

Surname <i>StemUp Model Solution</i>	Centre Number	Candidate Number
First name(s)		2



GCE AS/A LEVEL

2410U10-1



S25-2410U10-1

TUESDAY, 13 MAY 2025 – MORNING

CHEMISTRY – AS unit 1

**The Language of Chemistry, Structure of Matter
and Simple Reactions**

1 hour 30 minutes

Section A

Section B

ADDITIONAL MATERIALS

- A calculator, pencil and ruler
- **Data Booklet** supplied by WJEC

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions.

Section B Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q13(a)**.

For Examiner's use only		
Question	Maximum Mark	Mark Awarded
1. to 8.	10	
9.	15	
10.	13	
11.	14	
12.	15	
13.	13	
Total	80	

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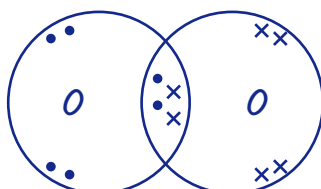


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SECTION A

Answer **all** questions.

1. Using outer electrons only, draw a dot and cross diagram to show the bonding in a diatomic molecule of oxygen. [1]



2. State why the coordination number of Na^+ in NaCl is different to that of Cs^+ in CsCl . [1]

The Na^+ ion is smaller than the Cs^+ ion, so fewer Cl^- ions can fit around it.

3. The visible emission spectrum of hydrogen shows prominent lines at wavelengths of 434 nm, 486 nm and 656 nm.

Complete the sentences by using the words **higher** or **lower**. [1]

The frequency of the line at 656 nm is *lower* than the frequency of the line at 434 nm.

The line at 656 nm is caused by an electronic transition of *lower* energy than the line at 486 nm.

4. The first four ionisation energies for an element, **X**, are shown in the table below.

Ionisation energy / kJ mol^{-1}			
1st	2nd	3rd	4th
402	2650	3850	5110

Give the formula for the chloride of **X**. [1]

XCl



5. State the total number of orbitals that are occupied in a nitrogen atom. [1]

5

6. Consider the following s-block elements.

Na	Mg
K	Ca
Rb	Sr
Cs	Ba

- (a) State which element forms the sulfate that is least soluble in water. [1]

barium, Ba

- (b) State which element forms compounds which give an apple-green flame test. [1]

barium, Ba

7. The hydrogencarbonate anion has the formula HCO_3^- .

Write the formula of magnesium hydrogencarbonate. [1]

