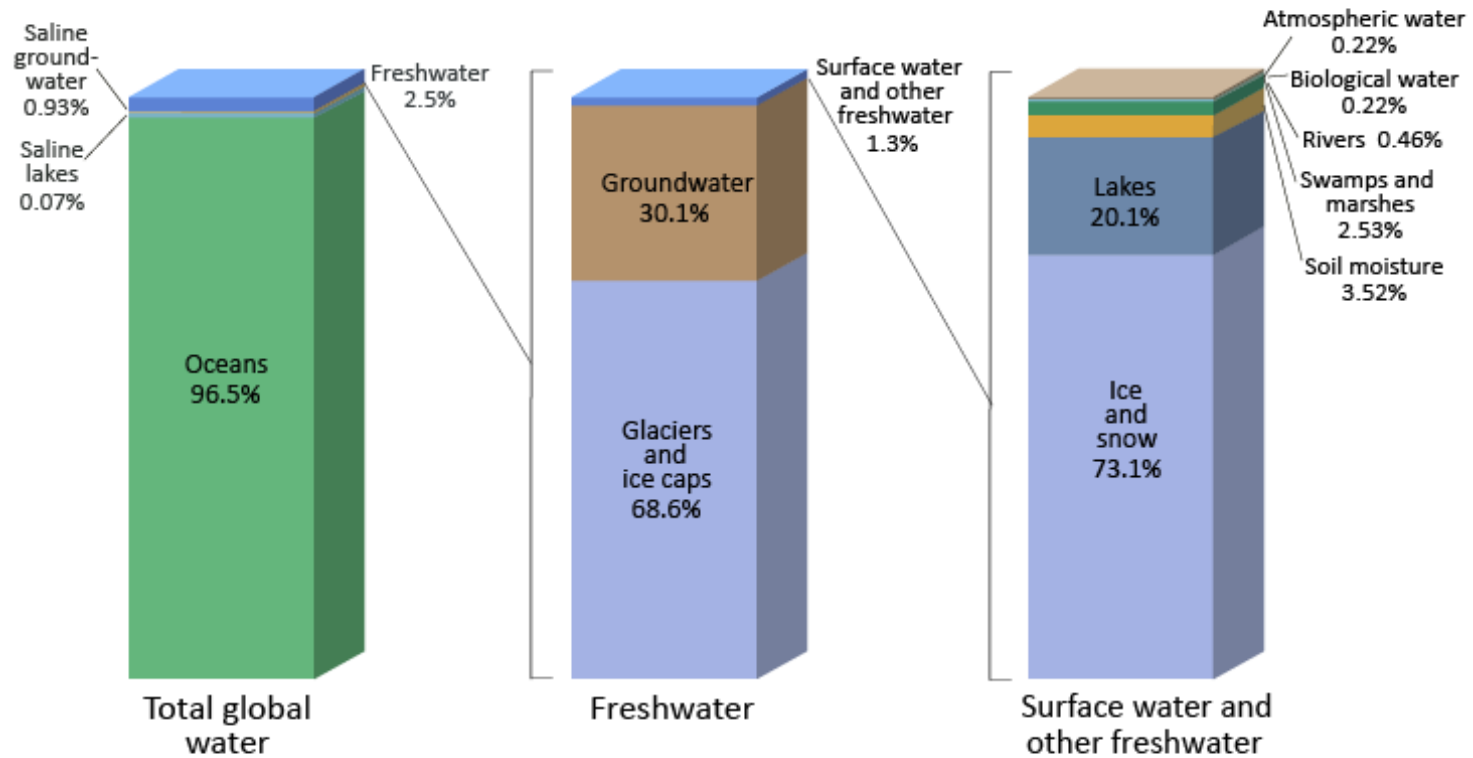
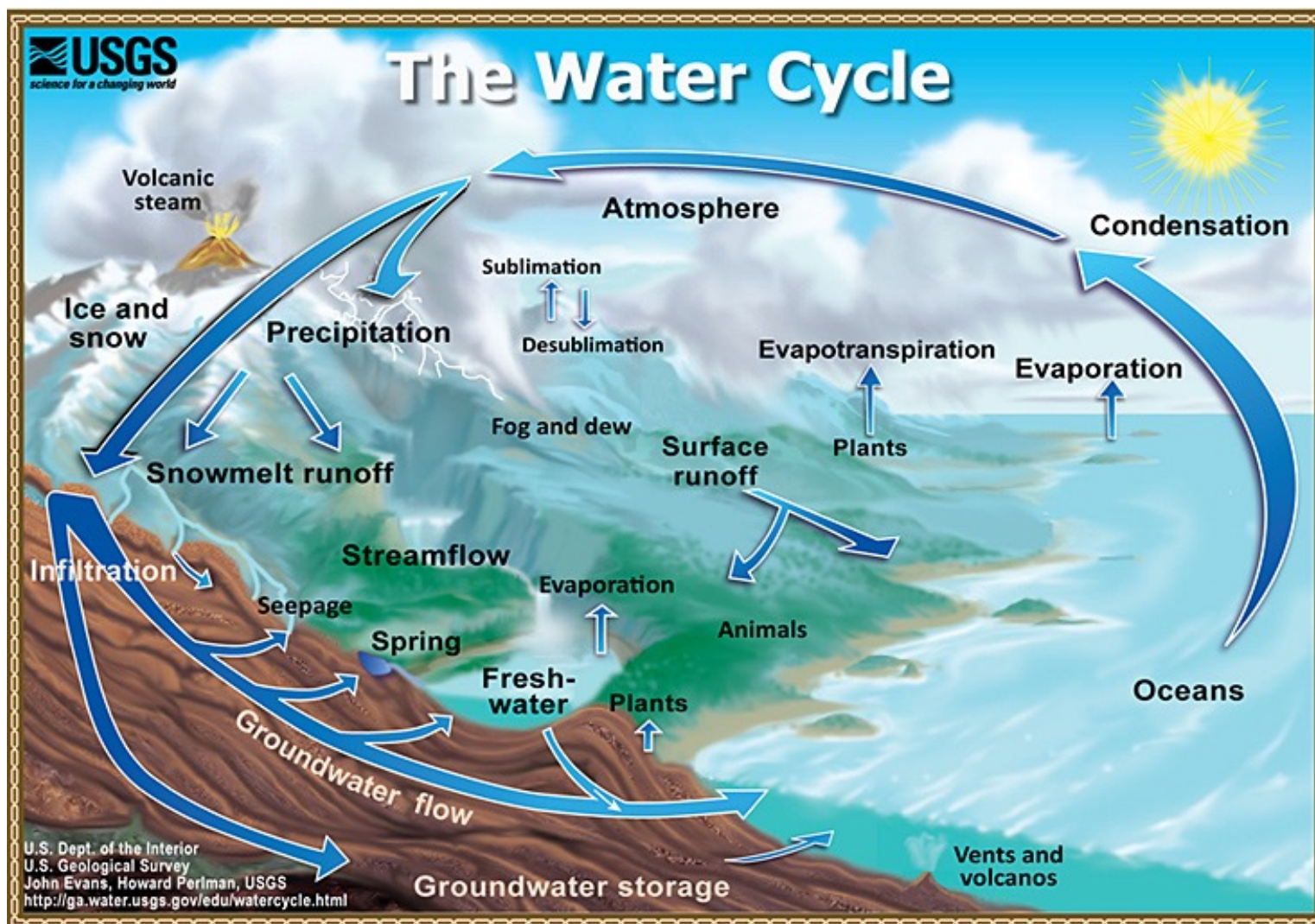


## (Reservoirs) Distribution of Earth's Water

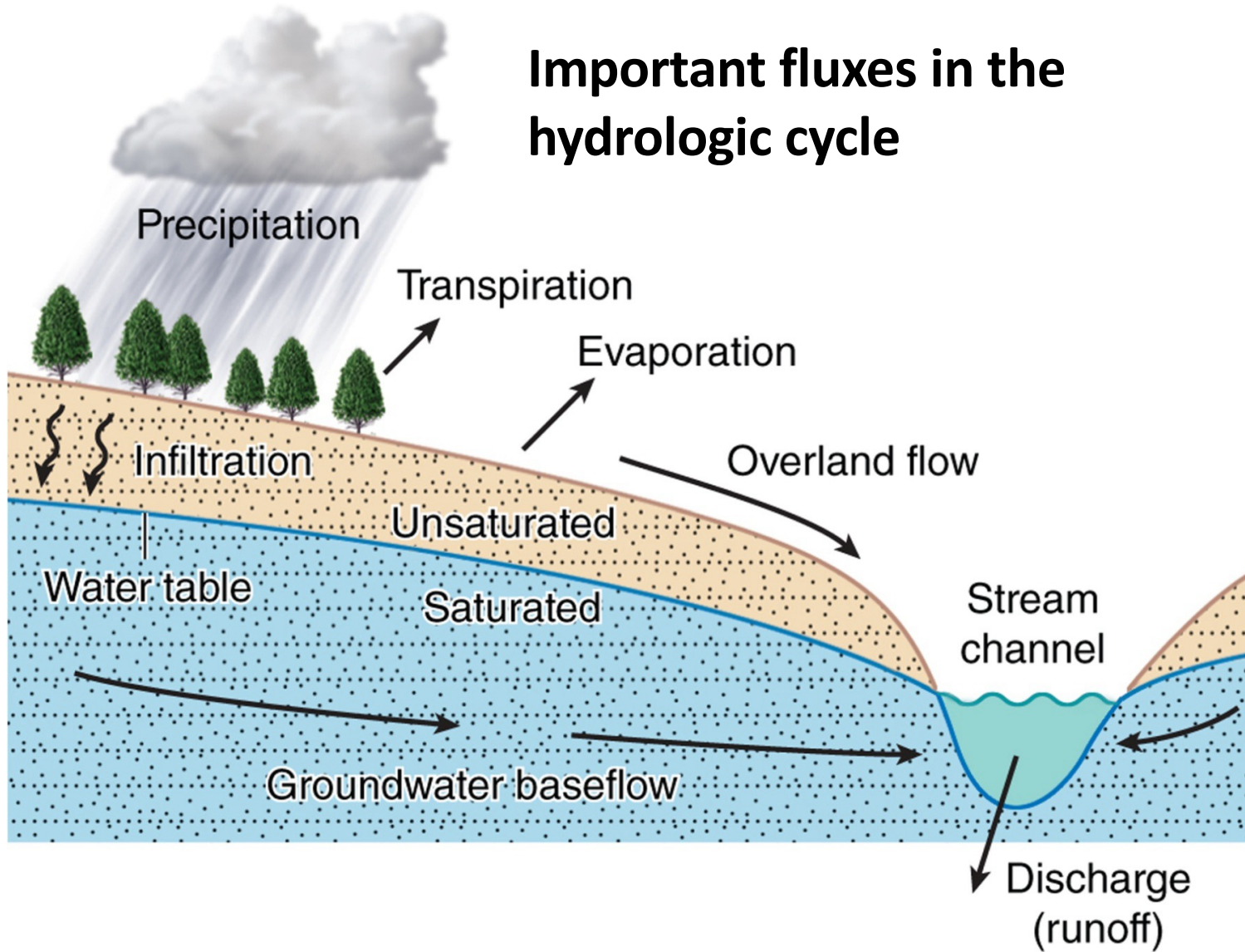


Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, *Water in Crisis: A Guide to the World's Fresh Water Resources*.

