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Acids & Bases
Practice Paper

Sec 3 & 4 · O-Level Chemistry

50 marks · Sections A, B and C · model answers in examiner wording included

How to use this paper. Sit it in 55 minutes without notes. Then mark it against the model answers at the back — the wording there is the wording that earns the mark, so compare your sentences word by word, not just your final answers.

Questions marked ★ **pure-only** (A4, B5, C1) are for Pure Chemistry students. Combined Science students: skip those three and mark yourself out of 39.

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Instructions: Section A — circle the best answer. Sections B & C — answer in the spaces provided. Use exam-correct language throughout: write chemical equations with state symbols; use $H^+(aq)$ for acids and $OH^-(aq)$ for alkalis; write $NH_3(aq)$ for aqueous ammonia; use arrow → for strong acid ionisation and equilibrium arrow ⇌ for weak acid ionisation. (Relative atomic masses, where needed, are provided in each question.)

SECTION A — Multiple Choice (8 marks)

A1 Which statement correctly defines an alkali? [1]

A. A substance that dissociates in water to produce $H^+(aq)$ ions
B. Any substance that neutralises an acid to produce a salt and water
C. A soluble base that dissociates in water to produce $OH^-(aq)$ ions
D. A substance that turns Universal Indicator orange

A2 A solution has a pH of 11. Which row correctly describes the solution? [1]

Relative ion concentrations	**Colour with Universal Indicator**	
A.	$[H^+] > [OH^-]$	Red
B.	$[H^+] = [OH^-]$	Green
C.	$[OH^-] > [H^+]$	Blue
D.	$[OH^-] > [H^+]$	Yellow

Which row is correct?
A. Row A
B. Row B
C. Row C
D. Row D

A3 Oxide P dissolves in aqueous sodium hydroxide but does not react with dilute hydrochloric acid. Which type of oxide is P? [1]

A. Basic
B. Neutral
C. Acidic
D. Amphoteric

A4 Solution J and Solution K each have a concentration of 0.10 mol/dm³. Solution J has a pH of 1 and Solution K has a pH of 3. Which statement correctly explains the difference in pH? [1]

A. J is more concentrated than K, so it produces more H^+ ions per dm³.
B. J is a strong acid that fully ionises in water; K is a weak acid that only partially ionises in water.
C. J is a weak acid and K is a strong acid; weak acids have more H^+ ions.
D. J reacts faster with water than K, producing more H^+ ions per unit time.

A5 Dry hydrogen chloride (HCl) gas is passed over a piece of dry blue litmus paper. Which observation is correct, and why?   [1]

A. The litmus turns red immediately, because HCl is an acid that releases H^+ ions.

B. The litmus turns white, because dry HCl gas bleaches the paper.

C. The litmus does not change colour, because dry HCl exists as covalent molecules and does not produce $H^+(aq)$ ions without water.

D. The litmus turns purple, because dry HCl is neutral in the absence of water.

A6 Excess copper(II) oxide (CuO) is added to dilute sulfuric acid in a beaker. After the acid is fully neutralised, excess solid CuO remains in the beaker. Which statement about the final pH is correct?   [1]

A. The pH is below 7, because CuO is a metal oxide and makes the solution acidic.

B. The pH is equal to 7, because CuO is insoluble and cannot release OH^- ions into solution.

C. The pH is above 7, approaching 14, because excess base always makes the solution strongly alkaline.

D. The pH cannot be determined without knowing the exact mass of CuO added.

A7 Which reaction does NOT show a characteristic acidic property?   [1]

A. $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

B. $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$

C. $CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

D. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

A8 A student titrates aqueous sodium hydroxide (strong alkali) with ethanoic acid (weak acid, CH_3COOH). At the end-point the solution is slightly alkaline (pH slightly above 7). Which indicator is most suitable?   [1]

A. Methyl orange (changes colour near pH 4: red in acid, yellow in alkali)

B. Litmus (changes near pH 7: red in acid, blue in alkali)

C. Universal Indicator (gives a gradual colour change across pH 0-14)

D. Thymolphthalein (changes near pH 10: colourless in acid, blue in alkali)

SECTION B — Structured Questions (32 marks)

B1 A student performs a titration to determine the concentration of a sodium hydroxide solution. 25.0 cm^3 of NaOH(aq) of unknown concentration is pipetted into a conical flask. Hydrochloric acid of concentration 0.200 mol/dm^3 is added from a burette. The mean volume of acid used is 22.5 cm^3.

