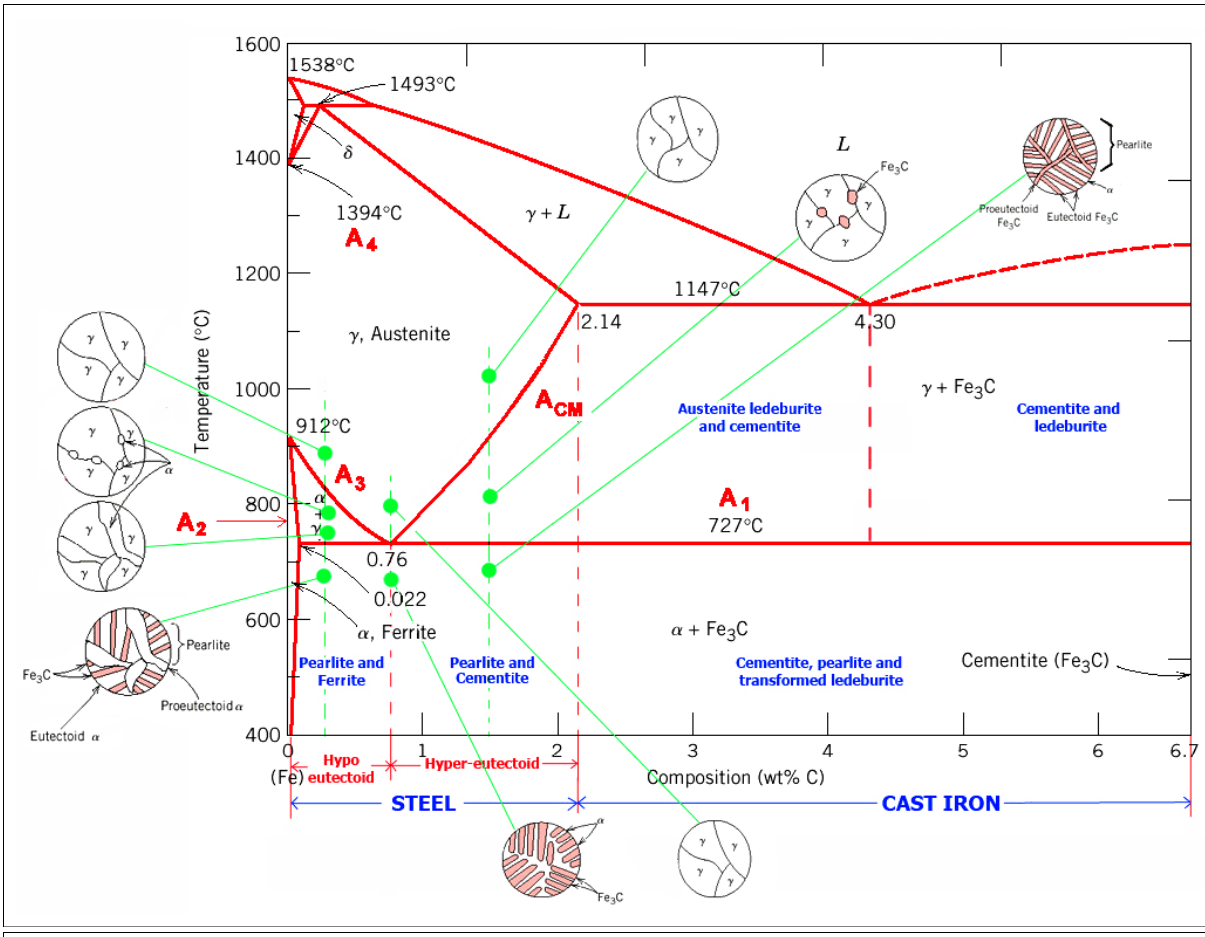
Science

The Iron Carbon Phase Diagram

There is more to the iron-carbon phase diagram than related in the backbone. In particular, there is some nomenclature that I avoided in the main text but that is important for understanding other writings about iron and steel. So let's start with a phase diagram that contains maximal information:



