ASTR/GEOL-2040: Search for life in the Universe, Lecture 7

Carbon in the Universe
Miller/Urey experiment
Murchison meteorite
Pages 16-21 in RGS

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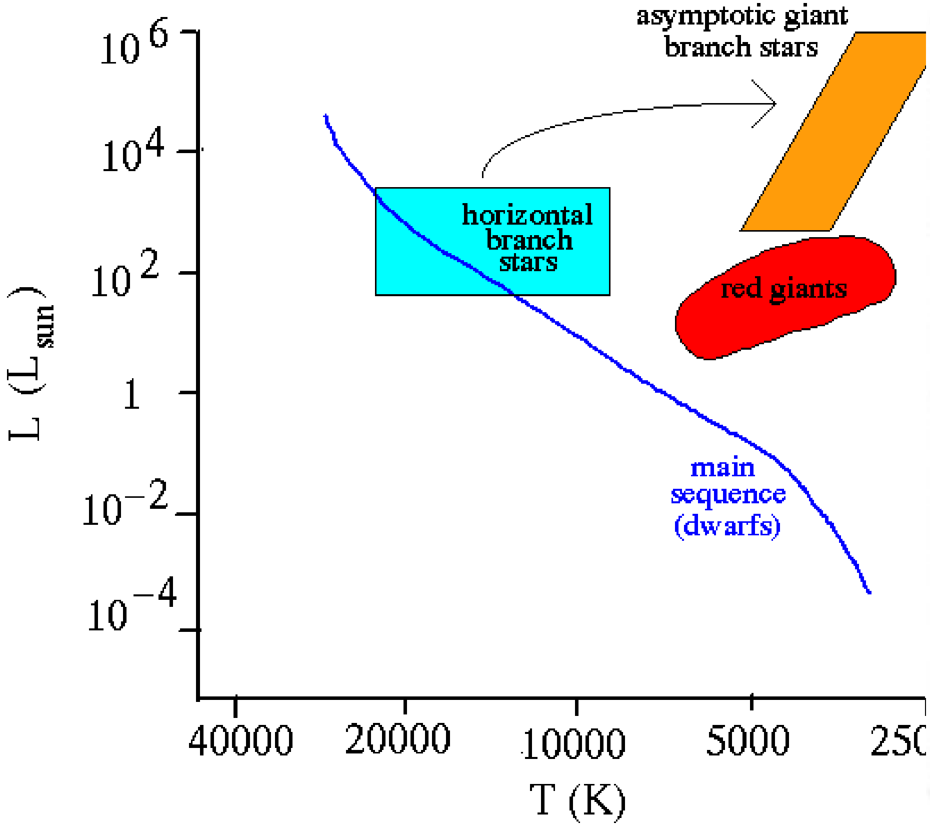
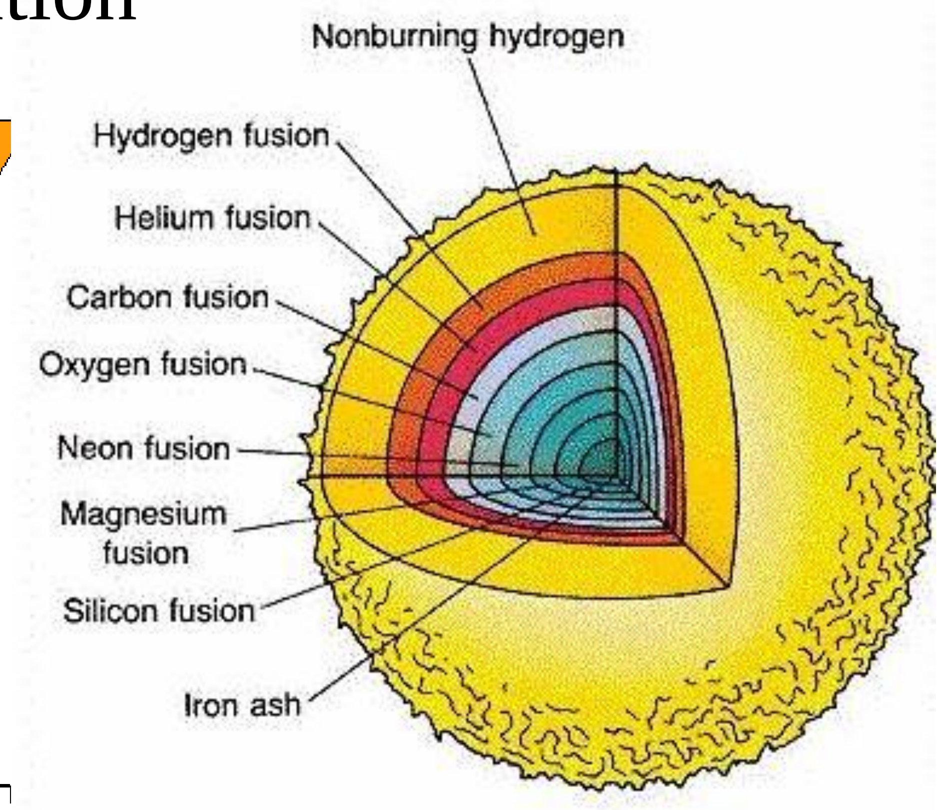
(Office hours: Mondays 2:30 – 3:30 in X590
and Wednesdays 11-12 in D230)

