

Acids and Alkalis

Mark Scheme



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1. Acids and alkalis, two groups of chemicals with opposing properties that are measured using the pH scale. Circle the letter of the correct answer for each of the following questions.

- a) When hydrochloric acid and sodium hydroxide react, water is formed.
Which two ions combine to produce the water?

D – is the only correct answer.	1 mark
	Total: 1 mark

- b) Four different solutions, P, Q, R and S, are tested with universal indicator.

Solution	P	Q	R	S
Colour with universal indicator	red	purple	orange	blue

Which solutions are alkali?

C – is the only correct answer.	1 mark
	Total: 1 mark

- c) A student tests an unknown substance, compound Z.
They observe that when it is dissolved in water and tested with methyl orange, the solution turns red.
What could compound Z be?

C – is the only correct answer.	1 mark
	Total: 1 mark

- d) Acidic soil contains an excess of hydrogen ions (H^+).
Which ion from calcium hydroxide reacts with the hydrogen ions to neutralise the soil?

C – is the only correct answer.	1 mark
	Total: 1 mark

- e) Acids undergo several key types of reactions. Which of the reactions shown below would not occur?

C – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 5 marks)

2. A student is planning to make three different salts in the lab.
They must choose the best method for each one.

For each salt listed in the table, help the student by:

- Choosing the most suitable method (titration, neutralisation of an insoluble solid, or precipitation).
- Naming the two chemicals they should react together.

- a) Complete the table.

Row 1: Reagent 1: <u>Hydrochloric acid</u> Accept: HCl.	
Row 2: Reagent 1: <u>Potassium hydroxide</u> Reagent 2: <u>Sulfuric acid</u> Allow correct formulae (KOH and H ₂ SO ₄). Reagents can be in either order.	
Row 3: Reagent 2: Sodium sulfate / Potassium sulfate / Magnesium sulfate / Sulfuric acid.	
Row 4: Reagent 1: Nitric acid. Reagent 2: Calcium carbonate / Calcium oxide / Calcium hydroxide	
Marking instructions for part (a): Award 1 mark for every two correct reagents. Any 2 correct = 1 mark, any 4 correct = 2 marks, all 6 correct = 3 marks.	
	Total: 3 marks

- b) The salt must be separated from the reaction mixture and purified.

- i. Describe the steps used to obtain a pure, dry sample of barium sulfate after the precipitation reaction is complete.

A description to include the following:	
• Filter (the mixture).	1 mark
• Wash the precipitate/solid (with distilled water).	1 mark
• Dry the solid/precipitate.	1 mark
Allow "residue" for solid/precipitate.	
	Total: 3 marks

- ii. Describe the steps used to obtain pure, dry crystals of magnesium chloride from the solution after the unreacted magnesium oxide has been removed by filtration.

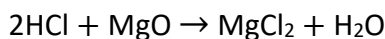
A description to include the following:	
• Heat the solution / Evaporate some of the water.	1 mark
• Until crystals start to form / until a saturated solution is formed.	1 mark
• Leave to cool and crystallise, then filter and dry the crystals.	1 mark
	Total: 3 marks

- c) Precipitation reactions can be represented by an ionic equation.

Write the balanced ionic equation, including state symbols, for the formation of barium sulfate.

$\text{Ba}^{2+} (\text{aq}) + \text{SO}_4^{2-} (\text{aq}) \rightarrow \text{BaSO}_4 (\text{s})$	2 marks
1 mark for the correct reactant ions and 1 mark for correct product.	
	Total: 2 marks

- d) In an experiment to make magnesium chloride, a student reacted excess hydrochloric acid with 4.0 g of magnesium oxide. The equation for the reaction is:



After purification, the student obtained an actual yield of 8.5 g of magnesium chloride. Calculate the percentage yield for this experiment.

(Relative atomic masses (A_r): O = 16, Mg = 24, Cl = 35.5)

Give your answer to three significant figures.

Moles $\text{MgO} = 4.0 \div (24 + 16) = 0.1 \text{ (mol)}$	1 mark
Max mass $\text{MgCl}_2 = 0.1 \times (24 + (2 \times 35.5))$	1 mark
Max mass $\text{MgCl}_2 = 0.1 \times 95 = 9.5 \text{ (g)}$	1 mark
$(8.5 / 9.5) \times 100 = 89.5 \%$	1 mark
	Total: 4 marks

- e) The student's calculated percentage yield was less than 100%.

State **two** reasons why the actual yield in this experiment might be less than the theoretical yield.

