

UNIT 5

ACIDS, BASES AND SALTS

Answers

Lesson 1 – What are acids, bases and salts?



Thinkabout Activity 1.1: What do you know about acids and alkalis?

Note: students should be encouraged to identify some common acids and alkalis and give some of their features

- acids: hydrochloric acid, sulphuric acid, nitric acid, lactic acid, citric acid
- vinegar (ethanoic acid), orange/lemon juice (citric acid); many fizzy sweet drinks (coke, sprite) also contain acids
- acids taste sour and bitter and they can sting if in contact with eyes or broken skin
- Alkalis: sodium hydroxide, calcium hydroxide, ammonia, soaps, detergents, bleach
- foods tend not to be strongly alkaline as they would be harmful
- alkalis are generally not good to eat; they feel and taste soapy



Test your knowledge 1.2: Acids, Bases and Salts

- | | |
|--|--------------------------------------|
| a) Na_2O (base) | j) $\text{Ca}(\text{NO}_3)_2$ (salt) |
| b) $\text{Ca}(\text{OH})_2$ (base) | k) H_2SO_4 (acid) |
| c) NH_4NO_3 (salt) | l) NH_4Cl (salt) |
| d) K_2CO_3 (base) | m) HNO_3 (acid) |
| e) SrSO_4 (salt) | n) K_2SO_4 (salt) |
| f) $(\text{NH}_4)_2\text{SO}_4$ (salt) | o) MgO (base) |
| g) HCl (acid) | p) CsBr (salt) |
| h) RbOH (base) | q) BaSO_4 (salt) |
| i) MgCO_3 (base) | r) $\text{Sr}(\text{NO}_3)_2$ (salt) |



Test your knowledge 1.3: Neutralisation Reactions

- | | |
|---|---|
| a) $\text{HNO}_3 + \text{KOH} \rightarrow \text{KNO}_3 + \text{H}_2\text{O}$ | g) $\text{HNO}_3 + \text{CaCO}_3 \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{CO}_2 + \text{H}_2\text{O}$ |
| b) $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$ | h) $2\text{HCl} + \text{BaCO}_3 \rightarrow \text{BaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$ |
| c) $2\text{HCl} + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCl}_2 + 2\text{H}_2\text{O}$ | i) $\text{H}_2\text{SO}_4 + \text{Na}_2\text{CO}_3 \rightarrow \text{Na}_2\text{SO}_4 + \text{CO}_2 + \text{H}_2\text{O}$ |
| d) $2\text{HNO}_3 + \text{CaO} \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{H}_2\text{O}$ | j) $\text{HNO}_3 + \text{NH}_3 \rightarrow \text{NH}_4\text{NO}_3$ |
| e) $2\text{HCl} + \text{BaO} \rightarrow \text{BaCl}_2 + \text{H}_2\text{O}$ | k) $\text{H}_2\text{SO}_4 + 2\text{NH}_3 \rightarrow (\text{NH}_4)_2\text{SO}_4$ |
| f) $\text{H}_2\text{SO}_4 + \text{MgO} \rightarrow \text{MgSO}_4 + \text{H}_2\text{O}$ | l) $\text{HCl} + \text{NH}_3 \rightarrow \text{NH}_4\text{Cl}$ |

Unit 5 – Acids, Bases and Salts

Lesson 2 – What are the physical properties of acids, bases and salts?



Test your knowledge 2.1: Some properties of acids, bases and salts

- (a) eg potassium hydroxide, sodium carbonate, ammonia etc
- (b) eg magnesium oxide, calcium carbonate, aluminium hydroxide etc
- (c) eg sodium chloride, magnesium nitrate, ammonium sulphate etc
- (d) eg silver chloride, lead chloride, barium sulphate etc
- (e) they contain ions and so conduct electricity when in solution
- (f) acids are sour due to H^+ ; bases are soapy due to OH^- ; salts are salty, often due to Na^+
- (g) absorbs water from the atmosphere; eg concentrated sulphuric acid, solid sodium hydroxide, solid calcium chloride
- (h) absorbs water from the atmosphere and then dissolves in the water it has absorbed; eg calcium chloride
- (i) a salt which has water locked into its crystal structure
- (j) Mr of $Ca(NO_3)_2 = 164.1$; $xH_2O = 236.1 - 164.1 = 72$, so $x = 72/18 = 4$, so $Ca(NO_3)_2 \cdot 4H_2O$
- (k) the loss of water from a crystal structure; eg $CaSO_4 \cdot 2H_2O$

Lesson 3 – What is the difference between strong and weak acids?



