Radiometer

P3-8105

BACKGROUND:

The Radiometer is a means of showing the relation between heat and molecular activity of a gas in a visible way. It also shows that light is a form of energy and that it can be converted into other forms of energy.

The Kinetic Theory of Gases states that the atoms and molecules in a gas or a mixture of gases are in constant random motion. This energy of movement (kinetic energy) depends only on the temperature of the gas. As the gas is heated, the molecules respond by moving faster and faster. This movement, when the gas in a contained system, give rise to gas pressure as the individual molecules strike the containing walls. As the temperature increases, the molecules move with ever increasing energy, striking the walls of the container more frequently and with greater force. Thus it can be seen that the pressure exerted by a gas is related to the temperature of the gas. (It should be noted that the volume of the container is also relevant in this relationship-see *Boyle's Law* in any physics text).

HOW IT WORKS:

Caution: Handle the Radiometer carefully – its delicacy is about that of an ordinary light bulb. Should the bulb break, glass fragments will be sharp! Cautiously dispose of the glass but retain the pivot and vanes for some optional experiments (number 5 and 6)

The Radiometer consists of a rotating shaft with four vanes, sealed in a glass container which has had over 99% of the air removed. The vanes are painted black on one side, silver on the other. In the presence of light with an infrared (heat) component, the remaining molecules inside the bulb begin to move faster. At the same time, the light is striking the surface of the vanes. The silver surface reflects much of this radiation, but the non-reflective black surface absorbs it and becomes warmer.

As the randomly-moving molecules strike the vanes from all sides, the ones striking the dark surface absorb some of this heat and bounce away with more kinetic energy. This results in a slightly greater" kick" being delivered to the dark side of the vane; the accumulation of thousands of these slightly greater "kick" to the dark side of the vanes case the vanes to spin. Because the movement of the gas molecules depend on the amount of heat in the system, and because increasing the light level results in additional heat delivery, it follows that the speed of vane rotation is dependent on the intensity of the light.

SHOW ME:

Some of your students may accept the previous as gospel. The more inquiring mind, however, usually demands a little more in the way of proof. Below are some suggested exercises for more advanced understanding.

1. **Place the bulb in sunlight on a partly cloudy day.** Note that the rate of spin is greatest in sunlight, less as a cloud blocks the sun.

2. **Apply heat alone to the bulb.** Do the vanes spin? Heat will cause an increase in molecular motion, but without radiated heat to differentially warm the vanes, the collision on each side of the vanes will occur with the same energy. The vanes will not spin.

3. **Use various filters (dark glass, clear glass of varying thickness, cardboard, paper) to block the light and note bow the rate of spin is affected.** Can you determine what effective component of the light is being blocked?

4. **Will the Radiometer spin backwards?** Because the dark side also radiates heat away faster than the silver side, if you put a piece of ice on the radiometer, it will spin the opposite direction, because now the dark side is cooler.

5. **Will the Radiometer work if the vanes are not in a vacuum?** You will need to be "lucky" enough to break your radiometer bulb to determine this. In a normal atmosphere, the differential warming of the vanes and increased kinetic energy of the gas molecules will still occur. But there are so many gas molecules in air compared to the evacuated bulb that the molecules will be hitting each other constantly and not be able to effect any movement of the vanes. Even if they did, the vanes would not be able to spin through the milling throngs of molecules-the resistance would be too great to overcome.

6. **Definitive proof.** Set up the vanes and pivot from a broken Radiometer (secured in a bit of clay) in a bell jar connected to a vacuum pump. Apply a constant source of light and see what happens. Turn on the pump and begin to evacuate the chamber. The vanes should begin spinning. If perfect vacuum could be reached, the vanes would once again fail to turn. Why? In this experiment, do you ever reach a point where enough air is removed to notice a decrease in peak spin?