the next step, such as locking into the lunar orbit, and six complete alternate missions, ranging from the lunar swing-around down to a low orbit around the earth. These are already completely computed and planned for, as thoroughly as if each were the primary goal of the flight.

The earliest that Apollo 8 could be launched, due to variables ranging from lighting on the moon to the inadvisability of hitting Cuba with falling rocket stages (SN: 12/7, p. 569), is 7:51 Saturday morning, Dec. 21. There are two opportunities a day to launch the spacecraft, through Dec. 27. If difficulties hold things up past that date, the flight will have to wait until the next launch window opens, from Jan. 18 to Jan. 24.

**Slightly more** than eight seconds after ignition, the first stage of the Saturn 5 booster will reach its full thrust of 7.5 million pounds, and lift the 363-foot-high stack of rockets and spacecraft on its way. About two and a half minutes later, the first stage will fall away and the second stage will take over, only to drop away itself after another six minutes. Then the S-4B third stage will ignite for the first time to push the spacecraft into a circular parking orbit, 119 miles above the earth.

For the next two and a half hours, the astronauts and controllers on the ground at the Manned Spacecraft Center in Houston will check over the spacecraft and its numerous subsystems to make sure it is ready for the big step. During the second or third earth orbit, if all is well, the third stage will fire again, to accelerate the spacecraft to more than 24,000 miles per hour, pushing it out of earth orbit toward the moon.

If the burn is successful, the spent third stage will be separated from the spacecraft shortly after injection onto the path to the moon. As the astronauts move to about 50 feet from the rocket, protective panels on the booster's forward end will be kicked away by springs and explosive charges, revealing the dummy lunar module that was decided on for Apollo 8 last August to replace the trouble-ridden real LM. The LM's first manned flight will be Apollo 9, possibly in late February.

**The Apollo 8** astronauts will practice, with the dummy, the docking maneuver they will need for the lunar landing mission, when the LM, returning from the lunar surface, will have to meet and couple with the command and service modules waiting in orbit around the moon.

After that, the remaining propellant in the free-floating rocket stage will be jettisoned to give the booster a kick into an orbit around the sun, while the spacecraft continues on toward the moon. During the outbound voyage, four small bursts of the spacecraft's engines are scheduled to make small changes in speed and direction. If by the last one a change of more than about seven miles per hour is still necessary, the correction will not be made; instead, the astronauts will simply let their spacecraft swing around the moon and head back to earth, without trying for a lunar orbit.

If speed and trajectory are as planned, however, the biggest decision of the mission will be at hand. To make matters more difficult, Apollo 8 will have been behind the moon, out of radio contact with earth, for more than 10 minutes when its SPS engine must fire to put it into lunar orbit. So the decision to go or not must be made before then.

Once Apollo is in orbit, the SPS engine will be fired again to lower the orbit into a circle some 69 miles above the surface. Then, on Christmas Eve, if there is a Dec. 21 launch, the astronauts will get down to their research tasks.

**The main** goal is to photograph the planned Apollo landing site—in black and white and color, still and motion pictures, and two and three dimensions—to aid the lunar landing crew in judging the terrain and learning local landmarks. Other tasks include photographing broader areas of the moon, zodiacal light along the plane of the ecliptic and the star field (to study fogging of the spacecraft window due to outgassing of seals and other materials). Live television pictures of the moon, the earth, the spacecraft and the astronauts themselves will be transmitted to earth from lunar orbit.

**Then comes** the SPS engine's critical burn. On the tenth revolution around the moon, after 19 hours and 52 minutes in orbit, the engine will be fired for 206 seconds. Again, the firing will take place on the moon's far side, leaving half-frantic ground controllers out of touch with the spacecraft for more than half an hour before they find out if the astronauts are on their way home.

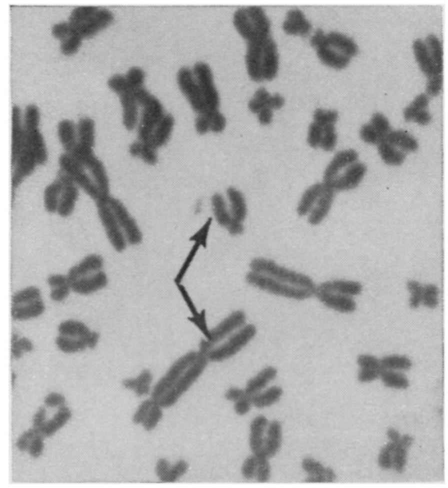
The trip back to earth should be fairly uneventful, and certainly anticlimatic. Reentry will be the fastest ever for a manned spacecraft—almost 24,700 miles per hour—but the unmanned Apollo 4 spacecraft proved that the heat shield could take the beating when it reentered at more than 24,800 mph.

