Is Schreibersite Prebiotic?

- Most massive meteorites are iron meteorites (P-rich)
- Small crater-forming impacts are almost all irons
- Phosphides in other ET material?

1
00:00:06,530 --> 00:00:03,190
okay welcome to the pre-thanksgiving

2
00:00:12,459 --> 00:00:06,540
obviously astrobiology seminar today's

3
00:00:16,460 --> 00:00:12,469
speaker is Matt pathak who's Cosmo

4
00:00:19,160 --> 00:00:16,470
biogeochemistry known as an

5
00:00:22,029 --> 00:00:19,170
astrobiologist obviously he's interested

6
00:00:26,480 --> 00:00:22,039
in phosphorus origins of life

7
00:00:31,220 --> 00:00:26,490
meteoritics which you'll be talking

8
00:00:36,410 --> 00:00:31,230
about today he comes to us from our nasa

9
00:00:37,850 --> 00:00:36,420
astrobiology institute debt parent i

10
00:00:40,729 --> 00:00:37,860
guess you'd call them seeing they've

11
00:00:42,819 --> 00:00:40,739
sort of adopted us as being homeless

12
00:00:46,279 --> 00:00:42,829
orphans from the nasa astrobiology

13
00:00:50,420 --> 00:00:46,289

institute from the university of arizona

14
00:00:55,100 --> 00:00:50,430
department of planetary sciences he's a

15
00:00:56,810 --> 00:00:55,110
nasa post-op they're about halfway

16
00:00:59,470 --> 00:00:56,820
through his tenure and looking for a job

17
00:01:02,180 --> 00:00:59,480
if anybody knows of any jobs out there

18
00:01:06,310 --> 00:01:02,190
he was got his PhD at the same

19
00:01:09,740 --> 00:01:06,320
institution same department and

20
00:01:12,820 --> 00:01:09,750
bachelor's degree at William and Mary

21
00:01:16,490 --> 00:01:12,830
which I believe is the second oldest

22
00:01:17,899 --> 00:01:16,500
university in the United States so today

23
00:01:21,020 --> 00:01:17,909
Matt will be talking about phosphorus

24
00:01:23,330 --> 00:01:21,030
and the origin of life all right well

25
00:01:26,060 --> 00:01:23,340
thank you very much and sorry I have a

26
00:01:29,060 --> 00:01:26,070
cold right now and as a result love my

27
00:01:31,819 --> 00:01:29,070
higher frequencies are out so I'm very

28
00:01:34,940 --> 00:01:31,829
low and not this today but hopefully it

29
00:01:38,359 --> 00:01:34,950
won't be too bad so today we are talking

30
00:01:42,740 --> 00:01:38,369
about as many of the astra biological

31
00:01:44,630 --> 00:01:42,750
approaches are several is he follow the

32
00:01:46,940 --> 00:01:44,640
approaches that we see in astrobiology

33
00:01:48,800 --> 00:01:46,950
we've seen a lot of different paolo the

34
00:01:51,139 --> 00:01:48,810
approaches we have follow the carbon

35
00:01:52,969 --> 00:01:51,149
yeah follow the water followed nitrogen

36
00:01:55,550 --> 00:01:52,979
follow the energy follow the trace

37
00:01:59,120 --> 00:01:55,560
elements and naturally i have my own to

38
00:02:00,080 --> 00:01:59,130

add follow the phosphorus so today we're

39
00:02:02,090 --> 00:02:00,090
going to be talked about the element

40
00:02:04,850 --> 00:02:02,100
phosphorus phosphorus has an atomic

41
00:02:07,210 --> 00:02:04,860
number of 15 kind of way to thirty one

42
00:02:09,550 --> 00:02:07,220
percent it's only one isotope that match

43
00:02:12,700 --> 00:02:09,560
occurs and that's 31 isotope hundred

44
00:02:15,070 --> 00:02:12,710
percent of it and has most importantly

45
00:02:17,470 --> 00:02:15,080
has a spin a nuclear spin of plus

46
00:02:20,500 --> 00:02:17,480
one-half and this becomes very important

47
00:02:22,720 --> 00:02:20,510
in terms of being able to observe it in

48
00:02:25,780 --> 00:02:22,730
terms of chemical environment and

49
00:02:28,240 --> 00:02:25,790
understanding what goes on so phosphorus

50
00:02:29,860 --> 00:02:28,250
is also important in the historical

51
00:02:32,460 --> 00:02:29,870
chemical contests because it was the

52
00:02:34,990 --> 00:02:32,470
first element to be discovered with a

53
00:02:36,900 --> 00:02:35,000
known discovery that's hi Nick grant

54
00:02:39,280 --> 00:02:36,910
right here we discovered it by

55
00:02:41,080 --> 00:02:39,290
distilling a lot of different various

56
00:02:43,060 --> 00:02:41,090
human and animal waste products then

57
00:02:45,630 --> 00:02:43,070
happened to come across it during age

58
00:02:48,460 --> 00:02:45,640
processes so it was one of the first

59
00:02:52,210 --> 00:02:48,470
chemists in a process of alchemy to

60
00:02:53,530 --> 00:02:52,220
discover a new new chemical element so

61
00:02:57,240 --> 00:02:53,540
phosphorus holds a special place in

62
00:02:59,620 --> 00:02:57,250
heart of several chemists industry guard

63
00:03:01,600 --> 00:02:59,630

so here we have a couple of the

64
00:03:04,180 --> 00:03:01,610
phosphorus and biochemistry to sort of

65
00:03:06,220 --> 00:03:04,190
bring it to the astrobiology phosphorus

66
00:03:08,620 --> 00:03:06,230
is important in several biochemical

67
00:03:10,360 --> 00:03:08,630
processes and perhaps is relevant to

68
00:03:12,580 --> 00:03:10,370
several days other searches for life

69
00:03:14,560 --> 00:03:12,590
elsewhere search for life the origin of

70
00:03:16,090 --> 00:03:14,570
life here on the earth and it is

71
00:03:18,130 --> 00:03:16,100
important here we have to sample

72
00:03:20,410 --> 00:03:18,140
molecules we have the metabolic molecule

73
00:03:22,570 --> 00:03:20,420
this is ATP adenosine triphosphate

74
00:03:24,520 --> 00:03:22,580
there's a Dineen ribose and a tri

75
00:03:26,590 --> 00:03:24,530
phosphate group right here and this is

76
00:03:30,850 --> 00:03:26,600
the major metabolic molecule that takes

77
00:03:32,590 --> 00:03:30,860
energy from chemical reactions stores

78
00:03:34,479 --> 00:03:32,600
that by adding a phosphate group right

79
00:03:36,640 --> 00:03:34,489
here or when you need to do work or

80
00:03:39,610 --> 00:03:36,650
break this phosphate group and they'll

81
00:03:41,979 --> 00:03:39,620
be move or do certain chemical reactions

82
00:03:45,670 --> 00:03:41,989
so it's one of the metabolic backbones

83
00:03:48,880 --> 00:03:45,680
of light as we know it today another one

84
00:03:51,850 --> 00:03:48,890
right here is structural molecules this

85
00:03:54,250 --> 00:03:51,860
is a phospholipid and a phospholipid has

86
00:03:57,310 --> 00:03:54,260
these nice big lipid tails two of them

87
00:03:58,840 --> 00:03:57,320
is bound to this glycerol glycerol count

88
00:04:02,080 --> 00:03:58,850

down right here as a phosphate head

89
00:04:04,240 --> 00:04:02,090
group and so phosphate or phosphorus

90
00:04:07,270 --> 00:04:04,250
biomolecules are important for the

91
00:04:09,190 --> 00:04:07,280
structural membranes of cells so we see

92
00:04:12,090 --> 00:04:09,200
both medicine metabolism here and

93
00:04:15,460 --> 00:04:12,100
structure and of course the big one is

94
00:04:17,770 --> 00:04:15,470
RNA and DNA and RNA and DNA the DNA

95
00:04:18,810 --> 00:04:17,780
molecule and RNA just has an o H group

96
00:04:21,900 --> 00:04:18,820
right here in a little

97
00:04:24,320 --> 00:04:21,910
nucleotides nucleobases right there and

98
00:04:26,640 --> 00:04:24,330
it consists of a phosphate sugar

99
00:04:28,560 --> 00:04:26,650
backbone kind of going down so we had a

100
00:04:31,500 --> 00:04:28,570
phosphate group and then deoxyribose or

101
00:04:34,650 --> 00:04:31,510
ribose here phosphate and the sort of

102
00:04:37,860 --> 00:04:34,660
shows the relevance of phosphorus to

103
00:04:40,800 --> 00:04:37,870
life and biochemistry origin la life and

104
00:04:43,320 --> 00:04:40,810
how we perceive organic chemistry and

105
00:04:44,730 --> 00:04:43,330
how life came about as well this sort of

106
00:04:46,260 --> 00:04:44,740
also highlights some of the important

107
00:04:48,950 --> 00:04:46,270
features of phosphorus that make it

108
00:04:51,870 --> 00:04:48,960
critical to formation of large

109
00:04:54,780 --> 00:04:51,880
biopolymers and other things one can

110
00:04:56,610 --> 00:04:54,790
form two bridges we have a sugar bound

111
00:04:58,230 --> 00:04:56,620
to this phosphate fountain mixture and

112
00:05:00,540 --> 00:04:58,240
when it forms these two bridges you can

113
00:05:02,130 --> 00:05:00,550

still have a charge right here so we

114
00:05:06,120 --> 00:05:02,140
have a nice charge right here of an oh

115
00:05:08,070 --> 00:05:06,130
minus and by keeping that charge on the

116
00:05:10,740 --> 00:05:08,080
polymer you prevent it from diffusing

117
00:05:13,230 --> 00:05:10,750
out of a membrane so that helps keep

118
00:05:15,690 --> 00:05:13,240
your your large informational polymer

119
00:05:17,250 --> 00:05:15,700
stuck in one place will be very bad if

120
00:05:19,320 --> 00:05:17,260
you're a DNA what's go floating off

121
00:05:21,410 --> 00:05:19,330
outside of your cell so this helps keep

122
00:05:23,490 --> 00:05:21,420
it where it's supposed to be

123
00:05:26,100 --> 00:05:23,500
additionally it's also kinetically

124
00:05:28,050 --> 00:05:26,110
stable but don't burn am to be unstable

125
00:05:29,790 --> 00:05:28,060
if it wasn't thurman ethically unstable

126
00:05:32,190 --> 00:05:29,800
it wouldn't be useful from the metabolic

127
00:05:34,170 --> 00:05:32,200
context you wouldn't be able to take it

128
00:05:37,140 --> 00:05:34,180
and break it down and use the energy and

129
00:05:38,940 --> 00:05:37,150
then transfer energy back into it but it

130
00:05:40,770 --> 00:05:38,950
is hard to do without doing using

131
00:05:43,020 --> 00:05:40,780
enzymes this bond right here is pretty

132
00:05:46,380 --> 00:05:43,030
stable it's hard to break without using

133
00:05:48,420 --> 00:05:46,390
several specific enzymes additionally

134
00:05:50,580 --> 00:05:48,430
the phosphate group helps make these

135
00:05:52,830 --> 00:05:50,590
organic compounds much more soluble and

136
00:05:54,570 --> 00:05:52,840
by having a solid buoy allowed to do a

137
00:05:56,220 --> 00:05:54,580
lot more organic chemistry than if you

138
00:05:57,510 --> 00:05:56,230

just had this thing sort of floating

139
00:06:01,440 --> 00:05:57,520
around in solution without having this

140
00:06:03,540 --> 00:06:01,450
phosphate group so this sort of

141
00:06:06,570 --> 00:06:03,550
highlights the rarity of phosphorus life

142
00:06:08,190 --> 00:06:06,580
really likes phosphorus and like

143
00:06:10,650 --> 00:06:08,200
scavengers phosphorus here we have a

144
00:06:13,560 --> 00:06:10,660
it's a very rare but a very necessary

145
00:06:16,050 --> 00:06:13,570
element and what we have here is a table

146
00:06:17,850 --> 00:06:16,060
which shows a cosmic abundances of the

147
00:06:20,220 --> 00:06:17,860
element the biogenic elements hydrogen

148
00:06:22,320 --> 00:06:20,230
oxygen carbon nitrogen sulfur and

149
00:06:26,040 --> 00:06:22,330
phosphorus and then the abundances of

150
00:06:26,850 --> 00:06:26,050
these elements in RNA and life is very

151
00:06:28,649 --> 00:06:26,860
similar to the bun

152
00:06:30,209 --> 00:06:28,659
here these are all normalized to one

153
00:06:32,429 --> 00:06:30,219
phosphorus atom so there's around about

154
00:06:36,240 --> 00:06:32,439
three million hydrogen atoms in the

155
00:06:38,490 --> 00:06:36,250
cosmos treat everyone phosphorus a 1400

156
00:06:41,399 --> 00:06:38,500
oxygen and about half that for carbon

157
00:06:42,510 --> 00:06:41,409
and so on and so forth so life if you

158
00:06:44,309 --> 00:06:42,520
take a look at these numbers there's

159
00:06:47,730 --> 00:06:44,319
only ten hydrogen atoms for every

160
00:06:49,709 --> 00:06:47,740
phosphorus atom and RNA and in some sort

161
00:06:51,719 --> 00:06:49,719
of the dry weight of bacteria you see

