NEON-HYDROGEN MIXTURES AND TRACK-SENSITIVE TARGETS FOR BUBBLE-CHAMBER EXPERIMENTS AT NAL

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ABSTRACT

The state-of-the-art of neon-hydrogen mixtures and track-sensitive targets for bubble-chamber experiments is reviewed and their usefulness for NAL experiments is discussed.

I. NEON-HYDROGEN MIXTURES

Prodell's studies[1] four years ago established the fact that heavy-liquid experiments could be run in bubble chambers designed for hydrogen-deuterium operation by using mixtures of neon and hydrogen as the track-sensitive liquid. Figure 1 shows radiation length as a function of the atomic percentage of neon in the neon-hydrogen mixture. Radiation lengths vary from 25 cm to 9.90 m, depending on the mixture chosen. As little as 20% atomic neon (33% molar) decreases the radiation length by an order of magnitude from the pure hydrogen value to ~ 1 m.

The multiple scattering error $\Delta p/p$ (%) is shown as a function of track length for various neon concentrations (atomic percent) for 20-kilogauss and 40-kilogauss fields in Fig. 2. For the 20-kilogauss field the multiple scattering error is of the order of 1% for a 1-meter track for 100% hydrogen, 4% for 50% neon-50% hydrogen, and 6% for pure neon. The advantages of the higher field are obvious.

As a bubble-chamber liquid, neon-hydrogen mixtures operate in the temperature-pressure regions between the usual hydrogen and deuterium operating conditions. Thermodynamic properties for various neon concentrations have been tabulated in an ANL report.[2] As the neon concentration is increased, the operating temperature and expanded pressure at which a given bubble density of track is obtained in the chamber is increased and the bubble growth for any particular temperature and pressure condition is slower. An unusual feature of binary mixtures is that it is possible to obtain a stable condition in which the two liquid phases coexist. Since the liquids become opaque at the onset of this condition, one wishes to avoid the region of temperatures and neon concentration on the left-hand side of the curve shown in Fig. 3, taken from the data of Streett and Jones.[3] Above the upper convolute temperature of 29°K, neon and hydrogen should be completely miscible in any neon concentration.

II. TRACK-SENSITIVE TARGETS

The close similarity in the operating conditions of neon-hydrogen mixtures and of pure hydrogen or pure deuterium have made the operation of a track-sensitive "target chamber" immersed in the neon-hydrogen bubble-chamber liquid an attractive possibility. The first prototype of such a system, in which heat-formed mylar "hats," bonded to an aluminum side wall, acted as both expansion diaphragms and viewing windows, was operated successfully[4] at DESY in 1967. The CERN group which designed this system has since designed a plexiglass target chamber for a study of $\pi^o\pi^o$ production in deuterium, to be run in the 1.5 m bubble chamber with ~ 95% neon filling at the Rutherford Laboratory in 1969. The Brookhaven Bubble Chamber Group has successfully operated a 20 in. × 5 in. diameter cylindrical plexiglass target chamber with hydrogen, expanded by a 5 mil mylar diaphragm, in a 20% (mole) neon-hydrogen mixture in the 30-in. bubble chamber. Systems including the possibility of (modest) independent temperature and/or pressure control for the target chamber have been considered at SLAC, Brookhaven, and Argonne.

III. PHYSICS AT NAL

Given the comparatively advanced state-of-the-art, hydrogen or deuterium target chambers operated within neon-hydrogen mixtures for γ-conversion are an attractive prospect for NAL experiments. One foresees two main types of use:

1. To "veto" on photons from slow π^o's in hydrogen chambers used in hybrid spectrometer arrangements. In this case the observation of a single conversion pair pointing back to the production vertex would be sufficient to indicate π^o production, and it is unnecessary to measure the momentum from the $e^\pm$ pair. In this case 50 cm of pure neon above and below the hydrogen chamber would be sufficient to provide better than 75% conversion probability for a single photon.

2. To select events with multiple-π^o production for study. In this case one needs both momentum and direction information from the $e^\pm$ to properly pair the photons from multiple-π^o decay. Photon paths of 5 radiation lengths will give 98% conversion efficiency for single photons, and therefore, will convert 3 of the 4 gammas emitted from $2\pi^o$ decay with 94% efficiency, and will convert 5 of the 6 gammas from $3\pi^o$ decay with 90% efficiency. This type of operation places a premium on bubble-chamber size. The proposed 25-ft bubble chamber, for example, would accommodate a hydrogen target chamber with a 12-ft dimension in the beam direction and allow 5 radiation lengths of a 50% neon-hydrogen mixture, for which $(\Delta p/p)_{sc}$ is about 4% for a one-meter track with a 20-kilogauss field, or about 2%

with a 40-kilogauss field. A bubble chamber of this size would be a unique facility for such studies. Although its greatest usefulness would be at energies $\gtrsim$ 20 GeV, where events without additional π^0 production would be rare, consideration might be given to providing beams at lower energies, since there is now no suitable facility for obtaining information on the $\pi^0\pi^0$ system at any accelerator.

