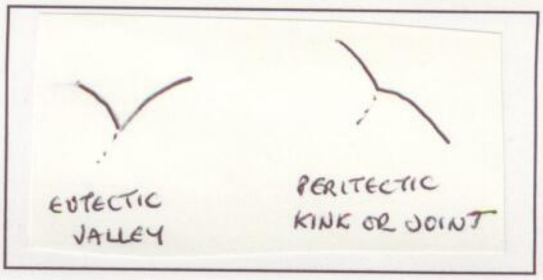
<u>ii) Peritectic Reaction: L + α → β</u>

Example comprises: 1 continous solid solution,
2 binary peritectic reactions.

The two liquidus surfaces (N.B. each surface has a different primary solidification product) meet at a **sloping "kink" or "joint" which is equivalent to the primary separation of α and β.**



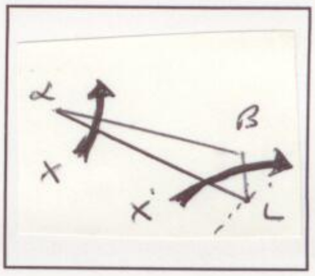
In the **binary peritectic reaction have a straight line, i.e. an invarient reaction**, but in the **ternary reaction, the peritectic reaction is NOT invarient**. I.e. there are surfaces for:

L → α solid solution,
L → β solid solution and
L + α → β peritectic reaction

since these do NOT lie in the same plane, except at the binaries. This implies, like the eutectic tie-triangles, the triangles narrow towards the binaries.

In peritectic tie triangles, the product is dragged behind, i.e. "bum drags".

The ternary reaction is like the binary peritectic, and depends on the compositions:



PRIMARY SOLIDIFICATION SURFACE	FINAL SOLID PRODUCT
α + L	α α + β β
β + L	β

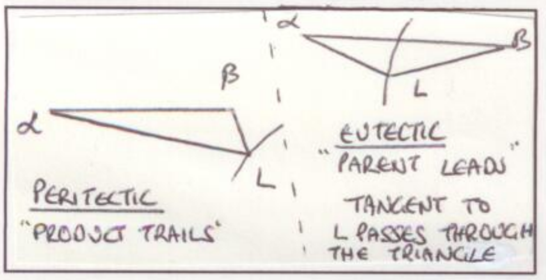
The peritectic reaction only occurs once the temperature has decreased to the liquidius, i.e. the liquid composition follows the liquidus by sliding down, until the liquid composition is on MN, and simultaneously the solid composition is on EF.

<u>Projected view:</u> This shows the **final products of solidification.** Anything in the area emnf undergoes the peritectic reaction:

emnf ↙ edgf → α + β

emnf ↘ dmng → β + L → β

iii) Transition between Eutectic and peritectic reactions:



The tie triangles change shape.: In the **peritectic reaction tie triangle, the joint lies outside**, whereas in the **eutectic tie triangle, the valley passes through the tie triangle**.

Microstructure: Inside the ternary, the microstructure is nearly all peritectic in nature close to the peritectic reaction, and the same is true for the eutectic reaction. In the middle of the ternary the is a mixture of microstructures (i.e. change over in reaction: from an intimate eutectic appearance to a "chewed" peritectic one, that is chunky in appearance, and has been consumed).

Can change from eutectic to peritectic (e.g. Mo-Ru-Pd) and vice versa.

v) Systems with a solid state miscibility gap:

Critical points: N on liquidus and F on solidus. The critical points appear to be disjointed on the eutectic, because N is in equilibrium with F.

SYSTEMS WITH 4 PHASES: L, α, β, γ

i) Ternary eutectic:

When there are 3 binary eutectic reactions, there is USUALLY a ternary eutectic of reaction:

$$L \rightarrow \alpha + \beta + \gamma$$

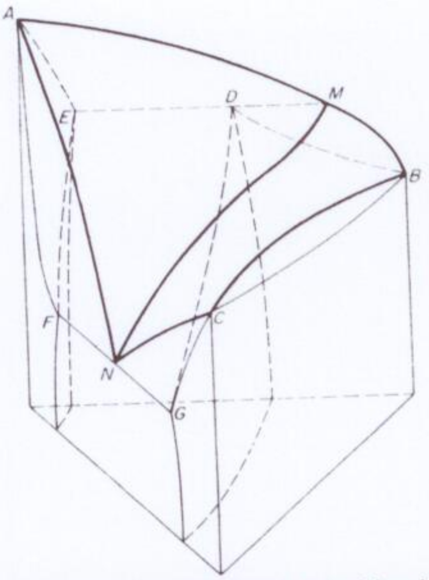
at a lower temperature. This reaction is a point, i.e. **invariant reaction**. The degrees of freedom = 0.

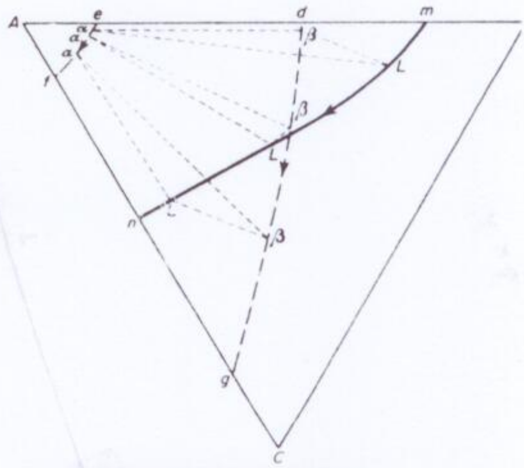
As the **liquid cools and solidifies, have 3 tie triangles moving closer together, and at the ternary eutectic (temperature) they meet, and join**.

On the projected view, all of the arrows (of the binary eutectic reactions) point inwards.

E.g. Solidification: (say A-rich)

L cools, until the liquidus is reached, then $L \rightarrow \alpha$. The liquid composition slides down the liquidus surface, until it meets the valley at which the binary reaction occurs: $L \rightarrow \alpha + \beta$
On more cooling, the liquid composition slides down this valley until the ternary eutectic "point" is reached, and the reaction: $L \rightarrow \alpha + \beta + \gamma$ occurs. Sometimes the liquid is used up prior to this, and this depends on the alloy composition.

