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: Recognising Acids, Bases and Salts

Deduce the formulae of the following substances and indicate whether they are acids, bases or salts:

a) Na_2O (base)
b) $Ca(OH)_2$ (base)
c) NH_4NO_3 (salt)
d) K_2CO_3 (base)
e) $SrSO_4$ (salt)
f) $(NH_4)_2SO_4$ (salt)
g) HCl (acid)
h) RbOH (base)
i) $MgCO_3$ (base)
j) $Ca(NO_3)_2$ (salt)
k) H_2SO_4 (acid)
l) NH_4Cl (salt)
m) HNO_3 (acid)
n) K_2SO_4 (salt)
o) MgO (base)
p) CsBr (salt)
q) $BaSO_4$ (salt)
r) $Sr(NO_3)_2$ (salt)

Test your knowledge 1.3: Understanding Neutralisation Reactions

Write balanced symbol equations for the following neutralisation reactions:

a) $HNO_3 + KOH \rightarrow KNO_3 + H_2O$
b) $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + H_2O$
c) $2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$
d) $2HNO_3 + CaO \rightarrow Ca(NO_3)_2 + H_2O$
e) $2HCl + BaO \rightarrow BaCl_2 + H_2O$
f) $H_2SO_4 + MgO \rightarrow MgSO_4 + H_2O$
g) $HNO_3 + CaCO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$
h) $2HCl + BaCO_3 \rightarrow BaCl_2 + CO_2 + H_2O$
i) $H_2SO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + CO_2 + H_2O$
j) $HNO_3 + NH_3 \rightarrow NH_4NO_3$
k) $H_2SO_4 + 2NH_3 \rightarrow (NH_4)_2SO_4$
l) $HCl + NH_3 \rightarrow NH_4Cl$

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

Test your knowledge 2.1: Describing 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 $Ca(NO_3)_2.4H_2O$
(k) the loss of water from a crystal structure; eg $CaSO_4.2H_2O$

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 acid

Equipment needed per group: two measuring cylinders (25 cm^3), polystyrene cup (250 cm^3), beaker (250 cm^3), thermometer, access to 2.0 moldm^{-3} HCl (50 cm^3 per group), 2 moldm^{-3} NH_3 (25 cm^3 each per group) and 2 moldm^{-3} NaOH (25 cm^3 each per group)

Caution: the alkalis are corrosive at this molarity and should be handled with great care

- **The temperature increase should be around 7 °C with NaOH and around 5 °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: Distinguishing between 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: Understanding 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 $CN^- + H_2O \rightarrow HCN + OH^-$

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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

Equipment needed per group: measuring cylinder (25 cm^3), beaker (100 cm^3), Bunsen burner, tripod, gauze, thermometer, weighing boat, spatula, stirrer, filter paper, funnel, conical flask (100 cm^3), access to a mass balance, access to 0.5 $moldm^{-3}$ H_2SO_4 (20 cm^3 per group), access to CuO (1 g per group)

- **0.02 x 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

Equipment needed per group: two measuring cylinders (25 cm^3), beaker (100 cm^3), stirring rod, Bunsen burner, tripod, gauze, evaporating dish, spatula, filter paper; access to 1.0 $moldm^{-3}$ H_2SO_4 (25 cm^3 per group), and 2.0 $moldm^{-3}$ NH_3 (25 cm^3 each per group)

- **$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$**
- **0.025 x 1 = 0.025**
- **0.025 x 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: Use acid-base reactions to identify cations, anions and gases

Equipment needed per group: three watch glasses, four test tubes, test tube rack, bung to fit test tube with delivery tube connected; access to solid samples of: Na_2SO_3 (labelled A), KOH (labelled B), Na_2CO_3 (labelled C), NH_4Cl (labelled D), each with their own spatula; access to 1 $moldm^{-3}$ HCl with dropping pipette (10 cm^3 per group), limewater (10 cm^3 per group), 1 $moldm^{-3}$ NaOH (5 cm^3 per group) with dropping pipette, 1 $moldm^{-3}$ NH_4Cl (5 cm^3 per group) with dropping pipette, powdered $CaCO_3$ (2 g per group) with its own spatula

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-}

A: $2H^+ + SO_3^{2-} \rightarrow SO_2 + H_2O$; $SO_2(g) + Ca(OH)_2(aq) \rightarrow CaSO_3(s) + H_2O(l)$; $CaSO_3(s) + SO_2(g) + H_2O(l) \rightarrow Ca(HSO_3)_2(aq)$
B: $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$
C: $2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$; $CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$; $CaCO_3(s) + CO_2(g) + H_2O(l) \rightarrow Ca(HCO_3)_2(aq)$
D: $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$

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: $2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$; $CO_2(g) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + H_2O(l)$; $CaCO_3(s) + CO_2(g) + H_2O(l) \rightarrow Ca(HCO_3)_2(aq)$