162
00:06:53,999 --> 00:06:51,729
similar numbers a little bit more heavy

163
00:06:56,339 --> 00:06:54,009

over here but RNA specifically if we're

164
00:07:00,450 --> 00:06:56,349
going to consider this RNA world arising

165
00:07:02,999 --> 00:07:00,460
first was one of the key places to have

166
00:07:05,309 --> 00:07:03,009
phosphate so having phosphate it's one

167
00:07:06,300 --> 00:07:05,319
of the more important things so if we

168
00:07:07,619 --> 00:07:06,310
need to do is sort of a thought

169
00:07:10,290 --> 00:07:07,629
experiment going along with these

170
00:07:13,200 --> 00:07:10,300
numbers kind of abstract and consider if

171
00:07:15,659 --> 00:07:13,210
people or atoms then the four people

172
00:07:18,679 --> 00:07:15,669
were atoms and population of people was

173
00:07:20,820 --> 00:07:18,689
proportional to the cosmic abundance

174
00:07:22,649 --> 00:07:20,830
Washington State has about six million

175
00:07:24,600 --> 00:07:22,659
people there would be about to

176
00:07:27,269 --> 00:07:24,610
phosphorus atoms living in the whole

177
00:07:29,760 --> 00:07:27,279
state so phosphorus is fairly rare and

178
00:07:32,610 --> 00:07:29,770
about maybe a hundred or so living in

179
00:07:35,939 --> 00:07:32,620
entire United States again not very many

180
00:07:38,070 --> 00:07:35,949
at about 2,000 total of the Earth's so

181
00:07:40,950 --> 00:07:38,080
very few phosphorus atoms phosphorus

182
00:07:43,230 --> 00:07:40,960
atom people living around conversely if

183
00:07:45,570 --> 00:07:43,240
this classroom were full it wasn't

184
00:07:47,850 --> 00:07:45,580
Thanksgiving time and we had and this

185
00:07:49,980 --> 00:07:47,860
classroom was an RNA molecule there

186
00:07:52,079 --> 00:07:49,990
would be three phosphorus atoms sitting

187
00:07:55,980 --> 00:07:52,089
here in the RNA molecule classroom as

188
00:07:58,409 --> 00:07:55,990

yet so life has a huge enrichment of

189
00:07:59,909 --> 00:07:58,419
phosphorus relative to the cosmos and it

190
00:08:04,890 --> 00:07:59,919
can put it this way phosphorus is a

191
00:08:07,800 --> 00:08:04,900
celebrity of the cosmos and of biology

192
00:08:11,279 --> 00:08:07,810
is one of the very important elements so

193
00:08:13,379 --> 00:08:11,289
this shows that we see this as well in

194
00:08:17,010 --> 00:08:13,389
sort of the environmental context this

195
00:08:19,290 --> 00:08:17,020
is a algae bloom and when the rip when

196
00:08:20,969 --> 00:08:19,300
our creeks off of Florida and what

197
00:08:22,890 --> 00:08:20,979
happened here is that there is a lot of

198
00:08:25,320 --> 00:08:22,900
fertilizer being used in the agriculture

199
00:08:27,269 --> 00:08:25,330
in this case detergent and here I'm just

200
00:08:29,909 --> 00:08:27,279
detergent detergent is loaded with

201
00:08:33,389 --> 00:08:29,919
phosphates and by introducing this very

202
00:08:35,760 --> 00:08:33,399
rare element it caused a huge life a

203
00:08:37,879 --> 00:08:35,770
bloom of life to occur in these sorts of

204
00:08:41,019 --> 00:08:37,889
environments so this shorter shows

205
00:08:43,249 --> 00:08:41,029
that'd be that life in general is

206
00:08:46,579 --> 00:08:43,259
limited in part by the amount of

207
00:08:48,799 --> 00:08:46,589
phosphorus so if we consider phosphorus

208
00:08:51,470 --> 00:08:48,809
from the origin life perspective here we

209
00:08:53,869 --> 00:08:51,480
have the there are essentially two

210
00:08:55,909 --> 00:08:53,879
options for the origin of life with

211
00:08:59,150 --> 00:08:55,919
regards to phosphorus since phosphorus

212
00:09:02,179 --> 00:08:59,160
is so elementally selected so heavily in

213
00:09:03,819 --> 00:09:02,189

life and since phosphorus plays a role

214
00:09:06,369 --> 00:09:03,829
in several different metabolic

215
00:09:08,869 --> 00:09:06,379
informational replication ille

216
00:09:10,819 --> 00:09:08,879
structural molecules it's one of the

217
00:09:13,129 --> 00:09:10,829
probably one of the key biological

218
00:09:14,659 --> 00:09:13,139
elements so you can consider it in two

219
00:09:19,539 --> 00:09:14,669
ways either we had an origin like

220
00:09:24,049 --> 00:09:22,009
intentional iment and such a unreactive

221
00:09:26,689 --> 00:09:24,059
element as i'll be showing shortly but

222
00:09:29,179 --> 00:09:26,699
this is not really rectifiable with the

223
00:09:31,069 --> 00:09:29,189
biochemistry that we see today it would

224
00:09:33,979 --> 00:09:31,079
require sort of a jumping horses from a

225
00:09:35,569 --> 00:09:33,989
non phosphate phosphate using life to a

226
00:09:37,429 --> 00:09:35,579
phosphate look using life and that

227
00:09:40,669 --> 00:09:37,439
doesn't seem to rectifiable with this

228
00:09:41,989 --> 00:09:40,679
sort of parsimony of life here the other

229
00:09:44,659 --> 00:09:41,999
option is that the origin of life

230
00:09:46,369 --> 00:09:44,669
occurred with phosphorus and the

231
00:09:48,350 --> 00:09:46,379
advantages of this is this is consistent

232
00:09:51,079 --> 00:09:48,360
with modern biochemistry received as

233
00:09:53,989 --> 00:09:51,089
phosphorus molecules everywhere in the

234
00:09:56,479 --> 00:09:53,999
various molecular functions in generally

235
00:09:59,569 --> 00:09:56,489
speaking with a couple exceptions but

236
00:10:01,729 --> 00:09:59,579
this is this is inhibited by the fact

237
00:10:03,710 --> 00:10:01,739
that phosphorus is kind of rare and it's

238
00:10:07,100 --> 00:10:03,720

also fairly hard to get into organic

239
00:10:09,319 --> 00:10:07,110
solutions so if we consider what they

240
00:10:12,409 --> 00:10:09,329
roll up oestrus in the origin of life we

241
00:10:14,329 --> 00:10:12,419
should consider how phosphorus was was

242
00:10:16,669 --> 00:10:14,339
involved in sort of the prebiotic

243
00:10:18,650 --> 00:10:16,679
chemistry of the early Earth what are

244
00:10:20,720 --> 00:10:18,660
some of these plausible prebiotic

245
00:10:25,039 --> 00:10:20,730
phosphorus compounds that may have been

246
00:10:26,689 --> 00:10:25,049
in relevant to origin of life so the one

247
00:10:29,389 --> 00:10:26,699
that's commonly invoked if we looked at

248
00:10:31,549 --> 00:10:29,399
what life uses today one of the major

249
00:10:33,739 --> 00:10:31,559
phosphorus shuffling and molecules is

250
00:10:35,989 --> 00:10:33,749
ATP which we saw just recently the

251
00:10:37,879 --> 00:10:35,999
adenosine triphosphate that is in group

252
00:10:40,549 --> 00:10:37,889
right here and triphosphate right here

253
00:10:44,059 --> 00:10:40,559
however you can invoke this as one of

254
00:10:45,829 --> 00:10:44,069
the prebiotic molecules for life but the

255
00:10:47,269 --> 00:10:45,839
real important part of this molecule is

256
00:10:50,090 --> 00:10:47,279
this business end right here this

257
00:10:50,400 --> 00:10:50,100
triphosphate this is the key part of the

258
00:10:52,559 --> 00:10:50,410
H

259
00:10:54,629 --> 00:10:52,569
p as far as phosphate shuffling and

260
00:10:56,519 --> 00:10:54,639
energy is concerned and this end right

261
00:10:58,980 --> 00:10:56,529
up here is just sort of a chunk left

262
00:11:02,910 --> 00:10:58,990
over from the RNA world when you had the

263
00:11:06,210 --> 00:11:02,920

RNA world of all on the pre DNA world

264
00:11:09,090 --> 00:11:06,220
DNA protein world you probably had just

265
00:11:12,420 --> 00:11:09,100
tags of this hooked on so this chunk

266
00:11:15,420 --> 00:11:12,430
right here is probably just relative who

267
00:11:17,550 --> 00:11:15,430
colleges a relict of the RNA world and

268
00:11:18,990 --> 00:11:17,560
is not really it's also very complex

269
00:11:20,850 --> 00:11:19,000
though it's hard to imagine how this

270
00:11:24,540 --> 00:11:20,860
would compound were deformed in a

271
00:11:26,490 --> 00:11:24,550
prebiotic context so for you to go sort

272
00:11:28,199 --> 00:11:26,500
of with the simple compounds of

273
00:11:31,889 --> 00:11:28,209
phosphorus that I've seen in in life

274
00:11:33,780 --> 00:11:31,899
today we have here orthophosphate which

275
00:11:36,449 --> 00:11:33,790
is one of the major phosphorus compounds

276
00:11:38,790 --> 00:11:36,459
or EC but i'm going to have several

277
00:11:40,559 --> 00:11:38,800
others we have pyrophosphates phosphorus

278
00:11:42,559 --> 00:11:40,569
oxygen phosphorus compound phosphite

279
00:11:44,610 --> 00:11:42,569
which is reduced phosphorus compound

280
00:11:46,259 --> 00:11:44,620
hypophosphite which is even more reduced

281
00:11:47,550 --> 00:11:46,269
that's just because there's two

282
00:11:49,740 --> 00:11:47,560
hydrogen's bound here and then we have

283
00:11:53,009 --> 00:11:49,750
triphosphates and even longer so these

284
00:11:56,189 --> 00:11:53,019
are sort of some potential inorganic

285
00:11:58,769 --> 00:11:56,199
very simple phosphorus compounds that

286
00:12:01,110 --> 00:11:58,779
may have preceded these sorts of ATP and

287
00:12:03,990 --> 00:12:01,120
other compounds that we see in life

288
00:12:07,759 --> 00:12:04,000

today as prebiotic phosphorus compounds

289
00:12:10,559 --> 00:12:07,769
either as sources or as ultimate

290
00:12:12,389 --> 00:12:10,569
phosphate phosphorylating agents

291
00:12:14,879 --> 00:12:12,399
compounds that are capable of sticking

292
00:12:16,259 --> 00:12:14,889
phosphates onto organic compounds so

293
00:12:18,389 --> 00:12:16,269
this is sort of just what we're kind of

294
00:12:21,559 --> 00:12:18,399
aiming for as far as the pre bodycon

295
00:12:24,120 --> 00:12:21,569
text goes for what we're seeing in life

296
00:12:25,949 --> 00:12:24,130
so here's sort of just a slide this

297
00:12:27,600 --> 00:12:25,959
shows a mineral called appetite right

298
00:12:30,360 --> 00:12:27,610
here and this is the phosphorus

299
00:12:33,150 --> 00:12:30,370
geochemistry so what does the earth

300
00:12:35,579 --> 00:12:33,160
provide as far as phosphorus compounds

301
00:12:38,069 --> 00:12:35,589
go and the major one is called appetite

302
00:12:39,809 --> 00:12:38,079
and most of the terrestrial phosphorus

303
00:12:41,939 --> 00:12:39,819
is in the middle appetite is calcium

304
00:12:44,220 --> 00:12:41,949
phosphate especially for igneous and

305
00:12:45,900 --> 00:12:44,230
metamorphic rocks so we have igneous and

306
00:12:47,819 --> 00:12:45,910
metamorphic rocks and its predominant

307
00:12:49,799 --> 00:12:47,829
it's dominated by the mineral appetite

308
00:12:52,740 --> 00:12:49,809
right here and presumably it's dominated

309
00:12:55,199 --> 00:12:52,750
in a lot of the other terrestrial system

310
00:12:57,720 --> 00:12:55,209
are on the early Earth as well this is

311
00:12:59,370 --> 00:12:57,730
one of these simple phosphate minerals

312
00:13:02,100 --> 00:12:59,380
that forms through igneous and

313
00:13:03,840 --> 00:13:02,110

metamorphic process and problem with

314
00:13:05,910 --> 00:13:03,850
appetite is that is under

315
00:13:07,710 --> 00:13:05,920
tiff and fairly insoluble so if you

316
00:13:09,840 --> 00:13:07,720
tried to take an organic compound and

317
00:13:11,460 --> 00:13:09,850
stick it in a pot with this it wouldn't

318
00:13:13,800 --> 00:13:11,470
do much of anything you would not get

319
00:13:15,509 --> 00:13:13,810
one of these organophosphorus compounds

320
00:13:18,930 --> 00:13:15,519
that are so critical to the development

321
00:13:20,639 --> 00:13:18,940
and evolution of life so this does not

322
00:13:22,740 --> 00:13:20,649
seem to work too well there's some other

323
00:13:26,040 --> 00:13:22,750
