Heat Treatments of Al-alloys
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What is Temper?

This is the quality of metal that describes it's ability to spring back after it is flexed . It doesn't have anything to do with how hard the metal is.

- **Soft temper** means that when it is bent, it stays bent, and it doesn't take much force to do it.

- **Hard temper** means that when it is bent, it springs back flat, and it takes a lot of force to put a kink into it.

What is Temper?

- The temper designation follows the alloy designation and shows the actual condition of the metal.
- alloy designation by a letter and dash.
- **The letter** *F* following the alloy designation indicates the "as fabricated condition, in which no effort has been made to control the mechanical properties of the metal,
- **The letter** *O* indicates dead soft, or annealed, condition.
- **The letter W** indicates solution heat treated.
- Solution heat treatment consists of heating the metal to a high temperature followed by a rapid quench in cold water
- , This in an unstable temper, applicable only to those alloys that spontaneously age at room temperature.

What is Temper?

- **The letter *H*** indicates:
- strain hardened, cold-worked, hand-drawn, or rolled. Additional digits are added to the *H* to indicate the degree of strain hardening.
- This letter designates a process of stretching or compressing in order to impart a particular temper.
- **H_1** 1/8 hard
  H_2 1/4 hard
  H_3 3/8 hard
  H_4 1/2 hard
  H_5 5/8 hard
  H_6 3/4 hard
  H_7 7/8 hard
  H_8 Full hard

What is Temper?

- **The letter *T* tempers** (thermally treated tempers) These tempers are imparted by heating, quenching, or cooling in a controlled way. Greater strength is obtainable in the heat-treatable alloys

T1 Cooled after being shaped to its final dimensions during a process involving a lot of heat (such as extrusion), then naturally aged to a stable condition.

T2 Cooled after being shaped to its final dimensions during a process involving a lot of heat (such as extrusion), then cold worked.

T3 Solution heat treated, cold worked and naturally aged to a stable condition.

T4 Solution heat treated and naturally aged to a stable condition

T5 Cooled after being shaped to its final dimensions during a process involving a lot of heat (such as extrusion), then artificially aged. T5 is T1 that has been artificially aged.

T6 Solution heat treated and artificially aged to a stable condition. T6 is T4 that has been artificially aged.

T7 Solution heat treated and naturally aged past the point of a stable condition. This process provides control of some special characteristics.

T8 Solution heat treated, cold worked and artificially aged. T8 is T3 that has been artificially aged.

T9 Solution heat treated, artificially aged and cold worked A stable temper T9 is T6 that has been cold worked.

T10 Cooled after being shaped to its final dimensions during a process involving a lot of heat (such as extrusion), then cold worked and artificially aged. T10 is T2 that has been artificially aged.

Heat Treatment for Aluminum -

- **Solution Heat Treatments**

Improve mechanical properties by developing maximum practical concentration of the hardening constituents in solid solution; involves heating to above the critical temperature, holding, and abrupt quenching.

- **Quenching**

Cooling alloy fast enough to retain a supersaturated solid solution of alloying constituents without introducing adverse metallurgical or mechanical conditions; Most common quenching media are water, air blast, soap solutions and hot oil

Heat Treatment for Aluminum -

- **Precipitation Hardening**:
- Some times called age hardening, used on aluminum, copper, nickel, magnesium and some stainless alloys
- **Ageing:**
- The ageing process can be divided into two main categories after the ageing temperature
- **Natural Ageing**:
- The Heat treatable alloys changes properties when stored at room temperature after solution heat treatment and quenching.
- **Artificial Ageing**: By heating the solution heat treated material to a temperature above room temperature and holding it there the precipitation accelerates and the strength is farther increased compare to natural ageing

Heat Treatment for Aluminum

- **Preheating or Homogenizing**

Typically a preliminary to other treatments to reduce chemical segregation of cast structures and improve their workability; reduce brittleness in cast structure

- **Annealing**

Aids in workability by softening aluminum and heat treated alloy structures to relive stresses and stabilize properties and dimensions of product

