6338 version 4
Characterise the behaviour of weak and strong acids and bases
Level 2 Credits 3

Compare the behaviour of weak and strong acids and bases, and perform calculations involving acid-base reactions.

SAMPLE QUESTIONS

element 1
Compare the behaviour of weak and strong acids and bases.

performance criteria

PC 1.1 Acids and bases are identified from selected equations involving proton transfer.

Species on the left of the $\rightleftharpoons$

Bases are proton acceptors

Acids are proton donors

Example 1
Underline the reactant that is a base and circle the reactant that is an acid

$$H_2SO_4(aq) + H_2O(l) \rightleftharpoons HSO_4^-(aq) + H_3O^+(aq)$$

Answer:

$$H_2SO_4(aq) + \underline{H_2O(l)} \rightleftharpoons HSO_4^-(aq) + H_3O^+(aq)$$

The H_2SO_4 is an acid because it is a proton donor, giving a H^+ to the water (and becomes HSO_4^- as a result)

The H_2O is acting is a base because it accepts a proton from the H_2SO_4 (and becomes H_3O^+ as a result)

Example 2
Underline the reactant that is a base and circle the reactant that is an acid

$$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

Answer:

$$\underline{CH_3NH_2(aq)} + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

Some helpful things to remember:

- *$H_3O^+(aq)$ is always an acid! $OH^-(aq)$ is always a base!*
- *Look at the products – that's what the reactants become…. Do they have a "proton more" or a "proton less" than when they were on the left (reactants)?*
- *To be an acid (proton donor), the species must have a "H" in its formula BUT not all "H's" are potential protons.*
- *Bases MUST have a lone pair of electrons eg the N of NH_3 or RNH_2. (R = rest of molecule) – and often (but not always) have a negative charge.*

*An acid-base conjugate pair are species on opposite sides of the $\rightarrow$ or $\rightleftharpoons$ **and** differ by a proton, H^+.*

Example 3
Identify the acid-base conjugate pairs in the equation below

$$CO_3^{2-}(aq) \quad + \quad H_3O^+(aq) \quad \rightleftharpoons \quad HCO_3^-(aq) \quad + \quad H_2O(l)$$

Answer:

$$\underset{base1}{CO_3^{2-}(aq)} \quad + \quad \underset{acid2}{H_3O^+(aq)} \quad \rightleftharpoons \quad \underset{acid1}{HCO_3^-(aq)} \quad + \quad \underset{base2}{H_2O(l)}$$

Why?
H_3O^+ is a proton donor (acid), donating a proton to CO_3^{2-} which is a proton acceptor (base).
CO_3^{2-} and HCO_3^- differ by a proton, H^+, so they are a conjugate pair. This is shown by using a "1" for each.
H_3O^+ and H_2O differ by a proton, H^+, so they are a conjugate pair. This is shown by using a "2" for each.
It doesn't matter which pair is 1 and which is 2, of course, as long as each sharing a number belongs to the pair.

Example 4
Identify the acid-base conjugate pairs in the equation below

$$HCOOH(aq) \quad + \quad OH^- \quad \rightleftharpoons \quad HCOO^-(aq) \quad + \quad H_2O(l)$$

Answer:

$$\underset{acid1}{HCOOH(aq)} \quad + \quad \underset{base2}{OH^-} \quad \rightleftharpoons \quad \underset{base1}{HCOO^-(aq)} \quad + \quad \underset{acid2}{H_2O(l)}$$

PC 1.2 Differences between the behaviour of strong and weak acids and bases are interpreted in terms of the extent of their reaction with water.

Why is a 0.10 mol L^{-1} solution of sodium bicarbonate alkaline? Include an equation.

Answer:

Sodium bicarbonate dissolves in water to form sodium ions and bicarbonate ions. $HCO_3^-(aq)$ ions are a base (proton acceptor) accepting a proton from water, and producing the $OH^-(aq)$ ion that is responsible for alkalinity.

