

Chemistry and the Earth

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How were the elements made?

How stars make elements.

http://www.valdosta.edu/~cbarnbau/astro_demos/stellar_evol/home_stellar.html

Low mass - do #3 first, then #2

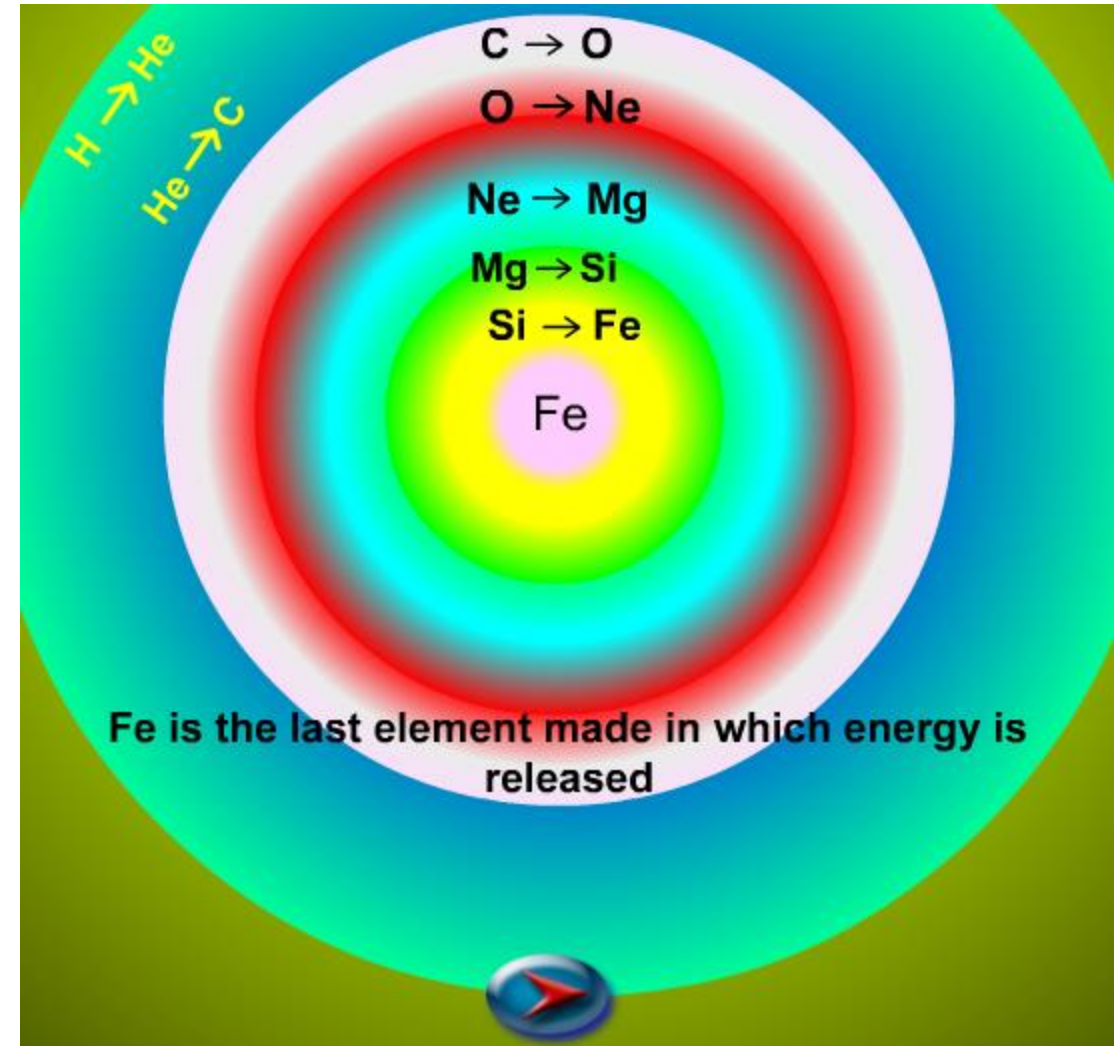
High mass - to supernova



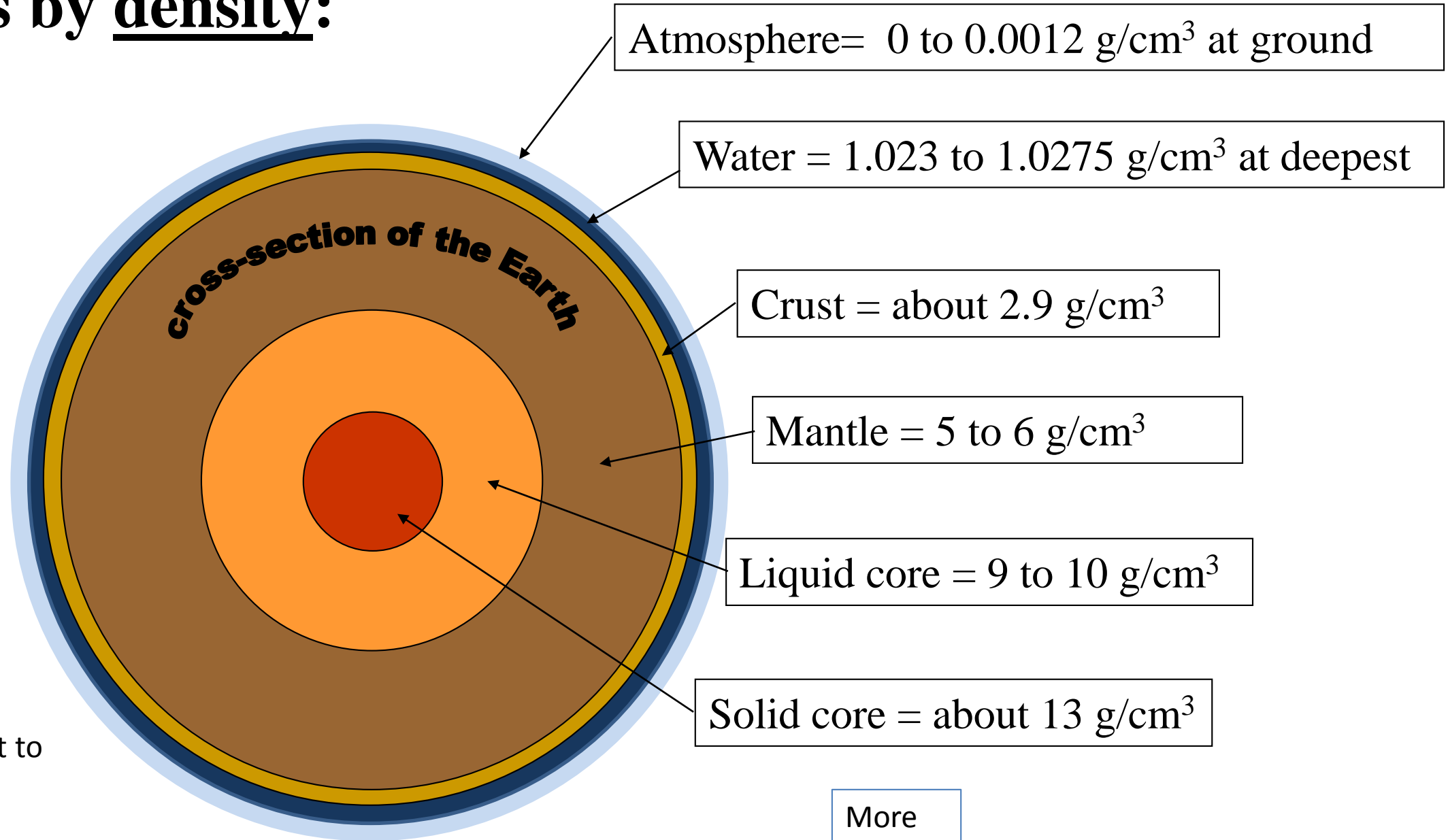
How elements come together to make sun & solar system.

http://www.valdosta.edu/~cbarnbau/astro_demos/stellar_evol/home_stellar.html

#1 star forms - good for solar system formation



Parts of the Earth system are generally arranged in layers by density:



Drawing not to
exact scale!

More

In what form do we find the elements?



- ▶ Minerals are naturally-occurring crystalline solids, composed of one or more elements in a specific ratio, formed by inorganic processes. Briefly, they are naturally occurring chemical compounds.
- ▶ Rocks are a natural aggregate of one or more minerals, or any essential or appreciable part of the solid Earth.

Mineral compositions

How would you generalize this?

quartz SiO_2

feldspars: K-feldspar..... KAlSi_3O_8

plagioclase..... $(\text{Na,Ca})\text{Al}(\text{Al,Si})\text{Si}_2\text{O}_8$

mafics: amphibole..... $\text{Ca}_2(\text{Mg}_4\text{Al})(\text{Si}_7\text{Al})\text{O}_{22}(\text{OH})_2$

pyroxene..... $\text{Ca}(\text{Mg,Fe,Al})(\text{Al,Si})_2\text{O}_6$

olivine..... $(\text{Mg,Fe})_2(\text{SiO}_4)$

micas: muscovite..... $\text{KAl}_2(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_2$

biotite..... $\text{K}(\text{MgFe})_3(\text{Al,Fe})\text{Si}_3\text{O}_{10}(\text{OH,F})_2$

calcite..... CaCO_3

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olivine.....

