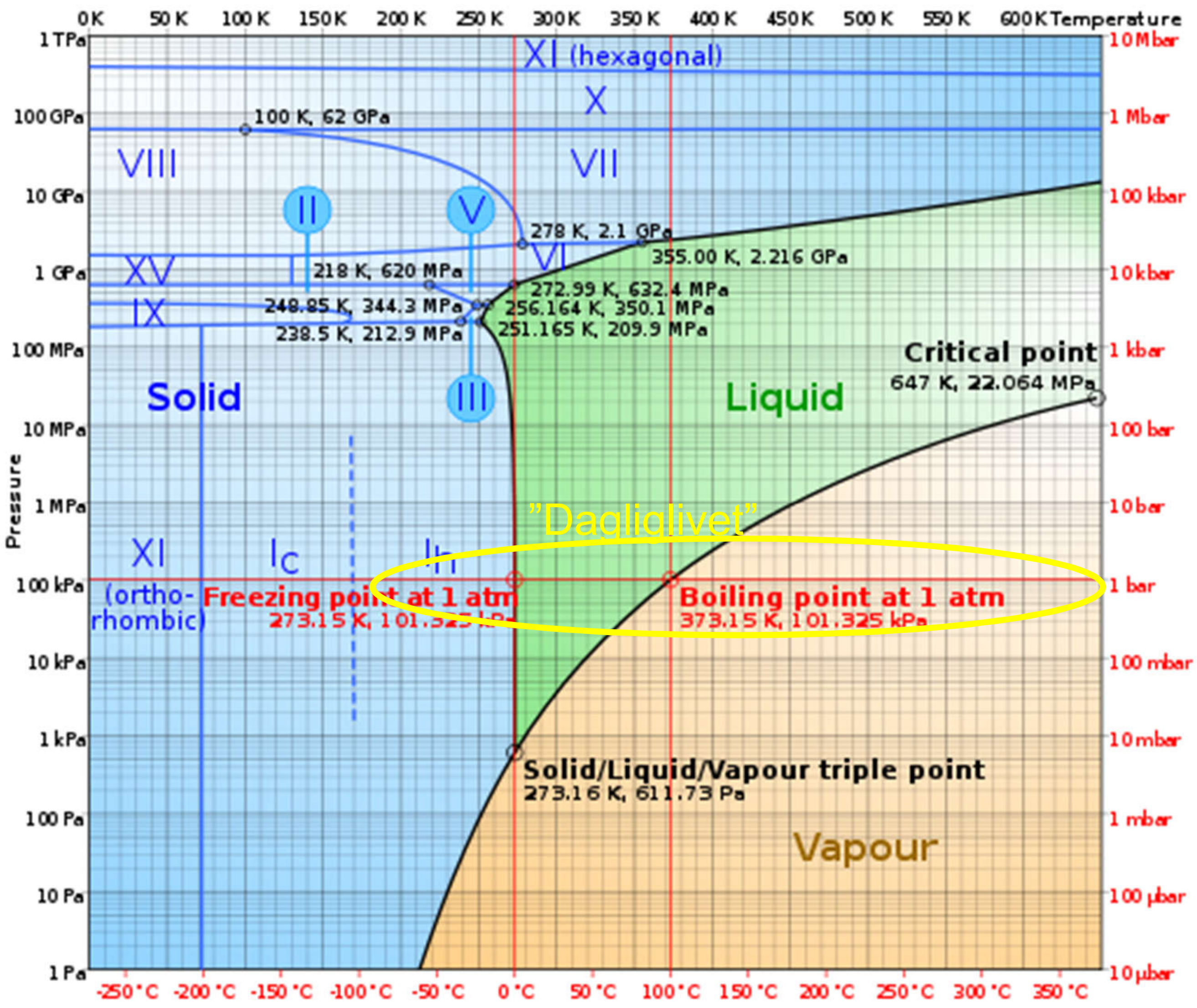
Fra: http://en.wikipedia.org/wiki/Dry_ice