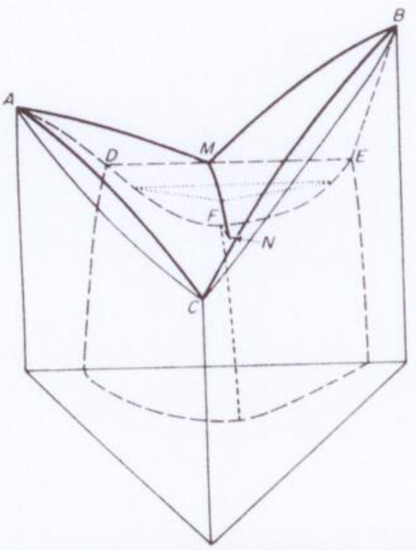


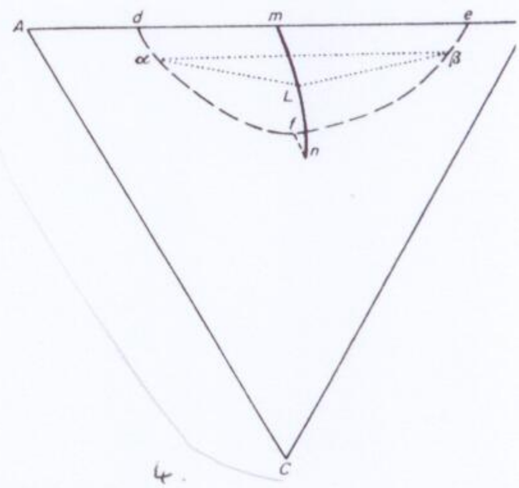


Projected view of system

2.

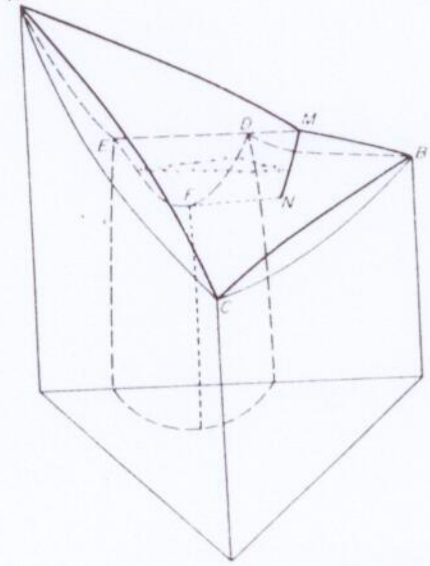
1. Space model of system showing a transition between a peritectic and a eutectic reaction

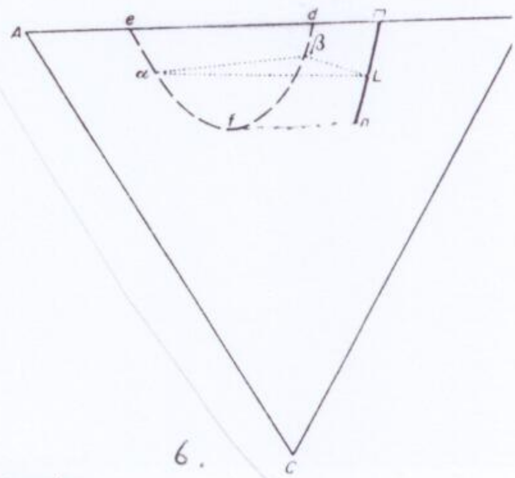




4.

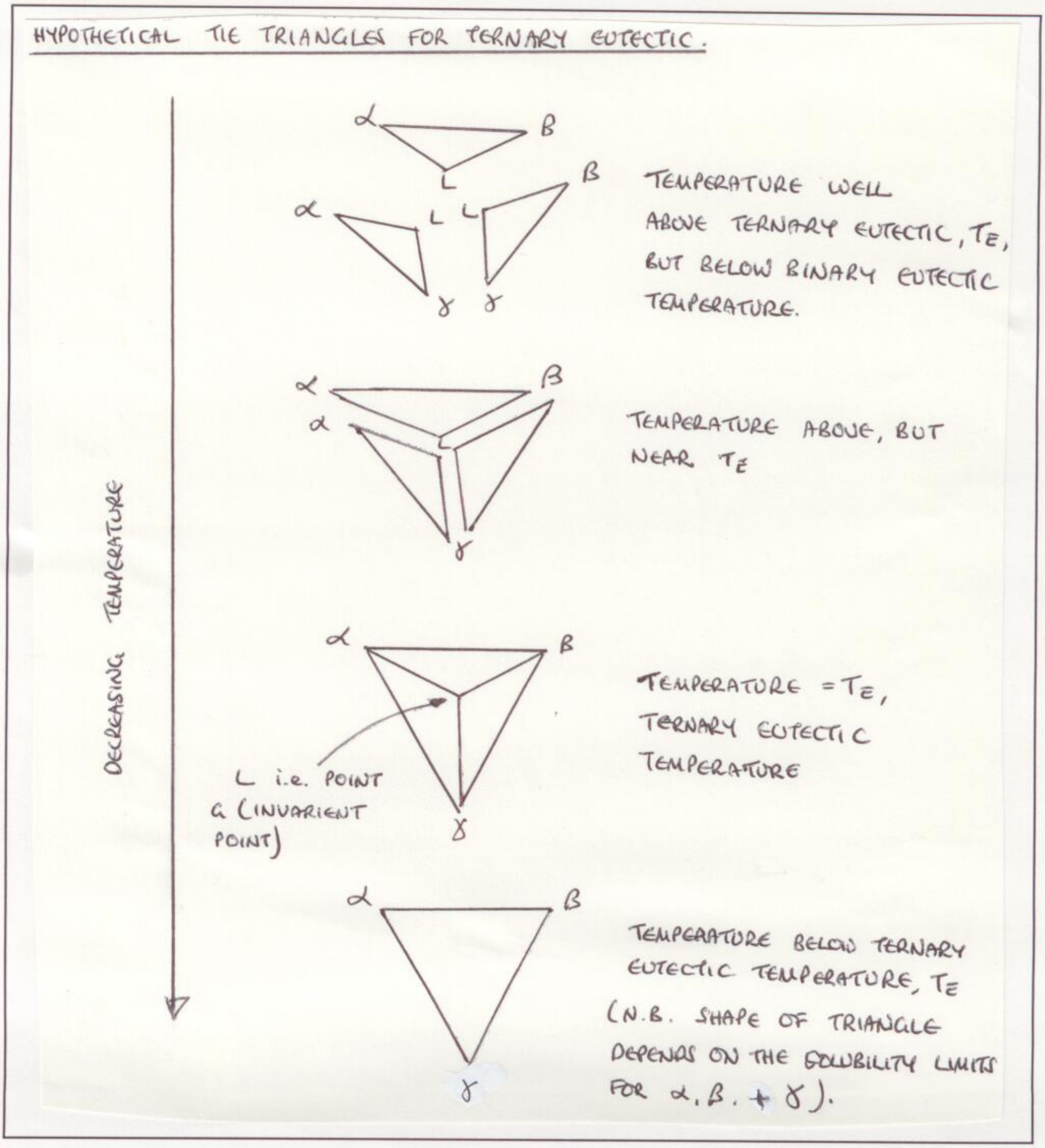
3. model of a system containing a eutectic reaction in solid state miscibility gap closes within the system





