Phase Diagrams of binary systems

A phase diagram is a type of graph used to show the equilibrium conditions between different phases (in the sense of gas, liquid, solid, compound, modification...). It shows regions or areas which contains either one or two phases. These areas are separated by curves.

**Information from phase diagram**
- Composition of compounds and solid solution series.
- Phase transitions, melting and boiling temperatures.

Fundamental Rule: \( P + F = C + 2 \)
- \( P \): number of phases
- \( C \): number of components
- \( F \): number of degree of freedom

**Some simple and classic phase diagrams in binary systems**
(two components designated as “A” and “B”):

*Generally, in binary system, pressure is considered to be constant. The phase diagrams below are “temperature verse composition” diagrams. The melting points of the pure components are on both vertical sidelines. Curves divided the phases are called liquidus and solidus curves, representing the liquid and solid states, respectively.*

1. **Binary system with complete range of solid solution.**
   This is the simplest solid system. The components A and B are complete miscible in the solid and liquid states. In this phase diagram, there are three areas separated by two smooth curves - “liquidus” and “solidus”: liquid state upside, liquid- solid state in the middle and solid state underside. If a liquid with a certain composition is cooled, a solid starts to crystallize when reaching the liquidus curve. The compositions of A and B at a given temperature in liquid and solid states is different. The values can be read from the diagram.

2. **Eutectic system with and without partial solid solubility.**
   A. **Eutectic system without partial solid solubility**
   In this diagram, there are four areas. The solid state is separated by a horizontal line at a certain temperature (eutectic temperature). In this solid area, a (macroscopic) mixture of the end-member phases A and B is present. At higher temperature, both components form a homogeneous liquid. The other two areas contain A + liquid and B + liquid, respectively.
One characteristic feature of this diagram is that there is a three-phase coexistent point which is an invariant (certain temperature and certain composition of A and B) on the horizontal line. The temperature at this point (eutectic temperature) is lower than the melting points of both A and B.

B. Eutectic system with partial solid solubility
The difference of this system in comparison to the upper one is that there is partial solid solubility. Temperature-dependent a small amount of B desolves in A and vice versa.

3. Binary system with the formation of a compound.

A. Binary system with congruently melting compounds
This phase diagram can be treated as two parts divided by a vertical line which represents the compound AB. The left part of the line can be considered as the eutectic system of A and AB, and the right part of the line can be treated as the eutectic system of AB and B. The characteristic feature of this system is that the maximum of the liquidus curve represents the melting point of AB. By cooling down a liquid mixture with the composition AB the compound AB crystallizes. In other words, the compound AB melts congruently.

B. Binary system with incongruently melting compounds
This diagram is more complicated. Between the liquid state and the vertical line which represents the compound AB, there is an area of A + liquid. There is no maximum melting point between pure A and pure B. The compound AB melts incongruently. It is not possible to obtain pure AB by cooling a melt with this composition.

Reference:
1. U. Müller, Inorganic Structure chemistry
2. A. West, Basic Solid State Chemistry

Questions:
1. Sketch an eutectic system with and without partial solid solubility and explain all curves, regions and points!
2. Sketch a binary system with the formation of an incongruently melting compound and explain all curves, regions and points! What happens if you cool down a liquid with the composition of the incongruently melting compound?