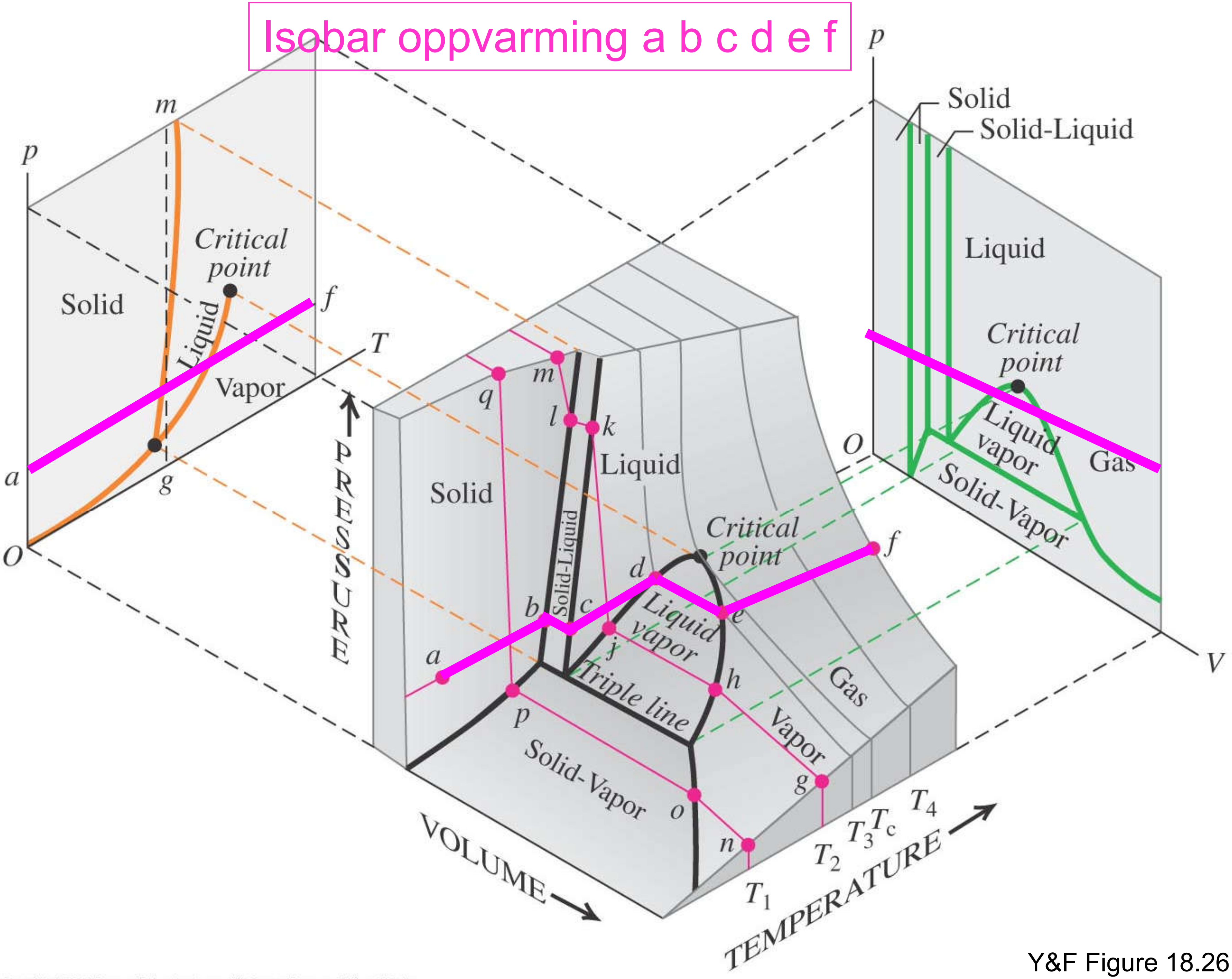
Fasediagram i log(*p*)-*T*-projeksjon for H_2O

Is har 15 ulike krystallfaser

(fra en.wikipedia.org)



