these in order to determine the excess temperature.

The radiation would have originated when the universe was much more highly concentrated than now. One assumes that in the early universe matter was uniformly distributed throughout space and was hot so that the matter uniformly filled space with black-body radiation. As the universe expanded, its contents (matter and radiation) would have been adiabatically decompressed and cooled with the blackbody radiation ending up at 3°K. Peebles has considered the conditions, especially those of helium production, that might have existed very early in the expansion. He discussed these matters at the January meeting and will publish a paper on them in *Physical Review Letters*. When the temperature was 10^{10}°K, thermal reactions would have produced neutrons and some protons. Thermal pair production would have flooded space with electron and neutrino pairs and these leptons would have reacted with nucleons according to one of the following eractions: proton-plus-electron yields neutron and neutrino or proton-plus-antineutrino yields neutron plus positron or the reverse of either reaction. The neutrons and protons together form deuterium, but photodissociation keeps the abundance low until the temperature has dropped to 10^{9}°K. Then deuterium starts to burn into helium, and the amount of helium increases as the temperature drops.

This calculation does not take account of possible gravitational radiation or a conceivable new kind of radiation. If they are present, the time scale for expansion of the fireball is reduced. The neutrons then become more abundant, and so does the helium.

For "a reasonable value of the mean mass density in the universe," Peebles concludes that the theory requires a large primeval helium abundance (27%–30%). If observation shows the helium, it will be a "remarkably stringent" test of general relativity. On the other hand, if the primeval helium is not very abundant and the 3° black body is confirmed, Peebles believes that the result will be difficult to explain by conventional general relativity. It remains for observation to determine whether the helium is there.

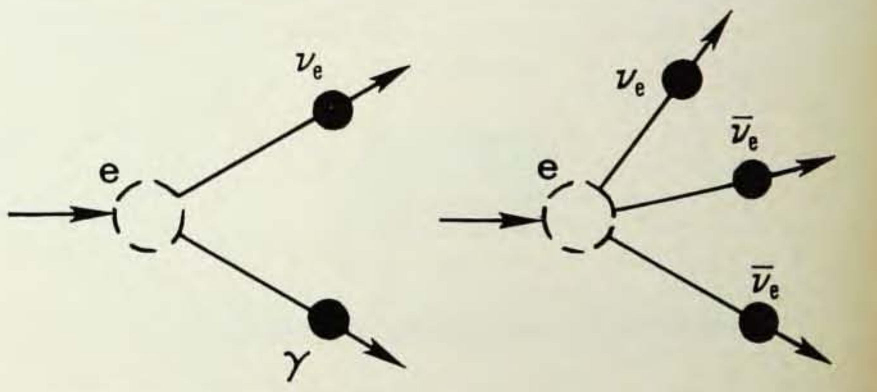
How long does an electron live?

Is the electron a stable particle? Much of physics goes on the assumption that it is. Electron stability is a necessary consequence of the law of conservation of charge since all particles lighter than the electron are electrically neutral and therefore it cannot decay into them and conserve charge at the same time. A lot of elementary-particle "spectroscopy" has been built on the assumption that the electron (along with the proton) represents a kind of "ground state" than which there is no lower. But as H. K. Moe and F. Reines point out in *The Physical Review* for 22 Nov. [**140**, B992 (1965)], "regardless of how attractive a law may appear theoretically, its validity rests on experimental evidence. The danger in the application of conservation laws to unexplored domains can be seen in the dramatic failure of parity conservation for weak interactions." In this spirit experiments are seeking evidence of electron decay. So far they have not found it. They have succeeded only in putting greatest lower bounds on the electron lifetime; that is, they conclude that an electron must live longer than certain lengths of time that they calculate.

The idea of searching for electron decay has been attributed to Maurice Goldhaber by two of his associates (G. Feinberg and Edward der Mateosian). It was formally presented by Feinberg and Goldhaber in a paper delivered at the National Academy of Sciences in April 1959 [Proc. Natl. Acad. Sci. U. S. **45**, 1301 (1959)]. The paper considered the theoretical status and experimental justification for three physical conservation laws that are usually considered absolute: conservation of charge, conservation of baryons and conservation of leptons. Various suggestions were made (and some preliminary results given) regarding experiments to test the laws. Indeed the tone of the entire paper is set by a statement that Moe and Reines seem to have paraphrased in the quotation above.

To search for a violation of a conservation law, as Feinberg and Goldhaber point out, one would like to begin by looking for an interaction that would be permitted by all other conservation laws but would violate the one in question. For conservation of charge, spontaneous electron decay would do this. If charge is not conserved, two reactions are possible according to Feinberg and Goldhaber: an electron yielding a gamma and a neutrino or an electron yielding two neutrinos and an antineutrino. Both free and atomic electrons could undergo such processes. The actual experiments deal with atomic electrons.

Goldhaber and der Mateosian began work on the problem before the presentation of the Feinberg and Goldhaber paper. Except for a short description in the Moe and Reines paper, the work of Goldhaber and der Mateosian has not yet been pub-



ELECTRON DECAY MODES. Could they happen?

lished. The work continues, however, and they hope to publish something later in the year.

