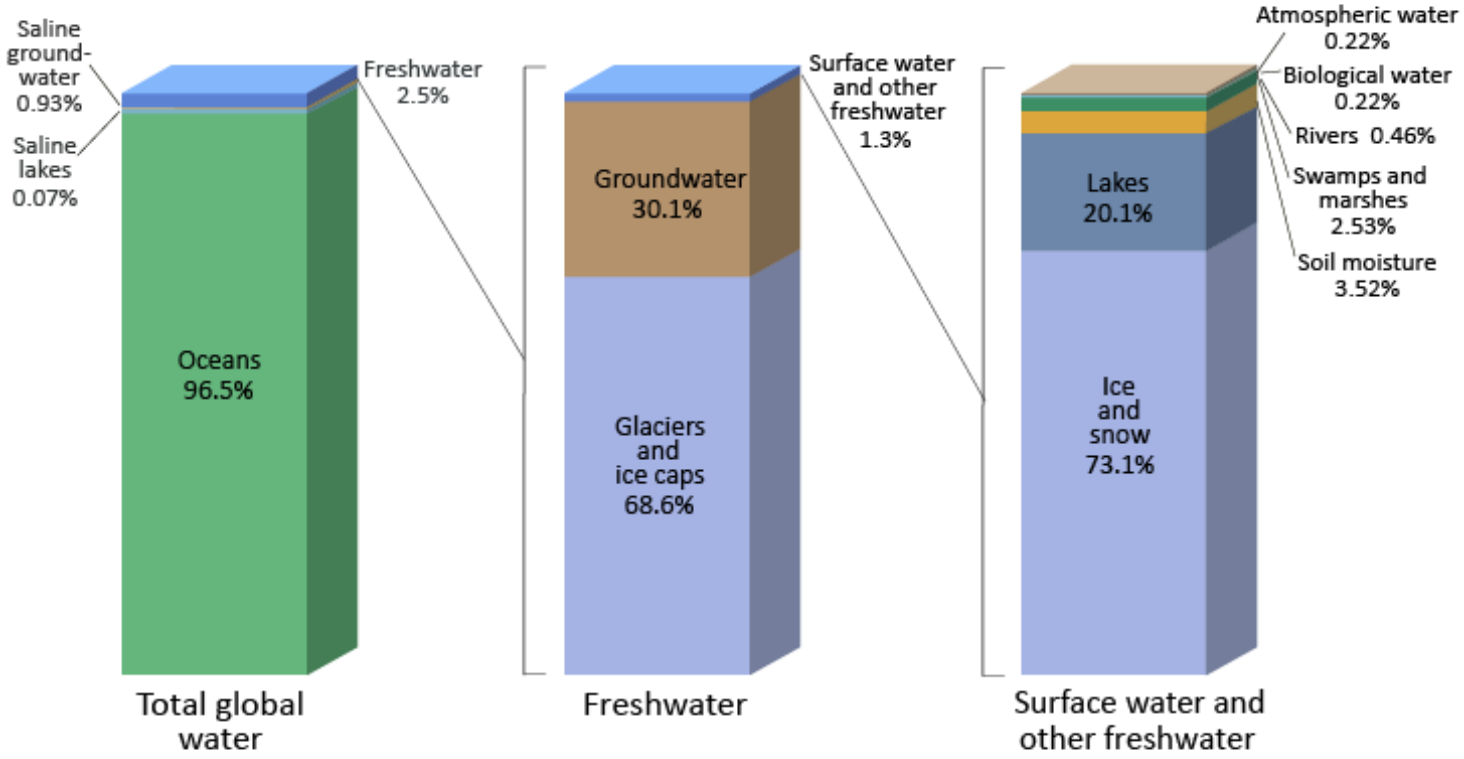
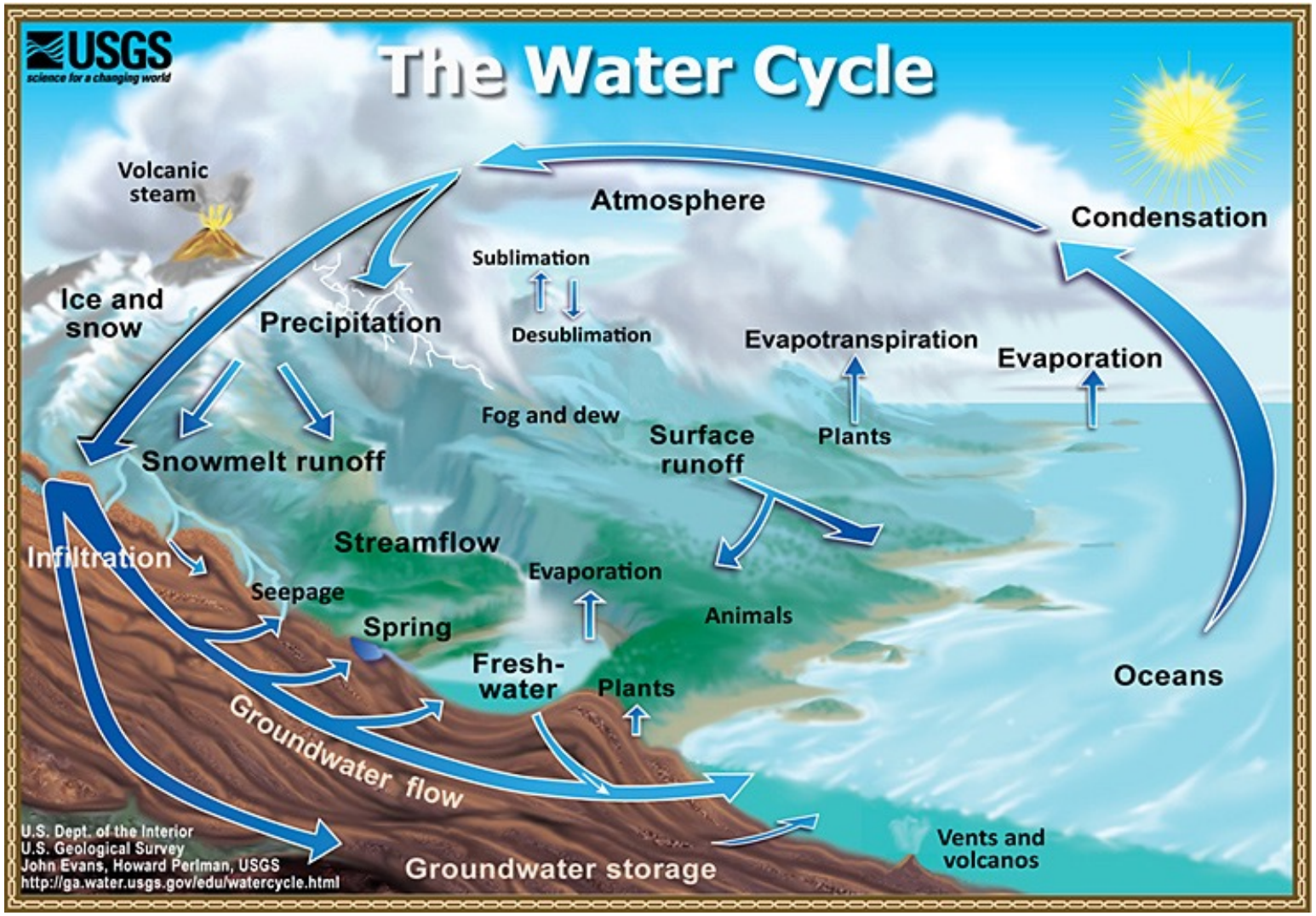
(Reservoirs)

Distribution of Earth's Water

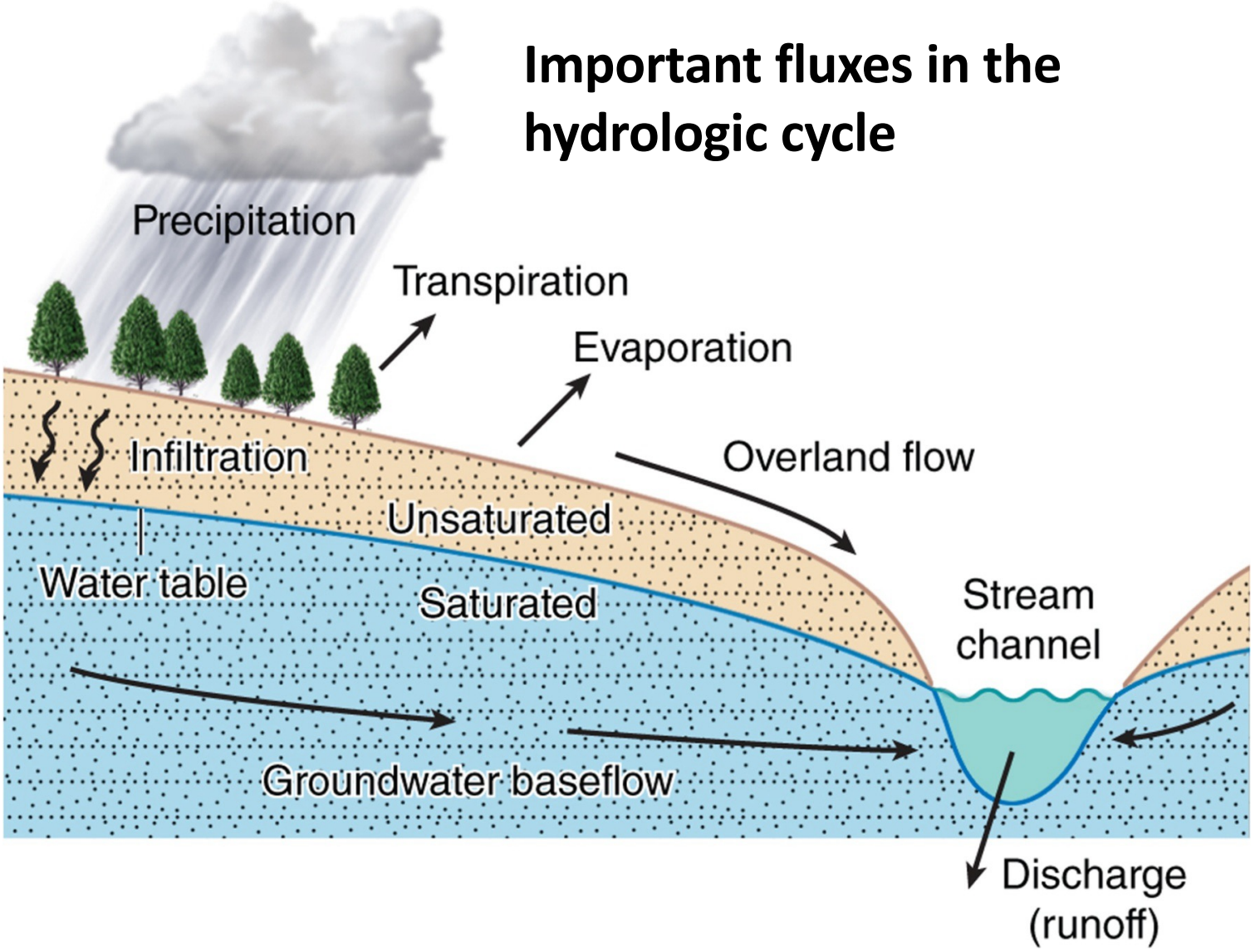


Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.

How does water move across the Earth?

