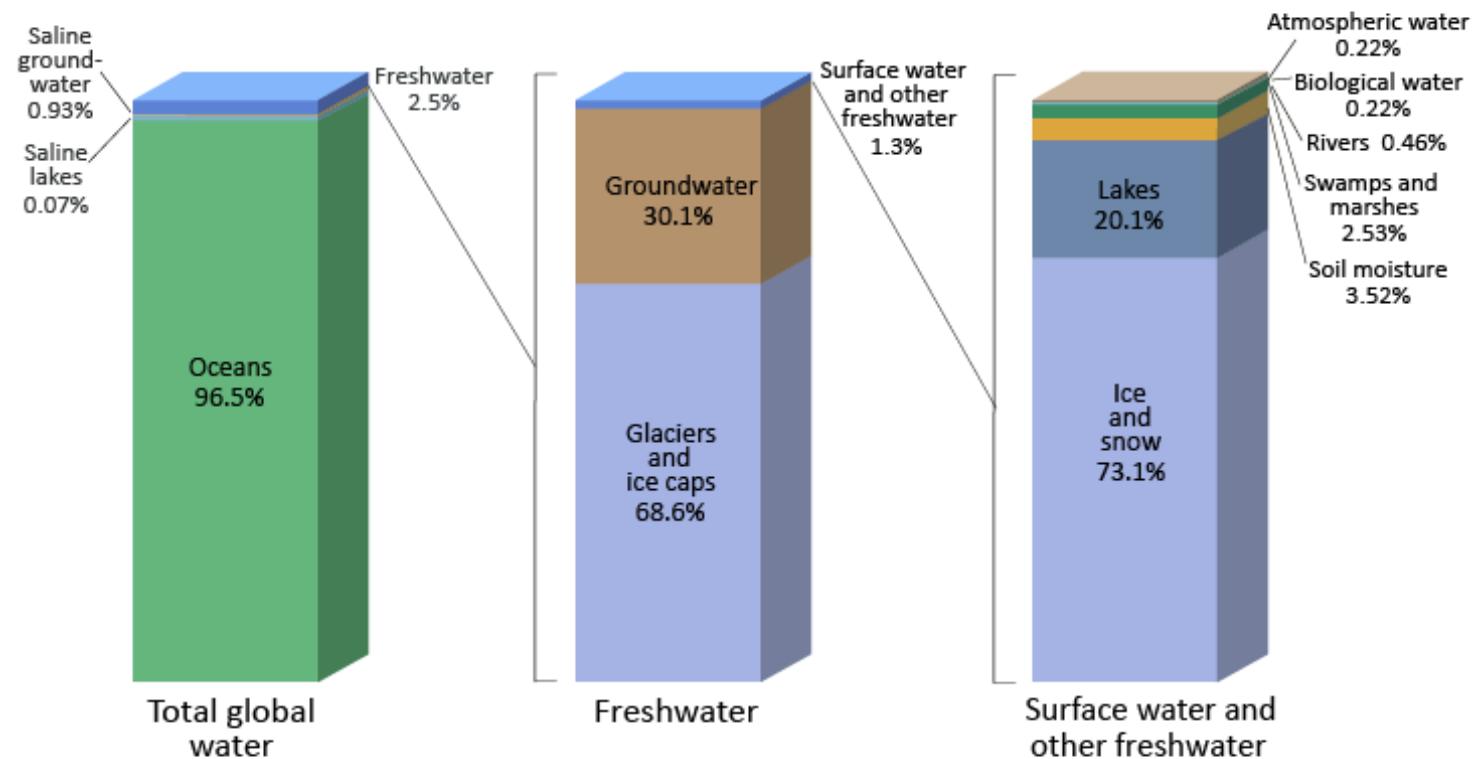
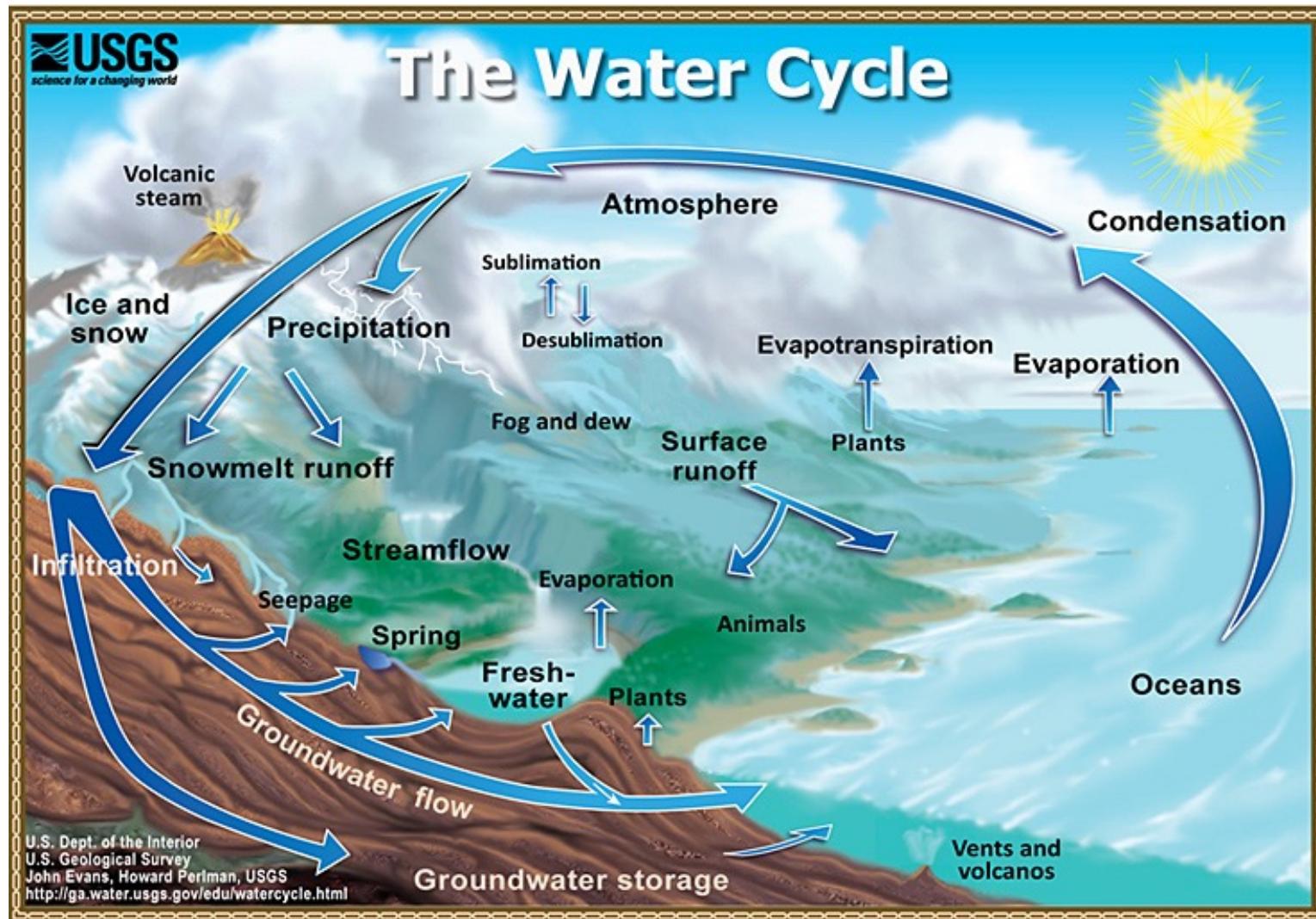


(Reservoirs) Distribution of Earth's Water

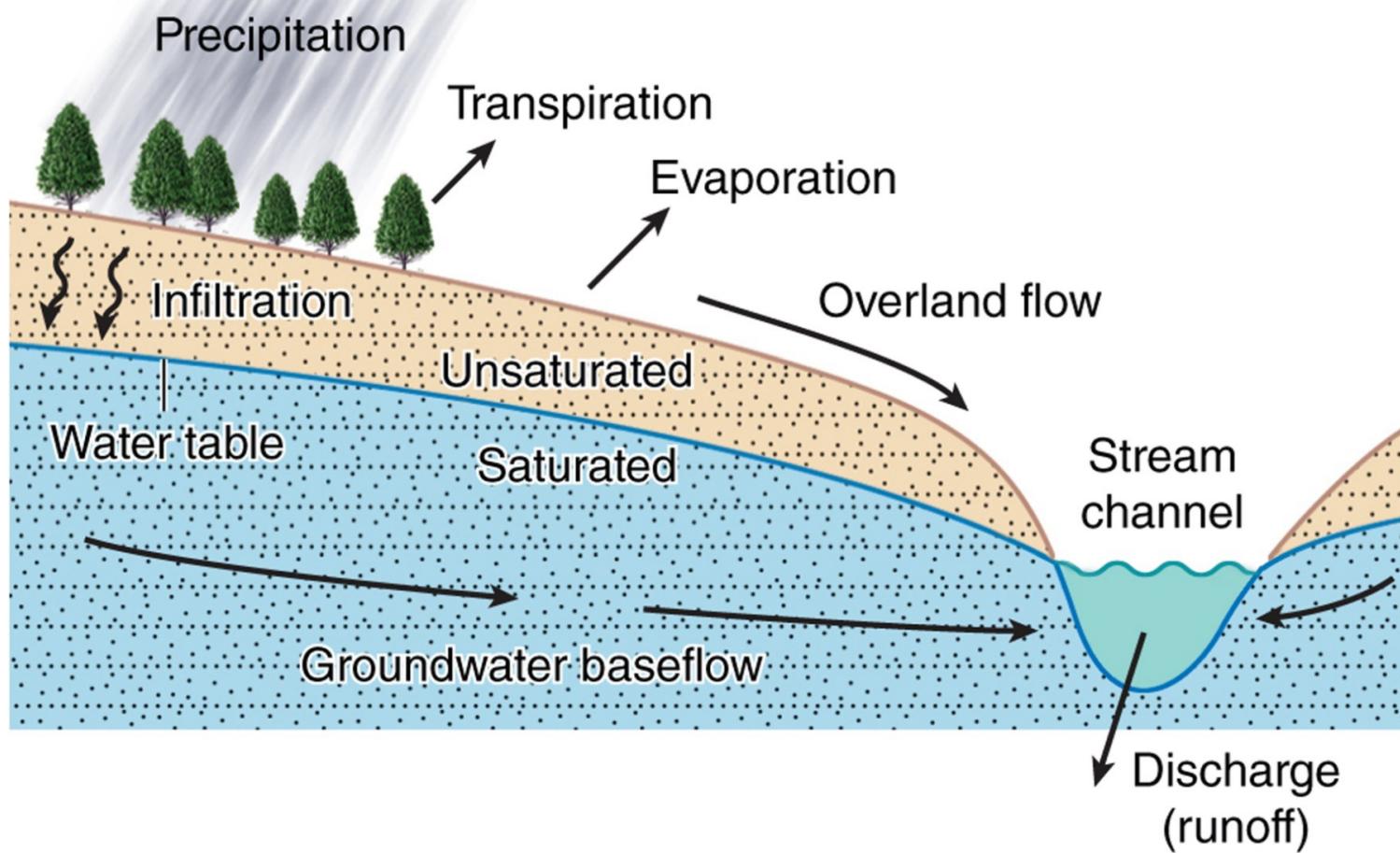


Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993,
Water in Crisis: A Guide to the World's Fresh Water Resources.

