CHEM1611 Answers to Problem Sheet 5

1. (a) **HCl is a strong acid and dissociates completely according to the reaction:**

$$\mathbf{HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)}$$

As [HCl] = 0.012 M, $[H^+]$ = 0.012 M. The pH is then:

$$\mathbf{pH = -\log_{10}[H^+] = \log_{10}(0.012) = 1.92}$$

(b) **NaOH is a strong acid and dissociates completely according to the reaction:**

$$\mathbf{NaOH(aq) \rightarrow Na^+(aq) + OH^-(aq)}$$

As [NaOH] = 0.005, $[OH^-]$ = 0.005. The pOH is then:

$$\mathbf{pOH = -\log_{10}[OH^-] = \log_{10}(0.005) = 2.30}$$

To work out the pH, the relationship pH + pOH = 14 can be used:

$$\mathbf{pH = 14 - 2.30 = 11.7}$$

(c) **The molar mass of NaOH is 22.99 (Na) + 16.00 (O) + 1.008 (H) = 39.998 g mol^{-1}. If 10.0 g of this is used, the number of moles is:**

$$\mathbf{\text{number of moles} = \frac{\text{mass}}{\text{molar mass}} = \frac{10.0\ g}{39.998\ g\ mol^{-1}} = 0.250\ mol}$$

This number of moles is dissolved in 500. mL or 0.500 L of water. As described in (c), the dissociation of the strong base NaOH is complete so the concentration of $[OH^-]$ is therefore:

$$\mathbf{[OH^-] = \frac{\text{number of moles}}{\text{volume}} = \frac{0.250\ mol}{0.500\ L} = 0.500\ M}$$

As $[OH^-]$ = 0.500 M. The pOH is then:

$$\mathbf{pOH = -\log_{10}[OH^-] = \log_{10}(0.500) = 0.30}$$

To work out the pH, the relationship pH + pOH = 14.00 can be used:

$$\mathbf{pH = 14.00 - 0.30 = 13.70}$$

(d) **The number of moles in 20. mL of 10 M nitric acid is:**

$$\mathbf{\text{number of moles} = \text{volume} \times \text{concentration}}$$
$$\mathbf{= (0.020\ L) \times (10.\ mol\ L^{-1}) = 0.20\ mol}$$

As the solution is then diluted to 1.0 L, the concentration of nitric acid becomes:

$$\text{concentration} = \frac{\text{number of moles}}{\text{volume}} = \frac{0.20\ \text{mol}}{1.0\ \text{L}} = 0.20\ \text{M}$$

Nitric acid is a strong acid, so this is also $[H^+]$. Hence, the pH is:

$$\text{pH} = -\log_{10}[H^+] = \log_{10}(0.20) = 0.70$$

(e) **The number of moles of sulfuric acid and potassium hydroxide at the start of the reaction are, respectively**:

$$\text{moles of } H_2SO_4 = \text{volume} \times \text{concentration}$$
$$= (0.030\ \text{L}) \times (2.0\ \text{mol L}^{-1}) = 0.060\ \text{mol}$$

$$\text{moles of KOH} = \text{volume} \times \text{concentration}$$
$$= (0.070\ \text{L}) \times (1.0\ \text{mol L}^{-1}) = 0.070\ \text{mol}$$

The strong acid dissociates to give *two* H^+, hence:

$$\text{number of moles of } H^+ = 2 \times 0.060\ \text{mol} = 0.120\ \text{mol}$$

The strong base dissociates to give one OH^-, hence:

$$\text{number of moles of } OH^- = 0.070\ \text{mol}$$

The neutralization reaction will be incomplete as there is not enough base, hence after neutralization:

$$\text{number of moles of } H^+ = (0.120 - 0.070)\ \text{mol} = 0.050\ \text{mol}$$

The volume of the solution after mixing is (30 + 70) mL = 100 mL or 0.100 L. The concentration of $[H^+]$ is therefore:

$$\text{concentration} = \frac{\text{number of moles}}{\text{volume}} = \frac{0.050\ \text{mol}}{0.100\ \text{L}} = 0.50\ \text{M}$$

Hence, the pH is:

