

T1. A journey through time: The secrets of Avicenna

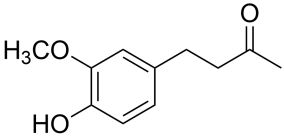
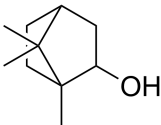
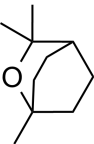
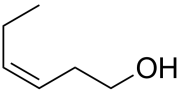
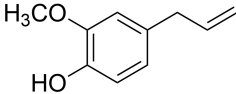
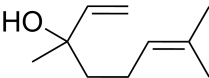
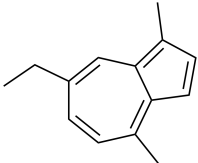
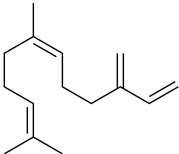
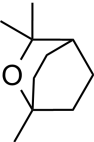
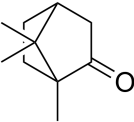
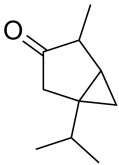
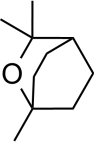
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A chemist found herself in the 11th Century, where she met the renowned physician Avicenna. In Avicenna's laboratory, she discovered a blue elixir and a yellow mysterious stone. She brought them back to 2026. Determined to uncover their composition, she began her research.

Part 1. The blue elixir

At first, the chemist compiled a table listing the names of the only four plants which she saw in Avicenna's lab that could have been used to prepare the elixir, and the compounds that can be extracted from these plants.

Plants	Compounds that can be extracted		
Zingiber			
	1 (C ₁₁ H ₁₄ O ₃)	2 (C ₁₀ H ₁₈ O)	3 (C ₁₀ H ₁₈ O)
Hypericum			
	4 (C ₆ H ₁₂ O)	5 (C ₁₀ H ₁₂ O ₂)	6 (C ₁₀ H ₁₈ O)
Chamomilla			
	7 (C ₁₄ H ₁₆)	8 (C ₁₅ H ₂₄)	3 (C ₁₀ H ₁₈ O)
Artemisia			
	9 (C ₁₀ H ₁₆ O)	10 (C ₁₀ H ₁₈ O)	3 (C ₁₀ H ₁₈ O)

Using chromatography, she determined that the elixir consists of four different substances (**X**, **Y**, **Z** and **W**).

The chemist then discovered that **X** can isomerise into **Y** in an acidic medium and that **Y** has a plane of symmetry.

1.1 Identify X and Y.

3.0 pt

Theory

Chromatography also revealed it was substance **Z** that gave the elixir its blue colour. **Z** is a derivative of the well-known substance **A**, which has two perpendicular planes of symmetry. When heated, **A** isomerises into aromatic compound **B**, which has three mutually perpendicular planes of symmetry. When substance **Z** is chlorinated, a pair of peaks with an intensity ratio of 3:1 is observed in the mass spectrum at m/z 218 and 220, respectively.

1.2 Identify **Z** and draw the structures of substances **A** and **B**.

4.0 pt

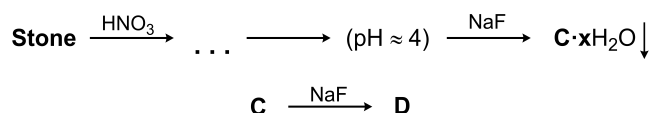
The chemist extracted **W** from the elixir. When **W** was added to an aqueous Fe^{3+} solution, a characteristic colour change was observed. Mass spectrometric analysis of **W** revealed the intensity ratio of $[M]^+ : [M + 1]^+ = 9:1$, where M is the molecular ion. Assume carbon consists exclusively of ^{12}C and ^{13}C , the natural isotopic abundance of ^{12}C is 98.9%, and all other elements are monoisotopic.

1.3 Determine the number of carbon atoms (n) from the mass spec data and identify **W**. Show your calculations.

3.0 pt

Part 2. The mysterious stone

Avicenna had told her the **stone** was a stoichiometric compound. She dissolved it in dilute nitric acid. After that, she adjusted the pH of the solution to ~ 4 and added NaF. This led to the formation of precipitate $\text{C} \cdot x\text{H}_2\text{O}$, which contained 39.16% water by mass. Anhydrous **C** reacts with an excess of NaF to yield compound **D**, which contains 32.85% sodium and 12.85% of metal **Q** by mass, and is used in the industrial production of **Q**.



1.4 Identify metal **Q** and compounds $\text{C} \cdot x\text{H}_2\text{O}$ and **D**.

4.0 pt

Avicenna told her that he found the **stone** in a coal deposit. The **stone** contains the anion of a highly symmetrical acid **F**. Reaction of **F** with P_2O_5 gives binary compound **G**, which contains 49.98% of oxygen by mass and has a three-fold symmetry axis. **F** can be prepared by oxidising compound **E** with potassium permanganate in an acidic solution. **E** contains 11.18% of hydrogen by mass and has a six-fold symmetry axis.



1.5 Draw the structures of **E**, **F**, and **G**.

7.0 pt

Then, she analysed the **stone** thermogravimetrically in open air. A 10.00 g sample began to lose mass

Theory



Q1-4

English (Official)

at approximately 100 °C and stopped at 5.75 g at 200 °C. A second drop in mass was observed at 400 °C, with a final mass of 1.50 g of compound **H** remaining constant at higher temperatures.

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|------------|--|--------|
| 1.6 | Determine the chemical formulae of the stone and compound H using thermogravimetric data. | 4.0 pt |
|------------|--|--------|