Marks 6

- Solution A consists of a 0.050 M aqueous solution of benzoic acid, C_6H_5COOH, at 25 °C. Calculate the pH of Solution A. The pK_a of benzoic acid is 4.20.

As benzoic acid is a weak acid, $[H_3O^+]$ must be calculated using a reaction table:

	C_6H_5COOH	$\rightleftharpoons$	H^+	$C_6H_5COO^-$
initial	**0.050**		**0**	**0**
change	$-x$		$+x$	$+x$
final	$0.050 - x$		x	x

The equilibrium constant K_a is given by:

$$K_a = \frac{[H^+][C_6H_5COO^-]}{[C_6H_5COOH]} = \frac{x^2}{0.050 - x}$$

As pK_a = $-\log_{10}K_a$, $K_a = 10^{-4.20}$ and is very small, $0.050 - x \sim 0.050$ and hence:

$x^2 = 0.050 \times 10^{-4.2}$ **or** $x = 1.78 \times 10^{-3}$ M $= [H^+]$

Hence, the pH is given by:

$\text{pH} = -\log_{10}[H^+] = -\log_{10}(1.78 \times 10^{-3}) = 2.75$

pH = **2.75**

What are the major species present in solution A?

K_a is very small and the equilibrium lies almost completely to the left. The major species present are water and the undissociated acid:
H_2O and C_6H_5COOH

Solution B consists of a 0.050 M aqueous solution of ammonia, NH_3, at 25 °C. Calculate the pH of Solution B. The pK_a of NH_4^+ is 9.24.

NH_3 is a weak base so $[OH^-]$ must be calculated by considering the equilibrium:

	NH_3	H_2O	$\rightleftharpoons$	NH_4^+	OH^-
initial	**0.050**	**large**		**0**	**0**
change	$-y$	**negligible**		$+y$	$+y$
final	$0.050 - y$	**large**		y	y

ANSWER CONTINUES ON THE NEXT PAGE

The equilibrium constant K_b is given by:

$$K_b = \frac{[NH_4^+][OH^-]}{[NH_3]} = \frac{y^2}{(0.050-y)}$$

For an acid and its conjugate base:

$pK_a + pK_b = 14.00$

$pK_b = 14.00 - 9.24 = 4.76$

As $pK_b = 4.76$, $K_b = 10^{-4.76}$. K_b is very small so $0.050 - y \sim 0.050$ and hence:

$y^2 = 0.050 \times 10^{-4.76}$ **or** $y = 9.32 \times 10^{-4}$ M = $[OH^-]$

Hence, the pOH is given by:

$pOH = -\log_{10}[OH^-] = \log_{10}[9.32 \times 10^{-4}] = 3.03$

Finally, pH + pOH = 14.00 so

$pH = 14.00 - 3.03 = 10.97$

pH = **10.97**

What are the major species present in solution B?

K_b is very small and the equilibrium lies almost completely to the left. The major species present are water and the unprotonated weak base:

H_2O and NH_3