$$\text{pH} = -\log_{10}[H^+] = \log_{10}(0.50) = 0.30$$

2. **In completing the table, the following relationships are used:**

(i) $pK_a. = -\log K_a$
(ii) $pK_b. = -\log K_b$
(iii) $pKa + pK_b = 14$

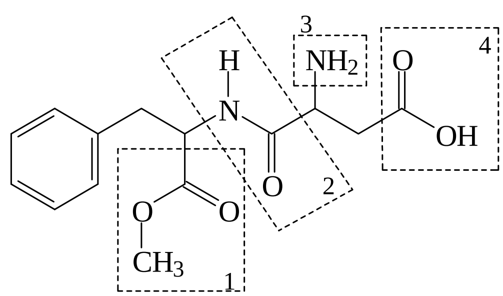
acid	K_a of acid	pK_a of acid	conjugate base	K_b of base	pK_b of base
HNO_2	$10^{-3.15}$	**3.15**	**NO_2^-**	**$10^{-10.85}$**	**14 – 3.15 = 10.85**
HCN	**$10^{-9.21}$**	9.21	**CN^-**	**$10^{-4.79}$**	**14 – 9.21 = 4.79**
NH_4^+	**$10^{-9.24}$**	**14 – 4.76 = 9.24**	**NH_3**	**$10^{-4.76}$**	4.76
CH_3CO_2H	$10^{-4.76}$	**4.76**	$CH_3CO_2^-$	**$10^{-10.24}$**	**14 – 4.76 = 9.24**
HCO_3^-	**$10^{-10.33}$**	**14 – 3.67 = 10.33**	CO_3^{2-}	$10^{-3.67}$	**3.67**
HF	**$10^{-3.17}$**	**14 – 10.83 = 3.17**	**F^-**	$10^{-10.83}$	**10.83**
HPO_4^{2-}	**$10^{-12.38}$**	12.38	PO_4^{3-}	**$10^{-1.62}$**	**14 – 12.38 = 1.62**
H_2O	**$10^{-15.74}$**	15.74	**OH^-**	**$10^{1.74}$**	**14 – 15.74 = -1.74**
H_3O^+	**$10^{1.74}$**	–1.74	H_2O	**$10^{-15.74}$**	**14 – (-1.74) = 15.74**
NH_3	10^{-34}	**34**	NH_2^-	**10^{20}**	**14 – 34 = -20**

3. **The ionic product is $K_w = [H^+][OH^-]$. Neutral blood has $[H^+] = [OH^-]$ and so**

$$K_w = [H^+]^2 = 2.49 \times 10^{-14} \quad \text{so } [H^+] = 1.58 \times 10^{-7}\ M$$

As $pH = -\log_{10}[H^+]$, the pH of neutral blood at 37 °C is $-\log_{10}(1.58 \times 10^{-14}) = 6.8$.

4.

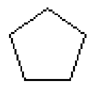


Molecular Formula: **$C_{14}H_{18}N_2O_5$**

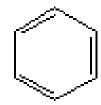
Functional Groups:

1. **ester**
2. **amide**
3. **amine**
4. **carboxylic acid**

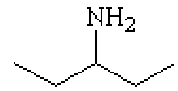
5.



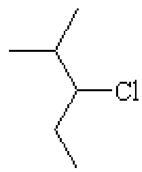
C_5H_{10}
no functional groups



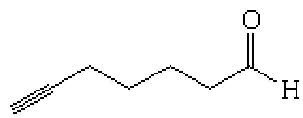
C_6H_6
aromatic



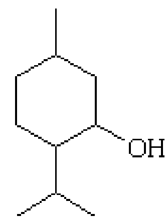
$C_5H_{13}N$
amine



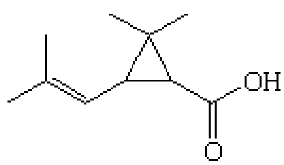
$C_6H_{13}Cl$
alkyl halide



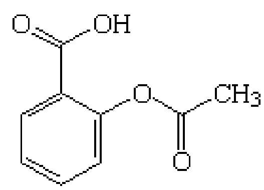
$C_7H_{10}O$
alkyne and aldehyde



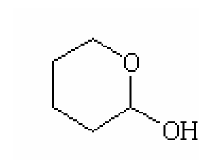
$C_{10}H_{20}O$
alcohol



$C_{10}H_{16}O_2$
alkene and carboxylic acid



$C_9H_8O_4$
carboxylic acid, ester and aromatic



$C_5H_{10}O_2$
hemi-acetal

6. **The boiling points depend on the strength and the number of the intermolecular forces. The X-H bonds in PH_3, H_2S and HCl are all much less polar than the analogues from the first period and so the dipole-dipole interactions are weaker than the H-bonds that exist in the latter.**

While the F atom in HF can potentially act as acceptor of three hydrogen bonds (corresponding to its three lone pairs), the HF molecule has only one point of donation (corresponding to one H atom). On average there are a total of two hydrogen bonds associated with each HF molecule (one donated, one accepted). NH_3 is similar as it has three H atoms but only one lone pair on nitrogen.

Water, however can participate in up to four hydrogen bonds (two donated and two accepted) giving greater intermolecular forces overall.

Thus, even though each hydrogen bond in HF is stronger than each hydrogen bond in H_2O, the greater number of these bonds possible in water lead to a higher boiling point.

7. **Aspro Clear is ionic and consequently water soluble. Although aspirin contains polar and hydrogen bonding groups, the hydrophobic aromatic ring dominates the solubility.**