Neutrino Interactions

While the discussion above is related to strong-interaction physics, similar considerations apply to neutrino-induced reactions in which the decay photons from π^0's and Σ^0's must be converted.[5] Regardless of the interaction, information on the photons converted in a bubble chamber with a target-chamber arrangement can be used to recover constraints lost in the kinematic fitting of events with "missing" neutral particles. Again, the need for large dimensions in the target chamber and in the bubble chamber itself are clearly evident in the case of neutrino-induced reactions.

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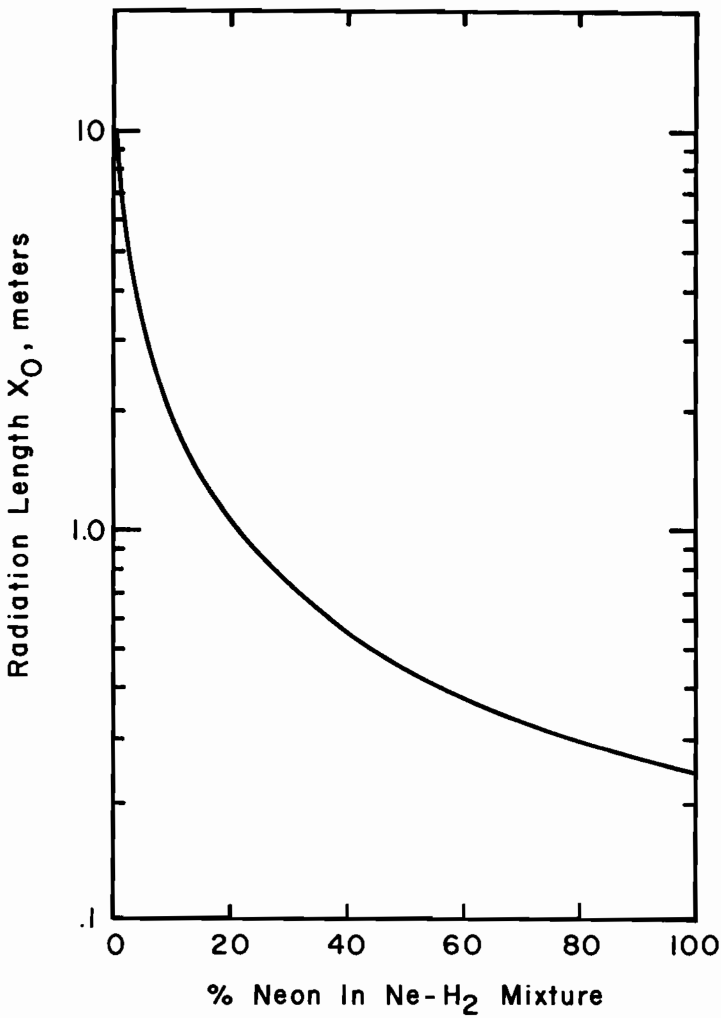

Fig. 1. Variation of radiation length with fraction of neon in neon-hydrogen mixtures.

