Answer on the question #62391, Chemistry / General Chemistry

Question:

Problem 4.115 (Chapter 4)

Federal regulations set an upper limit of 50 parts per million (ppm) of NH3 in the air in a work environment [that is, 50 molecules of NH3(g) for every million molecules in the air]. Air from a manufacturing operation was drawn through a solution containing 106 mL of 1.13×10−2 M HCl. The NH3 reacts with HCl as follows: NH3(aq)+HCl(aq)→NH4Cl(aq) After drawing air through the acid solution for 10.0 min at a rate of 10.0 L/min, the acid was titrated. The remaining acid needed 14.5 mL of 5.86×10−2 M NaOH to reach the equivalence point.

1)How many grams of NH3 were drawn into the acid solution?

2)How many ppm of NH3 were in the air? (Air has a density of 1.20 g/L and an average molar mass of 29.0 g/mol under the conditions of the experiment.)

3)Is this manufacturer in compliance with regulations?

Solution:

The reactions occur during the process:

$$NH_{3(aq)} + HCl_{(aq)} \rightarrow NH_4Cl_{(aq)}$$

and during the titration:

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O$$

1) Let's calculate the number of the moles of chloric acid, remained in the solution and reacted with sodium hydroxide:

$$n(HCl)_{titration} = n(NaOH) = c(NaOH) \cdot V(NaOH) = 5.86 \cdot 10^{-2}(M) \cdot 14.5 \cdot 10^{-3}(L) = 8.497 \cdot 10^{-4} mol$$

Then, the number of the moles of chloric acid that was used in reaction with NH_3 is:

$$n(HCl)_{tot} = n(HCl)_{titration} + n(HCl)_{NH_3}$$
$$n(HCl)_{NH_3} = n(HCl)_{tot} - n(HCl)_{titration}$$

$$n(HCl)_{NH_3} = c(HCl) \cdot V(HCl) - n(HCl)_{titration} = 1.13 \cdot 10^{-2}(M) \cdot 106 \cdot 10^{-3}(L) - 8.497 \cdot 10^{-4}(mol) = 3.481 \cdot 10^{-4}(mol)$$

The number of the moles of NH_3 is equal to the number of the moles of HCl used for NH_3 trap:

$$n(HCl)_{NH_3} = n(NH_3)$$

So, we simply multiply the number of the moles of NH3 by its molar mass to get the mass of NH3:

$$m(NH_3) = n(NH_3) \cdot M(NH_3) = 3.481 \cdot 10^{-4}(mol) \cdot 17.031 \left(\frac{g}{mol}\right) = 5.929 \cdot 10^{-3}(g)$$

2) The formula to calculate the ppm of NH3 in the air is:

$$(NH_3)_{ppm} = \frac{n(NH_3)}{n(air)} \cdot 10^6$$

The number of the moles of air can be calculated this way: first, we calculate the volume of air passed through HCl solution:

$$V_{air} = v \cdot t,$$

where v is the rate 10.0L/min, and t is the time, 10min.

$$V_{air} = 10\left(\frac{L}{\min}\right) \cdot 10(\min) = \ 100L$$

Then, we can get the mass and number of the moles of air:

$$m_{air} = V_{air} \cdot d_{air} = 100(L) \cdot 1.20\left(\frac{g}{L}\right) = 120\ g$$

$$n_{air} = \frac{m_{air}}{M_{air}} = \frac{120(g)}{29.0\left(\frac{g}{mol}\right)} = 4.14\ mol$$

So then, ppm of ammonia is:

$$(NH_3)_{ppm} = \frac{n(NH_3)}{n(air)} \cdot 10^6 = \frac{3.481\ \cdot 10^{-4}(mol)}{4.14\ (mol)} \cdot 10^6 = 84\ ppm$$

3) As 84ppm is > 50ppm, then the manufacturer is not in compliance with regulations.

Answer:

1) $5.929 \cdot 10^{-3}(g)$
2) $84\ ppm$
3) no, he is not.