6.

5. Space model of a system containing a peritectic reaction in which the solid state miscibility gap closes within the system



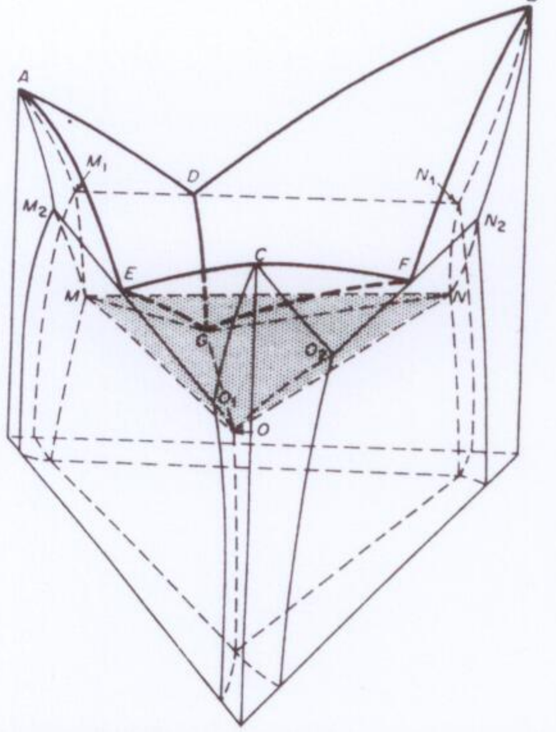
ii) Ternary Peritectic reactions:

a) E.g. Ternary Peritectic: 1 peritectic + 2 eutectic binaries:

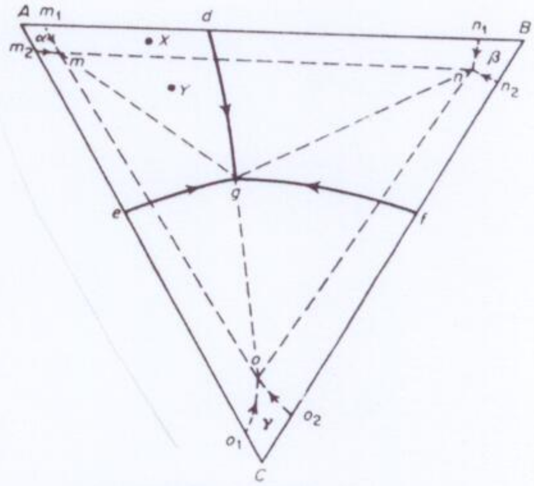
$L + \alpha \rightarrow \beta + \gamma$ at an invariant point G.

At DG = $L + \alpha \rightarrow \beta$ Peritectic reaction G: $L + \alpha \rightarrow \beta + \gamma$
At EG = $L \rightarrow \alpha + \gamma$
At GF = $L \rightarrow \beta + \gamma$

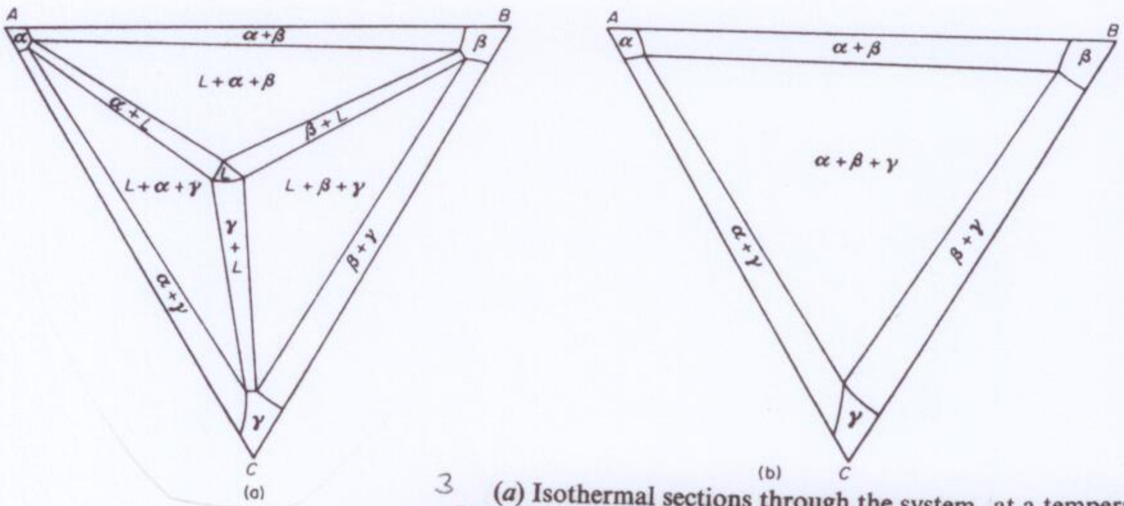
N.B. Each reaction curve (ie where liquidus surfaces meet) has a series of tie triangles. The whole ternary can be seen as two sets