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Most are silicates =
silicon + oxygen

Plus a metal like Na, Ca, K,
Mg, Fe, Al

Or a carbonate →

Element abundance in Earth's crust – 8 most abundant

<u>Element</u>	<u>Weight %</u>	<u>Atom %</u>	<u>Volume %</u>
O	46.6%	62.6%	93.8%
Si	27.7	21.2	0.9
	8.1	6.5	0.5
	5.0	1.9	0.4
	3.6	1.9	1.0
	2.8	2.6	1.3
	2.6	1.4	1.8
	<u>2.1</u>	<u>1.8</u>	<u>0.3</u>
Totals for 8	98.5%	99.9%	100.0%

Relative volumes of Si and O in SiO_4 tetrahedron

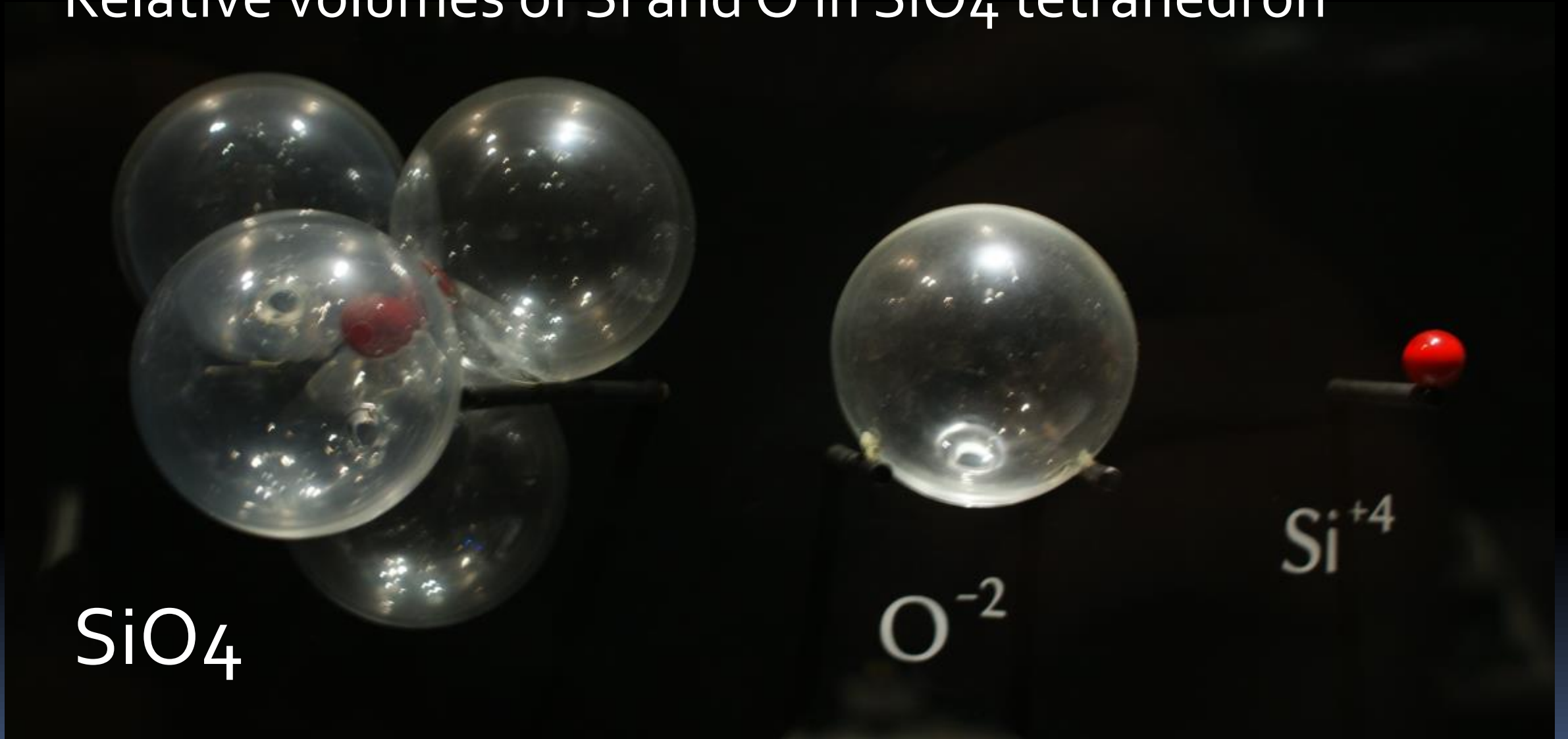


Photo by Martin Schmidt at Carnegie Museum, Pittsburgh, PA

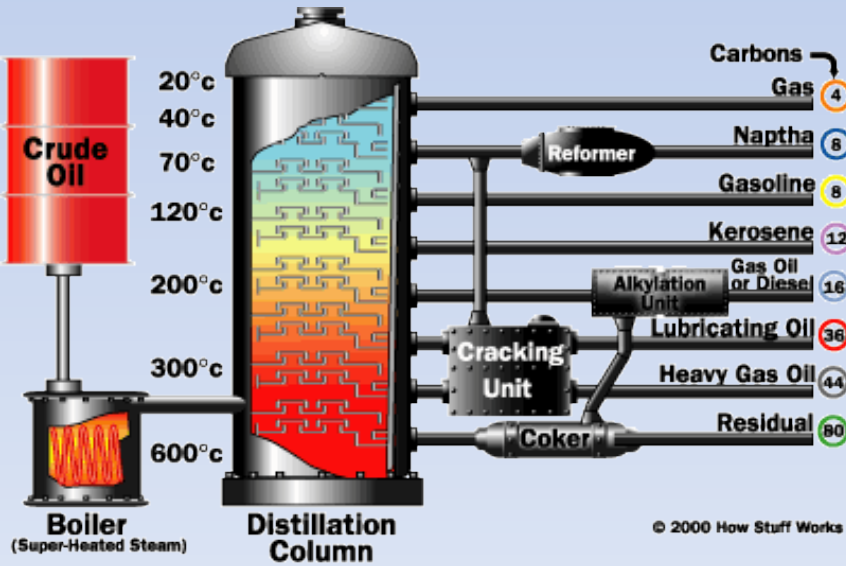
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Refineries – separating & concentrating materials