$\text{Mg}(\text{HCO}_3)_2$

8. Calculate the number of nitrogen atoms in 66.0g of N_2O . [2]

$$n(\text{N}_2\text{O}) = 66.0 \div 44.0 = 1.50 \text{ mol}$$

$$N \text{ atoms} = 1.50 \times 2 \times 6.02 \times 10^{23}$$

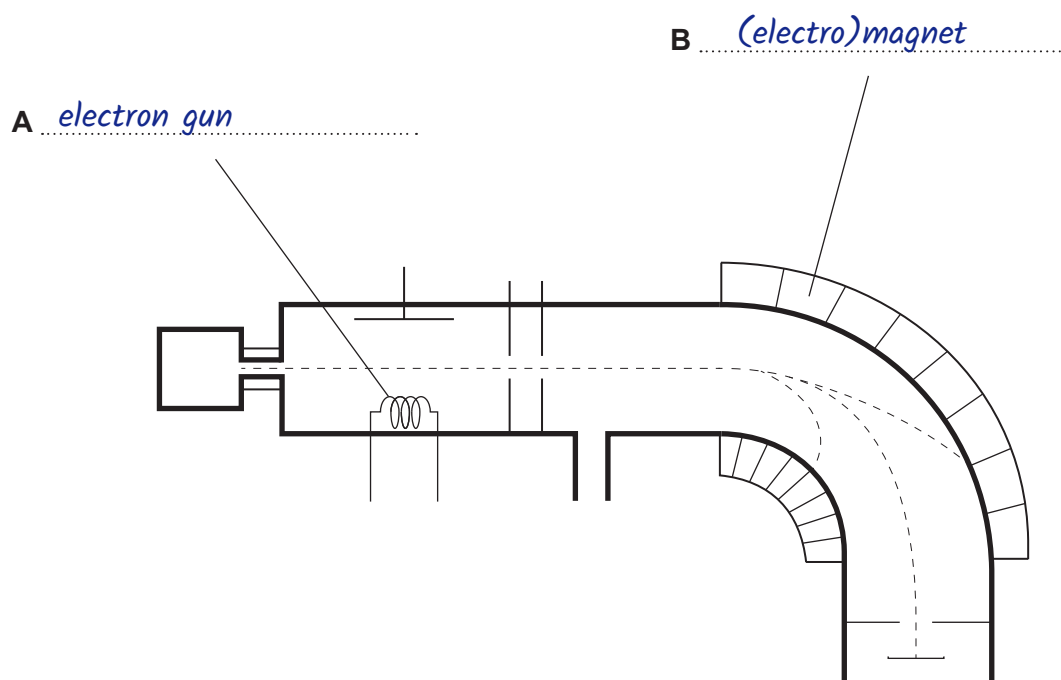
Number of nitrogen atoms = 1.81×10^{24}



SECTION B

Answer **all** questions.

9. (a) (i) A mass spectrometer can be used to find the relative atomic mass of an element. The following diagram shows a typical mass spectrometer.



- I. Label parts **A** and **B**. [2]
- II. Explain why a vacuum is needed inside the mass spectrometer. [1]

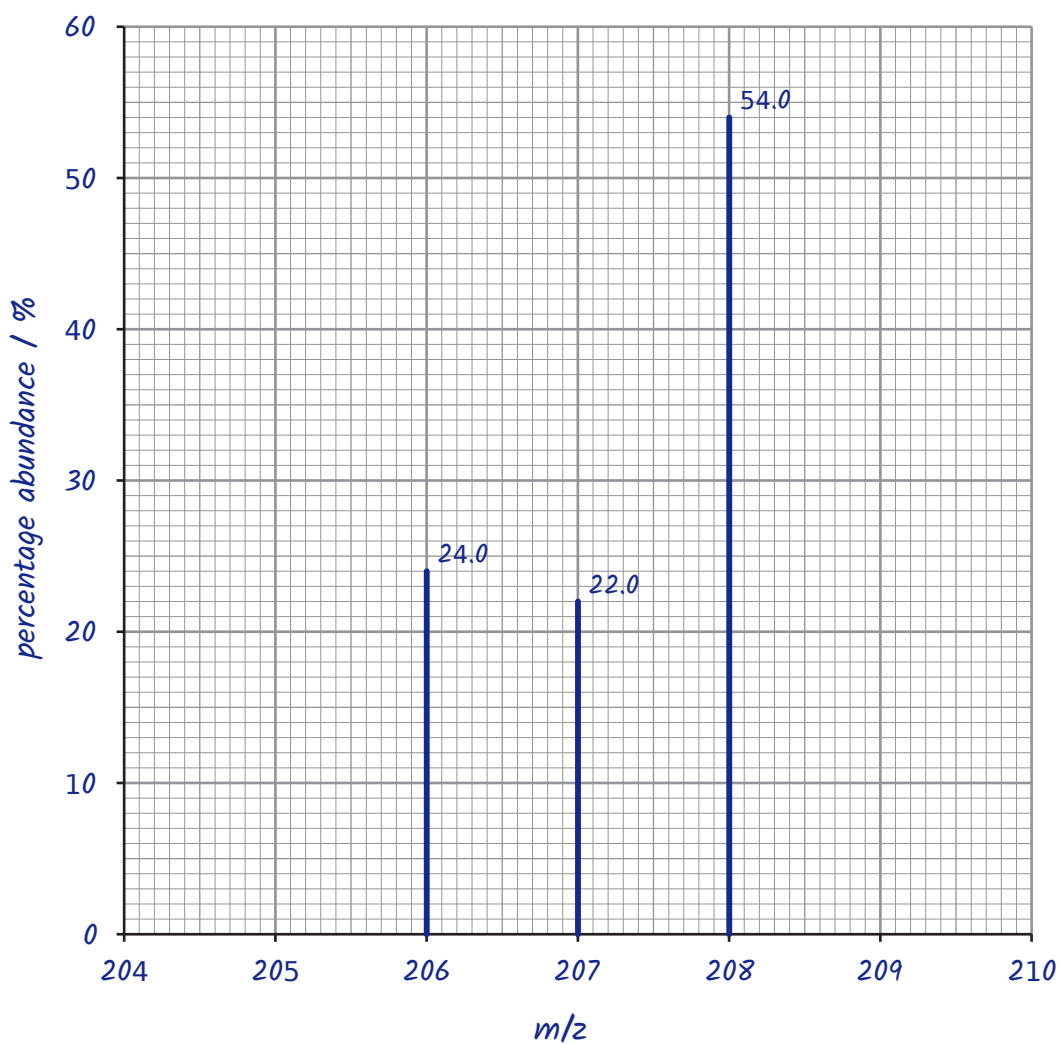
So that the ions are not slowed down or deflected by colliding with
air (other) particles.



