# Acids and Bases

## Properties of Substances

### Acids:

- Conduct electrical current
- Turns blue litmus paper red
- Has a sour taste
    - Most metal oxides have low solubilities (low K value)

### Bases:

- Conduct electricity
- Turns red litmus paper blue
- Has a soapy feel

## Data Sheet

- All Metals are silvery grey unless specified by data sheet as **Other Coloured Substances**
- Look at top table to determine colour as a solid
    - If solid is not present in table, go to end table. If it contains an ion from bottom table, solid takes its colour
- Look at bottom table to determine colour of aqueous substance
    - Solids often take colour as aqueous ion
- Look at third table to determine colour of free halogen (not mixed)
- Look at fourth table to determine colour of aqueous halogen
- Fifth table shows colour of halogen in organic solvent

## Terminology

- Acids are proton donors
- Bases are proton acceptors
- Alkali are soluble bases
- A strong acid is a substance that fully ionizes in solution and is a proton donor
- A weak acid is a substance that partially ionises in solution and is a proton donor
- A concentrated acid is a substance with a high number of acid moles per unit volume
- A diluted acid is a substance with a low number of acid moles per unit volume

## Strength

- Substances can be both weak and concentrated/strong and diluted
- Strong acids are:
    - $HNO_3$
    - $H_2SO_4$
    - $HCl$
- Weak acids are all other proton donors
- Strong bases are:
    - Group 1 and 2 metal oxides and hydroxides
- Weak bases are all other proton acceptors

- includes:
    - $NH_3$ which is a base
    - $H_3PO_4$ which is weak acid
    - HF which is weak acid
    - $HSO_4^-$ which is amphiprotic, but tends to be an acid
    - $H_2PO_4^-$ $\Rightarrow$ amphoteric, tends to be acidic
    - $HPO_4^-$ $\Rightarrow$ amphoteric, tends to be basic
    - $HC_2O_4^-$ $\Rightarrow$ tends to be acid
    - $HCO_3^-$ $\Rightarrow$ tends to be basic
- To determine strength of a substance, separate substance into ions then perform hydrolysis with acidic/basic substance

# Acid-Base Reactions

$$Acid + Base \rightarrow Salt + water \quad Acid + Metal \rightarrow Salt + H_{2(g)}$$

$$Acid + Metal\ Sulfite \rightarrow Salt + water + SO_{2(g)}$$

$$Base + NH_4^{+\text{¿}} \rightarrow Salt + water + NH_3\text{¿} \qquad Base + non\ metal\ oxide \rightarrow Salt + water$$

- Non-metal oxides are acidic (ex. SO2 or CO2), as they react with $H_2O$ to form an acid (ex. $H_2CO_3$ or $H_2SO_3$), which ionises

# Brønsted-Lowrey Theory

- Acid-base reactions are reversible
- Acids are proton donors
- Bases are proton acceptors
- **-no contrasting questions between BL and Arrhenius will come up (older questions)
- $H_3O^+ \Rightarrow H^+ \Rightarrow$ proton

## Conjugate Acid-Base Pair

$$A' + B' \rightarrow A + B$$

- If A' is acid, A is conjugate base
- If B' is base, B is conjugate acid
- A' and A are conjugate pairs $(A' \vee A)$
- B' and B are conjugate pairs $(B' \vee B)$

## Amphiprotic

- Substances that can both donate and accept protons $\Rightarrow$ amphiprotic
- Substances that can react as acid or base $\Rightarrow$ amphoteric
    - All amphiprotic substances are amphoteric, but all amphoteric substances are not necessarily amphiprotic
    - Amphiprotism $\Rightarrow$ Amphiterism NOT Amphiprotism $\Leftrightarrow$ Amphiterism
    - Ex. $Al_2O_3$ is amphoteric, but not amphiprotic $\Rightarrow$ cannot donate protons
- An amphiprotic substance will act as an opposite (acid/base) to the other substance
- Polyprotic acids that have a mid-charge are amphiprotic

## Solubility/Strength

- Use K to determine whether amphiprotic substance is more acidic or basic
- Carbon-based organic acids are generally weak
- Conjugate of strong substance is weak