How does water move across the Earth?



Important fluxes in the hydrologic cycle



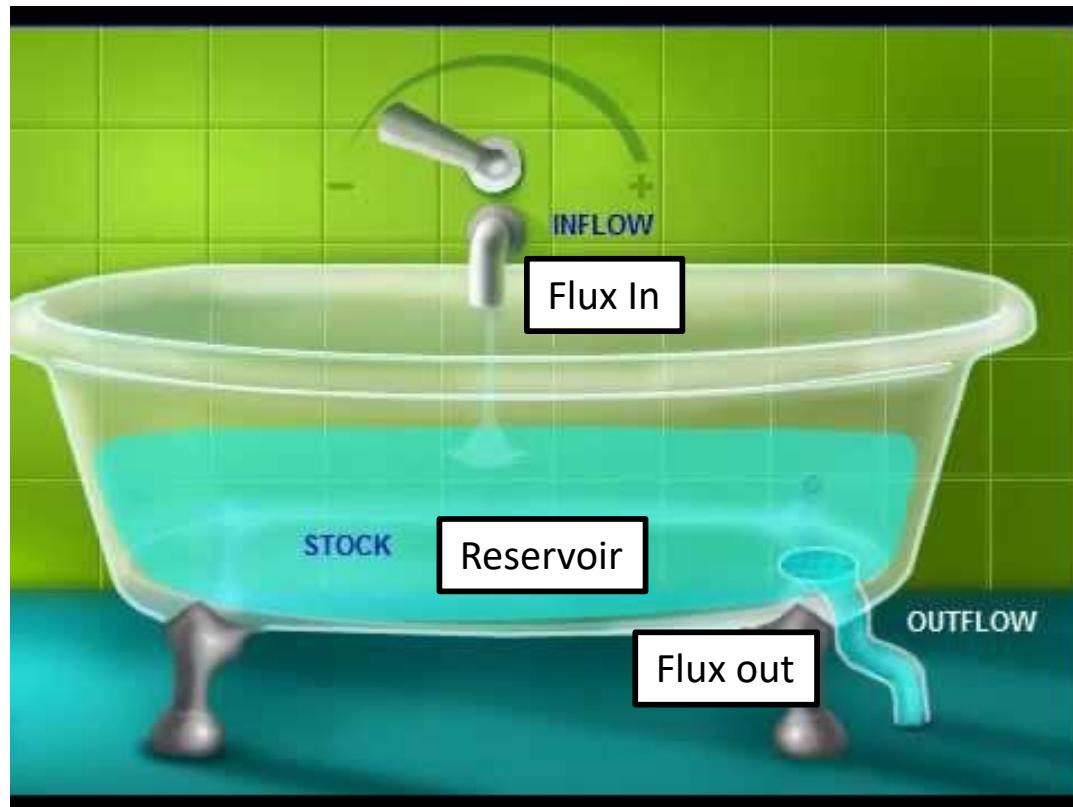
Understanding water transport through the environment

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?

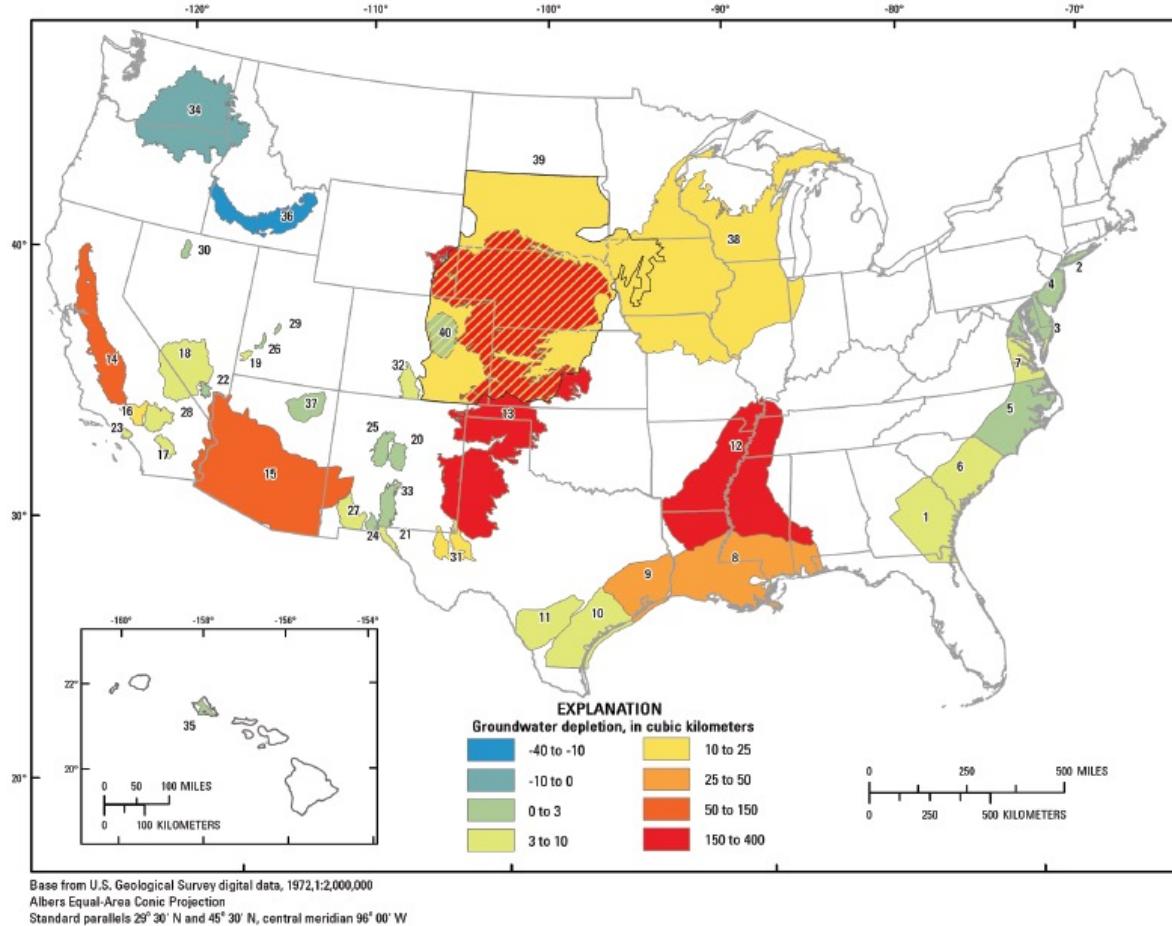
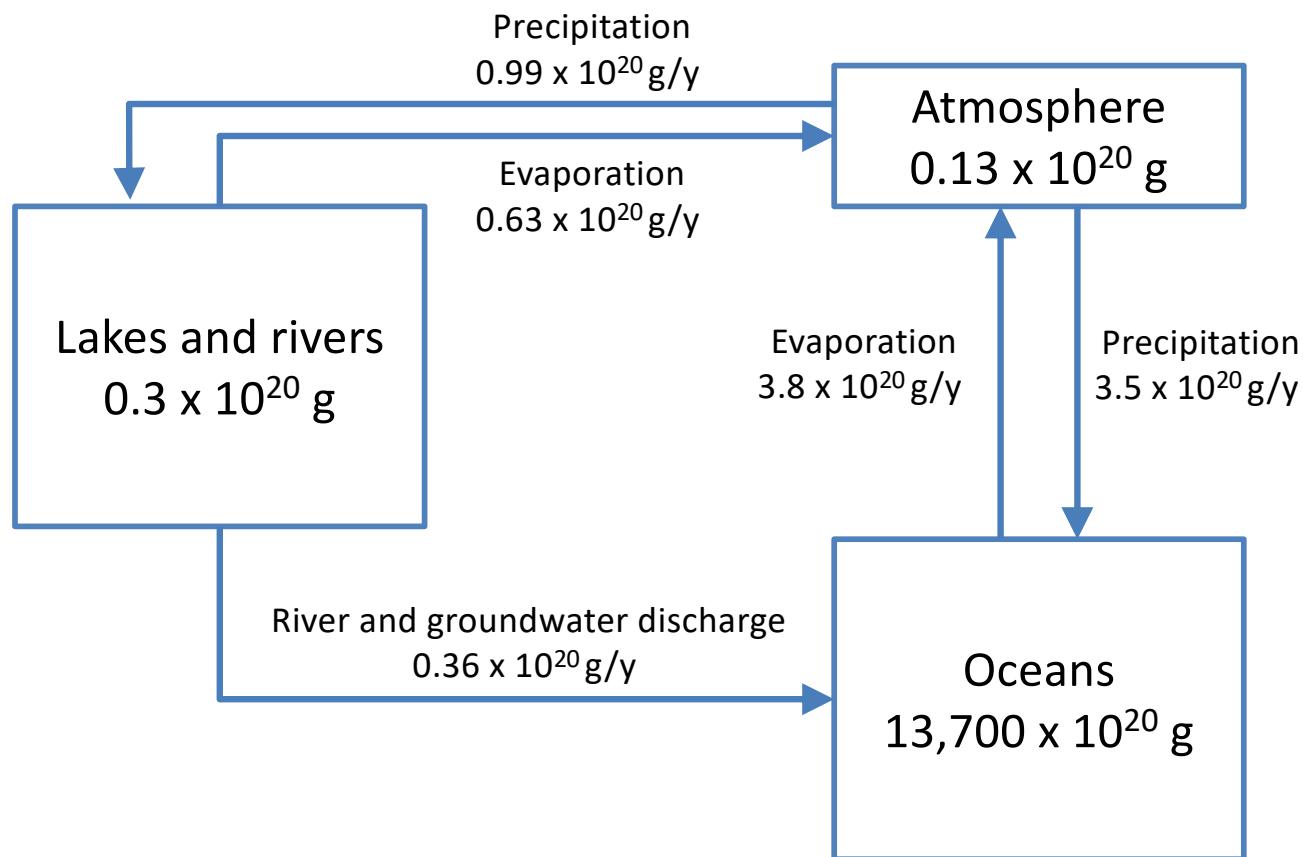


