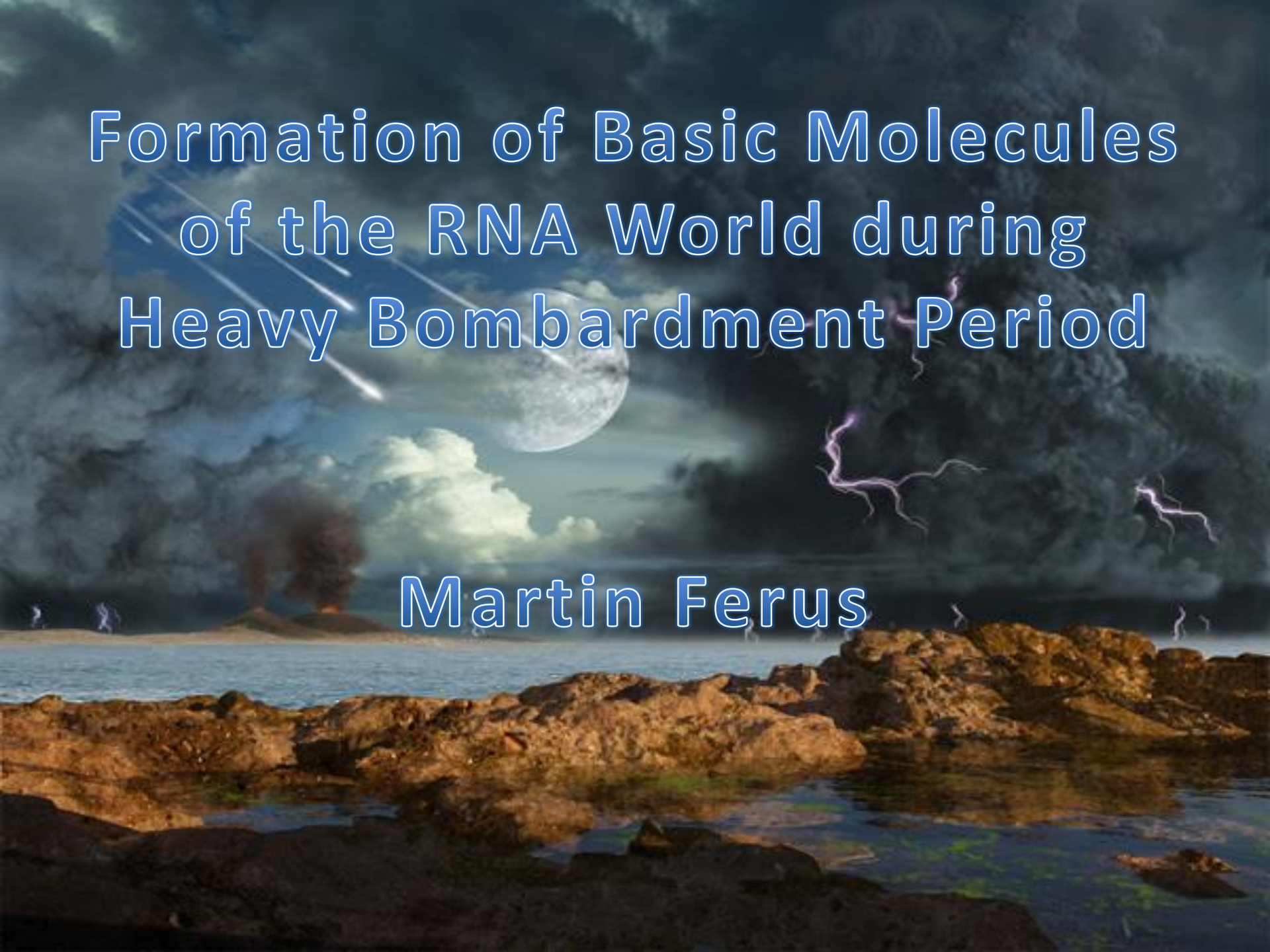
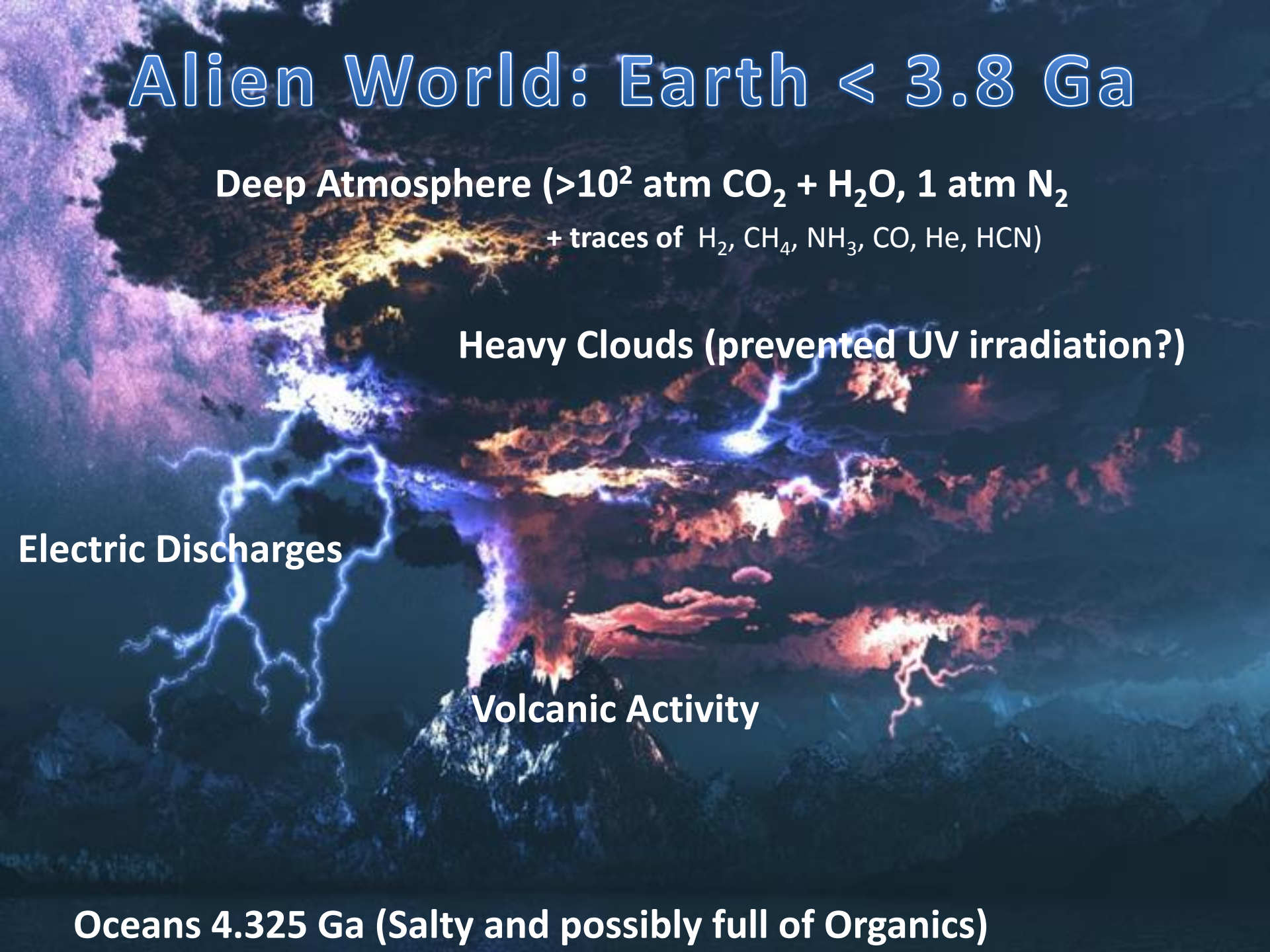

Formation of Basic Molecules of the RNA World during Heavy Bombardment Period
Martin Ferus


Alien World: Earth < 3.8 Ga
Deep Atmosphere (>10² atm CO_2 + H_2O, 1 atm N_2
+ traces of H_2, CH_4, NH_3, CO, He, HCN)
Heavy Clouds (prevented UV irradiation?)
Electric Discharges
Volcanic Activity
Oceans 4.325 Ga (Salty and possibly full of Organics)

