Inorganic Origin of Life

Several models of protocells have been studied during the last five decades in which coacervates of Oparin, microspheres of Fox, thiocyanate particles of Smith, marigranules of Egami and Jeewanu of Bahadur are important.

Study of the functional properties of organo molybdenum microstructures (OMM) as model for Protocells :-

OMM, a type of model of protocells, have been examined for ferredoxin-like activity. It is because these microstructures prepared by the action of light on sterilised aqueous mixture of ammonium molybdate, diammonium hydrogen phosphate, mineral solution and formaldehyde, have boundary wall, a central mass and chemicals of interest in the study of origin of life (1, 2, 3, 4). That they have ferredoxin-like material is evident because they can be used in the place of ferredoxin in the photobiological system chloroplast- ferredoxin - hydrogenase (5, 6). These microstructures were tested for nitrogenase-like activity. It was observed that if an aqueous mixture of OMM having acetylene in the over head space is exposed to light from a Xenon lamp, the amount of acetylene decreases and ethylene increases with the period of exposure (7).

If OMM and D_2O mixture is exposed to the radiation from Rayonet UPR 2537 nm keeping acetylene in the over-head space it is converted into CHD = CHD indicating that the protons come from water and that these particles are capable of splitting water (8). On irradiation of an aqueous mixture of OMM and $NaH^{14}CO_3$, with 254 nm, ^{14}C was found in the organic material formed in the mixture (8) indicating fixation of Carbon.

Bubbles of gas are observed to be evolved when an aqueous mixture of OMM is exposed to sunlight. The evolution of gas continues for 4 or 5 days and then ceases but it stops when sunlight is cut off. If the mixture is allowed to stand in dark overnight and then exposed to sunlight ~~again gas is evolved on exposure to sunlight~~ on the next day, again gas is evolved.

Warburg's study indicated that on exposure of OMM ~~aqueous mixture~~ suspended in water to sunlight, hydrogen and oxygen are produced. As OMM have nitrogenase-like material the hydrogen produced combines with ~~the~~ nitrogen in the ratio of 1 vol. of nitrogen ~~with~~ to 1 vol. of hydrogen indicating the formation of diimide (NH=NH) as an intermediate compound. If nitrogen fixation is inhibited a mixture of hydrogen and oxygen is ~~obt~~ obtained.

Experimental approach:- On treatment of the OMM with 1% sodium carbonate solution a fraction of OMM dissolves in it and insoluble bluish rod-like structures are left in the mixture. The dissolved fraction can be precipitated with HCl as a yellow precipitate. This is some complex of molybdenum which ~~has some the property~~ is capable of splitting water ~~to~~ and ~~of fixation of~~ fixing nitrogen.

In another specific mixture in which OMM are produced on exposure to sunlight, in the beginning for a few days ~~exposure~~ only spherical microstructures are formed. Then one day, after the day's exposure, the mixture ~~mixture~~ shows the presence of only ~~bl~~ blue rod structures which appear like crystals under the microscope. ~~are present in the mixture~~. On keeping this mixture in dark during the night, the next morning the mixture is full of blue, spherical particles of 1 to 2 μ in diameter. These show ~~both~~ distinct boundary wall and some dense mass in the center under phase contrast microscope. When this mixture is exposed to sunlight on the next day, by the evening the mixture again has only rectangular blue structures which appear like crystals under the microscope. This mixture, on standing in dark during night is again full of spherical particles the next morning and the process can be repeated for about one week when finally this interchange stops and only blue, rod shaped microstructures are left in the mixture.

(Typist: please continue with the matter on page 3B)

I wish to investigate the relationships between blue rod structures like crystals and the spherical OMM with boundary wall, both of which in ~~pelimary~~ preliminary examination by X-ray diffraction appear non crystalline, employing extensive X-ray diffraction and other techniques. I want to determine the chemical-physical factors that underlie the OMM structure and functional attributes.

Microstructures with a specific morphology, with ability to utilise the energy of sunlight for not only their formation but even for splitting of water in sunlight is of considerable interest in the study of 'Origin of life' because this process will set up an energy flow through the system and this will provide additional stability. ~~By introducing several~~ If to the mixture in which OMM are produced on exposure to sunlight, some ~~soluble~~ salts of semiconductors and or transitional elements is added some of these are incorporated in the OMM formed and their properties of photochemical splitting of water and fixation of nitrogen is significantly ~~affected~~ ~~increased~~ improved. By incorporating suitable amount of Mn, Cd, Co, Zn, La and ~~Fe~~ Ti ~~Bi~~ in the mixtures of OMM efficient OMM ~~may~~ can be prepared which may become of commercial interest. I have already done some work on these lines.

