Details	Unit: Acids & Bases
	pH & Indicators
Unit: Acids & Bases	
MA Curriculum Fr	ameworks (2016): HS-PS1-9(MA)
Mastery Objective	e(s): (Students will be able to)
• Calculate pH f	from [H <sup>+</sup> ] and pOH from [OH <sup>−</sup> ].
<ul> <li>Identify acids</li> </ul>	and bases from their pK <sub>a</sub> values.
<ul> <li>Select an appr</li> </ul>	ropriate indicator for a desired pH range.
Success Criteria:	
<ul> <li>pH and pOH a</li> </ul>	re calculated correctly.
<ul> <li>Acids and bas</li> </ul>	es are correctly identified from their $pK_a$ values.
<ul> <li>Indicator char base.</li> </ul>	nges color in a pH range that includes the pH of the given acid or
Tier 2 Vocabulary	: acid, base, indicator
Language Objectiv	ves:
<ul> <li>Explain why h</li> </ul>	igher [H⁺] results in a lower pH.
Notes:	
In water, a very sma	all amount of $H_2O$ dissociates into $H^+$ and $OH^-$ ions:
	$H_2O \longrightarrow H^+ + OH^-$
	ociation of any compound in a solvent is a constant that is attractions of the ions for each other <i>vs.</i> the attraction between vent.
In water at 25 °C, th	e product of the concentrations of H <sup>+</sup> and OH <sup>-</sup> ions (in $\frac{mol}{L}$ ) is
$1.0 \times 10^{-14}$ . This nur words, in water at 2	mber is called the "water dissociation constant" $K_w^*$ . In other 25 °C:
	$K_w = [H^+] [OH^-] = 1.0 \times 10^{-14}$
	uilibrium constant for the dissociation reaction. $K_{eq} = \frac{[H^+][OH^-]}{[H_2O]}$ .
it's just the density of	$H_2O$ is a pure liquid, the concentration of $H_2O$ in pure $H_2O$ is constant— divided by the molar mass, which works out to 55.6 M. Therefore, we ne equilibrium expression.

Use this space for summary and/or additional notes:

Big Ideas

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Big Ideas	Details	Unit: Acids & Bases	
	Recall that acids create $H^+$ (or $H_3O^+$ ) in water, and bases creat dissociation equation:	ate $OH^-$ in water. In the	
	$H_2O = H^+ + OH^-$		
	Le Châtelier's principle predicts that if we add acid, $[H^+]$ increasing equilibrium to the left, which means $[OH^-]$ decreases, and it $[H^+] [OH^-] = 1.0 \times 10^{-14} = K_w$ .		
	Similarly, if we add base, $[OH^-]$ increases and $[H^+]$ decreases $[H^+] [OH^-] = 1.0 \times 10^{-14} = K_w$ .	and	
	If we have exactly the same amount of acid and base, then [ equal to the square root of $1 \times 10^{-14}$ , which is $1 \times 10^{-7}$ M. As amount of acid and base is said to be <u>neutral</u> .		
	Working with concentrations in scientific notation that vary unwieldy, so we define a function "p" which means "take the quantity and multiply the result by $-1$ ." (See the "Logarithm page 99 for a brief description of the logarithm mathematical	e logarithm of the ns" topic starting on	
	Therefore, the quantity "pH" would be −log [H <sup>+</sup> ].		
	<u>pH</u> : a measure of the strength of an acidic or basic solution. Equal to -		
	Examples:		
	if $[H^+] = 0.001$ M, then pH = $-\log (0.001) = 3$ if $[H^+] = 0.000\ 000\ 01$ M (= $1 \times 10^{-8}$ M) then pH = $-\log (1$	× 10 <sup>-8</sup> ) = 8	
	<u>pOH</u> : another measure of the strength of an acidic or basic s −log [OH <sup>-</sup> ]. Much less commonly used that pH.	solution. Equal to	
	Examples:		
	if [OH <sup>-</sup> ] = 0.001 M, then pOH = −log (0.001) = 3 if [OH <sup>-</sup> ] = 0.000 000 01 M (= 1 × 10 <sup>-8</sup> M) then pOH = −log	$g(1 \times 10^{-8}) = 8$	
	pH & pOH Equations		
	pH = -log[H <sup>+</sup> ] pOH	H = −log[OH⁻]	
	$[H^+] = 10^{-pH}$ [O	H <sup>-</sup> ] = 10 <sup>-pOH</sup>	
	Because the (multiplication) product of $[H^+][OH^-] = 1 \times 10^{-14}$	, this means that:	
	pH + pOH = 14		