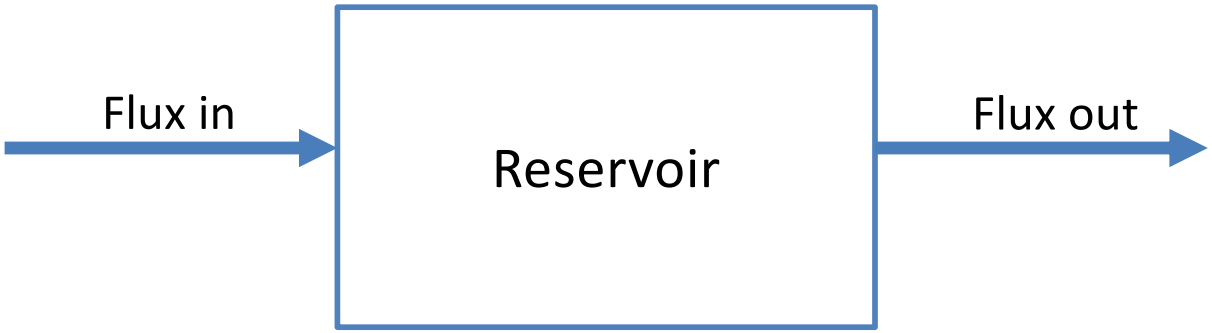


Important fluxes in the hydrologic cycle



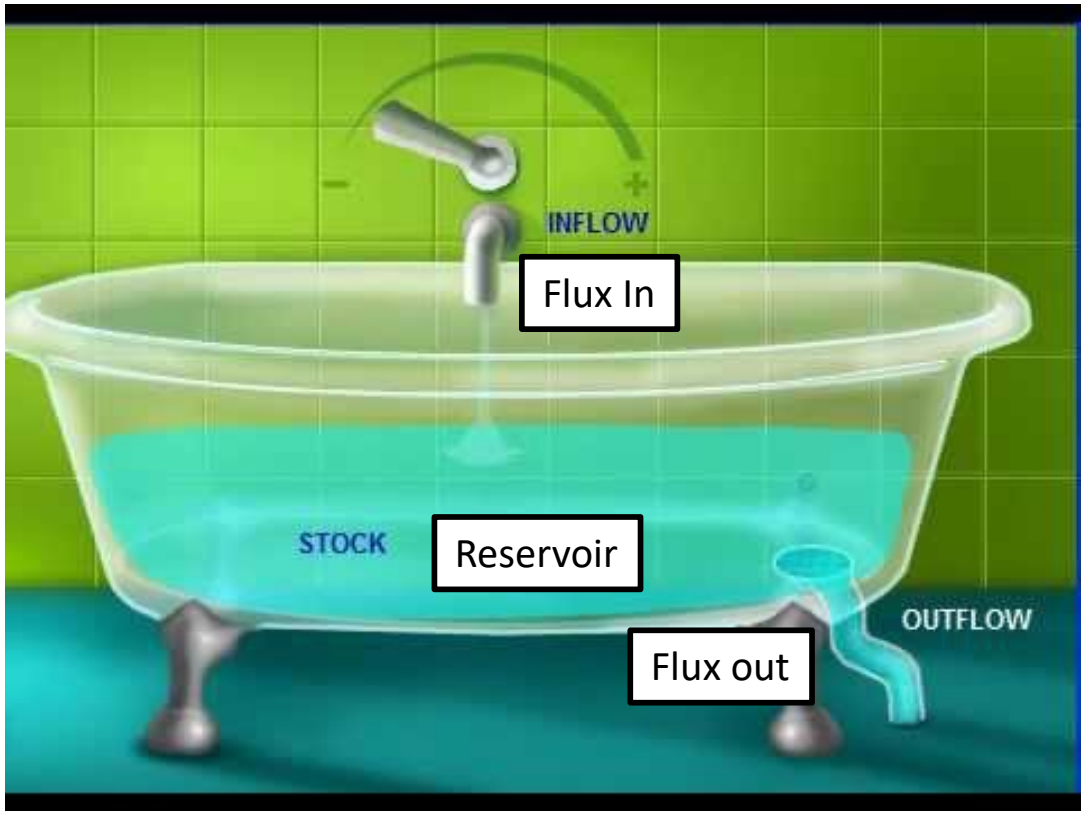
Understanding water transport through the environment

Box models (mass balance models) can be used as simple representations of complex systems



- ***Reservoir*** – an arbitrarily defined space containing a certain mass of a substance of interest
- ***Flux*** – transfer of material into and out of a reservoir
- ***Steady-state*** – describes a system where the amount of substance in a reservoir does not change with time (fluxes are balanced)
- ***Residence time*** – under steady-state conditions, the average amount of time a molecule of the substance of interest spends in a reservoir; calculated as the reservoir mass divided by input OR output fluxes

“Bathtub analogy”



https://www.youtube.com/watch?v=7Nt0v4YAAVg

Are these groundwater reservoirs in steady state?

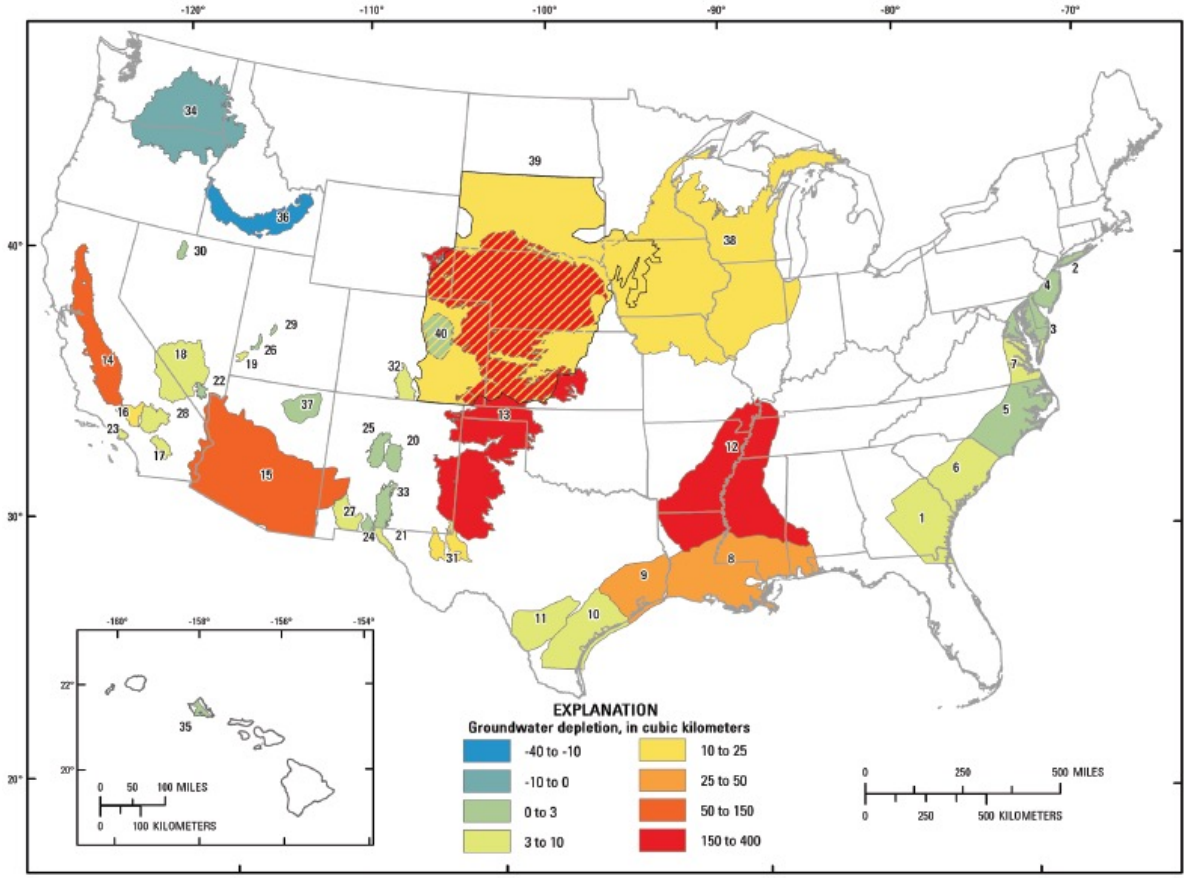
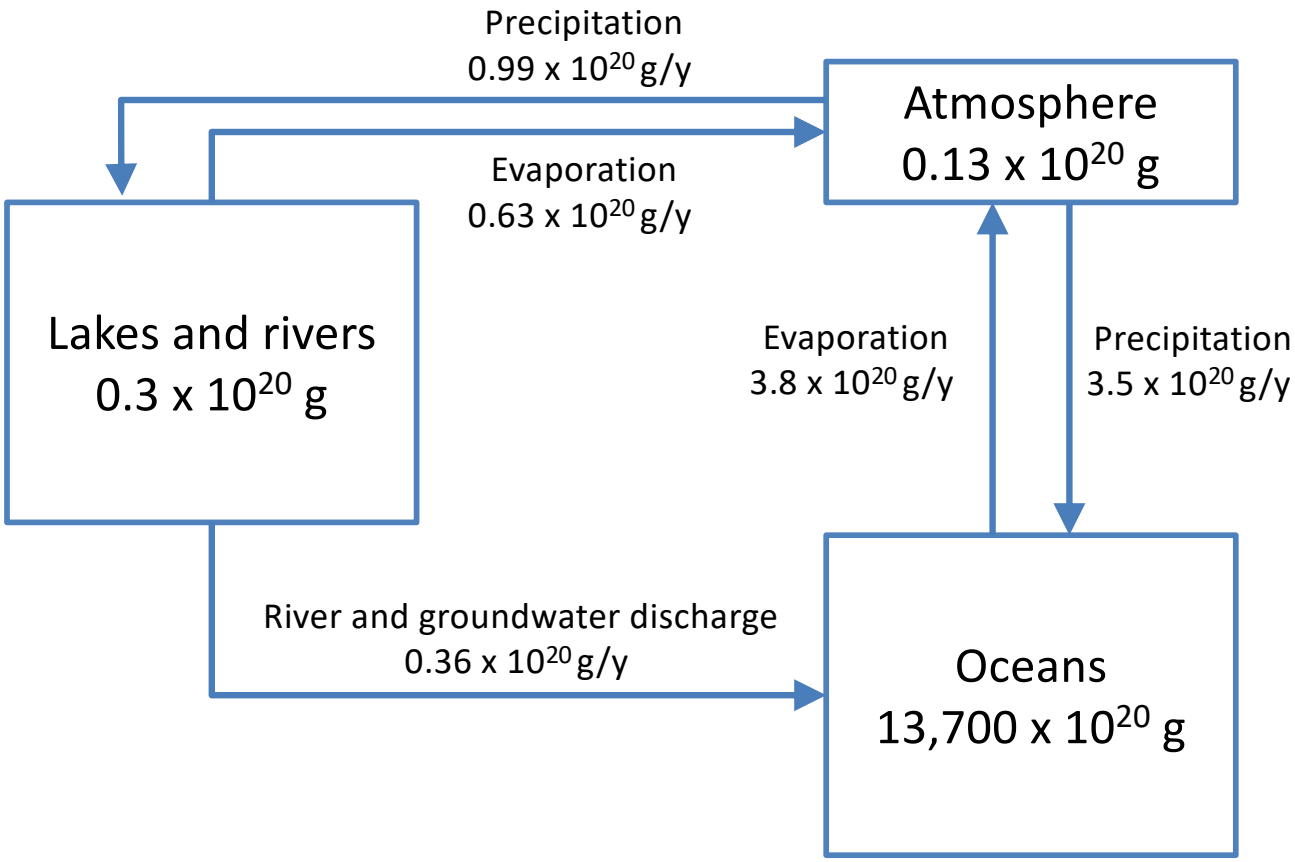


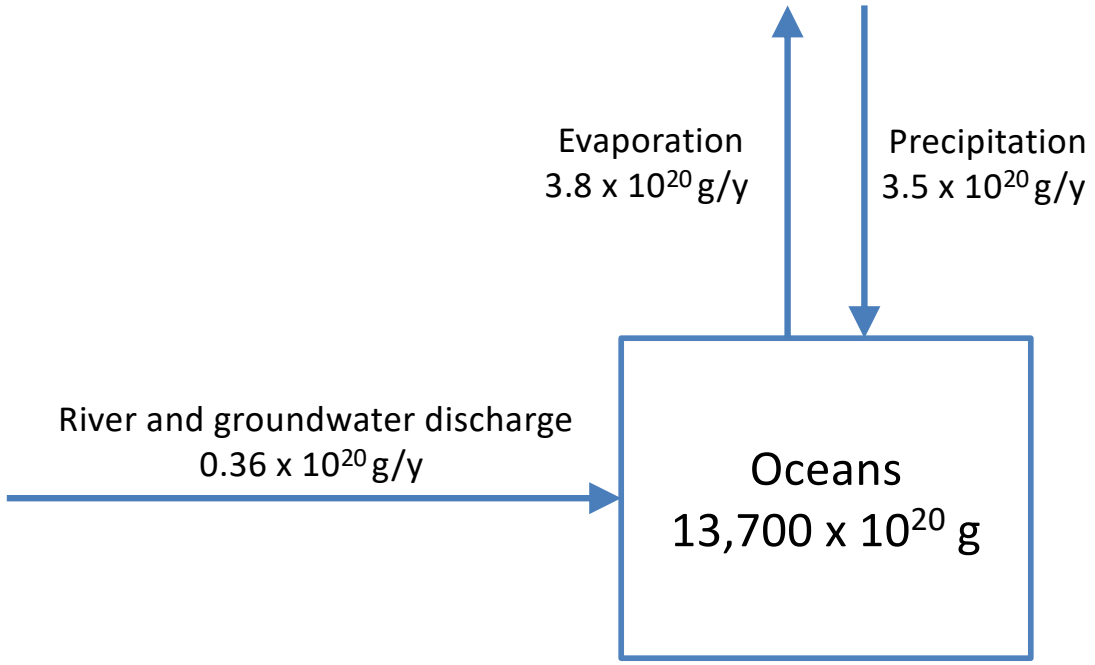
Figure 2. Map of the United States (excluding Alaska) showing cumulative groundwater depletion, 1900 through 2008, in 40 assessed aquifer systems or subareas. Index numbers are defined in table 1. Colors are hatched in the Dakota aquifer (area 39) where the aquifer overlaps with other aquifers having different values of depletion.