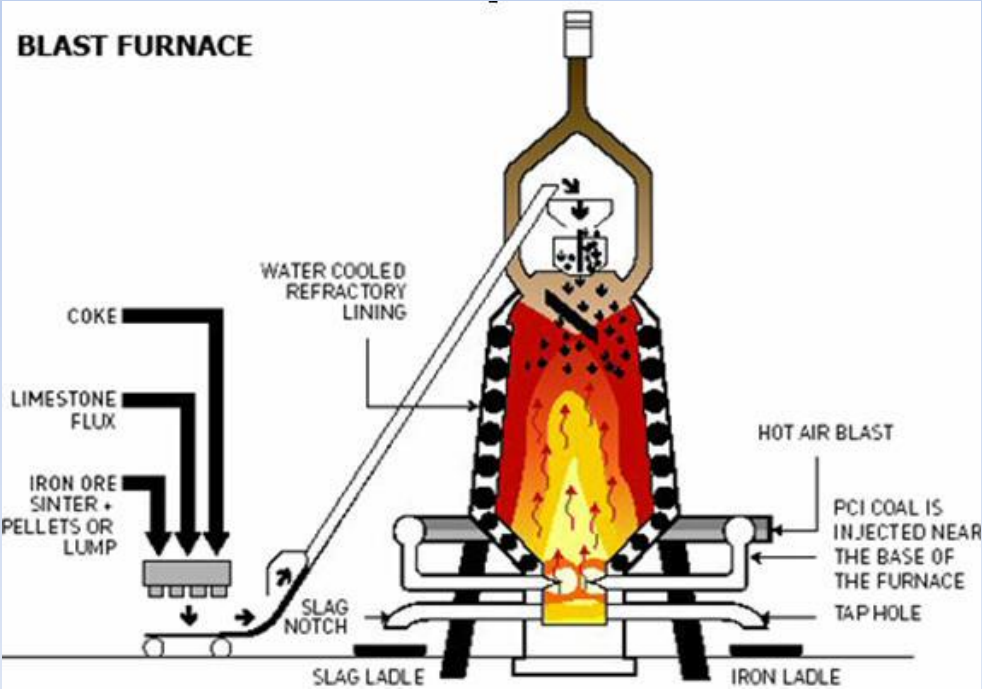
Oil and gas



Separates mainly by condensation/boiling points



Metal ores

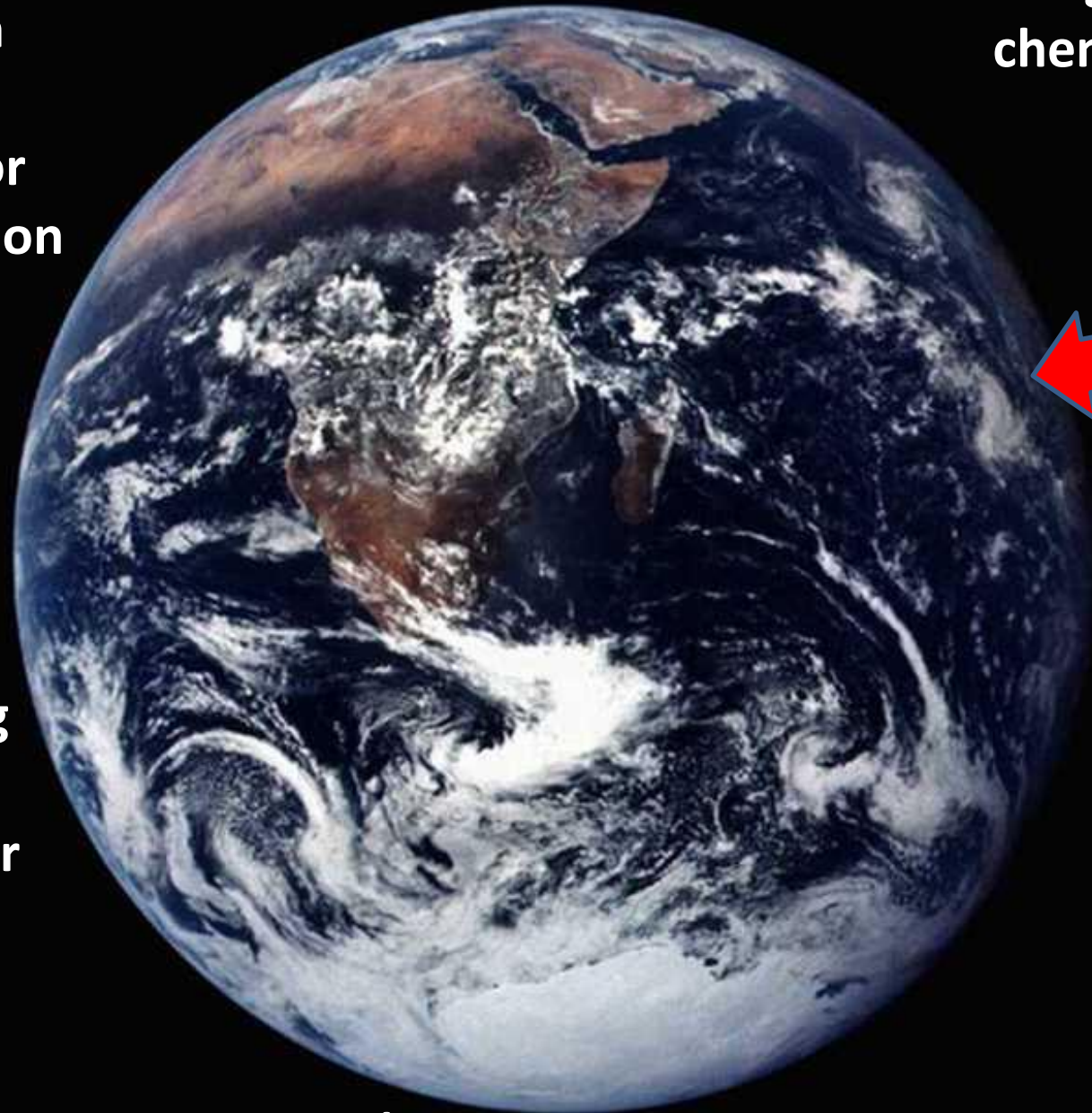


Separates mainly by density

**A refinery in
continuous
operation for
nearly 5 billion
years.**

**Separating &
concentrating
the materials
from the solar
nebula.**

**Separates by density, melting/freezing points, and other chemical
properties.**



**A big ball of
chemicals!!**



Chemical Evolution of the Earth

- As molten Earth cooled, last liquid fraction of **mantle** material solidifies as **basalt** surface.
- Outgassing of air & water covers entire planet in ocean.
- Motion of **basalt** surface causes subduction → partial melting makes **granite**, which floats higher on mantle to make continents.
- Magma with water rising through continents partially melt **granite** to give mineral-rich **pegmatites**.
- Increase in oxygen in air leads to **oxides** and **hydroxides**.

Magma composition is Life or Death!!



Low-silica basaltic magma is runny, so it doesn't trap gas and explode. Safe to watch, with care.

Source: <http://www.virtualuppermantle.info/Volcano-Mauna-Loa.htm>



High-silica granitic magma traps gas then explodes. These volcanoes are killers.

Source: https://www.geocaching.com/geocache/GC2DF5V_soufriere-hills-stratovolcano?guid=411aaeb-0502-406c-84f4-26c3f375a3f7

The chemistry of the magma controls its behavior and the volcano's effect on people.

Chemical Weathering Types

1. Carbonation:

$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$ (carbonic acid, a weak acid, from rainwater)

and solution:

$\text{H}_2\text{CO}_3 + \text{CaCO}_3$ (solid calcite) $\rightarrow 2\text{HCO}_3^- + \text{Ca}^{2+}$ (dissolved in water)