Practical 3.1: Compare the enthalpy of neutralisation of a strong base and a weak base by the same

- The temperature increase should be around $7^\circ C$ with $NaOH$ and around $5^\circ C$ with NH_3
- The temperature increase is higher with $NaOH$ because the OH^- ions are already in the solution; NH_3 dissociates during the neutralisation to give OH^- ions; this process is endothermic so the overall neutralisation process is less exothermic



Test your knowledge 3.2: Strong and Weak Acids and Bases

- (a) Strong acid fully dissociates in water to give H^+ ions (eg H_2SO_4 , HNO_3 , HCl); weak acid only partially dissociates in water to give H^+ ions (eg ethanoic acid etc)
- (b) Strong base: $NaOH$; weak base due to low solubility: $Ca(OH)_2$, weak base due to limited dissociation: NH_3
- (c) Strong acids are fully dissociated into ions, so the concentration of ions is greater, and the conductivity is due to the presence of ions
- (d) Weak acids must dissociate into ions during neutralisation; this process is endothermic, so the overall reaction is less exothermic

Lesson 4 - What are the other important reactions of acids, bases and salts?



Test your knowledge 4.1: Further Reactions of Acids, Bases and Salts

- (a) reacts with acids and bases/can behave as an acid or a base, eg $NaHCO_3$ or $Al(OH)_3$ or ZnO etc
- (b) (i) $H_2SO_4 + 2KCl \rightarrow K_2SO_4 + 2HCl$; (ii) $HNO_3 + NaF \rightarrow NaNO_3 + HF$; (iii) $H_3PO_4 + 3KBr \rightarrow K_3PO_4 + 3HBr$
- (c) (i) no; (ii) yes $NH_4^+ \rightarrow NH_3 + H^+$; (iii) yes $CH_3COO^- + H_2O \rightarrow CH_3COOH + OH^-$; (iv) no; (v) yes $Al^{3+} + H_2O \rightarrow Al(OH)^{2+} + H^+$; (vi) yes $CN^- + H_2O \rightarrow HCN + OH^-$

Unit 5 – Acids, Bases and Salts

Lesson 5 – How can we use acid-base reactions to prepare salts in the laboratory?



Practical 5.1: Prepare a salt by neutralising an acid with an insoluble base

- $0.02 \times 0.5 = 0.01$
- $1/79.5 = 0.0126$
- To ensure the H_2SO_4 fully reacts; excess CuO can be removed by filtration; it would be much more difficult to remove excess H_2SO_4



Practical 5.2: Prepare a salt by neutralising an acid with a soluble base

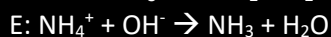
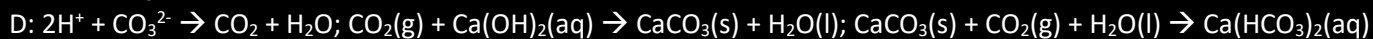
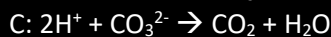
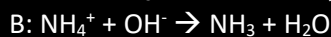
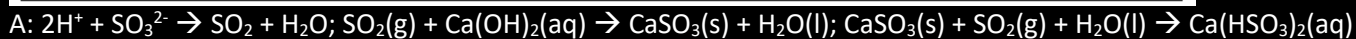
- $2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$
- $0.025 \times 1 = 0.025$
- $0.025 \times 2 = 0.05$
- to ensure that both reactants are fully used up and that there is no excess of either reactant in the solution at the end
- excess insoluble base can be removed easily by filtration; excess soluble base cannot be easily removed

Lesson 6 – How are acid-base reactions useful in qualitative analysis?



Practical 6.1: Qualitative Analysis Part 1a - use acid-base reactions to identify cations, anions and gases

Sample	Bubbles with HCl? Y/N	Smell with HCl?	Effect of gas on limewater?	Smell with NaOH?	Smell with NH_4Cl ?	Bubbles with CaCO_3 ? Y/N	Ion present
A	Y	Burning match	Milky then clear again	none	none	N	SO_3^{2-}
B	N (but it might get warm)	none	n/a	none	pungent	N	OH^-
C	N	none	n/a	none	none	Y	H^+
D	Y	none	Milky then clear again	none	none	N	CO_3^{2-}
E	N	none	n/a	pungent	none	N	NH_4^+




Test your knowledge 6.2: Using acid-base reactions to identify certain cations and anions