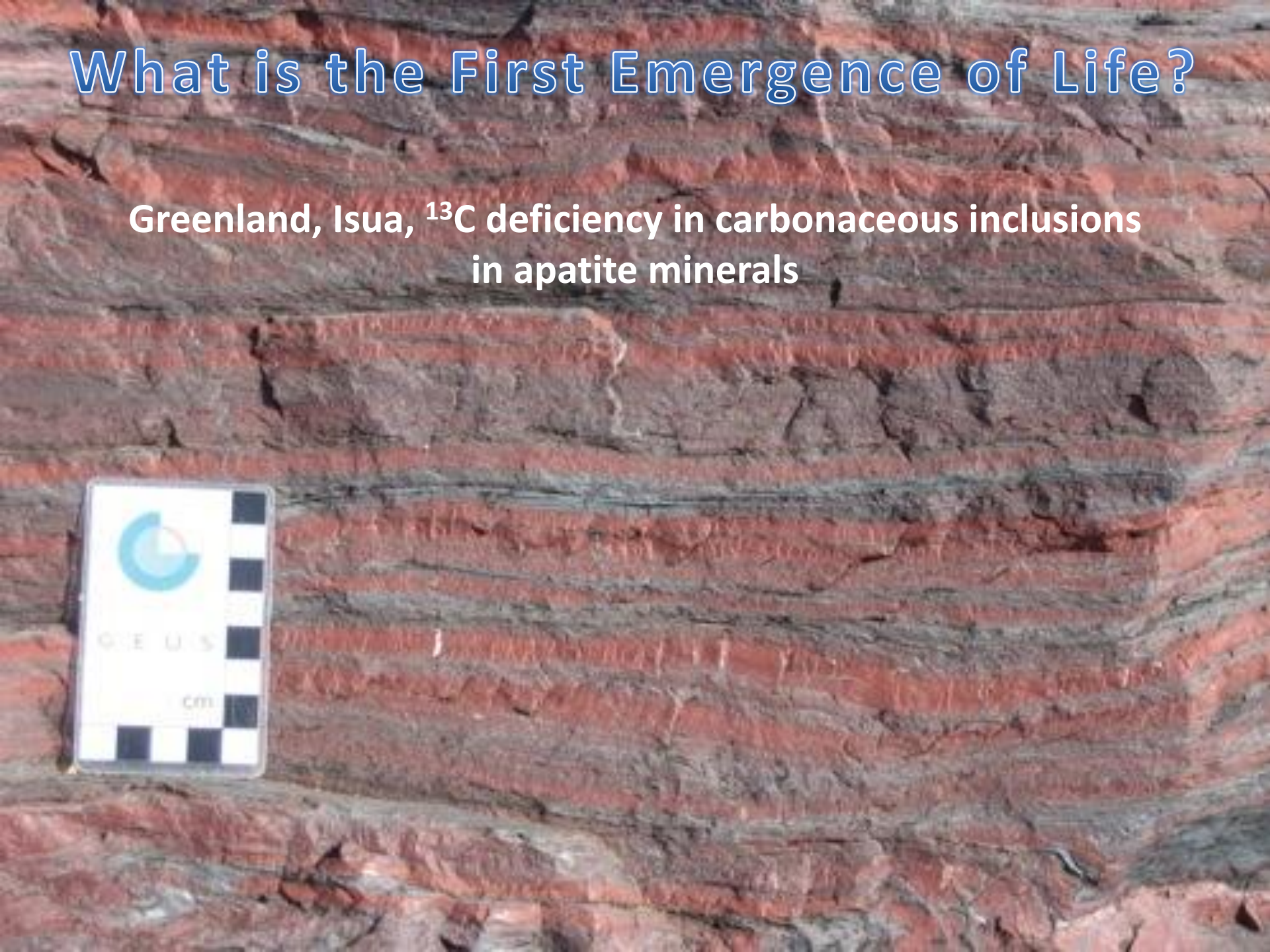
Alien World: Earth < 3.8 Ga

Heavy Bombardment

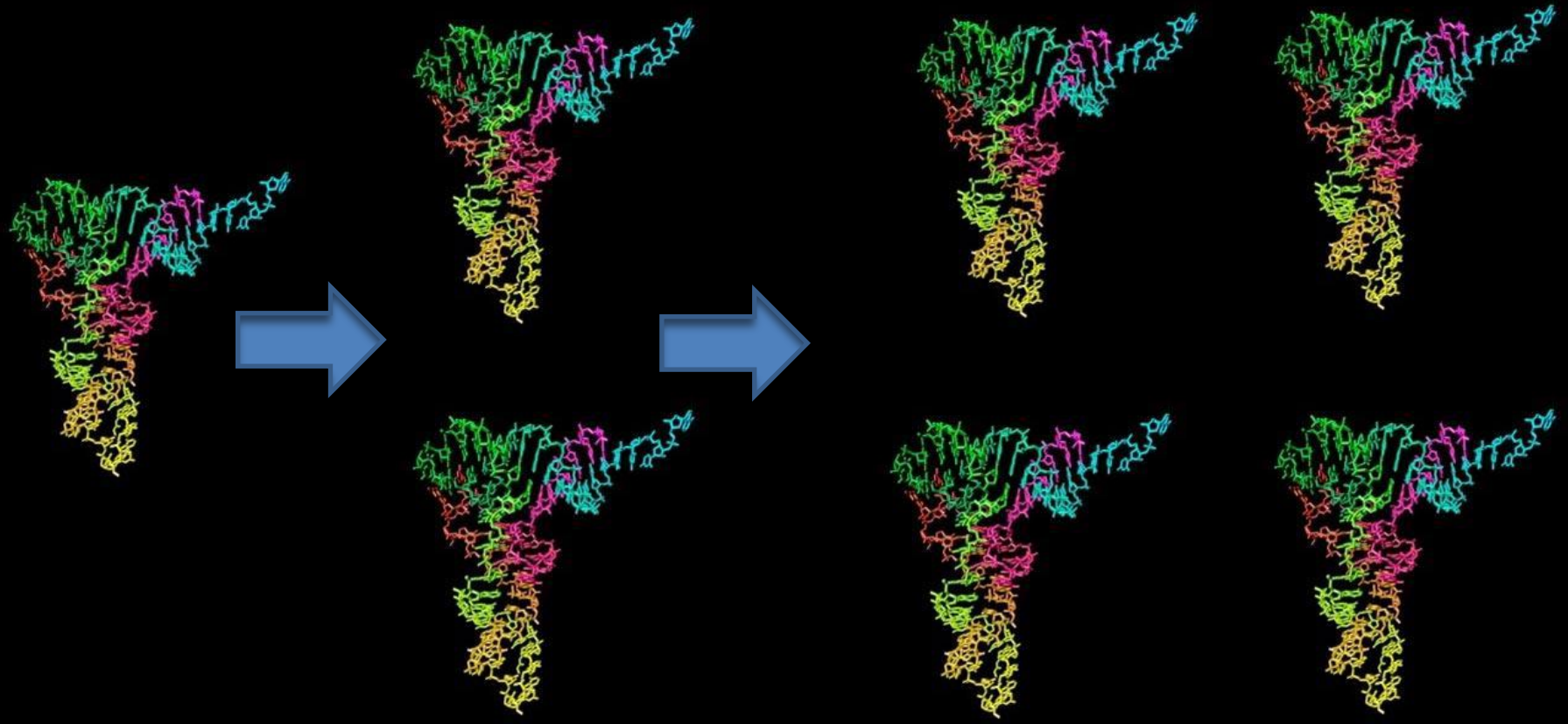
Origin of Biomolecules forming Molecular Life?

What is the First Emergence of Life?

Greenland, Isua, ^{13}C deficiency in carbonaceous inclusions in apatite minerals

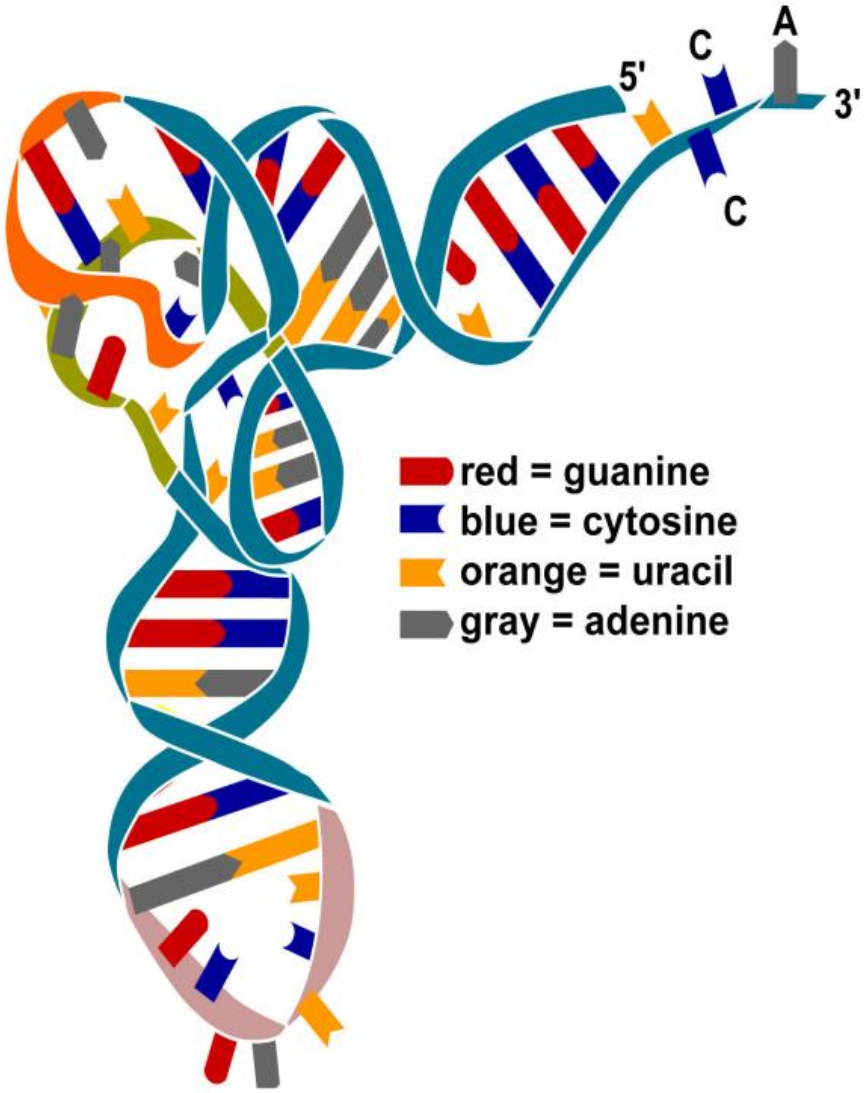


Maybe it was the RNA World

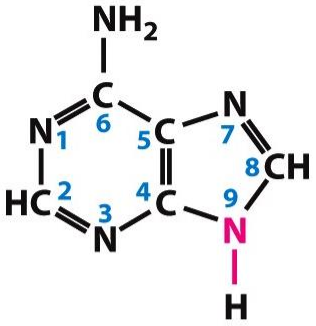


Molecular Life

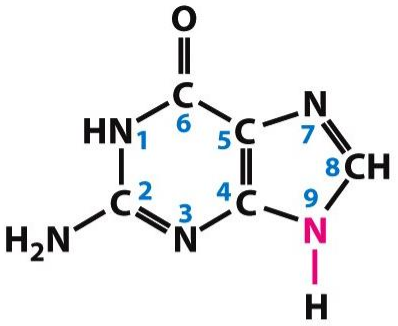
Bases of the RNA Code



PURINES

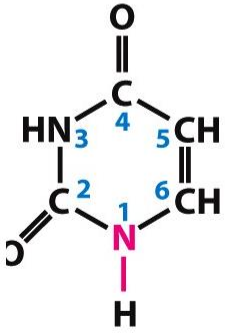


Adenine (A)

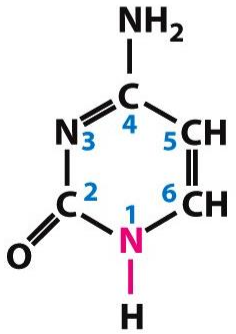


Guanine (G)

PYRIMIDINES



Uracil (U)

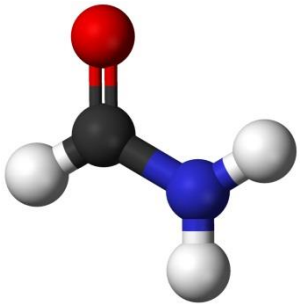


Cytosine (C)

