# *A Guide to Acids and Bases*

## Teaching Approach

In this series on acids and bases, we find out that new and exciting content has been added into the new curriculum. For instance we realise that acid base constants (Ka , Kw and Kb) and related calculations are now examinable. It is necessary therefore that this series deals with such new concepts.

As you shall find, question 6 has been designed in an attempt to cover areas that can easily lead to misconceptions. For example, a strong acid dissociates completely; thus we cannot represent its dissociation equation using double arrows. Double arrows will be used only when dealing with weak acids or bases which do not dissociate completely. In essence, the following is correct:

$$HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+{}_{(aq)} + Cl^-{}_{(aq)}$$

and this is incorrect: $HCl_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + Cl^-{}_{(aq)}$ because HCl is a strong acid and dissociates completely. Therefore, only a single arrow should be used. But for weak acids, such as ethanoic acid, a double/reversible arrow is appropriate as shown below:

$$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$$

Therefore lesson 8 and corresponding question six should be enriching and useful in helping the learner understand some tricky concepts.

This guide cannot be used in isolation; it however endeavours to cover as much content as would be relevant for the CAPS curriculum.

Learners are also introduced to the pH scale and the effect of indicators at different pH values with particular emphasis on use of indicators in titrations.

Generally, throughout the series, the acid-base definitions are discussed according to different models (Arrhenius and Bronsted-Lowry), and acid base titrations, neutralisation, equivalence and end points are also covered.

It is strongly advised that the lessons be covered in the order given.

## Video Summaries

Some videos have a 'PAUSE' moment, at which point the teacher or learner can choose to pause the video and try to answer the question posed or calculate the answer to the problem under discussion. Once the video starts again, the answer to the question or the right answer to the calculation is given

Mindset suggests a number of ways to use the video lessons. These include:

- Watch or show a lesson as an introduction to a lesson
- Watch or show a lesson after a lesson, as a summary or as a way of adding in some interesting real-life applications or practical aspects
- Design a worksheet or set of questions about one video lesson. Then ask learners to watch a video related to the lesson and to complete the worksheet or questions, either in groups or individually
- Worksheets and questions based on video lessons can be used as short assessments or exercises
- Ask learners to watch a particular video lesson for homework (in the school library or on the website, depending on how the material is available) as preparation for the next day's lesson; if desired, learners can be given specific questions to answer in preparation for the next day's lesson

### 1. Arrhenius' Acid-Base Model

The definition of an acid and base are discussed according to Arrhenius.

### 2. Lowry-Bronsted Acid-Base Model

The definition of an acid and base are discussed according to the Bronsted-Lowry theory.

### 3. Acid-Base Conjugate Pairs

The sometimes tricky concept of conjugate acid base pairs is discussed and covered in detail. Relevant examples are given.

### 4. Neutralisation

This lesson focuses on neutralisation reactions of acids and bases. Neutralisation reactions of acids and carbonates, hydroxides and oxides are taught.

### 5. Indicators

This lesson covers indicators as they are used in acid-base reactions. A selection of indicators for different reactions is also covered.

### 6. Titrations

The process of titration is explained.

### 7. pH Scale

This lesson discusses the pH scale as an indication of acid or base strength. The equation used to calculate pH is taught.

## 8. Ionisation and Dissociation Constants

Acid, base and water dissociation constants are discussed. Examples of how to use the dissociation expressions/equations are given. Question 6 deals with content covered in this lesson.

## 9. Acids and Bases in Chlor-Alkali Industry

This lesson shows acid base reactions in the massive chlor-alkali industry as a practical example.