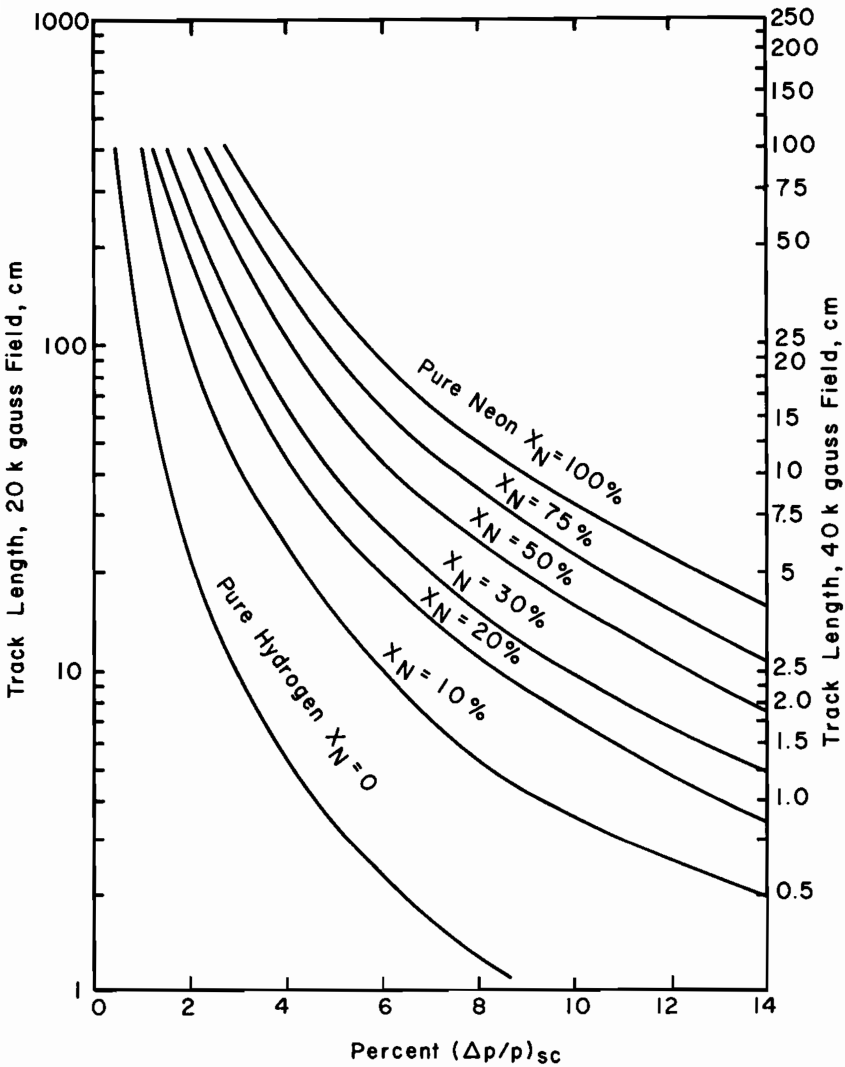

Fig. 2. Momentum error from multiple scattering as a function of track length and neon fraction, for two different magnetic field values.

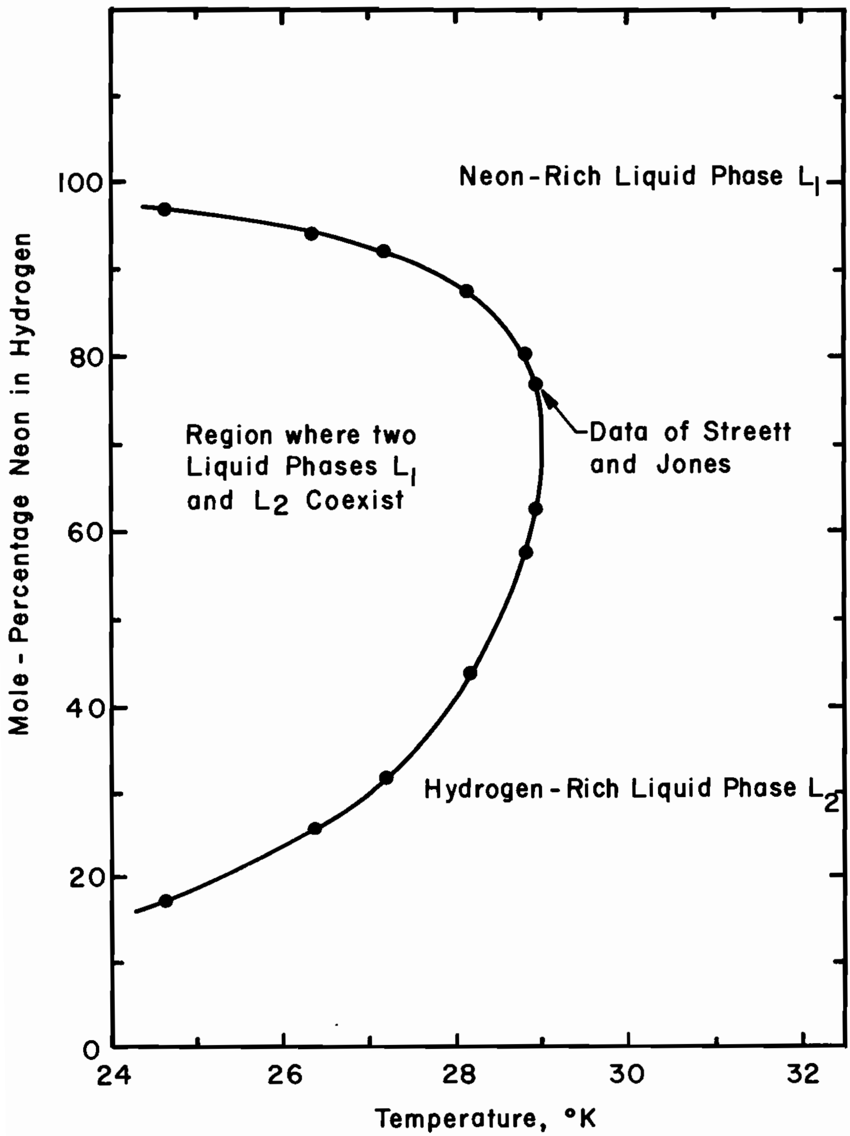

Fig. 3. Projection of the liquid-phase separation boundary on the temperature-neon percentage plane.