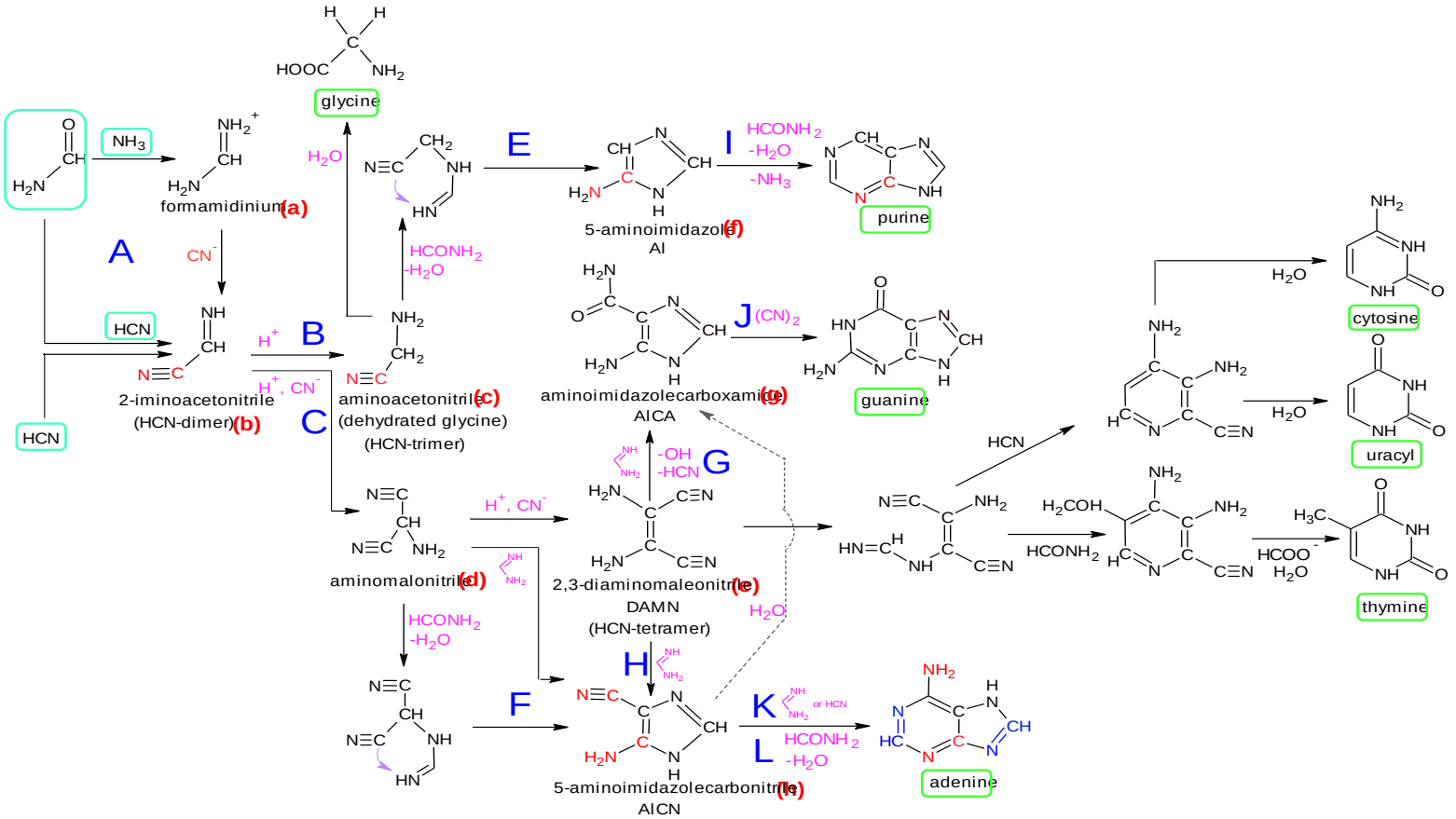
Searching for a Universal Parent Molecule

