# Chemical Properties

## pH

Aqua ammonia (ammonium hydroxide) is classified as a weak base. It ionizes much less completely in water than does a strong base such as sodium hydroxide. This is reflected in the pH's normally encountered with solutions of ammonia. Typically, the pH of an ammonia solution will be between 11 and 12, compared with a pH of about 14 for sodium hydroxide solutions. The theoretical pH's below are for ammonia in pure water at 77°F.

| ***Wt.%*** | | | |
|---|---|---|---|
| ***$NH_3$*** | ***Normality*** | ***pH*** | ***%Ionized*** |
| 17.0 | 10.0 | 12.1 | |
| 1.7 | 1.0 | 11.6 | 0.42 |
| 0.17 | 0.1 | 11.1 | 1.33 |
| 0.017 | 0.01 | 10.6 | 4.15 |
| 0.0017 | 0.001 | 10.1 | 12.52 |

### Dissociation

***Dissociation Constants (Kb's) of Aqua Ammonia From 0°C to 50°C***

| ***Temperature °C*** | ***pKb*** | ***Kb*** |
|---|---|---|
| 0 | 4.862 | $1.374 \times 10^{-5}$ |
| 5 | 4.830 | $1.479 \times 10^{-5}$ |
| 10 | 4.804 | $1.570 \times 10^{-5}$ |
| 15 | 4.782 | $1.652 \times 10^{-5}$ |
| 20 | 4.767 | $1.710 \times 10^{-5}$ |
| 25 | 4.751 | $1.774 \times 10^{-5}$ |
| 30 | 4.740 | $1.820 \times 10^{-5}$ |
| 35 | 4.733 | $1.849 \times 10^{-5}$ |
| 40 | 4.730 | $1.862 \times 10^{-5}$ |
| 45 | 4.726 | $1.879 \times 10^{-5}$ |
| 50 | 4.723 | $1.892 \times 10^{-5}$ |

±0.005, determined by emf method by R.G. Bates and G.D. Pinching

Note: pKb = pKw-pKa

where pKw = 14 and pKa = $[H+]\{NH_3\}/[NH4+]$

## Heat of Solution

When liquid anhydrous ammonia is dissolved in water, heat is liberated which varies with the final concentration of aqua ammonia produced.

| ***Final Wt % $NH_3$*** | ***BTU/lb. NH3*** |
|---|---|
| 10.0 | 343.8 |
| 20.0 | 328.5 |
| 30.0 | 308.2 |
| 40.0 | 270.0 |
| 50.0 | 218.8 |

## Reactivity

Aqua ammonia will react with many organic and inorganic acids to form ammonium salts and compounds; with certain metals to form complex-ion salts; with halogens to form haloamines (such as its reaction with sodium hypochlorite [bleach] to form toxic chloramines); and under extreme circumstances with silver and mercury to form explosive azides.

Aqua ammonia corrodes copper (and copper-containing alloys such as brass), zinc, cadmium and silver.

For chemical corrosivity information, see the Materials Compatibility section on page 6.

# Physical Properties

Aqua ammonia is a clear, colorless liquid having a strong pungent ammonia odor.

## Specific Gravity

The specific gravity of aqua ammonia is customarily expressed as its density at 60°F compared to the density of water at 60°F. Comprehensive tables of specific gravity, as well as corrections to use for temperature variations, are presented on pages 16-20 in Appendix A.