- (a) add HCl (aq); odourless gas evolved which turns limewater milky and then clear again:
 $2\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{CO}_2 + \text{H}_2\text{O}$; $\text{CO}_2(\text{g}) + \text{Ca}(\text{OH})_2(\text{aq}) \rightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$; $\text{CaCO}_3(\text{s}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}(\text{HCO}_3)_2(\text{aq})$
- (b) add HCl (aq); gas evolved with burning-match smell which turns limewater milky and then clear again: $2\text{H}^+ + \text{SO}_3^{2-} \rightarrow \text{SO}_2 + \text{H}_2\text{O}$; $\text{SO}_2(\text{g}) + \text{Ca}(\text{OH})_2(\text{aq}) \rightarrow \text{CaSO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$; $\text{CaSO}_3(\text{s}) + \text{SO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{Ca}(\text{HSO}_3)_2(\text{aq})$
- (c) add concentrated H_2SO_4 ; if gas given off, test with filter paper soaked in concentrated NH_3 ; a white smoke should be seen: $\text{H}_2\text{SO}_4 + \text{Cl}^- \rightarrow \text{HSO}_4^- + \text{HCl}$; $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$
- (d) add $\text{CaCO}_3(\text{s})$; gas evolved: $2\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
- (e) add $\text{NH}_4\text{Cl}(\text{aq})$ and warm; pungent smell given off: $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$
- (f) add $\text{NaOH}(\text{aq})$ and warm; pungent smell given off: $\text{NH}_4^+ + \text{OH}^- \rightarrow \text{NH}_3 + \text{H}_2\text{O}$
- (g) test with filter paper soaked in concentrated HCl; a white smoke should be seen: $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$
- (h) test with filter paper soaked in concentrated NH_3 ; a white smoke should be seen: $\text{NH}_3 + \text{HCl} \rightarrow \text{NH}_4\text{Cl}$

Lesson 7 - What is the pH scale?

Test your knowledge 7.1: Understanding the pH scale

- (a) acidic; (b) alkaline; (c) neutral; (d) acidic; (e) alkaline; (f) acidic; (g) alkaline; (h) neutral; (i) alkaline; (j) neutral; (k) (very) acidic; (l) alkaline; (m) acidic; (n) neutral; (o) acidic (due to salt hydrolysis); (p) alkaline (due to salt hydrolysis)


Practical 7.2: Investigate the effect of solutions of different pH values on different indicators

pH of solution	methyl orange colour	litmus colour	Phenolphthalein colour
3	pink	red	colourless
5	yellow	red	colourless
7	yellow	red/blue	colourless
9	yellow	blue	pink/colourless
11	yellow	blue	pink

- MO changes colour at pH = 5; L changes colour at pH 7; PP changes colour at pH 9

Lesson 8 - What is universal indicator and why is it useful?

Activity 8.1: Universal Indicator and pH

Answer: 1 – 3 red; 4 - 5 orange; 6 – yellow; 7 – green; 8 – blue; 9 – 11 indigo; 12 – 14 violet


Extension 8.2: Universal Indicator and pH

Eg pH 1 stomach acid (HCl); pH 2 lemon juice/vinegar; pH 3 orange juice; pH 4 tomato juice; pH 5 black coffee; pH 6 milk; pH 7 water; pH 8 sea water; pH 9 a solution of baking soda; pH 10 milk of magnesia; pH 11 ammonia solution; pH 12 soapy water; pH 13 bleach



Practical 8.3: Determine the pH value of various solutions by colorimetry

Solution	Colour it turns UI	pH	Possible identity
A	orange/yellow	5	rainwater (or urine)
B	green	7	water
C	violet	11	bleach
D	blue/indigo	9	soda or magnesia
E	red	3	lemon juice or vinegar



Practical 8.4: Determine the pH of different soil samples

Note: the soil samples should ideally cover a range of different types, ideally with a range of different acidities.

Lesson 9 – How can indicators be used in qualitative analysis?



Practical 9.1: Investigate the effect of acidic, alkaline and neutral solutions on litmus paper

Solution	Effect on red litmus paper	Effect on blue litmus paper
HCl	stays red	turns red
NaOH	turns blue	stays blue
Na ₂ CO ₃	turns blue	stays blue
NaCl	stays red	stays blue



Test your knowledge 9.2: Summary of Qualitative Analysis of Cations, Anions and Gases