In presence of OMM the fixation of nitrogen continues even after the exposure is stopped if the hydrogen set free by splitting of water is available. Under the conditions when rapid fixation of nitrogen takes place it is usually followed by loss of nitrogen. The ability of OMM of photolytic splitting of water has been considerably increased by ~~incorporating~~ adding titanium sulphate and acetic acid ~~by adding~~ in the mixture ~~before its exposure~~ used for the preparation of OMM. I wish to prepare OMM by introducing silicon in ~~the~~ these by adding soluble sodium orthosilicate in ~~the~~ the mixture before exposure and examine the OMM produced for their ability of splitting water in sunlight and fixation of nitrogen. For this the time lapse study of ~~their~~ the gas exchanges in sunlight and subsequently in shade will be ~~followed~~ carried out, using ~~by analysis of the gases~~ with a gas chromatograph ~~with time~~.

10 — 20mg

160 x 160 — $\frac{900 \times 100 \times 20}{10 \times 1000}$ 20gm

I also wish to explore the possibility of utilising the OMM or some of its modified variety for the commercial exploitation of solar energy.

Some quantitative idea of photochemical splitting of water and fixation of nitrogen by the OMM :—

Incorporation of lanthanum and then titanium in OMM renders them more efficient. The following table indicates the pressure changes observed on exposing 20 mg. of OMM suspended in 5 ml. water taken in a conical Warburg's flask (WF) of 14.5 ml. capacity and bottom area $9.5\ cm^2$. The pressure increase on an exposure of 30 minutes to sunlight (i), and the pressure decrease during this period as estimated by the decrease in pressure during the next 30 minutes on keeping the flask in shade (ii) were recorded. From this the amount of hydrogen set free per day per square meter using 20 gm. of the OMM on six hours of exposure (iii) and also the hydrogen consumed during this period in grams (iv) were calculated, assuming that the mixture is changed after each 30 minutes exposure.

Reference number of OMM	Condition	Pressure in W.F in cm. of mercury in 30 min. exposure (i)	Decrease in pressure in 30 min. in shade in cm of mercury (ii) in WF	Net increase in pressure in cm of mercury by photolysis of water in the WF.	g of H_2 produced in g/m^2/day (iii)	g of H_2 used up in N_2 fixation g/m^2/day
HM (Modi) J (Ac) 60	Oxygenic	4.75	−1.0	5.75	4.00	0.70
HM (Modi) J (Ac) La 60	Oxygenic	5.57	−5.0	10.50	7.60	4.57
HM (Modi) J (Ac) La Ti 60	Oxygenic	8.36	−3.5	11.80	8.32	2.50
HMJ60	Anoxygenic	8.00	−6.00	14.00	14.70	11.00

The gas transformation of the modified OMM when their aqueous mixture is exposed to sunlight and subsequently kept in shade will be investigated using gas chromatograph and Warburg's apparatus with time and some scanning will be done to see whether the process of water splitting and nitrogen fixation can be enhanced in some of these OMM at some particular pH using suitable buffer.

Facilities needed :- Apart from chemical and glass apparatus which a chemical laboratory usually has an autoclave, optical microscope with phase contrast arrangement and attached camera, photowarburg's apparatus, Xenon lamps, clinical mercury vapour lamps, mass gas chromatograph, X-ray instrument for taking diffraction X-ray photographs and analysis of elements at different points of the OMM and an electron microscope will be needed.

Outline of Second Year's work :- After getting some basic informations in the first year, in the second year I would like to use isotopically labelled H, C, O or N in molecular forms suitable for experiments ~~use~~ employing both radioactive and isotopic forms of these elements to understand the mechanism of the photochemical splitting of ~~nitrogen~~ water, fixation of nitrogen and nitrogen loss.

Anticipated results and their potential impact in understanding the origin of life :- Organo molybdenum microstructures (OMM) are models for protocells which have several chemicals of the present-day cell but are basically inorganic and have about 44.50 % of molybdenum (9). These have certain functional properties as splitting of water in sunlight and fixation of nitrogen. By incorporating semiconductor and transitional elements in these we may be able to produce particles which are efficient in these functional properties. If the secondary atmosphere of the prebiological era was made of carbon dioxide, nitrogen and water vapours and there was not enough organic matter on the surface of the earth or in the ocean, particles like these could act as chemical precursors to photoautotrophs.