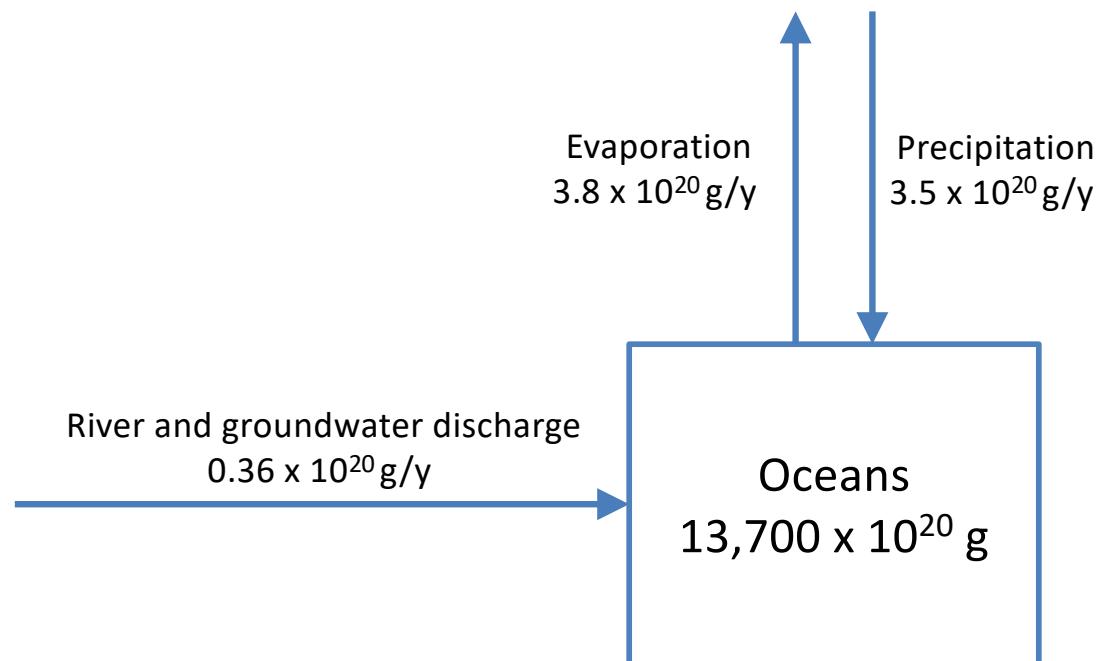
Figure 2. Map of the United States (excluding Alaska) showing cumulative groundwater depletion, 1900 through 2008, in 40 assessed aquifer systems or subareas. Index numbers are defined in table 1. Colors are hatched in the Dakota aquifer (area 39) where the aquifer overlaps with other aquifers having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

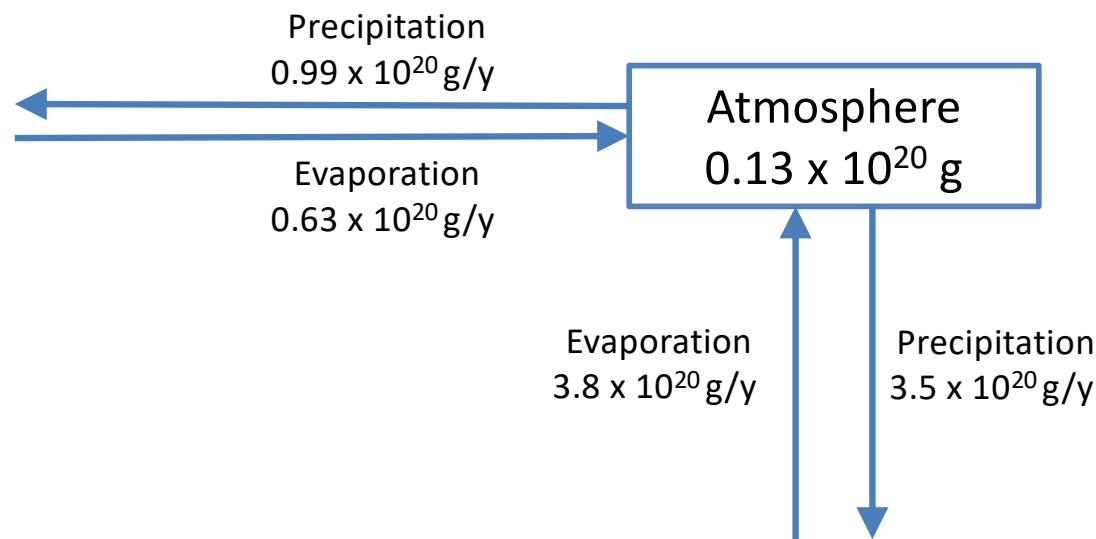
The Hydrologic Cycle: Simple Box Model for Water



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*



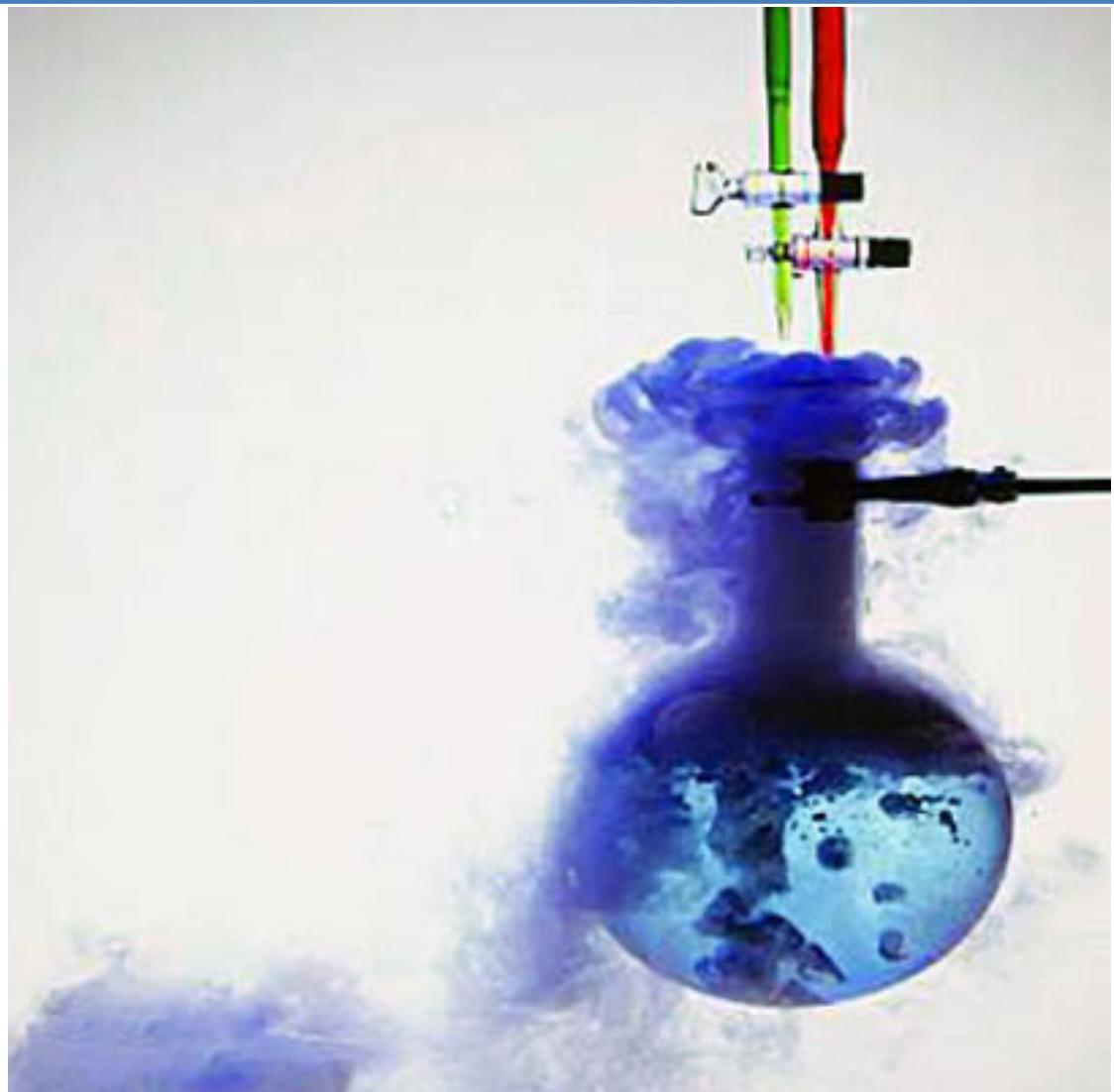


What is the **residence time** of a water molecule in the atmosphere?

