Polyprotic Buffer Example Problem (see Harris Chapter 11)

We have solutions of 0.500 M H_2SO_3 and 0.200 M KOH. How many mL of each solution should be mixed together to create 1.00 L of a buffer at pH 6.20?

As in the demo, $pH = pK_2 + \log \frac{[SO_3^{2-}]}{[HSO_3^-]} \Rightarrow\Rightarrow \frac{[SO_3^{2-}]}{[HSO_3^-]} = 0.10_{47}$

- Chem: Add enough KOH to convert ⓐ all $H_2SO_3 \rightarrow HSO_3^-$;
  ⓑ ~10% of $HSO_3^- \rightarrow SO_3^{2-}$ [like a titration!]
- Do stoichiometry in terms of mol, then convert to mL

ⓐ $H_2SO_3 + OH^- \longrightarrow HSO_3^- + H_2O \quad K = \frac{1}{K_{b_2}} >> 1$

	H_2SO_3	OH^-	HSO_3^-
I(mol)	X	X	0
F(mol)	0	0	X

where $X \equiv$ mol H_2SO_3. Now let $y \equiv$ <u>additional</u> mol OH^-, that is,

ⓑ $HSO_3^- + OH^- \longrightarrow SO_3^{2-} + H_2O \quad K = \frac{1}{K_{b_1}} >> 1$

	HSO_3^-	OH^-	SO_3^{2-}
I(mol)	X	Y	0
F(mol)	X-Y	0	Y

So $\frac{[SO_3^{2-}]}{[HSO_3^-]} = \frac{y}{x-y} = 0.10_{47}$ ①

and vol(H_2SO_3) + vol(KOH) = 1.00 L

note!

$\Rightarrow x \text{ mol } H_2SO_3 \left(\frac{L}{0.500 \text{ mol}}\right) + (x+y) \text{ mol } OH^- \left(\frac{L}{0.200 \text{ mol}}\right) = 1.00 \text{ L}$

$\Rightarrow 2.00x + 5.00x + 5.00y = 7.00x + 5.00y = 1.00$ ②

Solve for x, since that will immediately lead to vol H_2SO_3.

① $\Rightarrow y = 0.10_{47}x - 0.10_{47}y \Rightarrow 1.10_{47}y = 0.10_{47}x$

$\Rightarrow y = 0.094_{78}x$ ③

(over)

(2) $\Rightarrow \quad X = \frac{1}{7.00}(1.00 - 5.00y) = 0.142_{86} - 0.714_{29}\,y$ (4)

(3) into (4) $\Rightarrow \quad X = 0.142_{86} - 0.714_{29}(0.094_{78}\,X)$

$$X = 0.142_{86} - 0.067_{70}\,X$$

$$1.067_{70}\,X = 0.142_{86}$$

$$X = 0.133_{80} \text{ mol } H_2SO_3$$

i.e. $0.133_{80}\ \text{mol}\left(\frac{10^3 \text{ mL}}{0.500\ \text{mol}}\right) = \boxed{267.6 \text{ mL } H_2SO_3}$

$$\Downarrow$$

$$\boxed{732.4 \text{ mL KOH}}$$