(b) add HCl (aq); gas evolved with burning-match smell which turns limewater milky and then clear again: $2H^+ + SO_3^{2-} \rightarrow SO_2 + H_2O$; $SO_2(g) + Ca(OH)_2(aq) \rightarrow CaSO_3(s) + H_2O(l)$; $CaSO_3(s) + SO_2(g) + H_2O(l) \rightarrow Ca(HSO_3)_2(aq)$

(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: $H_2SO_4 + Cl^- \rightarrow HSO_4^- + HCl$; $NH_3 + HCl \rightarrow NH_4Cl$

(d) add $CaCO_3(s)$; gas evolved: $2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$

(e) add $NH_4Cl(aq)$ and warm; pungent smell given off: $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$

(f) add NaOH(aq) and warm; pungent smell given off: $NH_4^+ + OH^- \rightarrow NH_3 + H_2O$

(g) test with filter paper soaked in concentrated HCl; a white smoke should be seen: $NH_3 + HCl \rightarrow NH_4Cl$

(h) test with filter paper soaked in concentrated NH_3; a white smoke should be seen: $NH_3 + HCl \rightarrow NH_4Cl$

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

Equipment needed per group: five test tubes and one test tube rack; access to: 0.1 $moldm^{-3}$ CH_3COOH (labelled pH 3); a solution containing 0.1 $moldm^{-3}$ CHCOOH and 0.5 $moldm^{-3}$ $CHCOO^-Na^+$ (labelled pH 5); distilled water (labelled pH = 7); a solution containing 0.1 $moldm^{-3}$ NH_3 and 0.5 $moldm^{-3}$ NH_4Cl (labelled pH 9); 0.1 $moldm^{-3}$ NH_3 (labelled pH = 11); 5 cm^3 per group for each solution; each bottle should have its own dropping pipette; access to solutions of phenolphthalein, methyl orange and litmus, each with their own dropping pipette (1 cm^3 per group)

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

Students will need access to the different colours shown by universal indicator.
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

Equipment needed per group: five test tubes and one test tube rack; access to: rainwater (labelled A) (you can ensure a PH of 5 by bubbling CO_2 through it); distilled water (labelled B); a diluted solution of bleach (C); a solution of baking soda (D); diluted vinegar or lemon juice (E); the exact identity of the solution is not important but they should turn UI the following colours: A – orange/yellow ; B – green; C – violet; D – blue/indigo; E - red
5 cm^3 per group for each solution; each bottle should have its own dropping pipette; access to universal indicator solution with dropping pipette (1 cm^3 per group)

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

Equipment needed per group: one beaker (100 cm^3); one measuring cylinder (50 cm^3); one stirring rod; one funnel; three pieces of filter paper; three boiling tubes; access to three different soil samples (20 g per group), each with its own spoon; access to a mass balance; access to universal indicator with its own dropping pipette (1 cm^3 per group)
Note: the soil samples should ideally cover a range of different types, ideally with a range of different acidities.

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

Practical 9.1: Investigate the effect of acidic, alkaline and neutral solutions on different indicators

Equipment needed per group: one small beaker (<50 cm^3) and one small measuring cylinder (10 cm^3); four strips of red litmus paper, four strips of blue litmus paper, access to solutions of 0.1 $mol dm^{-3}$ HCl, NaOH, Na_2CO_3 and NaCl (10 cm^3 per group), access to phenolphthalein and methyl orange indicator solutions (1 cm^3 per group), 8 test tubes, 1 test tube rack

Solution	Effect on red litmus paper	Effect on blue litmus paper	Effect on methyl orange	Effect on phenolphthalein
HCl	stays red	turns red	pink	colourless
NaOH	turns blue	stays blue	yellow	pink
Na_2CO_3	turns blue	stays blue	yellow	pink
NaCl	stays red	stays blue	Yellow	colourless

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

(a) Add $CaCO_3$(s) - effervescence; (b) add blue litmus paper – it turns red; (c) add NH_4Cl and warm – apungent 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, SO_2 smells of burning matches and also turns blue litmus red; (h) hang filter paper soaked in concentrated NH_3 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 H_2SO_4 and then test the gas either with filter paper soaked in concentrated NH_3 – 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 CO_3^{2-} 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 cm^3
- 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

Equipment needed per group: 1 burette, 1 25 cm^3 pipette, 1 pipette filler, one conical flask, one funnel, two 100 cm^3 beakers and the means to label them; clamp, stand, boss; access to 0.1 $moldm^{-3}$ HCl, a solution of NaOH of approximately 0.08 $moldm^{-3}$ but with the concentration not labelled), (100 cm^3 per group) phenolphthalein indicator and suitable dropping pipette

Note: this practical is the most important practical in SS Chemistry; it is also the most challenging in terms of the techniques required; it is recommended that when carrying out this practical for the first time, each group performs each step together so that the teacher can check that the student is performing the practical correctly

Particular things to check in each group are: no air bubbles in burette tip, initial reading is recorded to 0.05 cm^3 and is correct, funnel is removed

- if the NaOH molarity is 0.08 $moldm^{-3}$ then a typical titre volume should be around 15 cm^3
- 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 cm^3 (using the above results)
- moles of HCl = 0.1 x 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 x 0.1 = 0.025 so mass of NaOH required = 0.025 x 40 = 1.0 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 cm^3 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 cm^3
  Pipette 25 cm^3 of 2.0 $moldm^{-3}$ H_2O_2 into a250 cm^3 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, $Na_2CO_3.xH_2O$, by titration ($Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$)