## Polyprotic

- Polyprotic substance donate multiple protons in solution
- K decreases with each donated proton:

$$K_1 > K_2 > K_3 \ldots$$

- Number of protons present provides no info about strength

## Self-Ionization of Water

$$K_w = ¿ 2H_2O \rightleftharpoons H_3O^{+¿+OH^{-¿¿}¿} ¿ \therefore ¿¿ \therefore ¿$$

- Reaction is endothermic
  - Therefore, when temperature increase [products] will increase
  - Therefore, [H3O+] increases, hence, as pH=-log[H3O+], pH decreases
  - However, solution remains neutral as $[H_3O^+]=[OH^-]$

## Hydrolysis

- Hydrolysis is the reaction between substance and water to produce an ion
- Model answer:
  - Hydrolysis of A' (proton donor) produces $H_3O^+$ in solution when reacting with $H_2O$ (proton acceptor). Therefore, A' is an acid
    - Supported by equation
- **$HCO_3^-$, $CO_3^{2-}$, $HPO_4^{2-}$, $PO_4^{3-}$ and $SO_4^{2-}$ an bases**
- **$HSO_4^-$, $H_2PO_4^-$ and group 13 metals are acids**

## Buffers

- A buffer is a solution that resists changes in pH when a small amount of acid or base is added
  - Ex. Weak acid and its conjugate base

$$CH_3COOH \vee CH_3COO^{-¿¿}$$

- Buffering capacity is the extent to which a buffer resists change in pH, when a small amount of acid or base is added
  - Substances that have higher buffer capacities are better buffers

## Factors that affect buffering capacity include:

- Exact concentration of each solution
- Relative concentration of each solution
  - Aquimolar amounts of acid and conjugate base is required, or buffering capacity will be low
- Type of chemical used

## How to explain Buffer chemistry

- Acid added
  - Always start with acid hydrolysis

$$x^{'}+H_2O\,x+\rightleftharpoons \text{¿}\, H_3O^{+\text{¿¿}}\text{¿}$$

- When acid added, $[H_3O^+]$ increases
- Therefore, equilibrium shifts to the left to partially oppose the change in $[H_3O^+]$ according to LCP (reverse reaction favoured)
- Therefore, most of the $H_3O^+$ added is removed
- Therefore, change in $[H_3O^+]$ will be negligible
- Therefore, as pH=-log$[H_3O^+]$, change in pH will be negligible
- Therefore, pH will be maintained within a narrow range

- Base added
  - When base is added, $[OH^-]$ increases, which reacts with $H_3O^+$ to form $H_2O$ (neutralisation reaction)

$$O\,H^{-\text{¿}+H_3O^{+\text{¿}\rightleftharpoons 2H_2O\text{¿}}}\text{¿}$$

- Therefore, $[H_3O^+]$ decreases… {continue with previous equilibrium explanation}

## Making Buffers

- Buffers are made from a weak acid and its conjugate base or weak base and its conjugate acid
- A weak substance and its conjugate is added in equal concentrations

## Double Equation Explanations

- After explaining buffer for acid added with equation:

$$A^{'}+B^{'}\rightleftharpoons A+B$$

- Write equation:

$$A+B\rightleftharpoons A^{'}+B\,'$$

- Such that conjugate (A) of initial reaction (A') is in forward reaction
- Then explain for base, using conjugate

# pH Calculations

- Assume 100% ionization for all pH questions

$$pH=-\log \text{¿}$$

# Primary Standard Solutions

- PSS are substances that have an accurately known concentration
- Prepared by weighing sample of PSS, dissolving in distilled water, then increasing volume to a precise value in a volumetric flask
- PSS must:
  - Be able to be obtained in a very pure form consistent with its chemical formula
  - Be sufficiently stable so that on exposure to air, it doesn't change its water content or react with $CO_2$ in the air
  - Have a relatively high molar mass

- Substances that do not fulfill PSS criteria must be standardised through a titration, and it can be used as a secondary standard solution
- Secondary standard solutions are not as accurate as PSS and therefore have higher uncertainty

## Acid-Base Titration

- Carefully measured volume of one solution (aliquot) is added to a conical flask
- Variable volume of known concentration (titre) is added from burette to conical flask until acid-base reaction is complete
- Equivalence point occurs when neither acid nor base is remaining
- End point occurs when indicator has changed colour to indicate equivalence has occurred
- Equivalence point must be very close to end point for the titration to be accurate
    - Therefore, suitable indicator must be chosen specific to substances used