How does water move across the Earth?



# Important fluxes in the hydrologic cycle



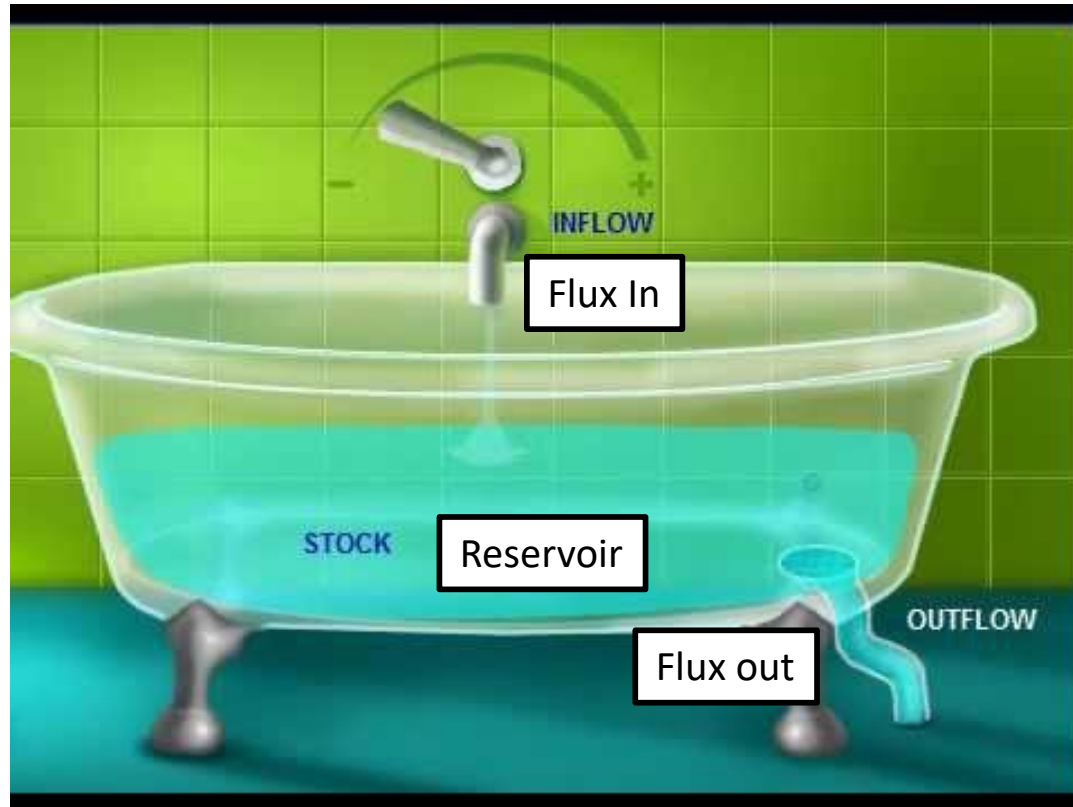
## Understanding water transport through the environment

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



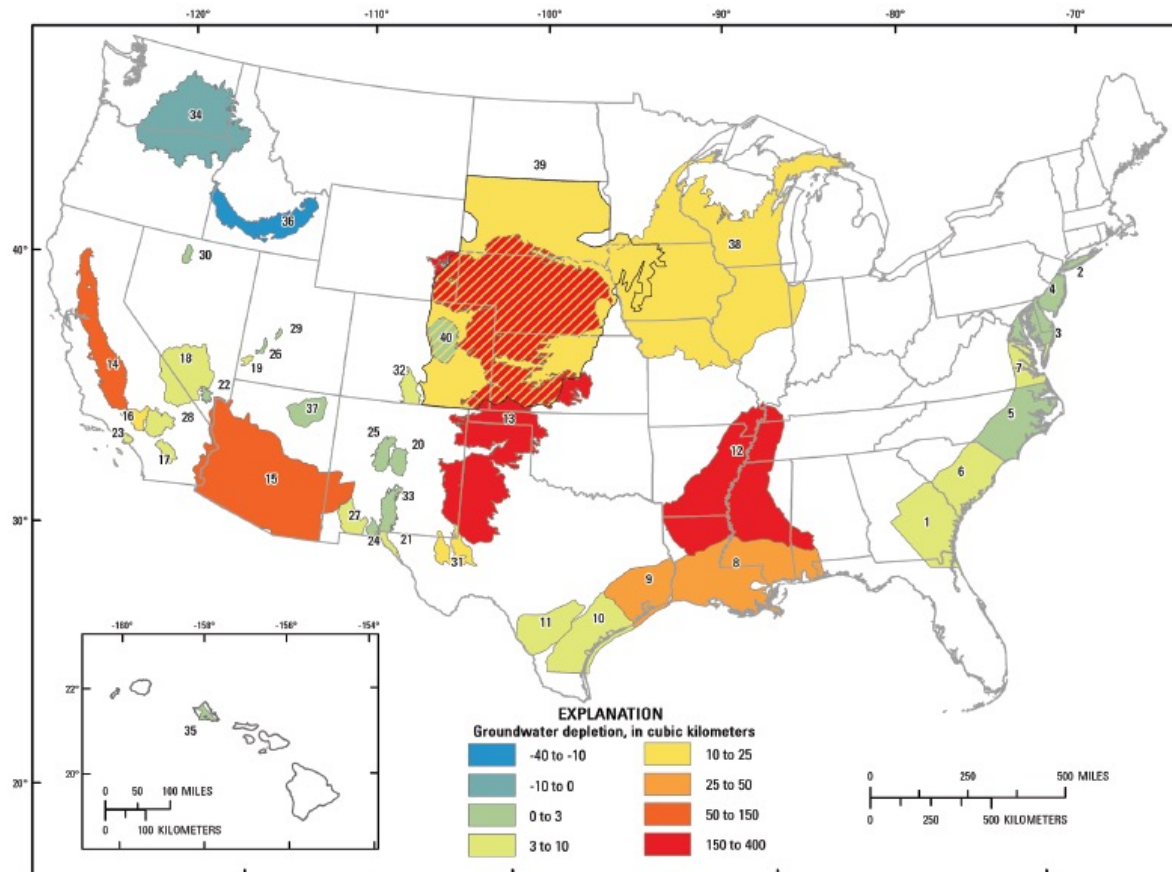
- **Reservoir** – an arbitrarily defined space containing a certain mass of a substance of interest
- **Flux** – transfer of material into and out of a reservoir
- **Steady-state** – describes a system where the amount of substance in a reservoir does not change with time (fluxes are balanced)
- **Residence 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>

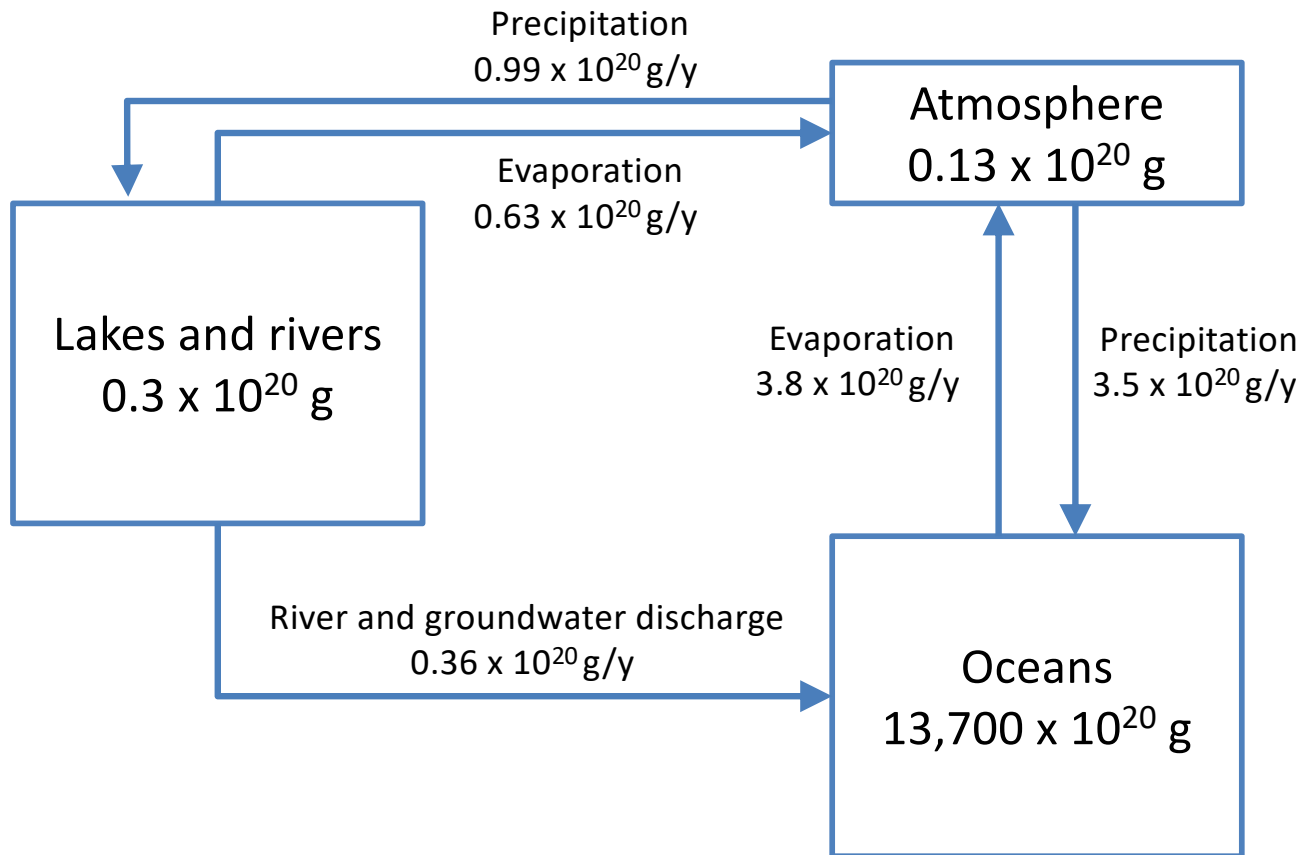
# Are these groundwater reservoirs in steady state?