2. Oxidation: $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$

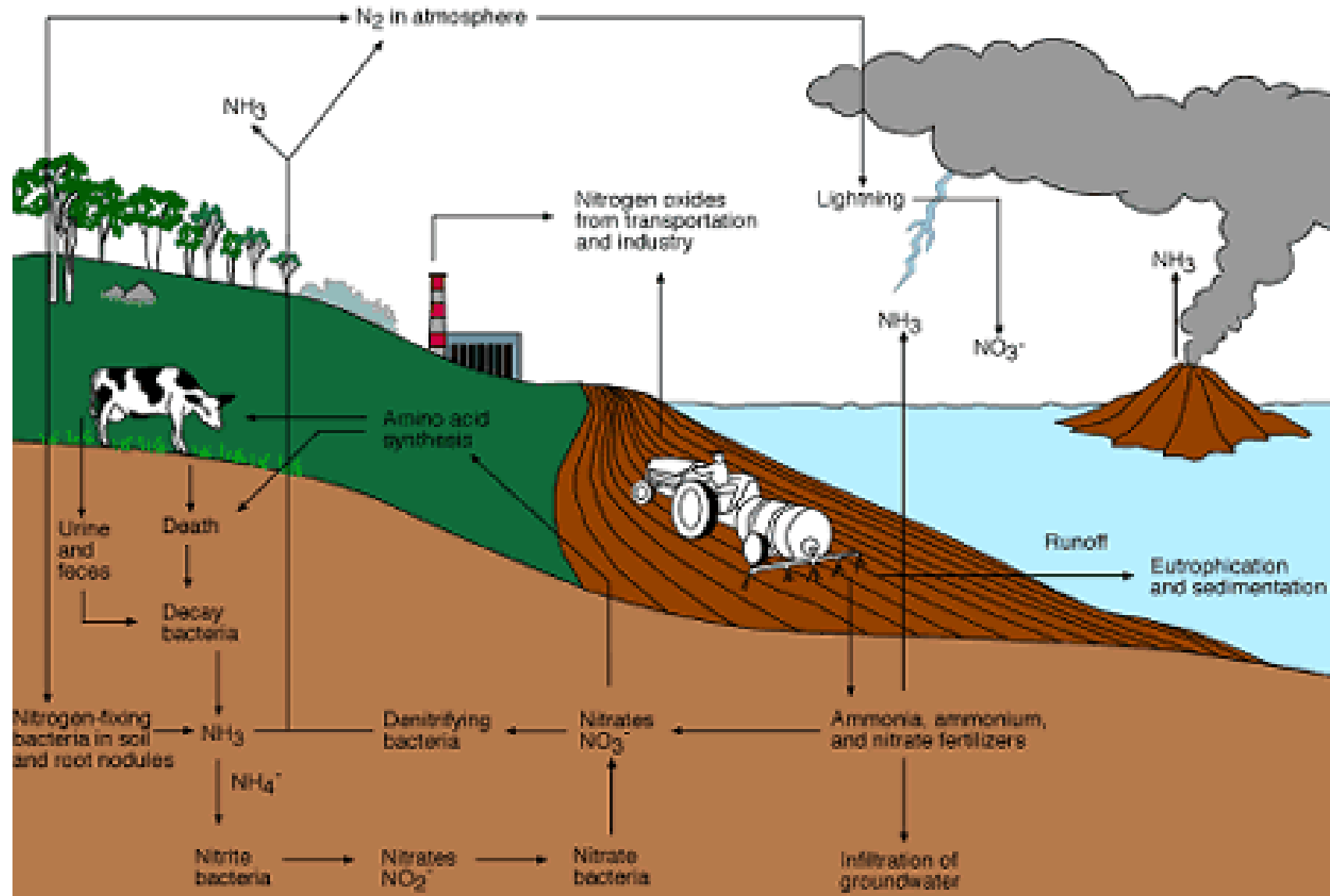
3. Hydrolysis:

Feldspar + carbonic acid \rightarrow clay minerals + silica (dissolved) + K^+ + Na^+ + other ions
