Unit 7, Lesson 08: The pH of Salt Solutions, Answers

1. Complete the following chart:

Ion	Parent Acid or Base	Is the parent strong or weak?	Will this ion hydrolyze?	If the ion will hydrolyze (react with water), write the ionization reaction. If not, write "no reaction" or NR.	pH of ion in solution (acidic, basic or neutral)
NH_4^{1+}	NH_3	weak	yes	$NH_4^{1+}{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3\,(aq)} + H_3O^+_{(aq)}$	acidic
PO_3^{3-}	H_3PO_3	weak	yes	$PO_3^{3-}{}_{(aq)} + H_2O_{(l)} \leftrightarrow HPO_3^{2-}{}_{(aq)} + OH^-_{(aq)}$	basic
Na^{1+}	NaOH	strong	no	NR	neutral
$N_2H_5^{1+}$	N_2H_4	weak	yes	$N_2H_5^{1+}{}_{(aq)} + H_2O_{(l)} \leftrightarrow N_2H_{4\,(aq)} + H_3O^+_{(aq)}$	acidic
HCO_3^{1-}	H_2CO_3	weak	yes	$HCO_3^{1-}{}_{(aq)} + H_2O_{(l)} \leftrightarrow H_2CO_{3(aq)} + OH^-_{(aq)}$	basic
SO_4^{2-}	H_2SO_4	strong	no	NR	neutral
Ca^{2+}	$Ca(OH)_2$	strong	no	NR	neutral
NO_3^{1-}	HNO_3	strong	no	NR	neutral

Notes and explanations:

- positive ions from weak bases are strong enough acids to hydrolyze. They will donate a proton to water and form the H_3O^+ ion. Because this reaction forms the H_3O^+ ion, it is a Ka reaction
- negative ions from weak acids are strong enough bases to hydrolyze. They will take a proton from water, leaving the OH- ion behind. Because this reaction forms the OH- ion, it is a Kb reaction

2. For each of the following salts:
- identify its parent acid and parent base and indicate if they are strong or weak
- for the ions which will react with water (hydrolyze) in solution, write the hydrolysis reaction
- state whether the salt solution is acidic, basic or neutral

a) sodium nitrate: $NaNO_3$ (aq)
- parent base is NaOH, a strong base ∴ no hydrolysis
- parent acid is HNO_3, a strong acid ∴ no hydrolysis
- salt solution will be neutral

b) ammonium chloride (NH_4Cl)
- parent base is NH_3, a weak base ∴ hydrolysis: $NH_4^{1+}{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3\,(aq)} + H_3O^+_{(aq)}$
- parent acid is HCl, a strong acid ∴ no hydrolysis
- salt solution will be acidic

c) lithium oxalate ($Li_2C_2O_4$)
- parent base is LiOH, a strong base ∴ no hydrolysis
- parent acid is $H_2C_2O_4$, a weak acid ∴ hydrolysis: $C_2O_4^{2-}{}_{(aq)} + H_2O_{(l)} \leftrightarrow HC_2O_4^{2-}{}_{(aq)} + OH^-_{(aq)}$
- salt solution will be basic

d) silver bromide (AgBr)
- parent base is AgOH, a weak base ∴ hydrolysis: $Ag^{1+}{}_{(aq)} + H_2O_{(l)} \leftrightarrow AgOH_{(aq)} + H_3O^+_{(aq)}$
- parent acid is HBr, a strong acid ∴ no hydrolysis
- salt solution will be acidic

e) magnesium fluoride (MgF_2)

- parent base is $Mg(OH)_2$, a strong base ∴ no hydrolysis
- parent acid is HF, a weak acid ∴ hydrolysis: $F^{1-}_{(aq)} + H_2O_{(l)} \leftrightarrow HF_{(aq)} + OH^{-}_{(aq)}$
- salt solution will be basic

f) potassium hydrogen carbonate ($KHCO_3$)