If efficient OMM could be prepared may be these could be used for commercial splitting of water utilising the energy of sunlight and the study of origin of life could be put to some economic use.

References:

(1) Bahadur, K. and Ranganayaki, S.. 1970, J. Brit. Interplanetary Soc., 23, (12), 813 - 829.

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Inorganic Origin of Life.

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Several models of protocells have been studied during the five decades in which coacervates of Oparin, microspheres of Fox, thiocyanate particles of Smith, marigranules of Egami, and Jeewanu of Bahadur are important. (9)

Organo molybdenum microstructures (OMM), a type of model of protocell, have been examined for ~~their possible~~ ferredoxin-like activity. It is because these microstructures prepared by the action of sunlight on sterilised aqueous mixture of ammonium molybdate, diammonium hydrogen phosphate, mineral solution and formaldehyde, have boundary wall, a central mass and chemicals of interest in the study of origin of life (1, 2, 3, 4). ~~The OMM~~ That they have ferredoxin-like material is evident because they ~~and~~ can be used in the place of ferredoxin in photobiological system ~~and~~ Chloroplast – ferredoxin ~~OMM~~ – hydrogenase, ~~system does split water to hydrogen and oxygen in sunlight~~ (5, 6). These microstructures were tested for ~~the presence~~ of nitrogenase-like activity. ~~in them~~. It was observed ~~that~~ that if an aqueous mixture of OMM is ~~is~~ exposed to light from a Xenon lamp, ~~Keeping~~ having acetylene in the overhead space, ~~with increasing period of exposure,~~ the amount of acetylene decreases and ethylene increases with the period of exposure. ~~in the overhead space~~ (7)

~~It was further observed that~~ If OMM and D_2O mixture is exposed to the radiation from Rayonet UPR 2537 nm Keeping acetylene in the overhead space, it is converted into CHD = CHD indicating that the protons come from water and that these microstructures are capable of splitting water (8). On irradiation of an aqueous mixture of ~~the~~ OMM and $NaH^{14}CO_3$ ~~on irradiation~~ with 254 nm, ~~and~~ ^{14}C was found in the organic material formed in the mixture (8) indicating fixation of ~~nitrogen~~ carbon.

~~It has been observed that~~ Bubbles of gas are ~~to~~ observed to be evolved when an aqueous mixture of OMM is exposed to sunlight. ~~bubbles of gas evolved from the mixture. The evolution stops when exposure~~ sunlight ~~is cut off~~. The evolution of gas continues for 4 or 5 hours each day and then ~~stops~~ ceases but it stops when sunlight is cut off.

If this mixture is allowed to stand in dark overnight, again gas is evolved on exposure to sunlight on the next day.

Warburg's study indicated that on exposure of OMM aqueous mixture to sunlight hydrogen and oxygen are produced. As OMM has nitrogenase-like material the hydrogen produced combines with the nitrogen in the ratio of 1 vol. of nitrogen with 1 vol. of hydrogen indicating the formation of diimide (NH = NH) as an intermediate compound. If nitrogen fixation is inhibited a mixture of hydrogen and oxygen is obtained.

Experimental approach:

On treatment of the OMM with 1% sodium carbonate solution, insoluble bluish rod-like structures are left in the mixture and a fraction of OMM dissolves in it. This fraction can be precipitated with HCl as a yellow precipitate. This is some compound of molybdenum which has property of splitting water in sunlight and of fixation of nitrogen.

In another specific mixture in which OMM are produced, on exposure to sunlight, in the beginning few days of start the spherical microstructures formed as in it are spherical but after a few days of exposure the structures become rod-like. On keeping this mixture in the dark during night, the next morning the mixture is full of blue spherical particles of 1 to 2 μ in diameter with distinct boundary wall and some denser mass in the center. When this mixture exposed to sunlight on the next day, by the evening the mixture again has only rectangular blue structures which appear like crystals under the microscope. This mixture, on standing in dark during night, is again full of spherical particles the next morning and this process can be repeated for about one week when finally this interchange stops and only blue rod shaped crystals are present.

But then after exposing the mixture to sunlight for the whole day in the evening only blue rod like things which appear like crystals under the microscope are present in the mixt.

416
14
1664
416
5824

416 ~~8.32~~ × 14
~~11.80~~
590

832
14
3328
832
11.648 (9.87
10620
10280
9440
8400

~~2.5~~ × 6
3.5
7) 30 (4.28
28
20
14
60

3.5)

5)

4.57 × 6
3 5
5) 27.42 (5.48
25
24
20
45

I ^also wish to explore the possibility of utilising OMM or some of its modified variety for the commercial exploitation of solar energy.

