Dilution Calculations for Aqua Ammonia

Calculating the amount of ammonia or water to make a specific concentration of aqua ammonia does not follow normal dilution rules.

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 correctly are as follows:
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

Determine specific gravities at 60ºF/60ºF of both original and final concentrations of aqua ammonias by referring to “Specific Gravity of Aqua Ammonia” table. Use interpolation to calculate intermediate values.

For anhydrous ammonia, use a specific gravity of 0.6182

Let SG_o= specific gravity of anhydrous ammonia or original concentration of aqua ammonia
SG_f = specific gravity of final concentration aqua ammonia
SGw = 1.0000 specific gravity of water.

Two laws are clear:

First, the weight of the original anhydrous ammonia or aqua solution plus the weight of the water added must equal the weight of the final solution.

Second, the weight of the ammonia (NH_3) present originally (either as anhydrous ammonia or in the original aqua ammonia) must equal the weight of the ammonia (NH_3) in the final solution.

Therefore, two equations with two unknowns are generated from which desired values can be calculated.

The "ammonia equation" becomes:
$(V_o)(SG_o)(C_o) = (V_f)(SG_f)(C_f)$

and the "weight equation"
$(V_o)(SG_o) + V_w = (V_f)(SG_f)$

Example: what volume of anhydrous ammonia (would you add to what volume of water to obtain 1,000 gallons of 29.4% aqua ammonia?

The "ammonia equation" becomes:
$V_o = V_f (SG_f)(C_f)/(SG_o)(C_o)$
Or V_o = 1,000 (0.8974)(0.294/(0.6182)(1.00)
Or V_o = 426.7 gallons

The "weight equation" becomes:
$V_w = (V_f)(SG_f) – (V_o)(SG_o)$
Or
V_w = (1,000)(0.8974) – (426.7)(0.6182)
Or
V_w = 633.6 gallons

Note that 426.7 = 633.6 does not equal 1,000.
There has been a decrease of about 6% in volume in the mixing process.

Specific Gravity of Aqua Ammonia

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Weight % Ammonia	Specific Gravity, at 60 ºF	Degrees Baumé	Weight % Ammonia	Specific Gravity, at 60 ºF	Degrees Baumé
0.00	1.0000	10.00	17.28	0.9349	19.75
0.40	0.9982	10.25	17.76	0.9333	20.00
0.80	0.9964	10.50	18.24	0.9318	20.25
1.21	0.9947	10.75	18.72	0.9302	20.50
1.62	0.9929	11.00	19.20	0.9287	20.75
2.04	0.9912	11.25	19.68	0.9272	21.00
2.46	0.9894	11.50	20.16	0.9256	21.25
2.88	0.9876	11.75	20.64	0.9241	21.50
3.30	0.9859	12.00	21.12	0.9226	21.75
3.73	0.9842	12.25	21.60	0.9211	22.00
4.16	0.9825	12.50	22.08	0.9195	22.25
4.59	0.9807	12.75	22.56	0.9180	22.50
5.02	0.9790	13.00	23.04	0.9165	22.75
5.45	0.9773	13.25	23.52	0.9150	23.00
5.88	0.9756	13.50	24.01	0.9135	23.25
6.31	0.9739	13.75	24.50	0.9121	23.50
6.74	0.9722	14.00	24.99	0.9106	23.75
7.17	0.9705	14.25	25.48	0.9091	24.00
7.61	0.9689	14.50	25.97	0.9076	24.25
8.05	0.9672	14.75	26.46	0.9061	24.50
8.49	0.9655	15.00	26.95	0.9047	24.75
8.93	0.9639	15.25	27.44	0.9032	25.00
9.38	0.9622	15.50	27.93	0.9018	25.25
9.83	0.9605	15.75	28.42	0.9003	25.50
10.28	0.9589	16.00	28.91	0.8989	25.75
10.73	0.9573	16.25	29.40	0.8974	26.00
11.18	0.9556	16.50	29.89	0.8960	26.25
11.64	0.9540	16.75	30.38	0.8946	26.50
12.10	0.9524	17.00	30.87	0.8931	26.75
12.56	0.9508	17.25	31.36	0.8917	27.00
13.02	0.9492	17.50	31.85	0.8903	27.25
13.49	0.9475	17.75	32.34	0.8889	27.50
13.96	0.9459	18.00	32.83	0.8875	27.75
14.43	0.9444	18.25	33.32	0.8861	28.00
14.90	0.9428	18.50	33.81	0.8847	28.25
15.37	0.9412	18.75	34.30	0.8833	28.50
15.87	0.9396	19.00	34.79	0.8819	28.75
16.32	0.9380	19.25	35.28	0.8805	29.00
16.80	0.9365	19.50			

Heat of Solution

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

Heat of Dilution	
Final Wt % of NH_3	BTU/lb. NH_3
10.0	343.8
20.0	328.5
30.0	308.2
40.0	270.0
50.0	218.8

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.

Solubility	
Temperature ºF	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

Freezing Point

The freezing point of 29.4% aqua ammonia is about -111 ºF.

Freezing Point of aqua ammonia at select points	
Wt% ammonia	Temperature ºF
28.5	-101.6
17.1	-19.5
4.22	23.4
0	32

Storage

Concentrated aqua ammonia will quickly lose strength during storage, particularly in warm weather. To prevent loss of the ammonia, several different arrangements can be used:

- Gaseous ammonia be injected upstream of the injector using an ammoniator. A venturi eductor or static mixer can be installed at this point, but the high affinity of ammonia for water typically will not require any type of mixing technology for low concentrations of ammonia

- A chemical chiller can be used to keep the aqua ammonia water to a temperature below 60 deg F. This will greatly reduce the loss of ammonia in a tank that is open to atmospheric pressure by reducing the partial pressure of the aqua ammonia. The advantage of dosing room pressure ammonia is that it is easier to regulate the dosing flow rate when the chemical additive is at room pressure. Inyo Process can provide chemical chillers that will allow for easy storage of aqua ammonia solutions.

- A pressurized tank can be used to hold the aqua ammonia. As the maximum pressure that the tank will see is low, there are some alternative poly tanks that can withstand the pressures that aqua ammonia will produce under normal conditions. The standard methodology is to use an ASME code pressure vessel (Max allowable working pressure of 25 psig). If you are using a pressurized tank, the tank should be equipped with a relief valve in accordance with the design pressure. Each tank should also be equipped with a vacuum breaker set at 2-4 ounces of vacuum. The discharge from relief valves shall be directed unobstructed to the air and away from personnel.