Feinberg and Goldhaber had suggested that if an electron in the K shell of an atom of iodine were to decay, then, even if the decay products could not be readily recorded (assuming the neutrino-antineutrino interaction), nevertheless the effect, of the atom's readjustment to the loss would be detectable in the form of characteristic gammas and Auger electrons. Goldhaber and der Mateosian looked for iodine K x rays and electron-decay gammas in a NaI (Tl) crystal. They accumulated a background spectrum for 6.5 hours in a shielded 4×5 in. crystal and assigned to electron decay all events within about 7 keV of a barium K x-ray calibration peak of 32.8 keV, the energy of x rays that would be associated with atomic readjustment due to loss of an electron. They deduced a limit on the electron lifetime in excess of 10^{18} years.

Moe and Reines also used a NaI (Tl) crystal and searched for 33-keV gammas and the gammas from gamma-neutrino decay of electrons. The latter, they calculated, should have an energy of 255 keV. They used a 3×3-in. crystal, which was large enough to reabsorb 59% of all 255-keV photons born within it. The crystal sat between two pieces of Lucite; a photomultiplier tube was attached to the outside end of each piece of Lucite. The whole assembly was partially surrounded by triple-distilled mercury and encased in a Lucite tube. Scrupulous precautions were taken against radioactive contamination. The crystal assembly components were scrubbed with detergent and handled with clean rubber gloves. (Fingerprints from supposedly clean hands, it has been reported, can contribute 20 counts/min to background.) The whole was enclosed in iron shielding and set up 585 m underground in a mine of the Morton Salt Company.

The system was run at medium energy for 362 hours and at high energy for 25.4 hours. The resulting spectra, after subtraction of background, did not show any peaks at the two desired energies. Moe and Reines made calculations based on the statistical flutuations, which might have obscured the spectrum expected from electron decay, and concluded that the electron lifetime is greater than 2×10^{21} years for processes without photons among the decay products and greater than 4×10^{22} years for the gamma-neutrino process.

But the question still remains. If electrons do indeed decay, Feinberg and Goldhaber point out that a microscopic interaction many times weaker than the currently denominated "weak" interaction would have to be invoked to account for the process. The problem is also of cosmological significance if the lifetime is really not much greater than 4×10^{22} years. The disappearance of enough electrons (unaccompanied by proton disappearance) to cause a charge imbalance of two parts in 10^{18} can account for the expansion of the universe [R. A. Littleton and Herman Bondi, Proc. Roy. Soc. (London) **A252**, 313 (1959)].

Intermediate boson

A nucleon-nucleon experiment that sought but did not find the intermediate vector boson was reported at the January meeting of the American Physical Society. The experiment was performed at the Zero Gradient Synchrotron at Argonne National Laboratory by M. L. Good, R. Hartung, M. W. Peters and A. Subramian of the University of Wisconsin and R. C. Lamb, R. A. Lundy, T. B. Novey and D. D. Yovanovitch of Argonne.

Since the intermediate boson is postulated to be the particle that transmits the weak-interaction force, earlier attempts to find it centered on bombardments of matter by beams of neutrinos. Negative results of these experiments showed that the boson, if it exists, must be a very heavy particle. Multi-BeV protons in collision with a solid target possess the energy to produce heavy particles, and the Argonne experiment was designed in the hope that the intermediate boson might be one of the many varieties manufactured. Particles directly created in such an interaction move off in directions very close to that of the original proton beam. If the intermediate boson were one of them, it would decay after a short time, producing muons as well as other particles. These muons would come off in directions oblique to the original beam, and so the actual experiment searched for muons at high angles to the beam. The muons that appeared, however, could all be explained as pion decay products, and the experimenters concluded that if the intermediate boson exists, it is too heavy to be made by 12-BeV protons.

Short notes

The research and advanced development division of the AVCO Corporation has received a one-year contract to measure, for the first time, the behavior of ions in the atmosphere at altitudes between 10 and 80 km. The US Army Ballistic Research Laboratories will support the work with \$150 000. Measurements will be made with instrumentation attached to a descending parachute. Hans Dolezalek will direct the work.

Massachusetts Institute of Technology's Lincoln Laboratories will use a new solar simulator for study of material degradation effects. The instrument, designed and manufactured by Aerospace Controls Corporation, will provide a light intensity of 1½ solar constants (solar intensity at the earth is about one half solar constant). It employs a 30 000-watt xenon arc. According to the manufacturer, previous set-ups of this intensity required at least 10 5000-watt lamps.

The AVCO-Everett Research Laboratory is engaged in a program to demonstrate the feasibility of producing repeated, short-duration impulses of high-energy electric power with a magnetohydrodynamic generator. The project is an outgrowth of previous work that developed a self-excited, steady-state, rocket-driven MHD generator. That generator, called "Mark V", has achieved a dc output of 31.3 million watts gross and 23.6 net. The difference represents excitation energy for the generator's magnetic field. Mark V will be modified for the new experiment.