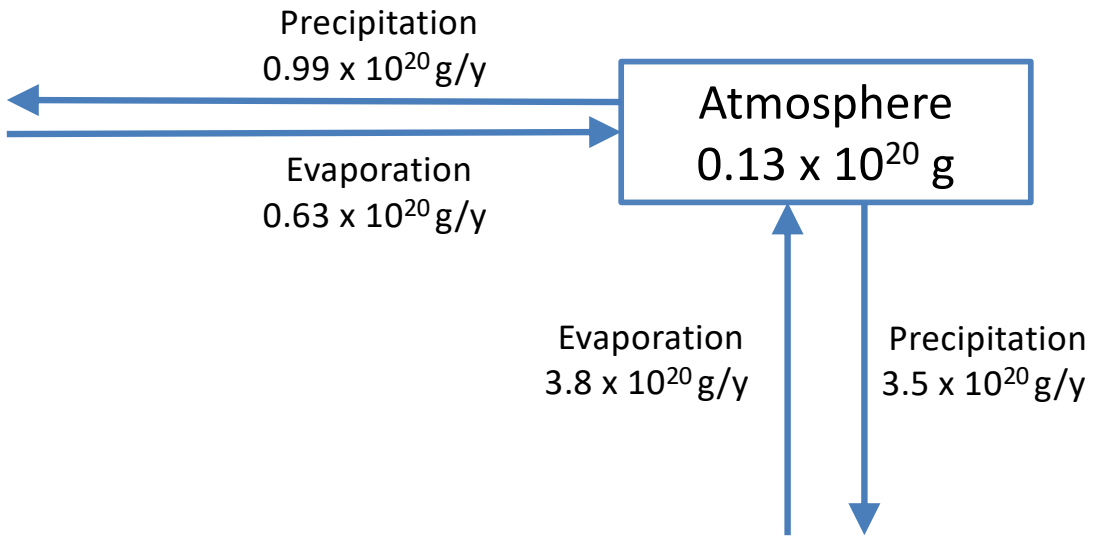
The Hydrologic Cycle: Simple Box Model for Water



What is the **residence time** of a water molecule in the ocean?

**assuming the mass of water in the oceans is at steady-state, i.e. does not change over time*



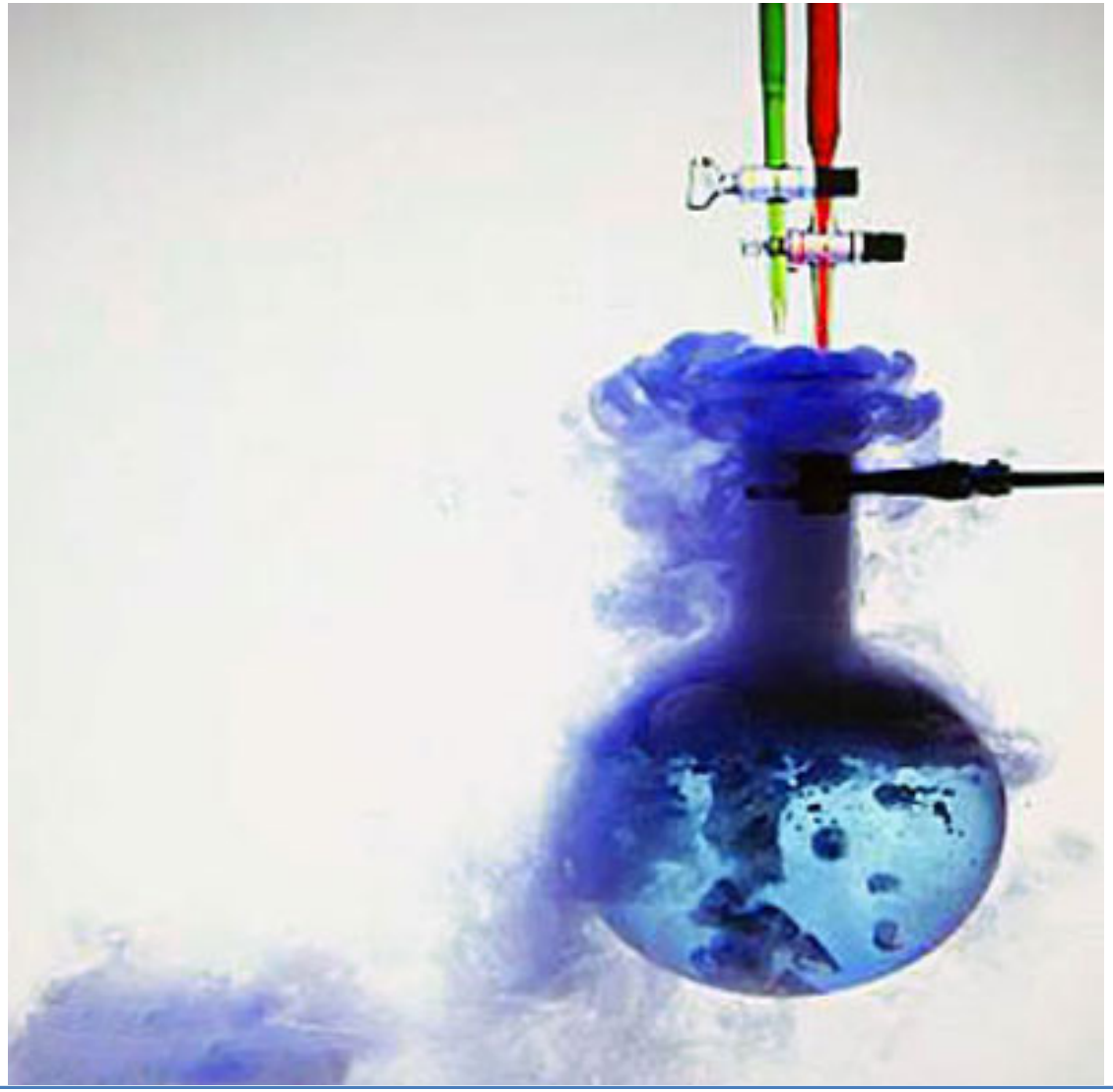


What is the **residence time** of a water molecule in the atmosphere?

**assuming the mass of water in the atmosphere is at steady-state, i.e., does not change over time*

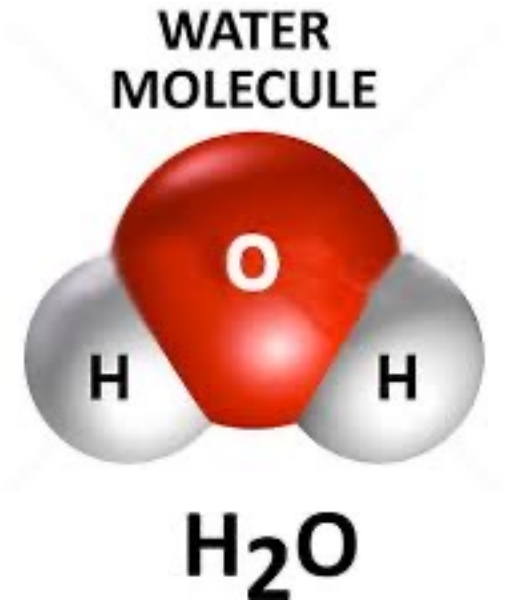
Chemical Reactions

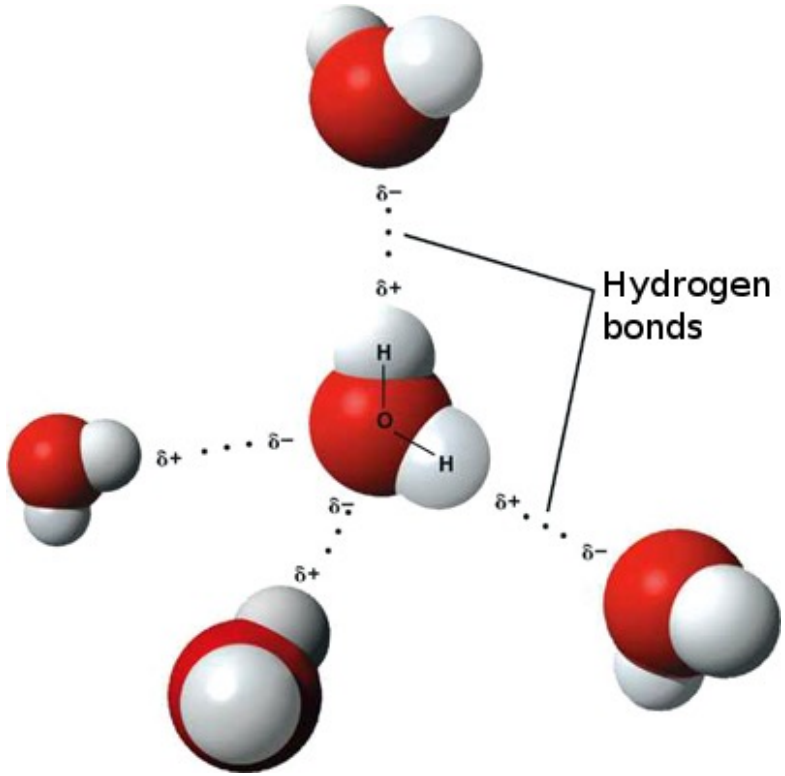
- Water
- The Periodic Table
- Unit Conversion
- Types of chemical reactions



Properties of water

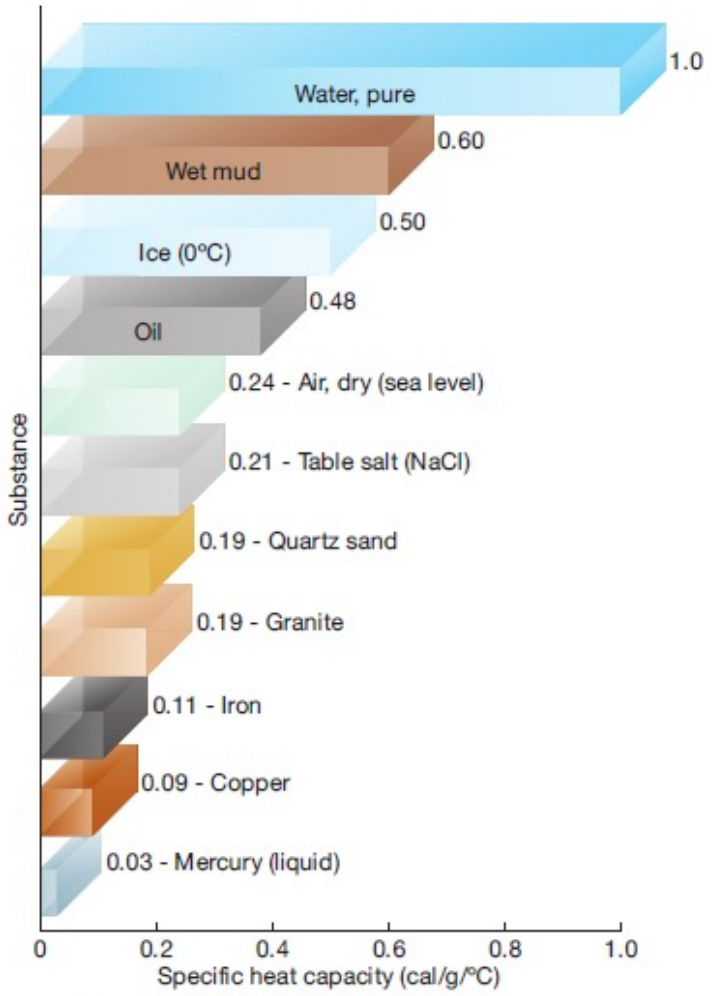
1. Dipolar
2. Hydrogen bonds
3. Strong cohesive and adhesive nature
4. High heat capacity
5. Low density (especially frozen)
6. Universal solvent
7. Participates in and facilitates chemical reactions