in solution

Mafic mineral + water \rightarrow Mg and Fe oxides + OH^- + silica (dissolved)

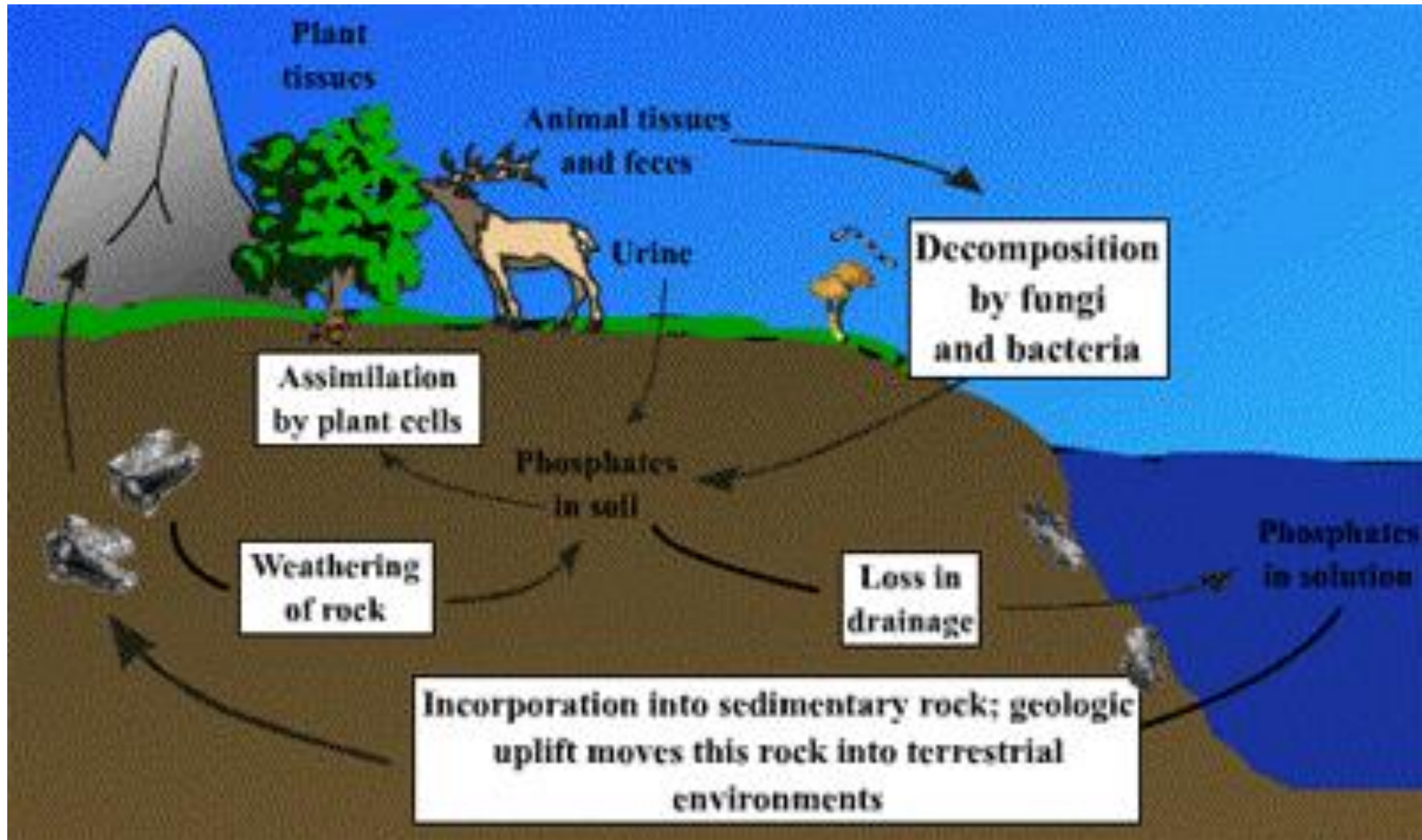
**No life would exist without these weathering reactions
because they release elements from rocks!**