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

Chemical Reactions

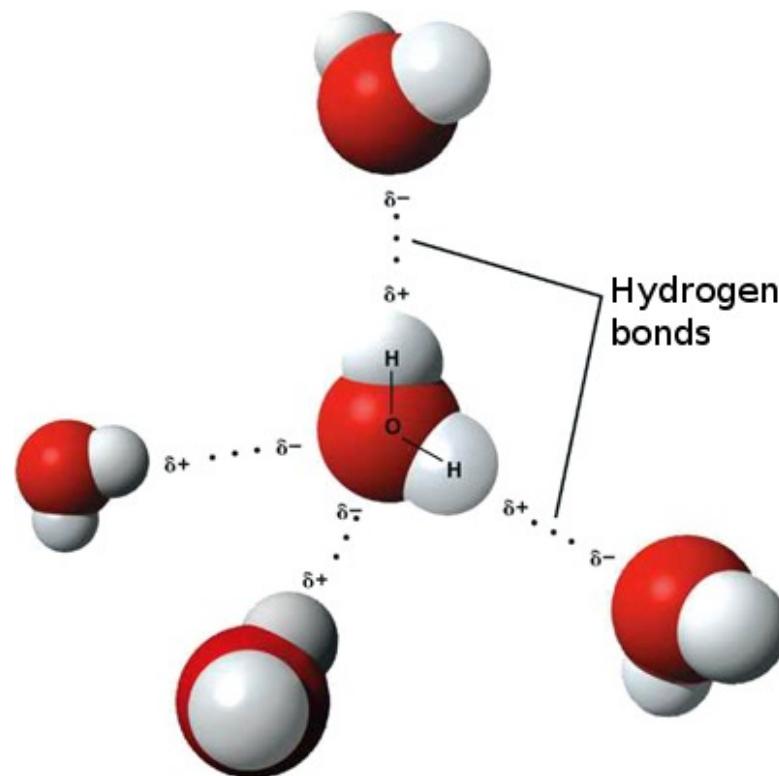
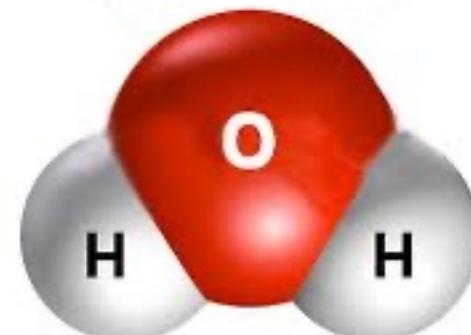
- Water
- The Periodic Table
- Unit Conversion
- Types of chemical reactions



Properties of water

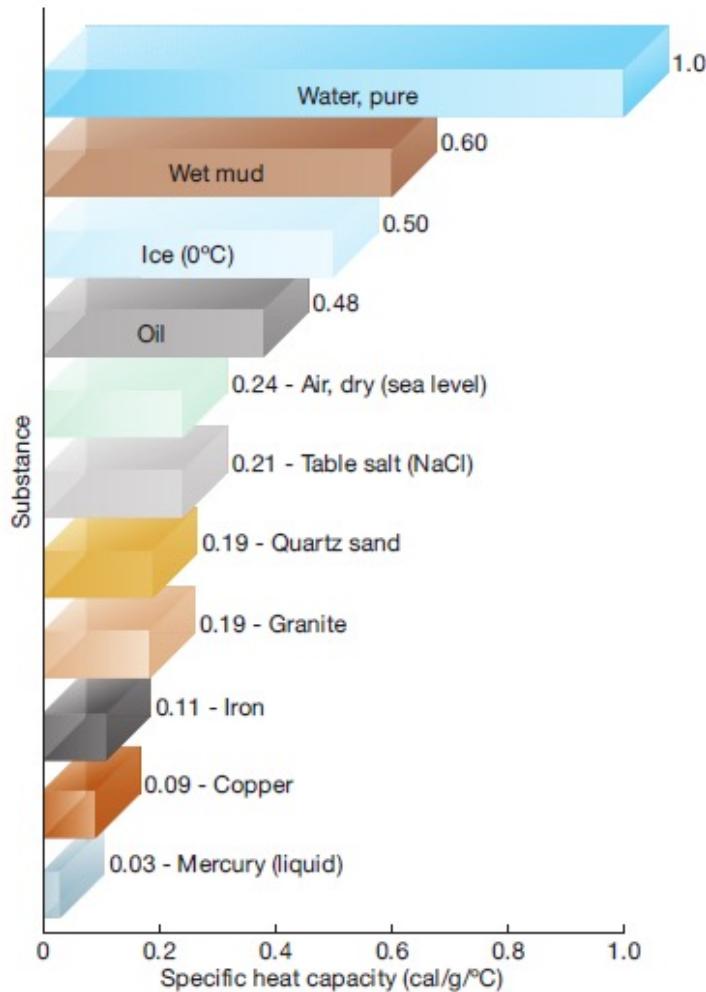
1. Dipolar
2. Hydrogen bonds
3. Strong cohesive and adhesive nature
4. High heat capacity
5. Low density (especially frozen)
6. Universal solvent
7. Participates in and facilitates chemical reactions

WATER MOLECULE



Properties of water

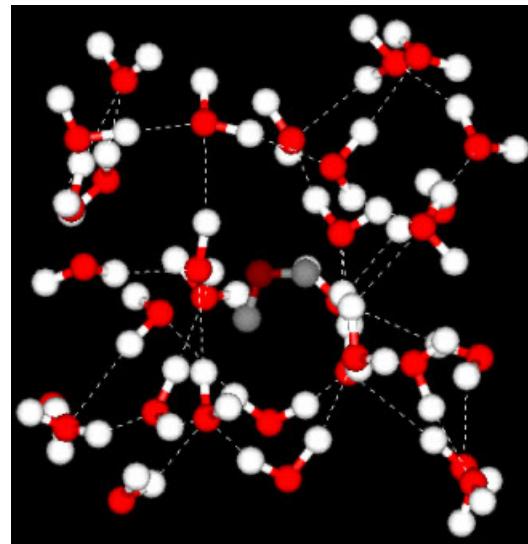
- Water has a high *specific heat capacity* relative to other substances