Organic matter in the Universe

- Carbon comes from nuclear fusion in stars
- Late stages of evolution





an “old” sun

Stellar evolution

- Stars consume food (H)
- Expell waste (light, gas, dust)
- Grow (protostar, main sequence, giant)
- Die, and produce offspring from their dust

…are stars alive?

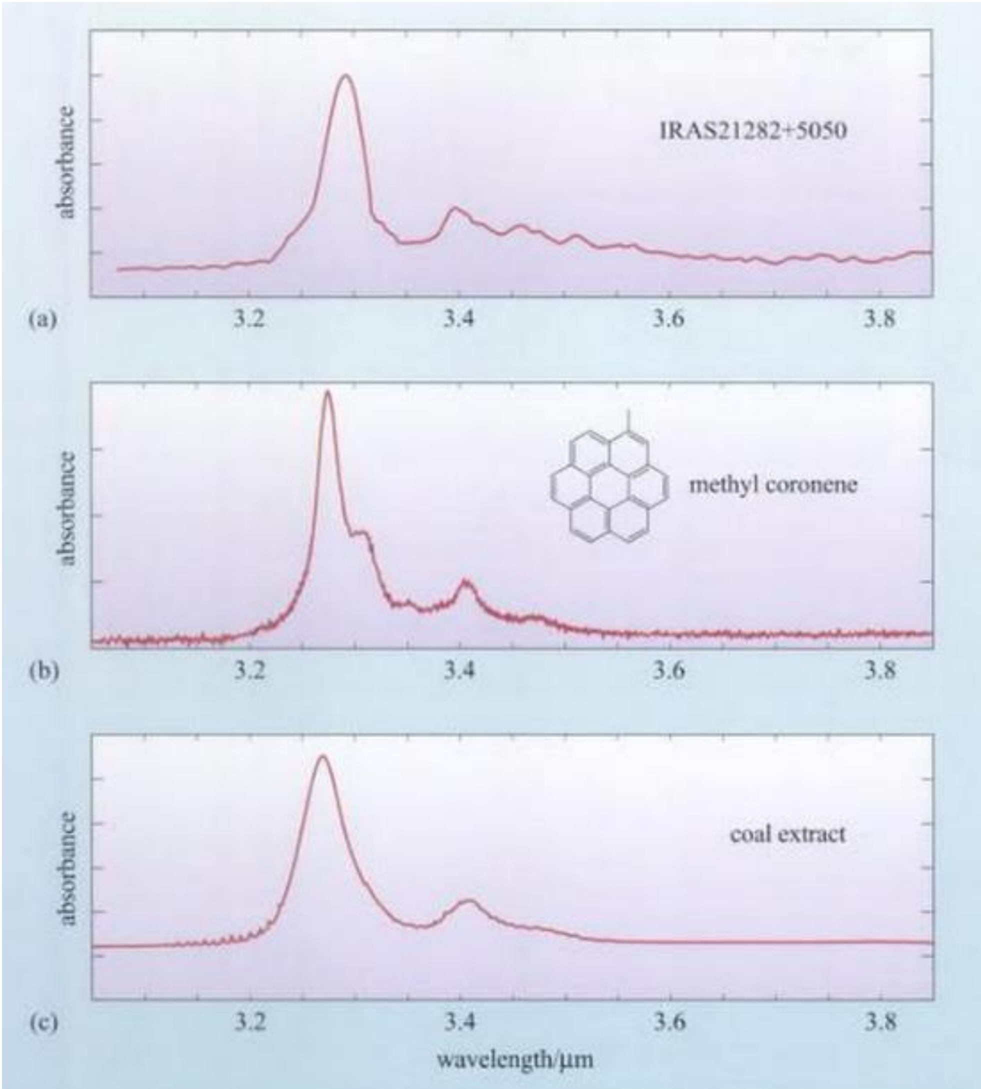
Stellar “evolution”

