
AbSciCon
2019

1
00:00:00,790 --> 00:00:07,320
[Music]

2
00:00:12,660 --> 00:00:09,440
[Applause]

3
00:00:14,910 --> 00:00:12,670
hi I am Christine and I'm gonna be

4
00:00:18,750 --> 00:00:14,920
talking about hydrothermal fluids on

5
00:00:20,580 --> 00:00:18,760
Europa so you've heard a couple talks

6
00:00:22,320 --> 00:00:20,590
about hydrothermal systems already and

7
00:00:24,359 --> 00:00:22,330
this is an ocean world session so I'm

8
00:00:25,380 --> 00:00:24,369
sure I'm not blowing anybody's mind when

9
00:00:29,040 --> 00:00:25,390
I suggest that there might be

10
00:00:31,140 --> 00:00:29,050
hydrothermal systems on ocean worlds and

11
00:00:33,210 --> 00:00:31,150
in particular you might have heard about

12
00:00:35,460 --> 00:00:33,220
this from the Cassini mission when it

13
00:00:37,250 --> 00:00:35,470

flew through the plumes of Enceladus and

14
00:00:39,780 --> 00:00:37,260
actually detected for the first time

15
00:00:42,030 --> 00:00:39,790
observational evidence that hydrothermal

16
00:00:44,700 --> 00:00:42,040
processes could be occurring on ocean

17
00:00:46,889 --> 00:00:44,710
worlds and this in particular was an

18
00:00:48,319 --> 00:00:46,899
interesting result so they found oh

19
00:00:51,510 --> 00:00:48,329
that's

20
00:00:53,400 --> 00:00:51,520
just kidding mixing up my buttons so

21
00:00:54,930 --> 00:00:53,410
they found molecular hydrogen which we

22
00:00:56,790 --> 00:00:54,940
think in the high abundances that it was

23
00:00:58,650 --> 00:00:56,800
detected on Enceladus must be a result

24
00:00:59,970 --> 00:00:58,660
of hydrothermal chemistry and they not

25
00:01:01,950 --> 00:00:59,980
only found it but they found it in

26
00:01:04,380 --> 00:01:01,960
disequilibrium concentrations with

27
00:01:07,230 --> 00:01:04,390
methane and carbon dioxide such that you

28
00:01:09,090 --> 00:01:07,240
get a high chemical affinity or abundant

29
00:01:11,160 --> 00:01:09,100
and abundance of free energy for this

30
00:01:12,570 --> 00:01:11,170
reaction with anna genesis which is

31
00:01:15,330 --> 00:01:12,580
exciting it's a big astrobiological

32
00:01:17,370 --> 00:01:15,340
buzzword because methanogens they use

33
00:01:22,320 --> 00:01:17,380
this reaction to fuel themselves as a

34
00:01:24,750 --> 00:01:22,330
metabolism on earth so how does this

35
00:01:26,070 --> 00:01:24,760
work exactly right so we have

36
00:01:28,109 --> 00:01:26,080
hydrothermal systems somehow they're

37
00:01:30,120 --> 00:01:28,119
they're providing stuff that's fueling

38
00:01:32,910 --> 00:01:30,130

energy for life how exactly does this

39
00:01:35,010 --> 00:01:32,920
happen well you have some rock it has

40
00:01:36,300 --> 00:01:35,020
this stuff in it you pour some water on

41
00:01:37,950 --> 00:01:36,310
it you heat it up and it starts

42
00:01:40,410 --> 00:01:37,960
outgassing interesting things like

43
00:01:42,480 --> 00:01:40,420
hydrogen methane carbon dioxide those

44
00:01:44,760 --> 00:01:42,490
methanogenesis ingredients as well as

45
00:01:44,940 --> 00:01:44,770
other things and that's all well and

46
00:01:46,590 --> 00:01:44,950
good

47
00:01:49,410 --> 00:01:46,600
everything in this hydrothermal system

48
00:01:51,120 --> 00:01:49,420
is in equilibrium but then once you mix

49
00:01:52,830 --> 00:01:51,130
it with the cold ocean water that has a

50
00:01:54,810 --> 00:01:52,840
totally different chemical composition

51
00:01:59,010 --> 00:01:54,820
they clash and you get disequilibrium

52
00:02:00,719 --> 00:01:59,020
