$0.100\ M\ NH_4Cl$ ... Find the pH of the solution

$$NH_4Cl \rightarrow NH_4^+ + Cl^-$$

$$NH_4^+: \quad NH_4^+ + H_2O \rightleftharpoons \boxed{NH_3} + H_3O^+$$

This is the WEAK BASE ammonia. Stable in water

$$Cl^-: \quad Cl^- + H_2O \rightleftharpoons \boxed{HCl} + OH^-$$

This is a STRONG ACID (hydrochloric acid), which means that it doesn't exist in the molecular form in water. In other words, this product isn't stable - it will lose the hydrogen again. Therefore, chloride ion is NOT a base.

We have two possible equilibria here, but only one is important. The ammonium ion will act as an acid in water, and the chloride ion will be neutral (won't affect pH). We need to solve:

$$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$$

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$

$$K_{a,NH_4^+} = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$$

We can get Ka for ammonium from Kb for its conjugate, ammonia:

$K_{b,NH_3} = 1.8 \times 10^{-5}$

$K_a \times K_b = 1.0 \times 10^{-14}$

So, $K_a = 5.56 \times 10^{-10}$

Species	[Initial]	Δ	[Equil.]
NH_3	0	+X	X
H_3O^+	0	+X	X
NH_4^+	0.100	−X	0.100 − X

$$\frac{x^2}{0.100 - x} = 5.56 \times 10^{-10}$$

$x \ll 0.100$

$0.100 - x \approx 0.100$

$$\frac{x^2}{0.100} = 5.56 \times 10^{-10}$$

$x = 7.45 \times 10^{-6}$

So, $[H_3O^+] = 7.46 \times 10^{-6}$

pH = 5.13

Compare:
pH = 1.00 for 0.100 M strong acid
pH = 2.16 for 0.100 M weak acid (nitrous acid
pH = 7.00 for distilled water

0.100 M $NaC_2H_3O_2$, Find pH

$$NaC_2H_3O_2 \rightarrow Na^+ + C_2H_3O_2^-$$

Check the ions formed by the salt to see if there's an acid or a base.

Na^+ : Not a B-L acid, since it has no protons to donate. Unlikely to be as base, since it has a positive charge. We expect sodium ion to be neutral.

$C_2H_3O_2^-$: Has hydrogens, but also a negative charge. It's PROBABLY a proton acceptor rather than a donor due to the negative charge.

$$C_2H_3O_2^- + H_2O \rightleftharpoons HC_2H_3O_2 + OH^-$$

Acetic acid. Acetic acid is a WEAK ACID and stable in water. We expect the ACETATE ION to function as a base.

$$K_{b,C_2H_3O_2^-} = \frac{[HC_2H_3O_2][OH^-]}{[C_2H_3O_2^-]}$$

As expected, Kb for acetate ion is not available on the chart on page A-14. . But we can find Ka for acetic acid (the conjugate of acetate ion) on the previous page.

$K_{a,HC_2H_3O_2} = 1.7 \times 10^{-5}$; $K_a \times K_b = 1.0 \times 10^{-14}$; $K_b = 5.88 \times 10^{-10}$

$$C_2H_3O_2^- + H_2O \rightleftharpoons HC_2H_3O_2 + OH^-$$

$$K_{b,C_2H_3O_2^-} = 5.88 \times 10^{-10} = \frac{[HC_2H_3O_2][OH^-]}{[C_2H_3O_2^-]}$$

Species	[Initial]	Δ	[Equil.]
$HC_2H_3O_2$	0	$+x$	x
OH^-	0	$+x$	x
$C_2H_3O_2^-$	0.100	$-x$	0.100

$$\frac{x^2}{0.100 - x} = 5.88 \times 10^{-10}$$

$x << 0.100$

$0.100 - x \approx 0.100$

$$\frac{x^2}{0.100} = 5.88 \times 10^{-10}$$

$x = 7.67 \times 10^{-6} = [OH^-]$

We need pH, but remember that we have calculated the HYDROXIDE concentration!

$pOH = -\log_{10}(7.67 \times 10^{-6})$

$pOH = 5.12$

$pOH = 5.12$

$pH + pOH = 14.00$

$pH = 8.88$

Compare:
pH = 7.00 for pure distilled water
pH = 11.13 for 0.100 M ammonia
pH = 13.00 for 0.100 M NaOH (strong base)

0.100 M NaCl, Find pH

$$NaCl \rightarrow Na^+ + Cl^-$$

As before, let's check the ions to see whether either of them have acidic or basic properties

Na^+: Not B-L acid, and unlikely to be B-L base due to the positive charge. It's a simple - neutral - alkali metal ion.

Cl^-: Not a B-L acid, since it has no protons to donate. It MIGHT be a proton acceptor, but as we see below that's not very likely.

$$Cl^- + H_2O \rightleftharpoons \boxed{HCl} + OH^-$$

This is hydrochloric acid, a strong acid. If completely ionizes in water, meaning that the chloride ion can't be a very good proton acceptor!

... so chloride ion is NEUTRAL

Since neither sodium ion nor chloride ion affect the water equilibrium, the pH of the solution will be the same as that of pure water: 7.00

POLYPROTIC ACIDS

Find pH of 0,10 M H_3PO_4

... what's special about phosphoric acid?

① $H_3PO_4 + H_2O \rightleftharpoons H_2PO_4^- + H_3O^+$

② $H_2PO_4^- + H_2O \rightleftharpoons HPO_4^{2-} + H_3O^+$

③ $HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$

Phosphoric acid has THREE acidic protons!

$K_{a1} = 6,9 \times 10^{-3}$

$K_{a2} = 6,2 \times 10^{-8}$

$K_{a3} = 4,8 \times 10^{-13}$

The first dissocation is dominant here, and for simple calculations of phosphoric acid in water, we will simply use the first ionization and ignore the other two.

Remember: This is a weak acid. It exists in water mostly as undissociated phosphoric acid molecules.