Note that the higher the concentration of H <sup>+</sup> ions (higher value of [H <sup>+</sup> ]), the lot the pH.         Low pH = acidic = more H <sup>+</sup> = less OH <sup>-</sup> High pH = basic = less H <sup>+</sup> = more OH <sup>-</sup> [H <sup>+</sup> ]       [OH <sup>-</sup> ]       pH       pOH       Acidic/Basic         1 M (= 1 × 10 <sup>0</sup> M)       1 × 10 <sup>-14</sup> M       0       14       very acidic         0.1 M (= 1 × 10 <sup>-1</sup> M)       1 × 10 <sup>-13</sup> M       1       13       1         0.01 M (= 1 × 10 <sup>-2</sup> M)       1 × 10 <sup>-12</sup> M       2       12       1         1 × 10 <sup>-3</sup> M       1 × 10 <sup>-11</sup> M       3       11       1         1 × 10 <sup>-4</sup> M       1 × 10 <sup>-10</sup> M       4       10       I		P''				Page
the pH. Low pH = acidic = more H <sup>+</sup> = less OH <sup>-</sup> High pH = basic = less H <sup>+</sup> = more OH <sup>-</sup> $\frac{[H^+]}{1 M (= 1 \times 10^0 M)} \frac{[OH^-]}{1 \times 10^{-14} M} \frac{pH}{0} \frac{pOH}{4 Cidic/Basic}$ 0.1 M (= 1 × 10 <sup>-1</sup> M) 1 × 10 <sup>-13</sup> M 1 13 0.01 M (= 1 × 10 <sup>-2</sup> M) 1 × 10 <sup>-12</sup> M 2 12 1 × 10 <sup>-3</sup> M 1 × 10 <sup>-11</sup> M 3 11 1 × 10 <sup>-3</sup> M 1 × 10 <sup>-10</sup> M 4 10 1 × 10 <sup>-5</sup> M 1 × 10 <sup>-9</sup> M 5 9 1 × 10 <sup>-6</sup> M 1 × 10 <sup>-9</sup> M 6 8 1 × 10 <sup>-6</sup> M 1 × 10 <sup>-8</sup> M 6 8 1 × 10 <sup>-7</sup> M 1 × 10 <sup>-7</sup> M 7 7 7 1 × 10 <sup>-8</sup> M 1 × 10 <sup>-6</sup> M 8 6 1 × 10 <sup>-9</sup> M 1 × 10 <sup>-5</sup> M 9 5 slightly basi 1 × 10 <sup>-10</sup> M 1 × 10 <sup>-3</sup> M 11 3 1 × 10 <sup>-11</sup> M 1 × 10 <sup>-3</sup> M 11 3 1 × 10 <sup>-12</sup> M 0.01 M (= 1 × 10 <sup>-1</sup> M) 12 2 1 × 10 <sup>-13</sup> M 0.1 M (= 1 × 10 <sup>-1</sup> M) 13 1 1 × 10 <sup>-14</sup> M 1 M (= 1 × 10 <sup>0</sup> M) 14 0 very basic Sample Problems: Q: What is the pH of a solution with [H <sup>+</sup> ] = 2.5 × 10 <sup>-4</sup> M? A: -log(2.5 × 10 <sup>-4</sup> ) = 3.60 Q: What is the concentration of H <sup>+</sup> ions in a solution with a pH of 11.4?	eas De	etails				Unit: Acids &
Low pH = acidic = more H* = less OH <sup>+</sup> High pH = basic = less H* = more OH <sup>-</sup> IM (= 1 × 10 <sup>0</sup> M)       1 × 10 <sup>-14</sup> M       0       14       very acidic         0.1 M (= 1 × 10 <sup>-1</sup> M)       1 × 10 <sup>-13</sup> M       1       13       0       14       very acidic         0.1 M (= 1 × 10 <sup>-1</sup> M)       1 × 10 <sup>-13</sup> M       1       13       0       14       very acidic         0.1 M (= 1 × 10 <sup>-2</sup> M)       1 × 10 <sup>-13</sup> M       1       13       1       1       1         0.01 M (= 1 × 10 <sup>-2</sup> M)       1 × 10 <sup>-14</sup> M       3       11       1		_	ncentration of H <sup>+</sup> ions (h	nigher	value c	of [H <sup>+</sup> ]), the low
High pH = basic = less H* = more OHTImage: High pH = basic = less H* = more OHTImage: Image: Image	th	-				