- No Darwinian evolution
- This ”life” cycle is more like a motor

- But let’s now look at their waste...

Similarity of spectra with coal

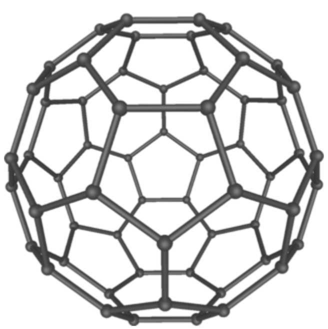
- Circumstellar envelope of IRAS21282+5050
- Aromatic carbons ***common*** in space
- Coal – the very bottom of bottom-up approach



p.15 of RGS

Molecules around stars

- H_2 smallest
- CO, CO_2
- HCOOH
- CH_3-CH_2-OH
- NH_3, HCN
- H_2S, N_2O
- C_{60}, C_{70} largest



hydrogen species			
H_2	HD	H_3^+	H_2D^+
hydrogen and carbon compounds			
CH	CH^+	C_2	CH_2
CH_3	C_2H_2	C_3H (lin)	C_3H (circ)
H_2CCC (lin)	C_4H	C_5	C_2H_4
CH_3C_2H	C_6H	H_2C_6	C_7H
hydrogen, carbon and oxygen compounds			
OH	CO	CO^+	H_2O
HOC^+	C_2O	CO_2	H_3O^+
C_3O	CH_2CO	HCOOH	H_2COH^+
C_5O	CH_3CHO	C_2H_4O (circ)	CH_3OCHO
CH_3OCH_3	CH_3CH_2OH	$(CH_3)_2CO$	
hydrogen, carbon and nitrogen compounds			
NH	CN	NH_2	HCN
NH_3	$HCNH^+$	H_2CN	HCCN
CH_2NH	HC_2CN	HC_2NC	NH_2CN
CH_3NC	HC_3NH^+	C_5N	CH_3NH_2
CH_3C_3N	CH_3CH_2CN	HC_7N	CH_3C_5N
hydrogen, carbon (possibly), nitrogen and oxygen compounds			
NO	HNO	N_2O	HNCO
other species			
SH	CS	SO	SO^+
SiC	SiN	SiO	SiS
AlCl	KCl	HF	AlF
H_2S	C_2S	SO_2	OCS
NaCN	MgCN	MgNC	H_2CS
$HSiC_2$	SiC_3	SiH_4	SiC_4

Darwin's early ideas

(letter to Hooker of 1871)

- ”... we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts, light, heat, electricity, etc, present that a protein compound was chemically formed ready to undergo still more complex changes”

