jection was correspondingly increased for a given NaCl concentration when the *p*H was raised (Table 1); with $0.03M$ NaCl, rejection increased from about 10 to 35 percent with increase in *p*H from 6 to 10; with $0.01M$ NaCl, from 35 to 55 percent between *p*H 9.4 and 10.2. The greater rejection observed with $0.01M$ than with $0.03M$ NaCl at *p*H about 10 is in the direction expected for an ion-exchange mechanism.

Permeation rates increased with time, the increase being much more rapid at high *p*H; this we attribute to dissolution of the glass, and this explanation is supported by surface-area measurements (*8*). These changes in permeability could be minimized by addition of sodium silicate to the feed.

As to the other technique for increasing charge density on the silica, we had little or no success in increasing rejection by treating the glass with several polyvalent cations [for example, Fe(III), Zr(IV), Bi(III), Al(III)], but the conditions tested so far are by no means exhaustive. Rejection was substantially modified by addition of thorium salts to the solution under study. For example, a frit which rejected 6 percent of solute from a $0.03M$ NaCl solution rejected 63 percent of total chloride during pretreatment with a solution $0.03M$ in NaCl and $0.05M$ in $ThCl_4$; it then rejected 55 percent of the salt from a solution $0.03M$ in NaCl and $0.001M$ in $ThCl_4$ and 31 percent from a solution $0.1M$ in NaCl and $0.001M$ in $ThCl_4$. The permeation rate was about 0.0035 cm $hour^{-1}$ $atm^{-1}$ [or $(cm^3/cm^2)$ $hour^{-1}$ $atm^{-1}$] before addition of thorium and 0.0025 cm $hour^{-1}$ $atm^{-1}$ in the presence of Th(IV). Although this example is typical, reproducibility with Th(IV) added is low (about ± 10 percent); frit behavior is to some extent dependent on past history.

Presumably adsorption of thorium converted the frit to an anion-exchange membrane of higher capacity than the untreated silica, a modification perhaps foreshadowed by earlier work on the properties of silica gel (*11*). With a feed of $0.015M$ $MgCl_2$ or $CaCl_2$ alone, the effluent was 5 to 10 percent more concentrated than the feed. With $ThCl_4$ added to bring the feed to $0.001M$ Th(IV), rejection (based on total chloride) from 0.02 to $0.03M$ $MgCl_2$ or $CaCl_2$ solutions was 40 to 50 percent. The permeation rate of the frit used in these experiments was about 0.01 cm $hour^{-1}$ $atm^{-1}$ in the absence of thorium and fell to about 0.005 cm $hour^{-1}$ $atm^{-1}$ when thorium was added.

From a practical point of view, the rejections are high enough to warrant at least marginal interest. Permeabilities (Table 1) of the frits studied are not striking, but should be quite high if thinner membranes can be prepared on supports having large pores, the glaze then being leached to form a fine-porosity Vycor layer. For a 1-$\mu$ layer, transmission is calculated at about 10 cm $hr^{-1}$ $atm^{-1}$, compared to 0.01 to 0.1 cm $hr^{-1}$ $atm^{-1}$ for cellulose acetate, equivalent to production rates, at 100-atm pressure, of about 60 gal $ft^{-2}$ $day^{-1}$ (2.4 m $day^{-1}$) for a 100-$\mu$ layer and 600 gal $ft^{-2}$ $day^{-1}$ for a 10-$\mu$ layer. Over the range of pressure studied by us, permeation per atmosphere and rejection are independent of pressure for a given frit.

Although the rejection properties of Vycor glass can be understood qualitatively in terms of ion-exchange properties of the solid and of their modification, we have not yet progressed to the point of testing to what extent simple theory can adequately explain rejection quantitatively; it appears clear that filtration of polyvalent cations by the glass in cation-exchange form is more complicated than simple ion-exclusion rejection.

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### References and Notes

1. J. G. McKelvey, K. S. Spiegler, M. R. J. Wyllie, *Chem. Eng. Prog. Symp. Ser.* **55** (24), 199 (1959).
2. J. G. McKelvey and I. H. Milne, in *Clays and Clay Minerals; Proceedings of the National Conference on Clays and Clay Minerals*, W. F. Bradley, Ed. (Macmillan, New York, 1962), p. 248.
3. W. H. Baldwin, D. L. Holcomb, J. S. Johnson, *J. Polymer Sci.* **A3**, 833 (1965).
4. L. Dresner and K. A. Kraus, *J. Phys. Chem.* **67**, 990 (1963).
5. L. Dresner, *ibid.* **69**, 2230 (1965).
6. M. E. Nordberg, *J. Amer. Ceram. Soc.* **27**, 299 (1944).
7. Supplied by Corning Glass Works.
8. We thank P. Dake, Physical Measurements Department, Oak Ridge Gaseous Diffusion Plant, for gas-adsorption analysis.
9. G. A. Parks, *Chem. Rev.* **65**, 177 (1965).
10. K. A. Kraus, H. O. Phillips, T. A. Carlson, J. S. Johnson, *Proc. Intern. Conf. Peaceful Uses Atomic Energy Geneva 2nd* **28**, 3 (1958).
11. H. Kautsky and H. Wesslau, *Z. Naturforsch.* **9B**, 569 (1954).
12. Research sponsored by the Office of Saline Water, U.S. Department of the Interior, under Union Carbide Corporation's contract with the U.S. Atomic Energy Commission. This is paper No. 2 of the series *Hyperfiltration Studies*; reference (*3*) is paper No. 1.