Properties of water

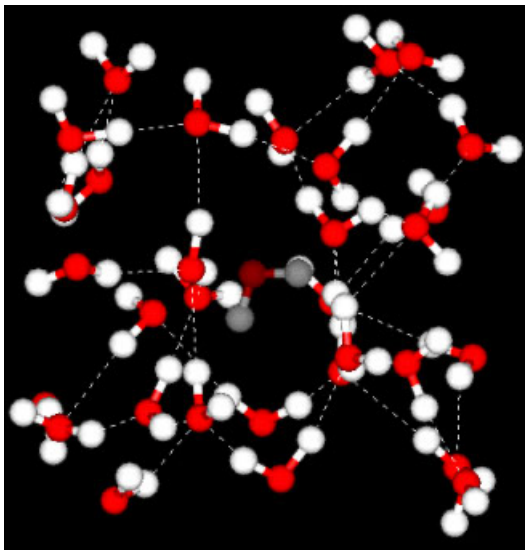
- Water has a high *specific heat capacity* relative to other substances



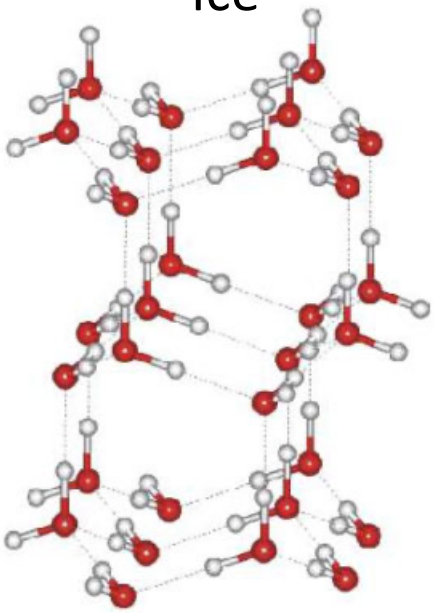
Properties of water

- Low density, especially when frozen

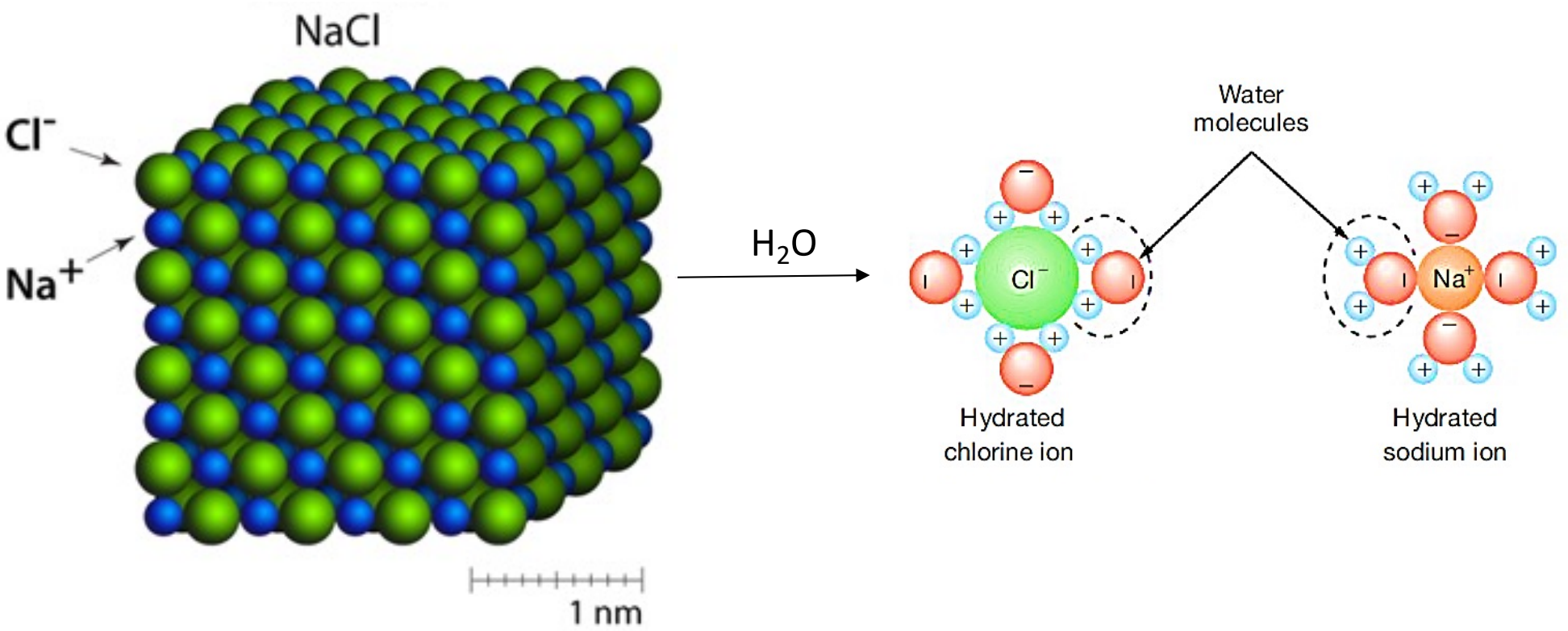
Liquid Water



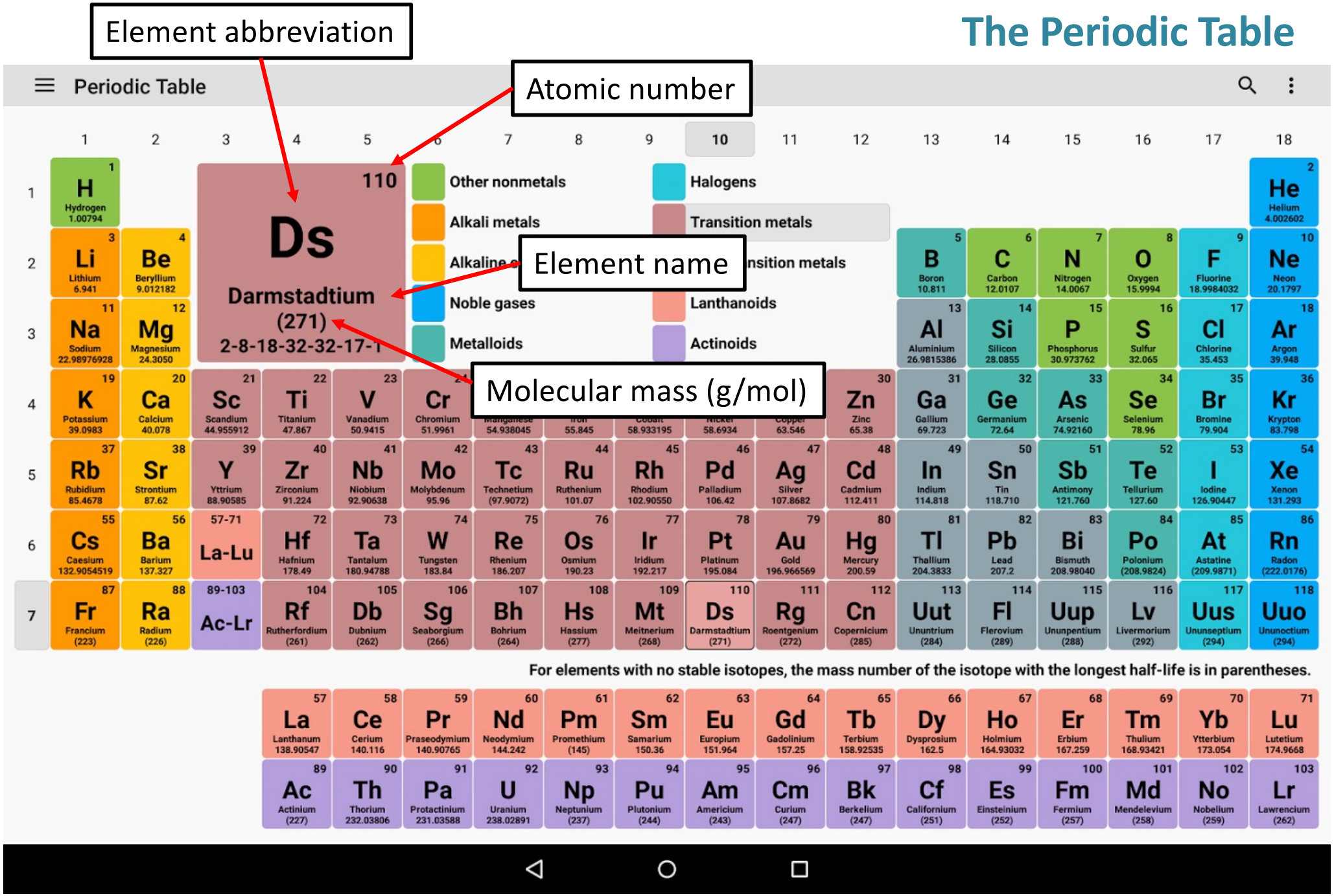
Ice



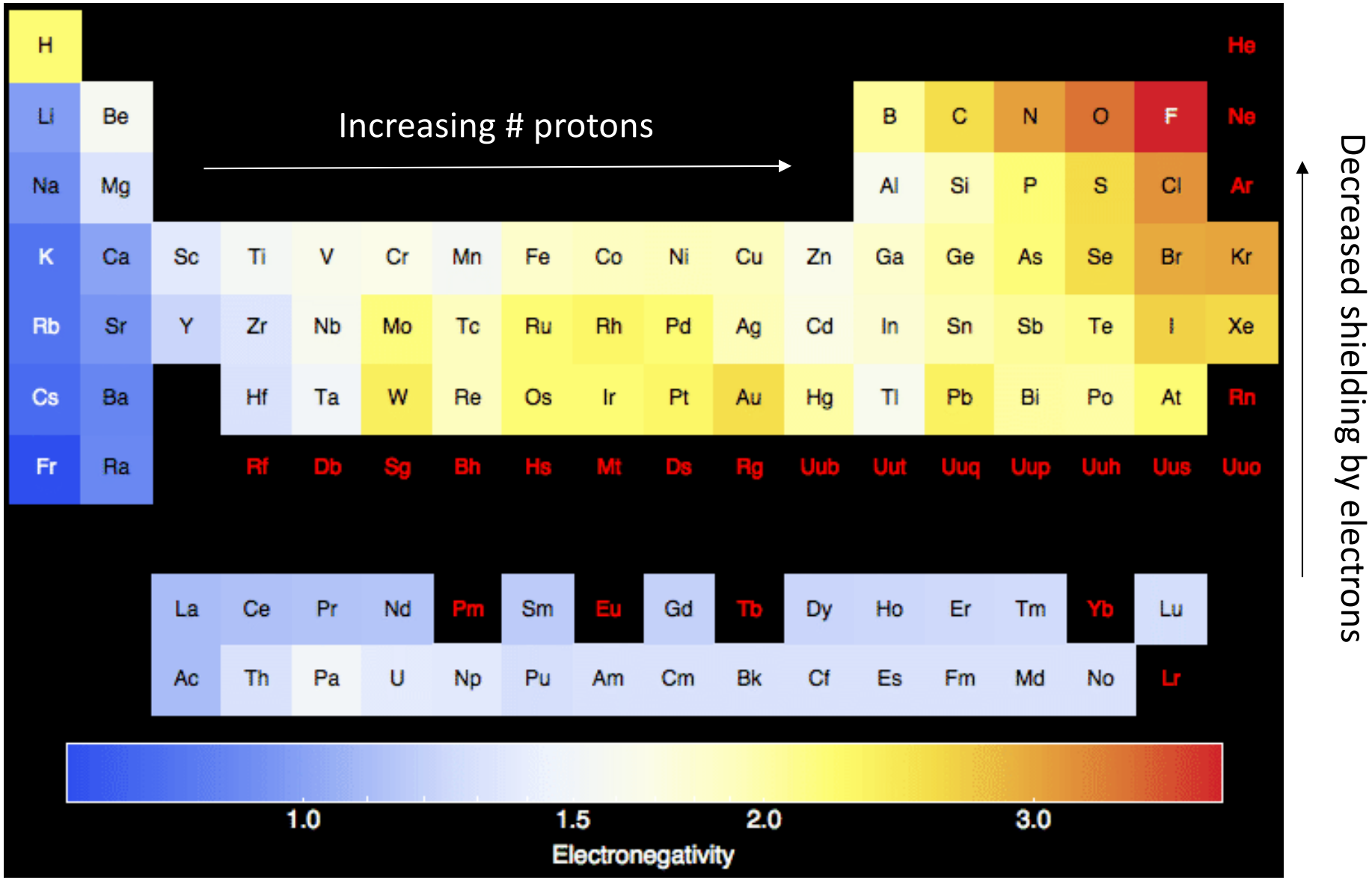
Rocks and minerals dissolve in water to form ions, which sometimes precipitate to form new minerals