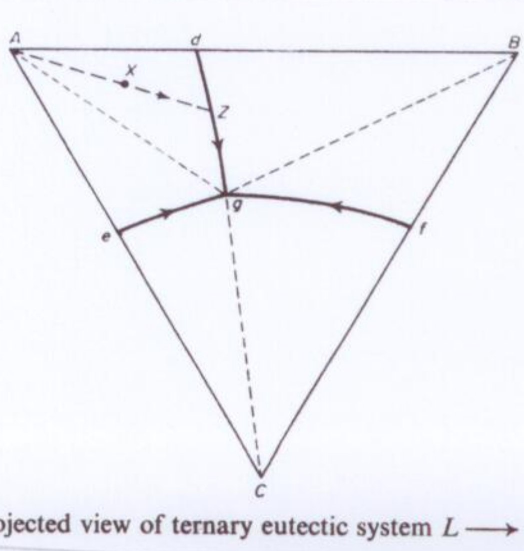
1. Space model of system showing a ternary eutectic reaction
$L \longrightarrow \alpha + \beta + \gamma$



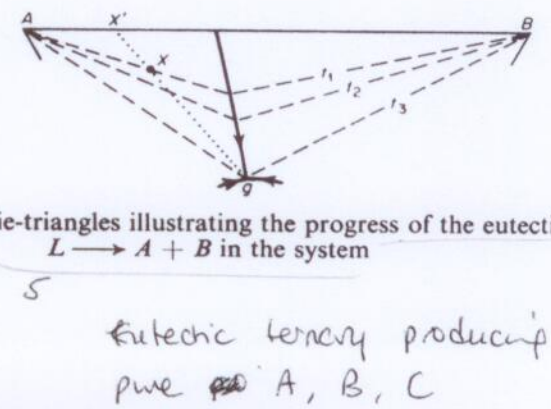
2. Projected view of system



3 (*a*) Isothermal sections through the system . at a temperature above the ternary eutectic temperature, but below the temperatures of the eutectic reactions in the three binary systems
(*b*) at a temperature below that of the ternary eutectic



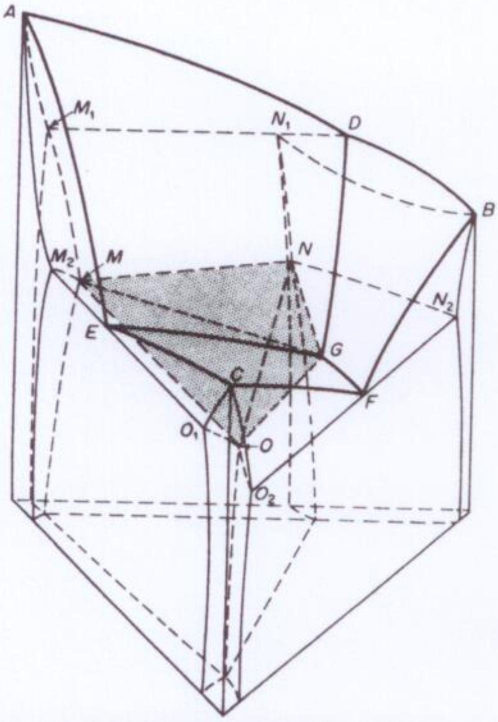
4 Projected view of ternary eutectic system $L \longrightarrow A + B + C$



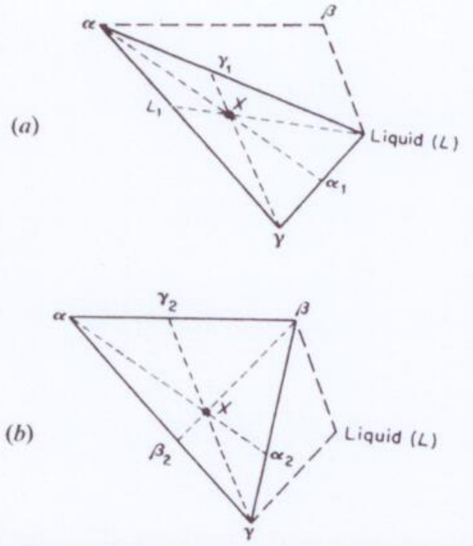
Tie-triangles illustrating the progress of the eutectic reactic
$L \longrightarrow A + B$ in the system

5

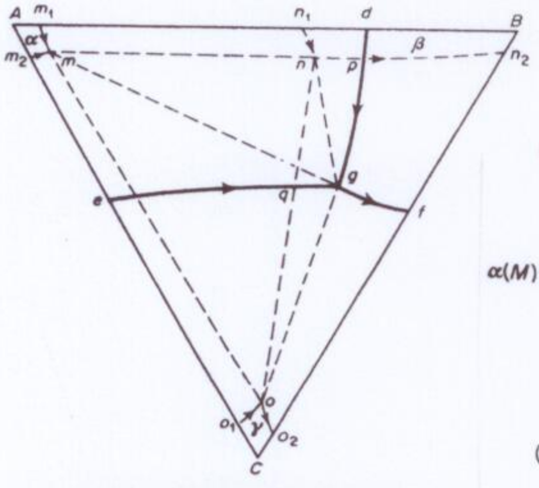
Eutectic ternary producing
pure A, B, C
(ie no solid solution)