Iron-carbon Phase Diagram

Source: Arabic Internet site

The important boundaries (the lines) separating phases have some universally used abbreviations:

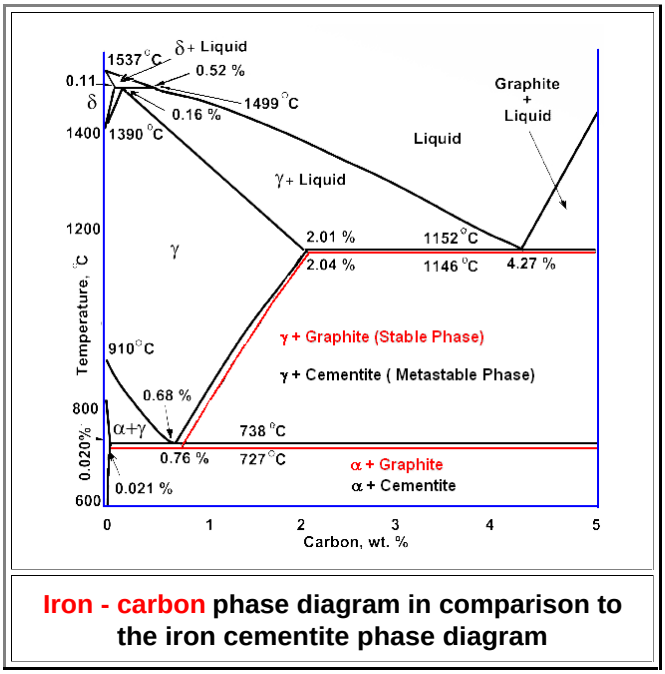
- **A_1**: The upper limit of the ferrite / cementite phase field (horizontal line going through the eutectoid point).
- **A_2**: The temperature where iron looses its magnetism (so-called **Curie temperature**). Note that for pure iron this is still in the α-phase.
- **A_3**: The boundary between the γ austenite and the austenite/ ferrite field.
- **A_4**: The point in this case where α changes to δ at high temperatures.
- **A_{CM}**: The boundary between the γ austenite and the austenite / cementite field.

Why would anybody abbreviate a temperature with the letter "A"? Well, it stands for "arrest", something that happens in the slope of dilatometric or thermal curves recorded whenever phase diagrams where first measured. Statements like "the addition of x lowers A_3" are now clear.

The circular insets give a schematic idea of what the structure would like at the compositions and temperatures indicated.

The next thing to know is that the phase diagrams above is actually *not* the true iron-carbon phase diagram. I lied to you. Some mixture of *cementite* and iron is *not* the configuration that allows the system to achieve total nirvana. That would be a iron - *graphite* mixture.

All the cementite forming is just a transient phase on the way to nirvana; it will decay into pure carbon (graphite) and iron *in due time*. Due time, however, means millennia and more at room temperature for plain carbon steel. Cementite, in other words, is a very long-lived metastable phase under normal conditions. It thus makes sense to use it for something that is *not* a true phase diagram for purists, but that sane normal folks will call "phase diagram" anyway.
We are also justified in doing this because the "real" iron - graphite phase diagram looks almost exactly like the iron - cementite "phase diagram". Here is the proof:



Iron - carbon phase diagram in comparison to the iron cementite phase diagram

- Does that mean that we don't have to worry about graphite being formed? Yes and no. Like almost always, it depends:
  - For *plain carbon* steel with carbon concentrations below 2 %, you needn't worry, indeed. Graphite is *never* formed and the usual phase diagram covers everything nicely.
    For *cast-iron*, with carbon concentrations up to a few percent you need to worry. Graphite might form, depending on conditions.
    For *alloy steel*, the usual thing nowadays, you need to worry, too. Some alloying elements, in particular silicon (Si) but also nickel (Ni), promote graphite formation.