6. (a) $n = C \times V$
(b) 0.5 moles per litre
(c) (i) 3 moles; (ii) 1 mol L^{-1}

20 Acid-Base Titrations

1. (a) A procedure used to find experimentally the concentration (molarity) of a solution. It is an accurate volumetric analysis technique.
(b) The solution, in a titration, whose accurate concentration is known.
(c) The point during a titration when the reaction is complete.
(d) A dye that changes colour in acid and base.
(e) The point during a titration when the indicator changes colour.

2. (a)

Acid	Strong or weak	Base	Strong or weak
HCl	Strong	KOH	Strong
H_2SO_4	Strong	NH_4OH	Weak
H_2CO_3	Weak	NaOH	Strong
CH_3COOH	Weak	KOH	Strong

(b)

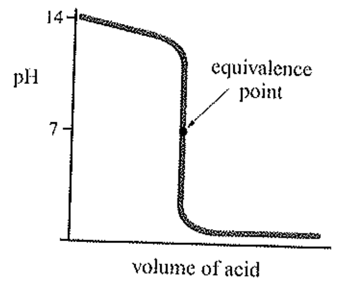
Acid	Base	Suitable indicator
HCl	KOH	Bromothymol blue
H_2SO_4	NH_4OH	Methyl orange
H_2CO_3	NaOH	Phenolphthalein
CH_3COOH	KOH	Phenolphthalein

3. (a) Neutralisation.
(b) Exothermic.
(c) $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
(d) 1:1
(e) 7
(f) Strong acid reacting with a strong base, forming the neutral salt sodium chloride and neutral water.
(g) Bromothymol blue.

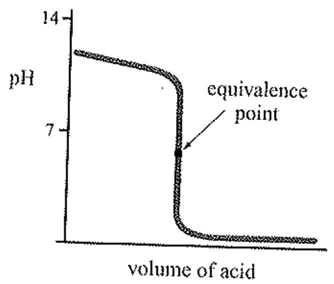
4. Weak base and a strong acid producing an acidic salt. Sulfuric acid will ionise fully whereas sodium carbonate will only partly ionise. The equivalence point will be in the acid range.
A suitable indicator would be methyl orange as it changes colour between pH 3.1–4.4 (acidic).

5. (a) Determining the actual quantities of substances present — involves measurements.
(b) Volumetric analysis includes measuring the volumes of reacting solutions. A volume of a solution of known concentration is reacted with a measured volume of a solution whose concentration is to be determined.
Use — find the concentration of an acid in wine or vinegar.
Gravimetric analysis is a method of chemical analysis involving the measurement of the masses of substances used in, and produced by, a chemical reaction.
Use — find the amount of metal in an ore.

6. (a) strong acid/strong base



(b) strong acid/weak base



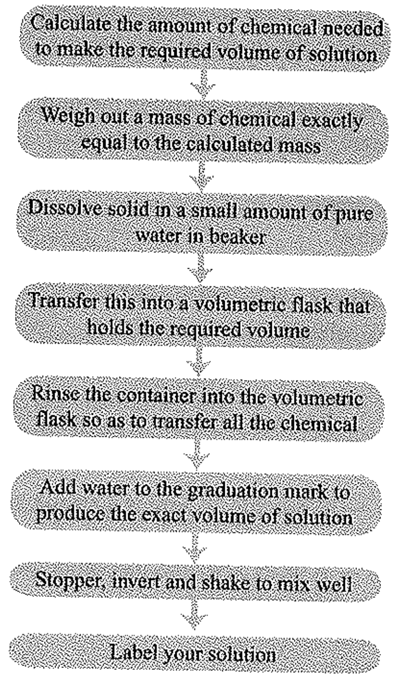
7. (a) (i) W = 7; X = 8; Y = 6
(ii) W = strong base with strong acid.
Equivalence point pH is 7, indicating equal concentrations of hydrogen and hydroxide ions so acid and base must both have ionised equally. The salt formed is neutral.
X = strong base with weak acid.
Equivalence point pH is >7, indicating the base ionised completely and the acid did not and a basic salt was formed.
Y = weak base with strong acid.
Equivalence point is < 7, indicating the acid ionised fully and the base did not, forming an acidic salt.
(iii) W = bromothymol blue.
X = phenolphthalein.
Y = methyl orange.
(b) (i) Graph W = strong acid with strong base.
(ii) None — weak base and weak acid — not suitable for titration with an indicator.
(iii) Graph Y = weak base and strong acid.
(iv) Graph X = strong base with a weak acid.