options including whitlock i which is

324
00:13:28,740 --> 00:13:26,050
calcium magnesium phosphate and there's

325
00:13:31,920 --> 00:13:28,750
also brew site which are potential

326
00:13:34,199 --> 00:13:31,930
sedimentary phosphates on a sort of

327
00:13:36,540 --> 00:13:34,209
early Earth environment and both of

328
00:13:39,900 --> 00:13:36,550
these are just sort of precipitates that

329
00:13:42,090 --> 00:13:39,910
form just by adding phosphate to water

330
00:13:43,980 --> 00:13:42,100
under normal pH conditions so those are

331
00:13:46,259 --> 00:13:43,990
two other options we're not too good

332
00:13:48,150 --> 00:13:46,269
either they the way you can actually get

333
00:13:50,370 --> 00:13:48,160
compounds out of these is by dehydrating

334
00:13:52,259 --> 00:13:50,380
either dehydrated of heating of

335
00:13:54,509 --> 00:13:52,269
phosphates and these tend to be local

336
00:13:56,900 --> 00:13:54,519
and extent which is a little bit not too

337
00:13:59,189 --> 00:13:56,910
good if you want to have sort of a very

338
00:14:01,050 --> 00:13:59,199

available source of phosphorus all

339
00:14:02,639 --> 00:14:01,060
across the surface of the earth so

340
00:14:03,960 --> 00:14:02,649
there's other sources of phosphorus in

341
00:14:06,360 --> 00:14:03,970
terms of geochemistry there's

342
00:14:08,129 --> 00:14:06,370
hydrothermal vents which in my thing one

343
00:14:11,129 --> 00:14:08,139
now I gotta and others show that

344
00:14:12,689 --> 00:14:11,139
hydrothermal vents release small

345
00:14:15,689 --> 00:14:12,699
concentrations micromolar concentrations

346
00:14:17,790 --> 00:14:15,699
of condensed phosphates we have immense

347
00:14:21,240 --> 00:14:17,800
posses now here the pyrophosphate and

348
00:14:23,490 --> 00:14:21,250
the triphosphate right here so in the

349
00:14:26,040 --> 00:14:23,500
vicinity of hydrothermal vents you do

350
00:14:27,990 --> 00:14:26,050
get some fairly interesting phosphorus

351
00:14:32,600 --> 00:14:28,000
compounds coming out many of these

352
00:14:35,100 --> 00:14:32,610
condensed phosphates right here and

353
00:14:37,050 --> 00:14:35,110
again if you take sort of these

354
00:14:38,460 --> 00:14:37,060
phosphates so to presume that may have

355
00:14:42,689 --> 00:14:38,470
been active on the early Earth is blue

356
00:14:44,189 --> 00:14:42,699
shading and wait like I you can actually

357
00:14:45,870 --> 00:14:44,199
get these compounds for me just by

358
00:14:47,660 --> 00:14:45,880
heating them up as well but that

359
00:14:49,350 --> 00:14:47,670
requires sort of a combination of

360
00:14:51,540 --> 00:14:49,360
environments that sedimentary

361
00:14:53,160 --> 00:14:51,550
environment plus they sort of very hot

362
00:14:57,329 --> 00:14:53,170
heating one that can get rid of all the

363
00:14:59,759 --> 00:14:57,339

water as well so if we look and see on

364
00:15:01,800 --> 00:14:59,769
our checklist of simple phosphorus

365
00:15:05,009 --> 00:15:01,810
compounds that are present in life today

366
00:15:06,900 --> 00:15:05,019
and presumably worth important on the

367
00:15:10,079 --> 00:15:06,910
prebiotic context we have a lot of

368
00:15:11,820 --> 00:15:10,089
orthophosphate available to do reactions

369
00:15:13,320 --> 00:15:11,830
however we have a little

370
00:15:15,690 --> 00:15:13,330
these other two compounds where the

371
00:15:17,940 --> 00:15:15,700
pyrophosphate and the triphosphate which

372
00:15:20,670 --> 00:15:17,950
both aren't very abundant except in some

373
00:15:23,100 --> 00:15:20,680
very specific conditions so these other

374
00:15:24,540 --> 00:15:23,110
compounds aren't yet present but and the

375
00:15:26,970 --> 00:15:24,550
shortest shows that perhaps the

376
00:15:29,250 --> 00:15:26,980
geochemical perspective isn't really the

377
00:15:32,280 --> 00:15:29,260
best perspective to take as far as the

378
00:15:35,060 --> 00:15:32,290
origin of phosphorus biomolecules so

379
00:15:38,010 --> 00:15:35,070
what we're going to take now is a Cosmo

380
00:15:40,350 --> 00:15:38,020
biogeochemical approach and this is a

381
00:15:42,540 --> 00:15:40,360
word I've made up completely but what it

382
00:15:45,030 --> 00:15:42,550
kind of influence it kind of means is

383
00:15:47,850 --> 00:15:45,040
how the in flaw of extraterrestrial

384
00:15:50,730 --> 00:15:47,860
material influence the geochemistry on

385
00:15:52,830 --> 00:15:50,740
the early Earth and hence influenced or

386
00:15:56,070 --> 00:15:52,840
affected the origin of life how these

387
00:15:58,350 --> 00:15:56,080
bio and geo and Cosmo chemical

388
00:16:00,270 --> 00:15:58,360

properties all sort of inter played and

389
00:16:02,220 --> 00:16:00,280
when I announced this word about half a

390
00:16:03,660 --> 00:16:02,230
year ago at a conference I said I don't

391
00:16:05,970 --> 00:16:03,670
think there's any way of fitting another

392
00:16:09,390 --> 00:16:05,980
prefix in there and someone yelled out /

393
00:16:12,930 --> 00:16:09,400
oh so here's the complete word cosmo

394
00:16:15,560 --> 00:16:12,940
proto biogeochemical system and this is

395
00:16:17,760 --> 00:16:15,570
our approach for phosphorus that again I

396
00:16:18,960 --> 00:16:17,770
don't know if you another word in there

397
00:16:22,290 --> 00:16:18,970
but I'm sure that there's some way or

398
00:16:24,540 --> 00:16:22,300
another so if we take a look at the

399
00:16:27,690 --> 00:16:24,550
Cosmo chemical approach of phosphorus

400
00:16:30,270 --> 00:16:27,700
this here is a very standard Cosmo

401
00:16:32,250 --> 00:16:30,280
chemical tool called a condensation

402
00:16:35,370 --> 00:16:32,260
sequence with shortest shows what the

403
00:16:37,950 --> 00:16:35,380
the major phases predicted from

404
00:16:40,650 --> 00:16:37,960
thermodynamic equilibrium calculations

405
00:16:43,050 --> 00:16:40,660
which suggests that a specific element

406
00:16:45,540 --> 00:16:43,060
were partaken so if you were to assume

407
00:16:48,090 --> 00:16:45,550
that the solar nebula was kind of very

408
00:16:52,170 --> 00:16:48,100
spread out and just sort of cooling down

409
00:16:54,420 --> 00:16:52,180
slowly as to form solids you have for

410
00:16:56,760 --> 00:16:54,430
three different types of materials that

411
00:16:59,610 --> 00:16:56,770
phosphorus to go into down here we have

412
00:17:01,650 --> 00:16:59,620
the temperature in Kelvin axis and along

413
00:17:03,210 --> 00:17:01,660

the side we just have an abundance scale

414
00:17:05,340 --> 00:17:03,220
and its work somewhat arbitrary units

415
00:17:08,400 --> 00:17:05,350
and at the highest temperatures

416
00:17:11,490 --> 00:17:08,410
phosphorus is a gaseous or a volatile

417
00:17:13,680 --> 00:17:11,500
element and will form phosphors oxide

418
00:17:15,480 --> 00:17:13,690
and various phosphorous gases these

419
00:17:17,670 --> 00:17:15,490
aren't too relevant because it's hard to

420
00:17:20,070 --> 00:17:17,680
when they when you start to cool things

421
00:17:21,410 --> 00:17:20,080
down you get some other phase it's down

422
00:17:23,720 --> 00:17:21,420
here at around seven

423
00:17:25,460 --> 00:17:23,730
kelvin and lower you get phosphate

424
00:17:27,140 --> 00:17:25,470
mineral so what we see on the surface of

425
00:17:31,040 --> 00:17:27,150
the earth today so these are two

426
00:17:33,650 --> 00:17:31,050
relevant to sort of increasing our

427
00:17:36,050 --> 00:17:33,660
repertoire of phosphorus compounds

428
00:17:38,450 --> 00:17:36,060
available for life and organic compounds

429
00:17:41,240 --> 00:17:38,460
but the center piece right here is iron

430
00:17:45,460 --> 00:17:41,250
phosphide and iron phosphide is a

431
00:17:48,500 --> 00:17:45,470
mineral known as schreiber site and

432
00:17:51,170 --> 00:17:48,510
schreiber site is a very common

433
00:17:53,150 --> 00:17:51,180
meteoritic mineral here we have a slice

434
00:17:55,730 --> 00:17:53,160
of the Brenham pallasite with a great

435
00:17:57,140 --> 00:17:55,740
big drain of shriver site in there kinda

436
00:17:59,900 --> 00:17:57,150
looks like a guy riding a horse and

437
00:18:02,870 --> 00:17:59,910
schreiber sites a very common meteoritic

438
00:18:05,270 --> 00:18:02,880

phosphorus mineral it has a boiler iron

439
00:18:08,600 --> 00:18:05,280
nickel phosphide there's no oxygen in

440
00:18:10,670 --> 00:18:08,610
here it's ubiquitous in meteorites but

441
00:18:12,950 --> 00:18:10,680
if you take this mineral and place it in

442
00:18:14,870 --> 00:18:12,960
water you can imagine that this since

443
00:18:16,700 --> 00:18:14,880
there's no oxygen here or scavenge

444
00:18:18,680 --> 00:18:16,710
oxygen from the environment and the fact

445
00:18:21,950 --> 00:18:18,690
it's fairly reactive it will react on

446
00:18:24,710 --> 00:18:21,960
the order of a couple percent per day or

447
00:18:26,540 --> 00:18:24,720
a week or so and it's fairly thought

448
00:18:29,180 --> 00:18:26,550
because it's thermodynamically unstable

449
00:18:30,950 --> 00:18:29,190
and perhaps if we were to take this

450
00:18:32,720 --> 00:18:30,960
compound and try to do some reactive

451
00:18:35,720 --> 00:18:32,730
chemistry with it it might be more

452
00:18:38,570 --> 00:18:35,730
beneficial or more intuitively useful

453
00:18:40,460 --> 00:18:38,580
than just a simple phosphate mineral we

454
00:18:42,950 --> 00:18:40,470
gotta gather was rare on earth yes it

455
00:18:45,050 --> 00:18:42,960
does not occur on earth well it does not

456
00:18:46,850 --> 00:18:45,060
occur on the surface of the earth if you

457
00:18:48,770 --> 00:18:46,860
take a look at the Earth's abundances in

458
00:18:50,390 --> 00:18:48,780
general a majority of the phosphorus

459
00:18:53,690 --> 00:18:50,400
about ninety five percent of it fosters

460
00:18:55,310 --> 00:18:53,700
actually in the Earth's core and since

461
00:18:57,590 --> 00:18:55,320
we had differentiation occur fairly

462
00:18:59,030 --> 00:18:57,600
rapidly on the earth there's not almost

463
00:19:00,800 --> 00:18:59,040

none occurring on the surface of the

464
00:19:03,860 --> 00:19:00,810
earth today step two meteorites and a

465
00:19:06,440 --> 00:19:03,870
couple other very unique environments so

466
00:19:08,960 --> 00:19:06,450
if we consider this phosphorus is a very

467
00:19:11,900 --> 00:19:08,970
common meteoric mineral can we even call

468
00:19:14,000 --> 00:19:11,910
this mineral prebiotic is it is it a

469
00:19:17,360 --> 00:19:14,010
very common mineral perhaps on the early

470
00:19:19,760 --> 00:19:17,370
Earth and in the answer it's not common

471
00:19:21,530 --> 00:19:19,770
as far as geochemistry is concerned

472
00:19:23,470 --> 00:19:21,540
there's very few ways of producing it

473
00:19:27,520 --> 00:19:23,480
through normal geochemical proper

474
00:19:31,610 --> 00:19:27,530
processes but there are ways shooting

475
00:19:33,210 --> 00:19:31,620
through the delivery by meteorites in

476
00:19:35,399 --> 00:19:33,220
fact most of them the most

477
00:19:37,860 --> 00:19:35,409
massive meteorites or iron meteorites

478
00:19:41,100 --> 00:19:37,870
and iron meteorites are phosphorous rich

479
00:19:43,680 --> 00:19:41,110
roundabout between two to twenty percent

480
00:19:45,690 --> 00:19:43,690
the volume of an iron meteorite is this

481
00:19:48,480 --> 00:19:45,700
mineral Schreiber site in general and

482
00:19:51,630 --> 00:19:48,490
also small craters like the meteor

483
00:19:54,500 --> 00:19:51,640
crater and nearby Flagstaff in Arizona

484
00:19:58,260 --> 00:19:54,510
are almost all dominated by large