- (ii) A sample of lead consisted of three isotopes: ^{206}Pb , ^{207}Pb and ^{208}Pb .

The percentage abundance of ^{207}Pb was 22.0 % and that of ^{208}Pb was 54.0 %.

On the grid below, label the axes and draw lines to show the mass spectrum that this sample of lead would be expected to give. [3]



(b) Radioactive radium, ^{226}Ra , decays to the gas radon, ^{222}Rn , and eventually forms the stable lead isotope, ^{208}Pb .

- (i) ^{222}Rn is a natural radioactive gas that comes from rocks and soils. It decays by alpha emission and has a half-life of 3.8 days. Scientists are concerned about the build-up of ^{222}Rn in homes since it may cause lung cancer.

I. Explain why ^{222}Rn may cause lung cancer.

[2]

Radon is a gas, so it is breathed in and enters the lungs.

The alpha particles it emits inside the lungs are highly ionising and damage cells, causing cell mutation.

II. Calculate how long it would take for 0.8 g of ^{222}Rn to decay to 0.1 g.

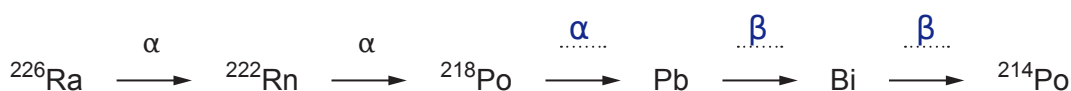
[1]

0.8 g $\rightarrow$ 0.4 g $\rightarrow$ 0.2 g $\rightarrow$ 0.1 g = 3 half-lives

time = 3 $\times$ 3.8 = 11.4 days

Time taken = 11.4 days

- (ii) Part of the radioactive decay series of ^{226}Ra is shown below.



Complete the series by **labelling the last three arrows** to indicate the nature of the radioactive decay occurring in each step.

[2]



- (c) In her PhD research, Marie Curie measured the atomic mass of the element radium, which she discovered. She knew that radium is in the same family as barium, so the formula for radium chloride is RaCl_2 .

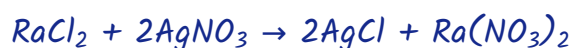
When 0.8779 g of pure RaCl_2 is dissolved and treated with excess AgNO_3 , 0.8490 g of AgCl is precipitated.

Calculate the relative atomic mass of radium.

Give your answer to **four** significant figures. You **must** show your working.

[4]

$$n(\text{AgCl}) = 0.8490 \div 143.5 = 5.916 \times 10^{-3} \text{ mol}$$



$$n(\text{RaCl}_2) = 5.916 \times 10^{-3} \div 2 = 2.958 \times 10^{-3} \text{ mol}$$

$$M_r(\text{RaCl}_2) = 0.8779 \div 2.958 \times 10^{-3} = 296.8$$

$$A_r(\text{Ra}) = 296.8 - (2 \times 35.5) = 225.8$$

$$A_r = \dots\dots\dots 225.8$$

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10. Some students wanted to determine the number of moles of water of crystallisation, x , in hydrated strontium chloride, $\text{SrCl}_2 \cdot x\text{H}_2\text{O}$.