8. (a) Quantitative.
(b) Titration.
(c) Equivalence.
(d) End.
(e) Bromothymol blue.
(f) Methyl orange.
(g) Phenolphthalein.

21 Standard Solutions

1. D
2. (a) A standard solution is one whose concentration is known accurately.
(b) A primary standard is a solution that is made by dissolving an accurately measured mass of a solute in a small amount of the solvent and making the volume up to a measured volume using a volumetric flask. A secondary standard is a solution whose concentration is determined by titration against a primary standard.
(c) Can be obtained in a pure form (common acids such as HCl and H_2SO_4 would not be suitable as their concentration varies from batch to batch); has a known chemical formula; is stable and does not change when exposed to air (sodium hydroxide would not be suitable as it absorbs water from air and reacts with carbon dioxide in the air); is soluble.
(d) Acidic — hydrated oxalic acid.
Basic — anhydrous sodium carbonate.

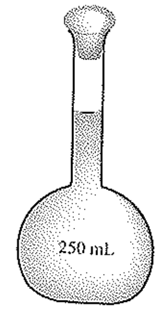
3.



4. (a) Sodium hydroxide — it will neutralise the acidic vinegar; you cannot titrate two acids against each other.
(b) No — you would be titrating two solutions of unknown concentration, you need to know the concentration of one and the volume of both.
(c) Titrate the hydrochloric acid with the sodium hydroxide. Use the results to calculate the concentration of the sodium hydroxide. Then titrate the sodium hydroxide with the vinegar.

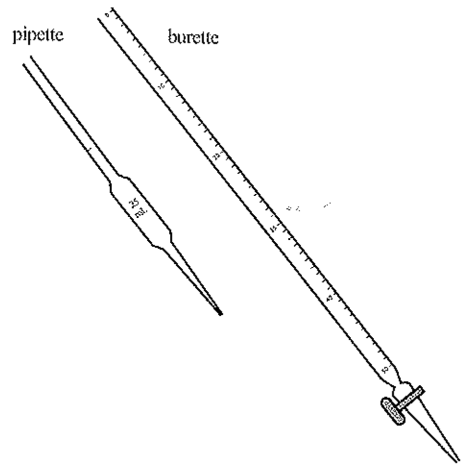
5. (a) Primary standard.
(b) Sodium carbonate.
(c) Secondary standard.

(d)



22 Titration Equipment

1.

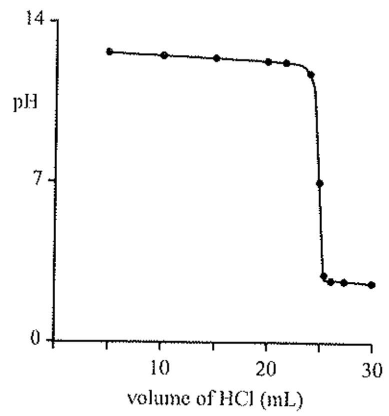


2. (a) Water.
(b) Sodium hydroxide.
(c) Hydrochloric acid.
3. Aliquot — the volume measured out by a pipette.
Titre — the volume delivered by the burette.
4. (a) Pipette fillers are safer — no chance of swallowing the liquid being pipetted.
(b) Various, e.g. create a negative pressure in the bulb. Open the bulb to pipette to suck up the solution, allow it to come up past the mark. Open bulb to air to expel liquid down to the mark.
(c) Calibrated to allow for this.
(d) Do not allow liquid to enter the pipette filler.
5. They are corrosive so can dissolve glass and affect the internal volume, making it inaccurate for measuring.
6. (a) Pipette, burette.
(b) Titration flask, volumetric flask.
(c) An aliquot.
(d) A titre.

23 Titration Procedure and Calculations

1. (a) 0.245 mol L^{-1}
(b) 0.52 mol L^{-1}
2. (a) 12.5 mL
(b) 25 mL
3. Essential to accurately measure the volume of the reacting solution and the concentration of the standard so as to be able to calculate accurately the concentration of the reacting solution.