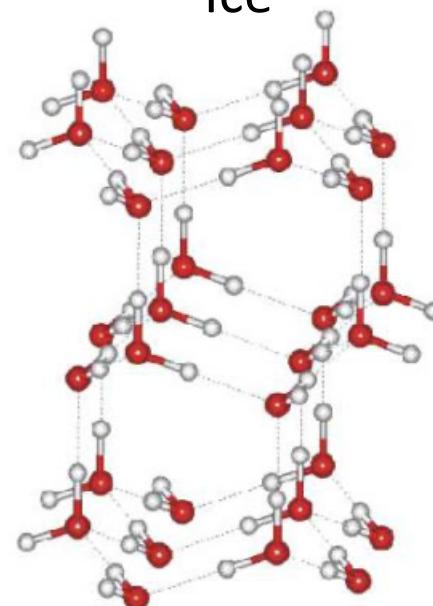
Properties of water

- Low density, especially when frozen

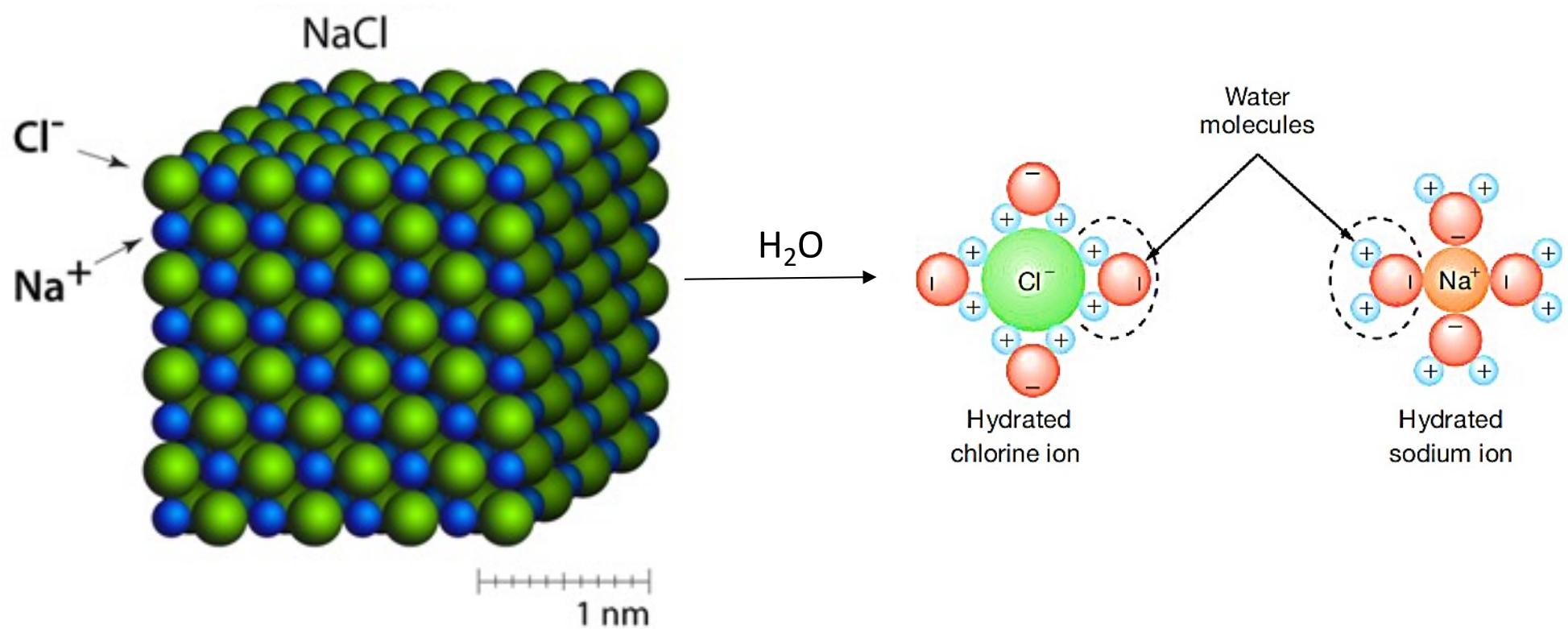
Liquid Water



Ice



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



Element abbreviation

The Periodic Table

≡ Periodic Table



Atomic number

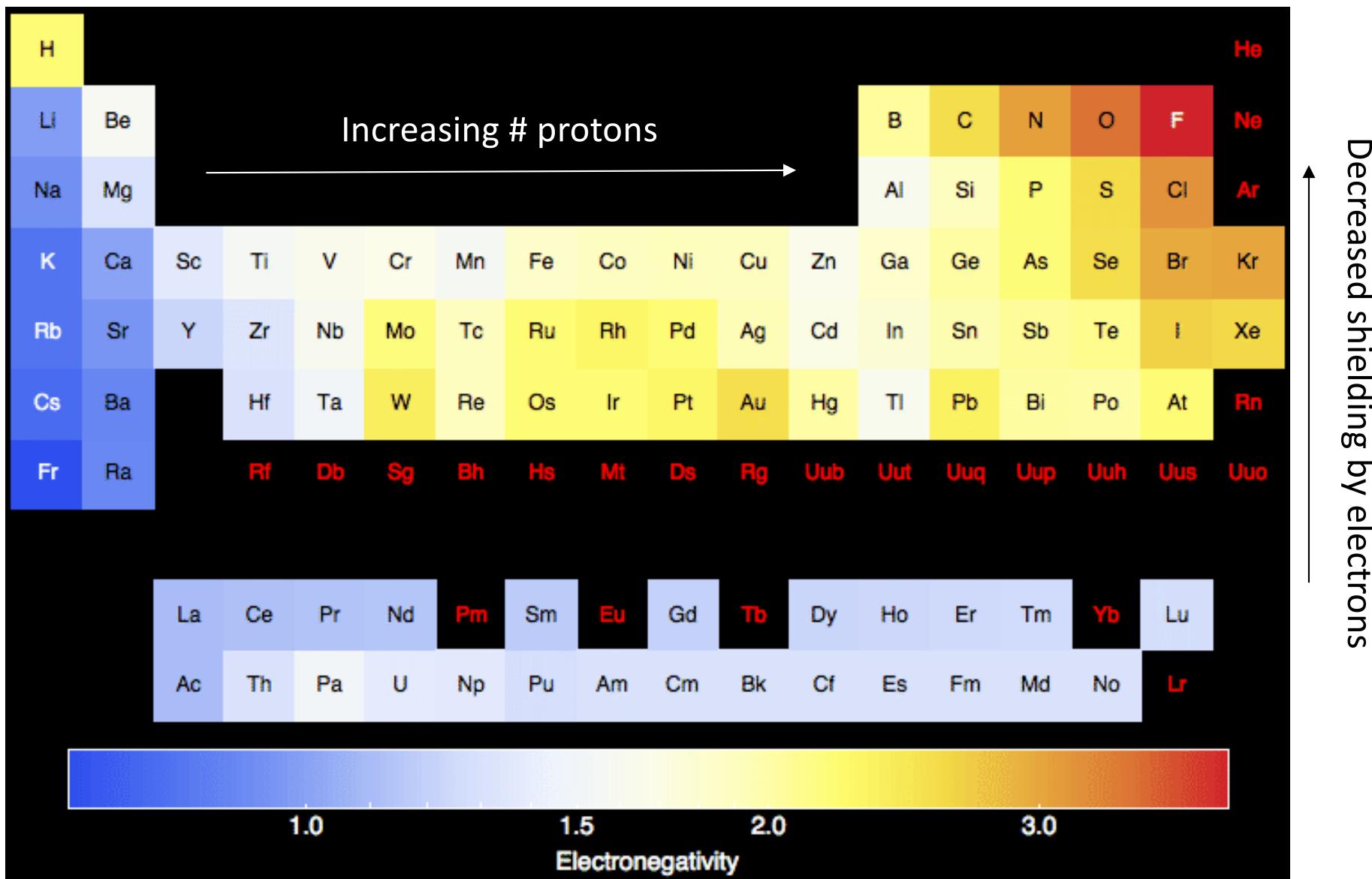
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.00794	2 He Helium 4.002602	3 Li Lithium 6.941	4 Be Beryllium 9.012182	5 Ds Darmstadtium (271) 2-8-18-32-32-17-1	6 110 Other nonmetals	7 Alkali metals	8 Alkaline earth metals	9 Halogens	10 Transition metals	11 B Boron 10.811	12 C Carbon 12.0107	13 N Nitrogen 14.0067	14 O Oxygen 15.994	15 F Fluorine 18.9984032	16 Ne Neon 20.1797	17 Ar Argon 39.948	18 K Potassium 39.0983
11 Na Sodium 22.9876928	12 Mg Magnesium 24.3050	13 Sc Scandium 44.955912	14 Ti Titanium 47.867	15 V Vanadium 50.9415	16 Cr Chromium 51.9961	17 Mn Manganese 54.938045	18 Fe Iron 55.845	19 Co Cobalt 58.933195	20 Ni Nickel 58.6934	21 Cu Copper 63.546	22 Zn Zinc 65.38	23 Ga Gallium 69.723	24 Ge Germanium 72.64	25 As Arsenic 74.92160	26 Se Selenium 78.96	27 Br Bromine 79.904	28 Kr Krypton 83.798
19 Rb Rubidium 85.4678	20 Sr Strontium 87.62	21 Y Yttrium 88.90585	22 Zr Zirconium 91.224	23 Nb Niobium 92.90638	24 Mo Molybdenum 95.96	25 Tc Technetium (97.9072)	26 Ru Ruthenium 101.07	27 Rh Rhodium 102.90550	28 Pd Palladium 106.42	29 Ag Silver 107.8682	30 Zn Zinc 114.818	31 Ga Gallium 118.710	32 Ge Germanium 121.760	33 As Arsenic 126.90447	34 Se Selenium 127.60	35 Br Bromine 131.293	36 Kr Krypton 132.9054519
37 Cs Caesium 132.9054519	38 Ba Barium 137.327	39 La-Lu	40 Y Yttrium 138.90547	41 Zr Zirconium 140.116	42 Nb Niobium 140.90765	43 Mo Molybdenum 144.242	44 Tc Technetium (145)	45 Ru Ruthenium 144.93032	46 Rh Rhodium 147.25	47 Pd Palladium 150.36	48 Ag Silver 151.964	49 Cd Cadmium 157.25	50 In Indium 158.92535	51 Sn Tin 162.5	52 Sb Antimony 164.93032	53 Te Tellurium 168.93421	54 Xe Xenon 173.054
55 Cs Caesium 132.9054519	56 Ba Barium 137.327	57-71 La-Lu	58 Hf Hafnium 178.49	59 Ta Tantalum 180.94788	60 W Tungsten 183.84	61 Re Rhenium 186.207	62 Os Osmium 190.23	63 Ir Iridium 192.217	64 Pt Platinum 195.084	65 Au Gold 196.966569	66 Hg Mercury 200.59	67 Tl Thallium 204.3833	68 Pb Lead 207.2	69 Bi Bismuth 208.98040	70 Po Polonium (208.9824)	71 Rn Radon (222.0176)	
72 Fr Francium (223)	73 Ra Radium (226)	74 Ac-Lr	75 Rf Rutherfordium (261)	76 Db Dubnium (262)	77 Sg Seaborgium (266)	78 Bh Bohrium (264)	79 Hs Hassium (277)	80 Mt Meitnerium (268)	81 Ds Darmstadtium (271)	82 Rg Roentgenium (272)	83 Cn Copernicium (285)	84 Uut Ununtrium (284)	85 Fl Flerovium (289)	86 Uup Ununpentium (288)	87 Lv Livermorium (292)	88 Uus Ununseptium (294)	89 Uuo Ununoctium (294)

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

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.5	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkellium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)



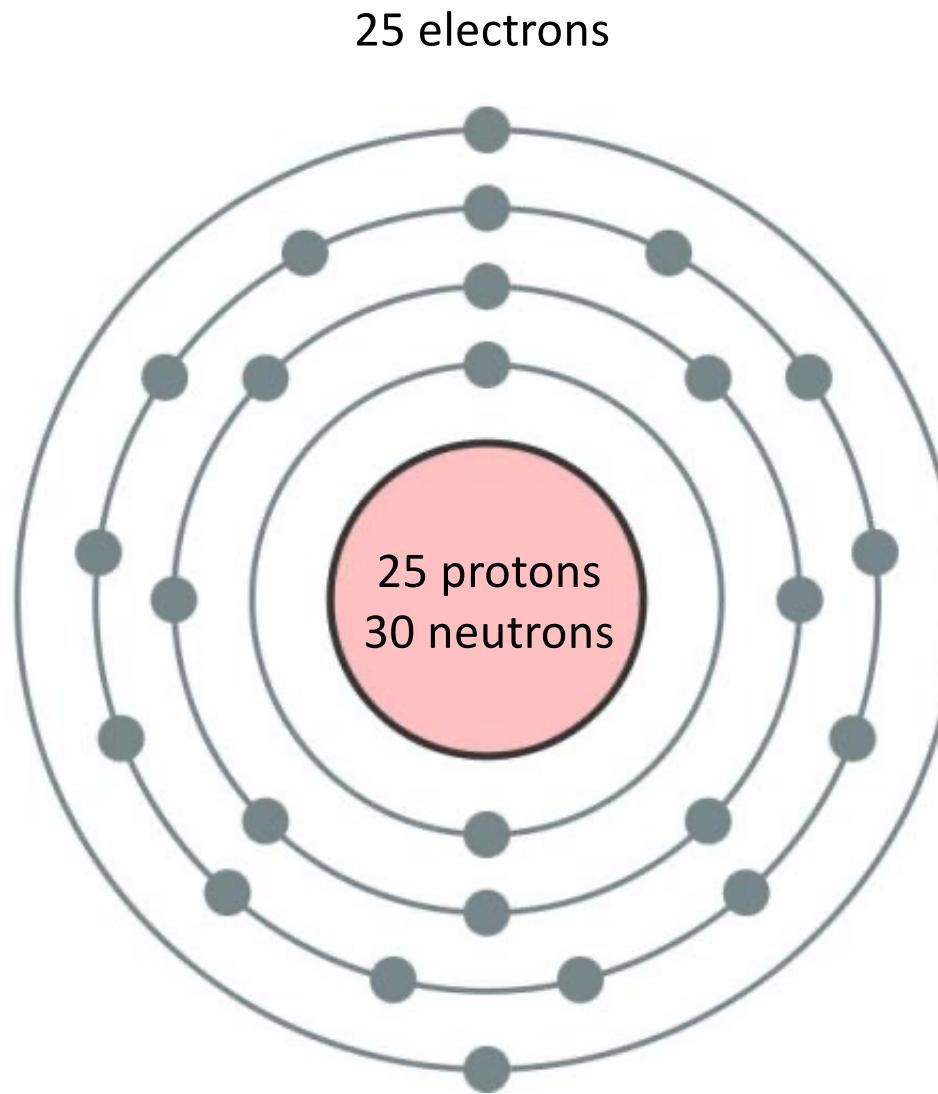
- Most elements gain and lose electrons to become more stable
- ***electronegativity*** is the ability of elements to attract electrons to themselves