Different OMM will be prepared incorporating Mn, Co, Zn, Cd, Ti and ~~also titanium~~ La ~~to~~ ~~where~~ by adding soluble salts of these elements in the mixtures in which OMM are synthesised by the action of sunlight. These have already been ~~OMM incorporating Mn, Co, Zn and Cd. salts have been~~ prepared ~~o~~ with encouraging results. ~~and OMM incorporating Ti and La have also been prepared. I wish to study~~ ~~these~~ ~~OMM prepared incorporating Ti and La with Mn, Co, Zn and Cd. with together with or without acetic acid. Here the amount of hydrogen formed per square m² per day considering~~ ~~(6 hrs sunlight)~~ ~~that irradiation mixture of are changed every 30 min is as follows:~~

Some quantitative idea of photochemical splitting of water and fixation of nitrogen by OMM

~~OMM have been made quite efficient.~~ ~~Addition~~ Incorporation of lanthanum and then titanium salt in OMM ~~made~~ render them ~~of~~ ~~still~~ more efficient. ~~Thus~~ In a ~~conical~~ Warburg flask of 14.5 ml total volume and bottom area 9.5 cm², in 30 min. of exposure to sunlight, the pressure increase ~~in the Warburg's flask~~ in cm. of mercury (I) and the decrease in pressure during this period as ~~recorded~~ estimated by the decrease in pressure during next 30 min. in shade (II) and the amount of hydrogen set free per day per ~~cm~~ m² considering 6 hours exposure time each day ~~or~~ (iii) and ~~of~~ hydrogen consumed during that 30 min in gm (IV) considering that the exposed sample is ~~changed~~ transferred to shade and new mixture is exposed after 30 min ~~is~~ are as shown in the following table.

Number of the OMM used	Reference Word	Condition	Pressure in Warburg's flask in cm. merc. (I)	Decrease in pressure in cm. of mercury due to fixation of N_2 (II)	Net increase in 30 min due to formation of H_2 by photolysis of water	gm. of H_2 produced per m² in one day. (iii)	gm. of H_2 used up in N_2 fixation/m²/day. (IV)
HM (Modi) J (Ac) 60	Shala	Oxygenic	4.75	−1.0	5.75	4.00	0.70
HM (Modi) J (Ac) La 60	Shala	Oxygenic	5.57	−5.0	10.50	7.60	4.57
HM (Modi) J (Ac) La Ti 60	Bakhat	Oxygenic	8.30	−3.5	11.80	8.32	2.50
HMJ 60	Harendra	Anoxygenic	8.00	−6.00	14.0	9.87 ~~[illegible]~~	~~[illegible]~~ 5.48

(8) The following table indicates the ~~results obtained~~ pressure changes observed ~~by~~ on exposing 20mg of OMM suspended in 5ml water taken in a conical Warburg flask of 14.5ml capacity and bottom area 9.5 cm^2. (1) The pressure increase on an exposure of 30 minutes to sunlight, and (2) the pressure decrease ~~in~~ during this period as estimated by the decrease in pressure during the next 30 minutes by keeping the flask in shade (3) were recorded. From this the amount of hydrogen set free per ~~6 hours exposure~~ ~~day~~ day per square metre using 20gm of OMM on six hours of exposure and also the hydrogen ~~fixed~~ consumed during this period in grams were calculated. assuming that ~~the~~ ~~exposed~~ the aqueous medium is changed after each 30 minutes exposure. ~~and~~ ~~and~~ ~~(30 minute shade are alternately given and two sets of have been used)~~

The Gas transformation of the modified OMM when their aqueous mixture is exposed to sunlight and subsequently kept in shade will be investigated using gas chromatograph and Warburg's apparatus with time and some scanning will be done to see whether the process of water splitting and nitrogen fixation can be enhanced in some of these OMM at some particular pH using suitable buffer.

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Organo molybdenum microstructures (OMM) are models for protocells which have several biochemicals of the present-day cell but are basically inorganic and have about 44.50 % of molybdenum[9]. These have certain functional properties as splitting of water in sunlight and fixation of nitrogen. By incorporating semiconductor and transitional elements in these we may be able to produce particles which are efficient in these functional properties. If the secondary atmosphere of the prebiological era was made of carbon dioxide, nitrogen and water vapours and there was not enough organic matter on the surface of the earth or in the ocean, particles like these could act as chemical precursors to photoautotrophs.

