CHEM 101
Chemistry II
Problem Set IV
Answers

1) a) $\text{CO}_3^{2-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O} + \text{CO}_2(\text{g})$

b) Using 27.8 mL ($=0.0278$ L) of 0.108 M NaOH gives us $3.0 \times 10^{-3}$ moles NaOH and therefore $3.1 \times 10^{-3}$ moles excess HCl. We initially added $(0.02500 \text{ L})(0.879 \text{ M}) = 2.20 \times 10^{-2}$ moles HBr, so $1.89 \times 10^{-2}$ moles reacted. Since two moles of HBr react with each mole of Na$_2$CO$_3$, there must have been \( \frac{1.89 \times 10^{-2}}{2} = 9.45 \times 10^{-3} \) moles Na$_2$CO$_3$ present.

c) The original sample was given as 2.775 g of a mixture of Na$_2$CO$_3$ and NaCl. The NaCl does not react with the acid. From above, we know we have $9.45 \times 10^{-3}$ moles of Na$_2$CO$_3$ ($M_m = 106.007$), which is 1.0018 g, and the percent composition is: 36.10% Na$_2$CO$_3$ and 63.90% NaCl.

2) a) $2\text{H}_2\text{SO}_4(\text{l}) \leftrightarrow \text{H}_3\text{SO}_4^+ + \text{HSO}_4^-$ (drawing a structural formula might help you see where the H$^+$ goes.)

b) KHSO$_4$, because it can increase the concentration of the anion, HSO$_4^-$, would be a base in pure sulfuric acid.

3) $\text{C}_2\text{H}_5\text{NH}_2 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_5\text{NH}_3^+ + \text{OH}^-$ is the relavent equation. We have 0.775 g of $\text{C}_2\text{H}_5\text{NH}_2$ ($M_m = 45.0845$) in 100 mL of solution or \( \frac{0.775 \text{ g}}{45.0845 \text{ g/mol}} = 1.72 \times 10^{-2} \) moles, which, when converted to molarity, yields $1.72 \times 10^{-1}$ M. Of this amount, 0.915% or $1.57 \times 10^{-3}$ M has reacted, yielding, from the above equation, $1.57 \times 10^{-3}$ M OH$^-$. If $\text{pH} = -\log([\text{H}_3\text{O}^+])$, then $\text{pOH} = -\log([\text{OH}^-]) = -\log(1.57 \times 10^{-3}) = 2.80$. Since we know that $\text{pH} + \text{pOH} = 14$, we can calculate $\text{pH} = 14 - \text{pOH} = 14 - 2.80 = 11.20$.

4) We are told that hypophosphorus acid, H$_3$PO$_2$, and phosphoric acid, H$_3$PO$_4$, have approximately the same acid strengths. In the chapter, we are told that acid strengths for oxoacids depend on the number of oxygen atoms bonded directly to the central atom. We are also given a hint--one or more hydrogens may be bonded to the phosphorus directly. We know the structure of phosphoric acid to be (HO)$_3$PO, with one oxygen bonded directly to phosphorus, so we can conclude, therefore, that hypophosphorus acid has the semi-structural formula (HO)H$_2$PO, and the structural formula (something similar is fine--geometry not described!!)
As shown the acid is monoprotic, and the neutralization equation is:

\[ \text{NaOH} + \text{H}_3\text{PO}_2 \rightarrow \text{NaH}_2\text{PO}_2 + \text{H}_2\text{O} \]

We can see that, since one moles NaOH is needed for one mole hypophosphorus acid, \( y = 1.52 \times 10^{-2} \) moles, and therefore \( x = 0.606 \text{ g NaOH} \).

5) Recall that a higher pH means a more basic solution. Therefore, we are asked which one of the two substances (NaOH or NH\(_3\)) will increase the hydroxide ion concentration more. From our text, we learn that NH\(_3\) is a weak base, whereas NaOH is a strong base; therefore, we would (correctly) predict that the solution of NaOH would have the higher (\textit{i.e.} more basic) pH.