The Periodic Table



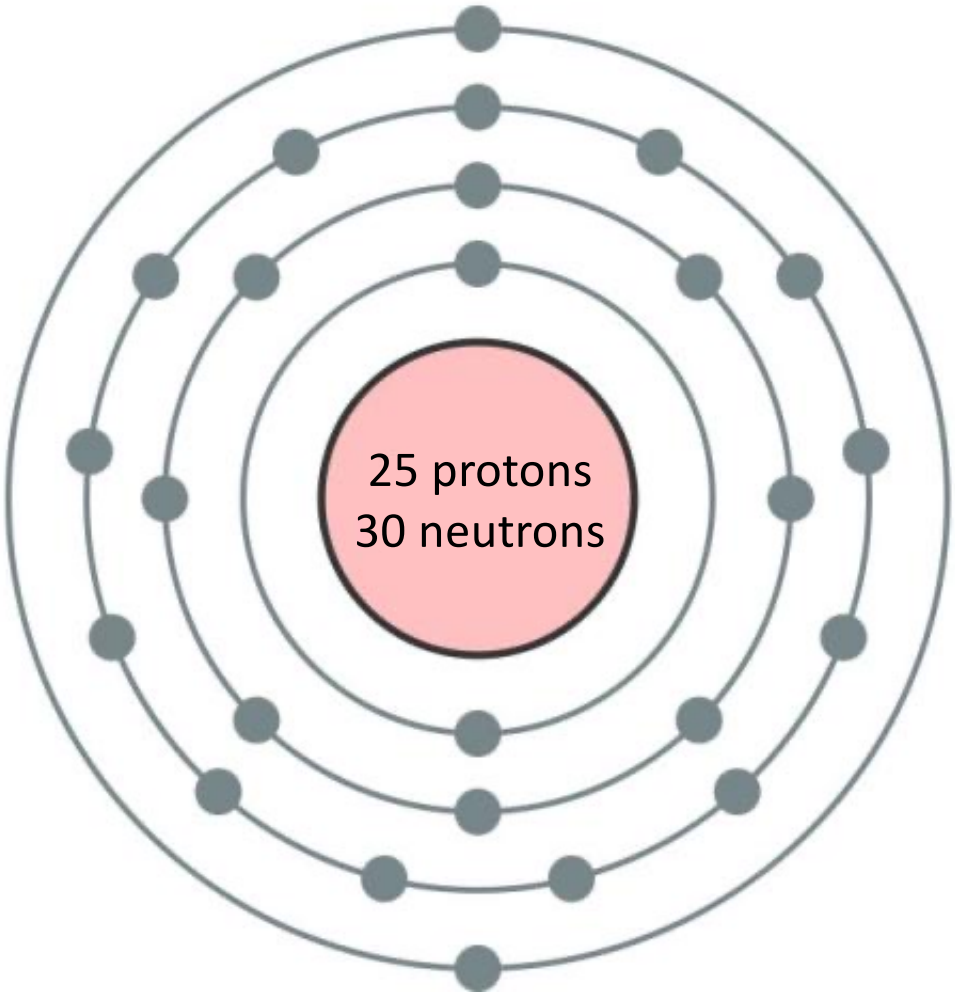
- Most elements gain and lose electrons to become more stable
- ***electronegativity*** is the ability of elements to attract electrons to themselves



Elements lose and gain electrons to form different ***oxidation states***

Manganese
25
Mn
54.938

25 electrons



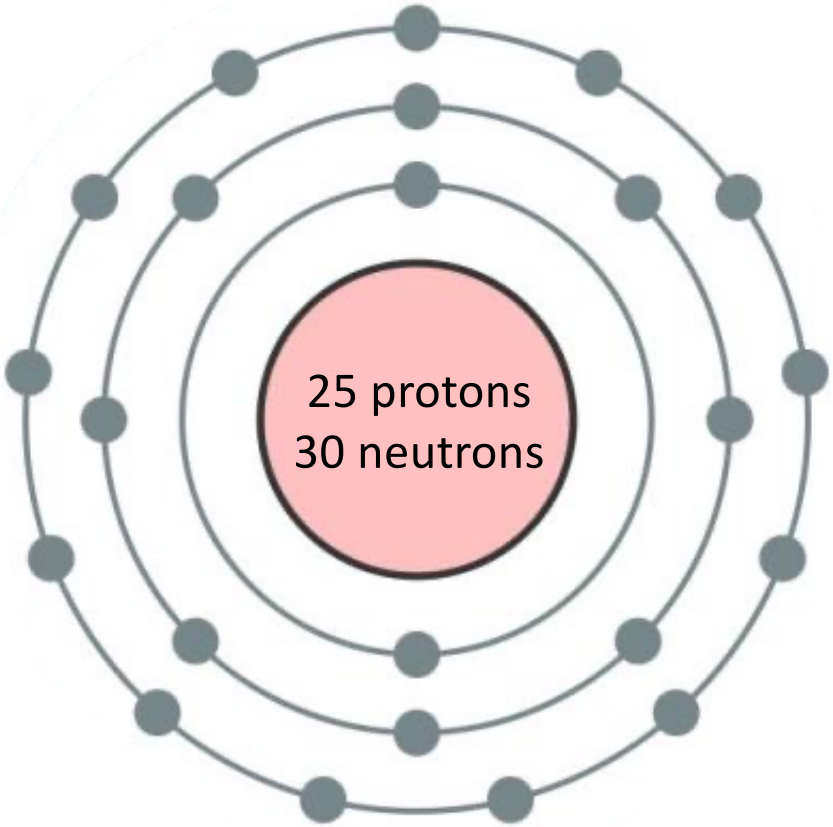
Metallic Mn – equal number of protons (+) and electrons (-)
Oxidation state = 0

Refer to the note

Elements lose and gain electrons to form different ***oxidation states***

Manganese
25
Mn
54.938

23 electrons



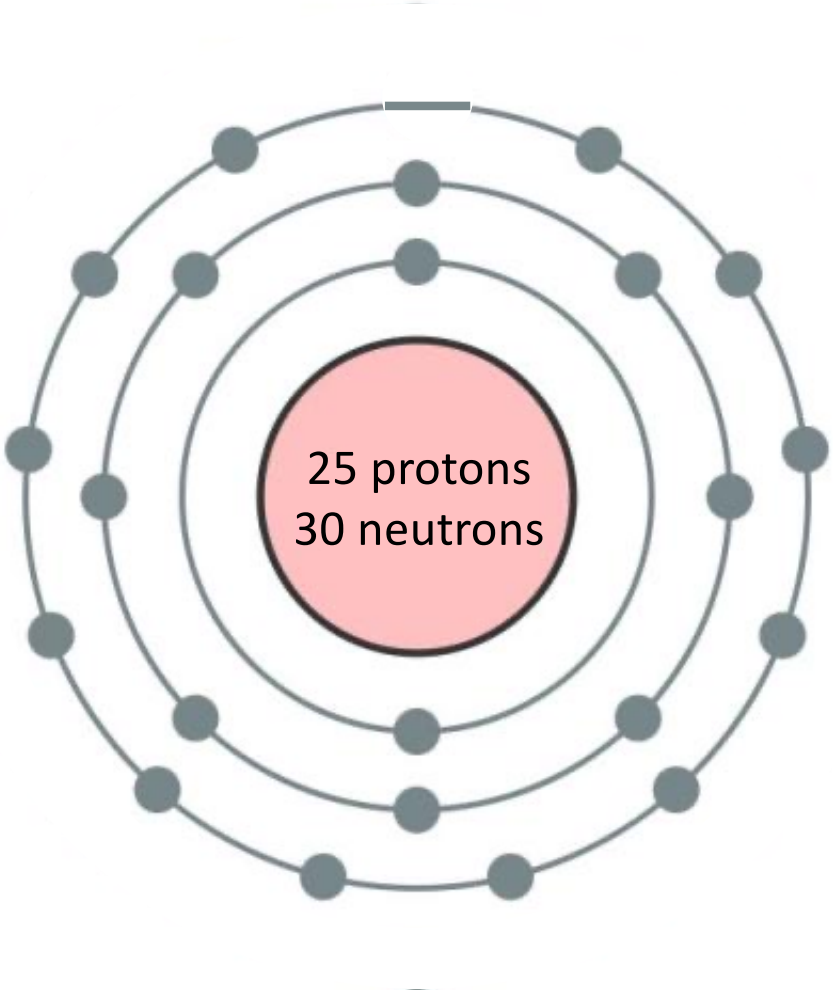
Mn^{2+} – gives up 2 electrons to create charge deficit