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7

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4 copies.

Answer of a few questions

1. What is meant by the "internal structures of OMM"?

The OMM have boundary wall and internal structures. The term internal structure means a comparative denser central part and localisation of the material of OMM within it as indicated under phase contrast microscope and localised staining with biological dyes after fixation with biological fixative (1.2.3,3,4)

2. Why it is said that OMM grows from within?

The OMM micrograph attached herewith show that these particles have boundary wall. This does not thicken as the particles increase in size indicating that it is not due to deposition from outside. These particles grow from about 0.2 μ in diameter to about 2 μ. Then there is bud formation on the particles which may separate out or may remain attached with the original particle and grow in size. As the composition of the ~~molecules in the~~ surrounding mixture of the particles is different from the material of the particles some chemical transformation does take place in the particles to produce the material of the particle from the molecules of its surrounding and this may be called as metabolic activity.

3. How are semiconductor or transitional elements incorporated in the OMM?

To incorporate semiconductor, transitional elements or ~~at that~~ any inorganic or organic substance in the OMM the best way is to add a soluble salt of the ~~material~~ element or ~~some~~ soluble organic substance in the mixture in which OMM are synthesised on exposure to sunlight before the exposure is started. The substance is usually incorporated in the OMM in some degree. Another way is to add the salt after a few hours of exposure of the mixture in which OMM are synthesised when some OMM are formed. In this process the added material may or may not be absorbed by the OMM. Under certain condition it is necessary to add the salt only after a few hours of exposure to sunlight. Thus if a large ~~high con.~~ volume of mineral solution is initially added in the mixture in which OMM are to be synthesised on exposure, no OMM is produced at all. However if the mixture had just one volume of the mineral solution to begin with and after each 4 hr. of exposure to sunlight 1 vol. of mineral solution is added 3 or 4 times, the OMM produced are less in yield but the particles formed are more efficient in splitting water in sunlight.

4. <u>What is meant by Crystal-like</u> ?

The particles are said to be crystal-like because under the microscope they are found to have a geometrical shape and are angular. But X-ray diffraction indicates that they are not crystalline.

5. <u>How will EM and X-ray diffraction studies will help to understand the factors which help to determine the relationship between the geometrical forms and spherical structures with boundary wall</u> ?

May be the OMM with geometrical forms are crystal and a thorough investigation ~~by~~ with X-ray diffraction will indicate it. If so it appears that ~~that~~ crystal and spherical walled structures are interchange-able and investigation of its scope will be of interest in the study of origin of life in other planets also. If both the structures are crystals or amorphous the study of the mechanism of ~~this~~ this interchange by fixing the particles after ~~suitable~~ regular time interval in suitable blocks during exposure and when the mixture stands in dark and cutting their sections and examining these sections under EM will be of considerable interest in the study of origin of life particularly when OMM are made of two types of substances of which one is acidic and the other alkaline.

6. <u>What is the possible factor of this interchange of forms?</u>

According to Bahadur matter has inherent ~~inherent~~ property of duplication under suitable conditions and a system of matter in equilibrium has inherent property of adaptibility. (5) So a set of molecules under suitable condition acquire ~~acquire~~ a structure with boundary wall and some heterogenous internal structure observable under phase contrast microscope. and These structures under suitable condition may show the property of growth from within, multiplication by budding and have some metabolic activity in a general sense. Thinking on these lines, in shade the molecules of a variety of material constituting the OMM autoorganise themselves into structures with boundary wall and some sort of internal architecture. During exposure the extra energy of the radiation destroyes this structure.

7. <u>What is meant by biological mineral solution?</u>

Biological minerals ~~solution~~ are the same as used for making microbial ~~solution~~ culture. It is prepared by dissolving 20 mg of sodium chloride, potassium sulphate, calcium acetate, magnesium sulphate. potassium dihydrogen phosphate and 50 mg of ferrous sulphate in 100 ml. of distilled water, In subsequent experiments of OMM several other salts as 20 mg. of zinc sulphate, Cobalt sulphate, manganese sulphate and cadmium acetate have also been included. This mineral solution ~~has~~ is then known as modified biological mineral solution. ~~May be a simple mineral solution is equally good but~~ It may be called as mineral solution but then it will be too ~~vage~~ vague and could mean anything.

~~What precautions~~

What precautions are taken to avoid infection during experiment?