They were given the following method.

- Weigh a sample of the hydrated strontium chloride crystals in a crucible
- Heat the crucible containing the sample strongly for about 3 minutes
- Allow the crucible to cool and then reweigh

- (a) One student's results are shown in the table below.

Weighing	Mass/g
crucible	12.12
crucible + $\text{SrCl}_2 \cdot x\text{H}_2\text{O}$ before heating	13.71
crucible + SrCl_2 after heating	13.09
$\text{SrCl}_2 \cdot x\text{H}_2\text{O}$ before heating	1.59
SrCl_2 after heating	0.97
H_2O removed	0.62

- (i) Complete the table. [1]

- (ii) Calculate the value of x to the nearest whole number. You **must** show your working. [3]

$$n(\text{SrCl}_2) = 0.97 \div 158.6 = 0.0061 \text{ mol}$$

$$n(\text{H}_2\text{O}) = 0.62 \div 18.02 = 0.0344 \text{ mol}$$

$$\text{ratio } \text{H}_2\text{O} : \text{SrCl}_2 = 0.0344 \div 0.0061 = 5.6$$

$$x = 6$$



- (iii) Each mass reading in the table has a maximum error of ± 0.005 g.

Calculate the percentage error in the mass of hydrated strontium chloride used. [1]

$$\text{two readings, so error} = 2 \times 0.005 = 0.01 \text{ g}$$

$$\% \text{ error} = 0.01 \div 1.59 \times 100$$

Percentage error = ... 0.6 %

- (b) (i) Another student heated the crystals using the yellow flame of the Bunsen burner instead of the blue flame.

Predict the effect, if any, of this mistake on the calculated value of x . Give your reasoning. [2]

The value of x decreases.

The yellow flame is not hot enough, so not all the water is lost and the mass of water removed decreases.

- (ii) A third student found that a few crystals spat out of the crucible during heating.

Predict the effect, if any, of this problem on the calculated value of x . Give your reasoning. [2]

The value of x increases.

Crystals lost from the crucible add to the loss in mass, so the apparent mass of water removed increases.

- (c) Suggest **two** improvements to the method that would help to achieve a more accurate result for the value of x . Explain your answers. [4]

First suggestion Heat to constant mass (reheat and reweigh until two masses agree), to ensure that all the water has been removed.

Second suggestion Put a lid on the crucible, to ensure that all the solid stays in the crucible and no crystals spit out.



11. (a) The boiling temperatures of some hydrides of Group 5 elements are shown below.

Hydride	Boiling temperature / °C
NH ₃	-33
PH ₃	-88
AsH ₃	-63

- (i) Explain why the boiling temperature of PH₃ is lower than that of NH₃. [2]

NH₃ has hydrogen bonding between its molecules whilst PH₃ has only van der Waals forces.

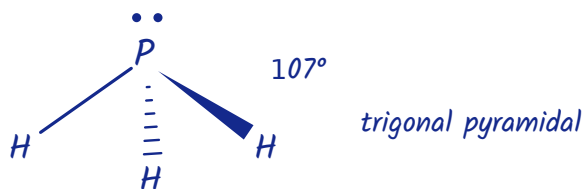
Hydrogen bonding is stronger, so more energy is needed to overcome it than the van der Waals forces.

- (ii) Explain why the boiling temperature of PH₃ is lower than that of AsH₃. [2]

AsH₃ has more electrons than PH₃.

So there are more / stronger van der Waals forces between AsH₃ molecules, which need more energy to overcome.

- (b) Use the VSEPR theory to predict the shape of PH₃. Explain your answer and suggest a bond angle for the H—P—H bonds. [4]



PH₃ has three bonding pairs and one lone pair of electrons around P. The pairs repel and move as far apart as possible (minimum repulsion). The shape is (trigonal) pyramidal. The lone pair repels more than the bonding pairs, so the angle is less than 109.5°, about 107°.



- (c) A student is given two solutions. Both solutions contain at least one of the anions chloride, bromide and iodide.

- (i) To the first solution she adds aqueous silver nitrate and a yellow precipitate is formed.

She says this means that the only halide in the solution is iodide.

Is she correct? Justify your answer.