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## Lunar Experiments: The Moon as a Site for Certain Physical Measurements

Abstract. *If the lunar surface becomes available for conducting physical experiments, it may be particularly suited to thermal neutron and molecular and atomic beam measurements. The application of these beams for the purpose of communication on the lunar surface appears possible.*

Because of freedom from atmospheric absorption and scattering, the surface of the moon should be an ideal location for conducting certain experiments with elementary particles. Some experiments of this nature are discussed in this report, and a possible application of particle beams on the moon's surface will be suggested.

As a consequence of a gravitational acceleration of 167 cm $sec^{-2}$, the escape velocity of a particle at the moon's surface is only $2.4 \times 10^5$ cm $sec^{-1}$. However, this limit is still sufficiently high to hold in trajectories those protons and neutrons whose energies are less than approximately 0.03 ev. This energy is slightly above the most probable thermal energy ($kt$) at 300°K. Thus thermal neutrons, and thermal molecular and atomic beams, should provide suitable particle sources for experiments at the moon's surface.

The velocity of a particle which describes a circular orbit at the moon's surface is $1.7 \times 10^5$ cm $sec^{-1}$. As first pointed out by Aston (*1*), and as subsequently analyzed by Purcell (*2*) and others for electrostatic forces, the force field, described by the inverse-square law, of spherical symmetry has the interesting property that particles of the correct energies, traversing great circle paths, are partially focused after 180°. Such transmissions could be very useful for the purpose of communication on the moon's surface where, because of the absence of an ionospheric layer, radio-wave transmission will not be as straightforward as on the earth's surface (*3*). In order to inspect the feasibility of particle transmissions, the following considerations of beam intensities were made.

According to Ramsey (*4*), beams of neutral Na and K atoms have been detected with intensities as low as 5 to 10 atoms per second. (The maximum sensitivity appears to have been achieved for alkali metal atoms with the Langmuir-Kingdon self-ionization technique.) Furthermore (*4, 5*), beam intensities at distances of the order of moon radii, from line sources with products of pressure, $p$, in millimeters of mercury and width, $b$, in centimeters of the order $pb \sim 10^{-3}$ and lengths of 1 cm, are approximately 4 to 1 atoms $\text{cm}^{-2}\ \text{sec}^{-1}$ for Li, Na, K, and Cs. For these intensities, which are single line sources of 1 cm length, one assumes no focusing properties of the beams. For multiple sources having total lengths of the order of 10 to 100 cm, ample particle intensities could be received at distant detectors, and therefore information could be transmitted between any two stations on the surface of the moon.

There is another interesting aspect if neutrons were to be used as a particle beam (and there could well be advantages of detector sensitivity in the use of thermal neutrons). For a neutron describing a circular orbit around the moon, the time of flight between points at opposite ends of a diameter is approximately 3200 seconds. Therefore, because of the lifetime of the neutron alone, the intensity at the receiver would be reduced by approximately a factor of 20. However, considering an increase of intensity due to the focusing effect, especially in pole-to-pole transmission, thermal neutron sources of relatively low intensities might be very useful in communications.

The moon's gravitational (and magnetic-free, *6*) field could be used to increase tremendously the dispersion of a molecular-beam apparatus. A typical molecular-beam spectrometer, with an inhomogeneous magnetic field of $10^5$ gauss $\text{cm}^{-1}$ and of 50 cm in length, produces a deflection of the order of $2 \times 10^{-4}$ radians in the trajectory of a 1-nuclear-magneton particle. If the axis of the beam apparatus were pointed vertically upwards at a point on the moon's surface, then the particles deflected by the inhomogeneous field would describe parabolic paths out to considerable distances from the moon's surface. The moon's gravitational field would serve as a velocity selector of a particle's horizontal velocity, and particles deflected at different angles to the vertical would fall back to the moon's surface at different distances from the beam source.

