ALL ENERGY COMES FROM PARTICLES MOVING OR INTERACTING

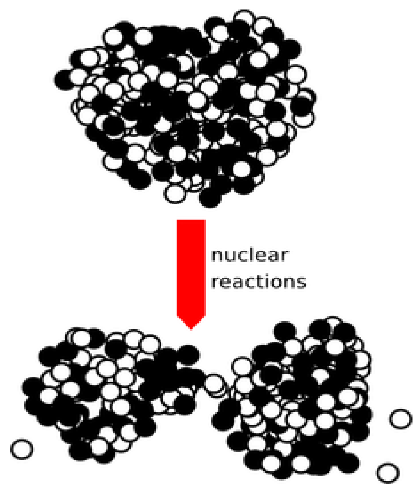
If I stretch the spring in figure c and then release it, it snaps taut again. The creation of some kinetic energy shows that there must have been some other form of energy that was destroyed. What was it?

c / The spring's energy is really due to electrical interactions among atoms.

We could just invent a new type of energy called “spring energy,” study its behavior, and call it quits, but that would be ugly. Are we going to have to invent a new forms of energy like this, over and over? No: the title of this book doesn't lie, and physics really is fundamentally simple. As shown in figure d, when we bend or stretch an object, we're really changing the distances between the atoms, resulting in a change in electrical energy.

Electrical energy isn't really our topic right now --- that's what most of the second half of this book is about --- but conceptually it's very similar to gravitational energy.

Like gravitational energy, it depends on 1/r, although there are some interesting new phenomena, such as the existence of both attraction and repulsion, which doesn't occur with gravity because gravitational mass can't be negative. The real point is that all the apparently dissimilar forms of energy in figure d turn out to be due to electrical interactions among atoms.



e / This figure looks similar to the previous ones, but the scale is a million times smaller. The little balls are the neutrons and protons that make up the tiny nucleus at the center of a uranium atom. When the nucleus splits (fissions), the source of the kinetic energy is partly electrical and partly nuclear.

Even if we wish to include nuclear reactions (figure e) in the picture, there still turn out to be only four fundamental types of energy:

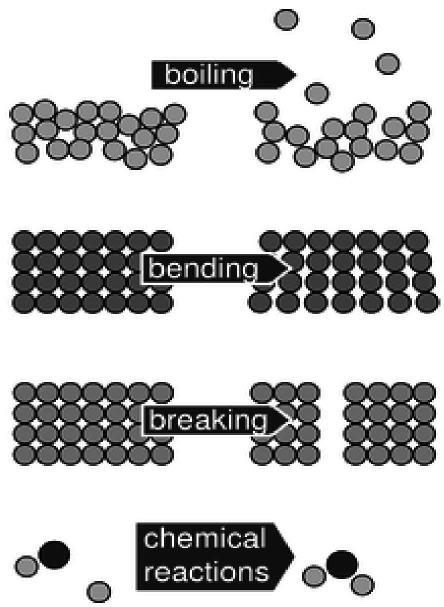
- **kinetic energy (including heat)**
- ***gravitational energy***
- ***electrical and magnetic energy***
- ***nuclear energy***

Astute students have often asked me how light fits into this picture. This is a very good question, and in fact it could be argued that it is the basic question that led to Einstein's theory of relativity as well as the modern quantum picture of nature. Since these are topics for the second half of the book, we'll have to be content with half an answer at this point. For now, we may think of light energy as a form of kinetic energy, but one calculated not according to (1/2)mv2 but by some other equation. (We know that (1/2)mv2 would not make sense, because light has no mass, and furthermore, high-energy beams of light do not differ in speed from low-energy ones.)

Temperature during boiling

▹ If you stick a thermometer in a pan of water, and watch the temperature as you bring the water to a boil, you'll notice an interesting fact. The temperature goes up until the boiling point is reached, but then stays at 100°C during the whole time the water is being boiled off. The temperature of the steam is also 100°C.

Why does the temperature “stick” like this? What's happening to all the energy that the stove's burner is putting into the pan?



d / All these energy transformations turn out at the atomic level to be due to changes in the distances between atoms that interact electrically.

▹ As shown in figure d, boiling requires an increase in electrical energy, because the atoms coming out as gas are moving away from the other atoms, which attract them electrically. It is only this electrical energy that is increasing, not the atoms' kinetic energy, which is what the thermometer can measure.

Diffusion

▹ A drop of food coloring in a cup of water will gradually spread out, even if you don't do any mixing with a spoon. This is called diffusion. Why would this happen, and what effect would temperature have? What would happen with solids or gases?

▹ Figure b shows that the atoms in a liquid mingle because of their random thermal motion. Diffusion is slow (typically on the order of a centimeter a minute), despite the *high* speeds of the atoms (typically hundreds of miles per hour). This is due to the randomness of the motion: a particular atom will take a long time to travel any significant distance, because it doesn't travel in a straight line.

Based on this picture, we expect that the speed of diffusion should increase as a function of temperature, and experiments show that this is true.

Diffusion also occurs in gases, which is why you can smell things even when the air is still. The speeds are much faster, because the typical distance between collisions is much longer than in a liquid.

We can see from figure b that diffusion won't occur in solids, because each atom vibrates around an equilibrium position.

Source:
http://physwiki.ucdavis.edu/Fundamentals/02._Conservation_of_Energy/2.4_Atomic_Phenomena