(a) Write the chemical equation, with state symbols, for this reaction.   [1]

____

(b) Write the ionic equation for this neutralisation.   [1]

____

(c) Calculate the number of moles of HCl used in the titration. Show your working. (Use $n = c \times V(dm^3)$.)   [1]

____

____

(d) Deduce the number of moles of NaOH that reacted.   [1]

____

(e) Calculate the concentration of the NaOH solution in mol/dm³. Show your working. [2]

(f) The student mixes 10.0 cm³ of 0.200 mol/dm³ HCl(aq) with 10.0 cm³ of 0.180 mol/dm³ NaOH(aq). Show by calculation which reactant is in excess, and state whether the pH of the resulting mixture is above 7, equal to 7, or below 7. [2]

B2 A student adds excess zinc to dilute sulfuric acid in a test tube.

(a) Write the balanced chemical equation, with state symbols, for this reaction. [1]

(b) Describe TWO observations the student would make during this reaction. [2]

(c) The student then adds lead(II) carbonate ($PbCO_3$) to a fresh sample of dilute sulfuric acid. Effervescence is observed initially, but soon stops even though solid $PbCO_3$ and dilute H_2SO_4 both remain.

(i) Write the balanced chemical equation, with state symbols, for this reaction. [1]

(ii) Explain why effervescence stops before all the reactants are used up. [2]

(d) State the name of the gas produced in part (a) and describe how you would test for this gas. [1]

B3 The table below shows the results of testing four unknown oxides D, E, F and G with dilute hydrochloric acid and with aqueous sodium hydroxide.

Oxide | Reacts with HCl(aq)? | Reacts with NaOH(aq)?

D	Yes	No
E	No	Yes
F	Yes	Yes
G	No	No

(a) Classify each oxide as acidic, basic, amphoteric or neutral. Give one mark for each correct classification. [4]

(b) Oxide F is one of the three amphoteric oxides you should know. Name one oxide that could be oxide F and write the balanced chemical equation, with state symbols, for its reaction with dilute hydrochloric acid. [2]

B4 Calcium oxide (CaO) is a liming agent used to treat acidic soil.

(a) State the name and formula of ONE other substance that can also be used as a liming agent to treat acidic soil. [1]

(b) Write the chemical equation, with state symbols, for the reaction of calcium oxide with water. [1]

(c) Write the ionic equation to show how the liming agent neutralises excess H^+ ions in the soil. [1]

(d) A farmer applies 112 g of calcium oxide to his field. Calculate the maximum mass of calcium hydroxide that could be produced. (A_r: Ca = 40, O = 16, H = 1.) Show all working. [3]

(i) Calculate the molar mass of CaO and the number of moles of CaO used.

(ii) Calculate the maximum mass of Ca(OH)2 produced.

B5 Solution X is 0.10 mol/dm³ hydrochloric acid (HCl). Solution Y is 0.10 mol/dm³ ethanoic acid (CH_3COOH). Solution X has a pH of 1; Solution Y has a pH of 3. (★ pure-only)

(a) Explain why Solution X has a lower pH than Solution Y, even though both have the same concentration. Your answer must refer to the extent of ionisation. [2]

(b) Write an equation, using the correct type of arrow, to show the ionisation of Solution Y (ethanoic acid) in water. [1]

(c) A student adds excess zinc to separate 25 cm³ samples of X and Y, both at 0.10 mol/dm³. She finds that X reacts more vigorously at the start, but the total volume of hydrogen gas collected at the end is the same for both. Explain both observations. [2]

SECTION C — Application (10 marks)

C1 A student titrates 25.0 cm³ of 0.100 mol/dm³ phosphoric acid (H_3PO_4) with 0.150 mol/dm³ sodium hydroxide solution. The pH curve shows three sharp vertical rises, at 16.7 cm³, 33.3 cm³ and 50.0 cm³ of NaOH added. (★ pure-only)

(a) State the basicity of H_3PO_4 and explain how you deduced this from the pH curve. [2]

(b) Write the chemical equation, with state symbols, for the reaction at the FIRST end-point (16.7 cm³ of NaOH added). [1]

(c) Calculate the number of moles of H_3PO_4 used. Then verify by calculation that 16.7 cm³ of 0.150

mol/dm³ NaOH is correct for the first end-point. Show all working. [2]

(d) The student wishes to collect only the product formed at the first end-point. She is choosing between methyl orange (changes near pH 4) and thymolphthalein (changes near pH 10). State which indicator she should use and explain your choice. [1]

C2 Sulfur dioxide (SO_2) is released when coal is burned. When SO_2 dissolves in rainwater, it forms sulfurous acid (H_2SO_3, a weak dibasic acid). This acidic rainwater then falls on agricultural soil.

