Nuclear Physics – A Qualitative Treatment

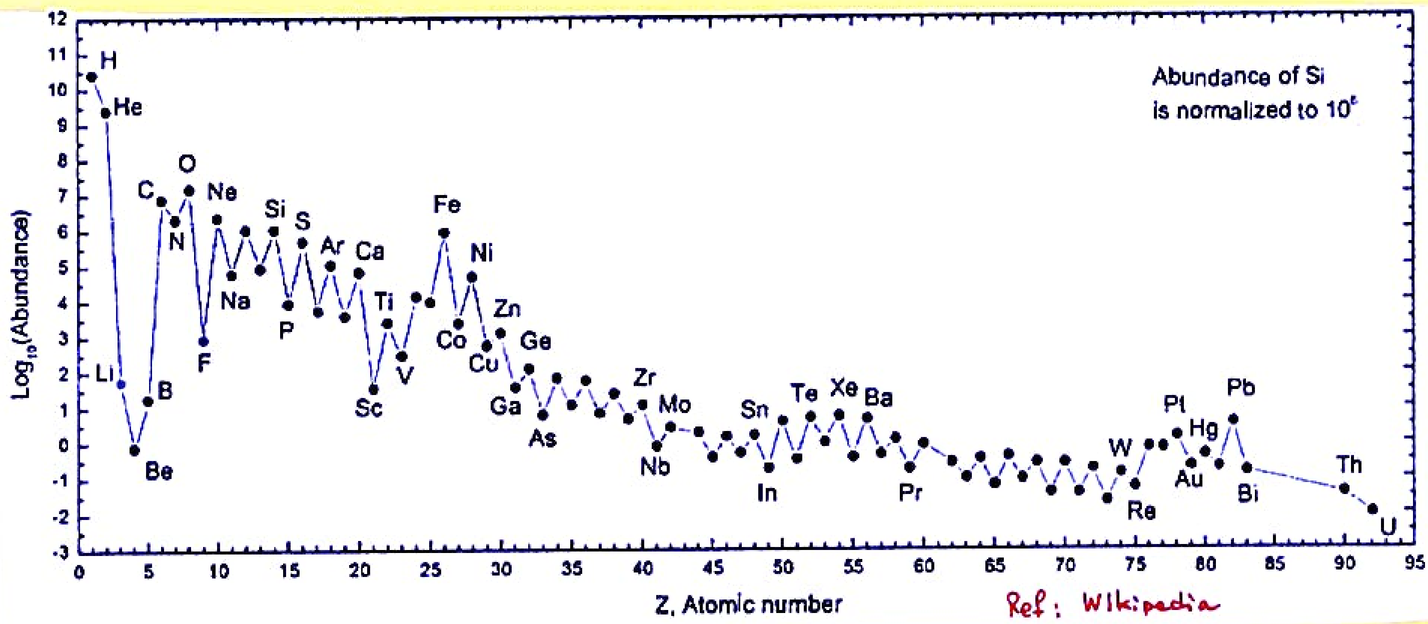
NB: In this part of the course, we shall favor breadth over depth!

General Setting

The characteristic energy scale in nuclear physics is of the order of MeV. Compare this with that of atoms which is of the order of 1 eV, hence for the atoms, at room temperature ($kT = 25\,meV$) they can be easily excited, and they have little difficulty in combining to form molecules and solids. For nuclei, the situation is quite different. Quoting from Weisskopf:

"In our immediate environment atomic nuclei exist only in their ground state; they affect the world in which we live only by their charge, mass (static properties) and not by their intricate dynamic properties. In fact, all interesting nuclear phenomena come into play only under conditions which we have created ourselves in accelerating machines. It is to some extent a man-made world.

It is not completely man made, however. The centers of all stars are regions of the universe where nuclear reactions go on, and thus where nuclear dynamics plays an essential role. Here, the nuclear phenomena are the basis of our energy supply on Earth, in reactors as well as in the Sun. But nuclear physics is even more important for the world in which we live from the point of view of the history of the universe. The composition of matter as we see it today is the product of nuclear reactions which have taken place a long time ago in the stars or in star explosions, where conditions prevailed [$kT \gtrsim$ MeV] which we simulate in a very microscopic way within our accelerating machines. I cannot better illustrate the interconnection of all facts of nature, the tightly woven net of the laws of physics, than pointing to the chart of abundances of elements in our part of the universe. Each maximum and minimum in the curve of abundances corresponds to some trait of nuclear dynamics, here a closed shell, there a strong neutron cross section, or a low binding energy. If the 7.65 MeV resonance in carbon did not exist then practically no carbon would have formed and we would probably not have evolved to contemplate these problems. Wherever we probe nature – be it studying the str. of nuclei, or by learning about macromolecules, or about elementary particles, or about the structure of solids – we always get some essential part of this universe."