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



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

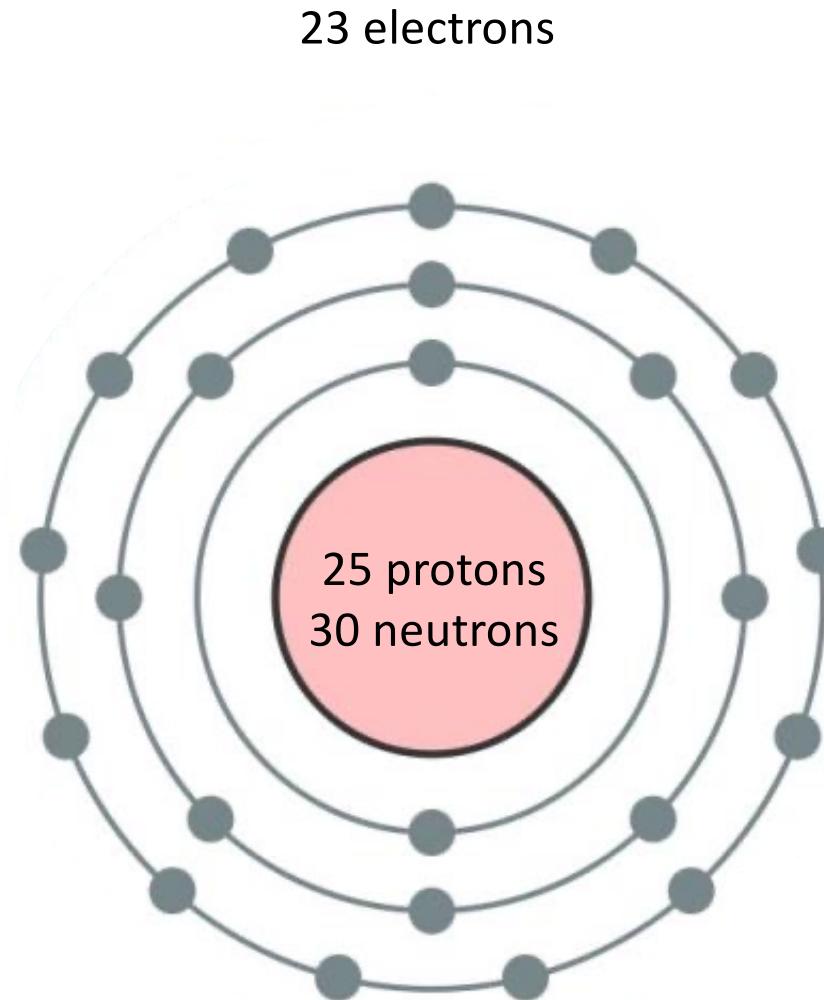


Refer to the note

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



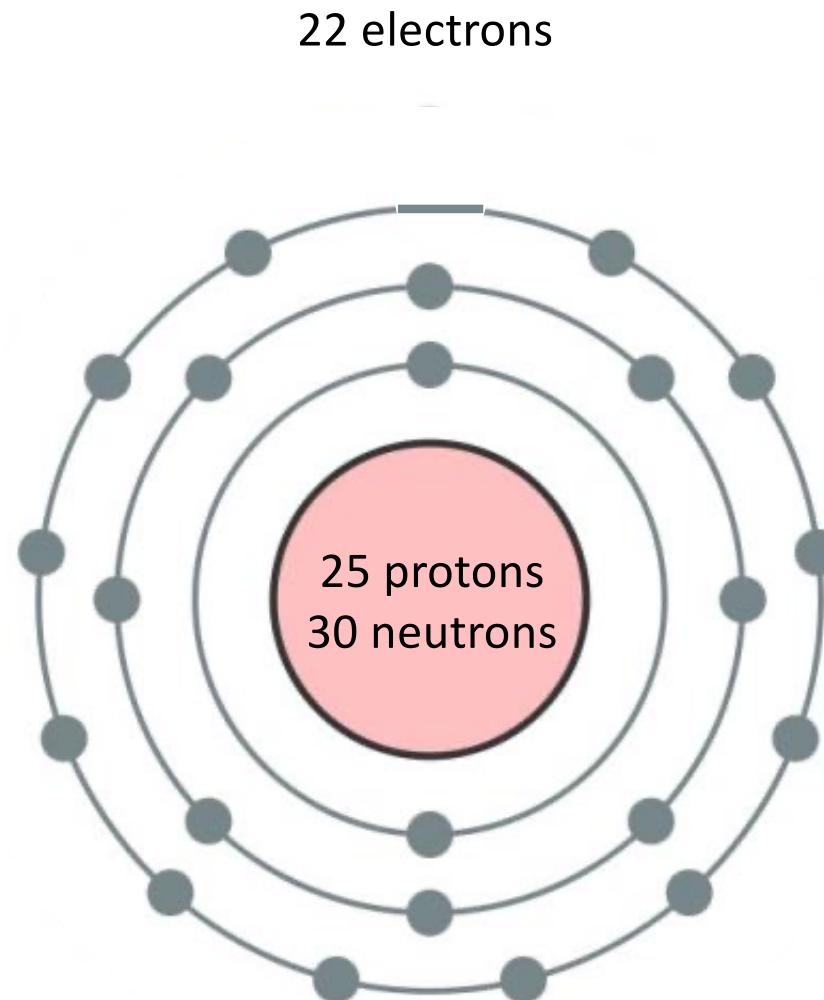
Mn^{2+} – gives up 2 electrons to create charge deficit
Oxidation state = +2



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



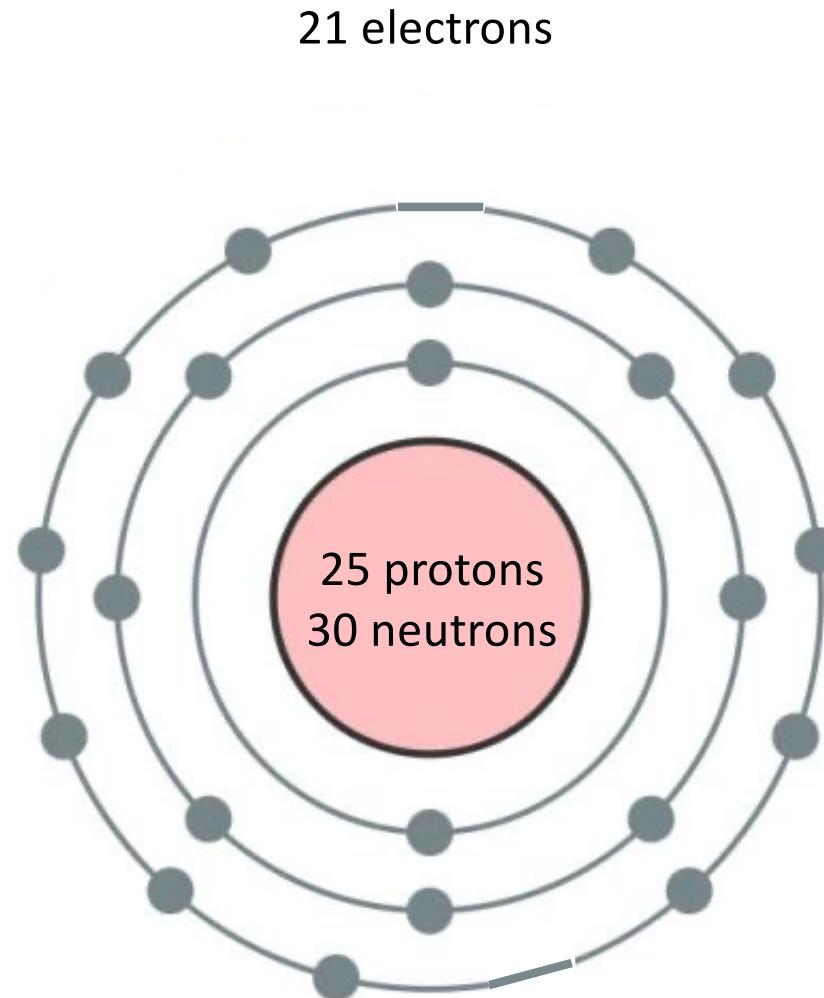
Mn^{3+} – gives up 3 electrons to create charge deficit
Oxidation state = +3



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



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



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



Dissolved
 Mn^{2+}



Solid Mn-oxyhydroxide
(MnOOH)