- parent base is KOH, a strong base ∴ no hydrolysis
- parent acid is H_2CO_3 , a weak acid ∴ hydrolysis: $HCO_3^{1-}{}_{(aq)} + H_2O_{(l)} \leftrightarrow H_2CO_3{}_{(aq)} + OH^{-}_{(aq)}$
- salt solution will be basic

g) barium hydrogen phosphate ($BaHPO_4$)

- parent base is $Ba(OH)_2$, a strong base ∴ no hydrolysis
- parent acid is H_3PO_3 , a weak acid ∴ hydrolysis: $HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \leftrightarrow H_2PO_4^{1-}{}_{(aq)} + OH^{-}_{(aq)}$
- salt solution will be basic

h) strontium sulfate ($SrSO_4$)

- parent base is $Sr(OH)_2$, a strong base ∴ no hydrolysis
- parent acid is H_2SO_4, a strong acid ∴ no hydrolysis
- salt solution will be neutral

i) calcium oxide (CaO)

- this is a strong base (remember?) so the solution will be basic

j) $(N_2H_5)ClO_4$

- parent base is N_2H_4, a weak base ∴ hydrolysis: $N_2H_5^{1+}{}_{(aq)} + H_2O_{(l)} \leftrightarrow N_2H_4{}_{(aq)} + H_3O^{+}_{(aq)}$
- parent acid is $HClO_4$, a strong acid ∴ no hydrolysis
- salt solution will be acidic

3. **Calculate the pH of the following solutions:**

a) 1.60 M solution of NH_4Cl

- parent base is NH_3, a weak base ∴ hydrolysis: $NH_4^{1+}{}_{(aq)} + H_2O_{(l)} \leftrightarrow NH_{3\,(aq)} + H_3O^+{}_{(aq)}$
- parent acid is HCl, a strong acid ∴ no hydrolysis
- salt solution will be acidic

This reaction shows the formation of an acidic solution, so we need to use the Ka for NH_4^+. NH_4^+ is the conjugate acid of NH_3, so calculate Ka as follows:

Ka = Kw / Kb

= 1.0×10^{-14} / 1.8×10^{-5}

= 5.56×10^{-10}

	$NH_4^{1+}{}_{(aq)}$ ⟺	$NH_{3\,(aq)}$ +	$H_3O^+{}_{(aq)}$
I	1.60 M (assume complete dissociation)	0	0
C	− x	+ x	+ x
E	1.60 - x	x	x

Can we ignore the –x?

$\frac{1.60}{5.56 \times 10^{-10}}$ is much greater than 500, so ignore -x

$$Ka = \frac{[NH_3]\,[H_3O^+]}{[NH_4^{1+}]}$$

$$5.56 \times 10^{-10} = \frac{x^2}{1.60}$$

x = 2.98×10^{-5} mol/L

so $[H_3O^+]$ at eq'm = 2.98×10^{-5} mol/L

pH = - log [2.98×10^{-5}]

= 4.53 (2 decimals, because 2 sd)

(this makes sense- we had predicted an acidic solution)

b) 0.0155 M solution of $NaHCO_3$

- parent base is NaOH, a strong base ∴ no hydrolysis
- parent acid is H_2CO_3, a weak acid ∴ hydrolysis: $HCO_3^{1-}{}_{(aq)} + H_2O_{(l)} \leftrightarrow H_2CO_{3\,(aq)} + OH^-{}_{(aq)}$
- salt solution will be basic

This reaction shows the formation of a basic solution, so we need to use the Kb for HCO_3^-. HCO_3^{1-} is the conjugate base of H_2CO_3, so calculate Kb as follows:

Kb = Kw / Ka

= $1.0 \times 10^{-14} / 4.5 \times 10^{-7}$

= 2.2×10^{-8}

Use an ICE table to calculate the concentration of the OH- in the solution:

	$HCO_3^{1-}{}_{(aq)}$ ⟺	$H_2CO_{3\,(aq)}$ +	$OH^{1-}{}_{(aq)}$
I	0.0155 M (assume complete dissociation)	0	0
C	− x	+ x	+ x
E	0.0155 - x	x	x

Can we ignore the –x?