485
00:20:00,090 --> 00:19:58,270
meteoritic impasse these big things fall

486
00:20:01,830 --> 00:20:00,100
and they form these small craters which

487
00:20:04,320 --> 00:20:01,840
are found all across the surface of the

488
00:20:06,180 --> 00:20:04,330

earth so it seems like there's lots of

489
00:20:08,460 --> 00:20:06,190
phosphorus in the form of phosphites

490
00:20:10,770 --> 00:20:08,470
coming to the surface of the earth we

491
00:20:13,380 --> 00:20:10,780
kind of had a big meteorites and then

492
00:20:15,600 --> 00:20:13,390
the small impact craters as well and the

493
00:20:17,340 --> 00:20:15,610
small impact craters often have

494
00:20:19,830 --> 00:20:17,350
meteorites associated with them as well

495
00:20:21,480 --> 00:20:19,840
so here's sort of just an example of

496
00:20:23,460 --> 00:20:21,490
several different types of meteorites

497
00:20:26,039 --> 00:20:23,470
some nice pictures of meteorites with

498
00:20:29,610 --> 00:20:26,049
phosphide circled in all of them just

499
00:20:31,860 --> 00:20:29,620
show that phosphides are very common in

500
00:20:33,630 --> 00:20:31,870
the iron meteorites we have some of

501
00:20:36,570 --> 00:20:33,640
these 180s and these are just various

502
00:20:39,960 --> 00:20:36,580
classifications of iron meteorites and

503
00:20:41,460 --> 00:20:39,970
fossilize are very common in the irony

504
00:20:42,930 --> 00:20:41,470
right and you can see that this one

505
00:20:45,630 --> 00:20:42,940
right here this is actually around about

506
00:20:47,310 --> 00:20:45,640
twenty percent on average is this

507
00:20:51,200 --> 00:20:47,320
mineral schreiber site so it's very

508
00:20:53,549 --> 00:20:51,210
common in some of the iron meteorites

509
00:20:55,680 --> 00:20:53,559
additionally there's some phosphorus at

510
00:20:57,930 --> 00:20:55,690
some of these other types of meteorites

511
00:21:00,240 --> 00:20:57,940
this is the gorgeous slice of the fukang

512
00:21:02,850 --> 00:21:00,250
pallasite you see these nice olivene

513
00:21:03,990 --> 00:21:02,860

grains and a thumb for scale this occurs

514
00:21:06,240 --> 00:21:04,000
in the thumbnail but that's not why I

515
00:21:08,399 --> 00:21:06,250
found them sell and you can see the nice

516
00:21:12,450 --> 00:21:08,409
i living arrangement right up on sort of

517
00:21:14,610 --> 00:21:12,460
a North corner you see a nice screen or

518
00:21:16,440 --> 00:21:14,620
Schreiber site so the Schreiber sites a

519
00:21:17,970 --> 00:21:16,450
very common constituent even of these

520
00:21:20,580 --> 00:21:17,980
sorts of other types of meteorites is

521
00:21:22,380 --> 00:21:20,590
the policy TT right and so you can see

522
00:21:24,450 --> 00:21:22,390
that it's a fairly common constituent of

523
00:21:26,159 --> 00:21:24,460
these two different types of meteorites

524
00:21:29,159 --> 00:21:26,169
talked about the irons and the stony

525
00:21:30,960 --> 00:21:29,169
irons here additionally it's also found

526
00:21:33,090 --> 00:21:30,970
a number of different other types of

527
00:21:35,810 --> 00:21:33,100
phases we have it fairly common this is

528
00:21:37,980 --> 00:21:35,820
an elemental map of a cons right and

529
00:21:39,480 --> 00:21:37,990
cons rights actually have around about

530
00:21:42,670 --> 00:21:39,490
ten percent of the phosphorus in

531
00:21:44,320 --> 00:21:42,680
chondrites is in an Schreiber site and

532
00:21:46,540 --> 00:21:44,330
can't really see it too well here but

533
00:21:48,220 --> 00:21:46,550
the blue backs right here are actually

534
00:21:50,800 --> 00:21:48,230
schreiber site and then we have the

535
00:21:53,590 --> 00:21:50,810
purple are the kalsa the appetite and a

536
00:21:55,660 --> 00:21:53,600
couple others as well additionally for

537
00:21:57,820 --> 00:21:55,670
the majority of the material that falls

538
00:21:59,320 --> 00:21:57,830

to the surface of the year today is in

539
00:22:01,510 --> 00:21:59,330
the form of interplanetary dust

540
00:22:04,030 --> 00:22:01,520
particles and the interplanetary dust

541
00:22:06,280 --> 00:22:04,040
particles are micro meteorites there's

542
00:22:09,580 --> 00:22:06,290
been three reports of phosphorous

543
00:22:12,460 --> 00:22:09,590
minerals in these materials and two of

544
00:22:13,660 --> 00:22:12,470
these are IDPs and one of those was a

545
00:22:15,550 --> 00:22:13,670
phosphite and the other words a

546
00:22:17,800 --> 00:22:15,560
phosphate and then there was a report

547
00:22:20,770 --> 00:22:17,810
very recently released on built two

548
00:22:22,840 --> 00:22:20,780
samples from Stardust which had a report

549
00:22:24,880 --> 00:22:22,850
of Schreiber site in the Stardust sample

550
00:22:27,070 --> 00:22:24,890
so comment seemed to have Schreiber site

551
00:22:30,070 --> 00:22:27,080
as well and even some micro meteorites

552
00:22:32,140 --> 00:22:30,080
collected all the Hubble telescope panes

553
00:22:34,390 --> 00:22:32,150
were enriched in Schreiber site so we

554
00:22:36,730 --> 00:22:34,400
see Schreiber site in the only small

555
00:22:38,350 --> 00:22:36,740
material as well so there seems to be a

556
00:22:42,790 --> 00:22:38,360
lot of phosphorous falling to the

557
00:22:44,350 --> 00:22:42,800
surface of the earth and here's sort of

558
00:22:47,320 --> 00:22:44,360
the early picture of the early Earth

559
00:22:49,150 --> 00:22:47,330
kind of taken from encarta here and we

560
00:22:51,010 --> 00:22:49,160
see all these things falling to the

561
00:22:53,290 --> 00:22:51,020
surface of the earth in sort of a very

562
00:22:55,300 --> 00:22:53,300
wet environment and this sort of shows

563
00:22:58,660 --> 00:22:55,310

that the early Earth was probably fairly

564
00:22:59,770 --> 00:22:58,670
different than what we have the picture

565
00:23:01,510 --> 00:22:59,780
that we have of the early Earth is

566
00:23:03,730 --> 00:23:01,520
different the present day earth and

567
00:23:11,110 --> 00:23:03,740
these meteorites are all falling and

568
00:23:13,440 --> 00:23:11,120
this has a net result of here we have a

569
00:23:15,700 --> 00:23:13,450
calculation presented in this paper in

570
00:23:18,340 --> 00:23:15,710
origin of life evolution of biospheres

571
00:23:21,520 --> 00:23:18,350
online now where we calculate among

572
00:23:23,230 --> 00:23:21,530
between the flux of extra material of

573
00:23:25,090 --> 00:23:23,240
carbon nitrogen and phosphorus and for

574
00:23:27,070 --> 00:23:25,100
the phosphorus you have a lot of

575
00:23:30,280 --> 00:23:27,080
phosphorus falling to the early Earth

576
00:23:32,980 --> 00:23:30,290
between 10 to 15 and 10 to 18 kilograms

577
00:23:37,350 --> 00:23:32,990
of reduced phosphorus falling to the

578
00:23:46,180 --> 00:23:43,570
excuse me so in this this earlier this

579
00:23:49,660 --> 00:23:46,190
massive flux of reduced phosphorus if

580
00:23:51,460 --> 00:23:49,670
you assume the present day volume of the

581
00:23:55,630 --> 00:23:51,470
ocean you would have had

582
00:23:57,760 --> 00:23:55,640
around about 10 micromolar to 10 milli

583
00:24:00,880 --> 00:23:57,770
molar concentration others reduce

584
00:24:02,560 --> 00:24:00,890
phosphorus in the early Earth ocean so

585
00:24:05,169 --> 00:24:02,570
there's a lot of reduced phosphorus

586
00:24:07,299 --> 00:24:05,179
potentially in the early Earth ocean so

587
00:24:10,539 --> 00:24:07,309
what happens to this phase when we take

588
00:24:12,789 --> 00:24:10,549

it and add it to water so here's a

589
00:24:15,779 --> 00:24:12,799
description of some of the experiments I

590
00:24:19,120 --> 00:24:15,789
did as part of my graduate thesis Anakin

591
00:24:22,000 --> 00:24:19,130
continuing to do a little bit as well to

592
00:24:24,549 --> 00:24:22,010
present day and that is to take this

593
00:24:35,980 --> 00:24:24,559
phosphide mineral and reacted in water

594
00:24:38,740 --> 00:24:35,990
and this phosphide mineral we actually

595
00:24:41,560 --> 00:24:38,750
took a sample of the same Chan pallasite

596
00:24:44,529 --> 00:24:41,570
and these were some shavings of the same

597
00:24:47,230 --> 00:24:44,539
Chen pallasite and placed them in water

598
00:24:49,000 --> 00:24:47,240
and by placing water we also controlled

599
00:24:50,860 --> 00:24:49,010
the atmosphere the temperature the pH

600
00:24:53,140 --> 00:24:50,870
and many other solution chemistry as

601
00:24:55,000 --> 00:24:53,150
well and then analyzed these things by

602
00:24:59,200 --> 00:24:55,010
nuclear magnetic resonance spectroscopy

603
00:25:01,210 --> 00:24:59,210
it's not a technique typically used in G

604
00:25:03,010 --> 00:25:01,220
ok the geosciences so I'm going to

605
00:25:06,720 --> 00:25:03,020
provide us brief outline of what this

606
00:25:09,580 --> 00:25:06,730
does in as far as a chemical technique

607
00:25:12,159 --> 00:25:09,590
phosphorus is a nucleus that has a spin

608
00:25:14,289 --> 00:25:12,169
and when it has a spin that means it has

609
00:25:16,840 --> 00:25:14,299
a preferred direction in the magnetic

610
00:25:19,149 --> 00:25:16,850
field so you take your sample you place

611
00:25:20,770 --> 00:25:19,159
it in the magnetic field and then

612
00:25:23,260 --> 00:25:20,780
there's a slight energy difference

613
00:25:26,039 --> 00:25:23,270

between one preferred spin spin state

614
00:25:29,260 --> 00:25:26,049
and the other and when you have these

615
00:25:31,930 --> 00:25:29,270
spin States relax when you hit them with

616
00:25:34,149 --> 00:25:31,940
a radio post then when they relax they

617
00:25:36,460 --> 00:25:34,159
release energy and this energy is a

618
00:25:39,340 --> 00:25:36,470
specific frequency and you can compare

619
00:25:45,549 --> 00:25:39,350
this frequency to a standard frequency

620
00:25:49,390 --> 00:25:45,559
and the deviation ok all right well the

621
00:25:53,470 --> 00:25:49,400
deviation of peak frequencies will give

622
00:25:55,299 --> 00:25:53,480
you the compound identity or given

623
00:25:57,580 --> 00:25:55,309
phosphorus compounds what we have here

624
00:26:01,270 --> 00:25:57,590
is the NMR spectrum and along this

625
00:26:03,710 --> 00:26:01,280
bottom axis is the deviation of peak

626
00:26:06,409 --> 00:26:03,720
frequency from a standard free

627
00:26:08,560 --> 00:26:06,419
in this case zero parts per million so

628
00:26:10,970 --> 00:26:08,570
what we have is right here this is

629
00:26:25,590 --> 00:26:10,980
specific phosphorus compounds that were

630
00:26:30,870 --> 00:26:29,730
I right back okay am I Heath and

631
00:26:34,320 --> 00:26:30,880
additionally when you take these

632
00:26:37,310 --> 00:26:34,330
phosphorus compounds and place them with

633
00:26:39,000 --> 00:26:37,320
a organic solution you will get some

634
00:26:41,299 --> 00:26:39,010
organophosphorus compounds that are

635
00:26:43,289 --> 00:26:41,309
being produced on the organic of

636
00:26:45,120 --> 00:26:43,299
organophosphorus compounds are the

637
00:26:47,730 --> 00:26:45,130
compounds that we are are especially

638
00:26:49,620 --> 00:26:47,740

relevant to origin of life studies what

639
00:26:51,240 --> 00:26:49,630
we have here are some of these compounds

640
00:26:53,490 --> 00:26:51,250
which reported in this paper and

641
00:26:56,010 --> 00:26:53,500
geochemical cosmic chemica acta where we

642
00:26:58,740 --> 00:26:56,020
have these carbon phosphorus bonds that

643
00:27:01,620 --> 00:26:58,750
are being formed just by placing in this

644
00:27:03,360 --> 00:27:01,630
case acetate in with this Schreiber site

645
00:27:05,700 --> 00:27:03,370
