Problem of the Day

2015.Jun.13

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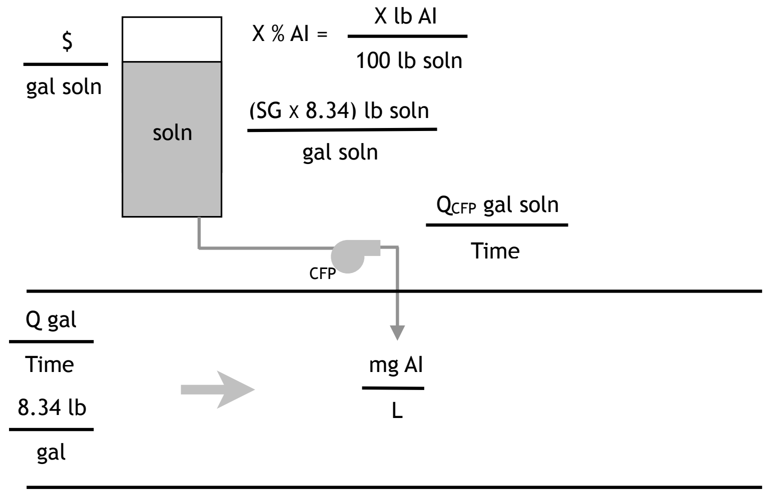
Aqueous ammonia is used to supply nitrogen to the influent of an industrial wastewater treatment plant. Aqueous ammonia is 30% ammonia, and ammonia is 82% nitrogen. The specific gravity of aqueous ammonia is 0.9. The influent flow averages 6.5 MGD. A nitrogen dose of 15 mg/L is needed to ensure adequate nutrients for biological growth. What should the feed rate be (gal/hr) of the aqueous ammonia dosing pump?

Introduction

This, like the past two Problems of the Day, is a chemical dosing problem. All chemical dosing problems can be described by the following graphic.



Generic graphic for setting up chemical dosing problems (AI = active ingredient, SG = specific gravity, CFP = chemical feed pump, Q_{CFP} = flow rate of chemical feed pump, and Q = process flow).

As described below, there are six pieces of information contained in this graphic. Typically, a certification exam question will give the examinee five of those pieces and ask to solve for the sixth. Many trainers will solve these kinds of problems with algebra: “Let x equal ...” If you label the information as taught by WWTT, the units will do the algebra for you! That’s pretty cool!

In today’s problem, the active ingredient is nitrogen (N), but two different concentrations are given for the solution, which is aqueous ammonia. Again, if I was writing this problem out on the white board, instead of labeling the solution tank “soln,” I’d label it “AqA” for “aqueous ammonia.” The two concentrations given for AqA, are expressed as:

1. Aqueous ammonia is 30% ammonia = 30 lb NH_3/100 lb AqA (NH_3 = ammonia)
2. Ammonia is 82% nitrogen = 82 lb N/100 lb NH_3.

A short solution bridge indicates how much active ingredient (N) is in each pound of solution (AqA)

30 ~~lb NH_3~~	82 lb N	=	0.246 lb N
100 lb AqA	100 ~~lb NH_3~~		lb AqA

While this is not the “usual” way that I have done these kinds of problems in WWTT’s Operator Certification and Math Review classes, it is shown here as an alternative way to do these problems. If you are true to the units and use them properly, one alternative is not “righter” than the other.

Again in today’s problem, the specific gravity (SG) of the solution (aqueous ammonia = AqA) is given. The density of the AqA is calculated using a small solution bridge where the density of water is multiplied by the SG, which has no units associated with it (specific gravity is one of the few numbers in wastewater math problems that does **not** have units). Take special note of the units after the equals sign.

8.34 lb	0.9	=	7.51 lb AqA
gal			gal AqA

Solution

Notice in the graphic that the suction to the chemical feed pump is coming from the solution (soln) tank, which in today's problem, as described above, will be labeled "AqA." Like yesterday, even though the question asks for the answer to be in gal/hr, we need to be specific with our labeling. Gallons of what per hour? Gallons of AqA. So, the units needed in the answer are gal AqA/hr. Therefore, as before, these units are entered between heavy vertical lines followed by an equals sign and the blank solution bridge.

