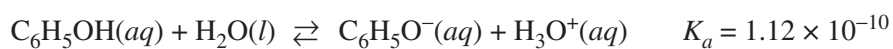


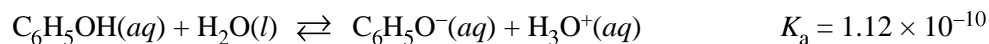
**2016 AP<sup>®</sup> CHEMISTRY FREE-RESPONSE QUESTIONS**

4. Phenol is a weak acid that partially dissociates in water according to the equation above.
- (a) What is the pH of a 0.75 M  $\text{C}_6\text{H}_5\text{OH}(aq)$  solution?
- (b) For a certain reaction involving  $\text{C}_6\text{H}_5\text{OH}(aq)$  to proceed at a significant rate, the phenol must be primarily in its deprotonated form,  $\text{C}_6\text{H}_5\text{O}^-(aq)$ . In order to ensure that the  $\text{C}_6\text{H}_5\text{OH}(aq)$  is deprotonated, the reaction must be conducted in a buffered solution. On the number scale below, circle each pH for which more than 50 percent of the phenol molecules are in the deprotonated form ( $\text{C}_6\text{H}_5\text{O}^-(aq)$ ). Justify your answer.

1      2      3      4      5      6      7      8      9      10      11      12      13      14

**AP<sup>®</sup> CHEMISTRY**  
**2016 SCORING GUIDELINES**

**Question 4**



Phenol is a weak acid that partially dissociates in water, according to the equation above.

(a) What is the pH of a 0.75 M  $\text{C}_6\text{H}_5\text{OH}(aq)$  solution?

$K_a = \frac{[\text{C}_6\text{H}_5\text{O}^-][\text{H}_3\text{O}^+]}{[\text{C}_6\text{H}_5\text{OH}]}$ $1.12 \times 10^{-10} = \frac{x^2}{(0.75 - x)} \quad \text{Assume that } x \ll 0.75.$ $x^2 = 8.4 \times 10^{-11}$ $x = \sqrt{8.4 \times 10^{-11}}$ $x = 9.2 \times 10^{-6} \text{ M}$ $\text{pH} = -\log[\text{H}^+] = -\log(9.2 \times 10^{-6}) = 5.04$	<p>1 point is earned for a correct setup and calculation of <math>[\text{H}^+]</math>.</p> <p>1 point is earned for the correct setup and calculation of pH based on a correct setup for the <math>[\text{H}^+]</math> calculation.</p>
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(b) For a certain reaction involving  $\text{C}_6\text{H}_5\text{OH}(aq)$  to proceed at a significant rate, the phenol must be primarily in its deprotonated form,  $\text{C}_6\text{H}_5\text{O}^-(aq)$ . In order to ensure that the  $\text{C}_6\text{H}_5\text{OH}(aq)$  is deprotonated, the reaction must be conducted in a buffered solution. On the number scale below, circle each pH for which more than 50 percent of the phenol molecules are in the deprotonated form ( $\text{C}_6\text{H}_5\text{O}^-(aq)$ ). Justify your answer.

<p>Numbers 10 through 14 should be circled.</p> <p>When <math>\text{pH} &gt; \text{p}K_a</math>, the deprotonated form will predominate.  <math>\text{p}K_a = -\log(1.12 \times 10^{-10}) = 9.95</math>, therefore at pH 10 and above, <math>[\text{C}_6\text{H}_5\text{O}^-] &gt; [\text{C}_6\text{H}_5\text{OH}]</math>.</p>	<p>1 point is earned for circling 10–14.</p> <p>1 point is earned for the justification.</p>
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1      2      3      4      5      6      7      8      9      10      11      12      13      14