R. Saladino E. Di Mauro

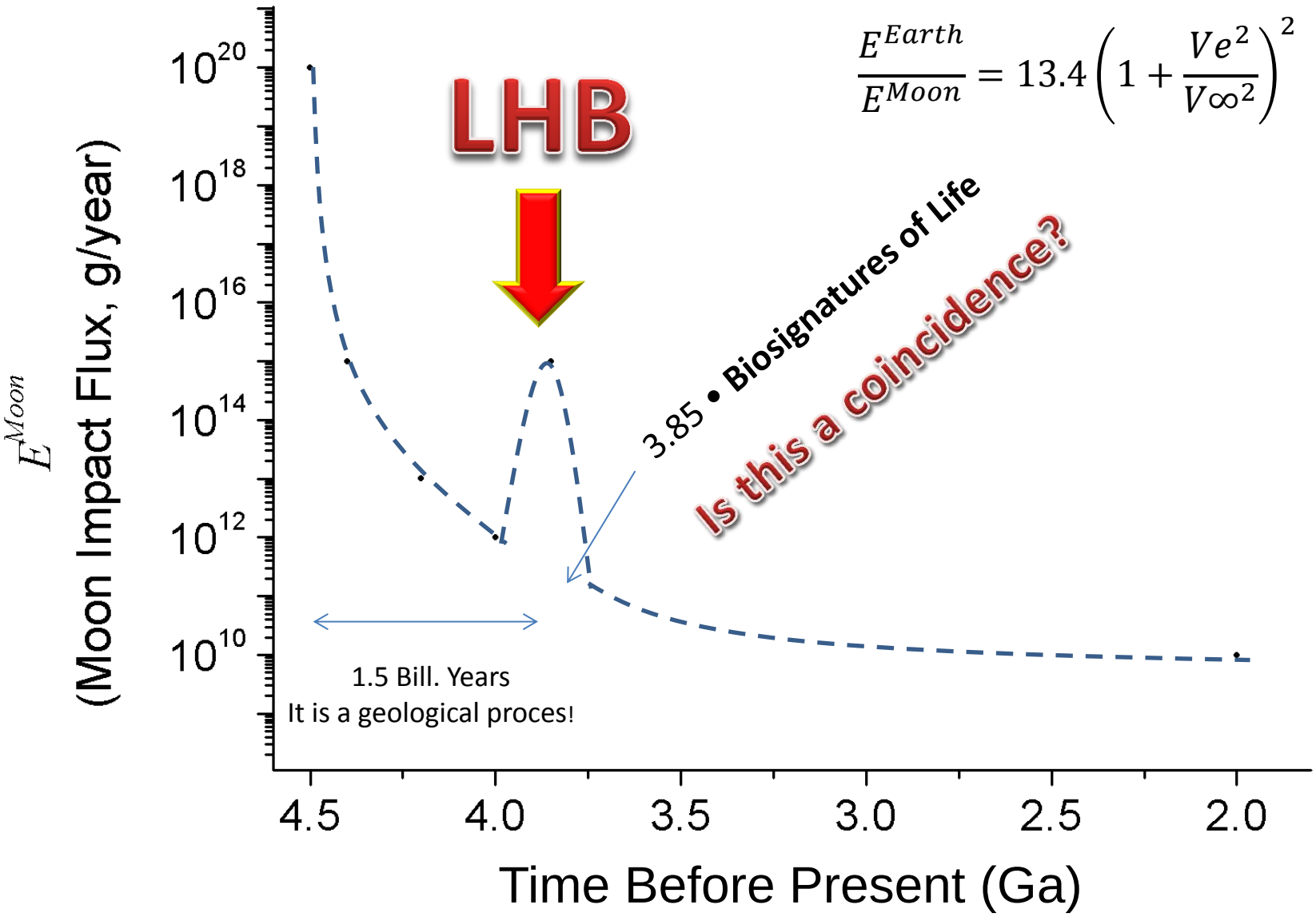
&



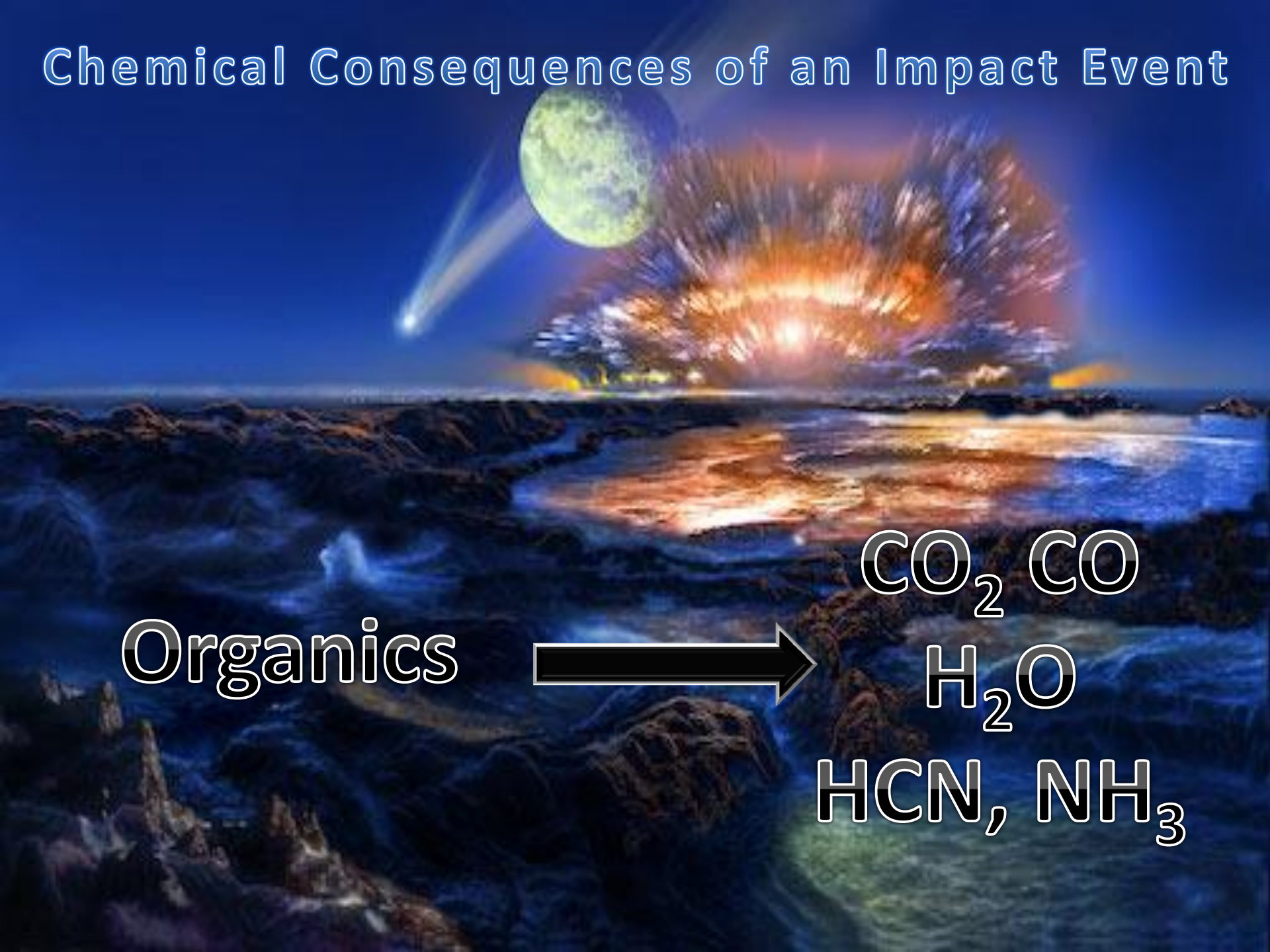
Formamide



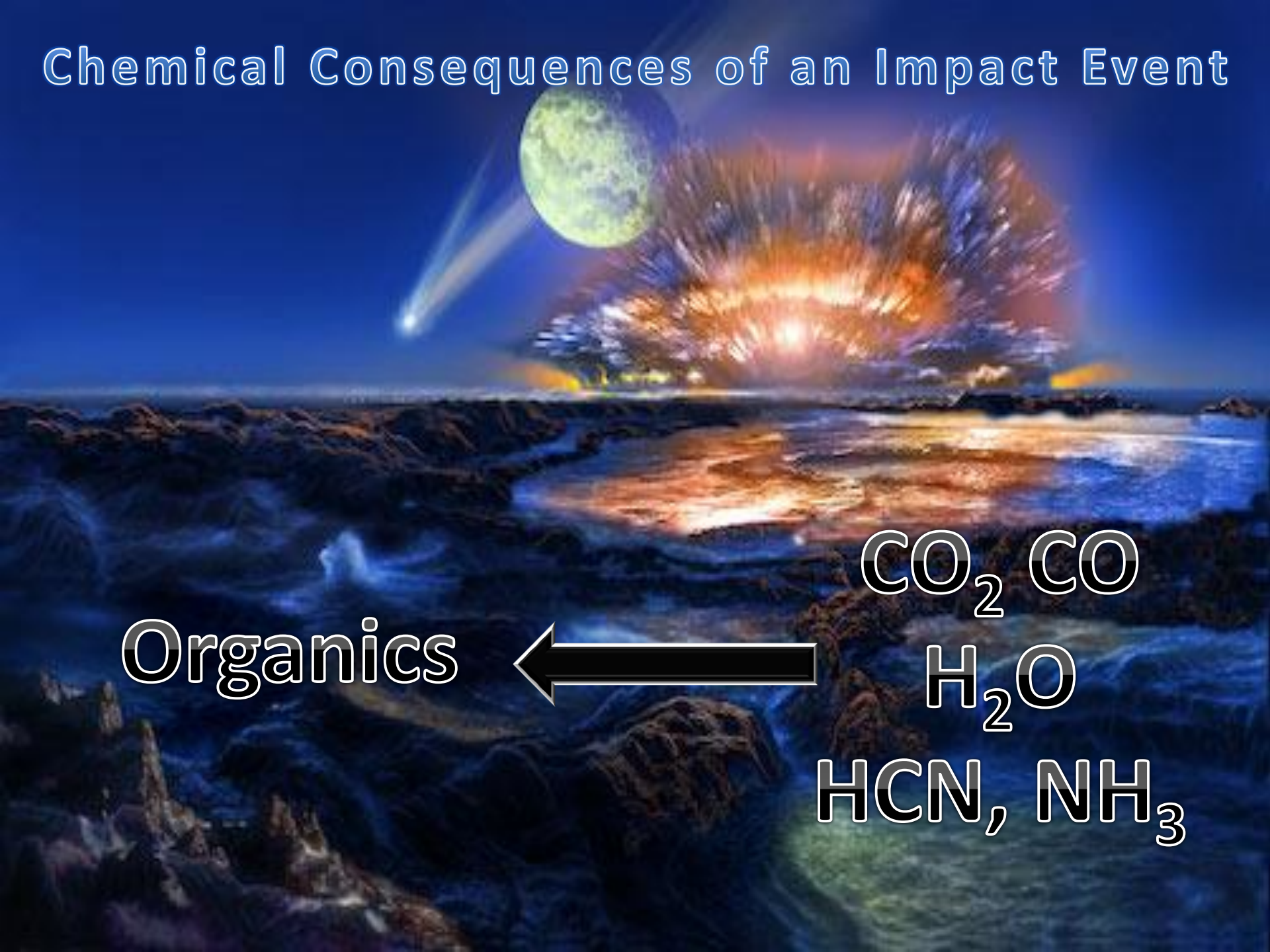
Early and Late Heavy Bombardment



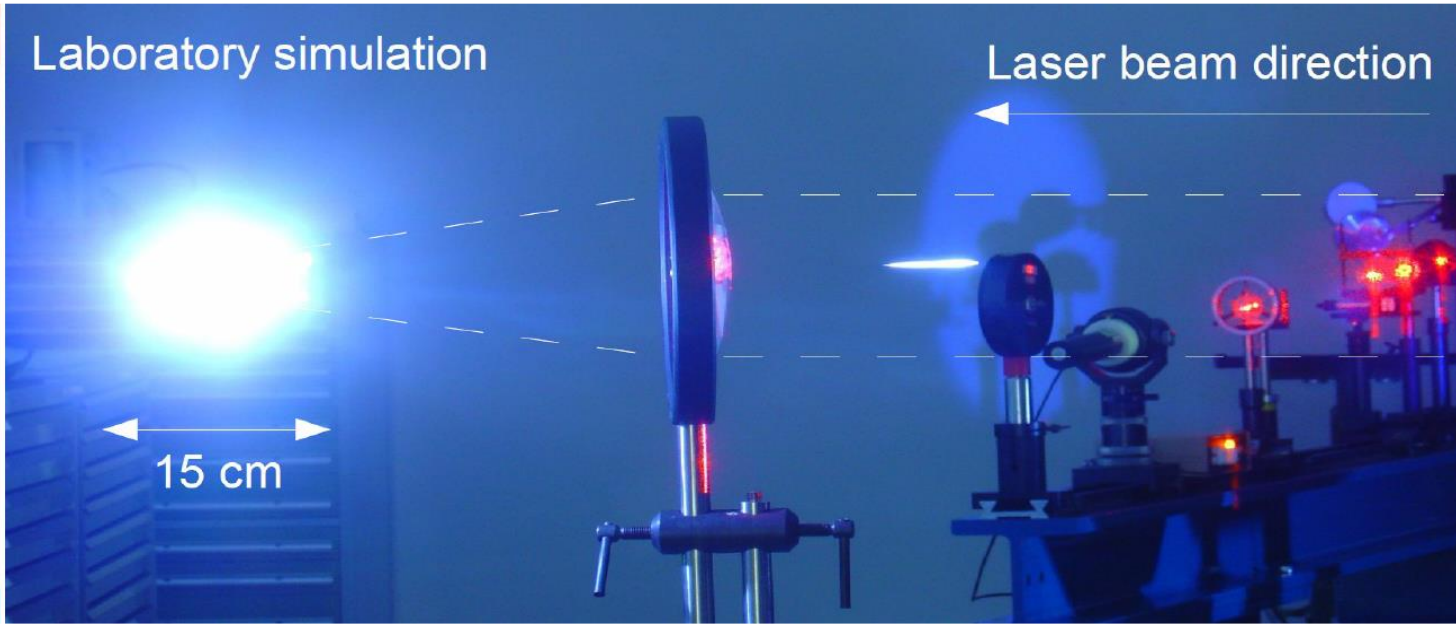
Chemical Consequences of an Impact Event



Chemical Consequences of an Impact Event



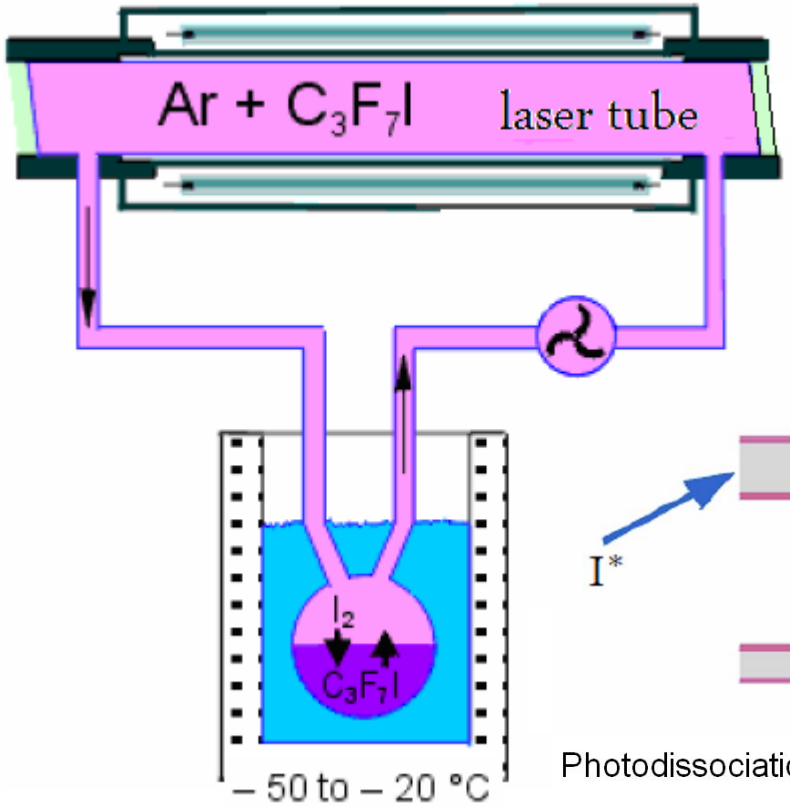
High Power Laser Mimics an Impact Plasma