Any two of the following:	
- Reaction is incomplete / reversible. - Some product is lost during transfer between apparatus (e.g. left in beaker). - Some product is lost during filtration / separation. - Some product remains dissolved in the solution after crystallisation. - There could be unwanted side reactions occurred.	2 marks
	Total: 2 marks

(Total for Question 2 is 17 marks)

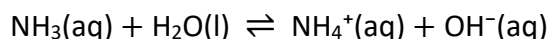
3. This question is about the properties of ammonia.

A student produces a gas they believe to be ammonia.

- a) Describe the chemical test they would perform to confirm this, and the expected positive result.

A description to include the following:	
Test: Damp red litmus paper "Damp" or "moist" is required.	1 mark
Positive result: (Litmus paper) turns blue.	1 mark
	Total: 2 marks

- b) Ammonia dissolves in water in a reversible reaction to form a basic solution. The equation is:



- i. Explain how the presence of the hydroxide ion (OH^-) in the equation confirms that ammonia forms a basic solution.

(The presence of OH^- ions) makes the concentration of hydroxide ions greater than the concentration of hydrogen ions.	1 mark
Allow "produces hydroxide ions".	
	Total: 1 mark

- ii. The term '**weak base**' is used to describe aqueous ammonia.
Suggest a likely pH value for this solution.

Any pH value from 8 to 11.	1 mark
	Total: 1 mark

- iii. A student adds aqueous ammonia dropwise to a test tube containing a solution of copper(II) sulfate, and then continues to add it in excess.

Describe the **two** main observations they would make during this process.

First observation: A (light) blue precipitate is formed.	1 mark
Final observation: The precipitate dissolves to form a deep / dark blue solution.	1 mark
	Total: 2 marks

- c) A student investigates the reaction between dilute sulfuric acid (H_2SO_4) and aqueous sodium hydroxide (NaOH), which is a strong alkali.

- i. Write the **balanced** chemical equation for this reaction.

$2\text{NaOH} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$ Accept multiples of this equation.	2 marks
	Total: 2 marks

- ii. What is the general name for the reaction between an acid and an alkali?

Neutralisation	1 mark
	Total: 1 mark

- iii. The reaction is exothermic. What would be observed to confirm this?

Temperature increases / rise in temperature is observed.	1 mark
Allow "it gets hot". Do not accept "heat is produced".	
	Total: 1 mark

- d) A titration was performed to determine the exact concentration of the sulfuric acid.

It was found that 15.00 cm³ of the sulfuric acid was neutralised by 25.0 cm³ of sodium hydroxide solution with a concentration of 0.0500 mol/dm³.

- i. Name a suitable indicator for this titration and state the colour change that would occur at the end-point.

Indicator: Methyl orange OR Phenolphthalein.	1 mark
Colour change: (methyl orange) orange/red to yellow OR (phenolphthalein) colourless to pink.	1 mark
	Total: 2 marks

- ii. Calculate the concentration of the sulfuric acid in mol/dm³.
First, calculate the moles of sodium hydroxide used.

Moles NaOH = $0.0500 \times (25.0 \div 1000) = 0.00125$ (mol)	1 mark
	Total: 1 mark

- iii. Using the mole ratio from your equation in part (c)(i), determine the moles of sulfuric acid that reacted.

Moles H ₂ SO ₄ = $0.00125 \div 2 = 0.000625$ (mol)	1 mark
	Total: 1 mark

- iv. Finally, calculate the concentration of the sulfuric acid. Give your answer to 3 significant figures.

Concentration = $0.000625 \div (15.00 \div 1000) = 0.0417$ (mol/dm ³)	1 mark
	Total: 1 mark

(Total for Question 3 is 15 marks)

4. Hydrogen chloride can be made by the reaction between hydrogen gas (H₂) and chlorine gas (Cl₂).

a) Complete the balanced equation for this reaction.

$\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$	1 mark
	Total: 1 mark

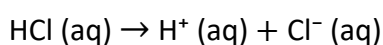
b) Hydrogen chloride (HCl) is a gas that dissolves in water to form hydrochloric acid, a common laboratory chemical.

i. What is meant by the term strong acid?

An acid that completely / fully ionises (or dissociates)	1 mark
In aqueous solution / water.	1 mark
	Total: 2 marks

ii. When hydrogen chloride dissolves in water, it fully ionises.

The equation for this process is:

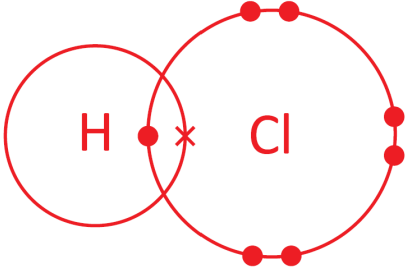


Explain how this equation shows that hydrochloric acid is a strong acid.

