Unit 3, Lesson 09: Comparing the Energy Changes in Physical, Chemical and Nuclear Changes

Chemical potential energy is found in a substance three ways:
a) as electrostatic attraction between an atom's nucleus and its electrons
b) as inter-molecular forces of attraction between molecules of the substance
c) as intra-molecular forces of attraction (chemical bonds) between the atoms within each molecule

It is the chemical potential energy of the bonds (c, above) that is responsible for most of the change in enthalpy (ΔH) during a chemical reaction, so we can use bond energies to estimate ΔH for a reaction. As we have just seen, chemical reactions involve breaking and forming chemical bonds. The ΔH values associated with chemical changes are usually quite large.

It is the int**er**-molecular forces of attraction (b, above) that is responsible for the state of a substance at SATP. Energy must be added to overcome these forces of attraction and convert a solid to a liquid (melting) and a liquid to a gas (boiling). These physical changes do not involve breaking chemical bonds. The ΔH associated with physical changes are usually much smaller than for chemical changes.

Because the energy changes in a physical change are relatively small, physical changes are readily reversible. If it takes + 6.02 kJ of energy to vapourize one mole of water, then 6.02 kJ of energy will be released when the water vapour condenses back to liquid water. Similarly, the amount of energy required to melt one mole of water is the same as the amount of energy that is released when one mole of water freezes. It is only the sign of the energy change that is different.

There is also potential energy related to the forces of attraction and repulsion between the protons and neutrons (collectively called nucleons) in the nucleus of an atom. In the nucleus, the positively charged protons are crammed together very tightly. The protons have electrostatic repulsion between them, but when they come close enough together, they are held together by the "strong nuclear force", although no one knows what this is.

A model may help you visualize the strong nuclear force:
Imagine a bunch of positively charged spheres (like magnets with only a north pole). The surface of these spheres is covered with Velcro. If you try to bring the spheres together, they repel each other. However, if you can exert enough pressure to make them touch, the Velcro on their surfaces will stick and hold them together. The Velcro represents the strong nuclear force- it is only activated when protons and neutrons are very, very close together. It is the strong nuclear force that holds the nucleus together, in spite of the electrostatic repulsion between the charged particles.

During a nuclear reaction, the strong nuclear force is disrupted. The protons and neutrons in a nucleus are rearranged and a tiny amount of mass is changed directly to energy. Einstein's equation: $E = mc^2$ relates the amount of energy (E) produced when a certain mass (m) is converted to energy. "c" represents the speed of light (3.0×10^8 m/s). Because the speed of light is such an large number, even a tiny amount of mass will generate an enormous amount of energy. This is the source of the energy that is released during nuclear reactions (either fission or fusion).

In summary, as a general rule, the energy changes in physical, chemical and nuclear reactions are in the order of 1: 10: 1,000,000 and this is directly related to the strength of the attractions between the particles involved:
a) inter-molecular forces are weak, so the energy changes involved in physical changes are small
b) intra-molecular forces are strong, so the energy changes involved in chemical changes are large
   the strong nuclear force is extremely strong, so the energy changes in nuclear changes are huge