Oxidation state = +2

Elements lose and gain electrons to form different ***oxidation states***

Manganese
25
Mn
54.938

22 electrons

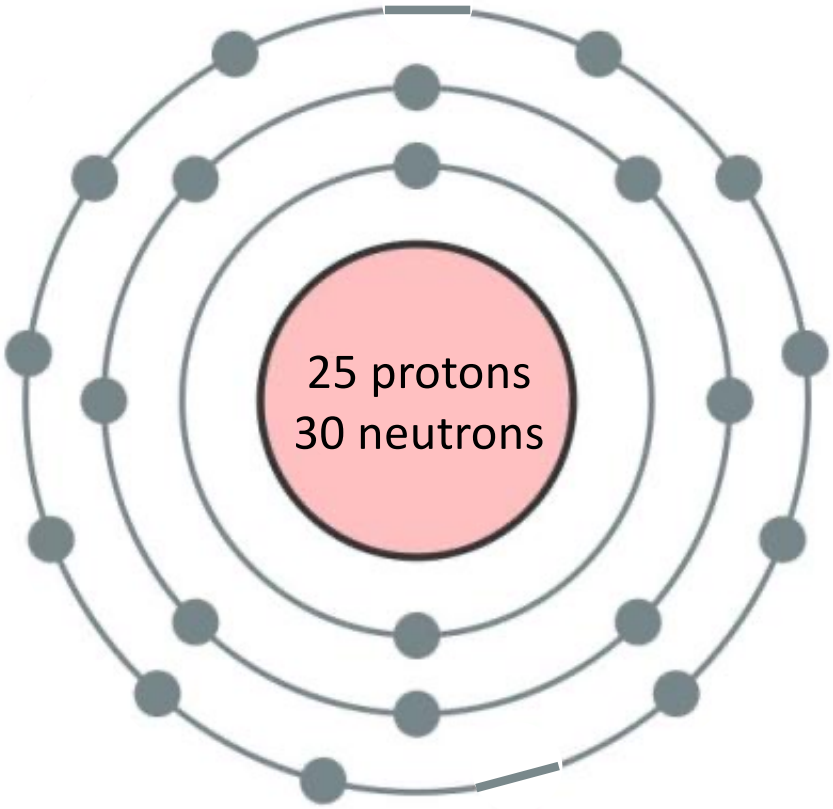


Mn^{3+} – gives up 3 electrons to create charge deficit

Oxidation state = +3

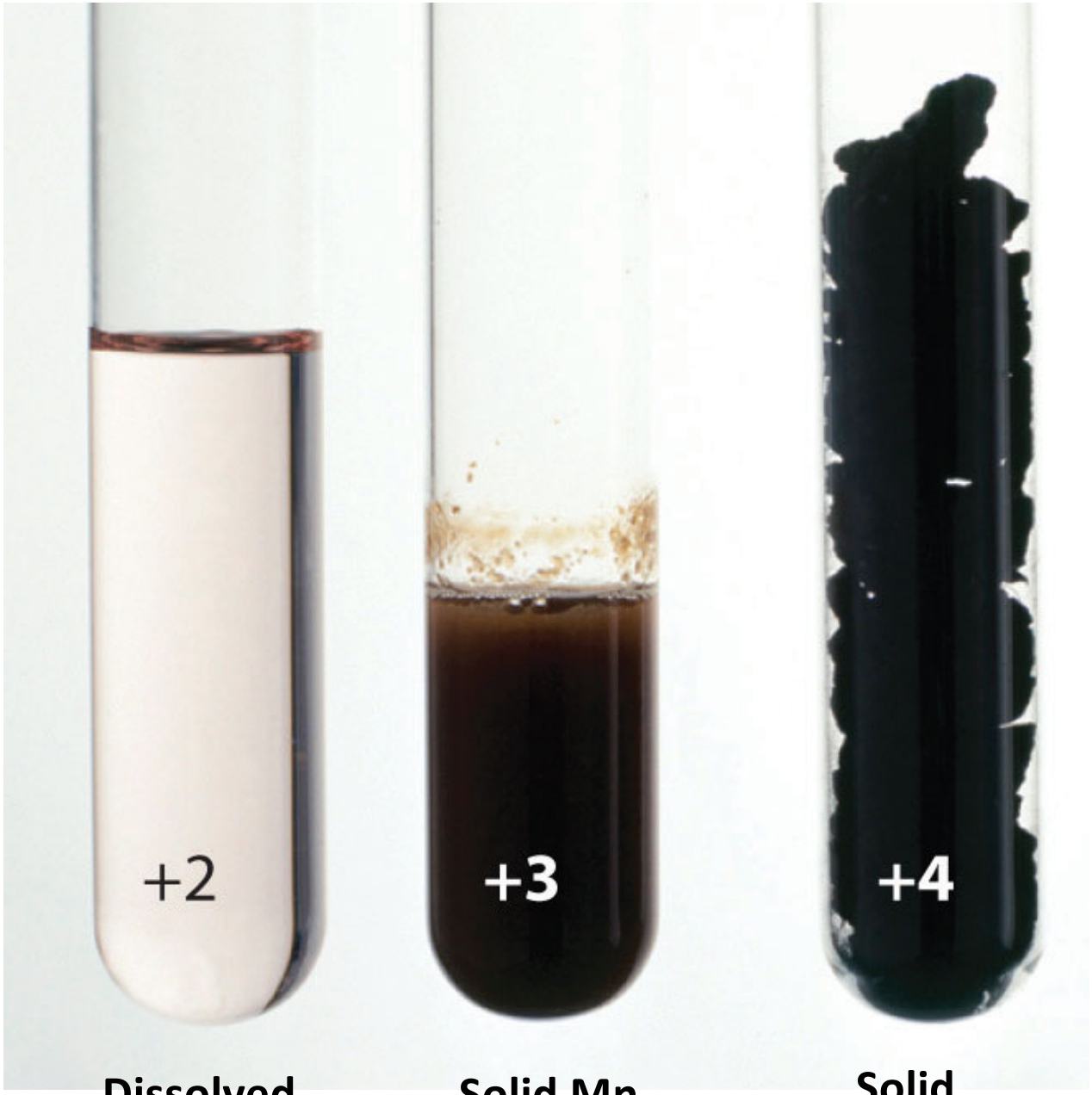
Elements lose and gain electrons to form different ***oxidation states***

21 electrons



Mn^{4+} – gives up 4 electrons to create charge deficit

Oxidation state = +4



Dissolved Mn^{2+}

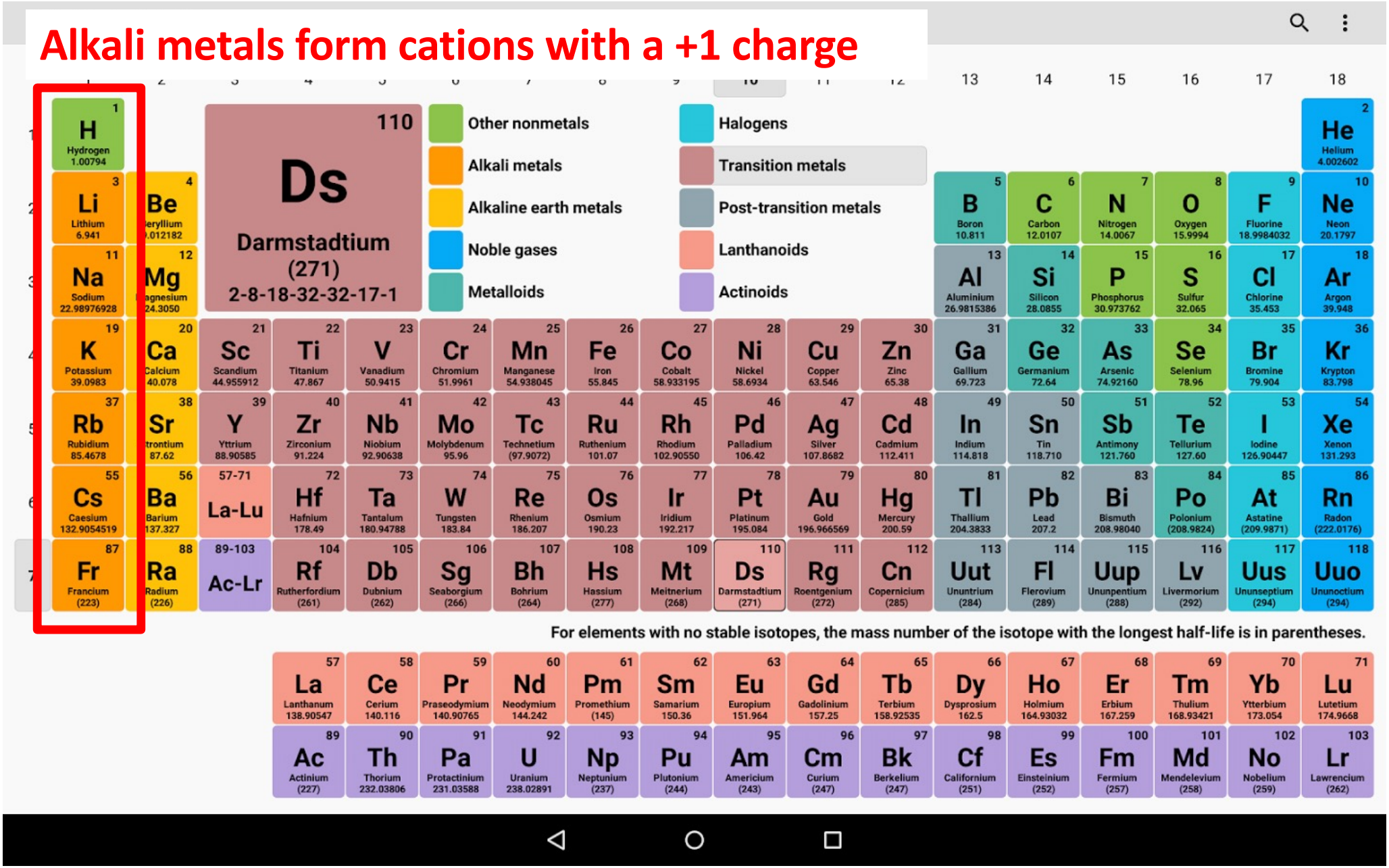
Solid Mn-oxyhydroxide (MnOOH)

Solid Mn-oxide (MnO_2)

An element's oxidation state can be an important control on its properties and reactivity with other elements