Isobar oppvarming a b c d e f

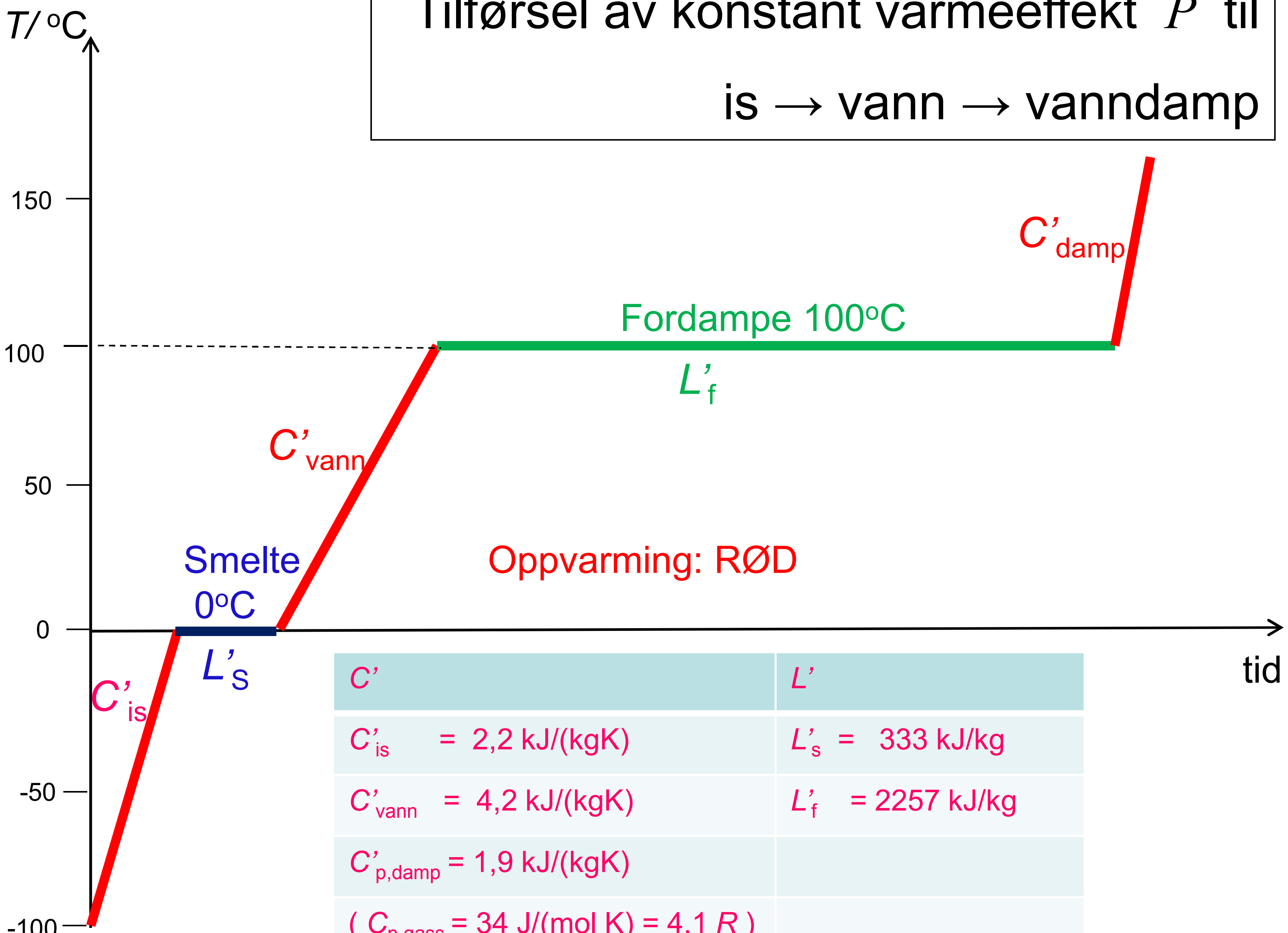


Y&F Figure 18.26

Isobar oppvarming (smelting og fordamping)

