Putting atoms in the balance, one by one

When a proton captures a neutron to create a nucleus of deuterium, the interaction releases energy in the form of gamma rays. The mass of the resulting nucleus ends up slightly less than the sum of the masses of the individual particles involved. This mass loss is presumed equivalent to the energy released.

Researchers have now measured the atomic masses of various isotopes with sufficiently high accuracy to permit direct, high-precision comparisons of mass differences with gamma-ray energies in nuclear processes. These improved mass measurements may also contribute to an ongoing effort to produce an atomic standard for mass, replacing the platinum-iridium cylinder currently representing a kilogram (SN: 4/24/93, p.264).

To make the measurements, David E. Pritchard and Frank DiFilippo of the Massachusetts Institute of Technology and their coworkers trapped different ions, one at a time, in a uniform magnetic field. The captive ion would circulate within the field at a characteristic frequency dependent on the ion's mass and electrical charge.

By comparing the frequencies of two different ions, the researchers could work out a mass ratio for the pair. From measurements involving 20 different pairs of alternately trapped ions, they extracted atomic masses for nine isotopes and the neutron (see table).

As reported in the Sept. 12 PHYSICAL REVIEW LETTERS, these masses are at least 20 times more precise than earlier values using other methods. The MIT results also agree closely with those achieved recently by Robert S. Van Dyck Jr. and his colleagues at the University of Washington in Seattle, who used a similar magnetic-trap technique. However, the uncertainties in the MIT measurements are smaller.

"They have put out some absolutely superb results," comments Ernest G. Kessler Jr. of the National Institute of Standards and Technology (NIST) in Gaithersburg, Md.

As one consequence, the atomic mass of silicon-28 is now known accurately enough to encourage further work on determining the density and atomic spacing of an ultrapure silicon crystal. Precisely characterized, such a crystal could serve as an alternative to the present kilogram standard.

The improved atomic masses have also added impetus to an effort by NIST researchers to increase the precision of measurements of gamma-ray wavelengths in nuclear processes. Kessler and his colleagues are preparing such an experiment at a nuclear research facility in Grenoble, France.

Meanwhile, Pritchard envisions the possibility of improving atomic mass determinations by another factor of 20. "If we can do that, we could 'weigh' chemical bonds and determine chemical binding energies," he says. "What we have to do is figure out how to make measurements on two different ions in the same trap."

— I. Peterson

Atom	Mass
Hydrogen-1	1.007 825 031 6
Neutron	1.008 664 923 5
Hydrogen-2 (deuterium)	2.014 101 777 9
Carbon-13	13.003 354 838 1
Nitrogen-14	14.003 074 004 0
Nitrogen-15	15.000 108 897 7
Oxygen-16	15.994 914 619 5
Neon-20	19.992 440 175 4
Silicon-28	27.976 926 532 4
Argon-40	39.962 383 122 0

Atomic masses of selected isotopes, as determined to 10 decimal places by Pritchard and his coworkers.

Adapted from DiFilippo *et al.*/Phys. Rev. Lett.

Accounting for missing airborne ozone

Far above Earth's surface, some 35 to 80 kilometers high, lies the ozone layer, an oxygen blanket that shields life from hazardous ultraviolet rays. In recent years, the ozone layer has garnered attention because of its reported thinning, brought on by what scientists believe are the effects of chlorofluorocarbons and other industrial pollutants in the upper atmosphere.

Yet some mysteries about the ozone layer persist.

Why, for example, do the best models for figuring high-altitude ozone production and destruction estimate 10 percent less ozone (O_3) enveloping the globe than scientists actually observe? This puzzling 10-percent difference between what the models predict and what exists has come to be known as the ozone deficit problem.

To explain this conundrum, scientists posit three possibilities. Ozone may be generated faster or destroyed more slowly than is now thought. "Or," says Tom G. Slanger, a molecular physicist at SRI International in Menlo Park, Calif., "a source of ozone production has been overlooked."

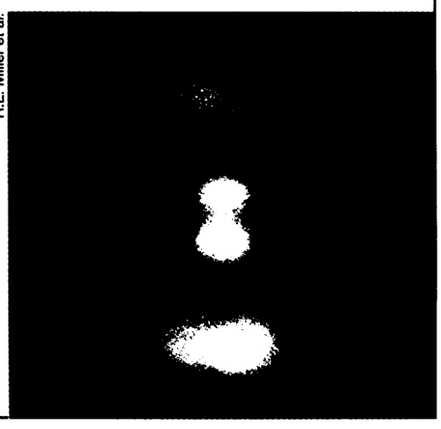
To account for the models' shortfall, Paul L. Houston, a chemist at Cornell University, and his colleagues propose an additional mechanism for stratospheric ozone production. Reporting in the Sept. 23 SCIENCE, they describe a chemical pathway by which two oxygen molecules (O_2), one highly energized and one ordinary, can combine in the upper atmosphere to yield extra ozone.

The energized oxygen arises by photodissociation, a process whereby the sun's energy breaks up high-altitude ozone and other oxygenated molecules, Houston says. The energetic oxygen then reenters high-altitude circulation and picks up an ordinary oxygen molecule. This reaction yields another ozone molecule and single oxygen atom as part of an ongoing cycle.

The scientists estimate that if the new pathway were used to figure ozone production at 43 km above sea level, the altitude at which the ozone deficit is greatest, it would account for all the missing ozone there.

The researchers base their theory on two experiments. In one, a "photo fragment imaging" test, they merged a beam of ozone molecules with a laser of 226 nanometers, taking electronic snapshots of the event. In the second, they used laser-induced fluorescence to measure the distribution of highly energized oxygen. Their results show "a substantial yield" of highly energized oxygen, enough to account for much of the ozone missing from many widely used atmospheric models.

Although the new pathway does not explain all the missing ozone at every altitude, it does account for a tenth of the deficit overall, they state. It also offers a possible route for the creation of additional, heavy ozone isotopes in the stratosphere that so far have remained unexplained. *— R. Lipkin*



An electronic picture of photodissociated ozone: Yellow bursts reveal clusters of energized oxygen molecules.

R.L. Miller *et al.*