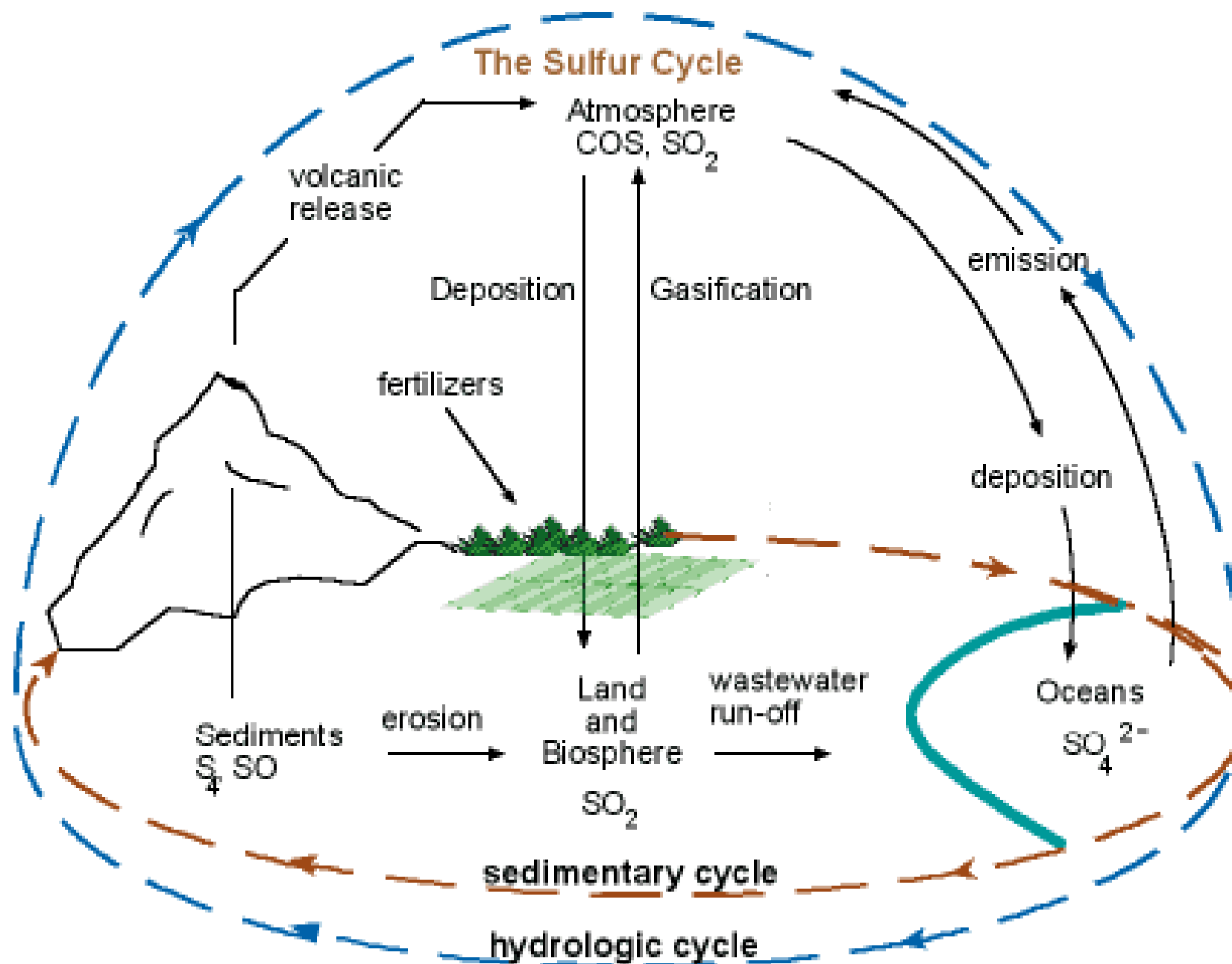
Nitrogen Cycle - a biogeochemical cycle



<http://web.ead.anl.gov/ecorisk/ind>

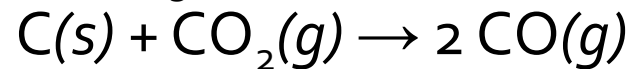
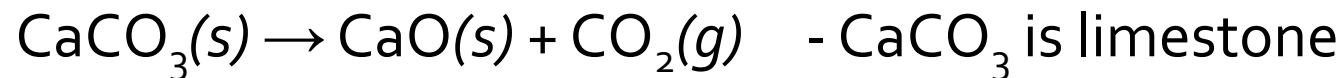
Phosphorus Cycle



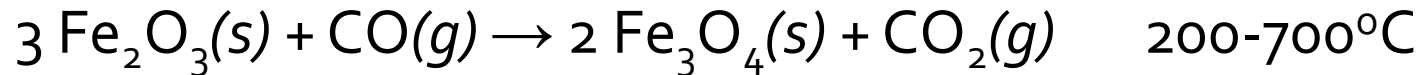


Refining Iron

- Sources of CO:



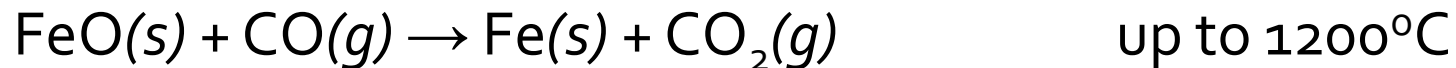
- Refine the iron ore (iron oxides + silicates) at increasing temperatures in a blast furnace:



hematite

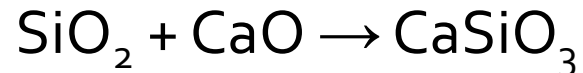


magnetite



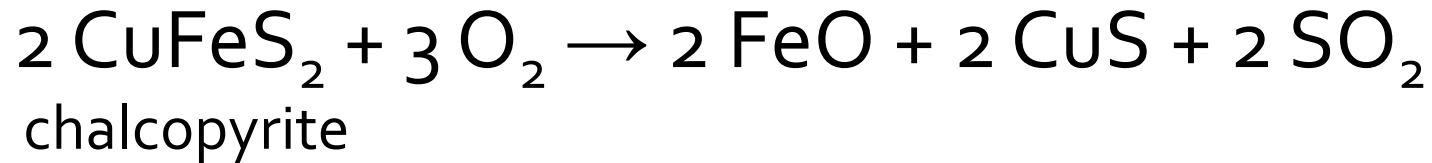
- Makes “pig iron”, which is further refined to make steel.

- Waste carried off in slag:

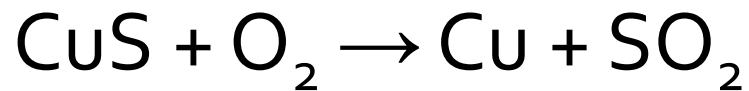
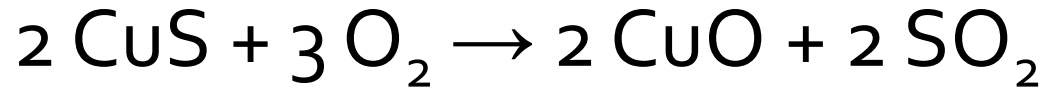