[2]

No. Although the yellow precipitate shows silver iodide is present, any white AgCl or cream AgBr precipitate formed as well would be masked and not seen clearly.

- (ii) She adds the second solution to bromine water and no obvious colour change is observed.

She says this means that the solution only contains bromide ions.

Do you agree? Justify your answer.

[2]

Disagree. No colour change shows that iodide ions are not present, but there could also be chloride ions, since bromine cannot oxidise (displace) chloride ions.

- (d) Chlorine can react with water to produce hydrogen chloride and oxygen.



Explain why this reaction is classified as a redox reaction.

[2]

Oxygen loses electrons, oxidation state -2 to 0, so it is oxidised. Chlorine gains electrons, oxidation state 0 to -1, so it is reduced.



12. (a) When lithium and hydrogen are heated together, lithium hydride is formed as colourless crystals. Lithium hydride conducts electricity when molten but not when solid.

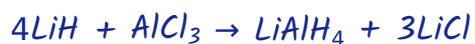
State the type of structure present in lithium hydride. Explain why your chosen structure type has this property. [2]

Giant ionic ($\text{Li}^+ \text{H}^-$).

It contains ions which are free to move in the molten state, but are fixed in the lattice in the solid.

- (b) Lithium hydride, LiH , reacts with aluminium chloride, AlCl_3 , to form lithium aluminium hydride, LiAlH_4 , and lithium chloride.

Write the equation for this reaction. [1]



- (c) When 1.9 g of lithium aluminium hydride is heated to 150°C , it decomposes to give 0.90 g of aluminium, 1.22 dm^3 of hydrogen (measured at 25°C and 1 atm) and one other product.

- (i) Calculate the molar ratio of the three named substances. [3]



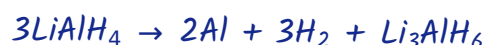
$1.9 \div 37.98 : 0.90 \div 27.0 : 1.22 \div 24.5$

$0.050 : 0.033 : 0.050$

$\div 0.0167 \text{ gives } 3 : 2 : 3$

- (ii) One other product is formed.

Determine the formula of this product by writing an equation for the decomposition reaction. [1]



- (d) 0.300 g of lithium reacts with an excess of water at 15 °C and 1 atm pressure to form lithium hydroxide and hydrogen.



Calculate the volume of hydrogen formed in cm^3 .

[4]

$$n(\text{Li}) = 0.300 \div 6.94 = 0.0432 \text{ mol}$$

$$n(\text{H}_2) = 0.0432 \div 2 = 0.0216 \text{ mol}$$

$$T = 15 + 273 = 288 \text{ K}, \quad p = 1.01 \times 10^5 \text{ Pa}$$

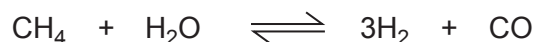
$$V = nRT \div p = (0.0216 \times 8.31 \times 288) \div 1.01 \times 10^5$$

$$V = 5.12 \times 10^{-4} \text{ m}^3 = 512 \text{ cm}^3$$

Volume of hydrogen = ...512..... cm^3



- (e) Hydrogen is produced industrially by the steam reforming of methane.



- (i) Write an expression for the equilibrium constant, K_c , and give its unit, if any. [2]

$$K_c = \frac{[\text{H}_2]^3 [\text{CO}]}{[\text{CH}_4] [\text{H}_2\text{O}]}$$

Unit $\text{mol}^2 \text{dm}^{-6}$

- (ii) The equilibrium constant, K_c , has a numerical value of 0.092 at a temperature of 1200 °C.

If the equilibrium concentration of water is 0.77 mol dm^{-3} , hydrogen is 0.55 mol dm^{-3} and carbon monoxide is 0.26 mol dm^{-3} , calculate the equilibrium concentration of methane at this temperature. [2]

$$[\text{CH}_4] = [\text{H}_2]^3 [\text{CO}] \div (K_c [\text{H}_2\text{O}])$$

$$[\text{CH}_4] = (0.55^3 \times 0.26) \div (0.092 \times 0.77) = 0.61$$

Concentration of methane = 0.61 mol dm^{-3}



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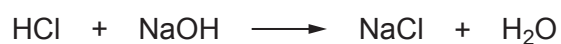


13. (a) A student is given a white powder and told to prove that the powder is pure calcium carbonate by finding its relative formula mass.

