## Qualitative Analysis

1(a). This question is about chemicals used by gardeners.
A garden product contains hydrated ammonium iron(II) sulfate, $\left(\mathrm{NH}_{4}\right)_{2} \mathrm{Fe}\left(\mathrm{SO}_{4}\right)_{2} \bullet \mathrm{xH}_{2} \mathrm{O}$. $\left(\mathrm{NH}_{4}\right)_{2} \mathrm{Fe}\left(\mathrm{SO}_{4}\right)_{2} \cdot \times \mathrm{H}_{2} \mathrm{O}$ contains $27.55 \%$ by mass of water of crystallisation.

Calculate the value of $x$ in the formula $\left(\mathrm{NH}_{4}\right)_{2} \mathrm{Fe}\left(\mathrm{SO}_{4}\right)_{2} \bullet x \mathrm{H}_{2} \mathrm{O}$.
Show your working.
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[3]
(b). The garden product in the previous question part is a solid mixture of the following ingredients:

- Hydrated ammonium iron(II) sulfate, $\left(\mathrm{NH}_{4}\right)_{2} \mathrm{Fe}\left(\mathrm{SO}_{4}\right)_{2} \cdot \times \mathrm{H}_{2} \mathrm{O}$, which is soluble in water
- Crushed limestone (calcium carbonate)
- Sand.
i. Suggest why crushed limestone has been included in this garden product.
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ii. *Plan a procedure on a test tube scale to show that the solid mixture contains the following ions:
- $\mathrm{NH}_{4}^{+}, \mathrm{Fe}^{2+}$ and $\mathrm{SO}_{4}{ }^{2-}$ present in $\left(\mathrm{NH}_{4}\right)_{2} \mathrm{Fe}\left(\mathrm{SO}_{4}\right)_{2} \cdot x \mathrm{H}_{2} \mathrm{O}$
- $\quad \mathrm{CO}_{3}{ }^{2-}$ present in crushed limestone.

Show your reasoning, including relevant equations.
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2.
A hydrated nickel(II) complex, $\mathbf{A}$, is heated in a crucible to remove the water of crystallisation.
The anhydrous complex $\mathbf{B}$ is formed. The results are shown below.

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\begin{array}{ll}
\text { Mass of crucible + hydrated complex A } & =59.554 \mathrm{~g} \\
\text { Mass of crucible + anhydrous complex B } & =58.690 \mathrm{~g} \\
\text { Mass of crucible } & =51.257 \mathrm{~g}
\end{array}
$$

The anhydrous complex $\mathbf{B}$ is analysed and found to have a molar mass of $309.7 \mathrm{~g} \mathrm{~mol}^{-1}$ and to contain the following percentage composition by mass:
Ni, 18.95\%; C, 23.25\%; N, 27.12\%; H, 7.75\%; CI, 22.93\%.

The anhydrous complex B contains a cation $\mathbf{C}$ comprising Ni, C, N and H only.
Cation $\mathbf{C}$ is six-coordinate, contains three molecules of the bidentate ligand $\mathbf{D}$, and exists as optical isomers.
Determine the formula of $\mathbf{A}, \mathbf{B}, \mathbf{C}$ and $\mathbf{D}$ and show the 3D structures for the optical isomers of $\mathbf{C}$. Show all your working.
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### 5.3.2 Qualitative Analysis

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3. Students work together in groups to identify four different solutions.

Each solution contains one of the following compounds:

- ammonium sulfate, $\left(\mathrm{NH}_{4}\right)_{2} \mathrm{SO}_{4}$
- sodium sulfate, $\mathrm{Na}_{2} \mathrm{SO}_{4}$
- sodium chloride, NaCl
- potassium bromide, KBr.

Your group has been provided with universal indicator paper and the following test reagents:

- barium chloride solution
- silver nitrate solution
- dilute ammonia solution
- sodium hydroxide solution.
* A student in your group suggests the following plan:
- Add about 1 cm depth of each solution into separate test-tubes.
- Add a few drops of barium chloride solution to each test-tube.
- A white precipitate will show which solutions contain sulfate ions.
- Two of the solutions will form a white precipitate.

Describe how you would expand this plan so that all four solutions could be identified using a positive test result.

You should provide observations and conclusions that would enable your group to identify all four solutions.
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### 5.3.2 Qualitative Analysis

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END OF QUESTION PAPER