Refining Copper – starting chemical processes

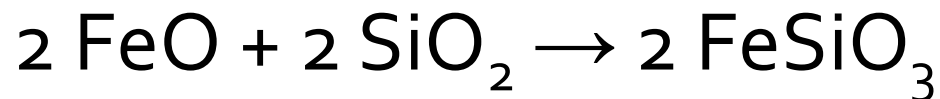
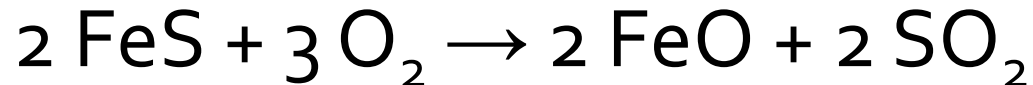
- Smelting process – add heat to get:



- Then these make copper “blister”



- These make slag:



Overall - Lots of Earth chemistry to learn!

- **Atomic-scale chemistry:**

- What are minerals and rocks made of?

- What reactions occur with these materials?

- **Earth-scale chemistry:**

- What is the chemistry (rock) under my feet? A geologic map is a chemistry map! How did plate tectonics create it?

- How have plate tectonics and other internal processes acted like a chemical refinery to form the materials we find today?

- **Wow! What a fascinating broadening of our chemistry course!**