and you actually do form some carbon

646
00:27:07,500 --> 00:27:05,710
phosphorus compounds and you also form

647
00:27:09,120 --> 00:27:07,510
additionally some carbon oxygen

648
00:27:12,210 --> 00:27:09,130
phosphorus compounds which are what we

649
00:27:15,659 --> 00:27:12,220
see a majority of in the life today so

650
00:27:18,270 --> 00:27:15,669
this miracle mineral does seem to have

651
00:27:20,130 --> 00:27:18,280
some of the abilities that wouldn't

652
00:27:22,529 --> 00:27:20,140
suggest it it's very important in the

653
00:27:26,880 --> 00:27:22,539
prebiotic context as far as phosphorus

654
00:27:28,890 --> 00:27:26,890
sources for these organic compounds so

655
00:27:30,779 --> 00:27:28,900
it does seem to these concentrations

656
00:27:32,130 --> 00:27:30,789
aren't to hide is running about three

657
00:27:34,260 --> 00:27:32,140
percent of the total dissolved

658
00:27:36,779 --> 00:27:34,270
phosphorus was in these organic

659
00:27:38,850 --> 00:27:36,789
compounds but it does suggest that there

660
00:27:43,080 --> 00:27:38,860
is some reactive capability of these

661
00:27:45,240 --> 00:27:43,090
compounds in this case it was part of

662
00:27:48,510 --> 00:27:45,250
the solution so it was just a solution

663
00:27:50,730 --> 00:27:48,520

of acetate and water so it wasn't what

664
00:27:52,710 --> 00:27:50,740
is trying to get results with carbon and

665
00:27:57,750 --> 00:27:52,720
phosphorus in them you see a preference

666
00:27:59,430 --> 00:27:57,760
for oxygen carbon there is definitely a

667
00:28:01,980 --> 00:27:59,440
preference in this case for the carbon

668
00:28:04,529 --> 00:28:01,990
phosphorus ponds as opposed to the

669
00:28:06,990 --> 00:28:04,539
phosphorous oxygen carbon bond so there

670
00:28:09,600 --> 00:28:07,000
is a preference for carbon phosphorus in

671
00:28:11,490 --> 00:28:09,610
this system which has it means that it's

672
00:28:13,200 --> 00:28:11,500
probably not completely the whole story

673
00:28:14,669 --> 00:28:13,210
as far as phosphorus for the origin of

674
00:28:18,659 --> 00:28:14,679
life but that's a really good question

675
00:28:20,100 --> 00:28:18,669
there so how these compounds formed

676
00:28:22,529 --> 00:28:20,110
again this is from this paper what we

677
00:28:25,350 --> 00:28:22,539
have here is sort of a very schematic

678
00:28:27,419 --> 00:28:25,360
diagram of radical chemistry and radical

679
00:28:29,190 --> 00:28:27,429
is not really a leftist or itís or

680
00:28:32,159 --> 00:28:29,200
anything of that but it just means in

681
00:28:33,840 --> 00:28:32,169
this case with an unpaired electron and

682
00:28:36,539 --> 00:28:33,850
what we have here are two radicals we

683
00:28:37,230 --> 00:28:36,549
have an acetyl radical on the left-hand

684
00:28:39,750 --> 00:28:37,240
side

685
00:28:42,840 --> 00:28:39,760
and a fuss fighting radical on the right

686
00:28:45,000 --> 00:28:42,850
hand side and both these compounds have

687
00:28:46,530 --> 00:28:45,010
are presumably may have had a free

688
00:28:48,720 --> 00:28:46,540

electron this one probably came about

689
00:28:51,000 --> 00:28:48,730
through some reaction later on the

690
00:28:54,090 --> 00:28:51,010
solution but when the phosphide prudes

691
00:28:56,400 --> 00:28:54,100
it forms this fuss fight radical and

692
00:28:59,400 --> 00:28:56,410
when two radicals come together they

693
00:29:01,260 --> 00:28:59,410
form a chemical bond very easily because

694
00:29:03,570 --> 00:29:01,270
these free electrons are highly

695
00:29:04,980 --> 00:29:03,580
energetic state so this is probably how

696
00:29:07,230 --> 00:29:04,990
you get these sort of carbon phosphorus

697
00:29:09,150 --> 00:29:07,240
ponds just by having this carbon with a

698
00:29:11,430 --> 00:29:09,160
radical and a phosphorus kind of coming

699
00:29:13,230 --> 00:29:11,440
together and forming these carbon

700
00:29:17,100 --> 00:29:13,240
phosphorus organophosphorus compounds

701
00:29:20,340 --> 00:29:17,110
very easily so the relevance of

702
00:29:22,950 --> 00:29:20,350
Schreiber site to the early Earth these

703
00:29:25,910 --> 00:29:22,960
simple experiments to suggests that the

704
00:29:28,500 --> 00:29:25,920
phosphide was probably a very major

705
00:29:31,170 --> 00:29:28,510
constituent of the earlier based on the

706
00:29:33,150 --> 00:29:31,180
flux calculations and based on the

707
00:29:35,700 --> 00:29:33,160
reactivity of this compound of this

708
00:29:37,110 --> 00:29:35,710
compound in water so if you take this

709
00:29:39,570 --> 00:29:37,120
compound you a form a couple other

710
00:29:42,120 --> 00:29:39,580
compounds as well I am fortunate with

711
00:29:43,830 --> 00:29:42,130
heart and slided missed but there's a

712
00:29:46,560 --> 00:29:43,840
number of different varieties of

713
00:29:49,680 --> 00:29:46,570

compounds that can be produced using

714
00:29:52,260 --> 00:29:49,690
Schreiber site in this in this context

715
00:29:56,280 --> 00:29:52,270
so additional changes may have occurred

716
00:29:58,470 --> 00:29:56,290
on the early Earth so if we take the

717
00:30:00,660 --> 00:29:58,480
shriver site and reacted this is was one

718
00:30:02,250 --> 00:30:00,670
of my collaborators who did this

719
00:30:04,500 --> 00:30:02,260
presented that worked where he took

720
00:30:06,840 --> 00:30:04,510
Schreiber site and reacted it under UV

721
00:30:09,200 --> 00:30:06,850
light he was actually able to get this

722
00:30:11,790 --> 00:30:09,210
highly reduced form of oestrus called

723
00:30:13,980 --> 00:30:11,800
hypophosphite and this has a phosphorous

724
00:30:15,600 --> 00:30:13,990
hydrogen hydrogen bond so that this is

725
00:30:17,700 --> 00:30:15,610
one of the compounds those very easily

726
00:30:19,980 --> 00:30:17,710
produced just by taking this compound

727
00:30:22,650 --> 00:30:19,990
and reacting under water under UV light

728
00:30:24,480 --> 00:30:22,660
so this is plausibly formed on the early

729
00:30:27,980 --> 00:30:24,490
Earth and we have a structure right here

730
00:30:30,210 --> 00:30:27,990
and you take this compound Plus this

731
00:30:32,460 --> 00:30:30,220
phosphite compound which is as this

732
00:30:35,310 --> 00:30:32,470
again has a phosphorous hydrogen bond a

733
00:30:37,230 --> 00:30:35,320
reduced form of phosphorous and assume

734
00:30:40,140 --> 00:30:37,240
that they were say prevalent all across

735
00:30:41,970 --> 00:30:40,150
the ocean or on a narrow in a small lake

736
00:30:44,340 --> 00:30:41,980
or something like that and the impact

737
00:30:46,770 --> 00:30:44,350
Lake perhaps you take these reduced

738
00:30:49,180 --> 00:30:46,780

forms of phosphorus and there's a couple

739
00:30:51,700 --> 00:30:49,190
properties of these that are making avin

740
00:30:54,640 --> 00:30:51,710
pages consider as primary sources of

741
00:30:56,890 --> 00:30:54,650
phosphorus for the evolution of life one

742
00:30:58,630 --> 00:30:56,900
they're much more soluble than phosphate

743
00:31:01,000 --> 00:30:58,640
by about a factor of thousand for his

744
00:31:02,710 --> 00:31:01,010
first one about two million for the

745
00:31:05,440 --> 00:31:02,720
second so they're much more readily

746
00:31:09,960 --> 00:31:05,450
available in many of the early Earth

747
00:31:11,710 --> 00:31:09,970
ocean environments excuse me

748
00:31:13,990 --> 00:31:11,720
additionally they're much more reactive

749
00:31:17,170 --> 00:31:14,000
in several situations you can get these

750
00:31:18,910 --> 00:31:17,180
things and organic chemistry's persist

751
00:31:21,070 --> 00:31:18,920
participate in several different

752
00:31:22,900 --> 00:31:21,080
reactions not going to any right now

753
00:31:25,810 --> 00:31:22,910
because that's part of my collaborators

754
00:31:28,210 --> 00:31:25,820
work but it's a license to say that

755
00:31:30,850 --> 00:31:28,220
these are very reactive compared to

756
00:31:32,650 --> 00:31:30,860
regular terrestrial orthophosphate so

757
00:31:35,530 --> 00:31:32,660
there's a lot more potential for these

758
00:31:38,080 --> 00:31:35,540
compounds to do things however and

759
00:31:41,710 --> 00:31:38,090
despite the reactivity with first

760
00:31:45,940 --> 00:31:41,720
compound is phosphite HP 03 is much more

761
00:31:48,160 --> 00:31:45,950
stable than might be assumed for reduced

762
00:31:50,830 --> 00:31:48,170
phosphorus because in order to break

763
00:31:53,170 --> 00:31:50,840

this phosphorus hydrogen bond requires a

764
00:31:56,020 --> 00:31:53,180
fair bit of energy and you need a fairly

765
00:32:00,880 --> 00:31:56,030
strong oxidant as well and in the case

766
00:32:03,340 --> 00:32:00,890
of phosphite on the early Earth given

767
00:32:05,770 --> 00:32:03,350
some simple calculations these are just

768
00:32:09,460 --> 00:32:05,780
using a kinetic calculator you can take

769
00:32:12,310 --> 00:32:09,470
the pressure of reductants on in the

770
00:32:14,320 --> 00:32:12,320
early Earth environment this bottom axis

771
00:32:17,140 --> 00:32:14,330
here is the log 10 pressure of hydrogen

772
00:32:23,080 --> 00:32:17,150
in the early earth atmosphere and this

773
00:32:25,390 --> 00:32:23,090
on the y-axis is the is the the estimate

774
00:32:28,390 --> 00:32:25,400
of the oceanic half-life for the

775
00:32:31,810 --> 00:32:28,400
oxidation of this compound so and these

776
00:32:33,640 --> 00:32:31,820
these are in log 10 base years so what

777
00:32:36,610 --> 00:32:33,650
we have is sort of this narrow range

778
00:32:38,950 --> 00:32:36,620
where under fairly moderately reducing

779
00:32:41,350 --> 00:32:38,960
environments you can get lifetimes on

780
00:32:43,690 --> 00:32:41,360
the order of a billion hundred million

781
00:32:46,180 --> 00:32:43,700
two billion years so if you had this

782
00:32:48,070 --> 00:32:46,190
compound delivered to the early Earth it

783
00:32:50,440 --> 00:32:48,080
could have persisted around provided

784
00:32:51,700 --> 00:32:50,450
that the oxidant swore to abundant which

785
00:32:53,410 --> 00:32:51,710
is what you might have estimate from

786
00:32:55,840 --> 00:32:53,420
depending on your atmospheric condition

787
00:32:59,920 --> 00:32:55,850
so perhaps this reduced phosphorus

788
00:33:00,840 --> 00:32:59,930

accumulated on the early Earth and even

789
00:33:03,600 --> 00:33:00,850
if it didn't take you

790
00:33:05,100 --> 00:33:03,610
has some very interesting other chemical

791
00:33:08,040 --> 00:33:05,110
reactions that it can participate it

792
00:33:09,990 --> 00:33:08,050
this one is a very recent work some work

793
00:33:11,760 --> 00:33:10,000
at that's in prep right now but what we

794
00:33:14,400 --> 00:33:11,770
did was we took these reduce phosphorus

795
00:33:16,590 --> 00:33:14,410
in this case hypophosphite or phosphite

796
00:33:21,660 --> 00:33:16,600
and using fairly low concentrations

797
00:33:23,430 --> 00:33:21,670
oxidized them by hydrogen peroxide type

798
00:33:24,750 --> 00:33:23,440
system about taking a hydrogen peroxide

799
00:33:27,090 --> 00:33:24,760
and mixing it with a little bit of

800
00:33:30,000 --> 00:33:27,100
catalyst you can actually get the

801
00:33:32,700 --> 00:33:30,010
oxidation can promote the oxidation of

802
00:33:34,680 --> 00:33:32,710
these compounds and when you do you get

803
00:33:36,480 --> 00:33:34,690
as you might expect a majority of the

804
00:33:38,070 --> 00:33:36,490
oxidized phosphorus in this case

805
00:33:41,210 --> 00:33:38,080
phosphate here's some starting out bound

806
00:33:43,290 --> 00:33:41,220