and in particular we think in the oceans

53
00:02:03,179 --> 00:02:00,729
of these icy moons you can actually be

54
00:02:05,700 --> 00:02:03,189
getting molecular oxygen so you can make

55
00:02:07,590 --> 00:02:05,710
oxygen in the icy surface radiation

56
00:02:09,479 --> 00:02:07,600
breaks apart water molecules there and

57
00:02:11,280 --> 00:02:09,489
if your surface is geologically active

58
00:02:13,229 --> 00:02:11,290
which we think they are an ocean world's

59
00:02:14,960 --> 00:02:13,239
then you can actually take this oxygen

60
00:02:17,000 --> 00:02:14,970
and deliver it

61
00:02:18,410 --> 00:02:17,010
into the ocean and then you have all

62
00:02:19,970 --> 00:02:18,420
these reduced species coming up from

63
00:02:22,240 --> 00:02:19,980

your hydrothermal fluids you have oxygen

64
00:02:23,630 --> 00:02:22,250
floating around in the ocean and

65
00:02:26,540 --> 00:02:23,640
disequilibrium

66
00:02:28,520 --> 00:02:26,550
for redox reactions so life takes

67
00:02:29,990 --> 00:02:28,530
advantage of the space equilibrium it

68
00:02:32,450 --> 00:02:30,000
extracts energy from that to push the

69
00:02:34,610 --> 00:02:32,460
system back toward equilibrium and uses

70
00:02:38,450 --> 00:02:34,620
that energy to sustain itself as a

71
00:02:40,460 --> 00:02:38,460
metabolism so could these things be

72
00:02:42,950 --> 00:02:40,470
happening on Europa we've seen evidence

73
00:02:45,290 --> 00:02:42,960
for it on Enceladus already the issue

74
00:02:46,580 --> 00:02:45,300
with Europa is that it's larger we think

75
00:02:49,610 --> 00:02:46,590
it's more complicated and we know

76
00:02:51,740 --> 00:02:49,620
nothing about it so how do we deal with

77
00:02:53,780 --> 00:02:51,750
something like that we consider all of

78
00:02:56,120 --> 00:02:53,790
the possible scenarios that it could be

79
00:02:57,890 --> 00:02:56,130
falling under so we know a lot about

80
00:02:59,030 --> 00:02:57,900
hydrothermal systems on earth we think

81
00:03:02,180 --> 00:02:59,040
we know something about how they might

82
00:03:03,800 --> 00:03:02,190
be working on Enceladus maybe on Io 2

83
00:03:05,120 --> 00:03:03,810
which is not hydrothermal but at least

84
00:03:06,950 --> 00:03:05,130
it's volcanic ly active and in the

85
00:03:08,600 --> 00:03:06,960
Jupiter system so we can apply all of

86
00:03:09,980 --> 00:03:08,610
these different geochemical constraints

87
00:03:11,810 --> 00:03:09,990
from all of these other bodies and say

88
00:03:13,550 --> 00:03:11,820

most likely your rope is falling

89
00:03:15,500 --> 00:03:13,560
somewhere within this parameter space of

90
00:03:16,700 --> 00:03:15,510
all these other analogs and look at

91
00:03:18,710 --> 00:03:16,710
exactly how these different parameters

92
00:03:20,930 --> 00:03:18,720
combine to affect hydrothermal

93
00:03:24,890 --> 00:03:20,940
geochemistry potentially an energy

94
00:03:27,320 --> 00:03:24,900
availability on Europa so we can start

95
00:03:29,540 --> 00:03:27,330
by making these lovely activity diagrams

96
00:03:32,210 --> 00:03:29,550
so let's pretend like we have a black

97
00:03:35,210 --> 00:03:32,220
smoker on Europa 300 degrees the open

98
00:03:36,560 --> 00:03:35,220
sea floor pressure 1,500 bar and we

99
00:03:38,300 --> 00:03:36,570
don't know what the pH of this black

100
00:03:39,800 --> 00:03:38,310
smoke or fluid is we don't know what the

101
00:03:41,570 --> 00:03:39,810
oxidation state is so we're just gonna

102
00:03:43,190 --> 00:03:41,580
let those vary and we're gonna look at

103