Base from U.S. Geological Survey digital data, 1972, 1:2,000,000  
Albers Equal-Area Conic Projection  
Standard parallels 23° 30' N and 45° 30' N, central meridian 96° 00' W

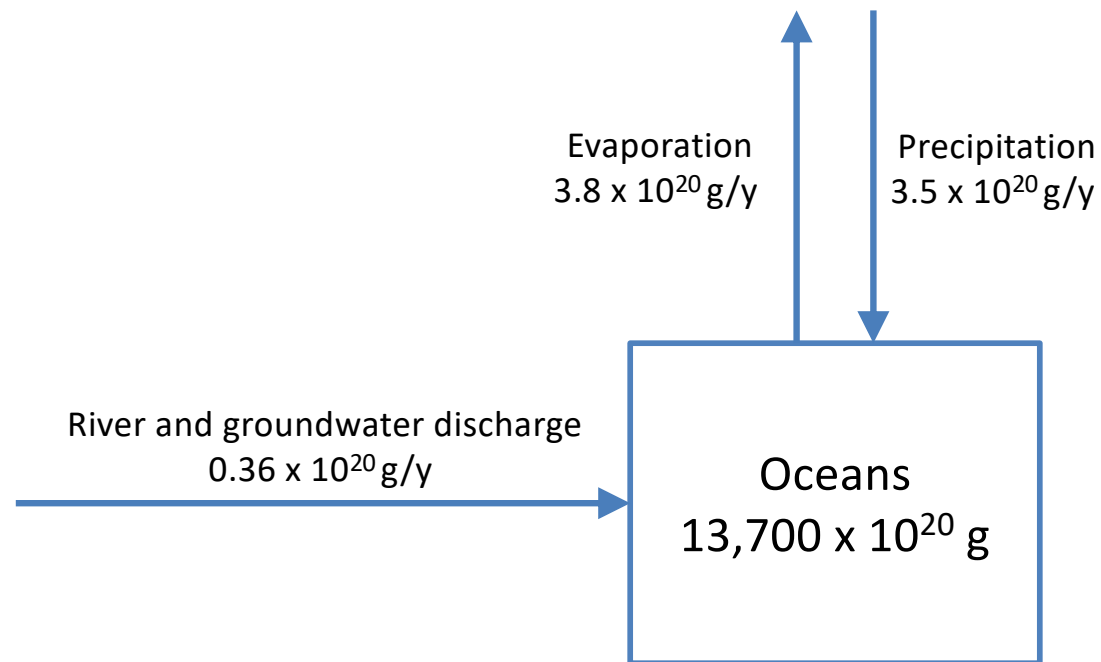
**Figure 2.** Map of the United States (excluding Alaska) showing cumulative groundwater depletion, 1900 through 2008, in 40 assessed aquifer systems or subareas. Index numbers are defined in table 1. Colors are hatched in the Dakota aquifer (area 39) where the aquifer overlaps with other aquifers having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

## The Hydrologic Cycle: Simple Box Model for Water

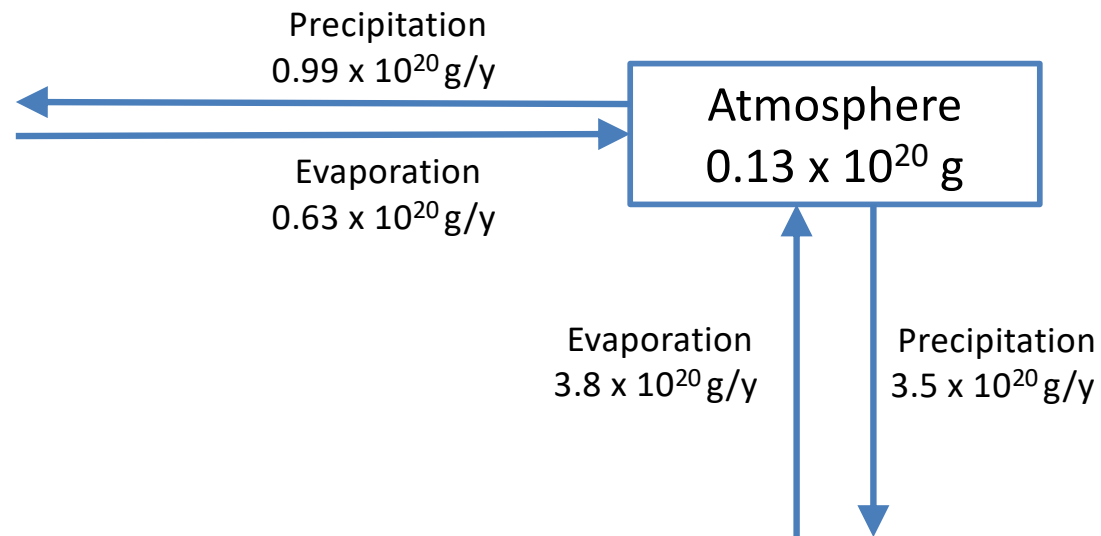


What is the **residence time** of a water molecule in the ocean?

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







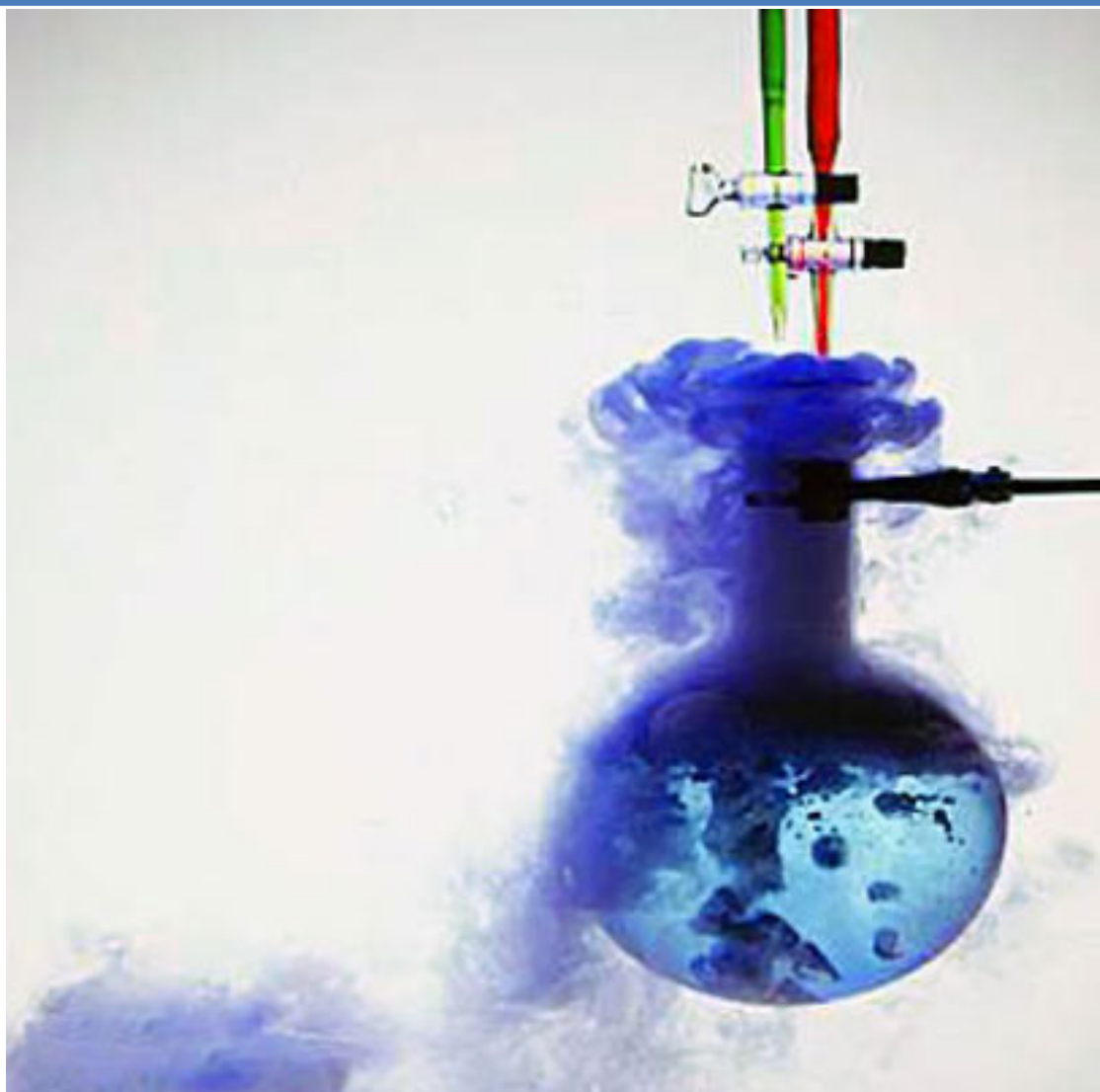
What is the **residence time** of a water molecule in the atmosphere?

