# Part VIII. Classification of transformations

## 1 Module 1. Types of transformations

### 1.1 Motivation

What is the order of a transformation?

### 1.2 Thermodynamic and mechanism based transformations

The phase transformations can be classified in several different ways.

The thermodynamic characteristics associated with the phase transformations can be used to classify transformations; in this classification methodology, if the $n^{th}$ derivative of the free energy ($G$) with respect to the temperature ($T$) and pressure ($P$) is discontinuous, it is defined as the $n^{th}$ order transformation. As shown in Fig. 1, in transformations such as melting, the

first derivative has the discontinuity; hence, melting is a first order transformation; on the other hand, in some of the order-disorder transformations, it is the second derivative which is discontinuous, making it the second order transformation.

Based on the mechanism of transformation, transformations can be classified as homogeneous (transformations which take place through spinodal mechanism in which transformation takes plce throughout the material) and heterogeneous (transformations which take place through nucleation and growth mechanism in which transformation takes place heterogeneously at a few places in the material at the start of the transformation).

Transformations can also be classified as diffusional (or, so called, 'civilian') and diffusionless (or, so called 'military') depending on the mechanism. In civilian transformations, the nucleation and growth take place via diffusion assisted atomic motion. On the other hand, in the military transformation, the nucleation and growth is by shear and shuffle of atoms by less than one atomic displacement and the movement of all the participating atoms is coordinated.

There are transformations which are thermally activated (which typically are based on diffusion) while there are others which are athermal.

The transformations can also be diffusion controlled or interface controlled.

Transformations can also be differentiated based on whether the interfaces formed are glissile or non-glissile.

In some transformations there are compositional changes while in some other there are no composition changes.

Further, transformations which are diffusional can either involve long range diffusion or short range diffusion.

From the above discusion, it is also clear that there are more than one way in which a transformation can be classified. For example, a thermally activated transformation such as melting might is also a first order transformation; in pure materials, it could be an interface controlled transformation requiring no long range mass transport.

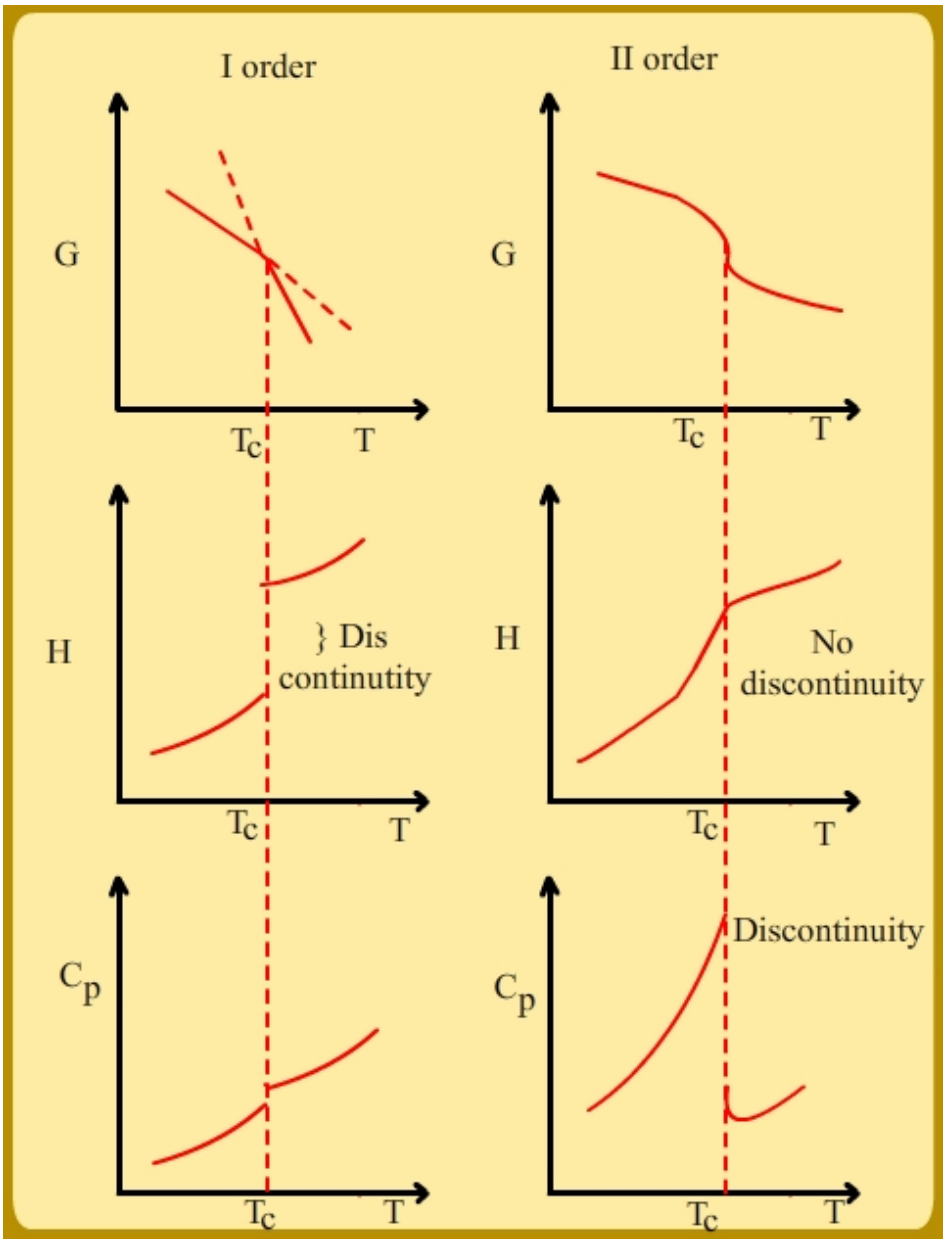


Figure 1: The thermodynamic classification of transformations: the first derivative of the free energy $G$ with respect to temperature $T$, that is the enthalpy $H$ is discontinuous at the transformation temperature $T_c$ as shown in the first column; the second derivative of the free energy with respective to temperature $C_p$ is discontinuous while $H$ is not in the second column, making the order of transformation second.

## 1.3 Tutorial problems and questions

1. Ledge growth mechanism is an example ..... controlled growth.

2. Order-disorder transformation involves ..... diffusion.

3. Martensitic twining is a thermally activated process. True or false?

4. Is grain growth a military transformation?

5. Consider a transformation that involves the evolution of latent heat. What is the order of such a transformation?

6. Consider a transformation in which there is a large volume change during transformation. What is the order of such a transformation?

## 1.4 Solutions to the tutorial

1. Interface

2. short-range

3. False. It is an athermal process.

4. No. It is a civilian transformation.

5. Any transformation that involves evolution of latent heat will have a discontinuity in the first derivative of the free energy. Hence, it is a first order transformation.

6. Volume changes during a transformation indicate that the first derivative of the free energy is discontinuous. Hence, it is a first order transformation.

## 1.5 Supplementary information

For a discussion on a type of classification (not mentioned above) due to Buerger of solid state transformations based on changes in coordination and bond type, please see [2].

# References

[1] David A. Porter, Kenneth E. Easterling, and Mohamed Y. Sherif, Phase transformations in metals and alloys, CRC press, Third edition, 2009.

[2] V Raghavan, Solid state phase transformations, Prentice-Hall India Pvt. Ltd., First edition, 1992.