Notes of music

- Carl Sagan:
  - Building blocks like notes to the music
  - Not the music itself
- Ramming right molecules together
  - as unlikely as hearing Beethooven's 9th when letting monkeys loose with roomfull of instruments

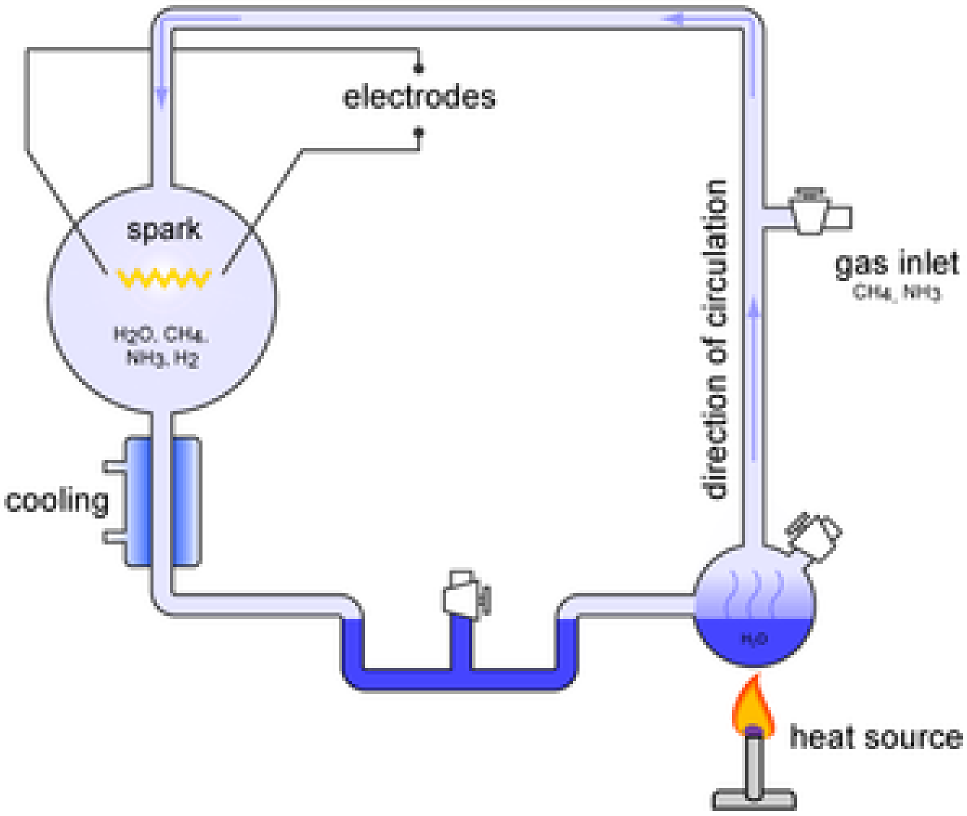
Putting the right molecules together

- Need to produce order
  → drive away from equilibrium
- Energy required to generate & sustain order

Source	Energy /J m^{-2} yr^{-1}
total radiation from the Sun	1 090 000.0
ultraviolet light	1 680.0
electric discharges (lightning)	1.68
cosmic rays	0.0006
radioactivity (to 1 km depth)	0.33
volcanoes	0.05
shock waves (atmospheric entry)	0.46

Comparison with Frankenstein experiment

- Reducing atmosphere:
- H_2, H_2O, NH_3, CH_4,
  Oparin/Haldane
- Discharges
- Steam



After 1 week….