Solid
 MnO_2

The Periodic Table

Alkali metals form cations with a +1 charge

H Hydrogen 1.00794	He Helium 4.002602
Li Lithium 6.941	B Boron 10.811
Be Beryllium 9.01282	C Carbon 12.0107
Na Sodium 22.98976928	N Nitrogen 14.0067
Mg Magnesium 24.3050	O Oxygen 15.994
Ds Darmstadtium (271) 2-8-18-32-32-17-1	F Fluorine 18.9984032
K Potassium 39.0983	Ne Neon 20.1797
Ca Calcium 40.078	Al Aluminium 26.9815386
Sc Scandium 44.955912	Si Silicon 28.0855
Ti Titanium 47.867	P Phosphorus 30.973762
V Vanadium 50.9415	S Sulfur 32.065
Cr Chromium 51.9961	Cl Chlorine 35.453
Mn Manganese 54.938045	Ar Argon 39.948
Fe Iron 55.845	Ga Gallium 69.723
Co Cobalt 58.933195	Ge Germanium 72.64
Ni Nickel 58.6934	As Arsenic 74.92160
Cu Copper 63.546	Se Selenium 78.96
Zn Zinc 65.38	Br Bromine 79.904
Ga Gallium 69.723	Kr Krypton 83.798
Ge Germanium 72.64	Rb Rubidium 85.4678
As Arsenic 74.92160	Sr Strontium 87.62
Se Selenium 78.96	Y Yttrium 88.90585
Br Bromine 79.904	Zr Zirconium 91.224
Kr Krypton 83.798	Nb Niobium 92.90638
Ca Calcium 40.078	Mo Molybdenum 95.96
Sc Scandium 44.955912	Tc Technetium (97.9072)
Ti Titanium 47.867	Ru Ruthenium 101.07
V Vanadium 50.9415	Rh Rhodium 102.90550
Cr Chromium 51.9961	Pd Palladium 106.42
Mn Manganese 54.938045	Ag Silver 107.8682
Fe Iron 55.845	Cd Cadmium 112.411
Co Cobalt 58.933195	In Indium 114.818
Ni Nickel 58.6934	Sn Tin 118.710
Cu Copper 63.546	Sb Antimony 121.760
Zn Zinc 65.38	Te Tellurium 127.60
Ga Gallium 69.723	I Iodine 126.90447
Ge Germanium 72.64	Xe Xenon 131.293
As Arsenic 74.92160	Cs Caesium 132.9054519
Se Selenium 78.96	Ba Barium 137.327
Br Bromine 79.904	La-Lu Lanthanides 138.90547
Kr Krypton 83.798	Hf Hafnium 178.49
Ca Calcium 40.078	Ta Tantalum 180.94788
Sc Scandium 44.955912	W Tungsten 183.84
Ti Titanium 47.867	Re Rhenium 186.207
V Vanadium 50.9415	Os Osmium 190.23
Cr Chromium 51.9961	Ir Iridium 192.217
Mn Manganese 54.938045	Pt Platinum 195.084
Fe Iron 55.845	Au Gold 196.966569
Co Cobalt 58.933195	Hg Mercury 200.59
Ni Nickel 58.6934	Tl Thallium 204.3833
Cu Copper 63.546	Pb Lead 207.2
Zn Zinc 65.38	Bi Bismuth 208.98040
Ga Gallium 69.723	Po Polonium (208.9824)
Ge Germanium 72.64	At Astatine (209.9871)
As Arsenic 74.92160	Rn Radon (222.0176)
Se Selenium 78.96	Fr Francium (223)
Br Bromine 79.904	Ra Radium (226)
Kr Krypton 83.798	Ac-Lr Actinides (261)
Ca Calcium 40.078	Rf Rutherfordium (261)
Sc Scandium 44.955912	Db Dubnium (262)
Ti Titanium 47.867	Sg Seaborgium (266)
V Vanadium 50.9415	Bh Bohrium (264)
Cr Chromium 51.9961	Hs Hassium (277)
Mn Manganese 54.938045	Mt Meitnerium (268)
Fe Iron 55.845	Ds Darmstadtium (271)
Co Cobalt 58.933195	Rg Roentgenium (272)
Ni Nickel 58.6934	Cn Copernicium (285)
Cu Copper 63.546	Uut Ununtrium (284)
Zn Zinc 65.38	Fl Flerovium (289)
Ga Gallium 69.723	Uup Ununpentium (288)
Ge Germanium 72.64	Lv Livermorium (292)
As Arsenic 74.92160	Uus Ununseptium (294)
Se Selenium 78.96	Uuo Ununoctium (294)
Br Bromine 79.904	
Kr Krypton 83.798	

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

La Lanthanum 138.90547	Ce Cerium 140.116	Pr Praseodymium 140.90765	Nd Neodymium 144.242	Pm Promethium (145)	Sm Samarium 150.36	Eu Europium 151.964	Gd Gadolinium 157.25	Tb Terbium 158.92535	Dy Dysprosium 162.5	Ho Holmium 164.93032	Er Erbium 167.259	Tm Thulium 168.93421	Yb Ytterbium 173.054	Lu Lutetium 174.9668
Ac Actinium (227)	Th Thorium 232.03806	Pa Protactinium 231.03588	U Uranium 238.02891	Np Neptunium (237)	Pu Plutonium (244)	Bh Bohrium (264)	Hs Hassium (277)	Mt Meitnerium (268)	Ds Darmstadtium (271)	Rg Roentgenium (272)	Cn Copernicium (285)	Uut Ununtrium (284)	Fl Flerovium (289)	Uup Ununpentium (288)

The Periodic Table

Alkaline earth metals form cations with a +2 charge

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

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.5	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)



The Periodic Table

Periodic Table



1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.00794																	2 He Helium 4.002602
2 Li Lithium 6.941	3 Be Beryllium 9.012182																
11 Na Sodium 22.9876928	12 Mg Magnesium 24.3050																
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Tl Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.293
55 Cs Caesium 132.9054519	56 Ba Barium 137.327	57-71 La-Lu	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (208.9824)	85 At Astatine (209.9871)	86 Rn Radon (222.0176)
87 Fr Francium (223)	88 Ra Radium (226)	89-103 Ac-Lr	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Uut Ununtrium (284)	114 Fl Flerovium (289)	115 Uup Ununpentium (288)	116 Lv Livermorium (292)	117 Uus Ununseptium (294)	118 Uuo Ununoctium (294)

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89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkellium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

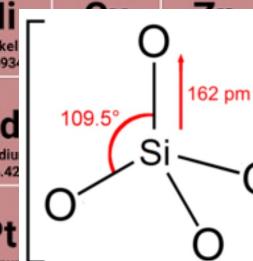


The Periodic Table

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

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

	13	14	15	16	17	18
1						
2		B	C	N	O	F
3	Li	Boron 10.811	Carbon 12.0107	Nitrogen 14.0067	Oxygen 15.9994	Neon 20.1797
4	Be					
5	Na					
6	Mg					
7	K					
8	Ca					
9	Sc					
10	Ti					
11	V					
12	Cr					
13	Mn					
14	Fe					
15	Co					
16	Ni					
17						
18						
19	Rb					
20	Sr					
21	Y					
22	Zr					
23	Nb					
24	Mo					
25	Tc					
26	Ru					
27	Rh					
28	Pd					
29						
30						
31						
32	Ge					
33	As					
34	Se					
35	Br					
36	Kr					
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53						
54						
55	Cs					
56	Ba					
57-71	La-Lu					
72	Hf					
73	Ta					
74	W					
75	Re					
76	Os					
77	Ir					
78	Pt					
79						
80						
81						
82						
83						
84						
85						
86						
87	Fr					
88	Ra					
89-103	Ac-Lr					
104	Rf					
105	Dub					
106	Sg					
107	Bh					
108	Hs					
109	Mt					
110	Ds					
111	Rg					
112	Cn					
113	Uut					
114	Fl					
115	Uup					
116	Lv					
117	Uus					
118	Uuo					



57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La Lanthanum 138.90547	Ce Cerium 140.116	Pr Praseodymium 140.90765	Nd Neodymium 144.242	Pm Promethium (145)	Sm Samarium 150.36	Eu Europium 151.964	Gd Gadolinium 157.25	Tb Terbium 158.92535	Dy Dysprosium 162.5	Ho Holmium 164.93032	Er Erbium 167.259	Tm Thulium 168.93421	Yb Ytterbium 173.054	Lu Lutetium 174.9668
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac Actinium (227)	Th Thorium 232.03806	Pa Protactinium 231.03588	U Uranium 238.02891	Np Neptunium (237)	Pu Plutonium (244)	Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (251)	Es Einsteinium (252)	Fm Fermium (257)	Md Mendelevium (258)	No Nobelium (259)	Lr Lawrencium (262)

The Periodic Table

☰ Periodic Table

🔍 ⋮

Other non-metals: can be present in a variety of oxidation states, from (-) to (+)

1	2	3	4												17	18	
H Hydrogen 1.00794															He Helium 4.002602		
Li Lithium 6.941	Be Beryllium 9.012182			Ds Darmstadtium (271) 2-8-18-32-32-17-1		Alkali metals		Transition metals			B Boron 10.811	C Carbon 12.0107	N Nitrogen 14.0067	O Oxygen 15.994	F Fluorine 8.9984032		
Na Sodium 22.9876928	Mg Magnesium 24.3050					Alkaline earth metals		Post-transition metals			Al Aluminium 26.9815386	Si Silicon 28.085	P Phosphorus 30.973762	S Sulfur 32.065	Ne Neon 20.1797		
K Potassium 39.0983	Ca Calcium 40.078	Sc Scandium 44.955912	Ti Titanium 47.867	V Vanadium 50.9415	Cr Chromium 51.9961	Mn Manganese 54.938045	Fe Iron 55.845	Co Cobalt 58.933195	Ni Nickel 58.6934	Cu Copper 63.546	Zn Zinc 65.38	Ga Gallium 69.723	Ge Germanium 72.64	As Arsenic 74.92160	Se Selenium 78.96	Br Bromine 79.904	Kr Krypton 83.798
Rb Rubidium 85.4678	Sr Strontium 87.62	Y Yttrium 88.90585	Zr Zirconium 91.224	Nb Niobium 92.90638	Mo Molybdenum 95.96	Tc Technetium (97.9072)	Ru Ruthenium 101.07	Rh Rhodium 102.90550	Pd Palladium 106.42	Ag Silver 107.8682	Cd Cadmium 112.411	In Indium 114.818	Sn Tin 118.710	Sb Antimony 121.760	Te Tellurium 127.60	I Iodine 126.90447	Xe Xenon 131.293
Cs Caesium 132.9054519	Ba Barium 137.327	La-Lu La-Lu	Hf Hafnium 178.49	Ta Tantalum 180.94788	W Tungsten 183.84	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.217	Pt Platinum 195.084	Au Gold 196.966569	Hg Mercury 200.59	Tl Thallium 204.3833	Pb Lead 207.2	Bi Bismuth 208.98040	Po Polonium (208.9824)	At Astatine (209.9871)	Rn Radon (222.0176)
Fr Francium (223)	Ra Radium (226)	89-103 Ac-Lr	104 Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Uut Ununtrium (284)	114 Fl Flerovium (289)	115 Uup Ununpentium (288)	116 Lv Livermorium (292)	117 Uus Ununseptium (294)	118 Uuo Ununoctium (294)

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

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.5	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkellium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)