$\frac{0.0155}{2.2 \times 10^{-8}}$ is much greater than 500, so ignore -x

$$Kb = \frac{[H_2CO_3]\ [OH^{1-}]}{[HCO_3^{1-}]}$$

$$2.2 \times 10^{-8} = \frac{x^2}{0.0155}$$

x = 1.8×10^{-5} mol/L

so [OH-] at eq'm = 1.8×10^{-5} mol/L

pOH = - log [1.8×10^{-5}]

= 4.73 (2 decimals, because 2 sd)

pH = 14 – pOH

= 14 – 4.73

= 9.27 (this makes sense- we had predicted a basic solution)

c) 0.750 M solution of KNO_2

- parent base is KOH, a strong base ∴ no hydrolysis
- parent acid is HNO_2 , a weak acid ∴ hydrolysis: $NO_2^{1-}{}_{(aq)} + H_2O_{(l)} \leftrightarrow HNO_{2\,(aq)} + OH^-{}_{(aq)}$
- salt solution will be basic

This reaction shows the formation of a basic solution, so we need to use the Kb for NO_2^-. NO_2^{1-} is the conjugate base of HNO_2, so calculate Kb as follows:

Kb = Kw / Ka

$= 1.0 \times 10^{-14} / 5.6 \times 10^{-4}$

$= 1.79 \times 10^{-11}$

Use an ICE table to calculate the concentration of the OH- in the solution:

	$NO_2^{1-}{}_{(aq)}$ ⟺	$HNO_{2\,(aq)}$ +	$OH^{1-}{}_{(aq)}$
I	0.750 M (assume complete dissociation)	0	0
C	− x	+ x	+ x
E	0.750 - x	x	x

Can we ignore the –x?

$\frac{0.750}{1.79 \times 10^{-11}}$ is much greater than 500, so ignore -x

$$Kb = \frac{[HNO_2]\ [OH^{1-}]}{[NO_2^{1-}]}$$

$$1.79 \times 10^{-11} = \frac{x^2}{0.750}$$

$x = 3.664 \times 10^{-6}$ mol/L

so [OH-] at eq'm = 3.664×10^{-6} mol/L

pOH = $-\log [3.664 \times 10^{-6}]$

= 5.44 (2 decimals, because 2 sd)

pH = 14 – pOH

= 14 – 5.44

= 8.56 (this makes sense- we had predicted a basic solution)

d) 0.335 M solution of $(N_2H_5)ClO_3$

- parent base is N_2H_4, a weak base ∴ hydrolysis: $N_2H_5^{1+}{}_{(aq)} + H_2O_{(l)} \leftrightarrow N_2H_{4\,(aq)} + H_3O^+{}_{(aq)}$
- parent acid is $HClO_3$, a strong acid ∴ no hydrolysis
- salt solution will be acidic

This reaction shows the formation of an acidic solution, so we need to use the Ka for $N_2H_5^{1+}$. $N_2H_5^{1+}$ is the conjugate acid of N_2H_4, so calculate Ka as follows:

Ka = Kw / Kb

= $1.0 \times 10^{-14} / 1.3 \times 10^{-6}$

= 7.69×10^{-9}

	$N_2H_5^{1+}{}_{(aq)}$ ⟺	$N_2H_{4\,(aq)}$ +	$H_3O^+{}_{(aq)}$
I	0.335 M (assume complete dissociation)	0	0
C	− x	+ x	+ x
E	0.335 - x	x	x

Can we ignore the –x?

$\frac{0.335}{7.69 \times 10^{-9}}$ is much greater than 500, so ignore -x

$Ka = \frac{[N_2H_4]\ [H_3O^+]}{[N_2H_5^{1+}]}$

$7.69 \times 10^{-9} = \frac{x^2}{0.335}$

x = 5.08×10^{-5} mol/L

so $[H_3O^+]$ at eq'm = 5.08×10^{-5} mol/L

pH = - log [5.08×10^{-5}]

= 4.29 (2 decimals, because 2 sd)

(this makes sense- we had predicted an acidic solution)