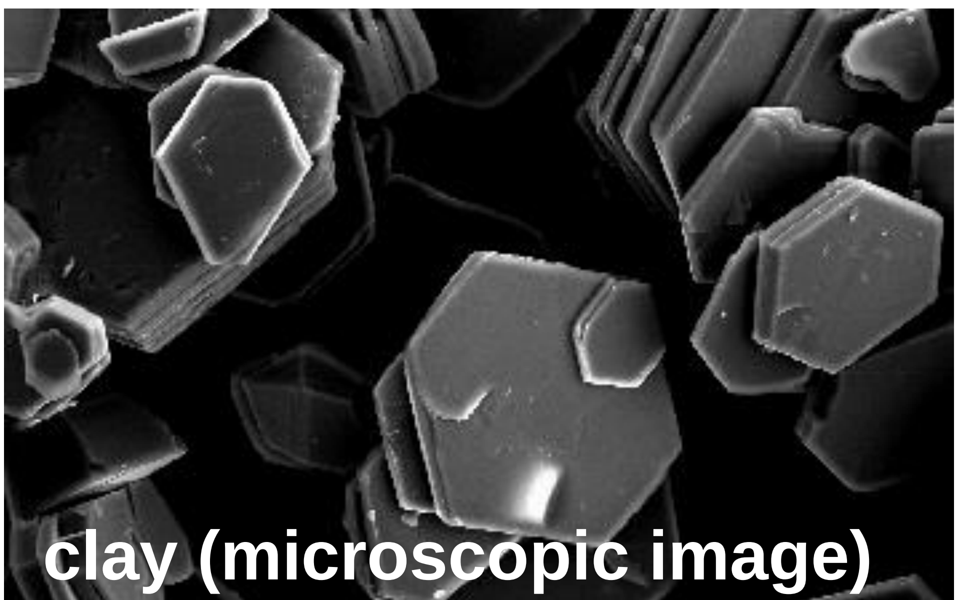
- Brown substance
- Glycine, alanine, (valine, proline, ...)

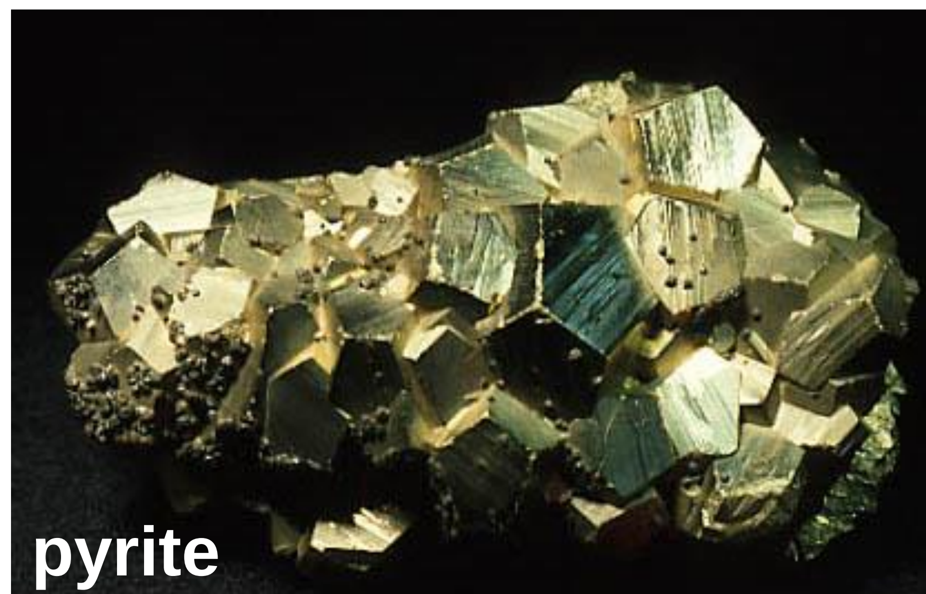
Role of minerals

- Support
  - Amino acids polymerize on surfaces
- Selection
  - Different crystal faces select left/right
  - Both possible → natural selection chose one
- Catalysis
  - N_2 to N_3H via metalic surfaces
  - Suitable in hydrothermal vents

Minerals as Templates?

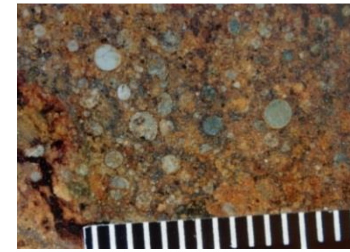
- How could first RNA “genetic” strands arise?
- Lab experiments: clays + water + organics ⇒ complex organics, including RNA strands.
- Repeating chemical structure of minerals may facilitate assembly of complex organics!