00:03:45,259 --> 00:03:43,200
generally for carbon at least what does

104
00:03:48,350 --> 00:03:45,269
the parameter space in that hydrothermal

105
00:03:49,580 --> 00:03:48,360
fluid look like so we see we can get all

106
00:03:51,979 --> 00:03:49,590
of these different things that depends

107
00:03:54,110 --> 00:03:51,989
on these parameters and now we can try

108
00:03:55,729 --> 00:03:54,120
to set some reference points to try and

109
00:03:58,640 --> 00:03:55,739
see if we're near this reference point

110
00:04:00,740 --> 00:03:58,650
what does our fluid look like so for pH

111
00:04:02,660 --> 00:04:00,750
we can calculate what neutral pH is as a

112
00:04:05,000 --> 00:04:02,670
function of temperature plot that on

113
00:04:07,400 --> 00:04:05,010

here and maybe say your rope is probably

114
00:04:10,430 --> 00:04:07,410
I don't know within two log units on

115
00:04:13,220 --> 00:04:10,440
either side ish of neutral pH so how

116
00:04:15,860 --> 00:04:13,230
would the speciation of carbon change as

117
00:04:18,090 --> 00:04:15,870
you move from higher pH to lower pH

118
00:04:20,370 --> 00:04:18,100
around that pH neutral point

119
00:04:24,810 --> 00:04:20,380
and same thing with oxidation state so

120
00:04:26,490 --> 00:04:24,820
the fmq buffer what is happening hey

121
00:04:29,430 --> 00:04:26,500
this is very dramatic the PHA late and I

122
00:04:31,470 --> 00:04:29,440
should take quartz buffer approximates

123
00:04:33,840 --> 00:04:31,480
redox conditions in ultramafic Rock on

124
00:04:34,710 --> 00:04:33,850
earth so we think there's alter mafic

125
00:04:37,380 --> 00:04:34,720
rock and some of these hydrothermal

126
00:04:40,080 --> 00:04:37,390
systems on earth it's not necessarily oh

127
00:04:41,940 --> 00:04:40,090
my gosh being buffered by these minerals

128
00:04:48,480 --> 00:04:41,950
but it's like around what you would

129
00:04:50,120 --> 00:04:48,490
predict the okay it's fine um so how do

130
00:04:52,620 --> 00:04:50,130
what you would predict the hydrogen

131
00:04:54,780 --> 00:04:52,630
activity to be if it were being buffered

132
00:04:56,550 --> 00:04:54,790
by these minerals so let's plot that on

133
00:04:58,260 --> 00:04:56,560
there again it's temperature dependent

134
00:05:00,660 --> 00:04:58,270
300 degrees this is where it falls and

135
00:05:02,340 --> 00:05:00,670
let's say maybe Europa is at the F and Q

136
00:05:03,540 --> 00:05:02,350
buffer maybe it's more reduced compared

137
00:05:05,160 --> 00:05:03,550
to that maybe it's more oxidized

138
00:05:07,980 --> 00:05:05,170

compared to that how would that affect

139
00:05:11,190 --> 00:05:07,990
the distribution the speciation of

140
00:05:12,450 --> 00:05:11,200
carbon there and then let's start

141
00:05:15,060 --> 00:05:12,460
playing around with the parameter space

142
00:05:16,890 --> 00:05:15,070
so we've seen that at 300 degrees this

143
00:05:18,090 --> 00:05:16,900
is what it looks like if we then change

144
00:05:20,190 --> 00:05:18,100
the temperature so let's make our

145
00:05:21,930 --> 00:05:20,200
hydrothermal fluid colder you can see

146
00:05:24,180 --> 00:05:21,940
that these more oxidized species get

147
00:05:26,310 --> 00:05:24,190
pushed out to zero degrees when you only

148
00:05:28,650 --> 00:05:26,320
have methane and vice versa when you

149
00:05:31,020 --> 00:05:28,660
make it hotter you're pushing ch4 out

150
00:05:32,750 --> 00:05:31,030
and getting more oxidized species so

151
00:05:37,710 --> 00:05:32,760
that tells us if you have higher hotter

152