The Periodic Table

Periodic Table



Halogens form anions with a (-1) charge

1	2	3	4	5	6	110	Other	18
H Hydrogen 1.00794						Ds	Alkali metals	He Helium .002602
Li Lithium 6.941	Be Beryllium 9.012182					Darmstadtium (271) 2-8-18-32-32-17-1	Alkaline earth metals	Ne Neon 20.1797
Na Sodium 22.9876928	Mg Magnesium 24.3050						Noble gases	Ar Argon 39.948
K Potassium 39.0983	Ca Calcium 40.078	Sc Scandium 44.955912	Ti Titanium 47.867	V Vanadium 50.9415	Cr Chromium 51.9961	Mn Manganese 54.938045	Fe Iron 55.845	Co Cobalt 58.933195
Rb Rubidium 85.4678	Sr Strontium 87.62	Y Yttrium 88.90585	Zr Zirconium 91.224	Nb Niobium 92.90638	Mo Molybdenum 95.96	Tc Technetium (97.9072)	Ru Ruthenium 101.07	Rh Rhodium 102.90550
Cs Caesium 132.9054519	Ba Barium 137.327	La-Lu	Hf Hafnium 178.49	Ta Tantalum 180.94788	W Tungsten 183.84	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.217
Fr Francium (223)	Ra Radium (226)	Ac-Lr	Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (266)	Bh Bohrium (264)	Hs Hassium (277)	Mt Meitnerium (268)
								Ds Darmstadtium (271)
								Rg Roentgenium (272)
								Cn Copernicium (285)
								Uut Ununtrium (284)
								Fl Flerovium (289)
								Uup Ununpentium (288)
								Lv Livermorium (292)
								Uus Ununseptium (294)
								Juo Junoctium (294)

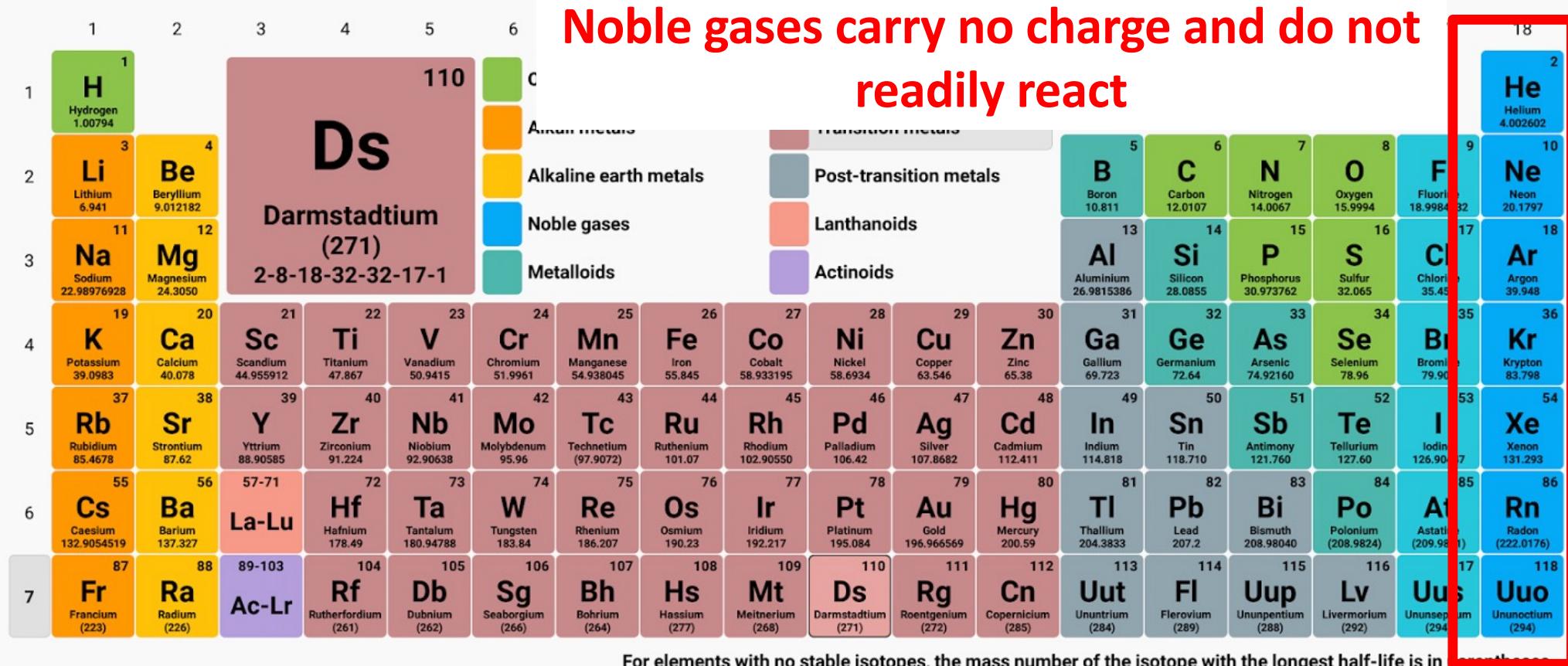
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

57 La Lanthanum 138.90547	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90765	60 Nd Neodymium 144.242	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.5	67 Ho Holmium 164.93032	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.054	71 Lu Lutetium 174.9668
89 Ac Actinium (227)	90 Th Thorium 232.03806	91 Pa Protactinium 231.03588	92 U Uranium 238.02891	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)



The Periodic Table

≡ Periodic Table



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

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La Lanthanum 138.90547	Ce Cerium 140.116	Pr Praseodymium 140.90765	Nd Neodymium 144.242	Pm Promethium (145)	Sm Samarium 150.36	Eu Europium 151.964	Gd Gadolinium 157.25	Tb Terbium 158.92535	Dy Dysprosium 162.5	Ho Holmium 164.93032	Er Erbium 167.259	Tm Thulium 168.93421	Yb Ytterbium 173.054	Lu Lutetium 174.9668
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac Actinium (227)	Th Thorium 232.03806	Pa Protactinium 231.03588	U Uranium 238.02891	Np Neptunium (237)	Pu Plutonium (244)	Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (251)	Es Einsteinium (252)	Fm Fermium (257)	Md Mendelevium (258)	No Nobelium (259)	Lr Lawrencium (262)



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



Dissolution Reaction



National Geographic

Precipitation Reaction

Evaporite deposits

Water removed through evaporation

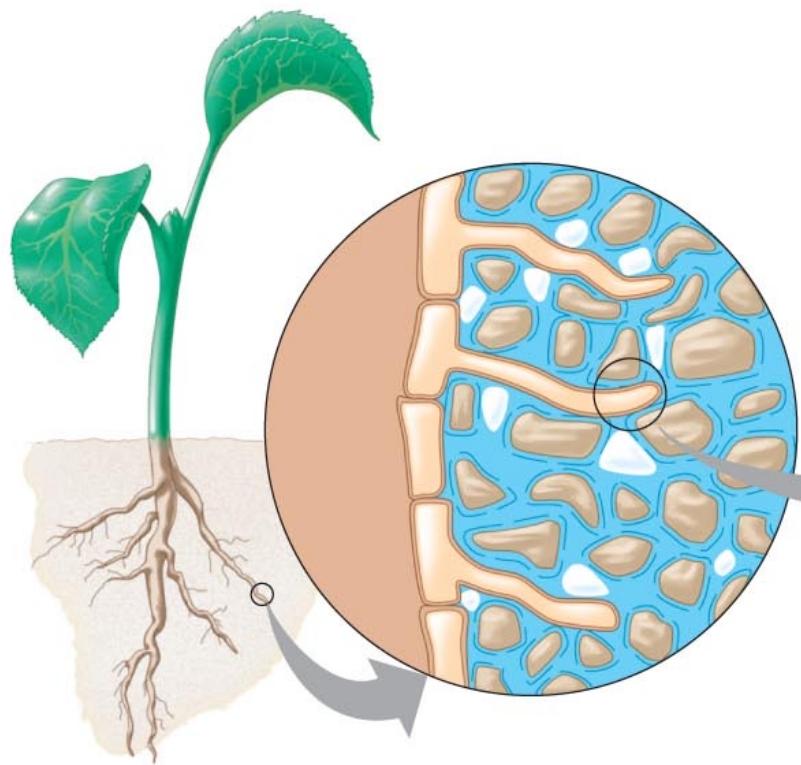


Pipe scaling

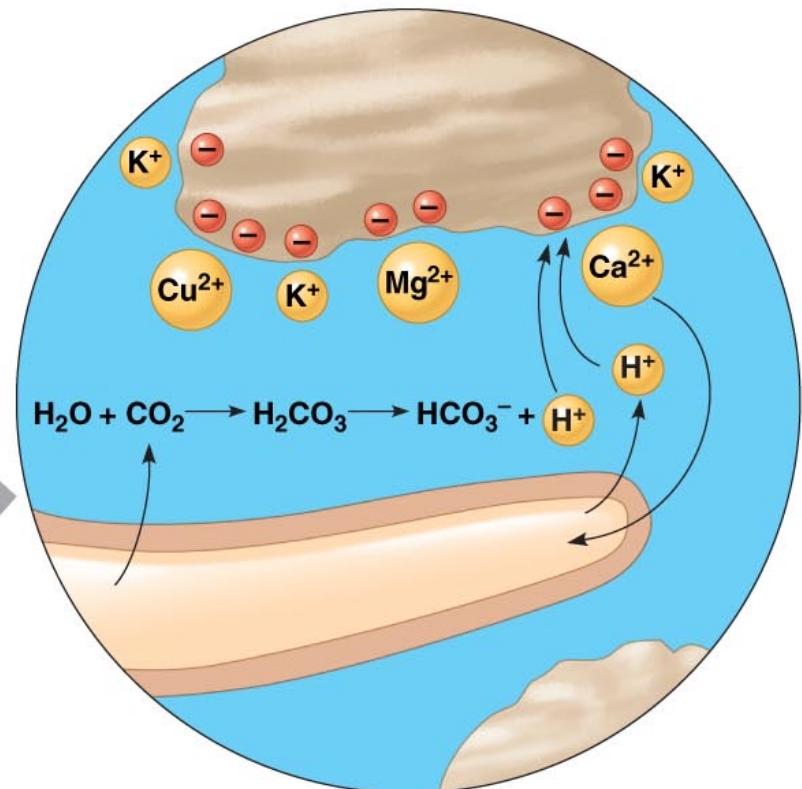
Acid-base reaction



Cation exchange in soils



(a)



(b)

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Redox reaction in acid mine drainage

- 1) $\text{FeS}_2 + \text{O}_2 \rightarrow \text{Fe}^{2+} + \text{SO}_4^{2-} + \text{H}_2\text{SO}_4$
- 2) $\text{Fe}^{2+} + \text{O}_2 \rightarrow \text{Fe}^{3+}$
- 3) $\text{Fe}^{3+} + \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3$

What is oxidized and what is reduced in each reaction?

**unbalanced reactions



Global Carbon Cycle