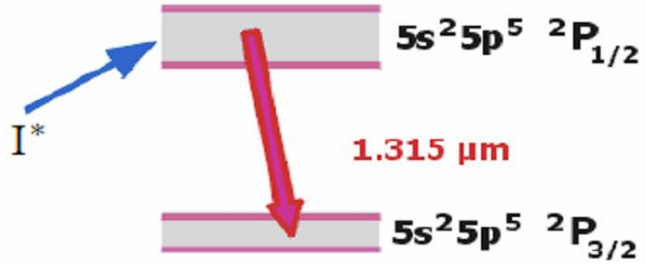


High Power Laser Mimics an Impact Plasma

Chemical laser (C_3F_7 + Ar), λ = 1315 nm, E = 1 kJ / 0.5 ns

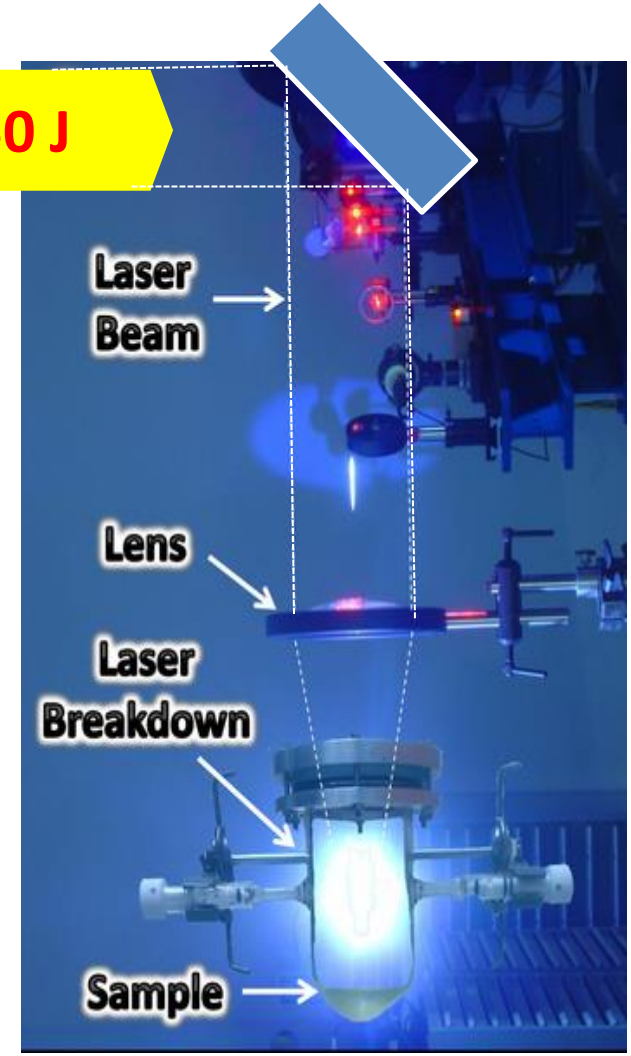
2 ml $HCONH_2$ + nitrogen, Irradiated by 15 pulses