4. Safety goggles, protective clothing, wash up spills with lots of water.
5. It gives an indication of how much solution is needed to reach the end point.
6. (a) 0.36 mol L^{-1} (remember to use the whole number in your calculator for calculating part (b).
   (b) 0.47 mol L^{-1}
7. (a) 13
   (b)



   (c) Graph starts off fairly level, sloping down slightly, indicating a slow drop in pH while the first 24 mL of HCl is added and the sodium hydroxide is being neutralised. During the addition of the next 1.5 mL there is a sudden drop in pH from 11.31 to 3.00. The graph then levels out, curving down slightly as excess acid is added.
   The sharp drop in pH indicates the equivalence point — the reaction between the acid and base is complete.
   The middle of this sharp drop is at pH=7, indicating a reaction between a strong base and a strong acid and the formation of a neutral salt.
8. (a) Various, e.g. sodium carbonate.
   (b) Various, e.g. this could be done as a flow chart using diagrams to show weighing out the sodium carbonate, dissolving it in a small volume of water, transferring it to a volumetric flask of the required volume, adding water to the required volume and mixing the solution.
   (c) Various, e.g hydrochloric acid
   (d) Diagrams here should include washing and rinsing the equipment, measuring out a volume of sodium carbonate with a pipette, transferring it to a conical flask, filling the burette with hydrochloric acid, carrying out the titration.
   (e) 4 times to obtain 4 titres, 1 rough and 3 accurate. Then average the 3 accurate readings.
   (f) Wear goggles; guard against spills, especially when filling burette with acid; wash hands thoroughly when finished.
9. Various, e.g. you might have titrated the hydrochloric acid from Question 8 (now a secondary standard) against a solution of sodium hydroxide of unknown concentration.
10. (a) $Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$
   (b) Down slope — ions combining to form an insoluble salt $BaSO_4$ so the concentration of ions in solution decreases causing the conductivity to decrease.
   Rise in slope — all the Ba^{2+} ions in the flask have reacted with SO_4^{2-} ions. All hydroxide and hydrogen ions have reacted. Extra acid is being added, so the concentration of H^+ ions and SO_4^{2-} ions in the flask is increasing and conductivity increases.
11. (a) Various, e.g. vinegar (contains ethanoic acid).
   (b) You could titrate it against the sodium hydroxide whose concentration was determined in Question 9.
   (c) The sodium hydroxide would be a secondary standard as its concentration was determined by titration against another solution of known concentration. Sodium hydroxide is a base so it would be a suitable substance to titrate against vinegar which is acidic.
   (d) Describe how you diluted the vinegar to a concentration suitable for titrating against your standard.
   Describe the titration — a diagram would be useful here. Remember to state that you performed a rough titration and then 3 accurate titrations.
   (e) Calculate the moles of standard used. Use the equation to find the moles of the commercial product reacting. Calculate the number of moles titrated. Correct for the dilution.
   (f) Describe any problems you encountered.
12. (a) Volumetric.
   (b) Conical.
   (c) Moles per litre (mol L^{-1}).
   (d) Pipette.
   (e) Equivalence.
   (f) End.

24 Buffers

1. (a) No — hydrochloric acid is a strong acid; no equilibrium exists.
   (b) Yes — a weak acid and its conjugate base.
   (c) No — sodium hydroxide is a strong base; no equilibrium exists.
2. (a) Reaction (i): the H^+ ions remove OH^- ions, so the reaction goes left to replace them.
   Reaction (ii): reaction moves right to use up the added H^+ ions.
   (b) $[HCO_3^-]$ stays constant — removed by 1 reaction, added by the other.
3. (a) The term 'buffer' means to protect against change. In chemistry, a buffer is a solution that resists rapid changes in pH when an acid or base is added.
   (b) Buffered systems contain one or more equilibrium reactions that can be shifted left or right by hydrogen or hydroxide ions. The effect of adding H^+ or OH^- is minimised by the equilibrium system. This occurs in blood, where it is important to maintain the pH at 7.4. Blood is buffered by the equilibrium set up with carbonic acid/bicarbonate

ions. Carbon dioxide dissolves in our blood, forming carbonic acid, a weak acid that ionises to form the hydrogen carbonate ion.

$CO_2(g) + H_2O(l) \Leftrightarrow H_2CO_3(aq)$

$H_2CO_3(aq) \Leftrightarrow H^+(aq) + HCO_3^-(aq)$

Because H_2CO_3 is a weak acid, an increase or decrease in the amount of carbonic acid present only produces a small change in hydrogen ion concentration and thus a small change in pH.
4. (a) The following equations are involved in the buffering of blood.