The relative formula mass can be found by performing a back titration.

A known mass of the powder is reacted with an excess of hydrochloric acid and the amount of unreacted acid is found by titrating against a solution of sodium hydroxide using a suitable indicator.

The equations for these reactions are as follows.



The student is provided with 0.500 g of the powder, 25.0 cm³ of 0.500 mol dm⁻³ hydrochloric acid in a conical flask and a standardised solution of 0.200 mol dm⁻³ sodium hydroxide.



Describe how he would carry out the experiment and how he would use his results to calculate the relative formula mass of calcium carbonate.

You may assume that all apparatus used is clean and that only one titration is required.

[6 QER]

Add the 0.500 g of powder to the 25.0 cm³ of 0.500 mol dm⁻³ HCl in the conical flask and swirl. When no more bubbles of CO₂ are formed, add a few drops of a suitable indicator (e.g. phenolphthalein) to the contents of the flask.

Using a funnel, fill the burette with the 0.200 mol dm⁻³ NaOH, ensure the jet below the tap is filled, and remove the funnel. Record the initial burette reading.

Add the NaOH to the flask, swirling continually, until the indicator changes colour (colourless to pale pink). Near the end-point wash down the sides of the flask with deionised water and add the NaOH drop by drop. Record the final reading and calculate the titre.

Original moles of HCl = $0.500 \times 25.0 \div 1000 = 0.0125$ mol.

Moles of HCl in excess = moles of NaOH added = $0.200 \times \text{titre (cm}^3) \div 1000$.

Moles of HCl used in the reaction = $0.0125 - \text{moles of HCl in excess}$.

Moles of CaCO₃ used = moles of HCl used $\div 2$ (1 : 2 ratio in the equation).

M_r of CaCO₃ = $0.500 \div \text{moles of CaCO}_3 \text{ used}$. If the powder is pure CaCO₃ this equals 100.1.



- (b) Hydrochloric acid is a strong acid while ethanoic acid is a weak acid.

The properties of a 1.00 mol dm^{-3} solution of hydrochloric acid are as follows.

- Gaseous carbon dioxide is evolved on reaction with sodium carbonate
- It turns pH paper red
- 25.0 cm^3 of this acid solution neutralises 25.0 cm^3 of 1.00 mol dm^{-3} sodium hydroxide solution

- (i) State what is meant by a strong acid.

[1]

An acid that fully dissociates (ionises) in solution.

- (ii) The first property listed above also applies to a 1.00 mol dm^{-3} solution of ethanoic acid.

State whether the second and third properties apply to a 1.00 mol dm^{-3} solution of ethanoic acid. Explain your answers.

[2]

Second property does not apply: pH paper turns orange/yellow, not red, because ethanoic acid is a weak acid (partially dissociated).

Third property applies: there are the same number of moles of both acids, so 25.0 cm^3 still neutralises 25.0 cm^3 of NaOH.

- (c) A sample of hydrochloric acid has a concentration of 2.00 mol dm^{-3} and a volume of 100 cm^3 .

Calculate the volume of water that should be **added** to this acid to dilute the sample to a concentration of 1.60 mol dm^{-3} .

[2]

$$n(\text{HCl}) = 2.00 \times 0.100 = 0.200 \text{ mol}$$

$$\text{new volume} = 0.200 \div 1.60 = 0.125 \text{ dm}^3 = 125 \text{ cm}^3$$

$$\text{water added} = 125 - 100 = 25 \text{ cm}^3$$

Volume of water added = ... 25 cm^3



- (d) Stagnant water has a potential for microbial growth. The bacteria legionella thrives in stagnant water that has a pH range of 5.5-8.1.

Calculate the **minimum** hydrogen ion concentration in which legionella can thrive. [2]

minimum $[H^+]$ is at the highest pH, 8.1

$$[H^+] = 10^{-8.1}$$

$$[H^+] = 7.9 \times 10^{-9} \text{ mol dm}^{-3}$$

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