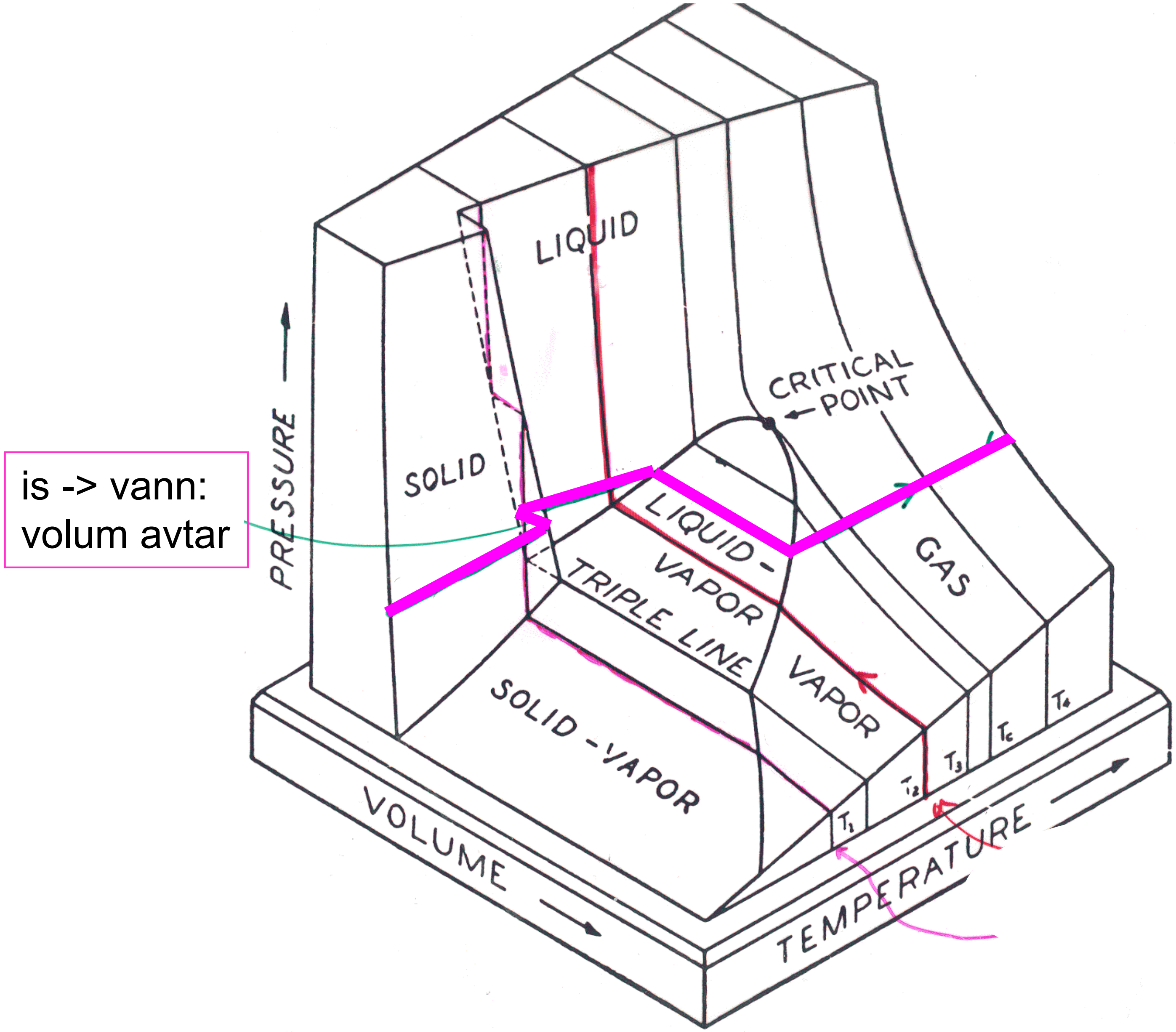
Tilførsel av konstant varmeeffekt P til

is → vann → vanndamp



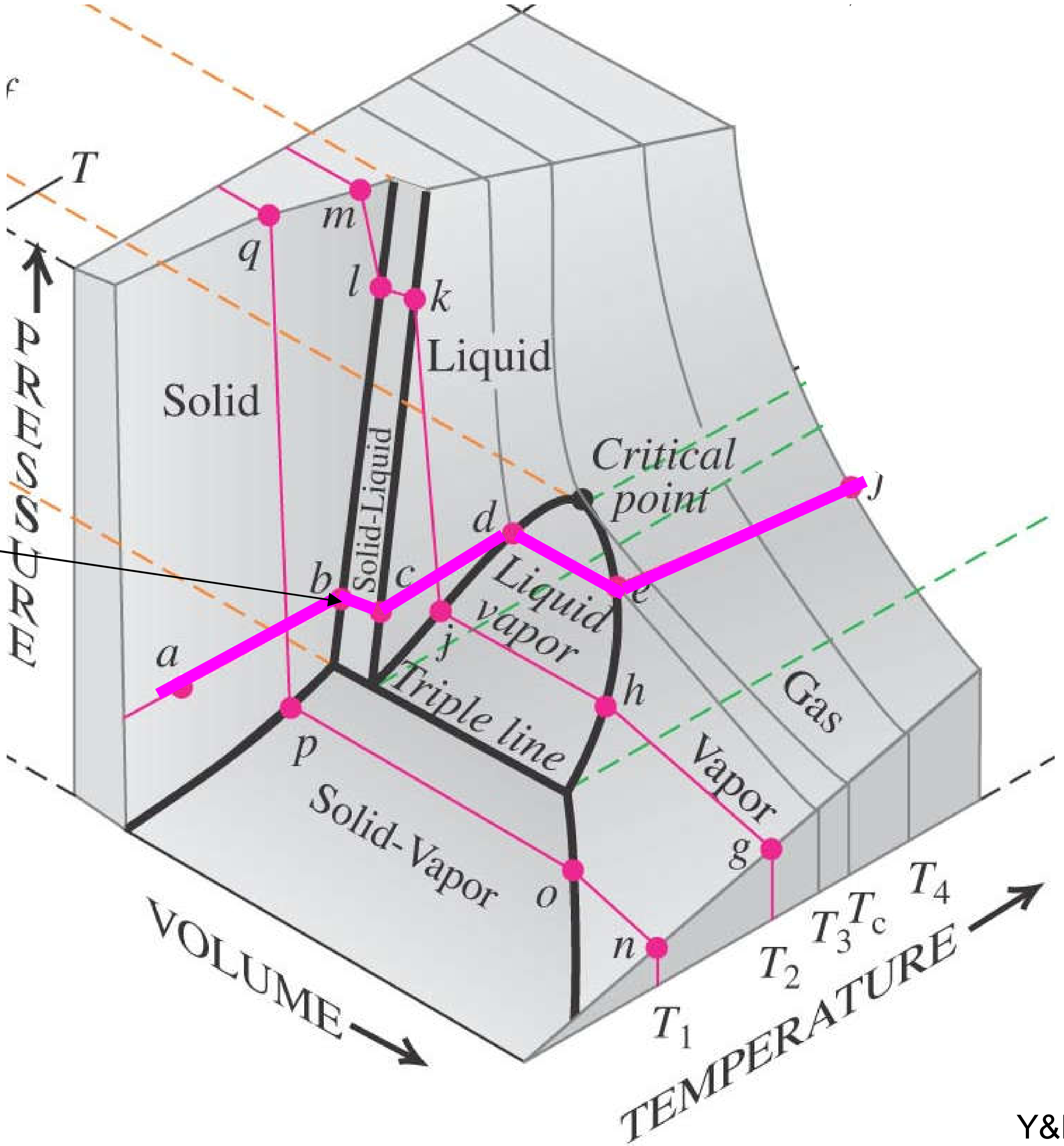
C'	L'
C'_{is} = 2,2 kJ/(kgK)	L'_s = 333 kJ/kg
C'_{vann} = 4,2 kJ/(kgK)	L'_f = 2257 kJ/kg
$C'_{p,damp}$ = 1,9 kJ/(kgK)	
($C_{p,gass}$ = 34 J/(mol K) = 4,1 R)	

Isobar oppvarming VANN



Isobar oppvarming STOFFER ≠ VANN

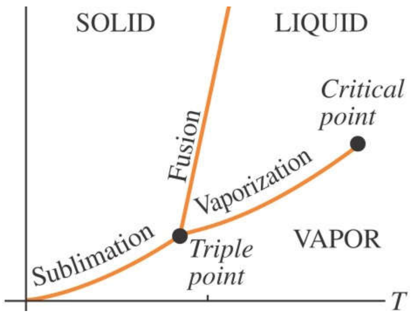
volum øker



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 $dp/dT > 0$.



- I *pT*-plott har sameksistenskurve fast/væske $dp/dT > 0$, **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.