(a) Classify SO_2 as acidic, basic, amphoteric or neutral. Justify your classification by describing its reaction with aqueous sodium hydroxide and writing a balanced chemical equation for that reaction, with state symbols. [2]

(b) A farmer applies calcium hydroxide to the field to counteract the acid. Write the ionic equation that represents the neutralisation of excess H^+ ions in the soil. [1]

(c) The farmer asks whether aluminium oxide (Al_2O_3) could also neutralise the acidic soil. State and explain whether Al_2O_3 would be effective. Name the category of oxide that Al_2O_3 belongs to and give the other TWO oxides in the same category. [1]

Model answers — the wording that earns the mark

For teacher / self-marking. Award marks per the [ ] allocation shown. Pure-only items are marked with a star (★ pure-only).

Section A — Multiple Choice

A1 C — an alkali is a soluble base that dissociates in water to produce $OH^-(aq)$ ions. (A describes an acid; B describes any base, not specifically an alkali; D is wrong — orange UI colour indicates pH 3-4, which is acidic, not alkaline.) [1]

A2 C — pH 11 is alkaline: $[OH^-] > [H^+]$; Universal Indicator turns blue (pH 8-12) and violet (pH 13-14). At pH 11, the correct colour is blue. Row C is correct. [1]

A3 C — an acidic oxide reacts with bases/alkalis (such as NaOH) but does not react with dilute acids (such as HCl). P fits this profile: reacts with NaOH, does not react with HCl. (An amphoteric oxide would react with BOTH; a basic oxide would react with HCl but not NaOH; a neutral oxide reacts with neither.) [1]

A4 ★ pure-only B — J is a strong acid (fully ionises in water: all molecules produce $H^+(aq)$ ions) giving pH 1. K is a weak acid (partially ionises: only a fraction of molecules produce $H^+(aq)$ ions) giving pH 3 at the same concentration. (A is wrong — both have the same concentration. C is wrong — J is the strong acid with the lower pH, not the weak acid.) [1]

A5 C — dry HCl gas exists as covalent molecules. Without water, HCl cannot dissociate into $H^+(aq)$ ions, so it shows no acidic properties. Dry blue litmus paper does not change colour. Acidic properties only appear when HCl dissolves in water: $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$. (B is wrong — HCl does not bleach; bleaching is a property of Cl_2.) [1]

A6 B — CuO is an insoluble base. Once all the acid is neutralised, excess CuO cannot dissolve further and so cannot release OH^- ions into solution. The pH stays at 7 (neutral salt solution). This is why excess insoluble base is the preferred method for salt preparation — the excess can be filtered off and the solution stays at pH 7. (C is wrong — only excess SOLUBLE alkali raises pH above 7.) [1]

A7 D — the reaction $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$ is a precipitation (double decomposition) reaction, not an acid reaction. No acid is involved. A, B and C all show characteristic acid reactions: acid + metal (A), acid + base (B), acid + carbonate (C). [1]

A8 D — for a weak acid + strong alkali titration, the end-point pH is slightly above 7 (the salt formed, sodium ethanoate, is slightly alkaline in solution). Thymolphthalein changes colour near pH 10, which is within the steep part of the pH curve at the end-point for this combination. Methyl orange (A) changes at pH ≈4, which is too acidic. Litmus (B) gives a gradual colour change, not suitable for precision titrations. Universal Indicator (C) gives no sharp colour change. [1]

Section B — Structured

B1(a) Chemical equation: [1]
$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$ [1]
Marker note: Award [1] for balanced equation with correct state symbols. Accept 'water' spelled out.

B1(b) Ionic equation for neutralisation: [1]
$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ [1]
Marker note: Accept without state symbols per LO 5.1(e). Charges on ions must be shown.

B1(c) Moles of HCl: [1]
$n(HCl) = c \times V = 0.200\ mol/dm^3 \times (22.5 \div 1000)\ dm^3$
$= 0.200 \times 0.0225 = 4.50 \times 10^{-3}$ mol [1]

B1(d) Moles of NaOH: [1]
From the equation, HCl : NaOH = 1 : 1 (molar ratio).
Therefore $n(NaOH) = 4.50 \times 10^{-3}$ mol [1]

B1(e) Concentration of NaOH solution: [2]
$c(NaOH) = n \div V = (4.50 \times 10^{-3}) \div (25.0 \div 1000)$ [1 method]
$= (4.50 \times 10^{-3}) \div 0.025 = 0.180\ mol/dm^3$ [1 answer]
Marker note: Method mark for correct division of n by V(dm3). Answer mark for 0.180 mol/dm3.