00:05:40,200 --> 00:05:37,720
hydrothermal fluids then maybe oops then

153
00:05:41,940 --> 00:05:40,210
maybe you have more oxidized species

154
00:05:43,620 --> 00:05:41,950
unless you're really really reduced if

155
00:05:44,880 --> 00:05:43,630
you have cooler hydrothermal fluids

156
00:05:49,290 --> 00:05:44,890
maybe you have more reduced species

157
00:05:50,580 --> 00:05:49,300
unless you're very very oxidized so now

158
00:05:52,950 --> 00:05:50,590
I'm going to flip the parameter space

159
00:05:55,770 --> 00:05:52,960
around on you a little bit and instead

160
00:05:57,300 --> 00:05:55,780
of fixing temperature and letting pH and

161
00:05:59,790 --> 00:05:57,310
oxidation state vary I'm gonna do the

162
00:06:01,800 --> 00:05:59,800
opposite so I've fixed the oxidation

163
00:06:05,070 --> 00:06:01,810

state at this fmq buffer reference point

164
00:06:07,050 --> 00:06:05,080
here I fixed the pH pH neutral and now

165
00:06:08,580 --> 00:06:07,060
we're gonna vary pH one at a time and

166
00:06:11,280 --> 00:06:08,590
see what happens and you can see that as

167
00:06:13,410 --> 00:06:11,290
you move to more alkaline pH values all

168
00:06:14,820 --> 00:06:13,420
these charge species like my carbonates

169
00:06:16,860 --> 00:06:14,830
and carbonates start showing up

170
00:06:18,980 --> 00:06:16,870
especially at higher temperatures so

171
00:06:22,260 --> 00:06:18,990
essentially

172
00:06:23,970 --> 00:06:22,270
ph's job sorry is to control the

173
00:06:27,690 --> 00:06:23,980
abundance of charged species in your

174
00:06:29,850 --> 00:06:27,700
fluid that's its primary role so this is

175
00:06:31,500 --> 00:06:29,860
a lot of lines but just bear with me

176
00:06:33,780 --> 00:06:31,510
here so this is what I showed you before

177
00:06:35,370 --> 00:06:33,790
right we decided as we move down here as

178
00:06:37,440 --> 00:06:35,380
we move through more alkaline pH values

179
00:06:39,780 --> 00:06:37,450
you get more charged species and now

180
00:06:41,340 --> 00:06:39,790
we're going to vary oxidation state one

181
00:06:45,120 --> 00:06:41,350
at a time and see what its general

182
00:06:47,310 --> 00:06:45,130
effect is so we're at fmq and move to

183
00:06:48,720 --> 00:06:47,320
more oxidized values you can see that

184
00:06:51,620 --> 00:06:48,730
methane of course is getting pushed out

185
00:06:54,720 --> 00:06:51,630
there and it looks like at this oxidized

186
00:06:56,010 --> 00:06:54,730
reference point the role of pH is really

187
00:06:57,750 --> 00:06:56,020
dramatic right these plots look

188
00:07:00,030 --> 00:06:57,760

drastically different from pH neutral to

189
00:07:02,130 --> 00:07:00,040
pH neutral +4 whereas if you're more

190
00:07:04,170 --> 00:07:02,140
reduced they look exactly the same

191
00:07:06,720 --> 00:07:04,180
so pH and temperature have less of an

192
00:07:09,240 --> 00:07:06,730
effect when you're at more reduced fluid

193
00:07:10,830 --> 00:07:09,250
values when you're more oxidized the

194
00:07:14,760 --> 00:07:10,840
effect of pH and temperature is much

195
00:07:16,800 --> 00:07:14,770
more dramatic so that's interesting

196
00:07:18,180 --> 00:07:16,810
right we have some idea of maybe how

197
00:07:19,680 --> 00:07:18,190
these different parameters could be

198
00:07:22,110 --> 00:07:19,690
affecting the hydrothermal fluid

199
00:07:24,000 --> 00:07:22,120
composition on Europa but let's tie this

200
00:07:25,950 --> 00:07:24,010
into astrobiology because this is an

201
00:07:28,890 --> 00:07:25,960
astrobiology conference so how do we do