but you get substantial amount of

807
00:33:45,120 --> 00:33:43,300
condensed phosphates here at

808
00:33:46,890 --> 00:33:45,130
pyrophosphate and even further down a

809
00:33:48,840 --> 00:33:46,900
small piece right here then blown up

810
00:33:51,270 --> 00:33:48,850
right here this is triphosphate and

811
00:33:52,920 --> 00:33:51,280
perhaps even some tri meta phosphate so

812
00:33:54,810 --> 00:33:52,930
we're forming on the very simple

813
00:33:57,030 --> 00:33:54,820

conditions using this reduced phosphorus

814
00:33:59,160 --> 00:33:57,040
just oxidizing it under fairly simple

815
00:34:01,820 --> 00:33:59,170
conditions you can form condensed

816
00:34:05,580 --> 00:34:01,830
phosphates from this sort of system so

817
00:34:08,010 --> 00:34:05,590
to bring this back to what reduced

818
00:34:10,560 --> 00:34:08,020
phosphorus can do as far as our simple

819
00:34:13,260 --> 00:34:10,570
prebiotic phosphorus compounds we can

820
00:34:15,210 --> 00:34:13,270
form the hope of the whole shebang here

821
00:34:16,860 --> 00:34:15,220
for your phosphorus can get the fourth

822
00:34:18,840 --> 00:34:16,870
of phosphate from the schreiber citing

823
00:34:20,730 --> 00:34:18,850
it these condensed phosphates by

824
00:34:23,670 --> 00:34:20,740
oxidizing the reduced forms of

825
00:34:25,740 --> 00:34:23,680
phosphorus which are so major forms of

826
00:34:27,810 --> 00:34:25,750
the phosphorus so that it seems like the

827
00:34:30,800 --> 00:34:27,820
amount of reactive possibilities are

828
00:34:36,270 --> 00:34:30,810
much larger with this Schreiber's site

829
00:34:38,070 --> 00:34:36,280
and meteoritic forms a phosphorus so how

830
00:34:40,070 --> 00:34:38,080
is this even relevant is this even

831
00:34:42,690 --> 00:34:40,080
relevant to what we see in sort of

832
00:34:44,970 --> 00:34:42,700
biochemistry today I show these simple

833
00:34:47,100 --> 00:34:44,980
phosphorus compounds and are these

834
00:34:49,620 --> 00:34:47,110
compounds if life developed shortly

835
00:34:52,860 --> 00:34:49,630
after or the Layton lavar in their heavy

836
00:34:55,410 --> 00:34:52,870
Mubarak period could be oceanic p have

837
00:34:58,020 --> 00:34:55,420
been controlled by reduced postures

838
00:35:00,410 --> 00:34:58,030

compounds and if so is this what we see

839
00:35:03,240 --> 00:35:00,420
in life today so I'm going to show some

840
00:35:05,010 --> 00:35:03,250
microbiology examples that suggests

841
00:35:06,600 --> 00:35:05,020
there's some of these simple phosphorus

842
00:35:09,750 --> 00:35:06,610
compounds that are produced very readily

843
00:35:11,790 --> 00:35:09,760
from this meteoritic source of

844
00:35:14,340 --> 00:35:11,800
phosphorus may in fact be

845
00:35:17,160 --> 00:35:14,350
used in some ancient organisms and this

846
00:35:19,830 --> 00:35:17,170
is what we're seeing for one the

847
00:35:23,520 --> 00:35:19,840
biochemistry the biochemistry of oceans

848
00:35:25,980 --> 00:35:23,530
is fairly largely influenced by reduced

849
00:35:29,760 --> 00:35:25,990
phosphorus species we have here is an

850
00:35:31,470 --> 00:35:29,770
NMR spectrum of sort of just goo taken

851
00:35:33,960 --> 00:35:31,480
from the ocean and then analyzed by

852
00:35:36,810 --> 00:35:33,970
again by NMR and there's a substantial

853
00:35:39,360 --> 00:35:36,820
peak around about twenty percent is in

854
00:35:40,740 --> 00:35:39,370
this organic phosphonate compound and

855
00:35:42,930 --> 00:35:40,750
phosphonate compounds have this

856
00:35:45,990 --> 00:35:42,940
phosphorous carbon bond which is what we

857
00:35:47,910 --> 00:35:46,000
see that it is easily produced just by

858
00:35:50,130 --> 00:35:47,920
taking the phosphide and every acting

859
00:35:52,560 --> 00:35:50,140
with organics so things as though there

860
00:35:55,650 --> 00:35:52,570
is a phosphorous carbon bond which is

861
00:35:58,040 --> 00:35:55,660
not very common in oceanic phosphorus

862
00:36:00,210 --> 00:35:58,050
chemistry it's not just simple phosphate

863
00:36:01,950 --> 00:36:00,220

organophosphorus chemistry around about

864
00:36:04,140 --> 00:36:01,960
twenty percent of the oceanic organic

865
00:36:06,450 --> 00:36:04,150
phosphorus is as phosphonate a five

866
00:36:08,130 --> 00:36:06,460
percent of soil organic phosphorus it's

867
00:36:09,750 --> 00:36:08,140
phosphonates and it's and these

868
00:36:11,700 --> 00:36:09,760
phosphates are found in nearly all

869
00:36:13,920 --> 00:36:11,710
organisms that have ever been analyzed

870
00:36:15,810 --> 00:36:13,930
including humans it's using some of our

871
00:36:17,580 --> 00:36:15,820
heart tissue and it's probably just a

872
00:36:19,170 --> 00:36:17,590
dietary thing we eat things and make it

873
00:36:22,380 --> 00:36:19,180
but it's still interesting to see it

874
00:36:25,910 --> 00:36:22,390
everywhere additionally we see this

875
00:36:28,860 --> 00:36:25,920
reduced phosphorus in the in some

876
00:36:31,380 --> 00:36:28,870
microbiological reactions we have here

877
00:36:33,390 --> 00:36:31,390
student homeless deuteride which takes

878
00:36:35,400 --> 00:36:33,400
which can take inorganic reduce

879
00:36:38,340 --> 00:36:35,410
phosphorus in this case phosphide and

880
00:36:40,980 --> 00:36:38,350
hypophosphite and use them as phosphorus

881
00:36:43,200 --> 00:36:40,990
sources for the formation of

882
00:36:46,410 --> 00:36:43,210
organophosphorus compounds so there

883
00:36:48,210 --> 00:36:46,420
seems to be a microbiological use for

884
00:36:51,540 --> 00:36:48,220
these forms of compounds neither these

885
00:36:53,700 --> 00:36:51,550
compounds are formed under typical early

886
00:36:55,770 --> 00:36:53,710
earth or modern earth or even early

887
00:36:58,020 --> 00:36:55,780
Earth environments so it seems like

888
00:37:02,220 --> 00:36:58,030

there is a microbial use for these

889
00:37:05,070 --> 00:37:02,230
compounds organism called when the

890
00:37:07,220 --> 00:37:05,080
sulfur bacteria which pops the toxins

891
00:37:11,280 --> 00:37:07,230
which uses reduced phosphorus and

892
00:37:14,130 --> 00:37:11,290
orthophosphate as its electron oxidated

893
00:37:16,890 --> 00:37:14,140
reductive couple so it seems like just a

894
00:37:19,100 --> 00:37:16,900
fair bit of microbiology that uses a

895
00:37:22,050 --> 00:37:19,110
reduced phosphorus despite the fact

896
00:37:22,380 --> 00:37:22,060
there is no real easy way of forming

897
00:37:25,109 --> 00:37:22,390
these

898
00:37:27,480 --> 00:37:25,119
a geochemical system it's only through a

899
00:37:29,970 --> 00:37:27,490
Cosmo chemical and Cosmo geochemical

900
00:37:32,460 --> 00:37:29,980
system so perhaps life retains the

901
00:37:34,140 --> 00:37:32,470
membrane of the early Earth conditions

902
00:37:39,150 --> 00:37:34,150
and that's what we're seeing in this

903
00:37:41,400 --> 00:37:39,160
microbiology today additionally we have

904
00:37:43,200 --> 00:37:41,410
here there's a substantial amount of

905
00:37:45,480 --> 00:37:43,210
biochemistry that goes on with these

906
00:37:47,940 --> 00:37:45,490
simple compounds we saw that this

907
00:37:49,859 --> 00:37:47,950
pyrophosphate compound is foreign very

908
00:37:53,309 --> 00:37:49,869
easily just during the oxidation of

909
00:37:55,349 --> 00:37:53,319
these reduced phosphorus species in on

910
00:37:56,819 --> 00:37:55,359
the early Earth either just by the

911
00:37:58,200 --> 00:37:56,829
production of hydrogen peroxide in the

912
00:38:00,390 --> 00:37:58,210
atmosphere and in the rain out and then

913
00:38:01,980 --> 00:38:00,400

forming these knots dialing the reduced

914
00:38:04,859 --> 00:38:01,990
phosphorus you inform this pyrophosphate

915
00:38:07,620 --> 00:38:04,869
very easily around thirty percent levels

916
00:38:09,839 --> 00:38:07,630
so if you take this pyrophosphate it's

917
00:38:14,250 --> 00:38:09,849
actually used by a number of archaea and

918
00:38:18,059 --> 00:38:14,260
bacteria as well to take pyrophosphate

919
00:38:20,940 --> 00:38:18,069
and use it in place of ATP in several

920
00:38:23,519 --> 00:38:20,950
key biochemical reactions and ATP is

921
00:38:25,230 --> 00:38:23,529
this sort of generic metabolic

922
00:38:27,029 --> 00:38:25,240
phosphorus molecule yet in some of these

923
00:38:28,620 --> 00:38:27,039
proton pumps and there's some of these

924
00:38:30,809 --> 00:38:28,630
other phosphorylating reactions

925
00:38:33,059 --> 00:38:30,819
pyrophosphate and some simpler

926
00:38:35,309 --> 00:38:33,069
phosphates can actually substitute very

927
00:38:37,710 --> 00:38:35,319
well and very easily this here is one of

928
00:38:40,079 --> 00:38:37,720
these of pyrophosphate proton pumps and

929
00:38:43,170 --> 00:38:40,089
it's actually more simple and easy to

930
00:38:45,779 --> 00:38:43,180
form than the ATP equivalent ETP

931
00:38:48,269 --> 00:38:45,789
phosphate proton pumps so it seems like

932
00:38:50,579 --> 00:38:48,279
there is a use in some of these ancient

933
00:38:52,769 --> 00:38:50,589
organisms for the even simpler form

934
00:38:55,259 --> 00:38:52,779
which made in proud the lint on the

935
00:38:59,190 --> 00:38:55,269
early Earth so perhaps this

936
00:39:01,680 --> 00:38:59,200
pyrophosphate preceded ATP in the origin

937
00:39:04,460 --> 00:39:01,690
and development of early life so to

938
00:39:06,990 --> 00:39:04,470

summarize phosphorus was scavenged is

939
00:39:08,900 --> 00:39:07,000
scavenged in environments today it was

940
00:39:11,759 --> 00:39:08,910
it is one of the critical elements and

941
00:39:14,460 --> 00:39:11,769
it's the celebrity of the biochemical

942
00:39:15,900 --> 00:39:14,470
world but maybe that was not the case on

943
00:39:18,660 --> 00:39:15,910
the early Earth maybe the early Earth

944
00:39:21,599 --> 00:39:18,670
was enriched in this reduced phosphorus

945
00:39:24,480 --> 00:39:21,609
in the oceans and rich in these other

946
00:39:26,400 --> 00:39:24,490
compounds and perhaps that is what life

947
00:39:28,980 --> 00:39:26,410
today uses phosphate because it was so

948
00:39:31,769 --> 00:39:28,990
abundant and got sort of incorporated

949
00:39:33,779 --> 00:39:31,779
into the early organisms so schreiber

950
00:39:34,950 --> 00:39:33,789
site is in the abundant constituent of

951
00:39:37,140 --> 00:39:34,960
meteorites and other X

952
00:39:39,540 --> 00:39:37,150
treasure material and we take this in

953
00:39:41,580 --> 00:39:39,550
uniform organic phosphorus compounds can

954
00:39:42,810 --> 00:39:41,590
form these reduced phosphorus compounds

955
00:39:44,730 --> 00:39:42,820
as well these inorganic reduce

956
00:39:47,160 --> 00:39:44,740
phosphorus compounds and we see that

957
00:39:49,530 --> 00:39:47,170
microbes are using them today so to

958
00:39:51,960 --> 00:39:49,540
conclude meteorites are perhaps highly

959
00:39:53,700 --> 00:39:51,970
relevant in the origin of life and not

960
00:39:56,340 --> 00:39:53,710
just from the carbonaceous chondrite

961
00:39:58,650 --> 00:39:56,350
perspective perhaps a lot of the other

962
00:39:59,970 --> 00:39:58,660
material contributed in terms of

963
00:40:02,670 --> 00:39:59,980

Schreiber site and all these reduced

964
00:40:03,690 --> 00:40:02,680
phosphorus piece as well and brass is

965
00:40:06,540 --> 00:40:03,700
high flux during the late heavy

966
00:40:08,340 --> 00:40:06,550
bombardment this putative late heavy

967
00:40:10,800 --> 00:40:08,350
bombardment period may have introduced a

968
00:40:13,530 --> 00:40:10,810
lot of the Swedish phosphorus to the

969
00:40:16,140 --> 00:40:13,540