Equipment needed per group: 1 burette, 1 25 cm^3 pipette, 1 pipette filler, clamp, boss, stand, one conical flask, two funnels, two 100 cm^3 beakers with the means to label them, one 250 cm^3 volumetric flask, one weighing boat; access to a mass balance, access to 0.1 $moldm^{-3}$ HCl, a sample of hydrated sodium carbonate with the formula not labelled, with spatula, methyl orange indicator and suitable dropping pipette

- If the student uses 3.5 g of solid the titre volume should be around 24 cm^3
- Using 24 cm^3, moles of HCl = 0.1 x 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 x 10 = 0.012
- Molar mass of Na_2CO_3 = 3.5/0.012 = 292
- 106 + 18x = 292 so x = 10

Practical 11.3: Determine the percentage purity of a sample of vinegar ($CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$)

Equipment needed per group: 1 burette, 1 25 cm^3 pipette, 1 pipette filler, one conical flask, two funnels, two 100 cm^3 beakers with the means to label them, one 250 cm^3 volumetric flask; access to 0.1 $moldm^{-3}$ NaOH, a sample of ethanoic acid (approx 1 $moldm^{-3}$) labelled "vinegar 62.3 gdm^{-3}"), phenolphthalein indicator and suitable dropping pipette

- If the ethanoic acid is around 1 $moldm^{-3}$ the titre volume should be around 13 cm^3
- moles of NaOH = 0.05 x 25/1000 = 0.00125 so moles of CH_3COOH in titration = 0.00125
- molarity of = CH_3COOH / (titre volume/1000); using 13 cm^3, C = 0.00125/0.013 = 0.096 $moldm^{-3}$
- so molarity before dilution = 0.096 x 250/25 = 0.96 $moldm^{-3}$
- mass concentration = 0.96 x 60 = 57.7 gdm^{-3}
- percentage purity = 57.7/62.3 x 100 = 92.6 %
- phenolphthalein necessary because acid is weak so methyl orange will not work

Test your knowledge 11.4: Volumetric Analysis – Titrations

(a) Moles of NaOH = 0.0025; moles of SA used = 0.0025/2 = 0.00125; moles of SA in volumetric flask = 0.00125 x 250/18.4 = 0.016984, mr of SA = 2/0.016984 = 118; $(CH_2)_n$ = 118 – 90 = 24 so n = 28/14 = 2
(b) Moles of HCl = 0.0245 x 0.1 = 0.00245; moles of Na_2CO_3 used = 0.00245/2 = 0.001225; moles of in volumetric flask = 0.001225 x 10 = 0.01225, molar mass of Na_2CO_3 = 3.5/0.001225 = 286; xH_2O = 280 – 106 = 180; x = 180/18 = 10
(c) Moles of NaOH = 0.025 x 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 x 250/25 = 1.80 $moldm^{-3}$; mass concentration = 1.8 x 60 = 108 gdm^{-3}
(d) Moles of NaOH = 0.0025; moles of acid used = 0.0025/2 = 0.00125; moles of acid in volumetric flask = 0.00125 x 250/21.3 = 0.0147; mass of pure acid = 0.0147 x 126 = 1.85 g; % purity = 1.85/2.5 x 100 = 73.9 %
(e) Moles of NaOH = 0.0025; moles of acid used = 0.0025; moles of acid in volumetric flask = 0.0025 x 250/21.3 = 0.0271; mass of acid = 0.0271 x 120.1 = 3.25; % purity = 57.2 %

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

12.1 END-OF-TOPIC QUIZ

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1. (a) $HCl + NaOH \rightarrow NaCl + H_2O$
   (b) $H_2SO_4 + MgO \rightarrow MgSO_4 + H_2O$
   (c) $CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$
2. Deliquescent – absorbs water from atmosphere and dissolves in it (eg NaOH or $CaCl_2$)
   Hygroscopic – absorbs water from atmosphere (eg conc. H_2SO_4 or any deliquescent substance)
   Efflorescent – contains water which it releases (eg $CaSO_4.2H_2O$)
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 $CaCO_3$; observe fizzing
   (b) Add NH_4Cl and warm – pungent smell
   (c) Add NaOH and warm – pungent smell
   (d) Add concentrated H_2SO_4 – white fumes which turn blue litmus red and give white smoke in presence of filter paper soaked in NH_3
   (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; NH_3 turns red litmus blue
7. Moles of HCl = 0.2 x 10.8/1000 = 0.00216; $M_2CO_3 + 2HCl \rightarrow 2MCl + CO_2 + H_2O$ so moles of M_2CO_3 used = 0.00216/2 = 0.00108; moles of M_2CO_3 in volumetric flask = 0.00108 x 10 = 0.0108; molar mass = 2.5/0.0108 = 231; 2M = 231 – 60 = 171; M = 171/2 = 85.5; M = Rb