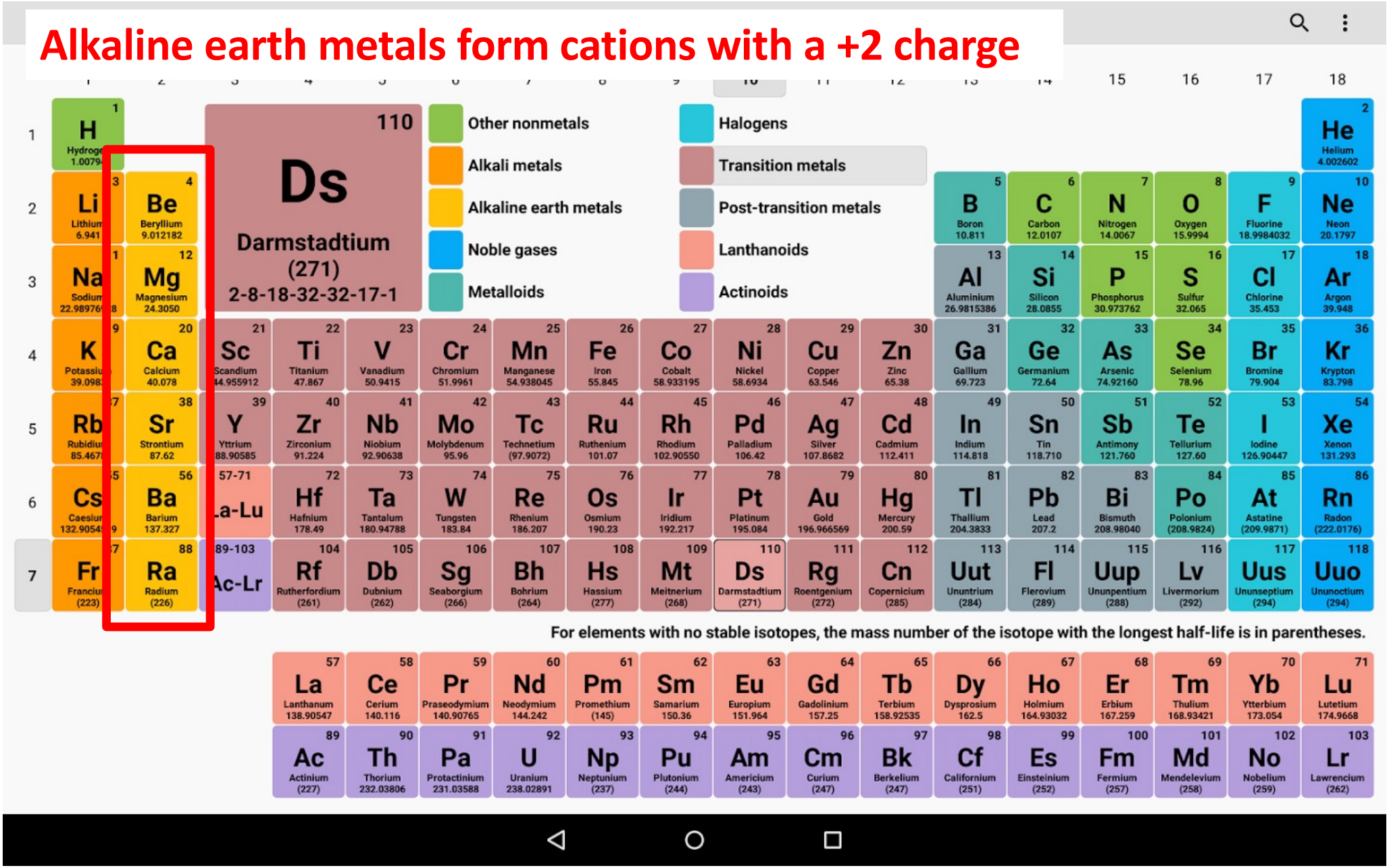
The Periodic Table

Alkali metals form cations with a +1 charge

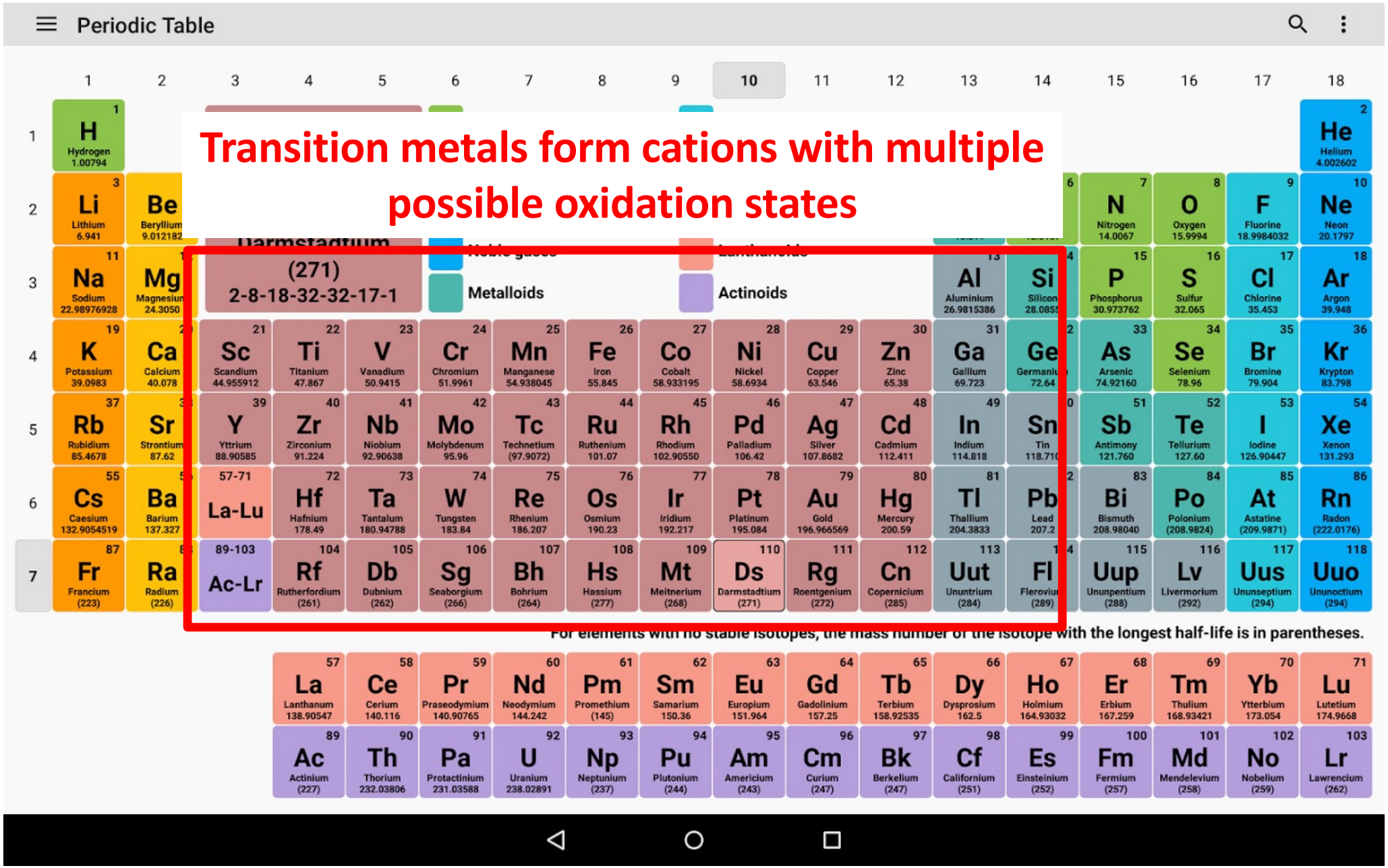


The Periodic Table

Alkaline earth metals form cations with a +2 charge



The Periodic Table

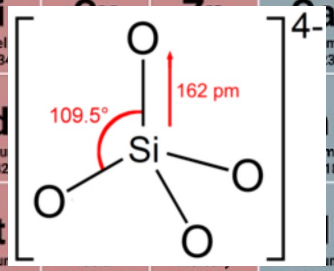


The Periodic Table

Metalloids form cations with multiple oxidation states that often bind to anions to form anionic compounds

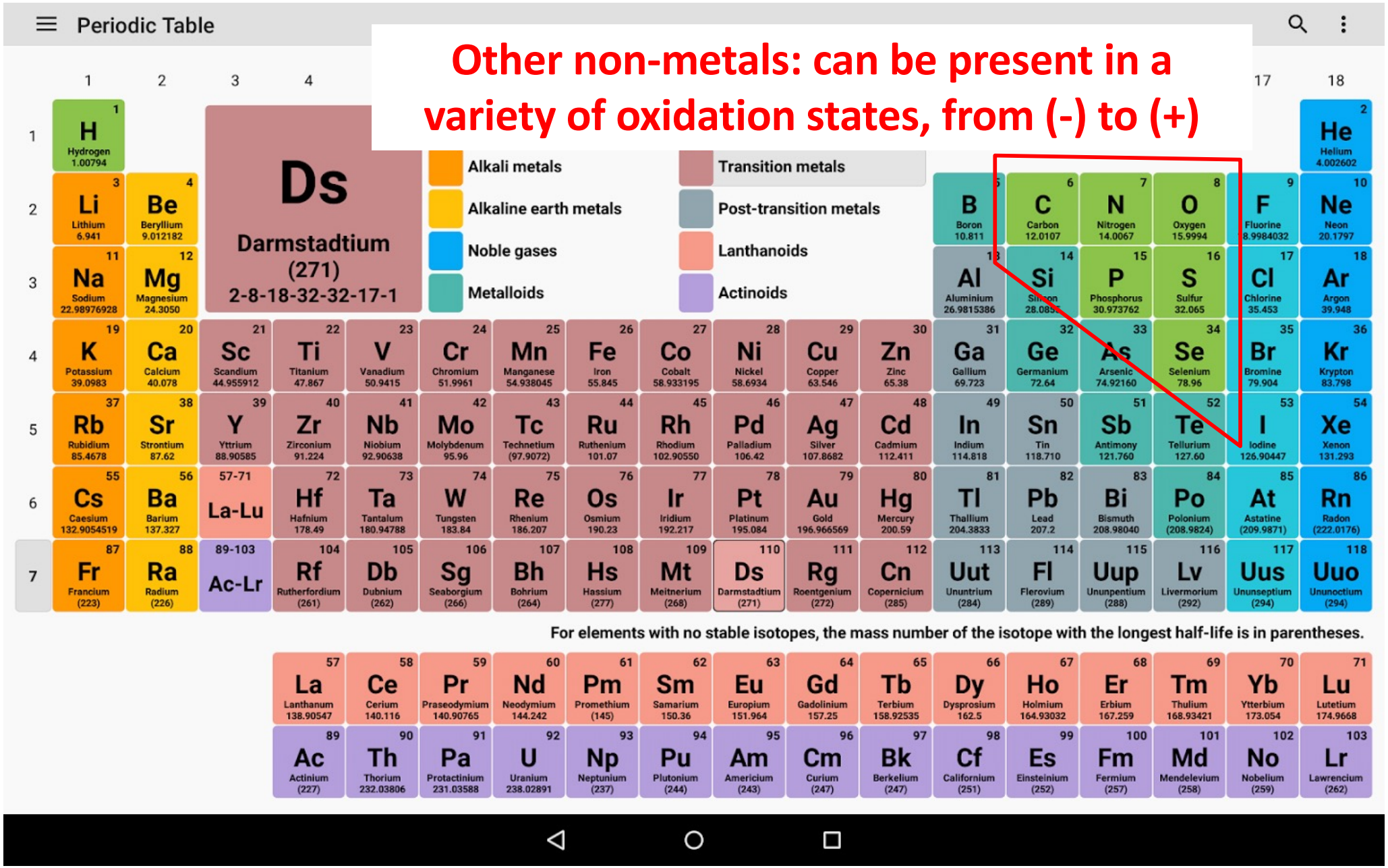
Alkaline earth metals
Noble gases
Metalloids
Post-transition metals
Lanthanoids
Actinoids