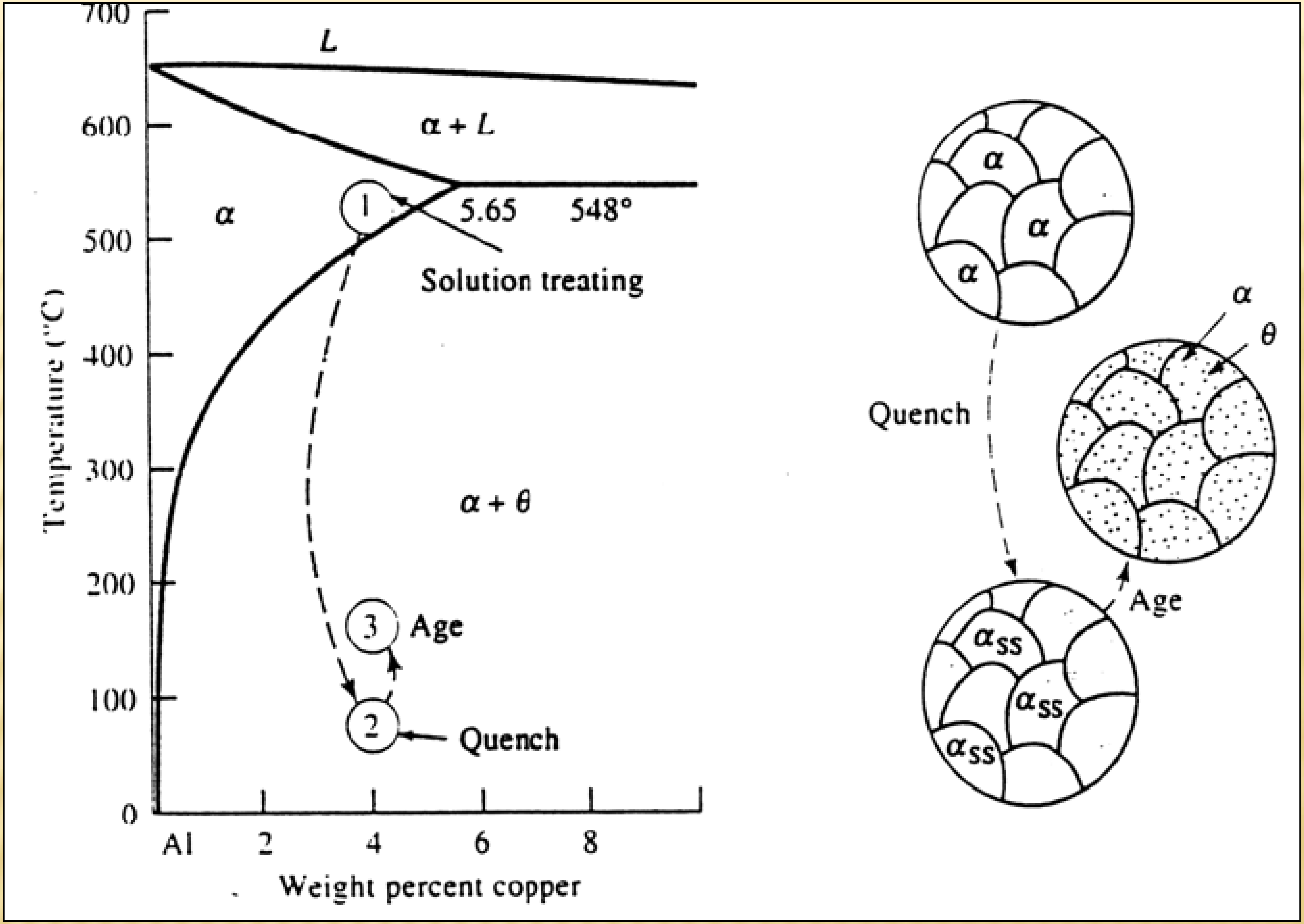


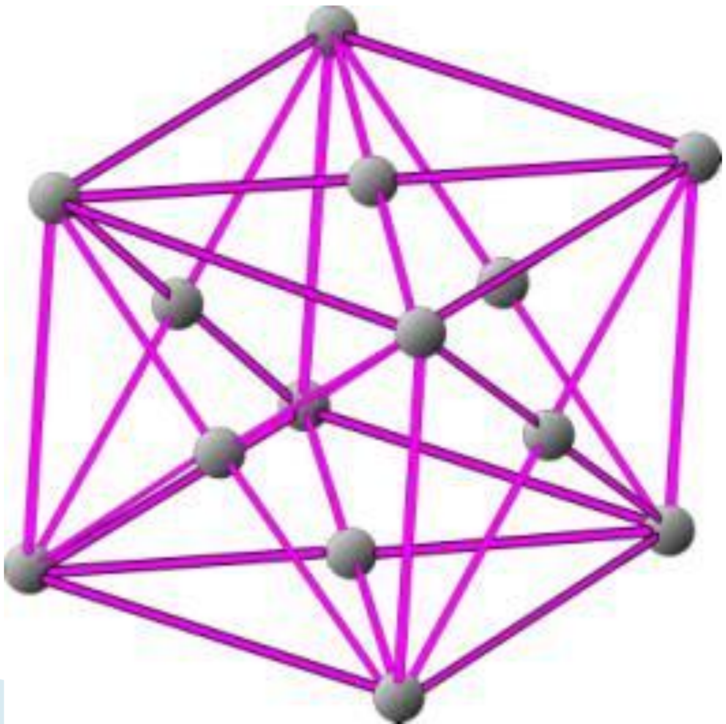
Figure 1: Al-Cu phase diagram (Al rich, partial), showing three

steps in precipitation hardening and the

Guinier –Preston Zones (GP zones).