(a) Add CaCO₃(s) - effervescence; (b) add blue litmus paper – it turns red; (c) add NH₄Cl and warm – a pungent smell; (d) add red litmus paper – it turns blue; (e) hydrogen chloride, sulphur dioxide and nitrogen dioxide; (f) ammonia; (g) carbon dioxide and sulphur dioxide, SO₂ smells of burning matches and also turns blue litmus red; (h) hang filter paper soaked in concentrated NH₃ close to the source – white smoke formed; (i) hang filter paper soaked in concentrated HCl close to the source – white smoke formed; (j) add concentrated H₂SO₄ and then test the gas either with filter paper soaked in concentrated NH₃ – white smoke formed, or with blue litmus paper – it turns red; (k) add NaOH and warm – pungent smell; (l) add HCl and bubble gas through limewater – odourless gas which turns limewater milky and then clear again; (m) add HCl and bubble gas through limewater – burning-match-smelling gas which turns limewater milky and then clear again and also turns blue litmus paper red; (n) conducts electricity which proves that ions are present; turns universal indicator green which shows that H⁺, OH⁻ and CO₃²⁻ are not present

Lesson 10 – How I determine how much of an acid or a base is present in a sample (practical)?



Summary Activity 10.1: What can you remember about the different instruments used to measure the volume of a solution?

- Pipette: very accurate but can only deliver one volume
- Volumetric flask: very accurate but can only store one volume
- Burette: slightly less accurate than a pipette but can deliver any volume up to 50 cm³
- Measuring cylinder: not accurate
- Pipettes and burettes are most useful for carrying out titrations



Practical 10.2: Determine the concentration of a solution of NaOH by titration against 1.0 moldm⁻³ HCl if the NaOH molarity is 0.08 moldm⁻³ then a typical titre volume should be around 15 cm³

- a correctly completed table would look something like this: it may be an idea to share this with the students beforehand:

	Titration 1	Titration 2	Titration 3	Titration 4	Titration 5
Final volume (cm ³)	23.30	24.85	23.15		
Initial volume (cm ³)	1.25	23.30	1.70		
Titre volume (cm ³)	22.05	21.55	21.45		
Concordant? (Y or N)	NO	YES	YES		

- the average titre volume (using concordant results only) should be $(21.55 + 21.45)/2 = 21.40 \text{ cm}^3$ (using the above results)
- moles of HCl = $0.1 \times \text{titre volume} / 1000$
- moles of NaOH = moles of HCl
- molarity of NaOH = moles of NaOH / 0.025

Lesson 11 – How I determine how much of an acid or a base is present in a sample II?



Summary Activity 11.1: How do you prepare a standard solution?

- Moles of NaOH required = $0.25 \times 0.1 = 0.025$ so mass of NaOH required = $0.025 \times 40 = 1.0 \text{ g}$
Weigh out exactly 1.0 g of NaOH on a mass balance using a weighing boat
Pour the NaOH into a beaker
Rinse the weighing boat with distilled water and ensure all the rinsings run into the beaker
Dissolve the NaOH in a small quantity of distilled water
Pour the solution into a 250 cm³ volumetric flask using a funnel
Rinse the beaker with distilled water and pour the rinsings into the volumetric flask
Add distilled water until the meniscus rests exactly on the graduation mark, shaking continuously
- Dilution factor = $2/0.2 = 10$ so volume needed = $250/10 = 25 \text{ cm}^3$
Pipette 25 cm³ of 2.0 moldm⁻³ H₂O₂ into a 250 cm³ volumetric flask
Add distilled water until the meniscus rests exactly on the graduation mark, shaking continuously



Practical 11.2: Determine the relative formula mass, and hence water of crystallisation, of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, by titration ($\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}$)

- If the student uses 3.5 g of solid the titre volume should be around 24 cm^3
- Using 24 cm^3 , moles of $\text{HCl} = 0.1 \times 0.0224 = 0.00224$ so moles of Na_2CO_3 in conical flask is $0.00224/2 = 0.00112$
- Moles of Na_2CO_3 in volumetric flask = $0.00112 \times 10 = 0.0112$
- Molar mass of $\text{Na}_2\text{CO}_3 = 3.5/0.0112 = 312.5$
- $106 + 18x = 312.5$ so $x = 10$



Practical 11.3: Determine the percentage purity of a sample of vinegar ($\text{CH}_3\text{COOH} + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$)

- If the ethanoic acid is around 1 mol dm^{-3} the titre volume should be around 13 cm^3
- moles of $\text{NaOH} = 0.05 \times 25/1000 = 0.00125$ so moles of CH_3COOH in titration = 0.00125
- molarity of $\text{CH}_3\text{COOH} = (\text{moles} \times 1000) / (\text{titre volume})$; using 13 cm^3 , $C = 0.00125/0.013 = 0.096 \text{ mol dm}^{-3}$
- so molarity before dilution = $0.096 \times 250/25 = 0.96 \text{ mol dm}^{-3}$
- mass concentration = $0.96 \times 60 = 57.6 \text{ g dm}^{-3}$
- percentage purity = $57.6/62.3 \times 100 = 92.4 \%$
- phenolphthalein necessary because acid is weak so methyl orange will not work