In the case of the beam apparatus just considered, if the beam particle velocity were of the order of $10^5$ cm $\text{sec}^{-1}$, then the time taken for the particles to return to the moon's surface would be approximately 1200 seconds, and the horizontal deflection of the 1 nuclear magneton particles would be approximately 200 m (as compared with displacements of the order of tenths of millimeters in typical molecular beam spectrometers). In order to retain the necessary resolution for this experiment, typical collimated beams of the order of $3 \times 10^{13}$ particles per second from a single 1-cm line source might be employed. After following the above trajectory, this beam would be reduced to an intensity at the detector of approximately 10 to 50 particles $\text{cm}^{-2}\ \text{sec}^{-1}$. For the alkali metal atoms these beams could be readily detected with present-day techniques.

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### References and Notes

1. F. W. Aston, *Phil. Mag.* **38**, 710 (1919).
2. E. M. Purcell, *Phys. Rev.* **54**, 818 (1938).
3. For general discussions of earth-ionosphere radio propagation, reference may be made to H. S. W. Massey and R. L. F. Boyd, *The Upper Atmosphere* (Hutchinson, London, 1958), chap. 5; J. A. Ratcliffe, *The Earth and Atmosphere*, D. R. Bates, Ed. (Basic Books, New York, 1960), chap. 12.
4. N. F. Ramsey, *Molecular Beams* (Oxford Univ. Press, Oxford, 1956), p. 387.
5. R. G. J. Fraser, *Molecular Rays* (Cambridge Univ. Press, Cambridge, England, 1931).
6. According to: S. H. Dolginov, E. G. Eroshenko, L. N. Zhugov, N. V. Pushkov, L. O. Tynrmina, *Artificial Earth Satellites* **5**, 16 (1960), the magnetic field at the surface of the moon is less than 50 to 100 $\gamma$ ($\gamma = 10^{-5}$ gauss). This corresponds to a magnetization intensity of less than 0.25 percent of the earth's intensity. Although quantitative measurements have not yet been made, experiments by N. F. Ness, C. S. Scearce, and J. B. Seek, *J. Geophys. Res.* **69**, 3531 (1964), on the magnetohydrodynamic wake from the moon passing through the solar wind, may provide the first direct evidence of magnetic field phenomena, associated with the moon. In any event, even from a field of $10^{-3}$ gauss at the lunar surface, it is found that the magnetic force considered as arising from the gradient of a dipole at the center of the moon, would be a factor of $10^{10}$ less for a Cs atom, and $10^{12}$ less for a neutron, than the gravitational force on these particles. Similarly, in the case of an electric field, even if the potential gradient at the lunar surface were $10^6$ volt/cm (the cold emission value), it is found that the electric force arising from the gradient of this field on a particle having a dipole electric moment of 1 Debye unit ($3.3 \times 10^{-29}$ coulomb-meter) is a factor $10^8$ less than the gravitational force on a particle of unit atomic mass. However, this matter is rather academic since a neutron has no observable dipole electric moment, and one would similarly not expect that the symmetric atoms of H, Cs, K, and others would have dipole electric moments either.

1 December 1965

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# Analysis of Copper and Brass Coins of the Early Roman Empire

Abstract. *X-ray fluorescence analysis of 14 copper and brass coins of the early Roman Empire shows differences in composition between coins minted in Rome and in France. Concentrations of tin, lead, and antimony are nearly always less than in coins minted before 29 B.C. or after 54 A.D. Older coins were not melted to make copper coins of the early empire.*

Analyses of ancient coins are important to numismatists and archeologists. Questions such as the location of the mint of a group of ancient coins, or the existence of counterfeits, may be answered by quantitative analyses. Coin analyses may show differences in sources of ore for the metals and yield information regarding ancient technology. Such questions may be answered by analysis of ancient coins by x-ray fluorescence (*1*).

Most early analyses of Roman brass coins are incomplete and inaccurate; Caley's (*2*) gravimetric and spectrographic analyses are the most accurate available. Chemical analyses are destructive; although less accurate, x-ray fluorescence analysis is less destructive than most techniques and is more suitable for rapid examination of large numbers of coins.

Hall (*3*) reported a surface depletion of copper in Roman imperial silver coins; he warned that such depletion may cause inaccuracy in x-ray fluorescence analyses because only a thin surface layer (not more than 0.002 cm) of the coin is analyzed. Carter (*4*) demonstrated that light electropolishing of Roman coins in certain solutions produces surfaces having essentially the same compositions as the interiors; accurate analysis by x-ray fluorescence is thus permitted. An improved method of cleaning coins before analysis by x-ray fluorescence is air blasting with a fine abrasive powder such as aluminum oxide (*5*); surface corrosion products and up to 0.002 cm of metal should be removed; despite change in appearance of the surface, the coin remains essentially intact.

Fourteen copper coins of the early Roman Empire, from 21 B.C. to about 54 A.D., were analyzed for 25 elements by x-ray fluorescence. The coins conveniently divide into two groups: 12 of almost-pure copper and two of brass (copper-zinc). Both brass