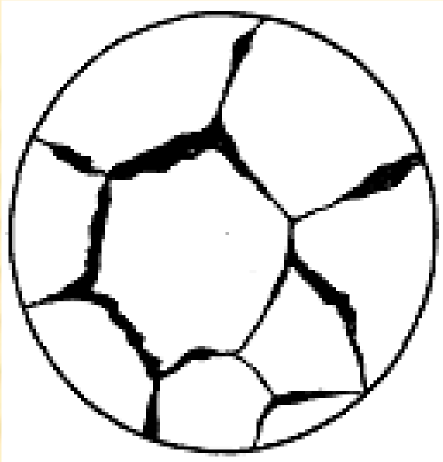
- The first step in the process of aging is the formation of **Guinier – Preston Zones (GP zones)**.
- GP Zones are solute atoms that have diffused into coherent clusters.
- Coherent clusters are clusters of the solute atoms that distort the crystal structure, but are still connected to the rest of the crystal structure.
- The GP Zones contain these solute clusters that stop the procession of dislocations, thus strengthening the material.

- **GP I Zone**s,
- which are very thin precipitates form first, right after the supersaturated solid solution has been heated below the solvus temperature (solution-treatment).
- Then the GP I Zones thicken into thin disks called **GP II** Zones. If diffusion continues, the GP II Zones will grow into coherent equiaxed theta prime precipitates.
- Finally, incoherent stable theta precipitates

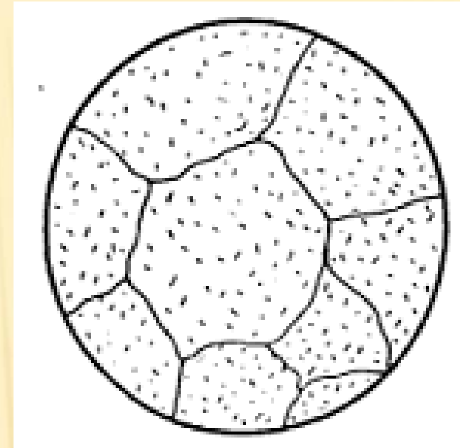


under aged, over aged, or critically aged.

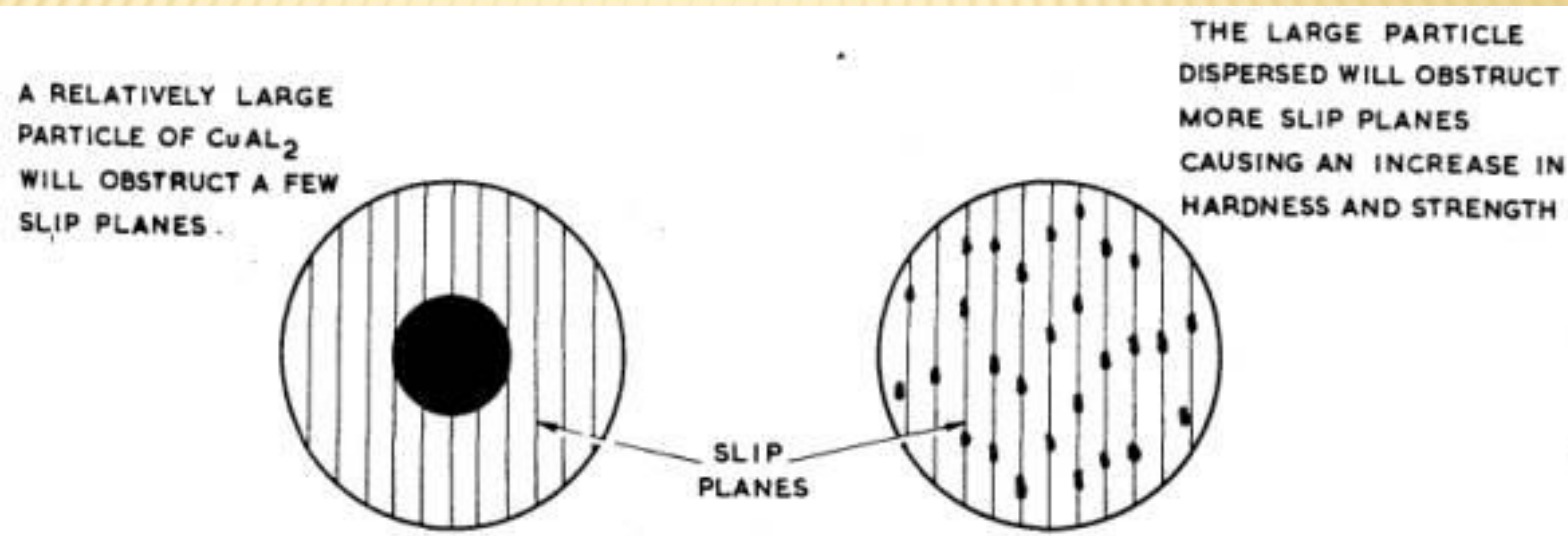
- **Under aging** occurs when the alloy is heated for too short of time. This will provide a relatively weak alloy due to the undeveloped GP zones.
- **Over aged,** which indicates that the alloy had been heated for too long of time, the final product will be a relatively weak alloy. Maximum strength is obtained when the alloy is critically aged.
- **Dimensional changes** can occur in the specimen during age hardening. The change depends on the type of alloy, size and shape of the specimen, quenching process, aging temperature an time.