$CO_2(g) + H_2O(l) \Leftrightarrow H_2CO_3(aq)$ .... (i)

$H_2CO_3(aq) \Leftrightarrow H^+(aq) + HCO_3^-(aq)$ .... (ii)

   Loss of excess CO_2 from the lungs would decrease the concentration of CO_2 in blood. This would push equilibrium (i) to the left, which would in turn push equilibrium (ii) to the left. The effect would be a decrease of the $[H^+]$ in blood (less acid). The resulting rise in pH would cause the person to collapse.
   (b) By breathing in and out from a paper bag, the patient is forced to inhale a higher concentration of CO_2. This will push equilibrium (i) and (ii) to the right, causing an increase in $[H^+]$ of the blood (more acid) and the pH would drop to normal.
5. During exercise, respiration in muscle cells produces carbon dioxide.

$C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$

Carbon dioxide enters the blood and dissolves to form carbonic acid, increasing the hydrogen ion concentration and thus decreasing the pH.
Blood is buffered by the following equilibrium reactions.

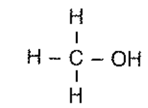
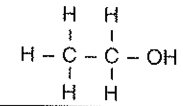
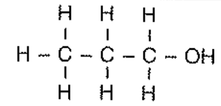
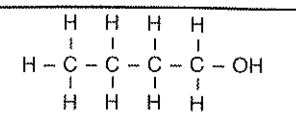
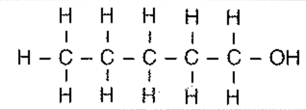
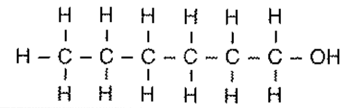
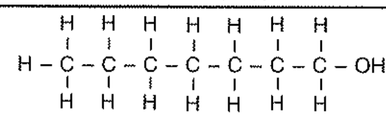
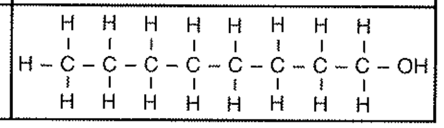
$CO_2(g) + H_2O(l) \Leftrightarrow H_2CO_3(aq)$

$H_2CO_3(aq) \Leftrightarrow H^+(aq) + HCO_3^-(aq)$

Because of this buffer system the extra CO_2 produced by exercise has only a tiny effect on the pH of blood.
6. (a) These two compounds ionise as follows:
   $H_2PO_4^-(aq) \Leftrightarrow H^+(aq) + HPO_4^{2-}(aq)$
   $HPO_4^{2-}(aq) \Leftrightarrow H^+(aq) + PO_4^{3-}(aq)$
   An equilibrium is set up involving the hydrogen ion concentration and the system can thus resist changes in pH.
   (b) $H_2PO_4^-$ and HPO_4^{2-} or HPO_4^{2-} and PO_4^{3-}.
7. (a) Any weak acid, e.g. acetic acid, and its salt, e.g. sodium acetate.
   (b) Carbonic acid and sodium bicarbonate.

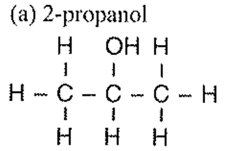
25 Revision of Alkanols

1.

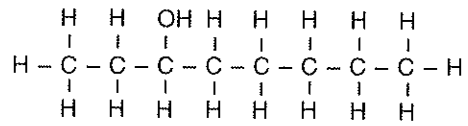
Name	Structural formulae
Methanol	
Ethanol	
Propanol	
Butanol	
Pentanol	
Hexanol	
Heptanol	
Octanol	

2.

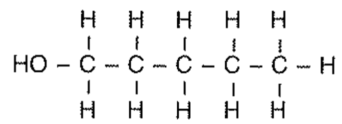
(a) 2-propanol



(b) 3-octanol



(c) 1-pentanol



3. (a) Compound based on carbon.
   (b) Attractive force between a hydrogen in one molecule and a fluorine, oxygen or nitrogen in another molecule.
   (c) OH group.
   (d) Series of carbon compounds with the same general formula and functional group.
   (e) Hydrocarbon chain composed of an alkane with one less hydrogen atom, e.g. methyl CH_3.