surface of the year in New York so the

970
00:40:18,000 --> 00:40:16,150
early years biogeochemistry perhaps was

971
00:40:21,840 --> 00:40:18,010
substantially different in the case of

972
00:40:24,420 --> 00:40:21,850
phosphorus by the effect of reduced

973
00:40:26,070 --> 00:40:24,430
phosphorus species and finally perhaps

974
00:40:28,410 --> 00:40:26,080
the development of life was this

975
00:40:30,390 --> 00:40:28,420
dependent on this source of reduced

976
00:40:57,840 --> 00:40:30,400
phosphorus if phosphorus was important

977
00:40:59,880 --> 00:40:57,850
to the origin of life yeah it's

978
00:41:02,190 --> 00:40:59,890
estimated there's around about between

979
00:41:04,050 --> 00:41:02,200
one and ten percent of the crustal

980
00:41:07,070 --> 00:41:04,060
phosphorus was that one time Schreiber

981
00:41:09,000 --> 00:41:07,080
site so it's not all of it but a

982
00:41:11,730 --> 00:41:09,010
substantial portion was probably at one

983
00:41:13,620 --> 00:41:11,740
time Schreiber site either and then you

984
00:41:16,470 --> 00:41:13,630
delivered during very early in the

985
00:41:21,420 --> 00:41:16,480
Earth's history or sometime later on so

986
00:41:23,160 --> 00:41:21,430
a lot of it Hilton all say is well known

987
00:41:27,570 --> 00:41:23,170
to struggle into manganese and iron

988
00:41:28,600 --> 00:41:27,580

oxide dark side on the reduced species

989
00:41:31,120 --> 00:41:28,610
there

990
00:41:33,370 --> 00:41:31,130
that's a good question I'm not certain

991
00:41:35,770 --> 00:41:33,380
offhand I haven't looked at it yet but

992
00:41:37,990 --> 00:41:35,780
it would be of interest to see how these

993
00:41:40,630 --> 00:41:38,000
compounds can be concentrated on either

994
00:41:43,390 --> 00:41:40,640
mineral surfaces or oxide layers as well

995
00:41:53,350 --> 00:41:43,400
it's a very interesting Avenue processor

996
00:41:56,050 --> 00:41:53,360
research pH and temperature dependence

997
00:41:58,330 --> 00:41:56,060
uh in terms of PA on what antalya

998
00:42:01,960 --> 00:41:58,340
billiton development in general der

999
00:42:03,700 --> 00:42:01,970
they're fairly soluble there are more

1000
00:42:06,190 --> 00:42:03,710
soluble as you increase the pH just like

1001
00:42:08,050 --> 00:42:06,200
phosphate they behave very similar to

1002
00:42:09,580 --> 00:42:08,060
phosphate in general so there if you

1003
00:42:12,310 --> 00:42:09,590
increase the pH you increase the

1004
00:42:14,170 --> 00:42:12,320
solubility as well as far as temperature

1005
00:42:16,540 --> 00:42:14,180
they behave fairly they're pretty much

1006
00:42:17,980 --> 00:42:16,550
in terms of thermodynamic properties

1007
00:42:19,570 --> 00:42:17,990
they're similar enough to phosphate it

1008
00:42:23,560 --> 00:42:19,580
you make a generalization for phosphate

1009
00:42:26,650 --> 00:42:23,570
same thing as well tom has some

1010
00:42:34,150 --> 00:42:26,660
questions from the ether and jen has

1011
00:42:39,190 --> 00:42:34,160
some questions hello like I just wanted

1012
00:42:42,550 --> 00:42:39,200
a fire if I one thing so during the

1013
00:42:45,340 --> 00:42:42,560

creation face a car is separated from

1014
00:42:48,990 --> 00:42:45,350
the rest of the earth where quickly and

1015
00:42:52,270 --> 00:42:49,000
in that precisely the phosphorus prefers

1016
00:42:57,760 --> 00:42:52,280
can they be dragged into the core more

1017
00:42:59,800 --> 00:42:57,770
efficiently in that case or not in

1018
00:43:02,410 --> 00:42:59,810
general phosphorus is a sitter file

1019
00:43:04,030 --> 00:43:02,420
element and it's if you do the mass

1020
00:43:06,370 --> 00:43:04,040
balance calculation around about

1021
00:43:08,380 --> 00:43:06,380
ninety-five percent phosphorus is

1022
00:43:10,390 --> 00:43:08,390
probably in the kursk or so it is

1023
00:43:11,680 --> 00:43:10,400
definitely a high temperature and will

1024
00:43:12,700 --> 00:43:11,690
be sucked into the court probably

1025
00:43:15,730 --> 00:43:12,710
preferentially during the

1026
00:43:18,310 --> 00:43:15,740
differentiation so the what's left over

1027
00:43:23,320 --> 00:43:18,320
can be distributed in the cross the

1028
00:43:25,720 --> 00:43:23,330
setter and they may resemble be the

1029
00:43:29,140 --> 00:43:25,730
included in to trust and eventually

1030
00:43:33,130 --> 00:43:29,150
going be available through when they

1031
00:43:36,280 --> 00:43:33,140
become sediments how does that mana

1032
00:43:41,670 --> 00:43:36,290
phosphors compelled to the meteorites

1033
00:43:44,199 --> 00:43:41,680
delivery after that during the day

1034
00:43:47,709 --> 00:43:44,209
well if you assume that about five

1035
00:43:49,089 --> 00:43:47,719
percent of the phosphorus survived to

1036
00:43:50,680 --> 00:43:49,099
make it into the mantle it becomes

1037
00:43:52,539 --> 00:43:50,690
phosphates at that point and it gets

1038
00:43:54,849 --> 00:43:52,549

mixed in with the silicates and the

1039
00:43:56,709 --> 00:43:54,859
majority of the crustal material but you

1040
00:44:00,400 --> 00:43:56,719
can imagine that this phosphate kind of

1041
00:44:03,219 --> 00:44:00,410
gets sort of spread throughout the earth

1042
00:44:05,199 --> 00:44:03,229
and if you do the whole balance it's

1043
00:44:06,849 --> 00:44:05,209
probably around about if you do the

1044
00:44:08,140 --> 00:44:06,859
amount of phosphorus in the crossing

1045
00:44:10,299 --> 00:44:08,150
compared to the amount of schreiber site

1046
00:44:11,890 --> 00:44:10,309
that's around but one to ten percent was

1047
00:44:13,269 --> 00:44:11,900
probably at one time Schreiber site but

1048
00:44:15,370 --> 00:44:13,279
if you do the whole mantle there's more

1049
00:44:17,589 --> 00:44:15,380
phosphorus in the mantle and it pens and

1050
00:44:19,150 --> 00:44:17,599
how much you can move out and move in in

1051
00:44:24,999 --> 00:44:19,160
the mantle it's probably on the order of

1052
00:44:29,400 --> 00:44:25,009
0 1 2001 to 10,000 as far as Schreiber

1053
00:44:34,479 --> 00:44:29,410
site total silicate phosphate phosphate

1054
00:44:38,499 --> 00:44:34,489
okay my last question if I may is there

1055
00:44:41,519 --> 00:44:38,509
any way that these are phosphors false

1056
00:44:43,989 --> 00:44:41,529
page in a cross that can become for

1057
00:44:49,299 --> 00:44:43,999
converted into reduce the format of

1058
00:44:51,489 --> 00:44:49,309
phosphorus during early Earth stay there

1059
00:44:54,099 --> 00:44:51,499
are very few ways of forming reduced

1060
00:44:56,859 --> 00:44:54,109
phosphorus on the early Earth but there

1061
00:44:58,989 --> 00:44:56,869
are a couple one you can use there's

1062
00:45:02,709 --> 00:44:58,999
some Schreiber site actually reported in

1063
00:45:05,049 --> 00:45:02,719

the sort of disco iron these disco

1064
00:45:07,569 --> 00:45:05,059
island iron deposits which are native

1065
00:45:08,979 --> 00:45:07,579
iron metal very unusual circumstance for

1066
00:45:12,609 --> 00:45:08,989
their formation what happened was

1067
00:45:14,589 --> 00:45:12,619
there's a coal bed and uh lava flowed

1068
00:45:18,099 --> 00:45:14,599
over it and the coal bed reduced all the

1069
00:45:21,400 --> 00:45:18,109
phosphorus and iron metal to iron our

1070
00:45:23,650 --> 00:45:21,410
I'm sorry ferric iron to iron metal and

1071
00:45:26,229 --> 00:45:23,660
schreiber site but that was a very

1072
00:45:29,199 --> 00:45:26,239
specific condition and probably not very

1073
00:45:34,089 --> 00:45:29,209
prevalent across the early Earth other

1074
00:45:35,380 --> 00:45:34,099
than that if you have water stable in or

1075
00:45:37,479 --> 00:45:35,390
if you take a look at the thermodynamics

1076
00:45:40,059 --> 00:45:37,489
of these species if you have water

1077
00:45:41,829 --> 00:45:40,069
present the phosphate is the most stable

1078
00:45:43,930 --> 00:45:41,839
phase relative to all these reduced

1079
00:45:46,299 --> 00:45:43,940
phosphorus so it seems like there's no

1080
00:45:51,969 --> 00:45:46,309
real way of reducing it beyond some very

1081
00:45:53,300 --> 00:45:51,979
unusual conditions thank you so Carnegie

1082
00:45:58,490 --> 00:45:53,310
has a question

1083
00:46:02,020 --> 00:45:58,500
oh hello could I ask I can understand as

1084
00:46:04,070 --> 00:46:02,030
a chemist how pulverized schreiber sighs

1085
00:46:06,470 --> 00:46:04,080
reacting with an organic in aqueous

1086
00:46:08,300 --> 00:46:06,480
media would produce phosphorylated

1087
00:46:10,700 --> 00:46:08,310
organics but do you have experiments

1088
00:46:14,480 --> 00:46:10,710

running in the background with massive

1089
00:46:17,300 --> 00:46:14,490
schreiber site slowly creo corroding in

1090
00:46:19,880 --> 00:46:17,310
quiescent conditions somewhere in your

1091
00:46:22,100 --> 00:46:19,890
lab that's a good question now we don't

1092
00:46:24,980 --> 00:46:22,110
have any large-scale samples just do too

1093
00:46:26,480 --> 00:46:24,990
in this case experimental difficulty but

1094
00:46:28,220 --> 00:46:26,490
the majority of the phosphorus may have

1095
00:46:31,250 --> 00:46:28,230
actually been distributed it's very fine

1096
00:46:34,370 --> 00:46:31,260
grain material either in the IDP form or

1097
00:46:36,950 --> 00:46:34,380
as sort of impact ejecta so it's if you

1098
00:46:38,870 --> 00:46:36,960
you can extrapolate we've had the

1099
00:46:42,440 --> 00:46:38,880
largest size review so far has been on

1100
00:46:44,780 --> 00:46:42,450
the order of a millimeter grain size

1101
00:46:46,850 --> 00:46:44,790
millimeter two portions of a centimeter

1102
00:46:48,620 --> 00:46:46,860
grain size so those are some of the

1103
00:46:50,900 --> 00:46:48,630
larger scale and they are very reactive

1104
00:46:53,090 --> 00:46:50,910
as well but if you take if you

1105
00:46:55,240 --> 00:46:53,100
extrapolate is not too far to go ahead

1106
00:46:57,650 --> 00:46:55,250
and assume that maybe perhaps these

1107
00:46:59,240 --> 00:46:57,660
small scale things were distributed

1108
00:47:03,140 --> 00:46:59,250
across the surface of the earth either

1109
00:47:10,990 --> 00:47:03,150
through various IDPs or impact ejecta in

1110
00:47:14,630 --> 00:47:11,000
this case any more question from here

1111
00:47:17,360 --> 00:47:14,640
Georgia calculated for us the flux of

1112
00:47:19,340 --> 00:47:17,370
phosphorus from here right have you made

1113
00:47:22,310 --> 00:47:19,350

the same calculation for the amount

1114
00:47:24,590 --> 00:47:22,320
emerging for hydrothermal vents sort of

1115
00:47:27,620 --> 00:47:24,600
dismiss that as a localized event right

1116
00:47:30,200 --> 00:47:27,630
tactic would be a flux over a period of

1117
00:47:31,400 --> 00:47:30,210
lazy years right whatever period of her

1118
00:47:33,750 --> 00:47:31,410
neighbors was

1119
00:47:36,180 --> 00:47:33,760
how does that compare the view already

1120
00:47:38,640 --> 00:47:36,190
there around about equal in the case of

1121
00:47:40,920 --> 00:47:38,650
hydrothermal phosphorus if you consider

1122
00:47:42,480 --> 00:47:40,930
over about a billion Peter period amount

1123
00:47:43,740 --> 00:47:42,490
of phosphorus gets cycled through it

1124
00:47:46,320 --> 00:47:43,750
surrounded by the equivalent amount of

1125
00:47:48,030 --> 00:47:46,330
phosphorus hours we've delivered to the

1126
00:47:49,740 --> 00:47:48,040
early Earth in a form of reduced

1127
00:47:53,250 --> 00:47:49,750
phosphorus from meteorites so they're

1128
00:47:55,890 --> 00:47:53,260
around there approximately equal as far

1129
00:47:59,040 --> 00:47:55,900