## Resource Material

| | | |
|---|---|---|
| **1. Arrhenius' Acid-Base Model**<br>**2. Lowry-Bronsted Acid-Base Model**<br>**3. Acid-Base Conjugate Pairs**<br>**4. Neutralisation**<br>**5. Indicators** | https://www.youtube.com/watch?v=bwzfp3hLp3c | A Mindset learn revision lesson on acid base reactions. |
| **6. Titration** | https://www.youtube.com/watch?v=R9tA2G6_2Tw | A lesson that discusses strong and weak acids and bases, acid reactions, neutralisation reactions as well as indicators. |
| **7. pH Scale** | http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_AcidsBasespHScale.shtml | Acids bases and the pH scale |
| **8. Ionisation and Dissociation Constants** | https://www.chem.wisc.edu/deptfiles/genchem/netorial/rottosen/tutorial/modules/acid_base/03ionization/ion1.htm | Ionisation of acids and bases |
| | https://www.boundless.com/chemistry/acids-and-bases/acids-and-bases/acid-dissosociation-constant-ka/ | A resource on acid dissociation constant. |
| **9. Acids and Bases in Chlor-Alkali Industry** | http://swgfl.skoool.co.uk/examcentre.aspx?id=791#anchor4 | Acids, alkalis and bases. |

# Task

## Question 1

1.1 Give the definition of an acid and a base according to Arrhenius' theory
1.2 Give the definition of an acid and a base according to the Bronsted theory
1.3 Give two examples common household acids.

## Question 2

2.1 An acid - base pair that differs from each other by a single proton ($H^+$ ion) is called a ............
2.2 The negative logarithm of $H^+$ ion concentration of a given solution is known as…
2.3 Write down the dissociation constant of water
2.4 A process of determining volume, moles or concentration of an acid or base by adding it to a standard solution of known concentration.

## Question 3

3.1 Copy and complete the table below:

| **Conjugate acid** | **Conjugate base** |
|---|---|
| $H_3O^+$ | |
| | $HSO_4^-$ |
| $HSO_4^-$ | |
| $NH_4^+$ | |
| | $H_2PO_4^-$ |
| $HPO_4^{2-}$ | |
| $CH_3CH_2NH_3^+$ | |

3.2 Identify the acid, conjugate- acid; base and conjugate-base in the following reactions

3.2.1 $HClO_4(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + ClO_4^-(aq)$
3.2.2 $H_2S(g) + H_2O(l) \rightleftarrows H_3O^+(aq)) + HS^-(aq)$
3.2.3 $NH_3(g) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq$
3.2.4 Complete the equation for the reaction of each of the following with water. Indicate whether each reaction is explained by Arrhenius, Bronsted-Lowry, or both.

I. $HI(aq) + H_2O(l)$
II. $HCl(aq) + H_2O(l)$
III. $HF(aq) + HSO_3^-(aq)$

## Question 4

Where on the pH scale would you find:
4.1 Acids?
4.2 Bases?
4.3 Neutral substances?

### Question 5

Copy and complete the following table:

| Indicator | Colour in acid | Colour in base |
|---|---|---|
| Bromothymol blue | | |
| Methyl orange | | |
| Phenolphthalein | | |

### Question 6

6.1 What is an endpoint as it is known during a titration? Explain how it differs from an equivalent point.

6.2 Describe two ways you could use to identify and confirm the end point of a reaction between a strong base and a strong acid. Give an example of the indicator you would use.

6.3 A solution made from pure barium hydroxide contained 2,74 g in exactly 100 $cm^3$ of water. Using phenolphthalein indicator, titration of 20,0 $cm^3$ of this solution required 18,7 $cm^3$ of a hydrochloric acid solution for complete neutralisation.

6.3.1 Write the equation for the titration reaction

6.3.2 Calculate the molarity of the barium hydroxide solution.

6.3.3 Calculate the moles of barium hydroxide neutralised.

6.3.4 Calculate the moles of hydrochloric acid neutralised.

6.3.5 Calculate the concentration of the hydrochloric acid in $mols \cdot dm^{-3}$

6.3.6 Using your result in question 6.2.5, calculate the pH of the hydrochloric acid solution

6.3.7 Therefore calculate the dissociation constant of this reaction and explain what is meant by the results.

6.4 The hydronium ion concentration of a 0,500 $mol \cdot dm^{-3}$ solution of HF at 25°C is found to be 0,0185 M. Calculate the dissociation constant for HF at this temperature.