Apollo 9, the first manned flight with a working lunar module, will be confined to earth orbit—the LM has been too troublesome to risk sending it to the moon so soon. Apollo 10 will take a LM to the moon, but not to land. Instead, Astronaut Eugene Cernan will fly the spidery module down to about 10 miles above the lunar surface for some close-in reconnaissance.

And then, Apollo 11, men on the moon, still sometime in this decade.

SINGLET OXYGEN

## Light on radiation damage



Oak Ridge National Laboratory

*Radiation breaks chromosomes*

Scientists have known that radiation damages all living things since shortly after Wilhelm Roentgen discovered X-rays in 1895, but they have been unable to find protection or remedy. With the advent of medical uses of X-rays for diagnosis and treatment and the development of nuclear weaponry and nuclear power came intensified efforts to solve the problem—efforts resulting in drugs that protect animals from radiation if they are dosed before exposure and treatment for human beings exposed to limited amounts.

But there are no proven drugs to protect men from nuclear fallout or industrial radiation accidents and none to cure them after total body exposure to large quantities: 400 roentgens (units of radiation) or more.

Radiation is most dangerous to animal life when it hits the whole body. One of its first effects is damage to blood-cell-producing bone marrow. If even a few marrow cells escape injury, they can repopulate the blood, markedly minimizing the threat of radiation sickness.

There has been no real understanding of how radiation destroys cells, making it all the more difficult for scientists to plan rational ways of blocking the destruction.

**Now, a** finding that radiation-excited oxygen molecules can combine and participate in chemical reactions previously thought impossible makes it reasonable to consider oxygen as an active intermediary in the process of cell destruction—an intermediary that can perhaps be tampered with.

It has long been known that cells rich in oxygen are more susceptible to radiation than those that are oxygen-starved. However, according to Dr.

Donald Fluke, a biophysicist at the Atomic Energy Commission, Germantown, Md., scientists dismissed the idea that oxygen played an active role in radiation damage because oxygen molecules have too little energy for biologically significant chemical reactions. Then Dr. Michael Kasha of Florida State University, Tallahassee, showed that radiation changes that picture. He has demonstrated that oxygen, boosted by radiation into a higher energy state, known as a singlet excited state, can be a highly active molecule.

Most molecules exist in one of three energy states: a ground state which has zero energy, a singlet state in which the molecule is highly energetic but short-lived, and a longer-lived but less energetic triplet state. Oxygen is unusual in having two loosely paired electrons, while in most molecules all electrons are closely paired.

It is possible that radiation will boost an oxygen molecule to a singlet excited state in which the two loose electrons become closely paired. Unlike other molecules that exist in this state for short periods, the singlet excited state of oxygen is long lived, giving it time to enter into biologically significant chemical reactions.

In this state, it no longer follows its normal channels, but moves randomly within the cell where it reacts with any cellular component in its way. If that component happens to be DNA (deoxyribonucleic acid), the singlet oxygen will react with it, irreparably damaging the cell's genetic information center. This reaction can cause chromosomal mutations or can damage genetic machinery so completely that it no longer functions and the cell dies.

**If you** sharply reduce the oxygen content of cells, Dr. Fluke observes, you significantly reduce the extent of radiation damage. Applying the same finding in reverse, cancer researchers are experimenting with the idea of increasing the oxygen content of tumors to make them more susceptible to radiation treatment. Dr. Mark Hofferman of the National Institutes of Health, Bethesda, Md., says the therapeutic value of this approach is still questionable but experiments on mice suggest it is worth pursuing. Most solid cancers, such as lung tumors, are naturally deficient in oxygen, which may partially explain their resistance to radiation therapy.

Radiation biologists are not the only ones interested in the chemical activity of singlet excited oxygen. It is possible, Dr. Fluke says, that it is an intermediary in the chain of reactions that makes a firefly glow and that it influences skin sensitivity to light, including ordinary sunburn.