| Weight % Ammonia | Specific Gravity at 60°F/60°F | Degrees Baumé |
|---|---|---|
| 0.00 | 1.0000 | 10.00 |
| 0.40 | 0.9982 | 10.25 |
| 0.80 | 0.9964 | 10.50 |
| 1.21 | 0.9947 | 10.75 |
| 1.62 | 0.9929 | 11.00 |
| 2.04 | 0.9912 | 11.25 |
| 2.46 | 0.9894 | 11.50 |
| 2.88 | 0.9876 | 11.75 |
| 3.30 | 0.9859 | 12.00 |
| 3.73 | 0.9842 | 12.25 |
| 4.16 | 0.9825 | 12.50 |
| 4.59 | 0.9807 | 12.75 |
| 5.02 | 0.9790 | 13.00 |
| 5.45 | 0.9773 | 13.25 |
| 5.88 | 0.9756 | 13.50 |
| 6.31 | 0.9739 | 13.75 |
| 6.74 | 0.9722 | 14.00 |
| 7.17 | 0.9705 | 14.25 |
| 7.61 | 0.9689 | 14.50 |
| 8.05 | 0.9672 | 14.75 |
| 8.49 | 0.9655 | 15.00 |
| 8.93 | 0.9639 | 15.25 |
| 9.38 | 0.9622 | 15.50 |
| 9.83 | 0.9605 | 15.75 |
| 10.28 | 0.9589 | 16.00 |
| 10.73 | 0.9573 | 16.25 |
| 11.18 | 0.9556 | 16.50 |
| 11.64 | 0.9540 | 16.75 |
| 12.10 | 0.9524 | 17.00 |
| 12.56 | 0.9508 | 17.25 |
| 13.02 | 0.9492 | 17.50 |
| 13.49 | 0.9475 | 17.75 |
| 13.96 | 0.9459 | 18.00 |
| 14.43 | 0.9444 | 18.25 |
| 14.90 | 0.9428 | 18.50 |
| 15.37 | 0.9412 | 18.75 |
| 15.84 | 0.9396 | 19.00 |
| 16.32 | 0.9380 | 19.25 |
| 16.80 | 0.9365 | 19.50 |
| 17.28 | 0.9349 | 19.75 |
| 17.76 | 0.9333 | 20.00 |
| 18.24 | 0.9318 | 20.25 |
| 18.72 | 0.9302 | 20.50 |
| 19.20 | 0.9287 | 20.75 |
| 19.68 | 0.9272 | 21.00 |
| 20.16 | 0.9256 | 21.25 |
| 20.64 | 0.9241 | 21.50 |
| 21.12 | 0.9226 | 21.75 |
| 21.60 | 0.9211 | 22.00 |
| 22.08 | 0.9195 | 22.25 |
| 22.56 | 0.9180 | 22.50 |
| 23.04 | 0.9165 | 22.75 |
| 23.52 | 0.9150 | 23.00 |
| 24.01 | 0.9135 | 23.25 |
| 24.50 | 0.9121 | 23.50 |
| 24.99 | 0.9106 | 23.75 |
| 25.48 | 0.9091 | 24.00 |
| 25.97 | 0.9076 | 24.25 |
| 26.46 | 0.9061 | 24.50 |
| 26.95 | 0.9047 | 24.75 |
| 27.44 | 0.9032 | 25.00 |
| 27.93 | 0.9018 | 25.25 |
| 28.42 | 0.9003 | 25.50 |
| 28.91 | 0.8989 | 25.75 |
| 29.40 | 0.8974 | 26.00 |
| 29.89 | 0.8960 | 26.25 |
| 30.38 | 0.8946 | 26.50 |
| 30.87 | 0.8931 | 26.75 |
| 31.36 | 0.8917 | 27.00 |
| 31.85 | 0.8903 | 27.25 |
| 32.34 | 0.8889 | 27.50 |
| 32.83 | 0.8875 | 27.75 |
| 33.32 | 0.8861 | 28.00 |
| 33.81 | 0.8847 | 28.25 |
| 34.30 | 0.8833 | 28.50 |
| 34.79 | 0.8819 | 28.75 |
| 35.28 | 0.8805 | 29.00 |

Data of Ferguson from Lange's Handbook of Chemistry (5th Edition).

## Pressure

The total vapor pressure of an aqua ammonia solution is comprised of the partial vapor pressure due to $NH_3$ plus the partial vapor pressure due to H2O. Information on these pressures as a function of temperature is provided in Airgas Technical Bulletin TB-9-1, which is reproduced in Appendix A, page 21. More comprehensive tables of this relationship are presented in Appendix A, pages 22-25. Note that any pressure due to the presence of air in a storage tank or system is additional to the aqua ammonia vapor pressure.

## Solubility

Water and ammonia are miscible in all proportions. When one refers to the solubility of ammonia in water, it is usually meant to be the solubility at a given temperature for which the vapor pressure is equal to atmospheric pressure.

| ***Temperature °F*** | ***Wt. % Ammonia Solubility*** |
|---|---|
| 32 | 47.3 |
| 50 | 40.6 |
| 68 | 34.1 |
| 86 | 29.0 |
| 104 | 25.3 |
| 122 | 22.1 |
| 140 | 19.2 |
| 158 | 16.2 |
| 176 | 13.3 |
| 194 | 10.2 |
| 212 | 6.9 |

