Extra Credit Problem 1: Calculation of the distribution of different forms of phosphate in a 0.01 M solution at pH 7.0. Use the values 2.2, 7.2 and 12.4 for pK_1, pK_2 and pK_3 respectively.

Youhavethefollowingfourequationsinfourunknowns

1. $\frac{[H_2PO_4^-]}{[H_3PO_4]} = 10^{pH-pK} = 10^{7.0-2.2} = 10^{4.8} = 6.31x10^4$

$[H_2PO_4^-] = [H_3PO_4] x 6.31x10^4$

2. $\frac{[HPO_4^{2-}]}{[H_2PO_4^-]} = 10^{pH-pK} = 10^{7.0-7.2} = 10^{-0.2} = 0.631$

$[HPO_4^{2-}] = [H_2PO_4^-] x0.631$

3. $\frac{[PO_4^{3-}]}{[HPO_4^{2-}]} = 10^{pH-pK} = 10^{7.0-12.4} = 10^{-5.4} = 3.98x10^{-6}$

$[PO_4^{3-}] = [HPO_4^{2-}] x3.98x10^{-6}$

4. $[H_3PO_4] + [H_2PO_4^-] + [HPO_4^{2-}] + [PO_4^{3-}] = 0.01M$

Substitute1for$[H_2PO_4^-]$in2:

2. $[HPO_4^{2-}] = [H_3PO_4] x6.31x10^4 \ x0.631$

Substitute2for$[HPO_4^{2-}]$in3:

3. $[PO_4^{3-}] = [H_3PO_4] \ x \ 6.31x10^4 \ x0.631x3.98x10^{-6}$

Substitute1,2,and3into4toget4asafunction of$[H_3PO_4]$

4. $[H_3PO_4]$

$+ [H_3PO_4] x6.31x10^4$

$+ [H_3PO_4] \ x \ 6.31x10^4 \ x0.631$

$+ [H_3PO_4] \ x \ 6.31x10^4 \ x0.631x3.98x10^{-6} = 0.01M$

Factor:

$[H_3PO_4](1 + 6.31x10^4 + 6.31x10^4 \ x0.631 + 6.31x10^4 \ x0.631x3.98x10^{-6}) = 0.01M$

$[H_3PO_4](1.02917x10^5) = 0.01M$

$[H_3PO_4] = \frac{0.01M}{1.02917x10^5} = 9.71654x10^{-8} M$

Thenplugthisvalueintoequations1,2,and3:

$[H_2PO_4^-] = 9.71654x10^{-8} M \ x \ 6.31x10^4 = 6.1311 \ x \ 10^{-3} = 0.0061311M$

$[HPO_4^{2-}] = 9.71654x10^{-8} M x6.31x10^4 \ x0.631 = 3.86875x10^{-3} = 0.00386875M$

$[PO_4^{3-}] = 9.71654x10^{-8} M x6.31x10^4 \ x0.631x3.98x10^{-6} = 1.53976x10^{-8} M$

Check theanswersbypluggingintoequation4:

$9.71654x10^{-8} + 0.0061311 + 0.00386875 + 1.53976x10^{-8} = 9.999996x10^{-3}$ or 0.01

Icarried thisouttowaytoomanysignificantfigures tomakeapoint. Actuallyoneshould roundoff for thetwomajorspecies:

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$[H_2PO_4^-] =$ 0.0061~~31~~1 and$[HPO_4^{2-}] =$ 0.003~~86875~~ M

andrecognizethat theminorspeciesarewellbelowsignificantconcentrations, yet thereissomeof eachspeciespresent.