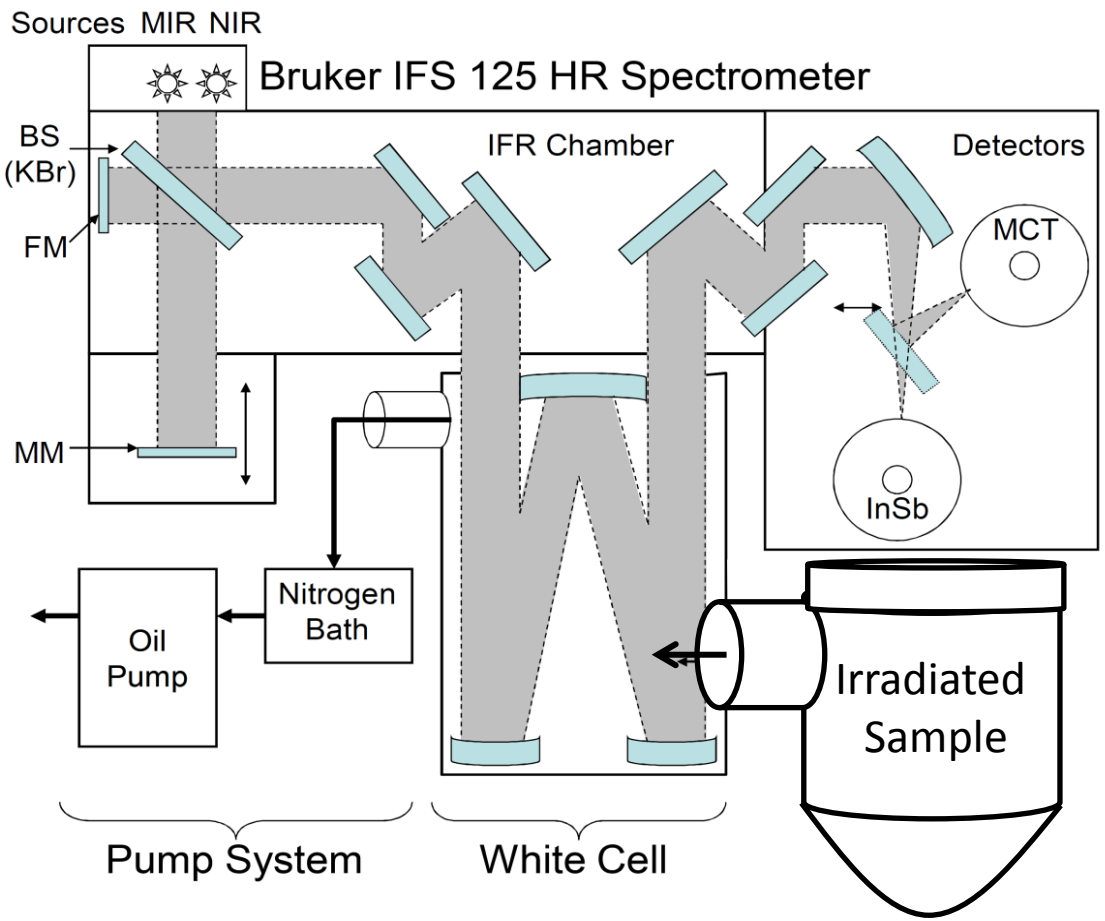


Photodissociation of C_3F_7I

Laser Shot = 150 J

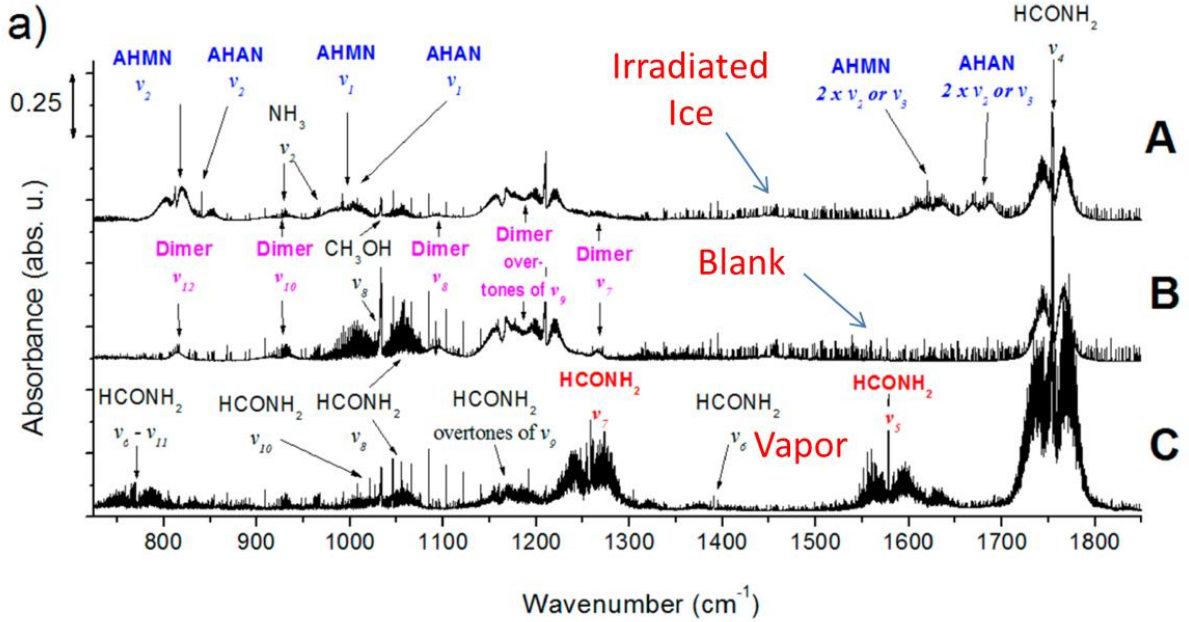


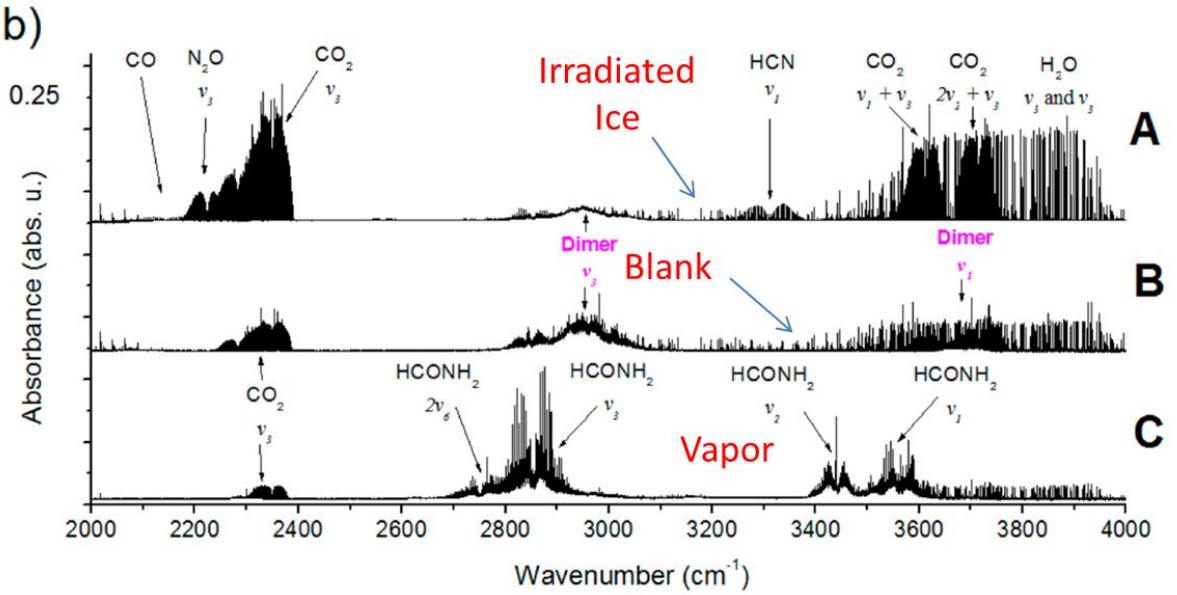
Step I. Gas Phase Analysis



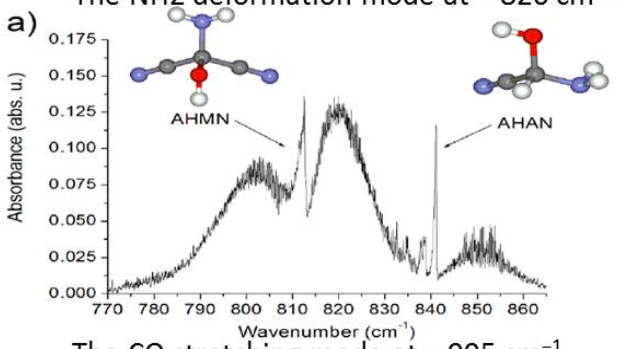
Step I. Gas Phase Analysis

Ferus M, Civis S et al. (2012) *J Am Chem Soc* 134:20788–20796

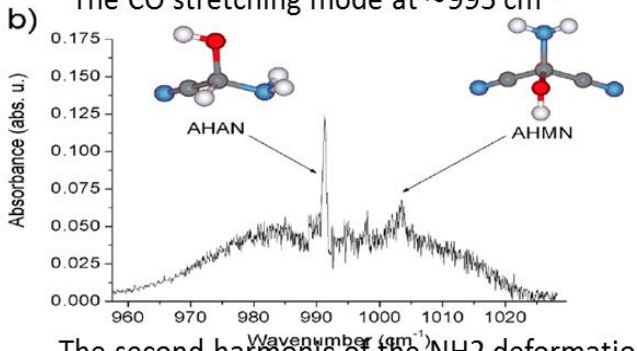




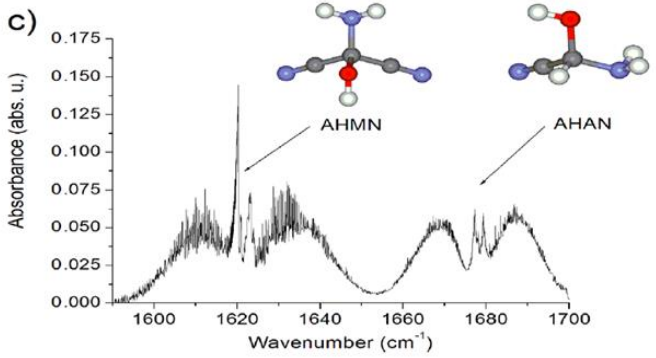
The NH2 deformation mode at ~820 cm^{-1}