The sterilisation is achieved:

(i) By autoclaving the mixture in which OMM are produced, ~~at~~ at ~~x~~ 15 lb. pressure for 30 min. Then the required volume of 36% formaldehyde is added aseptically. The mixture is then gently shaken and exposed to sunlight under sterilised condition, with ~~to~~ the cotton plug of the flask containing the mixture undisturbed.

(ii) No living cell can survive in more than 2% of formaldehyde. The exposure mixture ~~d~~ usually contains 7% of formaldehyde and at times ~~even~~ 14% or more.

(iii) Rate of formation of OMM can be controlled by manipulating the volume of 4% ammonium molybdate, 3% diammonium hydrogen phosphate, mineral solution or formaldehyde in the exposure mixture, ~~of OMM to OMM are synthesised~~ or by controlling the exposure time and can ~~be~~ even ~~by~~ be stopped by ~~excessively~~ increasing the ~~volute~~ volume of the mineral solution and the diammonium hydrogen phosphate excessively.

(iv) The OMM cannot be grown on any known ~~o~~ bacterial culture medium.

(v) Like the OMM described in this project, microstructures with boundary wall and some structures inside them ~~have~~ have been prepared from a variety of ~~mineral~~ materials absent in the present day cells.

(vi) The OMM contains about 44.5% of molybdenum and no microorganism is known to contain this ~~high~~ high concentration of molybdenum.

Whether the heterogenity of the OMM is chemical or physical?

The OMM have ~~amino~~ amino acids in free ~~and~~ form and in peptide combination, nucleic acid bases, sugars as ribose and deoxyribose, phospholipid boundary wall and a number of organic acids of Kreb's cycle (4). The elemental analysis of the OMM indicates that it contains C 13·75%, H 2·62%, O 28·96%, N 8·84% and Mo 44·50%, Iron 0·18%, Manganese < 0·005%, Magnesium < 0·003%, Potassium < 0·003%, Calcium < 0·006% and Sodium 0·10% (5)

The attached micrograph of the OMM shows the boundary wall and some structure inside it. Phase contrast microscope indicate that the OMM are not just beads of some homogeneous material. These particles can be fixed with biological dyes when different locales acquire different stain.

~~Then~~ The material of the OMM can be divided into acidic and basic groups as is apparent on treating ~~the~~ the OMM with sodium ~~chloride~~ carbonate solution. ~~and described in the text of the project.~~

These facts indicate that the material within the OMM are heterogeneous in nature both chemically and physically.

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INORGANIC ORIGIN OF LIFE

Several models of protocells have been studied during the last five decades in which coacervates of Oparin, microspheres of Fox, thiocyanate particles of Smith, marigranules of Egami and Jeewanu of Bahadur are important.

Study of the functional properties of organo molybdenum microstructures (OMM) as model for Protocells :-

OMM, a type of model of protocells, have been examined for ferredoxin - like activity. It is because these microstructures prepared by the action of light on a sterilised aqueous mixture of ammonium molybdate, diammonium hydrogen phosphate, mineral solution and formaldehyde, have boundary wall, a central mass and chemicals of interest in the study of origin of life (1,2,3,4). They have ferredoxin - like material because they can be substituted for ferredoxin in the photobiological system chloroplast - ferredoxin - hydrogenase (5.6). It was also observed that if an aqueous mixture of OMM having acetylene in the overhead space is exposed to light from a Xenon lamp, the amount of acetylene decreases and ethylene increases with the period of exposure (7), indicating the nitrogenase - like activity of OMM.

If OMM and D_2O mixture is exposed to the radiation from Rayonet UPR 2537 nm keeping acetylene in the overhead space it is converted into CHD = CHD indicating that the protons come from water and that these particles are capable of splitting water (8). On irradiation of an aqueous mixture of OMM and $NaH^{14}CO_3$, with 254 mm, ^{14}C was found in the organic material formed in the mixture (8) indicating fixation of carbon.

Bubbles of gas are observed to be evolved when an aqueous mixture of OMM is exposed to sunlight. The evolution of gas continues for 4 or 5 days and then ceases but it stops when sunlight is cut off. If the mixture is allowed to stand in dark overnight and then exposed to sunlight on the next day, again gas is evolved.

Warburg's study indicated that on exposure of OMM suspended in water to sunlight, hydrogen and oxygen are produced. As OMM have nitrogenase - like material the hydrogen produced combines with nitrogen in the ratio of 1 vol. of nitrogen to 1 vol. of hydrogen indicating the formation of diimide (NH = NH) as an