Test your knowledge 11.4: Volumetric Analysis – Titrations

- (a) Moles of $\text{NaOH} = 0.0025$; moles of SA used = $0.0025/2 = 0.00125$; moles of SA in volumetric flask = $0.00125 \times 250/18.4 = 0.016984$, $\text{Mr of SA} = 2/0.016984 = 118$; $(\text{CH}_2)_n = 118 - 90 = 28$ so $n = 28/14 = 2$
- (b) Moles of $\text{HCl} = 0.0245 \times 0.1 = 0.00245$; moles of Na_2CO_3 used = $0.00245/2 = 0.001225$; moles of in volumetric flask = $0.001225 \times 10 = 0.01225$, molar mass of $\text{Na}_2\text{CO}_3 = 3.5/0.01225 = 286$; $x\text{H}_2\text{O} = 286 - 106 = 180$; $x = 180/18 = 10$
- (c) Moles of $\text{NaOH} = 0.025 \times 0.1 = 0.0025$; moles of CH_3COOH used = 0.0025 ; molarity of CH_3COOH used = $0.0025/(13.9/1000) = 0.180$; molarity before dilution = $0.180 \times 250/25 = 1.80 \text{ mol dm}^{-3}$; mass concentration = $1.8 \times 60 = 108 \text{ g dm}^{-3}$
- (d) Moles of $\text{NaOH} = 0.0025$; moles of acid used = $0.0025/2 = 0.00125$; moles of acid in volumetric flask = $0.00125 \times 250/21.3 = 0.0147$; mass of pure acid = $0.0147 \times 126 = 1.85 \text{ g}$; % purity = $1.85/2.5 \times 100 = 73.9 \%$
- (e) Moles of $\text{NaOH} = 0.0025$; moles of acid used = 0.0025 ; moles of acid in volumetric flask = $0.0025 \times 250/21.3 = 0.0271$; mass of acid = $0.0271 \times 120.1 = 3.25$; % purity = $3.25/5.6 \times 100 = 57.9 \%$

Lesson 12 – What have you understood about Acids, Bases and Salts?

12.1 END-OF-TOPIC QUIZ
TOPIC 5 – ACIDS, BASES AND SALTS



1.
 - (a) $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
 - (b) $\text{H}_2\text{SO}_4 + \text{MgO} \rightarrow \text{MgSO}_4 + \text{H}_2\text{O}$
 - (c) $\text{CaCO}_3 + 2\text{HNO}_3 \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{CO}_2 + \text{H}_2\text{O}$
2.

Deliquescent – absorbs water from atmosphere and dissolves in it (eg NaOH or CaCl₂)
 Hygroscopic – absorbs water from atmosphere (eg conc. H₂SO₄ or any deliquescent substance)
 Efflorescent – contains water which it releases (eg CaSO₄·2H₂O)
3.
 - (a) strong acid – lower pH
 - (b) strong acid – more exothermic enthalpy of neutralisation
 - (c) strong acid – faster reaction with calcium carbonate
 - (d) strong acid – greater electrical conductivity
4.
 - (a) no - neutral (salt of strong acid and strong base)
 - (b) yes - acidic (salt of weak base)
 - (c) yes – basic (salt of weak acid)
5.
 - (a) Add CaCO₃; observe fizzing
 - (b) Add NH₄Cl and warm – pungent smell
 - (c) Add NaOH and warm – pungent smell
 - (d) Add concentrated H₂SO₄ – white fumes which turn blue litmus red and give white smoke in presence of filter paper soaked in NH₃
 - (e) Add acid; gas given off which smells like burning matches
 - (f) Gives white smoke in presence of filter paper soaked in concentrated HCl
6.
 - (a) water – green; lemon juice – red; bleach - violet
 - (b) HCl turns blue litmus red; NH₃ turns red litmus blue
7.

Moles of HCl = $0.2 \times 10.8/1000 = 0.00216$; $\text{M}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{MCl} + \text{CO}_2 + \text{H}_2\text{O}$ so moles of M₂CO₃ used = $0.00216/2 = 0.00108$; moles of M₂CO₃ in volumetric flask = $0.00108 \times 10 = 0.0108$; molar mass = $2.5/0.0108 = 231$; $2M = 231 - 60 = 171$; $M = 171/2 = 85.5$; $M = \text{Rb}$