The CO stretching mode at ~995 cm^{-1}

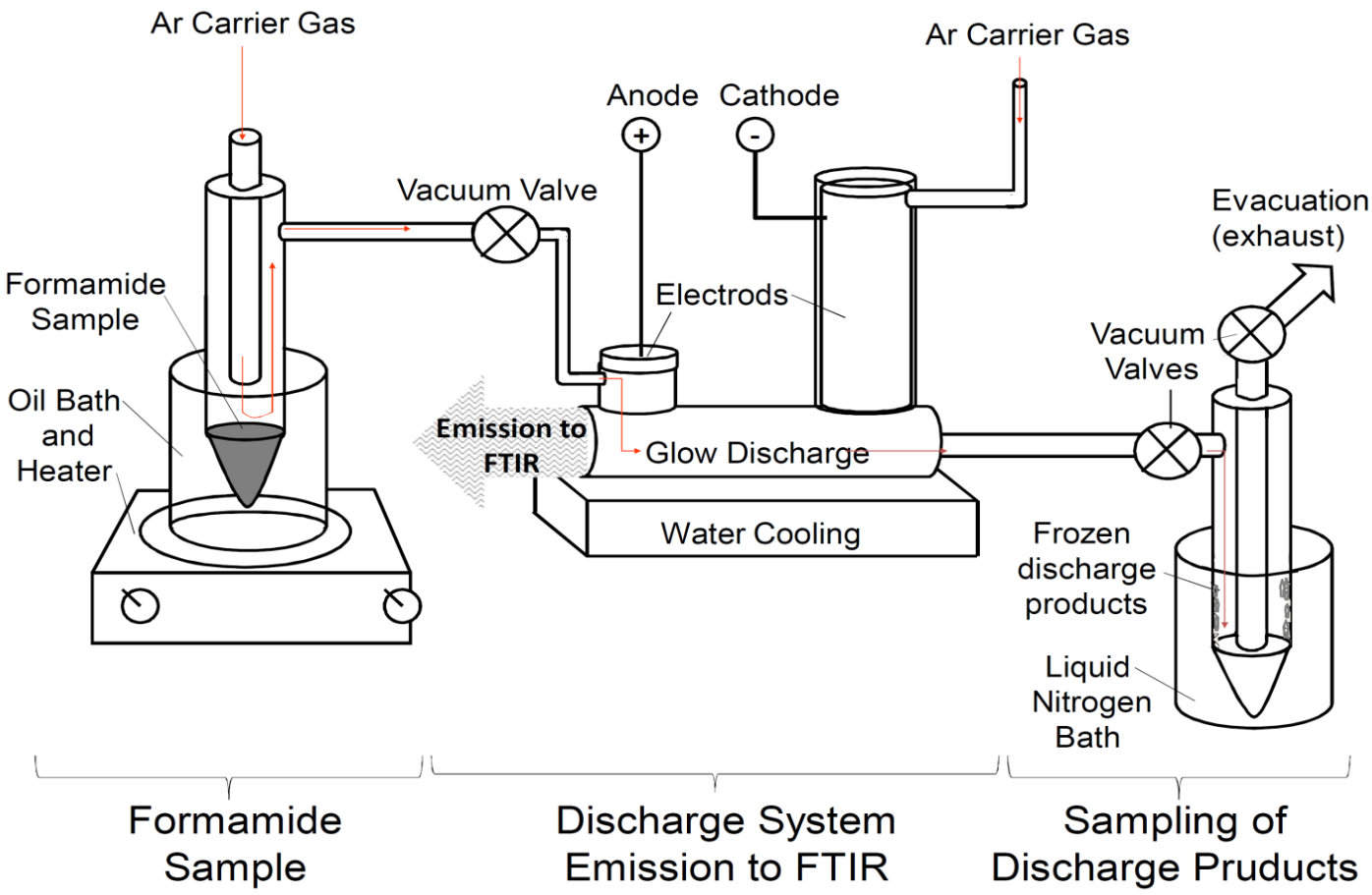


The second harmonic of the NH2 deformation

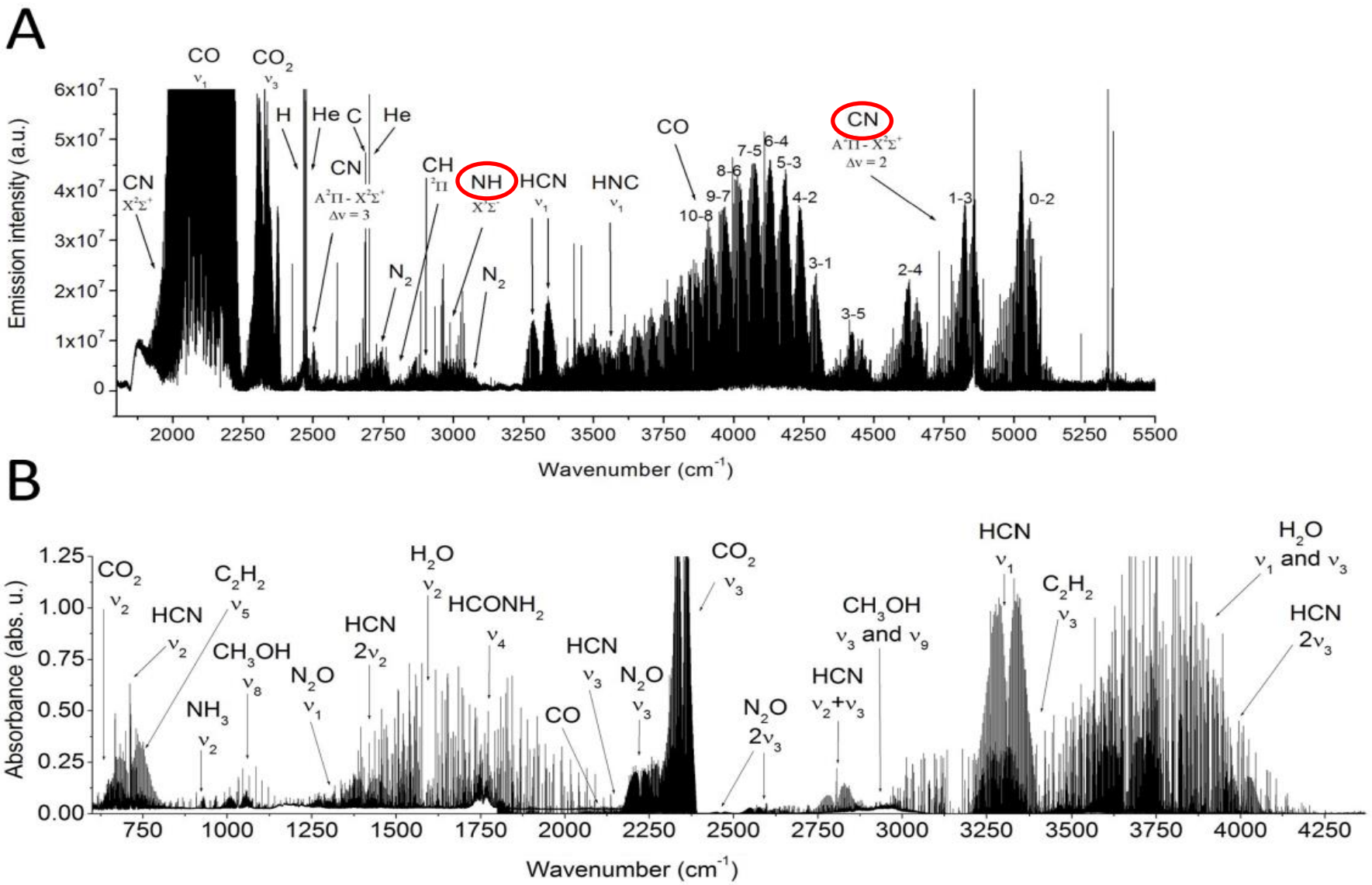


Step II. Formamide Chemistry

Electric Discharge and Time Resolved Spectroscopy of Formamide Plasma

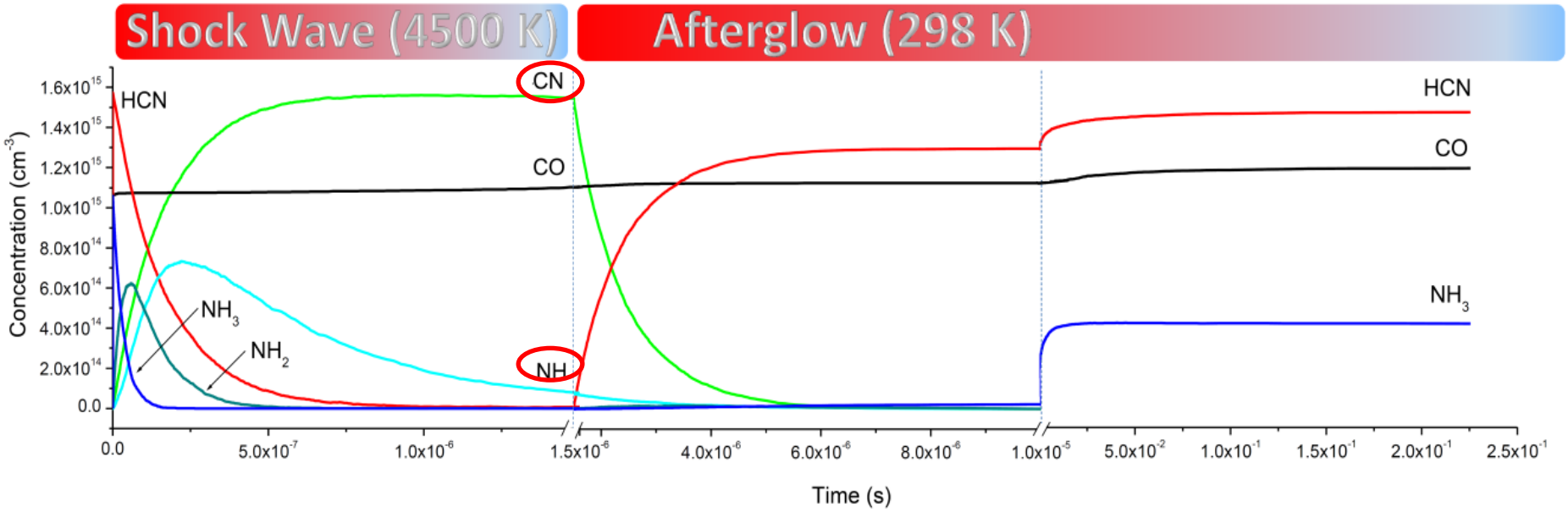


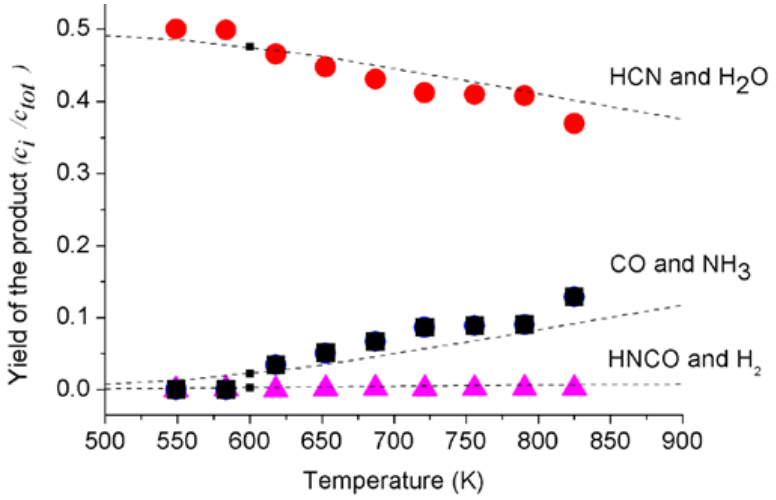
Step II. Formamide Chemistry

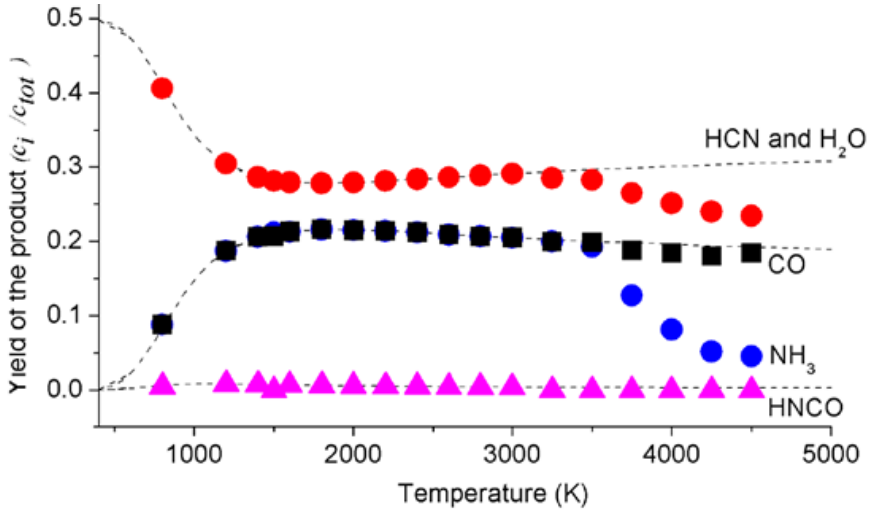


Step II. Formamide Chemistry

Chemical Models of Laser Spark Plasma – Calculations and Experimental Results of Pyrolysis

