Ammonia and water have been proposed to be a major constituents of such bodies as Neptune (1), Uranus (1, 2, 3), Titan (4), and Comet Bowell (5). D. J. Stevenson estimates the cosmic abundance of ammonia to be about 18% that of water (4). The P-T diagram for pure water has been examined by a number of researchers; we use the results of Mishima and Endo (6). At room temperature, the only phases seen at increasing pressures are liquid water, Ice VI, and Ice VII. The ammonia-water system under atmospheric pressure was explored by Rollet and Vuillard (7). They found three intermediate phases, NH$_3$·H$_2$O, NH$_3$·H$_2$O, and NH$_3$·H$_2$O, in addition to Ice I h and ammonia.

For this experiment, two sets of experiments were performed: first, the solid-liquid boundary for the NH$_3$·H$_2$O composition was determined at several temperatures and pressures; second, phase boundaries for several compositions up to 30 atom percent ammonia were determined at room temperature. Samples were compressed in a Holzapfel-type diamond cell with an Inconel gasket and a ruby chip for fluorescence determination of pressure (8); phase transitions were observed visually. For the first set of experiments, compositions were obtained from mixtures of distilled water and ammonia gas mixed at cryogenic temperatures and loaded as a slurry into the diamond cell. (This caused variation up to 3% in weight percent of ammonia, as determined by titration.) The diamond cell was enclosed in a cryostat for measurements at temperatures ranging from 360 to 120 K (the lowest temperature reached with liquid nitrogen as a cooling fluid), and pressures between 0 and 5 GPa. Temperatures were regulated through the use of a resistance heater. If we take into account compositional variations and assume that the composition NH$_3$·H$_2$O melts congruently at all temperatures and pressures, the melting curve for NH$_3$·H$_2$O (labeled "B" in figures; see below) must lie at or above (higher temperatures) the two-phase points shown in Figure 1.

For the second set of experiments, temperatures were constrained to 21 ± 2°C. Samples were mixed from distilled water and aqueous ammonium hydroxide, with compositions determined by hygrometry, and were loaded as liquids into the diamond cell. All phases were distinguished visually; polarized optics were employed. For the room-temperature results, some confusion in interpretation resulted from the difficulty in nucleating various ice phases; the phase diagram is drawn so as to include information from the direction of pressure change. In compositions with less than 30% NH$_3$, the following phases were seen:

* Liquid
* Liquid plus A (at 1.0 GPa or less), or Liquid plus Ice VI (at 0.98 GPa) followed by Liquid plus Ice VII (at 2.1 GPa)
* A plus Ice VII (at 2.4 GPa)
* B plus Ice VII (above 3.3 GPa).

The A-VII-Liquid triple point occurs at about 15% NH$_3$ and the Liquid-VI-VII triple point at about 11% NH$_3$. The A phase had low relief compared to the liquid and was anisotropic under crossed nicols, and tended to form two networks of cracks at a 70° angle to each other at low pressure. When squeezed above 3.3 GPa, the A phase reconstituted into myrmekitic intergrowths of Ice VII and a higher-relief phase.
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which was apparently isotropic. From estimation of the area of the diamond cell taken up by the various phases, the low-pressure phase was shown to have the composition \( \text{NH}_3 \cdot \text{H}_2\text{O} \), and the high-pressure phase to have the composition \( \text{NH}_3 \cdot 2\text{H}_2\text{O} \). The low temperature \( \text{NH}_3 \cdot \text{H}_2\text{O} \) phase is orthorhombic (9); the structure of the \( \text{NH}_3 \cdot 2\text{H}_2\text{O} \) phase has not been determined. There is no evidence that the structures of the A and B phases are the same as those of their low-temperature counterparts; in the absence of other information, they are assumed to be the same for Figure 3.

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REFERENCES