### Question 7

Ammonium thioglycolate is also known as a perm salt. Ammonium thioglycolate undergoes a reversible reaction to form thioglycolic acid and free ammonia.

$HSCH_2COO^-(aq) + NH_4^+(aq) \rightleftarrows HSCH_2COOH(aq) + NH_3(aq)$

Identify the conjugate acid base pairs in the above reaction

# Task Answers

## Question 1

1.1 An Arrhenius acid forms $H_3O^+$ in water (increases $[H_3O^+]$). An Arrhenius base forms $OH^-$ in water (increases $[OH^-]$).

1.2 According to Bronsted theory, an acid is a proton donor, and a base is a proton acceptor

1.3 Lemon juice, vinegar.

## Question 2

2.1 Conjugate acid base pair

2.2 pH

2.3 $K_w = [H_3O^+][OH^-]$

2.4 Titration

## Question 3

3.3 Copy and complete the table below:

| Conjugate acid | Conjugate base |
|---|---|
| $H_3O^+$ | $H_2O$ |
| $H_2SO_4$ | $HSO_4^-$ |
| $HSO_4^-$ | $SO_4^{2-}$ |
| $NH_4^+$ | $NH_3$ |
| $H_3PO_4$ | $H_2PO_4^-$ |
| $HPO_4^{2-}$ | $PO_4^{3-}$ |
| $CH_3CH_2NH_3^+$ | $CH_3CH_2NH_2$ |

3.4 Identify the acid, conjugate- acid; base and conjugate-base in the following reactions

3.4.1 .

| | | | |
|---|---|---|---|
| $HClO_4$(aq) | + $H_2O$(l) | $H_3O^+$(aq) | + $ClO_4^-$(aq) |
| acid | base | conj. acid | conj. base |

3.4.2

| | | | |
|---|---|---|---|
| $H_2S$(g) | + $H_2O$(l) | $H_3O^+$(aq) | + $HS^-$(aq) |
| acid | base | conj. acid | conj. base |

3.4.3

| | | | |
|---|---|---|---|
| $NH_3$(g) | + $H_2O$(l) | $NH_4^+$(aq) | + $OH^-$(aq) |
| base | acid | conj. acid | conj. base |

3.4.4 Complete the equation for the reaction of each of the following with water. Indicate whether each reaction is explained by Arrhenius, Bronsted-Lowry, or both.

I. HI(aq) + $H_2O$(l) ⇄ $I^-$(aq) + $H_3O^+$(aq)

Bronsted-Lowry and Arrhenius acid

II. HCl(aq) + $H_2O$(l) ⇄ $Cl^-$(aq) + $H_3O^+$(aq)

Bronsted-Lowry and Arrhenius acid

III. HF(aq) + $HSO_3^-$(aq) ⇄ $F^-$(aq) + $H_2SO_4$(aq)

Bronsted-Lowry

## Question 4

4.1 . pH less than 7
4.2 pH greater than 7
4.3 pH of 7

## Question 5

| Indicator | Colour in acid | Colour in base |
|---|---|---|
| Bromothymol blue | Yellow | Blue |
| Methyl orange | Red | Yellow |
| Phenolphthalein | Colourless | Pink |

## Question 6

6.1 An endpoint is the point for an acid –base titration when an indicator changes colour, whereas an equivalence point is when an equivalent amount of acid and base have reacted. Ideally they should be the same.

