Some of the assumptions that have become generally accepted in developing lunar atmosphere models fail to account properly for synodic phenomena associated with the relative positions of the sun, earth and moon. Specifically, the global distributions and abundances of short lived gases, particularly hydrogen and helium, vary greatly with lunar phase. The rates of supply of solar wind gases is modulated by the periodic passage of the moon through the geomagnetic tail. Furthermore, the energy needed for the escape of an atom or molecule from the moon is affected noticeably by the gravitational accelerations of the earth and sun.

Helium and hydrogen both have very short lifetimes on the moon because a thermal distribution of velocities of these gases includes a significant fraction with speeds in excess of escape velocity. Early models (1-3) were based on the assumption that the lunar atmosphere was a classical exosphere, and that Jean's thermal escape mechanism should describe the loss of light gases. However, the moon is not an isolated planet. Its gravitational acceleration becomes less than that of the earth at rather short distances from the moon.

The effect of the earth on lunar escape has been approximated by assuming that it decreases the actual escape velocity by a fixed fraction, regardless of lunar phase or initial direction (4). The approximation used was one suggested by Kopal (5), that particles with speeds greater than that required to reach the inner Lagrangian collinear point (0.978 times lunar escape speed) would not return to the moon. This has proved to be an oversimplification.

To make a realistic determination of the effects of lunar phase on the escape of light gases, the Monte Carlo lunar atmosphere simulation program used for previous models has been drastically modified. Briefly, the calculation follows random trajectories of a succession of individual Maxwellian atoms over the surface of the moon, from creation to annihilation or escape. The trail of each atom is recorded as the number of times it impacts the lunar surface in each of 150 zones of equal area. Synodic effects are traced by expanding each spatial zone into 8 phase zones. This provides both global and temporal data on gas distributions and permits introduction of a time varying source due to passages of the moon through the geomagnetic tail.

Ballistic trajectories are calculated by one of three methods, depending on initial energy. For energies less than 0.2 times escape energy a parabolic approximation is used, while at energies between 0.2 and 0.85 times escape energy an elliptical orbit is assumed. At still greater energies it has become apparent that it is necessary to consider the gravitational perturbations of orbits due to the earth and the sun. In this energy range some particles are accelerated sufficiently by the earth to achieve escape or to become trapped in terrestrial orbits. However, most particles return to the moon, although their orbits are usually extended. Some circle the earth
SYNODIC EFFECTS ON THE ESCAPE OF HELIUM AND HYDROGEN FROM THE MOON

R. R. Hodges, Jr.

before returning to the moon, while the trajectories of others are perturbed into nonimpacting lunar orbits. The result is an increase in time of flight and hence in the probability of photoionization.

Calculations of high energy trajectories are done by a numerical method in which gravitational potential and space-time relationships of the sun-earth-moon system are first approximated by assuming the moon to be a massless third body in a circular orbit about the earth-moon center of mass, which in turn is in a circular orbit about the sun.

A significant feature of these calculations is the fact that lifetimes tend to average longer than those found by approximation of the effect of terrestrial gravity as a uniform decrease in escape velocity (4). Another significant result is that lifetimes tend to be longer near new moon, while orbit perturbations are most effective on escape near full moon. In the geomagnetic tail total gas abundances decrease noticeably, initially in daytime, but eventually at night as well.

REFERENCES