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



# Chemical Reactions

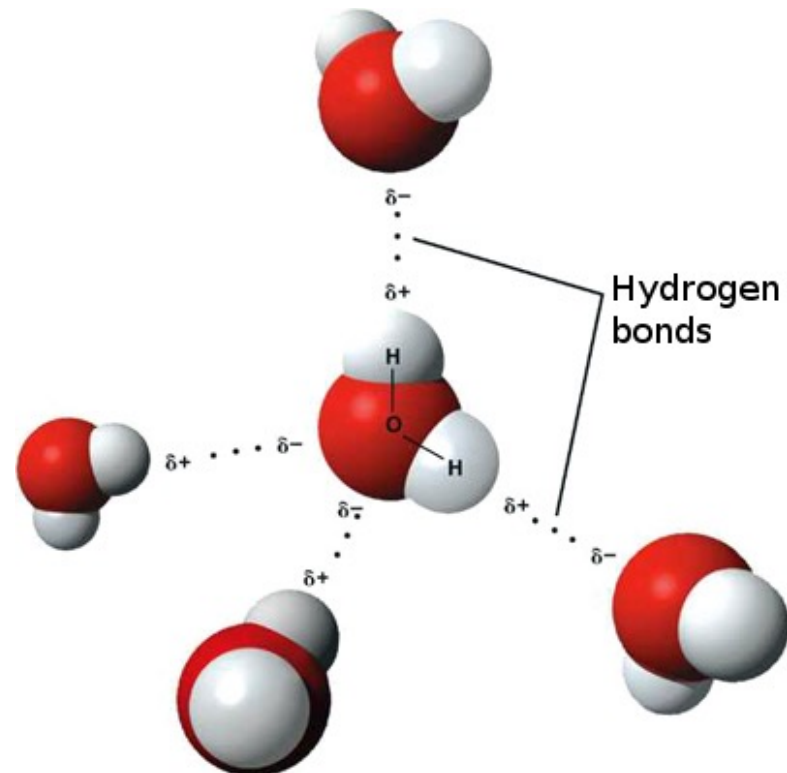
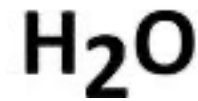
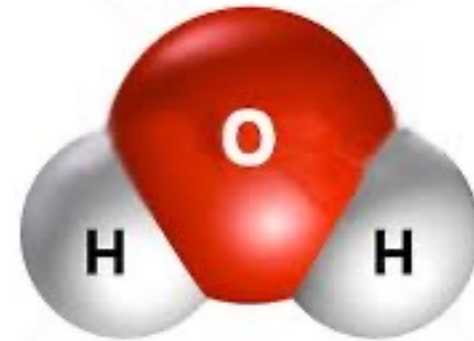
- Water
- The Periodic Table
- Unit Conversion
- Types of chemical reactions



## Properties of water

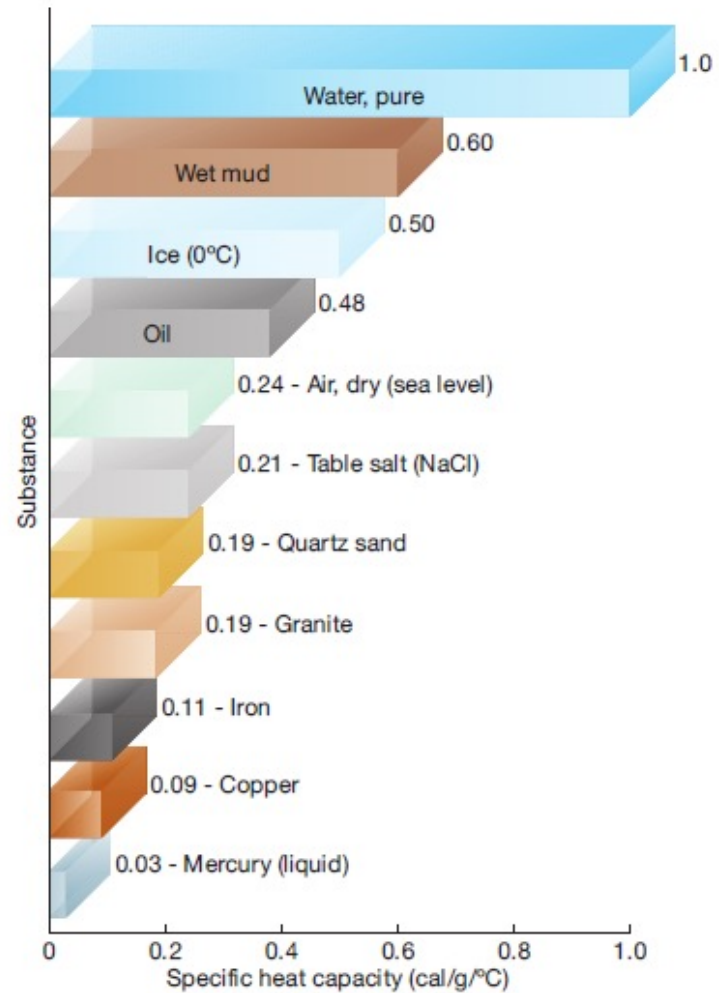
1. Dipolar
2. Hydrogen bonds
3. Strong cohesive and adhesive nature
4. High heat capacity
5. Low density (especially frozen)
6. Universal solvent
7. Participates in and facilitates chemical reactions

WATER  
MOLECULE



## Properties of water

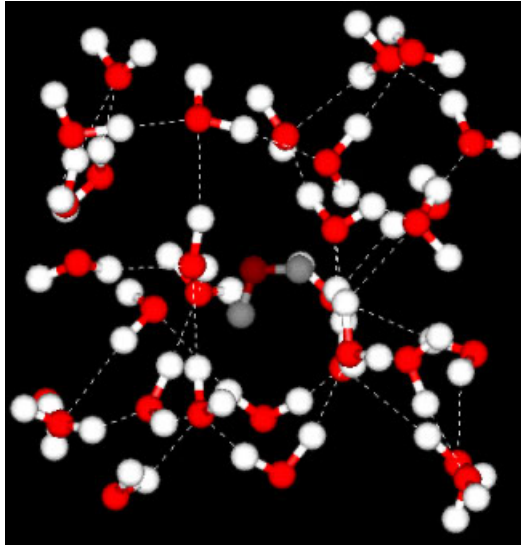
- Water has a high *specific heat capacity* relative to other substances