[H*][OH <sup>-</sup> ]PHPOHAcidic/Basic $1 M (= 1 \times 10^{-0} M)$ $1 \times 10^{-14} M$ 014very acidic $0.1 M (= 1 \times 10^{-1} M)$ $1 \times 10^{-13} M$ 11314 $0.01 M (= 1 \times 10^{-2} M)$ $1 \times 10^{-12} M$ 212 $1 \times 10^{-3} M$ $1 \times 10^{-11} M$ 311 $1 \times 10^{-6} M$ $1 \times 10^{-9} M$ 59 $1 \times 10^{-6} M$ $1 \times 10^{-8} M$ 68 $1 \times 10^{-6} M$ $1 \times 10^{-6} M$ 86 $1 \times 10^{-6} M$ $1 \times 10^{-6} M$ 86 $1 \times 10^{-9} M$ $1 \times 10^{-5} M$ 95 $1 \times 10^{-9} M$ $1 \times 10^{-5} M$ 95 $1 \times 10^{-9} M$ $1 \times 10^{-5} M$ 95 $1 \times 10^{-10} M$ $1 \times 10^{-5} M$ 95 $1 \times 10^{-10} M$ $1 \times 10^{-3} M$ 113 $1 \times 10^{-10} M$ $1 \times 10^{-3} M$ 113 $1 \times 10^{-10} M$ $1 \times 10^{-3} M$ 113 $1 \times 10^{-10} M$ $1 \times 10^{-3} M$ 113 $1 \times 10^{-10} M$ $1 \times 10^{-3} M$ 113 $1 \times 10^{-14} M$ $0.1 M (= 1 \times 10^{-2} M)$ 122 $1 \times 10^{-14} M$ $1 M (= 1 \times 10^{0} M)$ 140very basicSample Problems:Q:What is the pH of a solution with $[H^+] = 2.5 \times 10^{-4} M$ ?A: $-\log(2.5 \times 10^{-4}) = 3.60$ Q:What is the concentration of H <sup>+</sup> ions in a solution with a pH of 11.4?						
1 M (= 1 × 10 <sup>0</sup> M)       1 × 10 <sup>-14</sup> M       0       14       very acidic         0.1 M (= 1 × 10 <sup>-1</sup> M)       1 × 10 <sup>-13</sup> M       1       13       1         0.01 M (= 1 × 10 <sup>-2</sup> M)       1 × 10 <sup>-11</sup> M       3       11       13         1 × 10 <sup>-3</sup> M       1 × 10 <sup>-10</sup> M       4       10       1       1 × 10 <sup>-3</sup> M         1 × 10 <sup>-3</sup> M       1 × 10 <sup>-10</sup> M       4       10       1 × 10 <sup>-6</sup> M       1 × 10 <sup>-9</sup> M       5       9         1 × 10 <sup>-6</sup> M       1 × 10 <sup>-7</sup> M       7       7       neutral       1 × 10 <sup>-8</sup> M       6       8         1 × 10 <sup>-7</sup> M       1 × 10 <sup>-6</sup> M       8       6       8       1 × 10 <sup>-8</sup> M       1 × 10 <sup>-6</sup> M       8       6         1 × 10 <sup>-8</sup> M       1 × 10 <sup>-6</sup> M       8       6       8       1 × 10 <sup>-9</sup> M       1 × 10 <sup>-10</sup> M       10       4       1 × 10 <sup>-11</sup> M       1 × 10 <sup>-13</sup> M       11       3       1       1 × 10 <sup>-14</sup> M       1 M (= 1 × 10 <sup>-1</sup> M)       13       1       1 × 10 <sup>-14</sup> M       very basic         Sample Problems:         Q:       What is the pH of a solution with [H <sup>+</sup> ] = 2.5 × 10 <sup>-4</sup> M?       A: -log(2.5 × 10 <sup>-4</sup> ) = 3.60       Q:       What is the concentration of H <sup>+</sup> ion		Higi	h pH = basic = less H <sup>+</sup> = r	nore (	JH_	
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$1 \times 10^{-14}$ M $1$ M (= $1 \times 10^{0}$ M) $14$ $0$ very basicSample Problems:Q: What is the pH of a solution with $[H^+] = 2.5 \times 10^{-4}$ M?A: $-\log(2.5 \times 10^{-4}) = 3.60$ Q: What is the concentration of H <sup>+</sup> ions in a solution with a pH of 11.4?						
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A: $-\log(2.5 \times 10^{-4}) = 3.60$ Q: What is the concentration of H <sup>+</sup> ions in a solution with a pH of 11.4?	Sa	mple Problems:				
Q: What is the concentration of $H^+$ ions in a solution with a pH of 11.4?	Q:	What is the pH of a solu	ition with $[H^+] = 2.5 \times 10^{-1}$	<sup>−4</sup> M?		
Q: What is the concentration of $H^+$ ions in a solution with a pH of 11.4?	A:	$-\log(2.5 \times 10^{-4}) = 3.60$				
			on of H <sup>+</sup> ions in a solutio		h a nU /	of 11 12
A: $10^{-11.4} = 3.98 \times 10^{-12} M$	Q.	what is the concentration			na pri t	51 11.4:
	A:	10 <sup>-11.4</sup> = 3.98 x 10 <sup>-12</sup> M				