B1(f) Limiting reagent and pH: [2]
$n(HCl) = 0.200 \times 0.010 = 2.00 \times 10^{-3}$ mol
$n(NaOH) = 0.180 \times 0.010 = 1.80 \times 10^{-3}$ mol
HCl : NaOH = 1 : 1; n(HCl) > n(NaOH), so HCl is in excess. [1]
The mixture contains excess H^+ ions → the solution is acidic → pH < 7. [1]
Marker note: Both marks require correct mole calculation AND correct pH prediction. Allow error carried forward from (e) for the NaOH moles used here.

B2(a) Balanced equation: [1]
$Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$ [1]
Marker note: Must have state symbols and be balanced. ZnSO4 must be shown as aqueous.

B2(b) Two observations: [2]
[1] Effervescence (bubbles of gas) / zinc gradually dissolves.
[1] The lighted splint held at the mouth of the test tube is extinguished with a 'pop' sound.
Marker note: Award [1] for each valid observation. Accept 'colourless gas produced'. Must use the quoted 'pop' sound or describe the lighted-splint test explicitly.

B2(c)(i) Equation for PbCO3 + H2SO4: [1]
$PbCO_3(s) + H_2SO_4(aq) \rightarrow PbSO_4(s) + H_2O(l) + CO_2(g)$ [1]
Marker note: PbSO4 must be shown as solid (s) — this is critical to the explanation in (c)(ii).

B2(c)(ii) Explanation for effervescence stopping: [2]

[1] $PbSO_4$ is insoluble and forms on the surface of the solid $PbCO_3$.

[1] It forms a non-porous coating around the solid $PbCO_3$, preventing further contact between the acid and the carbonate. The reaction stops before all reactants are used up.

Marker note: Both marks needed: [1] for identifying PbSO4 as insoluble / forms a coating; [1] for explaining the blocking mechanism (prevents acid reaching unreacted PbCO3).

B2(d) Gas name and test: [1]

Hydrogen (H_2) gas. Hold a lighted splint at the mouth of the test tube — it is extinguished with a 'pop' sound. [1]

B3(a) Classification of oxides D, E, F, G: [4]

D: basic (reacts with acid, not with alkali) [1]

E: acidic (reacts with alkali, not with acid) [1]

F: amphoteric (reacts with BOTH acid and alkali) [1]

G: neutral (reacts with neither acid nor alkali) [1]

B3(b) Oxide F identity and equation: [2]

[1] Any ONE of the three amphoteric (ZAP) oxides: ZnO, Al_2O_3 or PbO.

Example using ZnO:

$ZnO(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2O(l)$ [1]

If Al_2O_3: $Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$

If PbO: $PbO(s) + 2HCl(aq) \rightarrow PbCl_2(aq) + H_2O(l)$

Marker note: Award [1] for naming any ZAP oxide. Award [1] for correct balanced equation matching the named oxide, with state symbols. Mark consequentially.

B4(a) Second liming agent: [1]

Calcium hydroxide, $Ca(OH)_2$ (slaked lime) [1]

Marker note: Must give both name and formula for the mark.

B4(b) CaO + H2O equation: [1]

$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$ [1]

B4(c) Ionic equation for neutralisation of H+ ions: [1]

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ [1]

Marker note: Accept without state symbols per LO 5.1(e). Charges must be shown.

B4(d) Mass calculation: [3]

(i) $M_r(CaO) = 40 + 16 = 56$ g/mol [part of working]

$n(CaO) = \text{mass} \div M_r = 112 \div 56 = 2.00$ mol [1]

(ii) From $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$, molar ratio = 1:1

$n(Ca(OH)_2) = 2.00$ mol [1 consequential]

$M_r(Ca(OH)_2) = 40 + 2(16 + 1) = 40 + 34 = 74$ g/mol

mass $= 2.00 \times 74 = 148$ g [1]

Marker note: [1] for n(CaO) = 2.00 mol; [1] for correct mole ratio; [1] for mass = 148 g. Allow error carried forward from (i) for the final mass mark.

B5(a) ★ pure-only Extent of ionisation explanation: [2]

[1] HCl (Solution X) is a strong acid: it fully (completely) ionises in water.

All HCl molecules produce $H^+(aq)$ ions: $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$.

This gives a high concentration of $H^+(aq) \rightarrow$ lower pH (pH 1).

[1] Ethanoic acid (Solution Y) is a weak acid: it only partially ionises in water.

Only a small fraction of CH_3COOH molecules produce $H^+(aq)$ ions.

Lower concentration of $H^+(aq)$ at the same total acid concentration → higher pH (pH 3).