For a graph of solubility vs. temperature, see Appendix A, page 26

## Freezing Point

The freezing point of 29.4% ammonia is about -111°F

| ***Weight Percent of Ammonia in Aqua Ammonia*** | ***Freezing Point °F*** |
|---|---|
| 100 | -107.7 |
| 94.4 | -113.6 |
| 89.9 | -118.7 |
| 85.8 | -123.7 |
| 80.7 | -134.5 |
| 77.5 | -127.7 |
| 72.4 | -116.0 |
| 69.9 | -112.0 |
| 68.7 | -111.5 |
| 65.4 | -109.8 |
| 64.5 | -110.0 |
| 63.3 | -110.6 |
| 60.6 | -113.8 |
| 59.9 | -115.1 |
| 59.3 | -116.1 |
| 58.9 | -117.2 |
| 57.6 | -121.4 |
| 55.6 | -119.4 |
| 51.6 | -112.4 |
| 48.8 | -110.4 |
| 48.7 | -110.2 |
| 47.9 | -110.4 |
| 42.3 | -117.4 |
| 40.8 | -122.8 |
| 39.2 | -126.8 |
| 38.4 | -131.8 |
| 37.7 | -133.1 |
| 34.4 | -142.8 |
| 32.7 | -142.1 |
| 31.4 | -128.5 |
| 28.5 | -101.6 |
| 27.5 | -91.8 |
| 26.4 | -82.7 |
| 25.4 | -74.9 |
| 22.0 | -46.3 |
| 19.3 | -30.8 |
| 17.1 | -19.5 |
| 4.22 | 23.4 |
| 0.00 | 32.0 |
| Eutectic I: 33.4% | -148.5 |
| Eutectic II: 57.1% | -122.8 |
| Eutectic III: 80.5% | -134.5 |

Data: S. Postma Recveil des Travaux Chimigues des Pays-Bas 39,515 (1920)

For a graph of freezing point versus temperature, see Appendix A, page 27.

## Boiling Point

The boiling point of aqua ammonia is defined as the temperature at which the partial vapor pressure of the ammonia vapor over the aqua ammonia equals atmospheric pressure.

| ***Degrees Be' at 60°*** | ***Weight % $NH_3$ Concentration*** | ***Boiling Point °F*** |
|---|---|---|
| 10 | 0.00 | 212 |
| 11 | 1.62 | 195 |
| 12 | 3.30 | 186 |
| 13 | 5.02 | 177 |
| 14 | 6.74 | 171 |
| 15 | 8.49 | 163 |
| 16 | 10.28 | 156 |
| 17 | 12.10 | 149 |
| 18 | 13.96 | 142 |
| 19 | 15.84 | 134 |
| 20 | 17.76 | 127 |
| 21 | 19.68 | 120 |
| 22 | 21.60 | 111 |
| 23 | 23.52 | 103 |
| 24 | 25.48 | 95 |
| 25 | 27.44 | 88 |
| 26 | 29.40 | 81 |
| 27 | 31.36 | 73 |
| 28 | 33.32 | 66 |
| 29 | 35.28 | 59 |

## Viscosity

Aqua ammonia viscosity is higher than that for liquid anhydrous ammonia. The viscosities shown below are for 26% concentration aqua ammonia.

| ***Temperature °F*** | ***Centipoise*** |
|---|---|
| -40 | 5.0 |
| 0 | 2.8 |
| 40 | 1.7 |
| 80 | 1.1 |
| 120 | 0.7 |

from Perry's *Chemical Engineer's Handbook* (1984)

## Surface Tension

The surface tension of aqua ammonia at 67°F for various concentrations is shown below:

| ***% $NH_3$*** | ***Surface Tension (dynes/cm)*** |
|---|---|
| 1.72 | 71.65 |
| 3.39 | 70.65 |
| 4.99 | 69.95 |
| 9.51 | 67.85 |
| 17.37 | 65.25 |
| 34.47 | 61.05 |
| 54.37 | 57.05 |

from Perry's *Chemical Engineer's Handbook* (1984)

# Conversions

## Dilutions

The calculations required to determine the volume of anhydrous ammonia or aqua ammonia of an initial concentration to mix with water to create a specific concentration aqua ammonia do not follow normal dilution rules since the anhydrous ammonia and aqua ammonia volumes are not additive with water volumes, i.e., one gallon of anhydrous ammonia added to nine gallons of water does not result in 10 gallons of solution. The final volume would be less than 10 gallons. For many aqua dilutions, the non-additive effects are minimal. For anhydrous additions, they are significant.

The steps to calculate dilutions are as follows:

1. Let $V_o$ = volume in gallons of original concentration aqua ammonia or anhydrous ammonia

   $C_o$ = concentration in wt. % $NH_3$ of anhydrous ammonia or original aqua ammonia solution used

   $V_f$ = volume in gallons of final solution desired

   $C_f$ = concentration in wt. % $NH_3$ of final aqua ammonia solution desired

   $V_w$ = volume in gallons of water to be added

2. Determine specific gravities at 60°F/60°F of both original and final concentrations of aqua ammonias by referring to tables in "Physical Properties" on page 11. Interpolation is used to