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Details

**Big Ideas** 

An aqueous solution is neutral when the concentration of  $H^+$  and  $OH^-$  are equal. This occurs in water at pH 7.00 at a temperature of 25 °C. However, remember that temperature affects equilibrium; as the temperature increases, more  $H^+$  and  $OH^$ dissociate. This means  $[H^+]$  and  $[OH^-]$  both increase with higher temperatures, which means  $K_w$  increases. When that happens,  $[H^+]$  and  $[OH^-]$  are still equal in a neutral solution, but both are larger, and because  $[H^+]$  and  $[OH^-]$  are larger, the pH and pOH are both lower.

Temp. (°C)	Kw	pH of a neutral solution
0	$0.114 \times 10^{-14}$	7.47
10	$0.293 \times 10^{-14}$	7.27
20	$0.681 \times 10^{-14}$	7.08
25	$1.008 \times 10^{-14}$	7.00
30	$1.471 \times 10^{-14}$	6.92
40	2.916 × 10 <sup>-14</sup>	6.77
50	5.476 × 10 <sup>-14</sup>	6.63
100	$51.3 \times 10^{-14}$	6.14

In other words, despite what your previous teachers may have taught you, a pH of 7 is only neutral at 25 °C. In fact, in warm-blooded animals with body temperatures around 37 °C, a neutral pH would be approximately 6.8.

This also means that pH + pOH = 14 is only correct at 25 °C.