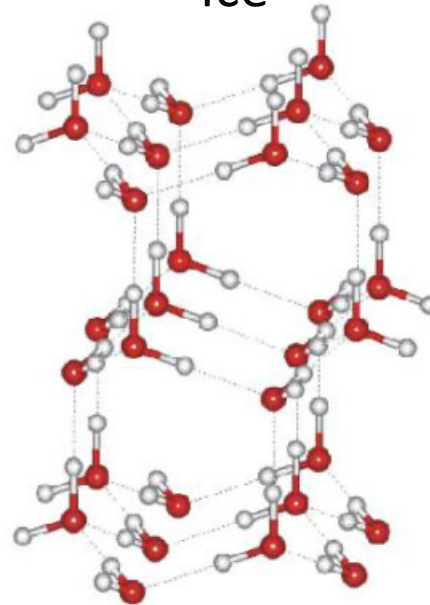
## Properties of water

- Low density, especially when frozen

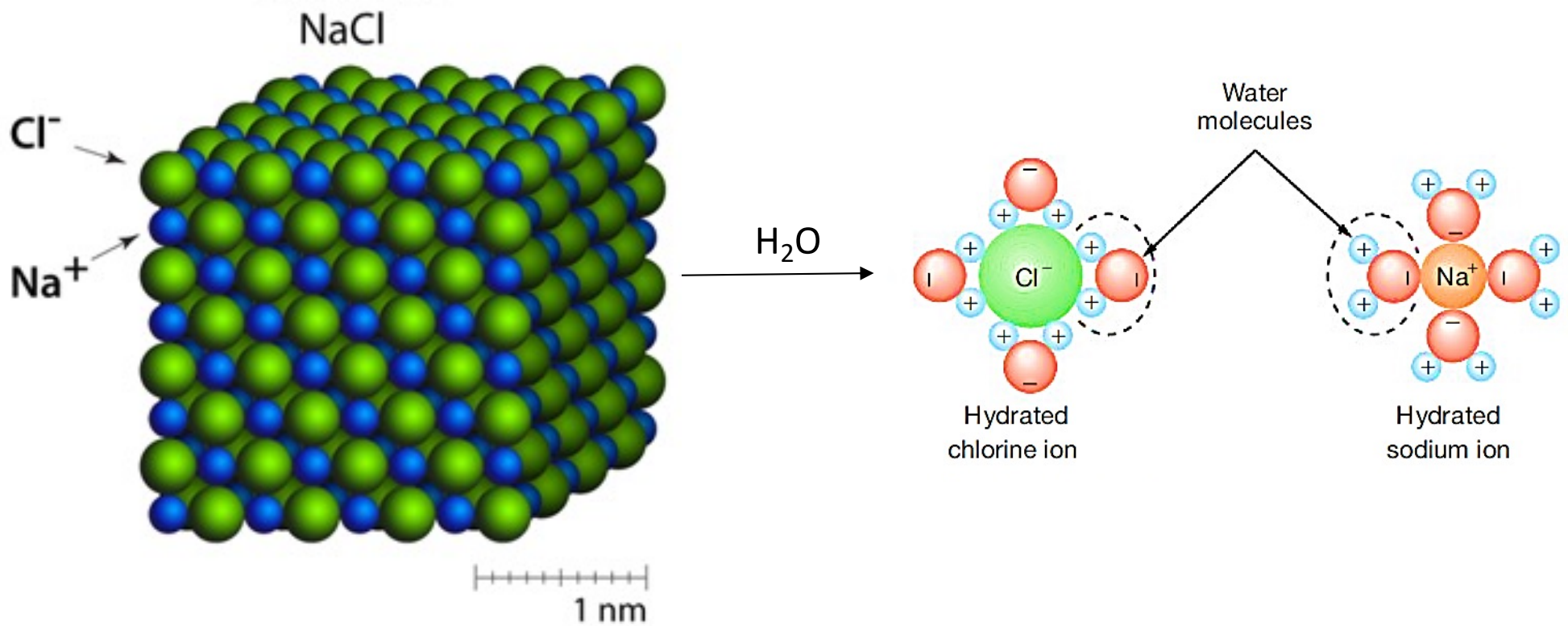
Liquid Water



Ice



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



# The Periodic Table

Element abbreviation

Atomic number

Element name

Molecular mass (g/mol)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1		<b>H</b> Hydrogen 1.00794																		<b>He</b> Helium 4.002602
2		<b>Li</b> Lithium 6.941	<b>Be</b> Beryllium 9.012182											<b>B</b> Boron 10.811	<b>C</b> Carbon 12.0107	<b>N</b> Nitrogen 14.0067	<b>O</b> Oxygen 15.9994	<b>F</b> Fluorine 18.9984032	<b>Ne</b> Neon 20.1797	
3		<b>Na</b> Sodium 22.98976928	<b>Mg</b> Magnesium 24.3050											<b>Al</b> Aluminum 26.9815386	<b>Si</b> Silicon 28.0855	<b>P</b> Phosphorus 30.973762	<b>S</b> Sulfur 32.065	<b>Cl</b> Chlorine 35.453	<b>Ar</b> Argon 39.948	
4		<b>K</b> Potassium 39.0983	<b>Ca</b> Calcium 40.078	<b>Sc</b> Scandium 44.955912	<b>Ti</b> Titanium 47.867	<b>V</b> Vanadium 50.9415	<b>Cr</b> Chromium 51.9961	<b>Mn</b> Manganese 54.938045	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933195	<b>Ni</b> Nickel 58.6934	<b>Cu</b> Copper 63.546	<b>Zn</b> Zinc 65.38	<b>Ga</b> Gallium 69.723	<b>Ge</b> Germanium 72.64	<b>As</b> Arsenic 74.92160	<b>Se</b> Selenium 78.96	<b>Br</b> Bromine 79.904	<b>Kr</b> Krypton 83.798	
5		<b>Rb</b> Rubidium 85.4678	<b>Sr</b> Strontium 87.62	<b>Y</b> Yttrium 88.90585	<b>Zr</b> Zirconium 91.224	<b>Nb</b> Niobium 92.90638	<b>Mo</b> Molybdenum 95.96	<b>Tc</b> Technetium (97.9072)	<b>Ru</b> Ruthenium 101.07	<b>Rh</b> Rhodium 102.90550	<b>Pd</b> Palladium 106.42	<b>Ag</b> Silver 107.8682	<b>Cd</b> Cadmium 112.411	<b>In</b> Indium 114.818	<b>Sn</b> Tin 118.710	<b>Sb</b> Antimony 121.760	<b>Te</b> Tellurium 127.60	<b>I</b> Iodine 126.90447	<b>Xe</b> Xenon 131.293	
6		<b>Cs</b> Caesium 132.9054519	<b>Ba</b> Barium 137.327	<b>La-Lu</b>	<b>Hf</b> Hafnium 178.49	<b>Ta</b> Tantalum 180.94788	<b>W</b> Tungsten 183.84	<b>Re</b> Rhenium 186.207	<b>Os</b> Osmium 190.23	<b>Ir</b> Iridium 192.217	<b>Pt</b> Platinum 195.084	<b>Au</b> Gold 196.966569	<b>Hg</b> Mercury 200.59	<b>Tl</b> Thallium 204.3833	<b>Pb</b> Lead 207.2	<b>Bi</b> Bismuth 208.98040	<b>Po</b> Polonium (208.9824)	<b>At</b> Astatine (209.9871)	<b>Rn</b> Radon (222.0176)	
7		<b>Fr</b> Francium (223)	<b>Ra</b> Radium (226)	<b>Ac-Lr</b>	<b>Rf</b> Rutherfordium (261)	<b>Db</b> Dubnium (262)	<b>Sg</b> Seaborgium (266)	<b>Bh</b> Bohrium (264)	<b>Hs</b> Hassium (277)	<b>Mt</b> Meitnerium (268)	<b>Ds</b> Darmstadtium (271)	<b>Rg</b> Roentgenium (272)	<b>Cn</b> Copernicium (285)	<b>Uut</b> Ununtrium (284)	<b>Fl</b> Flerovium (289)	<b>Uup</b> Ununpentium (288)	<b>Lv</b> Livermorium (292)	<b>Uus</b> Ununseptium (294)	<b>Uuo</b> Ununoctium (294)	