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gal AqA	=	
hr		

The six pieces of information shown in the graphic above, specific to this problem, are listed here (one of them is the unknown). Note it is very important to label each as shown. (Note: $/gal soln in the graphic is not used in this problem, but you should know it is often given instead of No. 3, which is the unknown in this case.)

3. Percent active ingredient (AI = N) in feed solution = 0.246 lb N/lb AqA (from calculation above)
4. Density of solution = 7.51 lb AqA/gal AqA (from calculation above)
5. Solution feed rate delivered by the chemical feed pump, Q_{CFP} = **unknown gal AqA/hr**
6. Flow rate of influent to which the chemical is being dosed, Q = 6.5 Mgal/d
7. Density of water (influent) = 8.34 lb/gal
8. Concentration of active ingredient (AI = N) needed in influent = 15 mg N/L

In this list, the only place the units gal AqA show up is in No. 2 (calculated above), so it is used to start the solution bridge.

gal AqA	=	**gal AqA**	
hr		7.51 lb AqA	

The units in the denominator, lb AqA, need to be canceled. No. 1 (calculated above) is the only other place in the list with these units, so it is entered next on the solution bridge. The unwanted units cancel, denominator and numerator.

gal AqA	=	**gal AqA**	~~lb AqA~~	
hr		7.51 ~~lb AqA~~	0.246 lb N	

The units in the denominator, lb N, need to be canceled. But the units lb N don't appear anywhere else in the list, but mg N do (No. 6). This is entered on the solution bridge so the unit N cancels in the denominator and numerator.

gal AqA	=	**gal AqA**	~~lb AqA~~	15 mg ~~N~~	
hr		7.51 ~~lb AqA~~	0.246 lb ~~N~~	L	

The units mg/L are canceled by using the conversion factor M·mg/L entered so the units cancel denominator and numerator.

gal AqA	=	**gal AqA**	~~lb AqA~~	15 ~~mg N~~	~~L~~	
hr		7.51 ~~lb AqA~~	0.246 lb ~~N~~	~~L~~	M·~~mg~~	

The M in this conversion factor reminds us that we need an Mgal to cancel the Ms. The units Mgal only show up in No. 4 so it is entered so the Ms cancel denominator and numerator.

gal AqA	=	**gal AqA**	~~lb AqA~~	15 ~~mg N~~	~~L~~	6.5 ~~M~~gal	
hr		7.51 ~~lb AqA~~	0.246 lb ~~N~~	~~L~~	~~M·mg~~	d	

Both lb and gal cancel when the density of water (No. 5) is entered.

gal AqA	=	**gal AqA**	~~lb AqA~~	15 ~~mg N~~	~~L~~	6.5 ~~Mgal~~	8.34 ~~lb~~	
hr		7.51 ~~lb AqA~~	0.246 ~~lb N~~	~~L~~	~~M·mg~~	d	~~gal~~	

Currently the unit d is in the denominator of the solution bridge, but we need hr so 24 hr/d is used to cancel the unwanted units and get the time unit needed in the answer. Since all the units have cancelled except those that are needed in the answer (in bold), the solution bridge is complete. The arithmetic gives the answer.

gal AqA	=	**gal AqA**	~~lb AqA~~	15 ~~mg N~~	~~L~~	6.5 ~~Mgal~~	8.34 ~~lb~~	~~d~~
hr		7.51 ~~lb AqA~~	0.246 ~~lb N~~	~~L~~	~~M·mg~~	~~d~~	~~gal~~	24 **hr**

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gal AqA	=	**gal AqA**	~~lb AqA~~	15 ~~mg N~~	~~L~~	6.5 ~~Mgal~~	8.34 ~~lb~~	~~d~~
hr		7.51 ~~lb AqA~~	0.246 ~~lb N~~	~~L~~	~~M·mg~~	~~d~~	~~gal~~	24 **hr**

15 x 6.5 x 8.34 ÷ 7.51 ÷ 0.246 ÷ 24 = **18.3 gal AqA/hr**.

Discussion

This approach makes all chemical dosing problems pretty easy. The trick is in the labeling and making sure the units work out, because they have to! Get the labeling down and you'll have these problems licked. Practice, practice, practice.

Happy calculating! Let us know, by leaving a comment, if you want us to do a specific problem, if you see a mistake, or if you have a question on any of the Problems of the Day you are looking at.