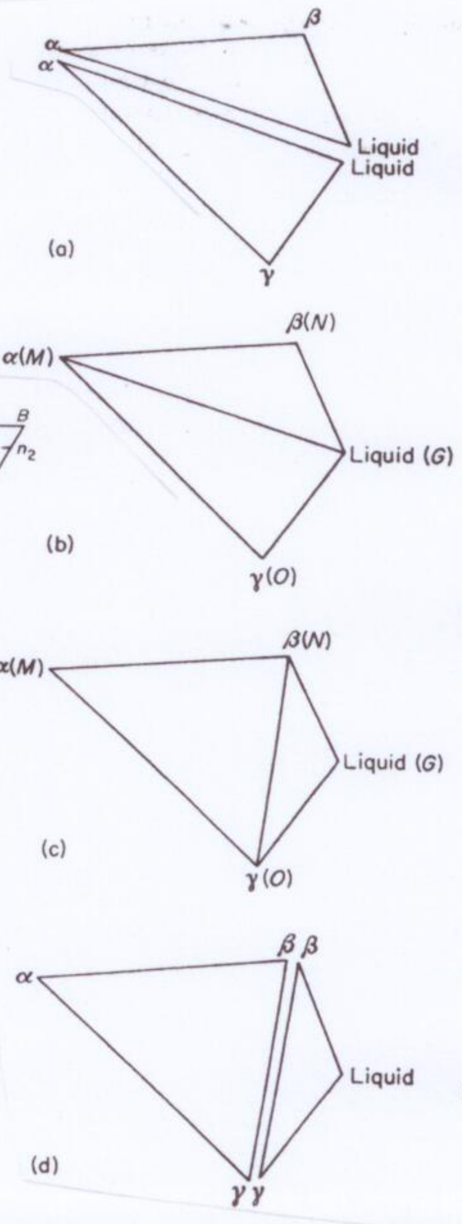
1. Space model of system showing a ternary peritectic reaction
$L + \alpha \longrightarrow \beta + \gamma$



2. Tie-triangles at the ternary peritectic temperature used to calculate the percentages of the phases present in alloy X before and after the occurrence of the invariant reaction



3. Projected view of system

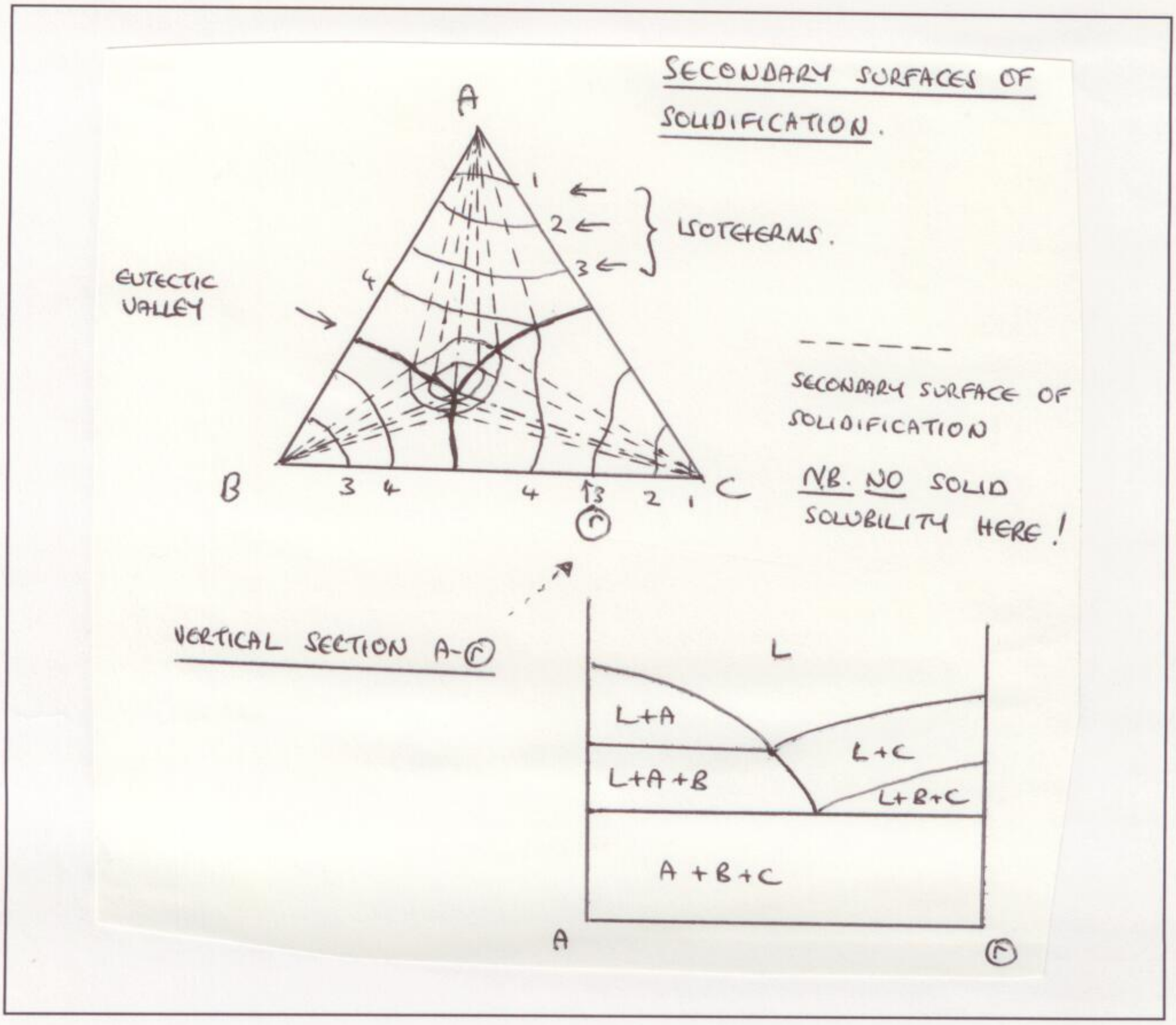


(a) at a temperature just abov[e] that of the ternary peritectic;

(b) and (c) at the ternary peritectic temperature;

(d) below the ternary peritectic temperature

4. Tie-triangles



of tie triangles:
One of the sets comprises **two individual triangles comes together: eutectic and peritectic. These are joined for an instant i.e. in the temperature of the peritectic plane:**

$$L + \alpha \rightarrow \beta + \gamma$$

At lower temperatures, there is a **separation: to the eutectic triangle, which changes location with lowering temperature (i.e. "flows away nose first"), and the stationary 3-phase triangle**, where there is no further reaction, since all liquid has been consumed.