Darmstadtium
(271)
2-8-18-32-32-17-1

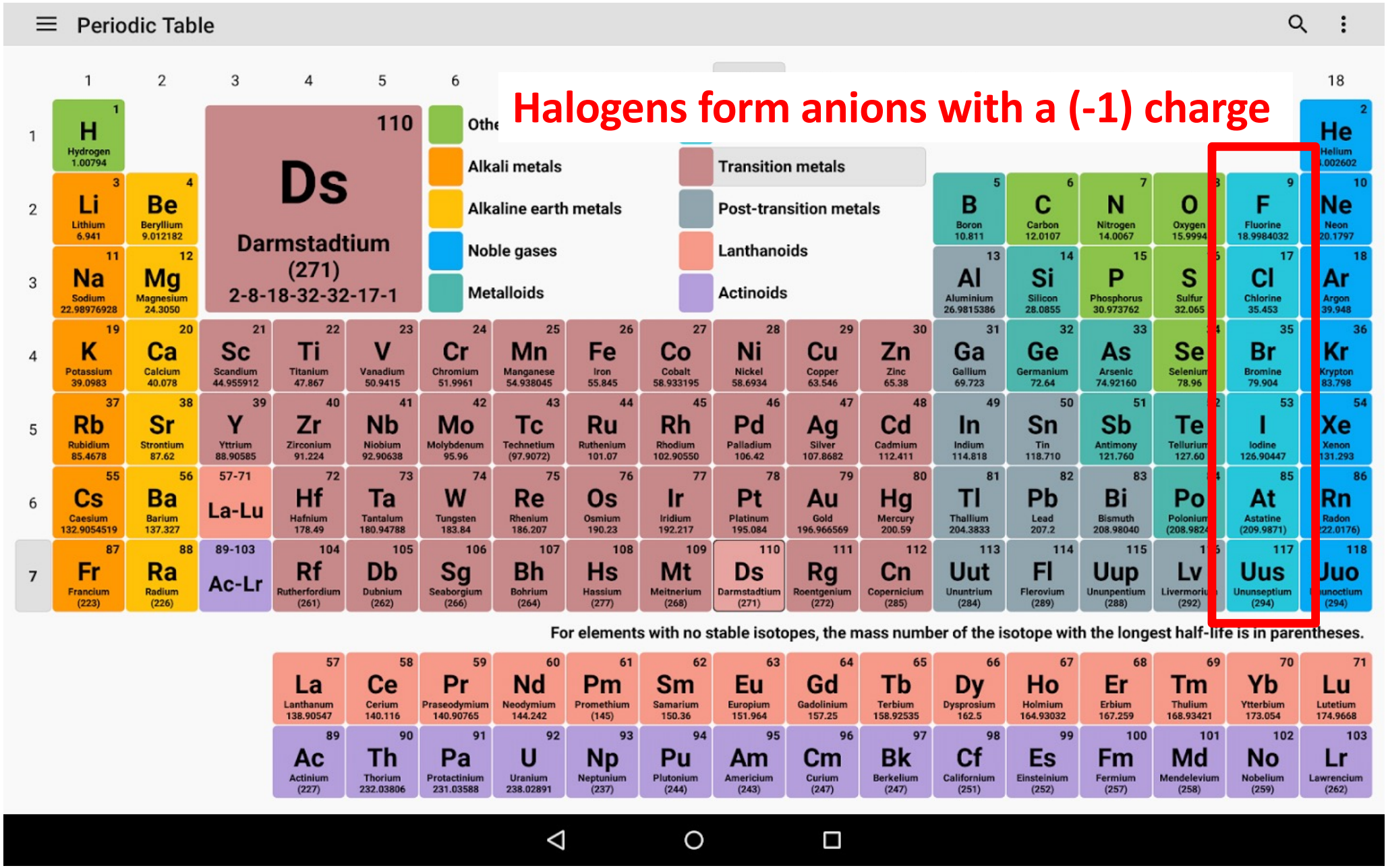


For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

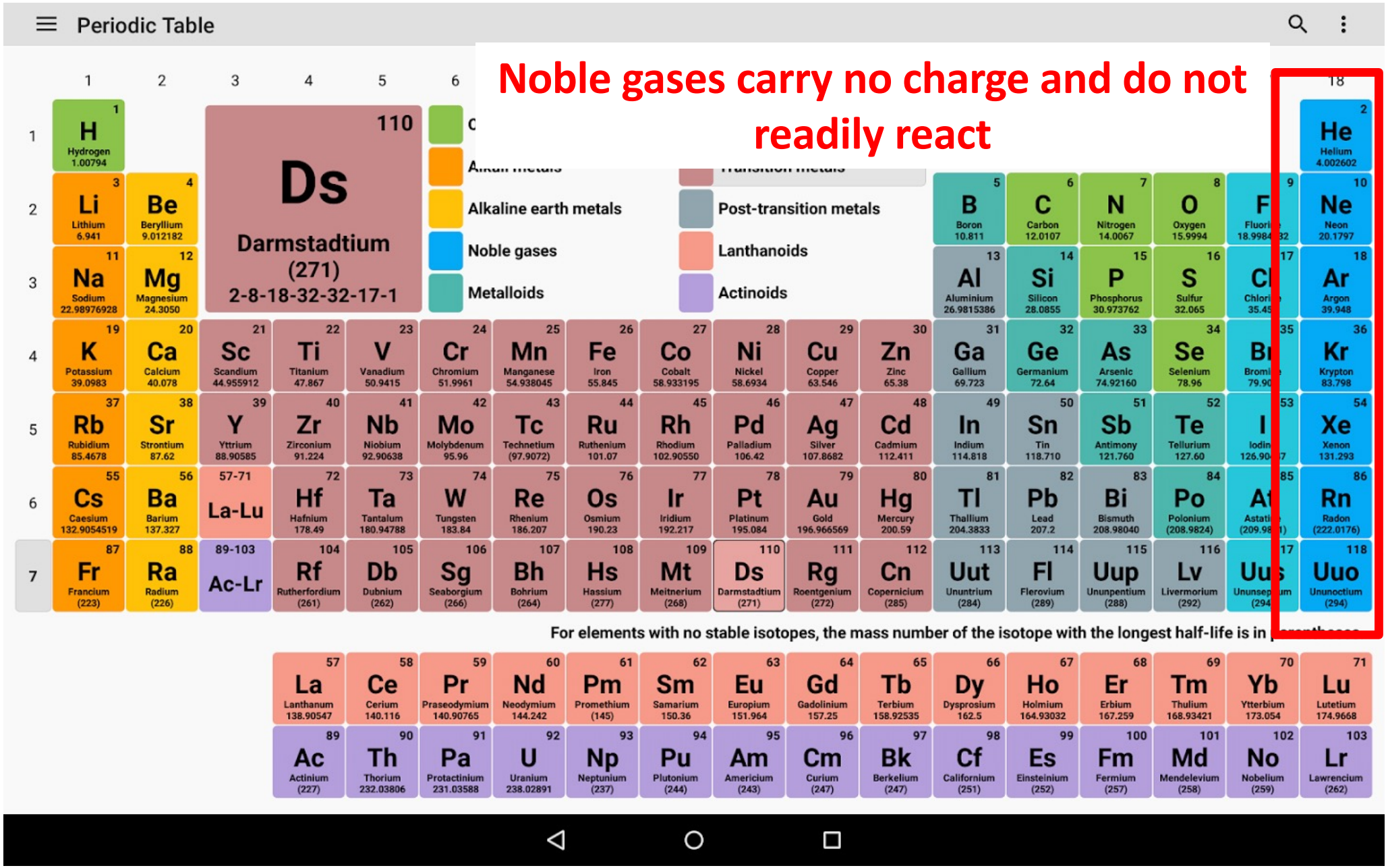
The Periodic Table



The Periodic Table



The Periodic Table



Refer to the note

Chemical Reactions!

Rearrangement of atoms and/or electrons to create new substances with different chemical and physical properties

Geochemical modeling

The practice of using thermodynamics and/or kinetics to analyze geochemical reactions that impact geologic systems

Refer to the note

National Geographic

Precipitation Reaction

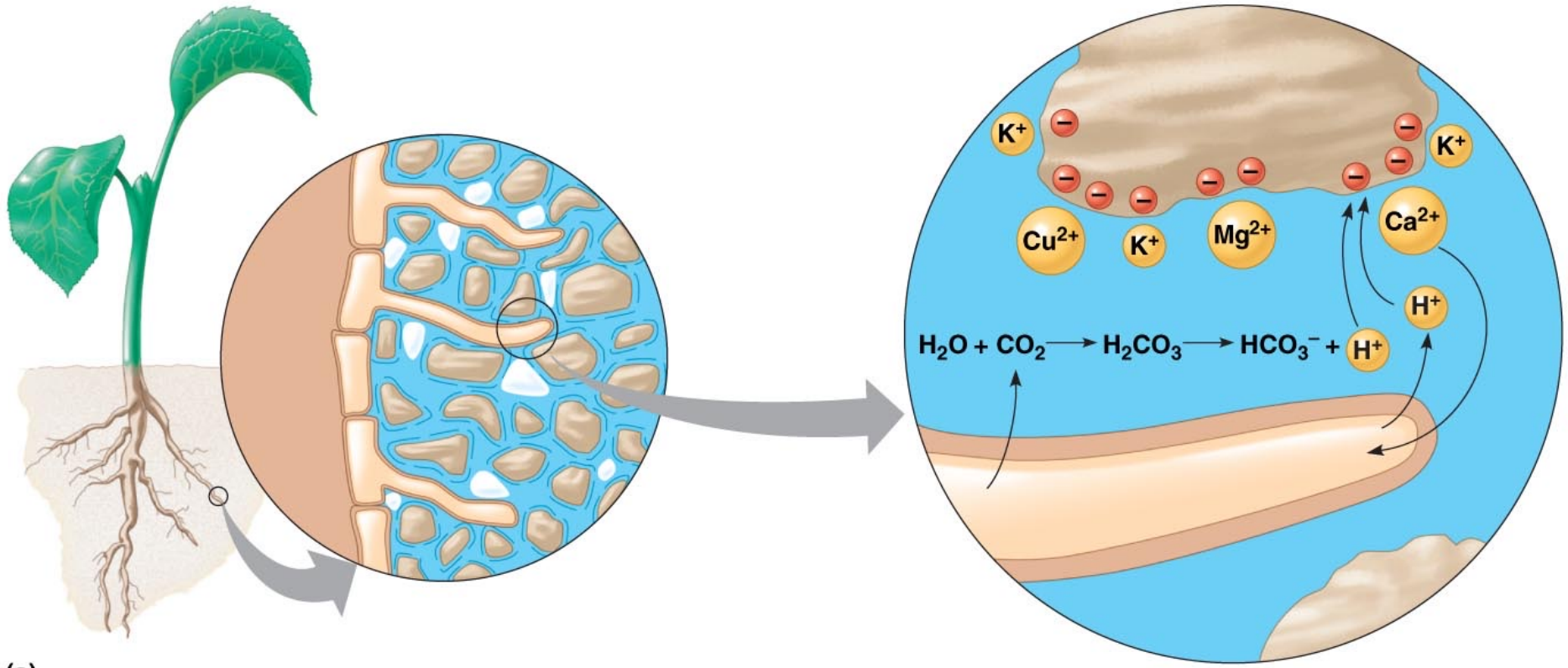
Evaporite deposits

Water removed through evaporation

Pipe scaling

Acid-base reaction

Cation exchange in soils



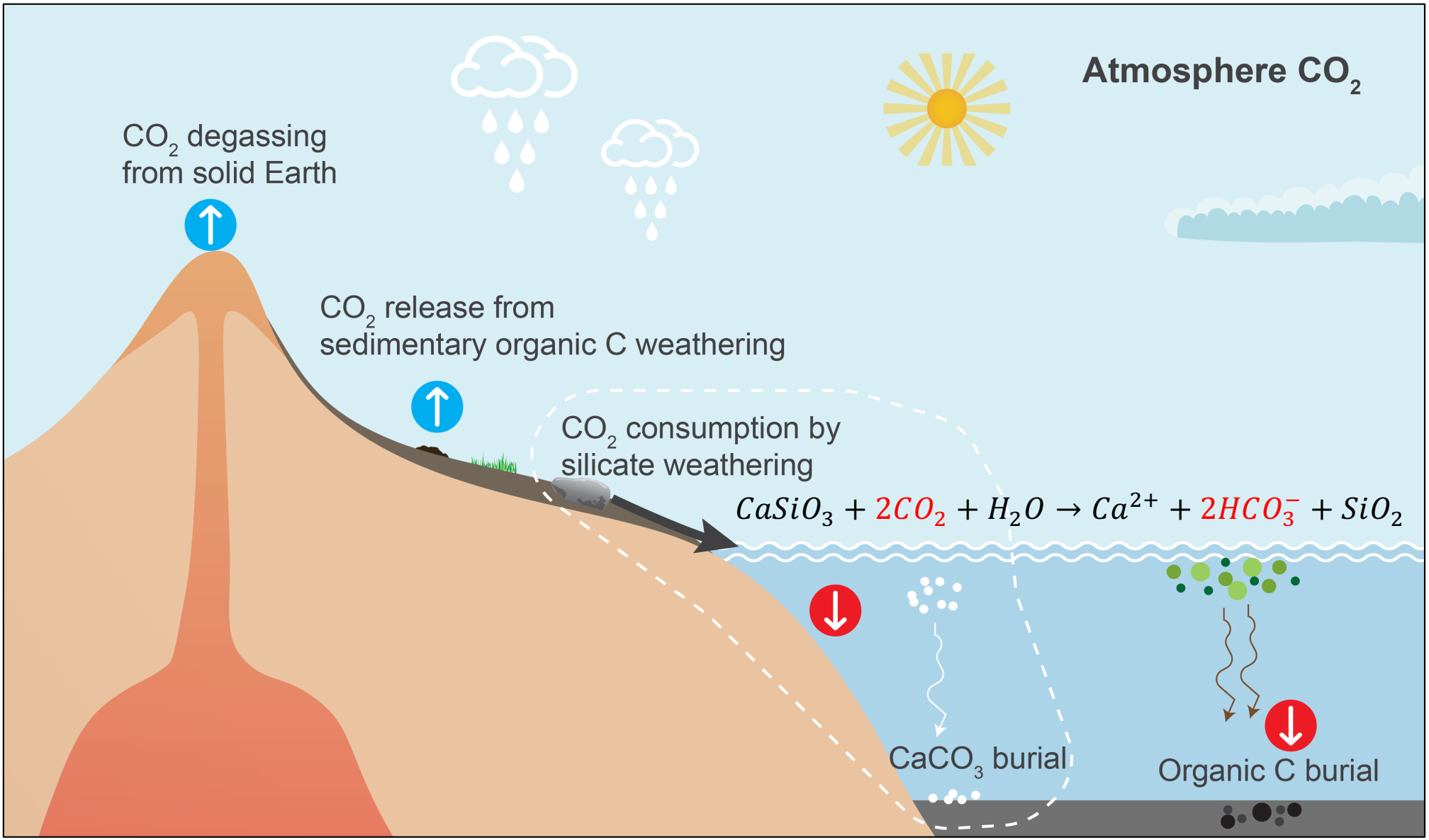
Redox reaction in acid mine drainage

1) $FeS_2 + O_2 \rightarrow Fe^{2+} + SO_4^{2-} + H_2SO_4$
2) $Fe^{2+} + O_2 \rightarrow Fe^{3+}$
3) $Fe^{3+} + H_2O \rightarrow Fe(OH)_3$

What is oxidized and what is reduced in each reaction?

**unbalanced reactions

Global Carbon Cycle



Courtesy of Shuang Zhang