202
00:07:30,810 --> 00:07:28,900
that well with Ana Genesis buzzword

203
00:07:31,980 --> 00:07:30,820
again we looked at it on Enceladus let's

204
00:07:34,770 --> 00:07:31,990
look at how it might be working on

205
00:07:36,450 --> 00:07:34,780
Europa so I showed you on Enceladus they

206
00:07:38,430 --> 00:07:36,460
calculated the free energy the chemical

207
00:07:40,409 --> 00:07:38,440
affinity for the system found a Genesis

208
00:07:42,780 --> 00:07:40,419
reaction the way to do that is by

209
00:07:44,670 --> 00:07:42,790
calculating this reaction quotient Q and

210
00:07:46,920 --> 00:07:44,680
for that you need the ratio of methane

211
00:07:52,380 --> 00:07:46,930
to carbon dioxide you also need the

212
00:07:54,480 --> 00:07:52,390
activity of hydrogen so just to explain

213
00:07:56,400 --> 00:07:54,490

this a little bit more this guy I've put

214
00:07:58,409 --> 00:07:56,410
in orange because this we're assuming is

215
00:08:00,030 --> 00:07:58,419
controlled entirely by those parameters

216
00:08:02,100 --> 00:08:00,040
that I was varying in the hydrothermal

217
00:08:03,510 --> 00:08:02,110
vent fluid so we're not assuming re

218
00:08:05,460 --> 00:08:03,520
speciation in the ocean yet we're

219
00:08:08,520 --> 00:08:05,470
assuming this ratio is set by our

220
00:08:10,200 --> 00:08:08,530
hydrothermal vent hydrogen on the other

221
00:08:12,540 --> 00:08:10,210
hand who are assuming is set by the

222
00:08:14,640 --> 00:08:12,550
parameters of the global ocean so again

223
00:08:17,250 --> 00:08:14,650
you have this hydrothermal ch4 - co2

224
00:08:19,020 --> 00:08:17,260
it's mixing with hydrogen in your ocean

225
00:08:20,490 --> 00:08:19,030
they're totally different chemical

226
00:08:22,710 --> 00:08:20,500
properties they clash they create

227
00:08:24,190 --> 00:08:22,720
disequilibrium that give you energy from

228
00:08:26,630 --> 00:08:24,200
without

229
00:08:28,790 --> 00:08:26,640
so the issue here is that we have no

230
00:08:30,590 --> 00:08:28,800
idea what the activity of hydrogen is in

231
00:08:32,510 --> 00:08:30,600
Europa's ocean but we can at least try

232
00:08:35,150 --> 00:08:32,520
and maybe get some upper limits and

233
00:08:37,040 --> 00:08:35,160
lower limits so I'm going to assume that

234
00:08:38,719 --> 00:08:37,050
the ocean is probably not more reduced

235
00:08:41,390 --> 00:08:38,729
than the hydrothermal vent fluid so the

236
00:08:43,660 --> 00:08:41,400
most reduced it can be is at this fmq

237
00:08:47,120 --> 00:08:43,670
plus two buffer that I showed you before

238
00:08:48,770 --> 00:08:47,130

on the other hand the more oxidized it

239
00:08:50,900 --> 00:08:48,780
can be is much much lower than that

240
00:08:52,520 --> 00:08:50,910
right so I mentioned that you can get

241
00:08:54,740 --> 00:08:52,530
radio lytic oxidants from your service

242
00:08:56,570 --> 00:08:54,750
being delivered to your ocean this paper

243
00:08:58,130 --> 00:08:56,580
down here has actually constrained how

244
00:09:00,230 --> 00:08:58,140
many of those oxygens might be in

245
00:09:02,120 --> 00:09:00,240
Europa's ocean so we can assume as a

246
00:09:05,000 --> 00:09:02,130
lower-end member that oxygen and

247
00:09:07,580 --> 00:09:05,010
hydrogen are in equilibrium in this zero

248
00:09:08,960 --> 00:09:07,590
Degree ocean and because you have a lot

249
00:09:10,700 --> 00:09:08,970
of radio lytic oxidants you have very

250
00:09:12,440 --> 00:09:10,710
very little hydrogen and we'll assume

251