An explanation to include:	
The arrow is one-way / not a reversible reaction arrow ($\rightleftharpoons$).	1 mark
This shows that all the HCl molecules dissociate / ionise.	1 mark
	Total: 2 marks

c) Draw a dot and cross diagram for a molecule of hydrogen chloride.

Show **all** electrons in your diagram.

 Marking note: accept any correct version of this diagram.	
1 mark to be awarded for the correct number of electrons.	1 mark
1 mark to be awarded for the correct sharing of electrons.	1 mark
	Total: 2 marks

d) Hydrogen chloride also reacts with magnesium metal.

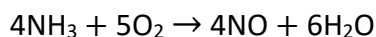
Complete the equation for the reaction of hydrochloric acid with magnesium.

magnesium chloride	1 mark
	Total: 2 marks

(Total for Question 4 is 8 marks)

5. There are several stages to the production of nitric acid in industry.

Nitrogen monoxide is required for the production of nitric acid. Nitrogen monoxide can be obtained by passing ammonia and air over a hot catalyst. The equation for the reaction is:



- a) Calculate the atom economy for the production of nitrogen monoxide, NO, in this reaction.

Relative atomic masses: H = 1 N = 14 O = 16

Give your answer to **three** significant figures.

Mass of desired product = $4 \times (14 + 16) = 120$	1 mark
Mass of all reactants = $4 \times (14 + 3) + 5 \times (16 + 16) = 68 + 160 = 228$	1 mark
$(120 \div 228) \times 100$	1 mark
= 52.6 %	1 mark
Total: 4 marks	

- b) Ammonia (NH₃), a reactant in this process, dissolves in water to form a weak alkaline solution.

Explain what is meant by the term **weak alkali**.

An explanation to include:	
An alkali that only partially / incompletely <u>ionises or dissociates</u> .	1 mark
in aqueous solution / water	1 mark
Total: 2 marks	

- c) Write the balanced ionic equation for the reversible reaction that occurs when ammonia dissolves in water.

$\text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_4^+(\text{aq}) + \text{OH}^-(\text{aq})$	2 marks
1 mark for the correct reactant ions and 1 mark for correct product.	
Total: 2 marks	

- d) The reaction between nitric acid (HNO₃) and an alkali like potassium hydroxide (KOH) is a neutralisation reaction.

Write the ionic equation, including state symbols, for this neutralisation.

$\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$	2 marks
1 mark for the correct reactant ions and 1 mark for correct product.	
Total: 2 marks	

(Total for Question 5 is 10 marks)

6. Ammonia is a compound which only contains the elements nitrogen and hydrogen. It is a weak alkali.

a) What is an alkali?

A <u>soluble base</u> .	2 marks
Accept: a substance that produces hydroxide ions (OH^-) in aqueous solution.	
	Total: 2 marks

b) A student has aqueous solutions of ammonia and sodium hydroxide.

Both solutions have a concentration of 0.2 mol/dm^3 how could the student show that ammonia is the weaker alkali?

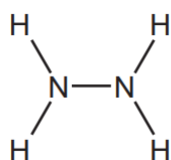
A description to include:	
Use a pH meter / universal indicator.	1 mark
Ammonia would have a lower pH / Universal indicator would be green-blue whereas for sodium hydroxide it would be purple	1 mark
	Total: 2 marks

c) Another compound which contains only nitrogen and hydrogen is hydrazine, N_2H_4 .

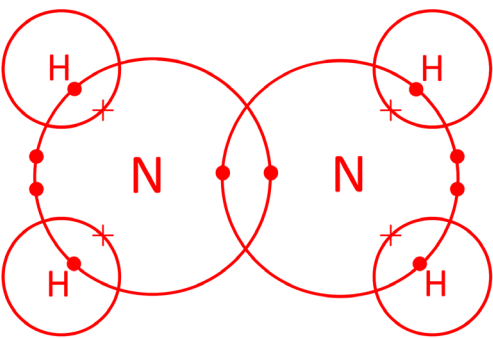
Complete the equation for the preparation of hydrazine from ammonia.

$2\text{NH}_3 + \text{NaClO} \rightarrow \text{N}_2\text{H}_4 + \text{NaCl} + \text{H}_2\text{O}$	2 marks
	Total: 2 marks

d) The structural formula of hydrazine is shown in the figure below.



Draw a diagram showing the arrangement of the electrons in one molecule of the covalent compound hydrazine.

 Marking note: accept any correct version of this diagram.	
1 mark to be awarded for the correct number of electrons.	1 mark
1 mark to be awarded for the correct sharing of electrons.	1 mark
	Total: 2 marks

(Total for Question 6 is 8 marks)