## Performing Titrations

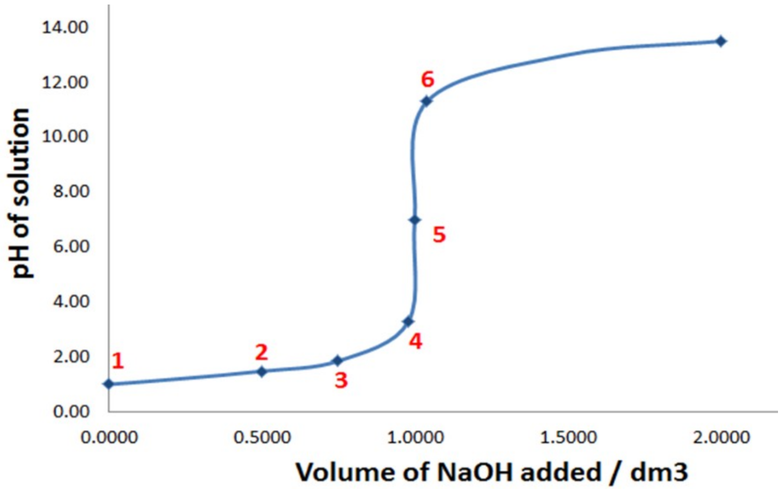
1. Aliquot volume is carefully measured with pipette (usually 20mL)
2. Solution is transferred to a clean **conical flask** that has been **pre-rinsed with distilled water**
3. Few drops of suitable indicator are added to conical flask
4. Titre is placed inside **burette** that has been **pre-rinsed with the titre**
5. Reagent is then released in a controlled way from burette into conical flask
6. When indicator changes colour, no more titre is added

- Back titration is similar to normal titration, except instead of aliquot consisting of substance to be determined, aliquot consists of excess hydrogen or hydroxide ions from a reaction with the unknown substance.

## Indicators

- Phenolphthalein is a basic indicator (8.3-10)
    - Colourless in acidic solution
    - Pink in basic solution
- Methyl orange is acidic indicator (3.1-4.4)
    - Methyl Orange ⇒ ROY (Red (acid), Orange (equivalence point), Yellow (base))
- To determine which indicator used, do hydrolysis of salt formed at equivalence point. Basic means phenolphthalein, acid mean MO
- Answer structure:
    1. [Base] is strong base, [Acid] is weak acid
    2. At equivalence point, basic salt is produced ([salt])
    3. Hydrolysis of [salt] (proton acceptor) forms $OH^-$ ions in solution, when reacting with water (proton donor)
    4. $salt + H_2O_{(l)} \rightleftarrows salt\ dissociated + OH^{-\text{¿¿}}_{(aq)}$
    5. Therefore, equivalence point will be higher than seven (ex. around 9), as $OH^-$ ions are produced
    6. Phenolphthalein has equivalence point at 8.3-10, therefore, phenolphthalein is a suitable indicator

- Use pH curve to support answer:




Errors in titrations

- ▯ Systematic errors cause lower accuracy
- Use correct technique to eliminate
- Examples
- Faulty balance
- Some of substance/solution being left in original container
- Primary standard inflated due to having absorbed water
- ▯ Random errors cause lower precision
- Minimise by averaging several titre values - don't include outlier/anomaly
- Can never be eliminated
- Examples
- Uncertainty in measurements (last value after decimal place) - includes

scales

- Whether meniscus sits on line when using pipette

# Back Titration

- Back titrations
  - When to use
    - One reactant is volatile (ammonia)
    - Acid/base is insoluble salt (calcium carbonate)
    - Reaction is too slow
    - Weak acid/base titration (no clear end point to approximate equivalence)
  - Method
    - React acid/base with a known amount of an excess reagent (standard solution that is a strong base/acid)
    - Excess reagent remaining is titrated with a standard solution that is a strong acid/base to determine the number of moles of the excess reagent remaining
    - Subtract this value from the initial number of moles of the excess reagent to give the number of moles that reacted with the unknown acid/base
    - Thus, can work out the number of moles and concentration of unknown acid/base in original substance