00:09:14,510 --> 00:09:12,450
that our hydrogen activity on Europa is

252
00:09:17,420 --> 00:09:14,520
somewhere between those two end members

253
00:09:19,490 --> 00:09:17,430
as you can see this varies drastically

254
00:09:21,500 --> 00:09:19,500
obviously you have free energy below

255
00:09:23,180 --> 00:09:21,510
zero that's not good for life but

256
00:09:25,970 --> 00:09:23,190
specifically you want to be above this

257
00:09:27,590 --> 00:09:25,980
reference point so biologists on earth

258
00:09:29,270 --> 00:09:27,600
have constrained the amount of energy

259
00:09:31,340 --> 00:09:29,280
you need from a metabolic reaction to

260
00:09:33,170 --> 00:09:31,350
actually sustain life it's about 10 to

261
00:09:35,540 --> 00:09:33,180
20 kilojoules per mole it's right here

262
00:09:37,970 --> 00:09:35,550
so you as you can see here if you want

263
00:09:43,700 --> 00:09:37,980

to meet this requirement you need to be

264
00:09:45,560 --> 00:09:43,710
up in this space up here so your ocean

265
00:09:47,420 --> 00:09:45,570
fluid needs to be pretty reduced maybe

266
00:09:49,550 --> 00:09:47,430
slightly more oxidized than the vent

267
00:09:54,680 --> 00:09:49,560
fluid but still it needs to be in this

268
00:09:57,080 --> 00:09:54,690
region over here yeah so reduced ocean

269
00:09:59,930 --> 00:09:57,090
good form without a Genesis oxidized

270
00:10:02,460 --> 00:09:59,940
ocean fabric without a Genesis does that

271
00:10:05,040 --> 00:10:02,470
mean if we have an oxidized ocean

272
00:10:06,090 --> 00:10:05,050
at fmq and ph-neutral that that's the

273
00:10:07,590 --> 00:10:06,100
end that methanogens

274
00:10:09,480 --> 00:10:07,600
in the sound of genesis the affinity

275
00:10:10,500 --> 00:10:09,490
can't change if we again start bearing

276
00:10:12,960 --> 00:10:10,510
these parameters No

277
00:10:15,150 --> 00:10:12,970
so let's look at what happens pH

278
00:10:16,500 --> 00:10:15,160
obviously we would expect not to have an

279
00:10:17,640 --> 00:10:16,510
effect right because we said that

280
00:10:19,140 --> 00:10:17,650
controls the abundance of charged

281
00:10:21,690 --> 00:10:19,150
species it has nothing to do with the

282
00:10:24,200 --> 00:10:21,700
siege for co2 ratio at least not if

283
00:10:26,820 --> 00:10:24,210
we're not considering reefs pca ssin

284
00:10:29,160 --> 00:10:26,830
whereas oxidation state we said does

285
00:10:30,660 --> 00:10:29,170
effect methane and co2 if you're more

286
00:10:32,250 --> 00:10:30,670
reduced to get more methane if you're

287
00:10:34,320 --> 00:10:32,260
more oxidized you get more oxidized

288
00:10:36,540 --> 00:10:34,330

species and you can see this right so

289
00:10:38,580 --> 00:10:36,550
this line shifts up and down ever so

290
00:10:42,060 --> 00:10:38,590
slightly as you change oxidation state

291
00:10:43,890 --> 00:10:42,070
but the takeaway is the same you still

292
00:10:47,880 --> 00:10:43,900
need to be in this more reduced region

293
00:10:49,860 --> 00:10:47,890
in order to be above that yellow line so

294
00:10:51,930 --> 00:10:49,870
does that mean that if we have a more

295
00:10:55,230 --> 00:10:51,940
oxidized ocean it's dead there's no life

296
00:10:57,150 --> 00:10:55,240
no because we can also consider aerobic

297
00:10:59,220 --> 00:10:57,160
reactions so let's say we have life

298
00:11:01,800 --> 00:10:59,230
that's using those radiologic oxidants

299
00:11:03,720 --> 00:11:01,810
to oxidize methane well we have

300
00:11:05,130 --> 00:11:03,730
constraints again on the amount of

301
