



Cosmic Chemistry: Cosmogony

Thought Experiments: Tracing Origins

STUDENT HANDOUT

Epoch 8 - Matter condenses: Galaxies, stars planets and life develop

3000 K to 3 K

Epoch 7- Atoms are formed from protons, neutrons. and electrons as temperature decreases

900 million K to 3000 K

Epoch 6 - Atomic nuclei and electrons

900 million K

Epoch 5 - Neutron decay

1 billion K

are free

10¹⁵ K

Epoch 4 - Quarks Epoch 3 - Quarks

are hot!

10²⁸ K to 10¹⁴ K

Epoch 2 - Quarks and anti-quarks dominate

10³² K to 10²⁸ K

Epoch

>10³² K

Epoch 1 - The

Mysterious

Late in the epoch, quarks and electrons are found in H and He atoms

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Early in the epoch, quarks made up H and He nuclei and electrons are separate particles.

300,000 years to 30 minutes

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> Θ **(**

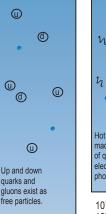
(Quarks make up protons and neutrons in the free nuclei. The universe is 87% protons (with equal numbers of electrons) and 13% neutrons.

30 minutes to 100 seconds

(1) \bigcirc \rightarrow \bigcirc **(II)** \oplus (10) At beginning of this epoch, number of (1)

protons equals number of neutrons so same number of up quarks and down quarks exist. As neutrons decay into protons, there are more up quarks than down quarks.

100 seconds to 10⁻³ seconds

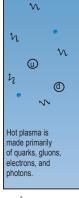


10⁻³ seconds to 10⁻⁶ seconds

Up and down

free particles.

quarks and



 10^{-6} seconds to 10⁻³³ seconds



 10^{-33} seconds to 10^{-43} seconds

??? 10⁻⁴³ seconds

universe.

electrons are found

superstructures in

Quarks and

in atoms of

all parts of the

15 billion years to 300,000 years

Time -

15 billion years