Projected View:

Liquidus valleys divide up the liquidus surface into areas of different primary solidification:

α - Aegd
β - Bdgf
γ - Cfge

For solid solubility regions:

α	-	A m_1 m m_2
β	-	B n_1 n n_2
γ	-	C o_1 o o_2

Anything in the region bounded by:
- **mngo:** undergoes the ternary peritectic reaction.
- **mno:** $\rightarrow \alpha + \beta + \gamma$.
- **ngo:** α is consumed, and the liquid composition goes down eutectic valley forming $\beta + \gamma$.
- **npg:** the liquid composition short-cuts, and goes from pg, across the β liquidus, to gf, i.e. no peritectic reaction occurs.

Isothermal sections: The second diagram should be similar to the ternary projection, assuming no change in solid solubility with decreasing temperature (usually can consider negligible differences).

b)E.g. Ternary Peritectic: Two peritectic and 1 eutectic binary:

Reaction $L + \alpha + \beta \rightarrow \gamma$ which is invariant (G).

From the invariant plane, 2 peritectic reactions "flow" (i.e. two series of tie triangles) with decreasing temperature:

$$GE = L + \alpha \rightarrow \gamma$$
$$GF = L + \beta \rightarrow \gamma$$
$$\text{Eutectic} = DG$$

Considering tie triangles:
three triangles:

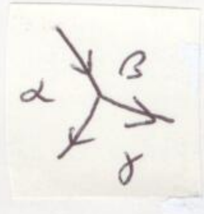
1) **$\alpha\beta$L triangle of the eutectic reaction**

2) **3 triangles "joined" at peritectic temperature** - actually a single peritectic plane, i.e **invarient reaction**

3) Below the peritectic temperature invariant plane, the **3 individual triangles split up**:

$\alpha\beta\gamma$	$\alpha + \beta + \gamma$ (All liquid has been consumed.)
$\alpha\gamma L$ =	$L + \gamma \rightarrow \gamma$
$\beta\gamma L$ =	$L + \beta \rightarrow \gamma$

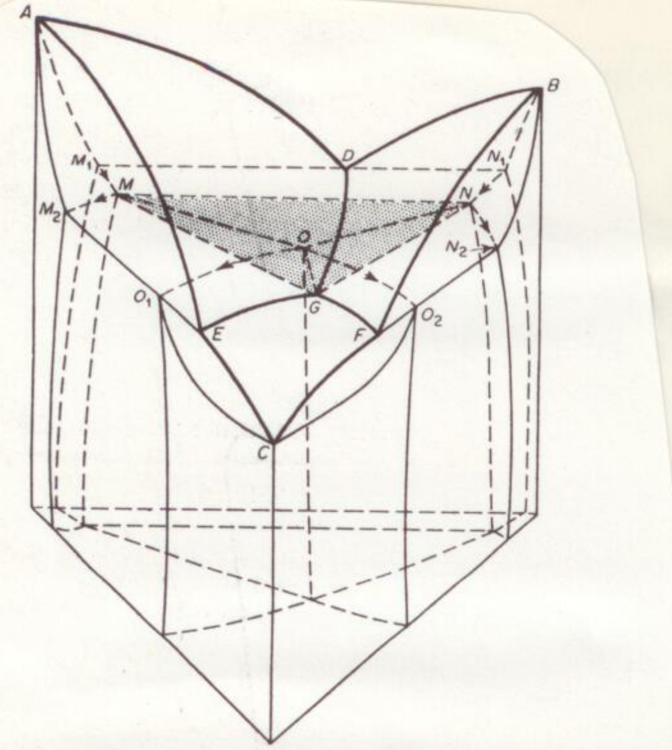
Projected view: The arrows of the reactions flow outwards, and divide the surface into areas of primary solidification.



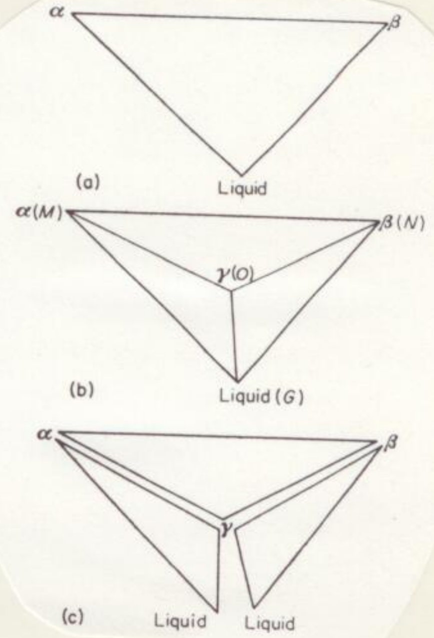
Areas of solid solubility:

α	-	A m_1 m m_2	
β	-	B n_1 n n_2	
γ	-	C o_1 o o_2	(N.B. Peritectic)

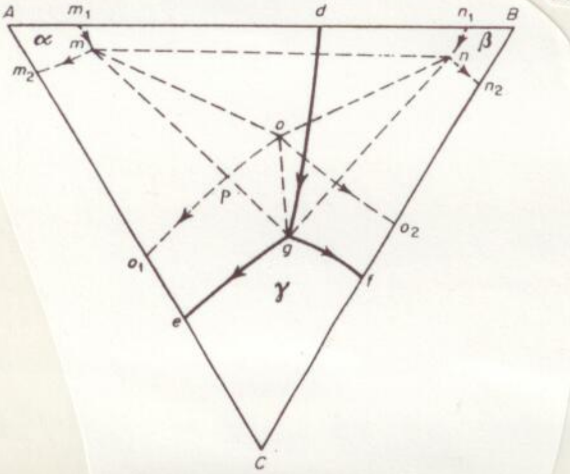
Isothermal Sections:
Anything within regions bounded by:
mng: undergoes eutectic reaction.
mno: Forms 3 phases: $\alpha + \beta + \gamma$
other parts of the triangle mng: follow on to peritectics.