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

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

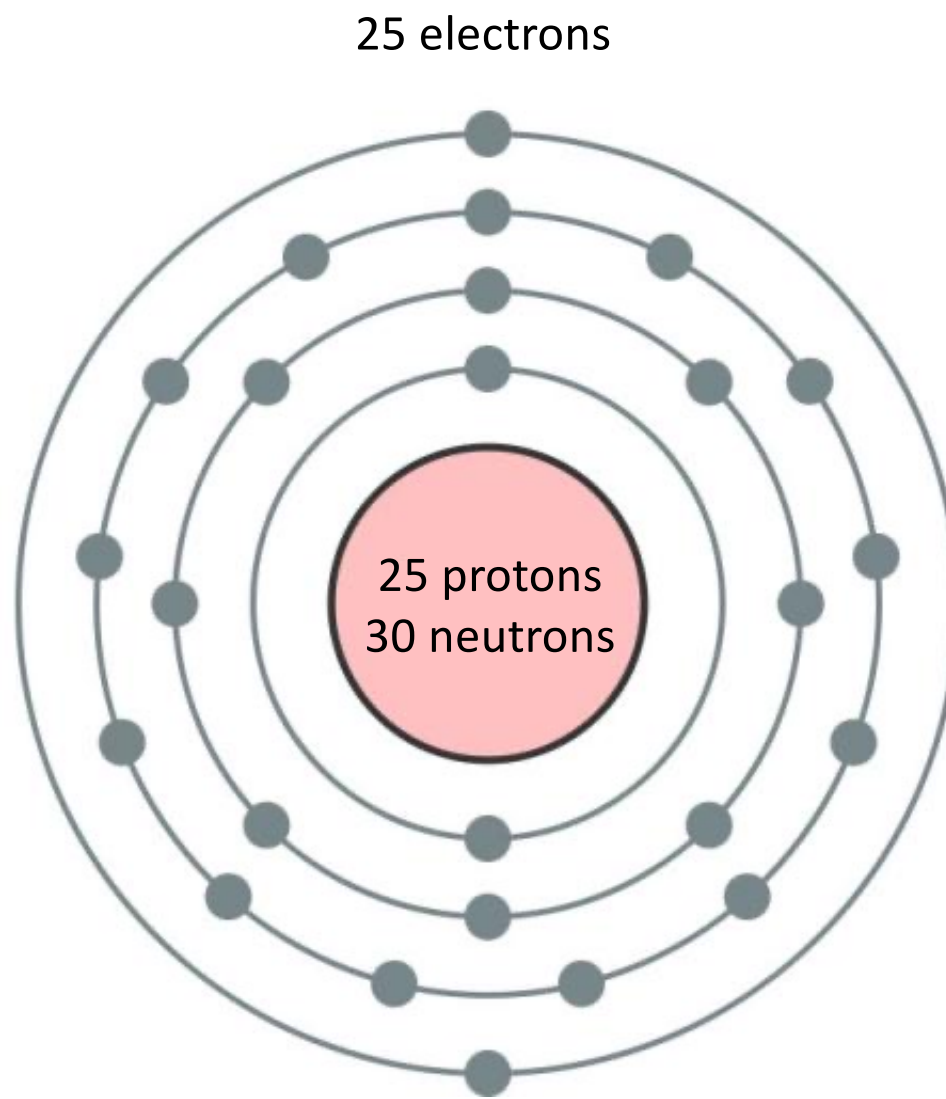




Elements lose and gain electrons to form different ***oxidation states***



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

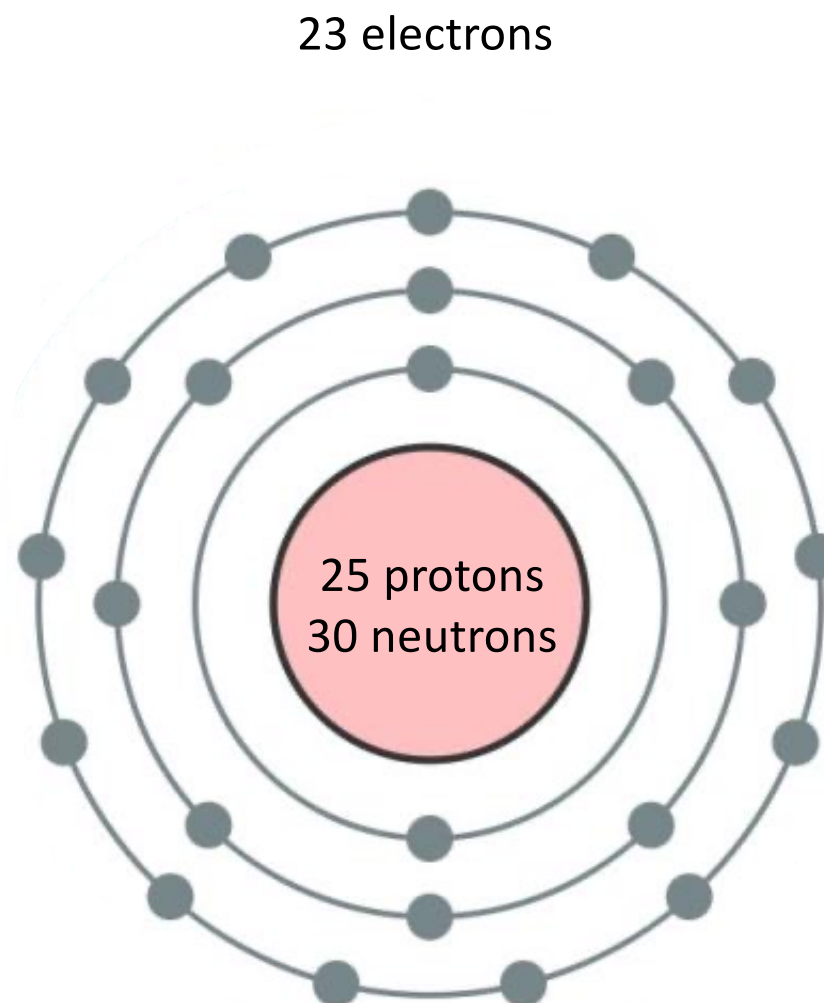


Refer to the note

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



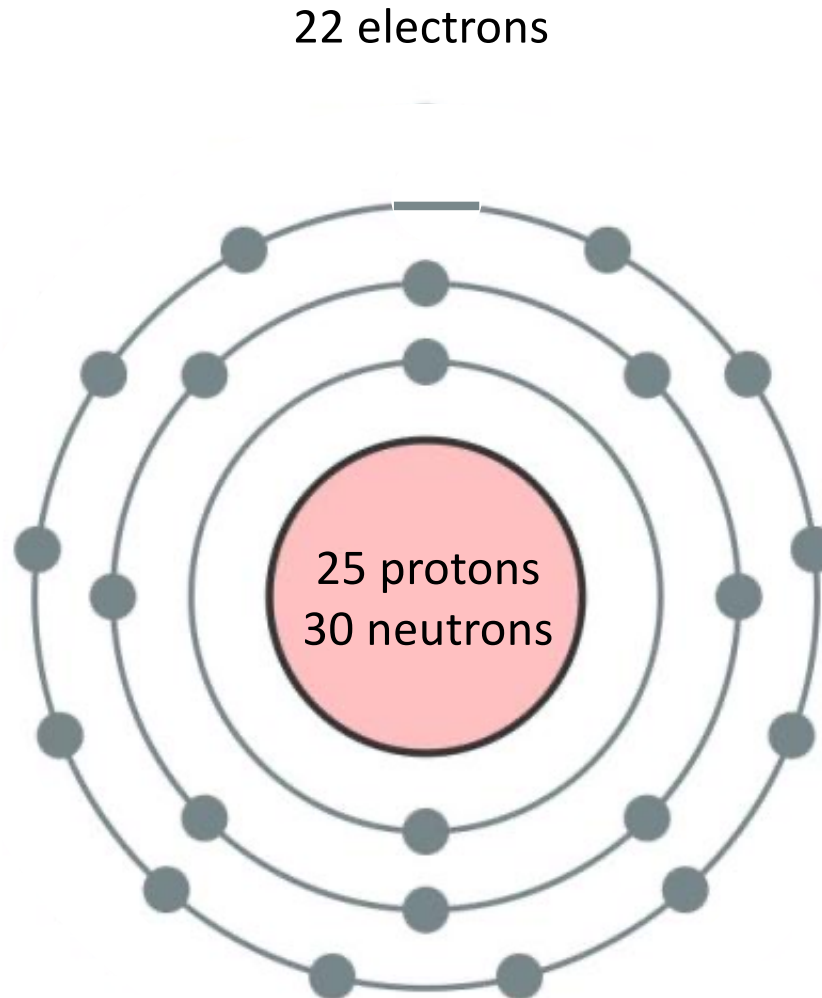
$\text{Mn}^{2+}$  – gives up 2 electrons to create charge deficit  
**Oxidation state = +2**



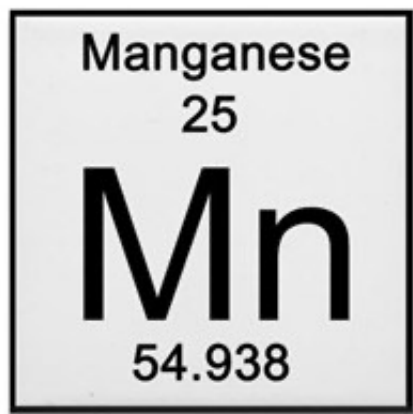
Elements lose and gain electrons to form different *oxidation states*



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

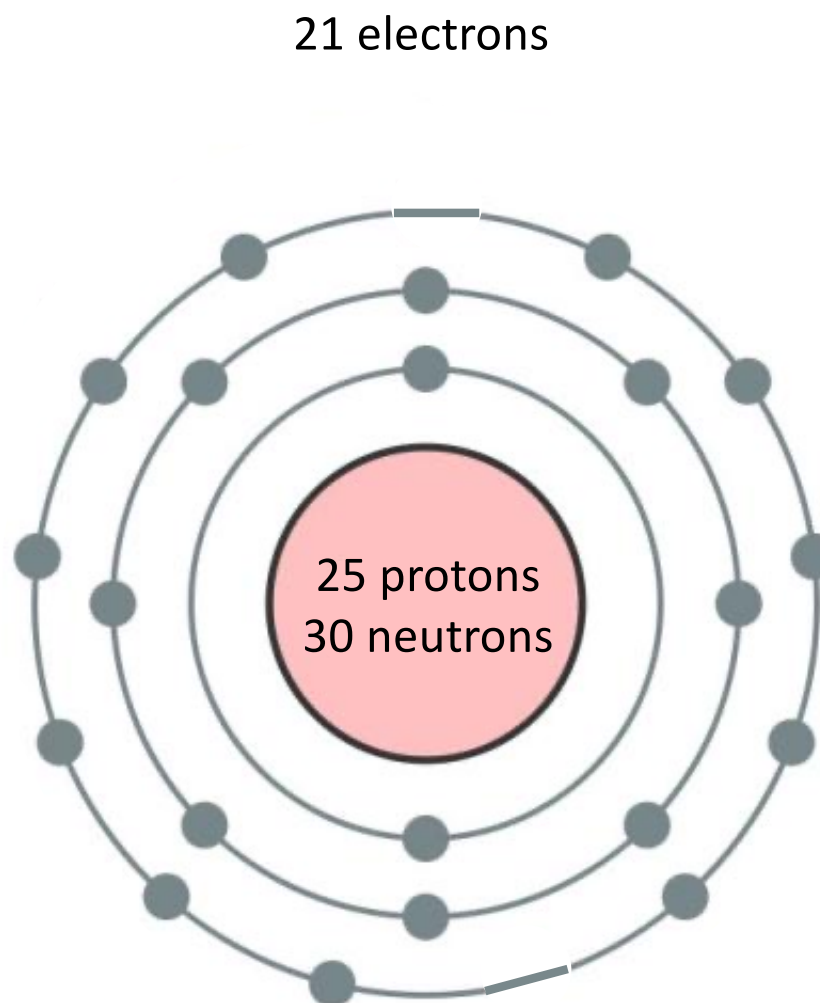


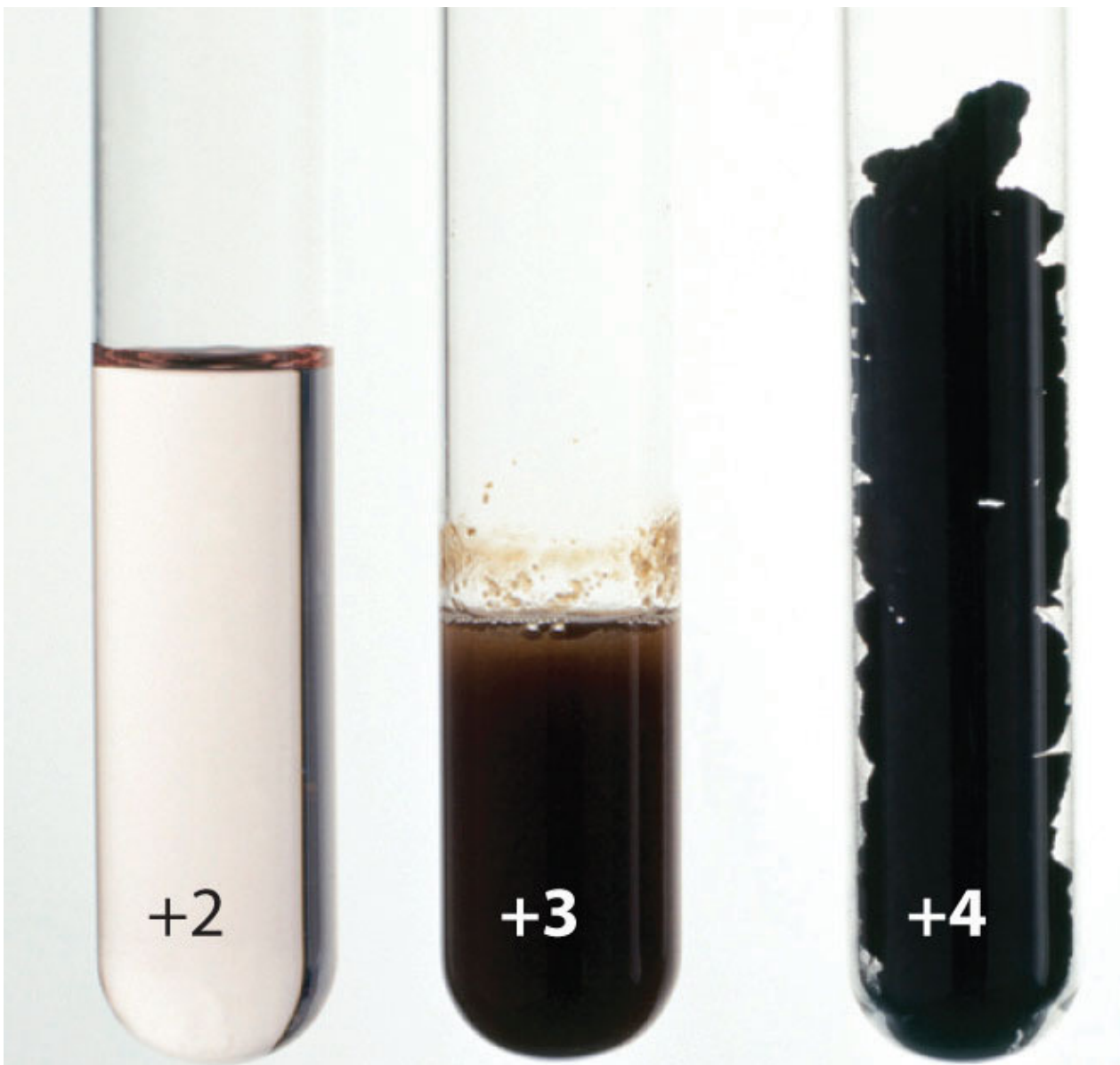
Elements lose and gain electrons to form different ***oxidation states***