00:11:07,590 --> 00:11:05,140
oxygen that might be in Europa's ocean

302
00:11:09,000 --> 00:11:07,600
from this paper here

303
00:11:10,980 --> 00:11:09,010
this is assuming hydrothermal processes

304
00:11:12,750 --> 00:11:10,990
or eating some of that oxygen this is

305
00:11:14,910 --> 00:11:12,760
assuming the oxygen is just building up

306
00:11:16,620 --> 00:11:14,920
and not really being reduced but even so

307
00:11:18,840 --> 00:11:16,630
even at these low levels of oxygen

308
00:11:20,850 --> 00:11:18,850
predicted in this paper you still have

309
00:11:24,720 --> 00:11:20,860
tons and tons of energy for aerobic

310
00:11:26,640 --> 00:11:24,730
methane oxidation and in fact it's well

311
00:11:29,610 --> 00:11:26,650
above again this 10 to 20 kilo Joule per

312
00:11:31,680 --> 00:11:29,620
mole level that you need to be at in

313
00:11:33,750 --> 00:11:31,690

order to sustain life so this looks

314
00:11:36,030 --> 00:11:33,760
really good but again I fix the

315
00:11:37,110 --> 00:11:36,040
oxidation state I fixed the pH we have

316
00:11:38,700 --> 00:11:37,120
no guarantee that your rope is

317
00:11:40,350 --> 00:11:38,710
hydrothermal fluid actually looks like

318
00:11:44,380 --> 00:11:40,360
that so what happens if we vary that

319
00:11:50,889 --> 00:11:48,160
well again we've decided oxidation state

320
00:11:53,100 --> 00:11:50,899
changes your ch4 to CO 2 ratio so we

321
00:11:55,630 --> 00:11:53,110
were here before as we move to more

322
00:11:57,280 --> 00:11:55,640
oxidized conditions the energy shifts

323
00:12:00,370 --> 00:11:57,290
down as we more to move to more reduced

324
00:12:04,210 --> 00:12:00,380
conditions the energy shifts up but even

325
00:12:07,480 --> 00:12:04,220
so again you're still like well above

326
00:12:09,310 --> 00:12:07,490
400 300 kilojoules per mole well above

327
00:12:10,630 --> 00:12:09,320
that 10 to 20 kilojoules per mole level

328
00:12:12,850 --> 00:12:10,640
that you need to be at in order to

329
00:12:18,130 --> 00:12:12,860
support life so good news for methane

330
00:12:19,930 --> 00:12:18,140
oxidation so summary here right

331
00:12:21,639 --> 00:12:19,940
but that agenda said oh my gosh with

332
00:12:23,680 --> 00:12:21,649
Nana Genesis you need to be above the

333
00:12:25,780 --> 00:12:23,690
yellow line if you're have a very

334
00:12:27,160 --> 00:12:25,790
reduced ocean fluid that's good news you

335
00:12:29,590 --> 00:12:27,170
meet that if you have more oxidized

336
00:12:31,060 --> 00:12:29,600
fluid that's bad and it doesn't look

337
00:12:32,889 --> 00:12:31,070
good from it down to Genesis but that's

338
00:12:35,199 --> 00:12:32,899

fine because even if you are at more

339
00:12:37,449 --> 00:12:35,209
oxidized conditions like here you can

340
00:12:41,230 --> 00:12:37,459
still use aerobic oxidation like

341
00:12:43,720 --> 00:12:41,240
methylene oxidation to support life so

342
00:12:45,579 --> 00:12:43,730
in general our hydrothermal parameters

343
00:12:47,230 --> 00:12:45,589
even though they changed drastically the

344
00:12:49,150 --> 00:12:47,240
composition of your hydrothermal fluid

345
00:12:50,860 --> 00:12:49,160
and they do change the amount of energy

346
00:12:53,380 --> 00:12:50,870
the amount of life you can support

347
00:12:55,540 --> 00:12:53,390
absolutely you still can support some

348
00:12:58,900 --> 00:12:55,550
life from aerobic reactions from methane

349
00:13:00,370 --> 00:12:58,910
oxidation regardless and I just wanted

350
00:13:01,900 --> 00:13:00,380
to add that this is also great for