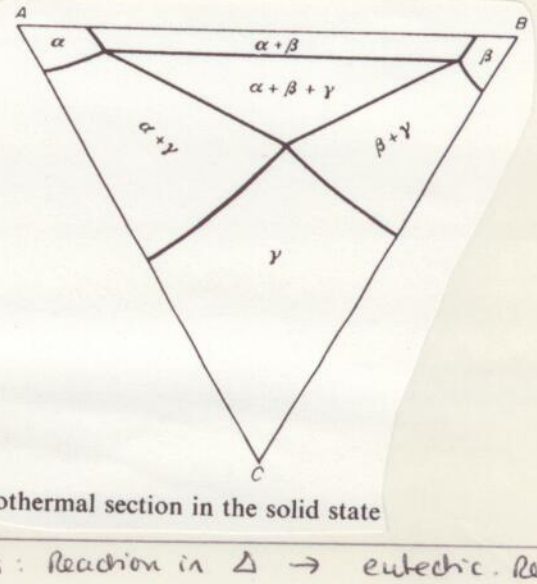
1. Space model of system showing a ternary peritectic reaction
$L + \alpha + \beta \longrightarrow \gamma$



2. Tie-triangles
(*a*) at a temperature just above that of the ternary peritectic
(*b*) at the peritectic temperature
(*c*) below the peritectic temperature

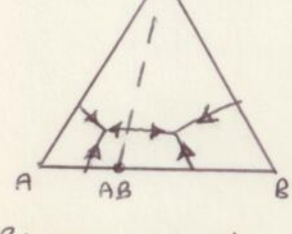


3. Projected view of system of Fig. 4.13



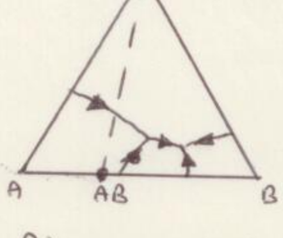
4. Isothermal section in the solid state

If have other phases, divide up into compatibility Δs: Reaction in Δ → eutectic. Reaction outside Δ → peritectic



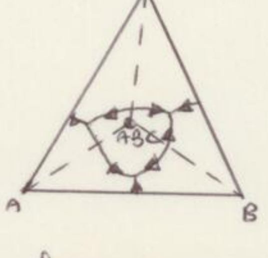
Binary compound melting congruently

2 eutectics



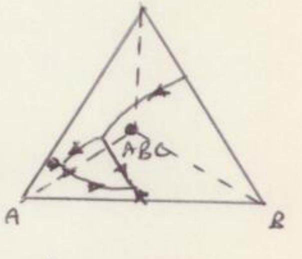
Binary compound melts incongruently

Peritectic + eutectic



Ternary compound melting congruently

3 eutectics



Ternary compound melting incongruently

peritectics + 2 eutectics

Isothermal section:
compare to projected view.

SYSTEMS WITH MORE THAN 4 PHASES: USE OF INTERPHASE COMPATIBILITY TRIANGLES

"Join the dots" of the phases. might have to use at least one of the pure phases (i.e. at the apex of composition triangle), to help starting.

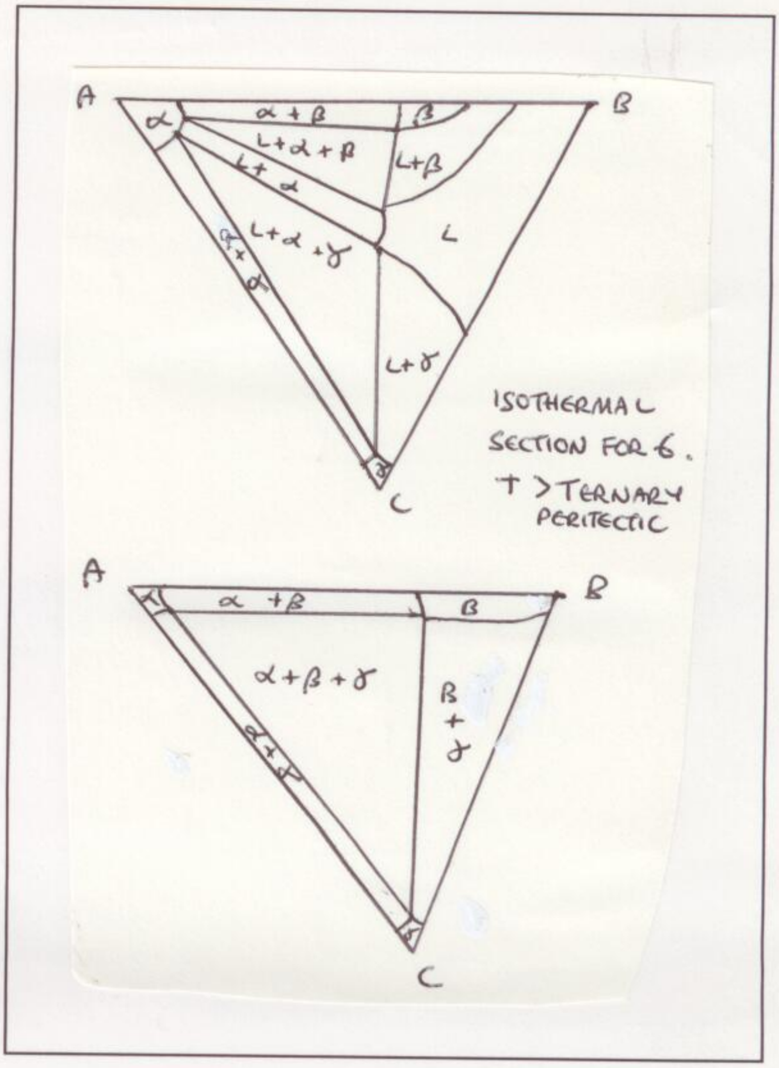
Now have drawn **"compatibility triangles"**

N.B. There should be as many of the compatibility triangles as there are 3 reactions valleys/joints meeting at a point. **(CHECK!!)**

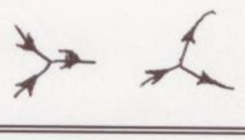
EACH compatibility triangle has a reaction associated with it:

REACTIONS LYING INSIDE THE TRIANGLE ARE EUTECTIC,

REACTIONS LYING OUTSIDE THE TRIANGLE ARE PERITECTIC. Always works!