IS	Details				Unit: A
			Indias	tore	
			Indica		
	indicator: a substance that are used as a visual way	-		-	c range of pH values
	are used as a visual way	tome	easure pr	•	
	The following table lists sor	ie com	nmon indi	cators.	
	Name o Indicato		color in acid	color in base	pH range where color change occurs
	bromopheno	blue	yellow	purple	3.0-4.6
	methyl red		red	yellow	4.4–6.2
	litmus		red	blue	5.5–8.2
	bromothymo	blue	yellow	blue	6.0–7.6
	phenol red		yellow	red	6.8–8.4
	phenolphtha	ein	clear	pink	8.2–10.0
	There are many others, and different color changes ove In fact, some clever chemis typically composed of wate red, bromothymol blue, and from 3 to 11, in ROYGBIV (r	a bro s have , prop thym	e develop anol, phe ool blue.	ange. ed a "univ molphtha	versal indicator," wh lein, sodium hydrox
	different color changes ove In fact, some clever chemis typically composed of wate red, bromothymol blue, and from 3 to 11, in ROYGBIV (r	a bro s have , prop thym ainbow	e develop banol, phe bol blue. T v) order:	ange. ed a "univ nolphtha Fhis mixtu	versal indicator," wh lein, sodium hydrov re indicates pH ove
	different color changes over In fact, some clever chemise typically composed of wate red, bromothymol blue, and from 3 to 11, in ROYGBIV (r	a bro s have , prop thym inbow ge D	e develop banol, phe banol blue. v) order: pescription	ange. ed a "univ molphtha This mixtu n	versal indicator," wh lein, sodium hydrox
	different color changes over In fact, some clever chemist typically composed of wate red, bromothymol blue, and from 3 to 11, in ROYGBIV (r <u>pH ran</u> < 3	a bro s have , prop thym ainbow ge D St	e develop banol, phe bol blue. v) order: pescription trong acid	ange. ed a "univ enolphtha This mixtu n I red	versal indicator," wh lein, sodium hydrox re indicates pH ove <b>Color</b>
	different color changes over In fact, some clever chemist typically composed of water red, bromothymol blue, and from 3 to 11, in ROYGBIV (r pH ran < 3 3–6	a bro s have , prop thym inbow ge D St W	e develop banol, phe bol blue. T v) order: <b>escriptio</b> trong acic /eak acid	ange. ed a "univ nolphtha Fhis mixtu n I red orang	versal indicator," wh lein, sodium hydrov re indicates pH ove
	different color changes over In fact, some clever chemist typically composed of wate red, bromothymol blue, and from 3 to 11, in ROYGBIV (r <u>pH ran</u> < 3 3–6 7	a bro s have , prop thym inbow ge D St 	e develop banol, phe bol blue. v) order: <b>escription</b> trong acic Veak acid	ange. ed a "univ molphtha This mixtu n red orange green	versal indicator," wh lein, sodium hydrox re indicates pH ove <b>Color</b>
	different color changes over In fact, some clever chemist typically composed of water red, bromothymol blue, and from 3 to 11, in ROYGBIV (r pH ran < 3 3–6	a bro s have , prop thym inbow ge D St W N W	e develop banol, phe bol blue. T v) order: <b>escriptio</b> trong acic /eak acid	ange. ed a "univ nolphtha This mixtu n red orang green blue indigo	versal indicator," wh lein, sodium hydrox re indicates pH ove <b>Color</b>

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Big Ideas	Details	Unit: Acids & Bases
	Homework Problems	
	For each of the following solutions, calculate the information i indicators from the "Common Acid-Base Indicators" table in yo	
	1. [H+] = 2.5 × 10 <sup>-4</sup> M	
	a. pH =	
	b. Is the solution acidic, basic, or neutral?	
	c. Which pH indicator would be best for this solu	ition?
	2. $[H+] = 4.59 \times 10^{-7} M$	
	a. pH =	
	b. Is the solution acidic, basic, or neutral?	
	c. Which pH indicator would be best for this solu	ition?
	3. pH = 9.1	
	a. [H+] =	
	b. Is the solution acidic, basic, or neutral?	
	c. Which pH indicator would be best for this solu	ition?
	Lise this space for summory and (or additional pates)	

		$\rho \pi \propto multators$	Page:
Big Ideas	Details		Unit: Acids & Ba
	4. pH =	5.5	
	ä	a. [H+] =	
		b. Is the solution acidic, basic, or neutral?	
		c. Which pH indicator would be best for this soluti	on?
	5 [OH-	-] = 7.9 × 10 <sup>−7</sup> M	
		a. [H+] =	
		о. pH =	
		c. Is the solution acidic, basic, or neutral?	
		d. Which pH indicator would be best for this soluti	on?