351
00:13:03,670 --> 00:13:01,910
Europa clipper which is going to go up

352
00:13:05,110 --> 00:13:03,680
hopefully sometime in the 2020s and

353
00:13:06,759 --> 00:13:05,120
measure the composition of the ocean

354
00:13:08,139 --> 00:13:06,769
from the plume so we can take those

355
00:13:10,960 --> 00:13:08,149
measurements and trace them back to

356
00:13:12,699 --> 00:13:10,970
these kind of models to figure out what

357
00:13:14,620 --> 00:13:12,709
kind of hydrothermal processes might or

358
00:13:15,880 --> 00:13:14,630
might not be happening on Europa and how

359
00:13:18,280 --> 00:13:15,890
much chemical energy might be in the

360
00:13:19,430 --> 00:13:18,290
ocean and with that I will take

361
00:13:26,679 --> 00:13:19,440
questions

362
00:13:29,569 --> 00:13:26,689
[Applause]

363
00:13:31,999 --> 00:13:29,579

okay so we have time for one or two

364
00:13:34,639 --> 00:13:32,009
questions and if anybody's cellphone we

365
00:13:37,489 --> 00:13:34,649
have some feedback going on so the front

366
00:13:43,939 --> 00:13:37,499
row right here does anyone else feel

367
00:13:46,069 --> 00:13:43,949
like okay nevermind carry on okay so if

368
00:13:49,789 --> 00:13:46,079
there's a measure disequilibrium that

369
00:13:52,819 --> 00:13:49,799
might suggest that life didn't use it so

370
00:13:55,100 --> 00:13:52,829
is there a way to use this modelling to

371
00:13:57,679 --> 00:13:55,110
calculate the maximum amount of

372
00:14:00,530 --> 00:13:57,689
measurable disequilibrium that still

373
00:14:02,119 --> 00:14:00,540
allows for some life to it around yeah

374
00:14:03,489 --> 00:14:02,129
so this is a big question and this is

375
00:14:06,199 --> 00:14:03,499
something people raised with the

376
00:14:07,609 --> 00:14:06,209
methanogenesis chemical affinity also

377
00:14:10,999 --> 00:14:07,619
like if there's all this free energy on

378
00:14:12,439 --> 00:14:11,009
Enceladus why isn't life using it and we

379
00:14:13,879 --> 00:14:12,449
don't really have this constrained well

380
00:14:15,650 --> 00:14:13,889
enough because we don't know how much

381
00:14:18,229 --> 00:14:15,660
life could be on Enceladus and based on

382
00:14:20,329 --> 00:14:18,239
that we don't know how much of this how

383
00:14:22,100 --> 00:14:20,339
much it's going to drive the system

384
00:14:23,629 --> 00:14:22,110
toward equilibrium so maybe without life

385
00:14:25,069 --> 00:14:23,639
you would have even more chemical

386
00:14:27,409 --> 00:14:25,079
affinity than what we actually measured

387
00:14:29,269 --> 00:14:27,419
we don't know something I would like to

388
00:14:30,679 --> 00:14:29,279

do on earth actually is look at in

389
00:14:32,449 --> 00:14:30,689
systems where we know there are

390
00:14:34,579 --> 00:14:32,459
methanogens how much free energy is

391
00:14:36,769 --> 00:14:34,589
there for methanogenesis is it zero or

392
00:14:38,239 --> 00:14:36,779
is it still some positive amount because

393
00:14:39,379 --> 00:14:38,249
you still if it's zero that kind of

394
00:14:41,449 --> 00:14:39,389
tells you the system might be in

395
00:14:43,400 --> 00:14:41,459
equilibrium you can't really support

396
00:14:44,869 --> 00:14:43,410
more life but is that necessarily true

397
00:14:46,189 --> 00:14:44,879
it would be really interesting to

398
00:14:50,239 --> 00:14:46,199
compare how we know this works on earth

399
00:14:55,949 --> 00:14:53,009
all right we will keep moving along

400
00:14:57,430 --> 00:14:55,959
thank you very much one more round of