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

**Oxidation state = +4**





**Dissolved  
Mn<sup>2+</sup>**

**Solid Mn-  
oxyhydroxide  
(MnOOH)**

**Solid  
Mn-oxide  
(MnO<sub>2</sub>)**

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 is color-coded by groups. A red box highlights the alkali metals: Hydrogen (H), Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Caesium (Cs), and Francium (Fr). A legend identifies the following categories:

- Other nonmetals (Green)
- Alkali metals (Orange)
- Alkaline earth metals (Yellow)
- Noble gases (Light Blue)
- Metalloids (Teal)
- Halogens (Cyan)
- Transition metals (Red/Pink)
- Post-transition metals (Grey)
- Lanthanoids (Light Orange)
- Actinoids (Purple)

1	110										2						
H Hydrogen 1.00794	Ds Darmstadtium (271) 2-8-18-32-32-17-1										He Helium 4.002602						
3	4											10					
Li Lithium 6.941	Be Beryllium 9.012182											B Boron 10.811	C Carbon 12.0107	N Nitrogen 14.0067	O Oxygen 15.9994	F Fluorine 18.9984032	Ne Neon 20.1797
11	12											18					
Na Sodium 22.98976928	Mg Magnesium 24.3050											Al Aluminum 26.9815386	Si Silicon 28.0855	P Phosphorus 30.973762	S Sulfur 32.065	Cl Chlorine 35.453	Ar Argon 39.948
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
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
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
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
55	56	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
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	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)
87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
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)	Uuo Ununoctium (294)

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

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

Alkaline earth metals form cations with a +2 charge

The periodic table is color-coded by groups. A red box highlights the alkaline earth metals: Lithium (Li), Beryllium (Be), Sodium (Na), Magnesium (Mg), Potassium (K), Calcium (Ca), Rubidium (Rb), Strontium (Sr), Caesium (Cs), Barium (Ba), and Francium (Fr), Radium (Ra). The legend includes: Other nonmetals (green), Alkali metals (orange), Alkaline earth metals (yellow), Noble gases (blue), Metalloids (teal), Halogens (cyan), Transition metals (brown), Post-transition metals (grey), Lanthanoids (pink), and Actinoids (purple). Darmstadtium (Ds) is highlighted in a large brown box with the text 'Darmstadtium (271) 2-8-18-32-32-17-1'.

1	2	110										15	16	17	18			
1	H	Ds										B	C	N	O	F	He	
2	Li	Be	Darmstadtium (271) 2-8-18-32-32-17-1										Boron	Carbon	Nitrogen	Oxygen	Fluorine	Neon
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La-Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac-Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

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

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



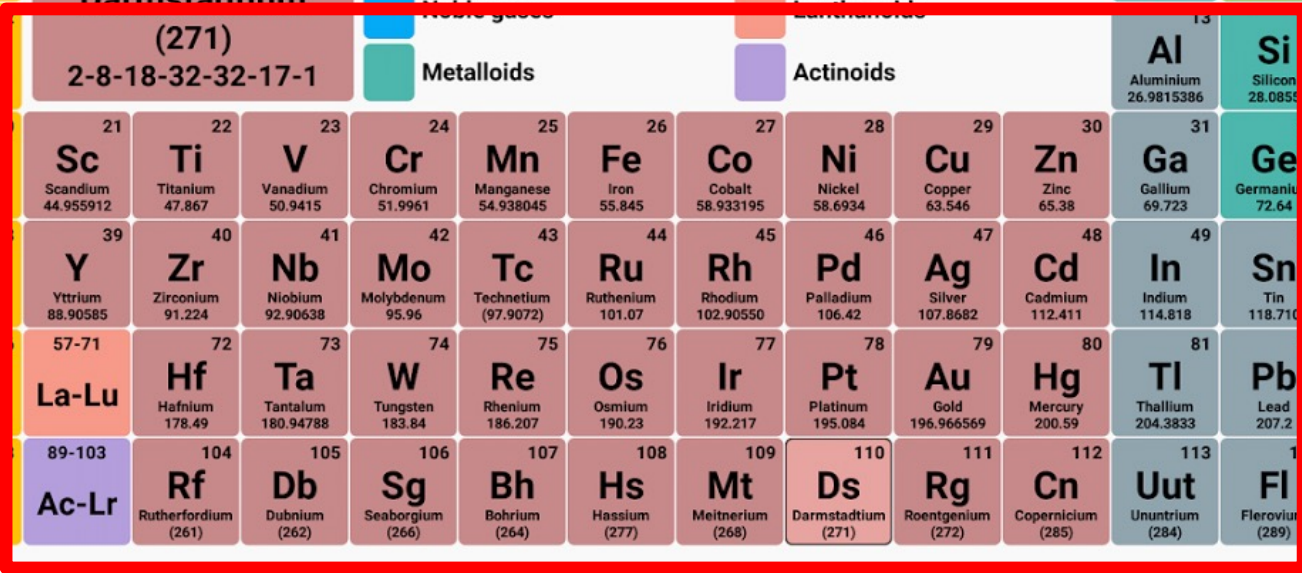
# The Periodic Table

Periodic Table



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	<b>H</b> Hydrogen 1.00794																	<b>He</b> Helium 4.002602
2	<b>Li</b> Lithium 6.941	<b>Be</b> Beryllium 9.012182													<b>N</b> Nitrogen 14.0067	<b>O</b> Oxygen 15.9994	<b>F</b> Fluorine 18.9984032	<b>Ne</b> Neon 20.1797
3	<b>Na</b> Sodium 22.98976928	<b>Mg</b> Magnesium 24.3050	<b>(271)</b> 2-8-18-32-32-17-1										<b>Al</b> Aluminum 26.9815386	<b>Si</b> Silicon 28.0855	<b>P</b> Phosphorus 30.973762	<b>S</b> Sulfur 32.065	<b>Cl</b> Chlorine 35.453	<b>Ar</b> Argon 39.948
4	<b>K</b> Potassium 39.0983	<b>Ca</b> Calcium 40.078	<b>Sc</b> Scandium 44.955912	<b>Ti</b> Titanium 47.867	<b>V</b> Vanadium 50.9415	<b>Cr</b> Chromium 51.9961	<b>Mn</b> Manganese 54.938045	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933195	<b>Ni</b> Nickel 58.6934	<b>Cu</b> Copper 63.546	<b>Zn</b> Zinc 65.38	<b>Ga</b> Gallium 69.723	<b>Ge</b> Germanium 72.64	<b>As</b> Arsenic 74.92160	<b>Se</b> Selenium 78.96	<b>Br</b> Bromine 79.904	<b>Kr</b> Krypton 83.798
5	<b>Rb</b> Rubidium 85.4678	<b>Sr</b> Strontium 87.62	<b>Y</b> Yttrium 88.90585	<b>Zr</b> Zirconium 91.224	<b>Nb</b> Niobium 92.90638	<b>Mo</b> Molybdenum 95.96	<b>Tc</b> Technetium (97.9072)	<b>Ru</b> Ruthenium 101.07	<b>Rh</b> Rhodium 102.90550	<b>Pd</b> Palladium 106.42	<b>Ag</b> Silver 107.8682	<b>Cd</b> Cadmium 112.411	<b>In</b> Indium 114.818	<b>Sn</b> Tin 118.710	<b>Sb</b> Antimony 121.760	<b>Te</b> Tellurium 127.60	<b>I</b> Iodine 126.90447	<b>Xe</b> Xenon 131.293
6	<b>Cs</b> Caesium 132.9054519	<b>Ba</b> Barium 137.327	<b>La-Lu</b>	<b>Hf</b> Hafnium 178.49	<b>Ta</b> Tantalum 180.94788	<b>W</b> Tungsten 183.84	<b>Re</b> Rhenium 186.207	<b>Os</b> Osmium 190.23	<b>Ir</b> Iridium 192.217	<b>Pt</b> Platinum 195.084	<b>Au</b> Gold 196.966569	<b>Hg</b> Mercury 200.59	<b>Tl</b> Thallium 204.3833	<b>Pb</b> Lead 207.2	<b>Bi</b> Bismuth 208.98040	<b>Po</b> Polonium (208.9824)	<b>At</b> Astatine (209.9871)	<b>Rn</b> Radon (222.0176)
7	<b>Fr</b> Francium (223)	<b>Ra</b> Radium (226)	<b>Ac-Lr</b>	<b>Rf</b> Rutherfordium (261)	<b>Db</b> Dubnium (262)	<b>Sg</b> Seaborgium (266)	<b>Bh</b> Bohrium (264)	<b>Hs</b> Hassium (277)	<b>Mt</b> Meitnerium (268)	<b>Ds</b> Darmstadtium (271)	<b>Rg</b> Roentgenium (272)	<b>Cn</b> Copernicium (285)	<b>Uut</b> Ununtrium (284)	<b>Fl</b> Flerovium (289)	<b>Uup</b> Ununpentium (288)	<b>Lv</b> Livermorium (292)	<b>Uus</b> Ununseptium (294)	<b>Uuo</b> Ununoctium (294)

