**CSEC Physics Handout**

**Topic:** Theories of Heat

Scientists by the mid-eighteenth century developed a theory which considered heat to be an invisible fluid called “caloric”. This caloric theory said that heat was present in all matter in the form of caloric. This theory explained temperature changes in a body as being due to the addition or removal of caloric. The temperature of a body was said to depend directly on the amount of caloric it contained.

This theory was supported by experiments involving the mixture of substances initially at different temperatures since, after a while, both substances acquired the same temperature (which is in between the two initial temperatures). The caloric theory explained this by saying that the heat (caloric) lost by one body was gained by the other.

Some weaknesses of the theory are listed below:

1. If caloric was a material substance as the theory said it was, then if a body gained in caloric its weight should increase. Similarly, if it lost caloric, then its weight should decrease. But since neither was discernible the theory was revised to say that caloric was “mass-less” to make up for this weakness.

2. Two bodies initially at the same temperature may have the same amount of heat (caloric) supplied to them and yet do not reach the same temperature. The theory could not account for this.

3. Addition of heat (caloric) to a substance does not necessarily produce a temperature rise, e.g. at the melting and boiling points. Again, the theory had no explanation for this observation.

4. The theory also could not account for all the heat generated by friction. If two or more substances are rubbed together continuously then the heat liberated is practically limitless. But if caloric is a substance, then objects must have it in fixed amounts. This argument was a crippling blow to the theory.

**Rumford’s Work:**

Count Rumford (Benjamin Thompson) supervised canon-boring in the late eighteenth century. He noticed that when a canon was being bored a lot of heat was produced. The caloric theory explained this by saying that heat (caloric) was squeezed out along with the metal chips by the borer.

But when the borer became very dull and little boring was taking being done (even though the borer was still turning and few chips were being produced), a large amount of heat was still being generated. Rumford explained this by saying that the amount of heat produced depended only on the work done by the horses which powered the boring machine and was not due to any caloric being squeezed out of the canon. You can see an analogy with a sponge which can hold only so much water. After squeezing out the water, none is left in the sponge. But Rumford showed that heat could be produced so long as work was being done by the horses, just like the sound produced when one hits a bell is limitless, so long as the bell is hit.

Rumford concluded that heat can be produced in large amounts by the performance of mechanical work and is therefore not a material substance at all.

**The Kinetic Theory**

The kinetic theory is a rival theory which was introduced to explain the phenomena which could not be accounted for by the caloric theory. The theory states that the heat content of a body is the sum of the kinetic energy of the individual particles of matter contained in the body.

Thus, the kinetic theory proposed that heat is not a material substance, but a form of energy. When the horses did work by turning the borer in the canon, some of the energy of the horses was converted into kinetic energy of the particles of the canon and so it became hot.

The chief objection to this theory at the time was the lack of direct experimental evidence supporting it since individual particles are too small to be seen.

**Joule’s Work**

James Joule performed experiments in the mid-19th century which finally overturned the caloric theory. He provided strong evidence in support of the kinetic theory and laid the foundation for the conservation of energy principle.

Joule used a metal paddle-wheel which was fitted inside a large can of water. As the paddle-wheel churned up the water the temperature of the water was observed to rise. Elaborate precautions were taken to stop heat loss from the apparatus during the experiment. (*See Textbook for apparatus*)

Joule observed that the mechanical energy used up in causing the paddle to rotate produced a similar amount of heat energy. Thus, he concluded that heat was just another form of energy.

When an account of Joule’s work became known in the middle of the 19th century it aroused little interest, as the concept of work and energy was new to science. At the time, it was not generally realized that Joule’s experiments provided the first reliable experimental evidence for the truth of the principle of conservation of energy.

This principle was put forward by the German Physicist, Hermann Von Helmholtz in a book (published 1847) but it had earlier been accepted by other far-seeing scientists.

Joule’s experiments had shown that internal molecular energy could be put into a substance by mechanical work and that there was an exact equivalence between these two forms of energy. Later it was demonstrated that the same exact relationship existed between other forms of energy, e.g. electrical, chemical and heat. One can readily appreciate why Joule’s memory has been honoured by giving his name to the SI unit of energy.