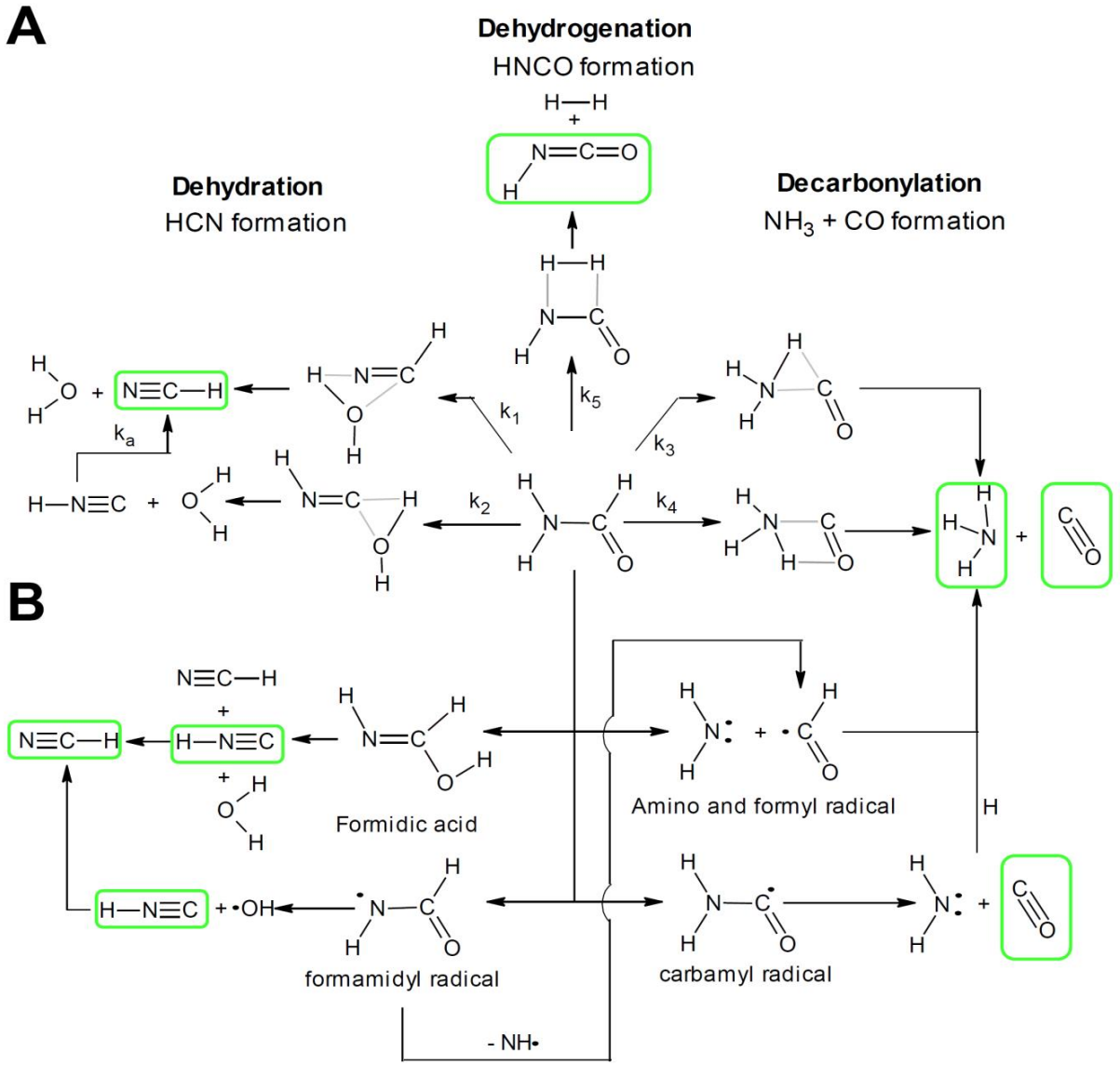


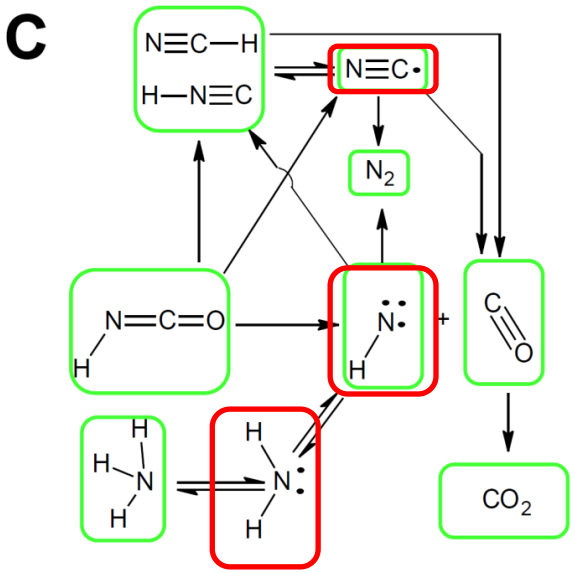


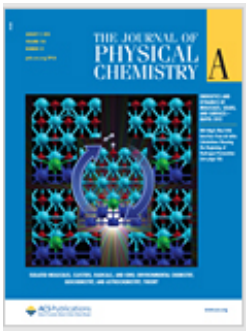


Step II. Formamide Chemistry

Unified Mechanism of Formamide Dissociation

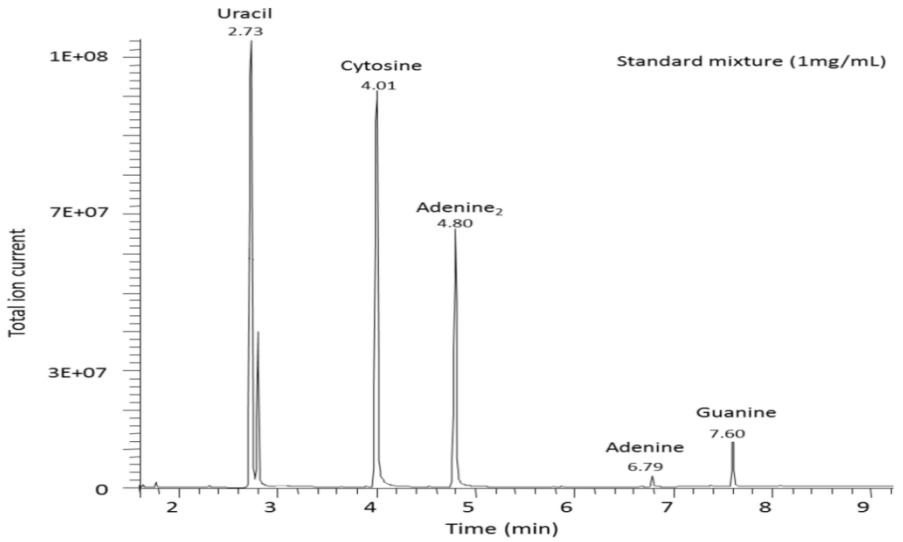


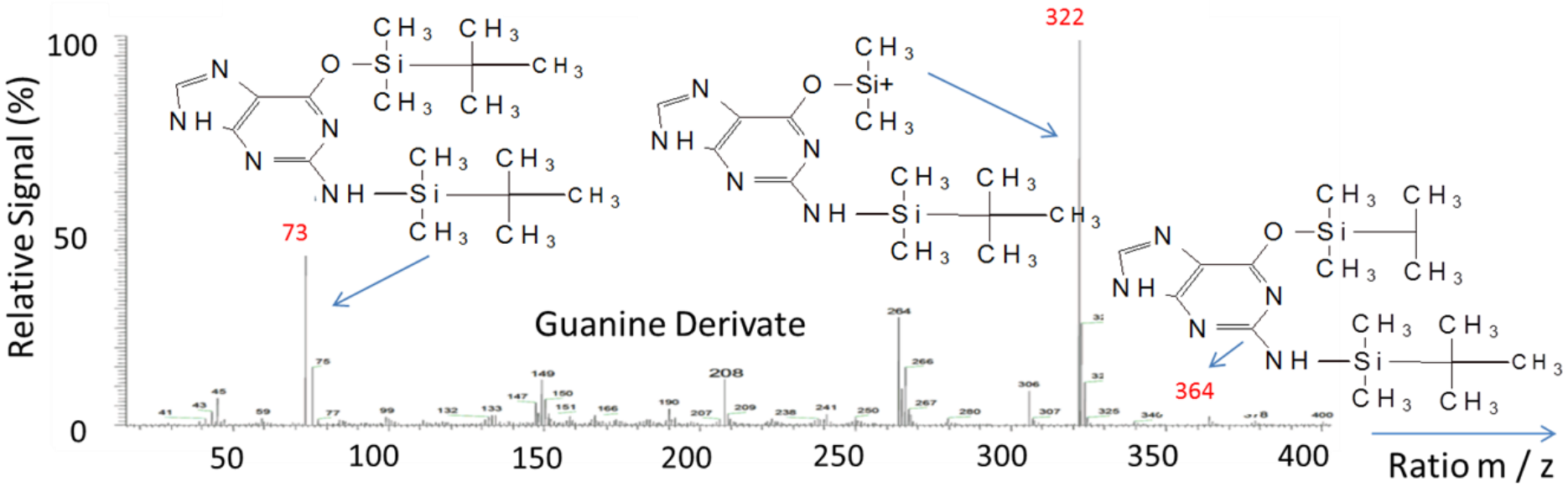




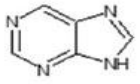
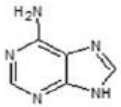
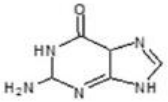
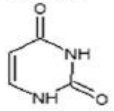
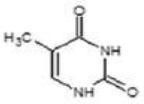
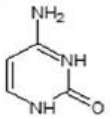
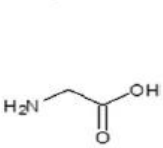
Ferus M , Civis S et al. (2014)
J Phys Chem 118:719–736.

Step III. Nucleic Bases Detection





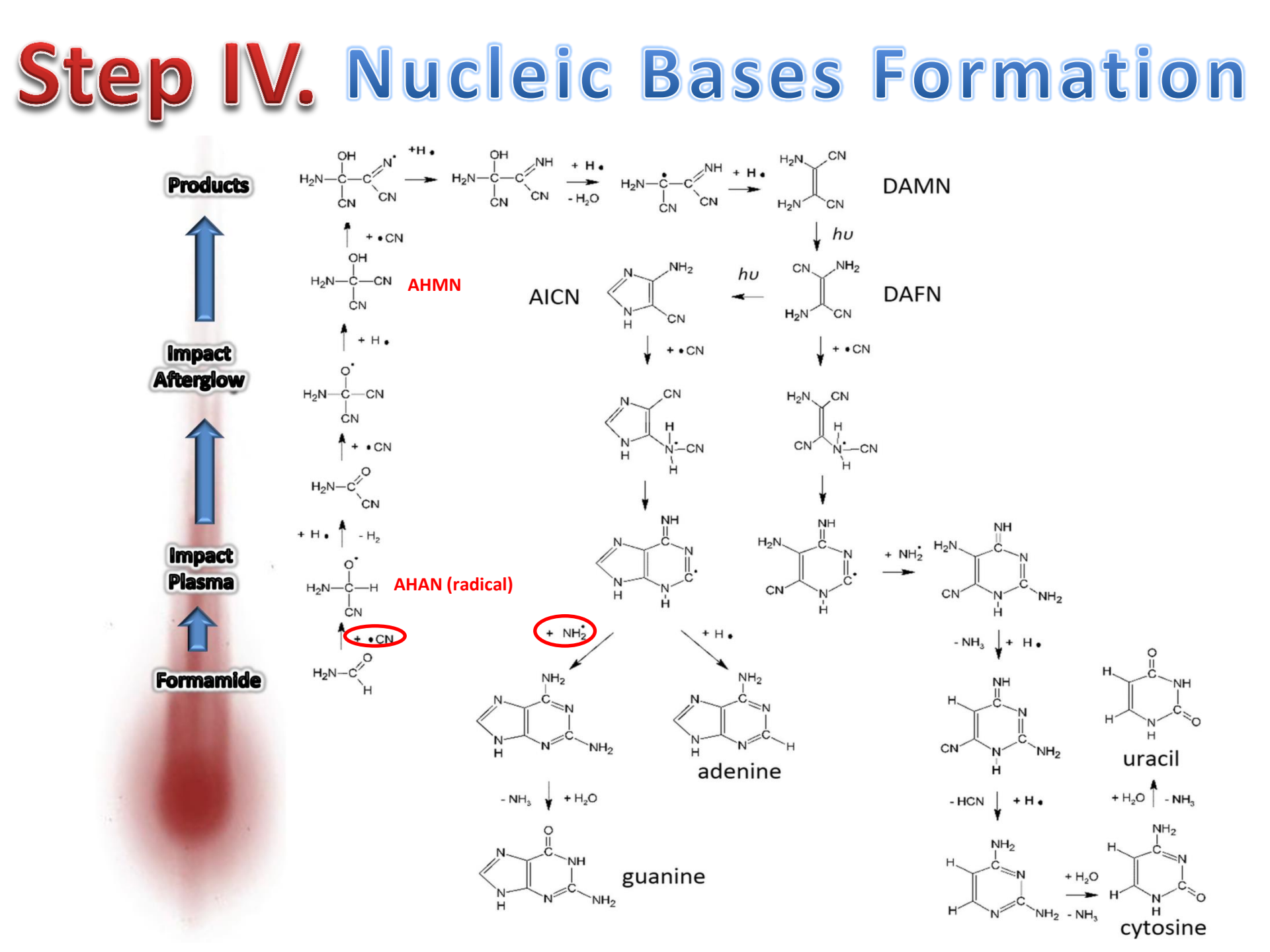
Step III. Nucleic Bases Detection

No. assig.	State	Buffer Gas	Catalyst	Purine 	Adenine 	Guanine 	Uracil 	Thymine 	Cytosine 	Glycine 
L1	Ice	N_2	no cat.							
L2	Liquid	N_2	no cat.	22.11%	0.03%	5.59%	0.78%	0.12%		
L3	Ice	N_2	NiFe	1.13%		6.77%	29.60%			
L4	Liquid	N_2	NiFe	9.54%			1.80%			
L6	Ice	N_2	TiO_2			9.29%				15.81%
L7	Liquid	N_2	TiO_2	0.90%	0.03%	34.15%	1.03%			10.86%
L8	Ice	N_2	Chondrite	0.49%	0.06%	46.81%	1.58%			
L9	Liquid	N_2	Chondrite	0.76%	0.03%	35.23%	1.19%			
L10	Ice	N_2	Clay	3.02%	0.31%	16.08%		0.83%	8.84%	20.99%
L11	Liquid	N_2	Clay	1.58%	100.00%	100.00%	100.00%	15.43%	100.00%	60.96%
DAMN	Ice	N_2	no cat.	100.00%	1.26%	71.51%	0.72%	100.00%	0.08%	100.00%

Ferus M , Civis S, Šponerová J et al. (2015)
PNAS 112:657–662.

Experiment	Adenine, %	Guanine, %	Cytosine, %	Uracil, %	Yield, mg/L
$HCONH_2$	61.9	24.0	0.0	14.1	3.71
$HCONH_2$ + chondrite	54.5	33.0	0.0	12.5	3.51
$HCONH_2$ + clay	79.4	4.4	13.1	3.1	47.07
DAMN	7.8	4.5	86.0	1.8	24.74

Step IV. Nucleic Bases Formation



The results answer several fundamental questions:

1. Destruction of biomolecules during LHB
   Maybe it was source of energy!

2. One pot synthesis problem.
   One molecule, one system, one catalyst.

3. Emergence of living structures after LHB.
   LHB was a geological process leading to biomolecules.

4. RNA world is highly probable.
   The synthesis of basic components is reasonably simple.