6.2 a pH of 7; use an indicator such as litmus to show end point

6.3

6.3.1 $Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

6.3.2 Formula mass of $Ba(OH)_2$ = 171g·mol$^{-1}$,

$n = \frac{m}{M}$

$= \frac{2.74}{171}$

= 0.016 mol in 100 cm$^3$,

∴ there are 0.16 mol in 1000 cm$^3$, (scaling up x 10)

so concentration of $Ba(OH)_2$ is 0.16 mol·dm$^{-3}$

6.3.3 moles $Ba(OH)_2$ used in titration = 0.16 x $\frac{20}{1000}$ (converted 20cm$^3$ to dm$^3$ by dividing by 1000)

= 0,0032 mol

6.3.4 $Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$

According to molar ratios (2:1 in equation)

moles HCl titrated = 2 x moles of $Ba(OH)_2$ used

= 2 x ,0032

= 0,0064 mol HCl in 18.7 cm$^3$ of the acid solution, (18,7 cm$^3$ = 0,0187 dm$^3$)

6.3.5

Concentration of HCl(aq) $= \frac{moles}{volume\ (dm^3)}$

$= \frac{0.0064}{0.0187}$

= 0,342 mol·dm$^{-3}$

6.3.6 The pH of the HCl is calculated as follows:

$pH = -\log [H_3O^+]$

= -log (0,342)

= 0,47

6.3.7 **Dissociation constant of HCl** (enrichment question)

The $K_a$ relates to the concentration of hydronium ion, acid anion, and *original acid*, in this case HCl acid.

NB: Since HCl is a strong acid therefore dissociates completely in aqueous solution/ water and we represent the reaction using one arrow, not a reversible arrow, as shown below

| | HCl | --> | $H^+$ | + | $Cl^-$ |
|---|---|---|---|---|---|
| Initial moles | 0,342 | | 0 | | 0 |
| [@ equilibrium] | 0 | | 0,342 | | 0,342 |

Therefore we cannot use an equilibrium constant to represent dissociation of HCl or a strong acid since there is no equilibrium.

So $K_a$ calculations are useful for weak acids and bases, which do not ionise/dissociate completely. These go into equilibrium hence we are able to calculate an equilibrium constant, $K_a/K_b$

6.4

| | Data |
|---|---|
| Molar concentration of $H_3O^+$ at equilibrium | 0,0185 M |
| Molar concentration of $F^-$ at equilibrium | ? M |
| Initial molar concentration of HF | 0,500 M |
| Molar concentration of HF at equilibrium | ? M |
| *Ka* of HF | ? |

**Write balanced equation:**

$HF(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + F^-(aq)$

Write expression;

$$K_a = \frac{\overset{given}{[H_3O^+]}\ [F^-]}{\underset{given}{[HF]_{initial}} - \underset{given}{[H_3O^+]}}$$

$$K_a = \frac{[0.0185]\,[0.0185]}{[0.500] - [0.0185]}$$

(remember $[H_30^+] = [F^-]$ during dissociation
Therefore $[F^-] = 0{,}0185 mol\cdot dm^{-3}$)

$$= 7.11 \times 10^{-4}$$

## Question 7

| | | | | |
|---|---|---|---|---|
| $HSCH_2COO^-$ (aq) | $NH_4^+$ (aq) | $\rightleftarrows$ | $HSCH_2COOH(aq)$ | $NH_3(aq)$ |
| conj. base | conj. acid | | acid | base |

## Acknowledgements

| | |
|---|---|
| Mindset Learn Executive Head | Dylan Busa |
| Content Manager Classroom Resources | Jenny Lamont |
| Content Coordinator Classroom Resources | Helen Robertson |
| Content Administrator | Agness Munthali |
| Content Developer | Angela Stott |
| Content Reviewers | Xolani Sithenjwa |
| | Duncan Chiriga |

## Produced for Mindset Learn by Traffic

| | |
|---|---|
| Facilities Coordinator | Cezanne Scheepers |
| Production Manager | Belinda Renney |
| Director | Alriette Gibbs |
| Editor | Nonhlanhla Nxumalo |
| Presenter | Banji Longwe |
| Studio Crew | Abram Tjale |
| | James Tselapedi |
| | Wilson Mthembu |
| Graphics | Wayne Sanderson |

## Credits

http://upload.wikimedia.org/wikipedia/commons/4/4d/Titration_Apparatus.png