Meteorites: organics from space

- Stony:
  - – Chondrites: 86%
    - Ordinary (80% of those)
    - Carbonateous (5% of those)
    - ....
  - – Achondrites:8%
- Iron: 6%



Chelyabinsk (2013)

1500 people injured!

Meteorites: different types

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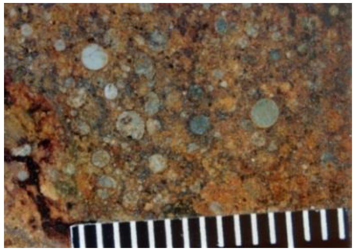

Murchison meteorite

- September 28, 1969, 10:58 am, Melbourne
  - Observed as fireball, w/ smoke for 30s
  - Broke up into pieces, altogether >100kg
- Carbonaceous chondrite
  - Smelly when found
- Analyzed like moon rocks
  - >15 amino acids, etc

Comparison

Amino acid	Abundance of amino acids: synthesized in the Miller–Urey experiment	Abundance of amino acids: Found in the Murchison meteorit
glycine	●●●●	●●●●
alanine	●●●●	●●●●
α-amino-*N*-butyric acid	●●●	●●●●
α-aminoisobutyric acid	●●●●	●●
valine	●●●	●●
norvaline X	●●●	●●●
isovaline X	●●	●●
proline	●●●	●
pipecolic acid X	●	●
aspartic acid	●●●	●●●
glutamic acid	●●●	●●●
β-alanine	●●	●●
β-amino-*N*-butyric acid X	●●	●●
β-aminoisobutyric acid X	●	●
γ-aminobutyric acid X	●	●●
sarcosine X	●●	●●●
N-ethylglycine X	●●	●●
N-methylalanine X	●●	●●

not used in life

Organics in Muchison & Life

	Role	Life	Murchison meteorite
water	solvent	yes	yes
lipids (hydrocarbons and acids)	membranes, energy storage	yes	yes
sugars (monosaccharides)	support, energy storage	yes	yes
polysaccharides (polymerized sugars)		yes	no
amino acids	many (support, enzymes, etc.)	yes	yes
proteins (polymerized amino acids)		yes	no
phosphate	genetic information	yes	yes
nitrogenous bases		yes	yes
nucleic acids (polymerized sugars, phosphates and nitrogenous bases)		yes	no

- Long polymers absent (single sugars, no proteins)
- No nucleotide nor nucleic acids

Monomers *of building blocks: …what is **not** found*

A. amino acids
B. sugars
C. nucleotides
D. lipids
E. none (all are found)

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X	nucleic acids (polymerized sugars, phosphates and nitrogenous bases)		yes	no

- Long polymers absent (single sugars, no proteins)
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X: building block of life (→ all present in Muchison!)

The importance of the Miller/Urey experiment is

A. It proved beyond doubt that life could have arisen natually on Earth;
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Check by elimination

- proved beyond doubt that life could have arisen natually on Earth?
  - There was no life in this experiment
  - Just amino acids and other organics
- showed that clay can catalyze the production of RNA?
  - Clays were not involved here