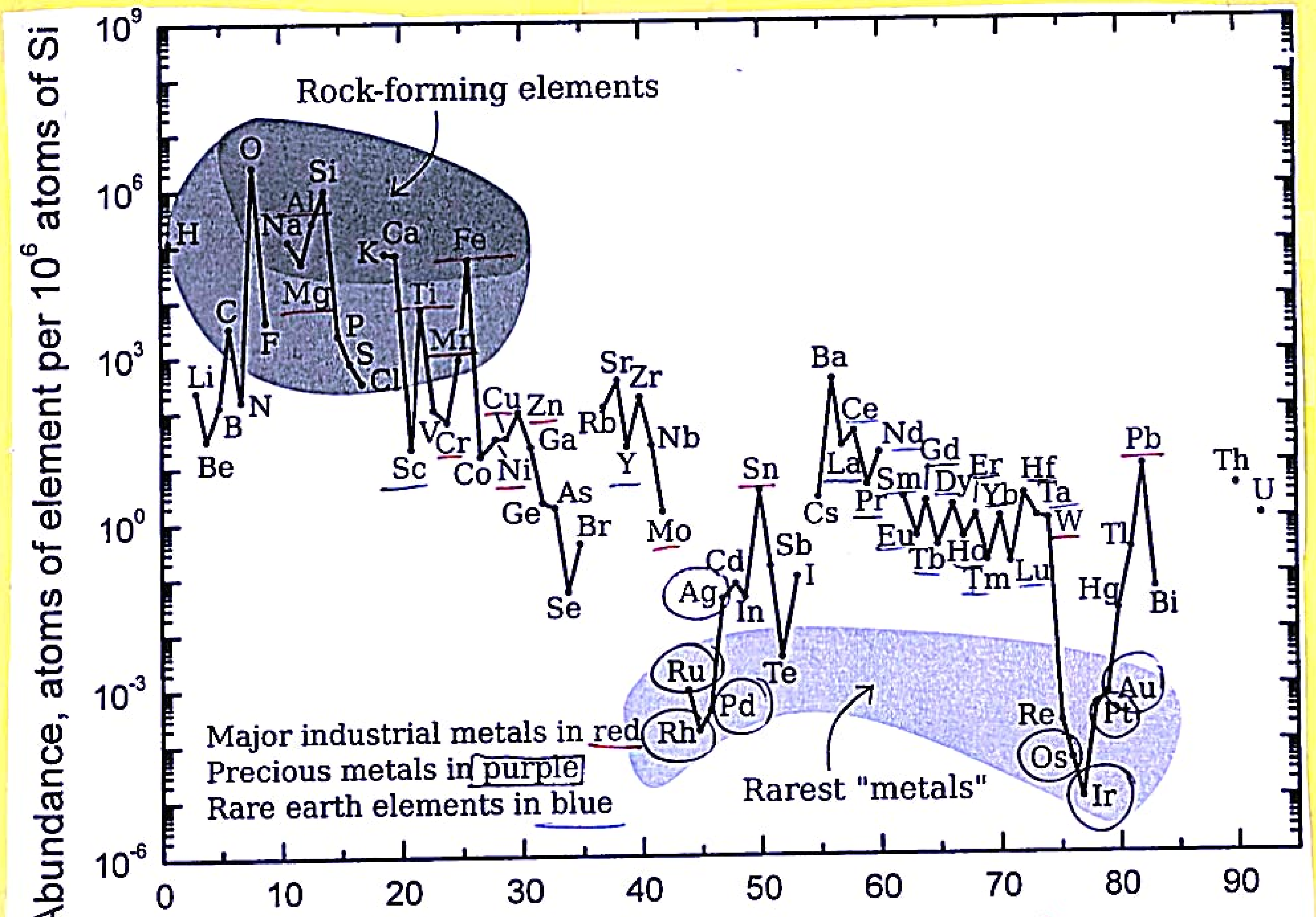
Ref: Wikipedia

Estimated abundance of chemical elements in our Solar system

Observe that H & He are most common, from the Big Bang. The next three elements (Li, Be, B) are rare because they are poorly synthesized in the Big Bang and in the stars. The two general trends in the remaining stellar-produced elements are: (1) an alternation of abundance in elements as they have even or odd atomic numbers, and (2) a general decrease in abundance, as elements become heavier.

Earth's Crustal Elemental Abundance

O and Si are quite common elements, frequently combined with each other to form common silicate minerals. The Rare-Earths are not rare, this is a misnom



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