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$$

FAQ! Can't HCO_3^- also act as an acid? I remember it being amphiprotic!
Answer. Yes! You could have written this "correctly balanced equation" $HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$ BUT that wouldn't have explained why a solution of sodium bicarbonate is alkaline.

Acid A and acid B are of the same concentration. Acid **A** reacted slowly with sodium bicarbonate to produce slow bubbling. Acid **B** reacted vigorously with sodium bicarbonate producing a rapid evolution of gas.
Which acid, **A** or **B**, is the stronger acid? Justify your choice in terms of the rates of reaction with sodium bicarbonate and relate this to the **degree of dissociation** of the acids in water.

The acids are the same concentration but B reacted at a much faster rate than A – indicating more available $H_3O^+(aq)$ ions for collision with the sodium bicarbonate. Therefore B must have been fully ionised / dissociated in water – the strong acid.
$HB(aq) + aq \rightarrow H^+(aq) + B^-(aq)$ ($\rightarrow$ implies complete reaction).

PC 1.3	The description identifies that the amount of acid required for complete reaction is independent of the acid strength

A student has two acids, hydrochloric (strong acid) and hypochlorous acid (weak acid) of the same concentration. A student finds that she needs the same volume of hypochlorous acid (HOCl) and hydrochloric acid (HCl) for complete reaction. Explain why.

The same volume is needed because both acids have same number of hydrogen ions available for reaction (since same concentration and same volume).

This is enough explanation for the US.

For an AS answer looking towards M or E you would need to explain this further, including appropriate equations:

A strong acid such as HCl is fully ionised or fully dissociated in water:
$HCl(aq) + aq \rightarrow H^+(aq) + Cl^-(aq)$
A weak acid such as HOCl is partially ionised or partially dissociated in water:
$HOCl(aq) + aq \rightleftharpoons H^+(aq) + OCl^-(aq)$.
Equal volumes of the same concentration acids will have the same number of H^+ ions available for reaction but with the strong acid they are all "available" at once to react, where as in the weak acid, there are less "available" at any time but as they are used up, the equilibrium position shifts to the right to replace them, until eventually all the available H^+ ions will have been released from the weak acid HOCl. The total number of H^+ ions is the same in each case so they will react with the same amount of…[Mg / $NaHCO_3$ / $CaCO_3$] … reactant. They would also produce the same amount of product… [salt + H_2 / CO_2 + H_2O]. The only difference will be the RATE at which the reaction occurs.

element 2

Perform calculations involving acid-base reactions.

performance criteria

PC 2.1	Calculations determine the concentration of an acid or base from acid-base titration data.

Example 1

The following results were obtained from a titration between a solution of oxalic acid ($H_2C_2O_4$) and standard sodium hydroxide (NaOH).

$$H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O$$

Volume of oxalic acid samples = 20.0 mL
Concentration of sodium hydroxide = 0.145 mol L^{-1}
Average volume of sodium hydroxide used = 23.8 mL

What is the ratio of moles $H_2C_2O_4$**:** moles NaOH?

Answer:

1 mole $H_2C_2O_4$: 2 moles NaOH

$H_2C_2O_4 + 2NaOH \rightarrow Na_2C_2O_4 + 2H_2O$
1 mol 2 mol
So mole ratio $H_2C_2O_4$: NaOH is 1:2

Calculate the concentration of $H_2C_2O_4$ (in mol L^{-1} to 3 significant figures.).

n(NaOH) = 0.145 x 23.8 / 1000 = 0.003451 mol

n($H_2C_2O_4$) = 0.003451 / 2 = 0.0017255 mol

C($H_2C_2O_4$) = 0.0017255 / (20.0 / 1000) = 0.086275 mol L^{-1}

So concentration of $H_2C_2O_4$ =0.0863 mol L^{-1}(3 s.f.)

STRATERGY

- *n(the thing you know C and V for)*
- *n (the thing whose C you are finding, that you know V for – and don't forget to check mole ratio)*
- *C(the thing you have been asked to find out)*
- *Need to know n = C.V and C =n/V*

REMEMBER: All volumes must be converted to L by dividing the volume in mL by 1000.
When it's a 1:2 or 2:1 ratio then look carefully. If you "know the 2 mol thing and are finding the 1 mol thing" then divide by 2. If you "know the 1 mol thing and are finding the 2 mol thing" then multiply by 2.