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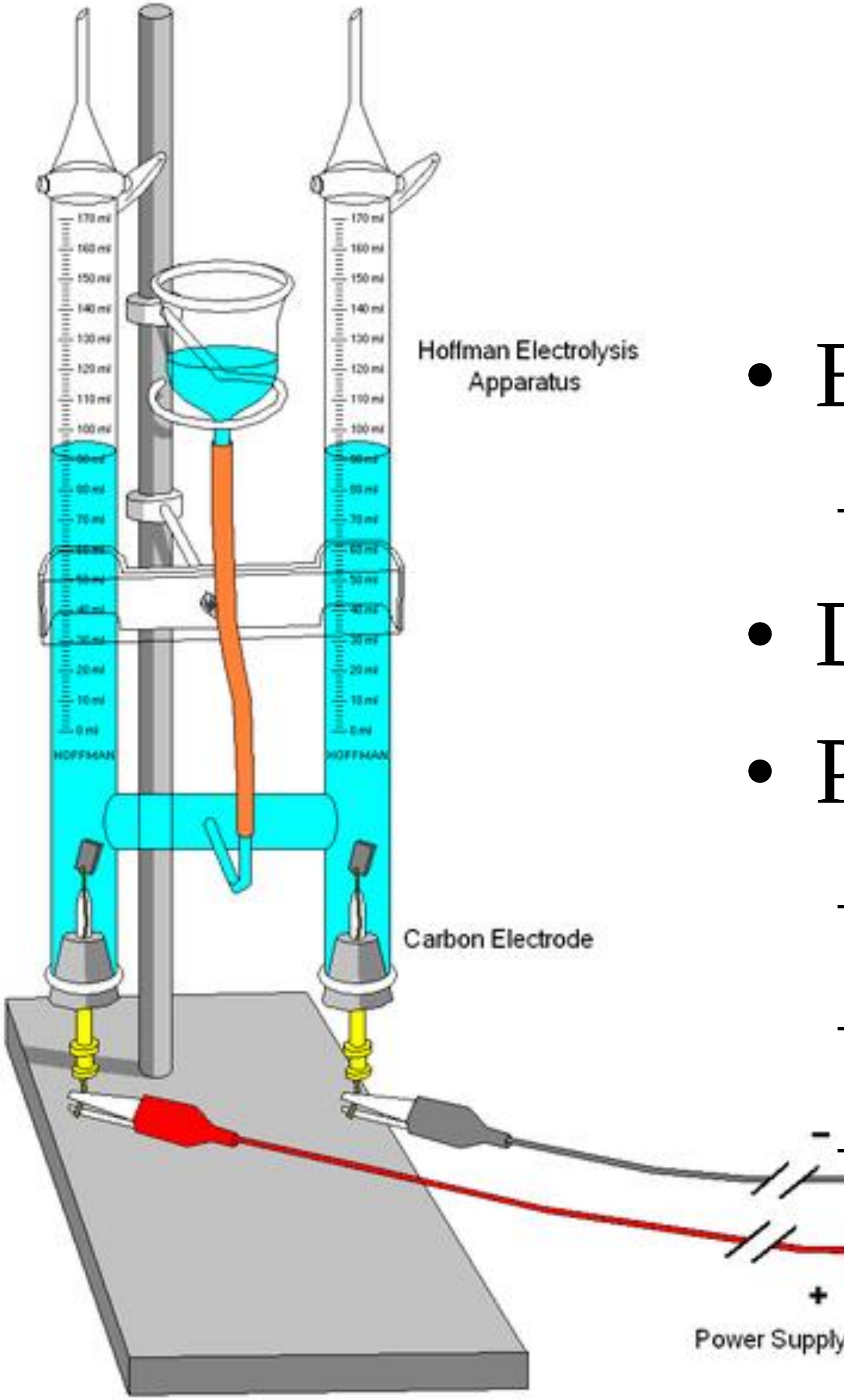
What this really tells us:

- Making many of the building blocks is easy
  - delived from space
  - early atmospheric ?reducing conditions
  - Deep-sea vents (discussed later)
  - Heat & pressure from impacts
- Many possibilities ← no conclusive answ.
- Unclear how to assemble them

What we talked about

- Carbon produced in stars!
- Planetary system made of star dust
- Meteorites deliver amino acids and some of the bases of DNA
- Similar to Miller/Urey experiment
- Organics easy to make → no proofs they have to come from space



Next time

- Electrolysis experiment
  - $2H_2O \rightarrow 2H_2 + O_2$
- Delivery by comets
- Panspermia Reading:
  - RGS pp. 22-24, 28-29
  - Lon pp. 383-384
  - BS pp. 121-125