Marker note: Must reference 'fully ionises' and 'partially ionises' (or equivalent) for both marks. Do NOT accept 'X is more concentrated' — both are 0.10 mol/dm3.

B5(b) ★ pure-only Ionisation equation for ethanoic acid: [1]

$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$ [1]

Marker note: Equilibrium arrow (⇌) is required for the mark. A single forward arrow (→) scores zero.

B5(c) ★ pure-only Rate observation and total volume explanation: [2]

[1] X (HCl) reacts more vigorously at the start because it fully ionises, giving a higher concentration of $H^+(aq)$ ions initially → higher initial reaction rate. Y (CH_3COOH) only partially ionises, so $[H^+(aq)]$ is lower initially → slower initial rate.

[1] The total volume of H_2 is the same because both solutions have the same molar concentration (0.10 mol/dm³) and the same volume (25 cm³), so n(acid) is equal. With excess Zn, all acid molecules eventually react: as H^+ is consumed, the equilibrium $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ shifts to the right, replenishing H^+ until all the acid is used up.

Marker note: Both marks require correct reference to concentration of H+(aq) (not just 'strength'). Second mark must mention equal moles of acid OR equal n leading to equal H2.

Section C — Application

C1(a) ★ pure-only Basicity of H3PO4: [2]

[1] The basicity of H_3PO_4 is 3 (tribasic).

[1] This is deduced from the pH curve: there are THREE sharp vertical rises (end-points), one for each H^+ ion released per molecule of H_3PO_4.

Marker note: Both marks required: [1] state basicity = 3; [1] link to number of vertical rises in curve.

C1(b) ★ pure-only Equation at first end-point: [1]

$H_3PO_4(aq) + NaOH(aq) \rightarrow NaH_2PO_4(aq) + H_2O(l)$ [1]

Marker note: Must show NaH2PO4 as the product (acid salt, not normal salt). State symbols needed.

C1(c) ★ pure-only Mole verification: [2]

[1] $n(H_3PO_4) = c \times V = 0.100 \times 0.025 = 2.50 \times 10^{-3}$ mol

At the first end-point, H_3PO_4 : NaOH = 1 : 1 (one H^+ removed per molecule).

n(NaOH) needed = 2.50×10^{-3} mol [1 method]

$V(NaOH) = n \div c = (2.50 \times 10^{-3}) \div 0.150 = 0.01667$ dm³ = 16.7 cm³ ✓ [1 answer]

Marker note: [1] for correct n(H3PO4); [1] for correct V calculation matching 16.7 cm3. Accept 0.01667 dm3 or 16.7 cm3 as equivalent.

C1(d) ★ pure-only Indicator choice: [1]

Methyl orange. [1]

At the first end-point, the solution contains NaH_2PO_4 (slightly acidic, pH ≈4-5). Methyl orange changes colour near pH 4, the closest match to the first end-point; its colour change is complete just before the exact end-point. Thymolphthalein changes near pH 10, which corresponds to the third end-point, not the first.

Marker note: Award [1] for methyl orange WITH a valid reason linking its transition pH (~4) to the slightly acidic nature of the first end-point product. Do NOT award the mark for 'methyl orange' alone without a reason.

C2(a) SO2 classification and reaction with NaOH: [2]

[1] SO_2 is an acidic oxide. It dissolves in water / reacts with bases but does not react with dilute acids.

[1] Reaction with NaOH:

$SO_2(g) + 2NaOH(aq) \rightarrow Na_2SO_3(aq) + H_2O(l)$

Marker note: [1] for correct classification as acidic WITH justification (reacts with alkali/base, not with acid). [1] for balanced equation with state symbols. Na2SO3 is sodium sulfite (accept sodium sulfate(IV)).

C2(b) Ionic equation for neutralisation: [1]

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ [1]

Marker note: This is the universal ionic equation for acid-alkali neutralisation (LO 5.1e). Accept without state symbols.

C2(c) Al2O3 as liming agent; ZAP category: [1]

[1] Al_2O_3 would be effective: it is an amphoteric oxide (ZAP category), which means it reacts with acids. It would neutralise the excess H^+ ions in the acidic soil. The other two oxides in the ZAP category are ZnO and PbO.

Marker note: Award [1] only if all three are correct: (i) effective/yes; (ii) amphoteric named as the category; (iii) ZnO and PbO both identified. Giving only one other ZAP oxide does not score.

Marker note: Totals: Section A 8 + Section B 32 (B1:8 + B2:7 + B3:6 + B4:6 + B5:5) + Section C 10 = 50 marks. Backport scope -- pure-only: A4, B5, C1. All others are universal.