TERNARY EUTECTIC REACTION: 

TERNARY PERITECTIC REACTION: 

QUATERNARY SYSTEMS

These are systems with **4 components**, and are more difficult to represent.

The **quaternary isothermal "section" is a tetrahedron, where the faces are the ternaries, and the edges are the binaries (at whatever temperature)**.

Application of the phase rule gives:

Invariant points have 5 phases in equilibrium.
There are 4 phases in equilibrium on line, and 3 phases in equilibrium on a surface.

von Alkemade's rule:

The direction of falling temperature of the liquid in equilibrium with two solid phases is always away from the tie-line between the solid phases. If the liquid falls on the tie-line, then the 3-phase equilibrium is at a temperature maximum

... or minimum

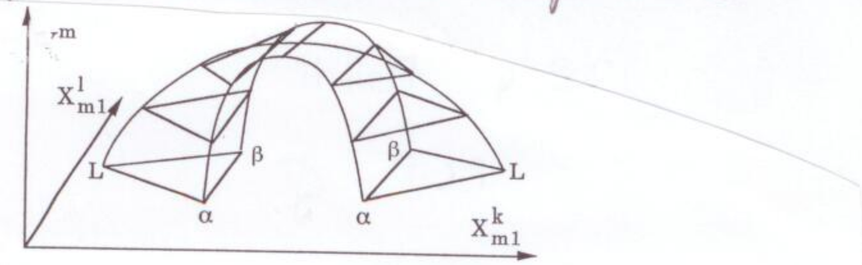
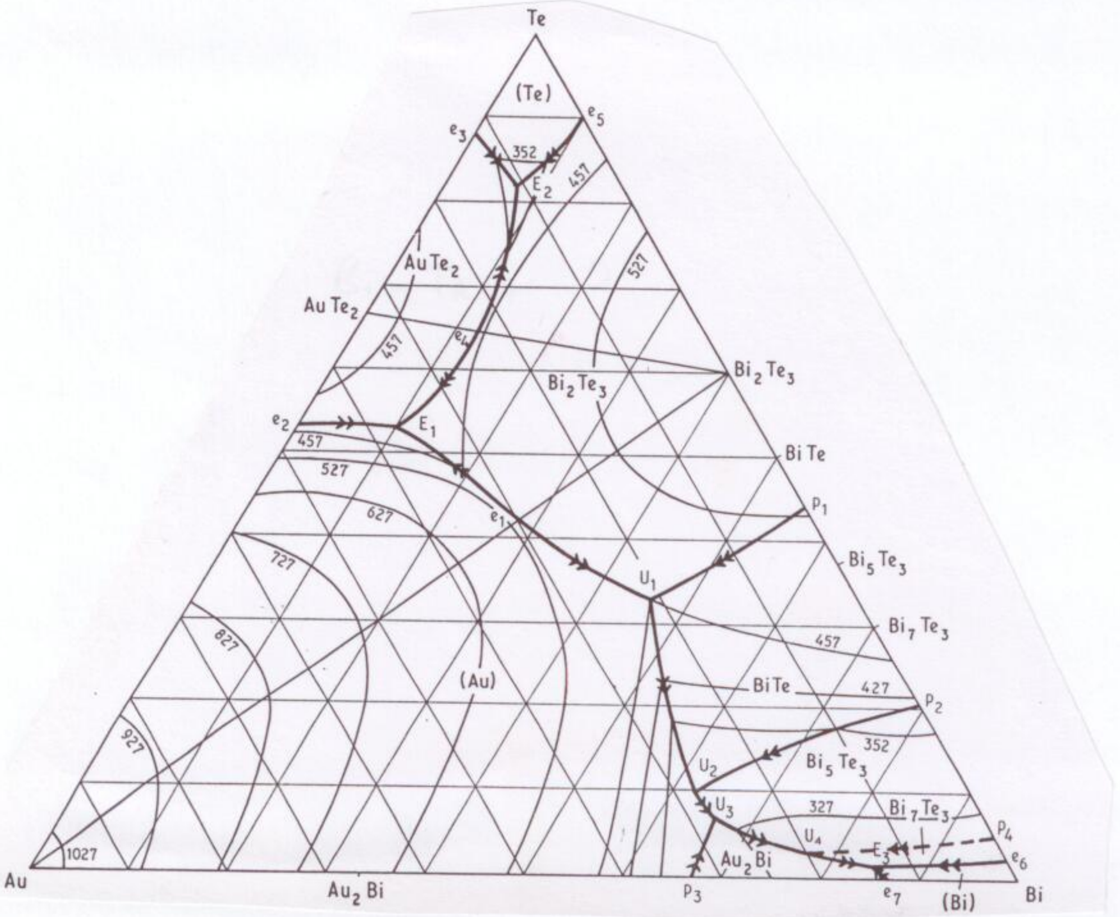


Figure 9.26 Ternary phase diagram at constant P and with two molar axes showing a three-phase equilibrium with an extremum for T (here represented by Y^m), illustrating von Alkemade's rule. The triangles are parallel to the X^k_{m1}, X^l_{m1} plane.



Alkemade's Line – joins two phases of constant content ≡ 2 phase field