Star chemistry

Life - but not as we know it

The question, 'Is there life out in space?' has fascinated people for hundreds of years. We still cannot answer the question, but astrochemists and astronomers are working on it, investigating the large number of molecules known to exist in space.

The basis for life: analysing large molecules in space

What you need

- A molecular modelling kit
- Molecules in space table
- Periodic Table

What you do

A team of astrochemists is analysing data obtained from a radio telescope (refer to Did you know? About radio telescopes) trained on the Milky Way. As part of the team, you have been asked to prepare a presentation or a short scientific article based on your analysis. The team needs to answer the question, 'Molecules in the ISM: are these clues to life in space?'

Tasks for members of the team are given below. The data are in the table Molecules in space.

Points to include and what to look for:

- Each team member should work on one task, but the final presentation or article must be agreed by everyone.
- Help each other with the tasks by discussing answers to the questions or suggesting where the answers could be found.
- Don't forget that the conclusion should answer the question 'Molecules in the ISM: Are these clues to life in space?'
- If you are asked to write an article, use a computer to make it look professional.
- If you are asked to prepare a presentation, the class can agree criteria for assessing presentations.

Researching background: Element analysis

Use a Periodic Table to find out the names of the elements that are found in space.

What to look for

- The three most common elements
- The element with the highest atomic number
- How many metals and non-metals are found

Questions

1. Which elements are needed to support life?
2. Are these present in space?
3. One group of elements does not appear in space. Find out which group and explain why.
4. What is the total number of molecules in the table? Is this surprising? Explain your thinking.
5. Have any more molecules been detected? Do some research to find out.

Testing the data: molecular modelling

Make some of the molecules in the Molecules in space table using the modelling kit

Molecules to make

- HCl, CN, CO, CO₂, C₃, NH₃, C₂H₂, C₂H₄ and CH₃CHO. These have bonds which we think of as 'covalent' in conditions on Earth.
- NaCl, KCl, NaCN and MgCN. These have bonds which we think of as 'ionic' in Earth conditions. They may be covalent in space, as conditions are very different.
- Try any others from the table.
- Make drawings of some molecules for your results.

Questions

1. All available bonds are not always used. Why is this important for forming larger molecules?
2. (Optional) Use the What's in a name? handout to give names to un-named molecules.
3. Work out and explain the differences between an atom, a molecule a radical and an ion. Give examples from the Molecules in space table.

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Collecting data: practical techniques
Find out how the molecules in the Molecules in space table are detected. Describe this for your 'experimental procedures' section.

Questions
1. How can such tiny molecules be detected from so far away?
2. How do we know that the signals are from a particular molecule?
3. What molecules would need to be detected to show there is life elsewhere?

Making conclusions
Do some research or use the article in Chemical reactions in the Interstellar Medium to work out how molecules might form in space.

Questions
1. Explain why there are more molecules with smaller numbers of atoms.
2. To make life large molecules called polymers are needed. Molecules with double and triple carbon-carbon bonds could form polymers. List these from the Molecules in space table.
3. (Optional) How could these polymers form in space?
4. Look at the largest molecules in the Molecules in space table. Could these be the basis for life?
5. What other experiments could be done to help find out if there could be life elsewhere?

Advice about writing a scientific article
1. Length: the article must be no more than 700 words long.
2. Sections: the article must have these sections (the word limits are shown in brackets):
   - Abstract (40 words) - introduces the article; gives the question and outlines the answer.
   - Introduction (100) - explains why the research was done.
   - Experimental Procedures (200) - explains how the research was done.
   - Results (150) - explains what was found out.
   - Conclusions (150) - describes the answer to the question and compares the results with the work of other scientists.
   - Other, eg Title, Acknowledgements, References (max 60) - shows who helped and what reading was done to support the work.
3. Keep to the word limits or the article will be unbalanced. Readers will be other scientists working in the same area. A lot of scientists publish in the same journal, so the number of words needs to be limited to be fair to everyone. Journal editors will not publish articles which are longer than the word limit.
4. Include pictures, diagrams and tables in the results. These do not count in the word limit. Examples of items may be: pictures of molecules, a table showing analysis of the elements present, a diagram or picture of a radio telescope used to collect the data.
5. References: write a list of any books, websites or other articles used in writing the article. Put the list at the end in alphabetical order, by the surname (last name) of the first author. Use the following guidelines to write your references:
   - Books: Author, *title (in italic)*, place of publication: publisher, date of publication. [Ensure all punctuation is accurate, ie commas, colons in correct places]
   - Websites: give the URL - remember to state the date that the site was last accessed, eg [www.rsc.org](http://www.rsc.org) (accessed July 2020)
### Star Chemistry—Molecules in space table

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<thead>
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<th>Molecules with..</th>
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<tbody>
<tr>
<td>H₂ hydrogen</td>
<td>H₂O water</td>
<td>NH₃ ammonia</td>
<td>CH₄ methane</td>
<td>CH₂OH methanol</td>
<td>CH₃CHO ethanal</td>
<td>CH₃COOH ethanoic acid</td>
<td>C₂H₂OH ethanol</td>
<td>(CH₂)₂CO propanone</td>
<td>HC₅CN cyano-octatetrayne</td>
<td>C₆H₆ benzene</td>
<td>HC₆CN cyanodecapentayne</td>
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<tr>
<td>KCl potassium chloride</td>
<td>HCN hydrogen cyanide</td>
<td>H₂O⁺ hydroxonium ion</td>
<td>SiH₄ silane</td>
<td>C₂H₄ ethene</td>
<td>C₃H₂ (unnamed)</td>
<td>HCOOH₃ methyl methanoate</td>
<td>(CH₃)₂CO methoxy-methane</td>
<td>NH₄HCO₂O ethanoic acid</td>
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<td>HCl hydrogen chloride</td>
<td>NaCN sodium cyanide</td>
<td>CH₃ methyl radical</td>
<td>HCOOH₃ methanoic acid</td>
<td>C₃H₂ butadiyne</td>
<td>CH₅CH(OH) hydroxyl-ethene</td>
<td>C₆H₄ triethyne</td>
<td>CH₅C≡H methylbuta-diyne</td>
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<td>CO carbon monoxide</td>
<td>CO₂ carbon dioxide</td>
<td>C₂H₂ ethyne</td>
<td>Cs (unnamed)</td>
<td>CH₃SH methanethiol</td>
<td>CH₅CHCN acrylonitrile</td>
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<td>NaCl sodium chloride</td>
<td>Mg₂CN₂ tricarbon cyanide</td>
<td>HNCS thiosiocyanic acid</td>
<td>CH₂CO ketene</td>
<td>C₅H (unnamed)</td>
<td>NH₂CHO formamide</td>
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<td>HF hydrogen fluoride</td>
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<td>C₃S tricarbon sulfide</td>
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<tr>
<td>CS carbon monosulfide</td>
<td>NO₂ nitrous oxide</td>
<td>NH₄CN cyanamide</td>
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<td>OH hydroxyl radical</td>
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<td>CN cyanide radical</td>
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<td>PN phosphorus mononitride</td>
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<td>SiO silicon monoxide</td>
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<td>AIF aluminium monofluoride</td>
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Note: This resource can be downloaded as part of a set of activities investigating the chemistry of outer space ([https://rsc.li/3jPAUBC](https://rsc.li/3jPAUBC)) or for use with a lesson plan for 14–16 year olds exploring molecules in space and the possibility of extraterrestrial life ([https://rsc.li/3ic3s7D](https://rsc.li/3ic3s7D)).