Example 2

The following results were obtained from a titration between a solution of sodium carbonate (Na_2CO_3) and standard hydrochloric acid (HCl).

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

Volume of sodium carbonate samples = 25.0 mL. Concentration of hydrochloric acid = 0.120 mol L^{-1}. Average volume of hydrochloric acid used = 18.8 mL

What is the ratio of moles Na_2CO_3 **:** moles HCl? *1 mole Na_2CO_3 : 2 moles HCl*
Calculate the concentration of Na_2CO_3 (in mol L^{-1} to 3 significant figures.).
n(HCl) = 0.120 x 0.0188 = 0.002256 mol. n(Na_2CO_3) = 0.002256 / 2 = 0.001128 mol.
C(Na_2CO_3) = 0.001128 / 0.0250 = 0.04512 = 0.0451 mol L^{-1} (3 sf)

PC2.2 The relationship between hydronium ion concentration, hydroxide ion concentration and pH is established by interconversion calculations.

For the following questions, use $K_w = 1 \times 10^{-14}$
Convert the following concentrations in mol L^{-1} to pH (to **three significant figures**)

a) $[H_3O^+] = 1.05 \times 10^{-9}$ pH = *8.97*

b) $[H_3O^+] = 5.62 \times 10^{-3}$ pH = *2.25*

c) $[OH^-] = 1.20 \times 10^{-5}$ pH = *9.08*

$[H_3O^+]=10^{-14}/1.20 \times 10^{-5} = 8.33 \times 10^{-10}$
pH = - log 8.33×10^{-10} = 9.08 (3 sf)

d) $[OH^-] = 2.85 \times 10^{-6}$ pH = *8.45*

$[H_3O^+]=10^{-14}/2.85 \times 10^{-6} = 3.51 \times 10^{-9}$
pH = - log 3.51×10^{-9} = 8.45 (3 sf)

pH = - log $[H_3O^+]$
Learn the sequence of key presses to achieve this in your particular calculator!! Write answer to 3 sf.

$Kw = 10^{-14} = [H_3O^+].[OH^-]$
so if you are given a $[OH^-]$ and asked to calculate the pH…
- *first calculate $[H_3O^+]$*
  $[H_3O^+] = 10^{-14} / [OH^-]$
- *then use the $[H_3O^+]$ to calculate the pH*
  pH = - log $[H_3O^+]$
- *and write answer to 3 sf.*

Determine **both** the $[H_3O^+]$ and $[OH^-]$ concentrations (to **three significant figures**) of solutions with the following pH values.

a) pH = 5.50 $[H_3O^+]$ = *3.16×10^{-6} mol L^{-1} (3 sf)* $[OH^-]$ = *3.16×10^{-9} mol L^{-1} (3 sf)*

b) pH = 9.73 $[H_3O^+]$ = *1.86×10^{-10} mol L^{-1} (3 sf)* $[OH^-]$ = *5.37×10^{-5} mol L^{-1} (3 sf)*

$[H_3O^+]$ = inv log (- pH)
Learn the sequence of key presses to achieve this in your particular calculator!! Write answer to 3 sf. Eg on a Casio fx-82MS, SHIFT LOG (–) 5.50 = 3.16227766 $_{x10}$ $^{-06}$ (SHIFT LOG = 10^x)

To find $[OH^-]$ use the fact that $Kw = 10^{-14} = [H_3O^+].[OH^-]$ so $[OH^-] = 10^{-14} / [H_3O^+]$

Learn to enter the numbers properly and how to use your calculator! Learn how to write them down from your calculator!

1.05×10^{-9} is 1.05 EXP - 9 and NOT 1.05 x 10 and then EXP – 9 (which gives you 1.05×10^{-8} instead)

Display says 2.85 ^{x10} $^{-06}$? Then write it down as 2.85×10^{-6}