Name:………………………………………………..…. Date:…………………………………………………………

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, CO_2, C_3, NH_3, C_2H_2, C_2H_4 and CH_3CHO. 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]
   eg T. Lister, Classic Chemistry Demonstrations, London: Royal Society of Chemistry, 1995.
   Journals: Author, *journal title (in italic),* year, **volume (in bold),** page.
   eg S.C. Rust, School Science Review, 1988, **70(250),** 73.
   Websites: give the URL - remember to state the date that the site was last accessed, *eg* www.rsc.org (accessed July 2020)

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Star Chemistry—Molecules in space table

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Molecules with..

2 atoms	**3 atoms**	**4 atoms**	**5 atoms**	**6 atoms**	**7 atoms**	**8 atoms**	**9 atoms**	**10 atoms**	**11 atoms**	**12 atoms**	**13 atoms**
H_2 hydrogen	H_2O water	NH_3 ammonia	CH_4 methane	CH_3OH methanol	CH_3CHO ethanal	CH_3COOH ethanoic acid	C_2H_5OH ethanol	$(CH_3)_2CO$ propanone	HC_8CN cyano-octa-tetrayne	C_6H_6 benzene	$HC_{10}CN$ cyanodeca-pentayne
KCl potassium chloride	HCN hydrogen cyanide	H_3O^+ hydroxonium ion	SiH_4 silane	C_2H_4 ethene	C_6H (unnamed)	$HCOOCH_3$ methyl methanoate	$(CH_3)_2O$ methoxy-methane	NH_2CH_2COOH amino-ethanoic acid			
HCl hydrogen chloride	NaCN sodium cyanide	CH_3 methyl radical	HCOOH methanoic acid	C_4H_2 butadiyne	$CH_2CH(OH)$ hydroxyl-ethene	C_6H_2 triethyne	CH_3C_4H methylbuta-diyne				
CO carbon monoxide	CO_2 carbon dioxide	C_2H_2 ethyne	C_5 (unnamed)	CH_3SH methane-thiol	CH_2CHCN acrylonitrile						
NaCl sodium chloride	$Mg(CN)_2$ magnesium cyanide	HNCS thioisocyanic acid	CH_2CO ketene	C_5H (unnamed)							
HF hydrogen fluoride	SO_2 sulfur dioxide	C_3S tricarbon sulfide	C_4H (unnamed)	NH_2CHO formamide							
CS carbon monosulfide	N_2O nitrous oxide		NH_2CN cyanamide								
NS nitrogen monosulfide	C_3 triatomic carbon										
OH hydroxyl radical	OCS carbonyl sulfide										
CN cyanide radical	H_2S hydrogen sulfide										
NO nitrogen monoxide											
C_2 diatomic carbon											
SO sulfur monoxide											
PN phosphorus mononitride											
SiO silicon monoxide											
AlF aluminium monofluoride											
16	**10**	**6**	**7**	**6**	**4**	**3**	**3**	**2**	**1**	**1**	**1**

Note: This resource can be downloaded as part of a set of activities investigating the chemistry of outer space (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).