MACROMOLECULES

## Super water causes flurry

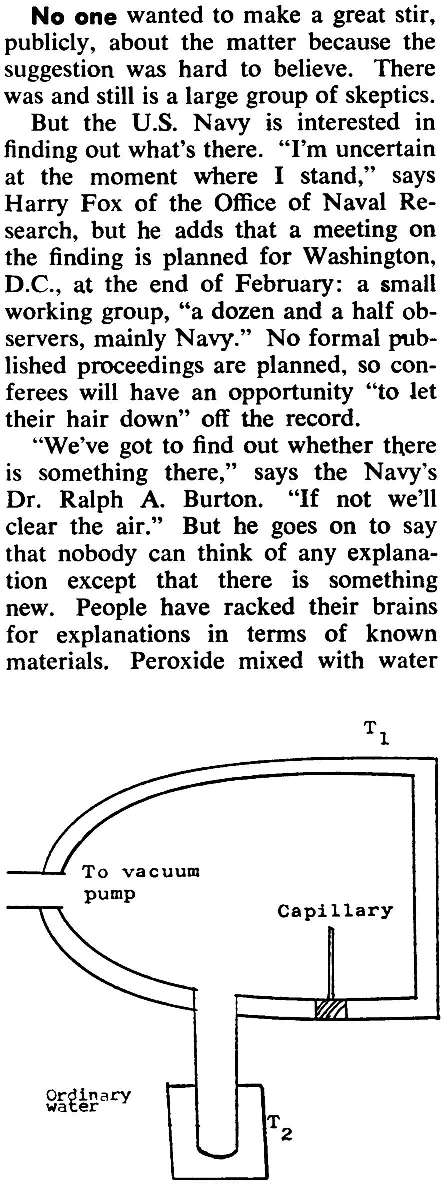
An anomalous form of water that may be a kind of macromolecule is causing serious but very quiet excitement among interested scientists.

**The anomalous** water, which in some measurements appears to show a high viscosity and a molecular weight about four times that of ordinary water, was first noticed by Dr. Boris V. Derjaguin, who is director of the department of surface phenomena in the Institute of Physical Chemistry of the Soviet Academy of Sciences. He was studying forces extending from solid surfaces in liquids condensed in tubes when he came across a water condensate that showed abnormal properties. His report was greeted with a good deal of skepticism but with some effort he was at last able to persuade groups at two British laboratories to check his work.

**No one** wanted to make a great stir, publicly, about the matter because the suggestion was hard to believe. There was and still is a large group of skeptics.

But the U.S. Navy is interested in finding out what's there. "I'm uncertain at the moment where I stand," says Harry Fox of the Office of Naval Research, but he adds that a meeting on the finding is planned for Washington, D.C., at the end of February: a small working group, "a dozen and a half observers, mainly Navy." No formal published proceedings are planned, so conferees will have an opportunity "to let their hair down" off the record.

"We've got to find out whether there is something there," says the Navy's Dr. Ralph A. Burton. "If not we'll clear the air." But he goes on to say that nobody can think of any explanation except that there is something new. People have racked their brains for explanations in terms of known materials. Peroxide mixed with water would have the viscosity but not the molecular weight, for example. "Until someone is able to give a mechanism for this it's an annoying mystery," he says.



*Gear for making anomalous water.*

It's annoying to theorists, whose current theories of liquids don't predict this sort of behavior. The implications can go far beyond water. Some observers feel that if water shows this anomalous state, so might other substances and a new field of research into materials with unusual properties may open up.

**Early measurements** seemed to show that the anomalous water had a molecular weight of 72. This is four times that of an ordinary water molecule and leads some people to suggest that the anomalous water may be some kind of polymer built of four ordinary water molecules. Other data, especially the ratio of electric charge to mass, seem to indicate, however, that the situation is more complicated, and the substance may be a mixture of several different agglomerates or macromolecules.

Anomalous water has no direct connection with the heavy water of nuclear research. Heavy water, whose molecular weight is about 20, is deuterium oxide. That is, it gets its heaviness from deuterium, a form of hydrogen with a neutron and a proton instead of a single proton in its nucleus. Anomalous water seems to be made with ordinary hydrogen.

Anomalous water is not technologically very difficult to make. The apparatus is so simple that one English boy is preparing to duplicate the experiments as a science fair project.

Needed is a clean capillary tube and a small pressure chamber to set it up in. A well attached to the vacuum chamber that serves as a source of water vapor is maintained at a temperature well below that of the main chamber. In this situation the vapor pressure in the chamber is less than the equilibrium pressure for the chamber. In spite of that, condensation occurs in the capillary tube and this condensate shows the properties of anomalous water.

The explanation, as Dr. Derjaguin sees it, is that the condensed phase grows outward from the glass walls in a manner similar to certain kinds of solid crystals. This mode of growth forms "a network of hydrogen bonds of unusual structure" in the liquid.

Though the glass tube seems to be necessary in forming anomalous water, once the substance is formed it can be taken away from the tube and will still retain its structure. It appears to be