JAMES TREFIL, 101 THINGS YOU DON'T KNOW ABOUT SCIENCE AND NO ONE ELSE DOES EITHER, 1996

How Much Is a Kilogram?

WHEN YOU BUY hamburger in a supermarket, you aren't likely to worry that the weight written on your package is incorrect. This is because there is a system stretching from your neighborhood store to scientific laboratories around the world devoted to making sure that scales are correctly calibrated. Maintaining accurate standards of measurement has always been a traditional responsibility of governments, and today it is a major scientific undertaking. But old-fashioned or modern, the basic idea is the same — the government sets the standard for weight or length or whatever, to which everyone within that government's jurisdiction must adhere.

The oldest such standard we know of is the Babylonian *mina*, a unit of weight equal to about a pound and a half. The standards were kept in the form of carved ducks (five mina) and swans (ten mina), and were presumably used in balances to weigh merchandise. In the Magna Carta, King John agreed that "there shall be standard measures for wine, corn, and ale throughout the kingdom." The marshal of the great medieval fairs at Champagne kept an iron rod and required that all bolts of cloth sold at the fair be as wide as the rod. For most of recorded history each country has kept various different standards for different purposes. In America, for example, we measure land in acres, grain production in bushels, and height in feet and inches. According to the *Handbook of Chemistry and Physics*, there are no fewer than eighteen different kinds of units called the barrel, for measuring everything from liquor to petroleum. There is even a barrel used exclusively to measure cranberries!

It was, I suppose, to get away from these sorts of confusions that the nations of the industrialized world signed the Treaty of the Meter in 1875. According to this treaty, "the" kilogram and "the" meter were to be kept at the International Bureau of Weights and Measures near Paris, and secondary standards were to be maintained in other national capitals. In the United States, they were kept at the Bureau of Standards (now the National Institutes of Standards and Technology, or NIST) in Washington, D.C. The meter was the distance between two marks on a length of platinum-iridium alloy, the kilogram the mass of a specific cylinder of the same stuff.

But since the setting of these simple, intuitive standards, advances of technology have made them obsolete. It's all very well for "the" meter to reside in a vault in Paris, but it would be much more convenient if everybody could have access to a uniform standard. Thus the trend has been away from the kind of centralized standard-keeping codified in the Treaty of the Meter and toward standards based on the one truly universal thing we know about — the properties of atoms. The development of the atomic clock is one example of such a move, the new standards for the meter another. In 1960 the platinum-iridium bar was discarded and the meter redefined as 1,650,763.73 wavelengths of a particular color of light emitted by a krypton atom. Since every krypton atom in the world is the same, this redefinition meant that every laboratory in the world could maintain its own standard meter. In 1983, following further development of the atomic clock, the meter was redefined as the distance light travels through the vacuum in 1/299,792,458 second. Again, this standard can be maintained in any laboratory.

But the kilogram hasn't changed. It's still that same cylinder sitting inside three protective bell jars on a quartz slab inside a vault in Paris. Even in such an environment, however, atoms of other substances stick to the cylinder's surface. Until 1994 it was cleaned periodically by an old technician using a chamois cloth. (I remember listening to an absolutely fascinating argument at a NIST lunch over whether or not removing atoms by washing was worse than letting gases accumulate on the surface.) When the United States wants to check whether its version of the kilogram still matches the standard in Paris, the American kilogram has to be carried overseas for tests. The last time this was done, in 1984, two scientists went with it — one to carry it, the other to catch it if it fell.

This is no way to run a high-tech society, and there is an enormous push to develop an atomic mass standard and put "the" kilogram into a museum. One technology that may allow us to do this is the new technique of isolating single atoms in a complex "trap" made of electrical and magnetic forces so that they can be studied for months at a time. These single atoms stay in the traps so long that they acquire names (the first, a barium atom trapped in Munich in the 1980s, was called Astrid). It is not too difficult to determine the mass of individual atoms to high accuracy; the problem is counting the number of atoms in a sample big enough to serve as a mass standard.

The cylinder that now constitutes "the" kilogram contains approximately 10,000,000,000,000,000,000,000,000 atoms, so even if we knew how much each one weighed to incredible accuracy, we'd have a real problem knowing how many to add. At the moment, at least five different techniques are being developed to give the kilogram an atomic definition, and I don't imagine it will be long before one of them succeeds. When this happens, the kilogram will join the meter in its museum.