as total flux of phosphorus but it's

1130
00:48:03,630 --> 00:47:59,050
just question maybe of extending

1131
00:48:08,700 --> 00:48:03,640
globalization in that case Laura how

1132
00:48:11,670 --> 00:48:08,710
does the IDP flux in the earth that is

1133
00:48:14,160 --> 00:48:11,680
it is fairly well constrained up into a

1134
00:48:16,650 --> 00:48:14,170
runabout and 65 million years but beyond

1135
00:48:19,140 --> 00:48:16,660
that there's not too much that we have

1136
00:48:21,990 --> 00:48:19,150
as far as understanding what the flux of

1137
00:48:24,390 --> 00:48:22,000
ITV's was at this early stime but if you

1138
00:48:25,800 --> 00:48:24,400

assume that it most of the IDP a lot of

1139
00:48:27,240 --> 00:48:25,810
the ibps actually result from the

1140
00:48:29,370 --> 00:48:27,250
ablation of meteorites as they fall to

1141
00:48:31,230 --> 00:48:29,380
the surface of the earth a little bit

1142
00:48:33,240 --> 00:48:31,240
Center just kind of chunked off when the

1143
00:48:36,120 --> 00:48:33,250
meteorite loses ninety to ninety nine

1144
00:48:38,280 --> 00:48:36,130
percent of its mass so it's possible

1145
00:48:40,170 --> 00:48:38,290
that if you have this sort of increase

1146
00:48:42,440 --> 00:48:40,180
of flux from the late heavy bombardment

1147
00:48:45,150 --> 00:48:42,450
would have been an equivalent

1148
00:48:51,510 --> 00:48:45,160
substantial increase of flux of the IDPs

1149
00:48:54,540 --> 00:48:51,520
as well aim for the earlier dissolved in

1150
00:48:57,000 --> 00:48:54,550
an ocean right that's a good question

1151
00:48:58,800 --> 00:48:57,010
you can look at the paper in part but a

1152
00:49:00,390 --> 00:48:58,810
lot of it is from these lunar

1153
00:49:03,030 --> 00:49:00,400
calculations that we see the cratering

1154
00:49:04,920 --> 00:49:03,040
and the age dates of the Lunars the

1155
00:49:06,240 --> 00:49:04,930
lunar impacts as well and we see that

1156
00:49:08,190 --> 00:49:06,250
the clustering around about a certain

1157
00:49:11,609 --> 00:49:08,200
time there's dispute over all this but

1158
00:49:13,050 --> 00:49:11,619
the general idea is that there was a lot

1159
00:49:15,150 --> 00:49:13,060
of reduced phosphorus delivered during

1160
00:49:18,000 --> 00:49:15,160
this time period and if you do the

1161
00:49:20,609 --> 00:49:18,010
calculation based on that it even if you

1162
00:49:22,710 --> 00:49:20,619
have to spread it over several hundred

1163
00:49:24,630 --> 00:49:22,720

million years as opposed to just not

1164
00:49:28,970 --> 00:49:24,640
hundred then it might give similar

1165
00:49:31,790 --> 00:49:28,980
results as well Bruce

1166
00:49:33,950 --> 00:49:31,800
that overestimates how much phosphorus

1167
00:49:36,790 --> 00:49:33,960
is available for life the sense that

1168
00:49:39,140 --> 00:49:36,800
maybe nerd there's probably very rapid

1169
00:49:41,150 --> 00:49:39,150
recycling the crustal material into the

1170
00:49:43,099 --> 00:49:41,160
mantle and all that's really available

1171
00:49:46,460 --> 00:49:43,109
for life was that which was delivered

1172
00:49:47,780 --> 00:49:46,470
after the last sterilization it's

1173
00:49:49,520 --> 00:49:47,790
possible it depends on how much

1174
00:49:52,520 --> 00:49:49,530
recycling you get into the haiti and

1175
00:49:54,740 --> 00:49:52,530
earth i mean if you the late environment

1176
00:49:58,370 --> 00:49:54,750
is leaves about 3.8 billion years ago

1177
00:50:00,980 --> 00:49:58,380
and that sort of follow well well past

1178
00:50:03,500 --> 00:50:00,990
the differentiation period so the idea

1179
00:50:05,330 --> 00:50:03,510
and part is that you had may have had

1180
00:50:07,760 --> 00:50:05,340
sterilization events but they would

1181
00:50:09,109 --> 00:50:07,770
still have delivered at this inorganic

1182
00:50:10,940 --> 00:50:09,119
reduced phosphorus all across the

1183
00:50:12,440 --> 00:50:10,950
surface of the earth and it wouldn't

1184
00:50:14,990 --> 00:50:12,450
probably have had a large effect on

1185
00:50:24,920 --> 00:50:15,000
mixing it into this into the mantle

1186
00:50:26,870 --> 00:50:24,930
material or trust as well okay regards

1187
00:50:31,160 --> 00:50:26,880
your lab experiments am I correct in

1188
00:50:33,410 --> 00:50:31,170

assuming that you dissolve your

1189
00:50:36,680 --> 00:50:33,420
meteoritic material into the still-warm

1190
00:50:38,990 --> 00:50:36,690
yep what would happen if you dissolved

1191
00:50:42,200 --> 00:50:39,000
it into something or resembling an

1192
00:50:44,390 --> 00:50:42,210
oceanic we do have experiments with

1193
00:50:46,880 --> 00:50:44,400
calcium magnesium salts in roughly

1194
00:50:49,280 --> 00:50:46,890
oceanic conditions and all you see in

1195
00:50:52,940 --> 00:50:49,290
this case I don't have a slide here but

1196
00:50:54,890 --> 00:50:52,950
it's of you have only the soluble

1197
00:50:57,320 --> 00:50:54,900
reduced phosphorus being observed in

1198
00:50:58,880 --> 00:50:57,330
solution in that case so and the soluble

1199
00:51:01,970 --> 00:50:58,890
reduced phosphorus is in this case hypo

1200
00:51:03,890 --> 00:51:01,980
is a phosphite the ADA there the

1201
00:51:07,280 --> 00:51:03,900
phosphorus in a three plus oxidation

1202
00:51:09,500 --> 00:51:07,290
state you don't get the phosphate and

1203
00:51:11,000 --> 00:51:09,510
you don't get the hypo phosphate and you

1204
00:51:14,050 --> 00:51:11,010
don't get too much of the pyrophosphate

1205
00:51:17,000 --> 00:51:14,060
but you can get a lot of these others

1206
00:51:18,099 --> 00:51:17,010
locally concentrated if you imagine sort

1207
00:51:20,180 --> 00:51:18,109
of environments where they might have

1208
00:51:27,530 --> 00:51:20,190
concentrated the reduced phosphorus and

1209
00:51:31,160 --> 00:51:27,540
then reacted that as well what would be

1210
00:51:34,340 --> 00:51:31,170
how would have a basic and an acidic pH

1211
00:51:35,859 --> 00:51:34,350
the fact that there are two models out

1212
00:51:42,500 --> 00:51:35,869
there right word

1213
00:51:44,089 --> 00:51:42,510

very awkward position right the good

1214
00:51:46,819 --> 00:51:44,099
thing about these reactions is that they

1215
00:51:50,420 --> 00:51:46,829
do occur very similarly in under arrange

1216
00:51:52,789 --> 00:51:50,430
of conditions between about three ph of

1217
00:51:54,289 --> 00:51:52,799
three and a ph of 10 they get fairly

1218
00:51:56,150 --> 00:51:54,299
similar conditions as you start to get

1219
00:51:58,940 --> 00:51:56,160
more acidic you actually start producing

1220
00:52:00,799 --> 00:51:58,950
some phosphine gas which can throw in a

1221
00:52:02,710 --> 00:52:00,809
little bit of a monkey wrench into some

1222
00:52:06,200 --> 00:52:02,720
of these calculations but in general

1223
00:52:10,849 --> 00:52:06,210
under normal 3 to 10 it's very similar

1224
00:52:16,190 --> 00:52:10,859
reaction results that happen under these

1225
00:52:17,660 --> 00:52:16,200
sorts of conditions right now that's

1226
00:52:19,280 --> 00:52:17,670
another one of the possible ways of

1227
00:52:21,230 --> 00:52:19,290
reducing phosphorus is by the production

1228
00:52:23,539 --> 00:52:21,240
of hosstene for the question that we had

1229
00:52:26,480 --> 00:52:23,549
a little bit of all this make when we're

1230
00:52:28,549 --> 00:52:26,490
on Arden Gordon flies one of them took

1231
00:52:31,400 --> 00:52:28,559
the vector waves of earliest review

1232
00:52:38,870 --> 00:52:31,410
papers for the fighter he's brought a

1233
00:52:40,370 --> 00:52:38,880
life out of high rank carbon dioxide is

1234
00:52:43,370 --> 00:52:40,380
the other production of phosphate

1235
00:52:45,170 --> 00:52:43,380
occurring on highrise my knowledge that

1236
00:52:47,960 --> 00:52:45,180
hasn't really looked at experimental

1237
00:52:52,099 --> 00:52:47,970
just want to get your it would be under

1238
00:52:53,690 --> 00:52:52,109

Hydra provocation yeah well if you have

1239
00:52:56,000 --> 00:52:53,700
reduction of phosphate I'm trying to

1240
00:52:59,030 --> 00:52:56,010
think how he it'll did a lot of energy

1241
00:53:03,130 --> 00:52:59,040
being dumped in from I guess presumably

1242
00:53:15,049 --> 00:53:06,260
he's done the thermodynamic calculations

1243
00:53:20,099 --> 00:53:18,420
okay well if you have that some of the

1244
00:53:23,069 --> 00:53:20,109
other interesting things of the

1245
00:53:24,539 --> 00:53:23,079
meteorites is that a lot of the bring it

1246
00:53:28,079 --> 00:53:24,549
back is that a lot of these phosphites

1247
00:53:29,700 --> 00:53:28,089
actually surrounds sulfides and if you

1248
00:53:31,140 --> 00:53:29,710
want to kind of extrapolate there

1249
00:53:33,390 --> 00:53:31,150
perhaps there's a connection between the

1250
00:53:35,160 --> 00:53:33,400
sulfides and phosphorus in those

1251
00:53:38,309 --> 00:53:35,170
conditions and that's of course in a

1252
00:53:42,269 --> 00:53:38,319
meteorite parent body but if you had a

1253
00:53:43,410 --> 00:53:42,279
reduction of phosphorus on on sulfides I

1254
00:53:46,230 --> 00:53:43,420
had to take a look at that paper as well

1255
00:53:51,890 --> 00:53:46,240
as but it's very interesting possibility

1256
00:53:56,670 --> 00:53:51,900
there tom another question from LinkedIn

1257
00:54:00,210 --> 00:53:56,680
hi men in one of your slide you are you

1258
00:54:03,269 --> 00:54:00,220
mentioned that under UV radiation

1259
00:54:06,779 --> 00:54:03,279
phosphorus from meteorites from reduced

1260
00:54:11,370 --> 00:54:06,789
species I could you please see me

1261
00:54:13,799 --> 00:54:11,380
something more about this for example do

1262
00:54:17,539 --> 00:54:13,809
you mean that these of phosphors related

1263
00:54:19,769 --> 00:54:17,549

species becomes more reduced after

1264
00:54:24,120 --> 00:54:19,779
you'll be on them or something else

1265
00:54:27,900 --> 00:54:24,130
thank you okay a very good question this

1266
00:54:30,150 --> 00:54:27,910
is again what happens is under UV what

1267
00:54:32,089 --> 00:54:30,160
happened this is an experimental setup

1268
00:54:36,329 --> 00:54:32,099
what happened is they had the phosphide

1269
00:54:39,359 --> 00:54:36,339
in the water and then UV lamp right next

1270
00:54:41,730 --> 00:54:39,369
to it so it was very reducing conditions

1271
00:54:44,309 --> 00:54:41,740
where he formed a lot of h2 and it

1272
00:54:46,289 --> 00:54:44,319
probably forced this reaction taking the

1273
00:54:48,329 --> 00:54:46,299
what normally occurs in this case

1274
00:54:50,069 --> 00:54:48,339
probably the phosphite or a phosphite

1275
00:54:52,559 --> 00:54:50,079
radical and reduced it down to the

1276
00:54:54,720 --> 00:54:52,569
hypophosphite but it's definitely not

1277
00:54:58,589 --> 00:54:54,730
too clear as to what happened there and

1278
00:55:01,470 --> 00:54:58,599
it was a very low UV I think was around

1279
00:55:03,599 --> 00:55:01,480
mala I think it was 185 nanometers that

1280
00:55:08,430 --> 00:55:03,609
was able to do this but not the 260

1281
00:55:15,059 --> 00:55:08,440
nanometers so it was a very energetic UV

1282
00:55:17,670 --> 00:55:15,069
in this case okay if there are no

1283
00:55:19,670 --> 00:55:17,680
further questions anyone who would like

1284
00:55:27,420 --> 00:55:19,680
to go out to dinner with Matt and myself

1285
00:55:29,250 --> 00:55:27,430
tonight at six please see me in a moment

1286
00:55:31,200 --> 00:55:29,260
for those of you who don't want to go

1287
00:55:32,790 --> 00:55:31,210
out to dinner would pass tonight you