Before Solution Heat Treatment



After Solution Heat Treatment



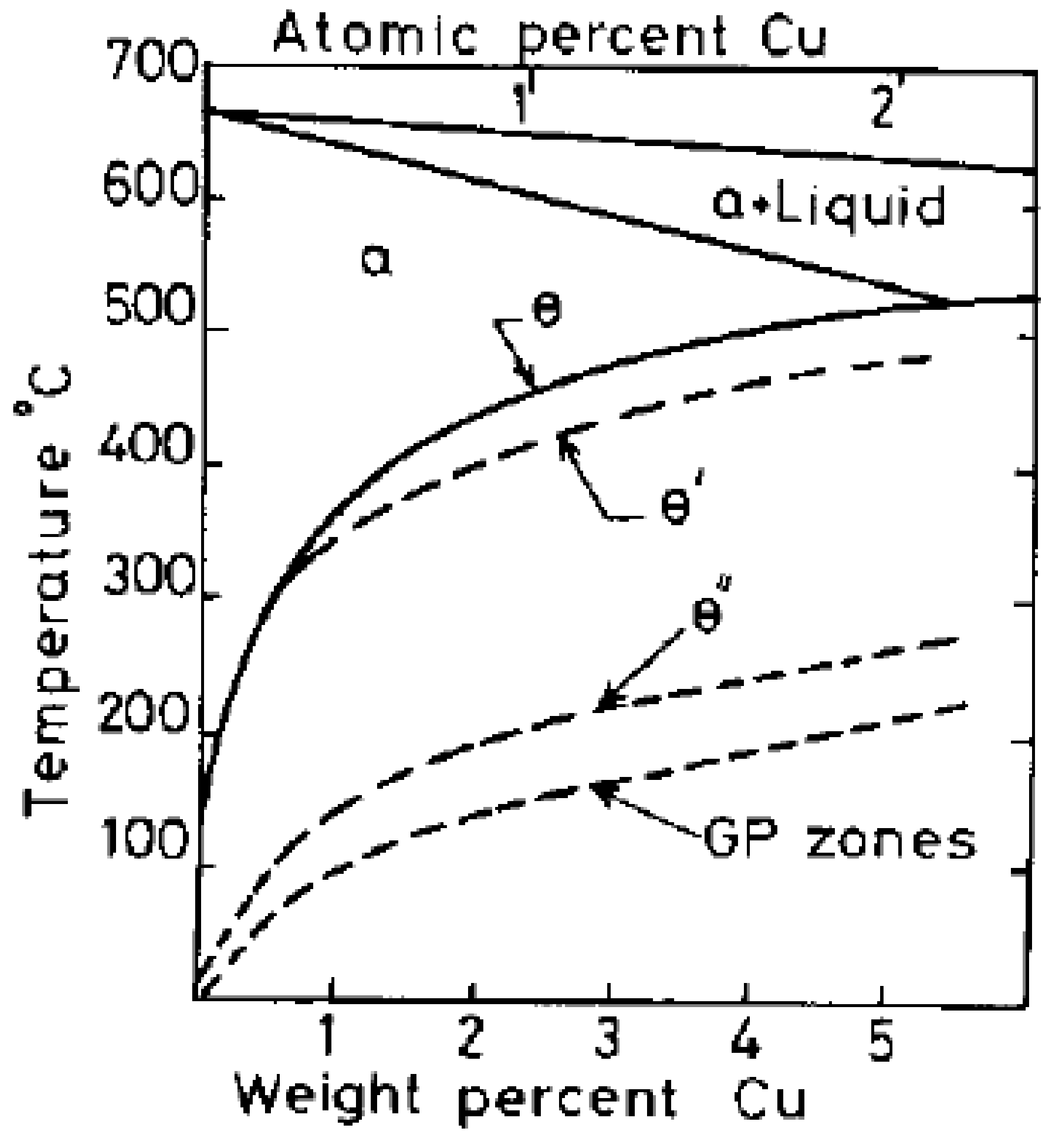


Figure 2:
Al-Cu phase diagram showing GP Zones

Example

Composition of Al-4% Cu Alloy Phases

Compare the composition of the a solid solution in the Al-4% Cu alloy at room temperature when the alloy cools under equilibrium conditions with that when the alloy is quenched.

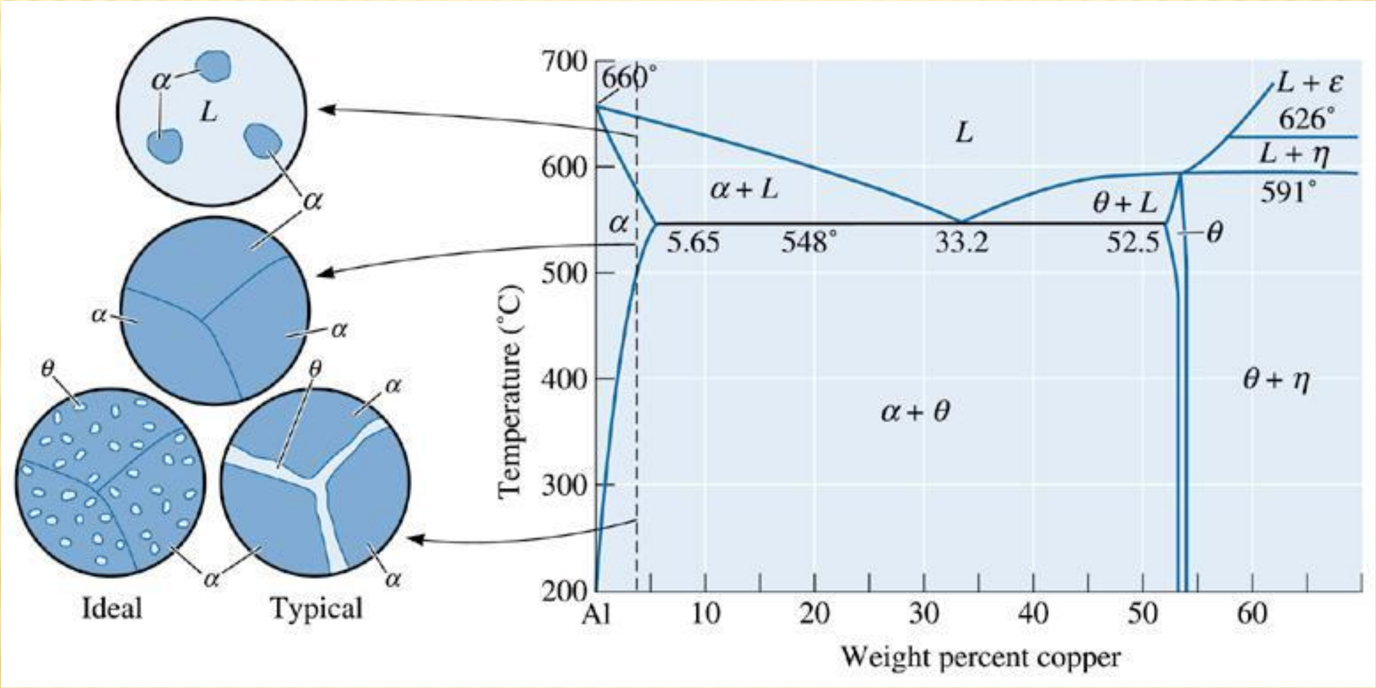


Figure 11.5 The aluminum-copper phase diagram and the microstructures that may develop curing cooling of an Al-4% Cu alloy.

SOLUTION

From Figure 11.5, a tie line can be drawn at room temperature. The composition of the α determined from the tie line is about 0.02% Cu. However, the composition of the α after quenching is still 4% Cu. Since α contains more than the equilibrium copper content, the α is supersaturated with copper.