Transition metals form cations with multiple possible oxidation states



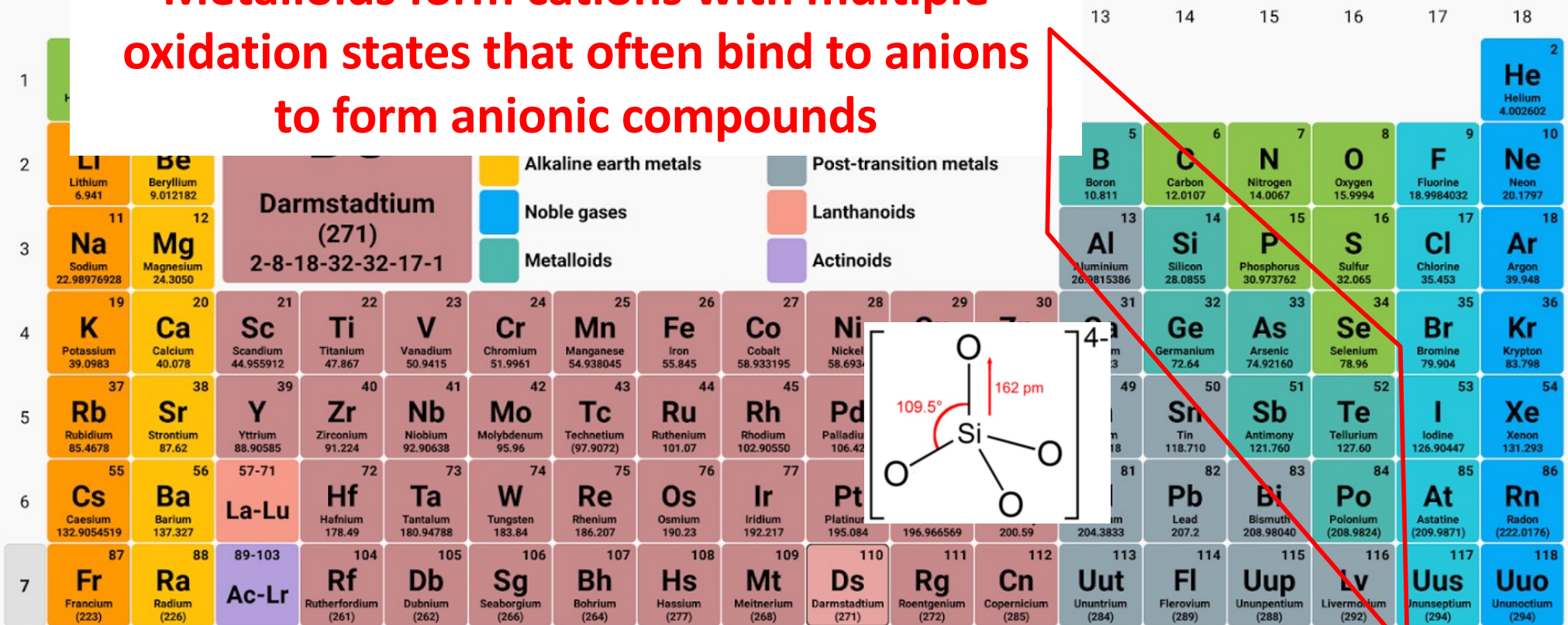
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

<b>La</b> Lanthanum 138.90547	<b>Ce</b> Cerium 140.116	<b>Pr</b> Praseodymium 140.90765	<b>Nd</b> Neodymium 144.242	<b>Pm</b> Promethium (145)	<b>Sm</b> Samarium 150.36	<b>Eu</b> Europium 151.964	<b>Gd</b> Gadolinium 157.25	<b>Tb</b> Terbium 158.92535	<b>Dy</b> Dysprosium 162.5	<b>Ho</b> Holmium 164.93032	<b>Er</b> Erbium 167.259	<b>Tm</b> Thulium 168.93421	<b>Yb</b> Ytterbium 173.054	<b>Lu</b> Lutetium 174.9668
<b>Ac</b> Actinium (227)	<b>Th</b> Thorium 232.03806	<b>Pa</b> Protactinium 231.03588	<b>U</b> Uranium 238.02891	<b>Np</b> Neptunium (237)	<b>Pu</b> Plutonium (244)	<b>Am</b> Americium (243)	<b>Cm</b> Curium (247)	<b>Bk</b> Berkelium (247)	<b>Cf</b> Californium (251)	<b>Es</b> Einsteinium (252)	<b>Fm</b> Fermium (257)	<b>Md</b> Mendelevium (258)	<b>No</b> Nobelium (259)	<b>Lr</b> Lawrencium (262)



# The Periodic Table

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



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

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

# The Periodic Table

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

The periodic table is color-coded by groups: Alkali metals (orange), Alkaline earth metals (yellow), Noble gases (light blue), Metalloids (teal), Transition metals (brown), Post-transition metals (grey), Lanthanoids (pink), and Actinoids (purple). Darmstadtium (Ds) is highlighted in a large pink box with the number 271 and the configuration 2-8-18-32-32-17-1. A red box highlights the non-metal region, including elements from Boron (B) to Xenon (Xe).

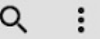
1	2	3	4																	17	18			
1	H Hydrogen 1.00794	Ds Darmstadtium (271) 2-8-18-32-32-17-1																He Helium 4.002602						
2	Li Lithium 6.941	Be Beryllium 9.012182																	B Boron 10.811	C Carbon 12.0107	N Nitrogen 14.0067	O Oxygen 15.9994	F Fluorine 8.9984032	Ne Neon 20.1797
3	Na Sodium 22.98976928	Mg Magnesium 24.3050																	Al Aluminium 26.9815386	Si Silicon 28.0855	P Phosphorus 30.973762	S Sulfur 32.065	Cl Chlorine 35.453	Ar Argon 39.948
4	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						
5	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						
6	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	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)						
7	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)	Uuo Ununoctium (294)						

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

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



1	2	3	4	5	6	Halogens form anions with a (-1) charge																18
1	<b>H</b> Hydrogen 1.00794	<b>Ds</b> Darmstadtium (271) 2-8-18-32-32-17-1										Other	Transition metals						<b>He</b> Helium 4.002602			
2	<b>Li</b> Lithium 6.941	<b>Be</b> Beryllium 9.012182											Alkali metals	Post-transition metals						<b>Ne</b> Neon 20.1797		
3	<b>Na</b> Sodium 22.98976928	<b>Mg</b> Magnesium 24.3050											Alkaline earth metals	Lanthanoids						<b>Ar</b> Argon 39.948		
4	<b>K</b> Potassium 39.0983	<b>Ca</b> Calcium 40.078	<b>Sc</b> Scandium 44.955912	<b>Ti</b> Titanium 47.867	<b>V</b> Vanadium 50.9415	<b>Cr</b> Chromium 51.9961	<b>Mn</b> Manganese 54.938045	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933195	<b>Ni</b> Nickel 58.6934	<b>Cu</b> Copper 63.546	<b>Zn</b> Zinc 65.38	<b>Ga</b> Gallium 69.723	<b>Ge</b> Germanium 72.64	<b>As</b> Arsenic 74.92160	<b>Se</b> Selenium 78.96	<b>Br</b> Bromine 79.904	<b>Kr</b> Krypton 83.798				
5	<b>Rb</b> Rubidium 85.4678	<b>Sr</b> Strontium 87.62	<b>Y</b> Yttrium 88.90585	<b>Zr</b> Zirconium 91.224	<b>Nb</b> Niobium 92.90638	<b>Mo</b> Molybdenum 95.96	<b>Tc</b> Technetium (97.9072)	<b>Ru</b> Ruthenium 101.07	<b>Rh</b> Rhodium 102.90550	<b>Pd</b> Palladium 106.42	<b>Ag</b> Silver 107.8682	<b>Cd</b> Cadmium 112.411	<b>In</b> Indium 114.818	<b>Sn</b> Tin 118.710	<b>Sb</b> Antimony 121.760	<b>Te</b> Tellurium 127.60	<b>I</b> Iodine 126.90447	<b>Xe</b> Xenon 131.293				
6	<b>Cs</b> Caesium 132.9054519	<b>Ba</b> Barium 137.327	<b>La-Lu</b>	<b>Hf</b> Hafnium 178.49	<b>Ta</b> Tantalum 180.94788	<b>W</b> Tungsten 183.84	<b>Re</b> Rhenium 186.207	<b>Os</b> Osmium 190.23	<b>Ir</b> Iridium 192.217	<b>Pt</b> Platinum 195.084	<b>Au</b> Gold 196.966569	<b>Hg</b> Mercury 200.59	<b>Tl</b> Thallium 204.3833	<b>Pb</b> Lead 207.2	<b>Bi</b> Bismuth 208.98040	<b>Po</b> Polonium (208.9824)	<b>At</b> Astatine (209.9871)	<b>Rn</b> Radon (222.0176)				
7	<b>Fr</b> Francium (223)	<b>Ra</b> Radium (226)	<b>Ac-Lr</b>	<b>Rf</b> Rutherfordium (261)	<b>Db</b> Dubnium (262)	<b>Sg</b> Seaborgium (266)	<b>Bh</b> Bohrium (264)	<b>Hs</b> Hassium (277)	<b>Mt</b> Meitnerium (268)	<b>Ds</b> Darmstadtium (271)	<b>Rg</b> Roentgenium (272)	<b>Cn</b> Copernicium (285)	<b>Uut</b> Ununtrium (284)	<b>Fl</b> Flerovium (289)	<b>Uup</b> Ununpentium (288)	<b>Lv</b> Livermorium (292)	<b>Uus</b> Ununseptium (294)	<b>Juo</b> Ununoctium (294)				

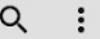
For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

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



# The Periodic Table

Periodic Table



**Noble gases carry no charge and do not readily react**

The main periodic table is color-coded by groups: Alkali metals (yellow), Alkaline earth metals (orange), Transition metals (grey), Post-transition metals (light blue), Lanthanoids (red), Actinoids (purple), Metalloids (green), and Noble gases (blue). A red box highlights the noble gas column (Group 18), which includes Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe), and Radon (Rn). The Darmstadtium (Ds) element is highlighted in a large pink box with the text '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 Lanthanide series (La-Lu) and Actinide series (Ac-Lr) are shown below the main table. The Lanthanide series includes elements from Lanthanum (La) to Lutetium (Lu), and the Actinide series includes elements from Actinium (Ac) to Lawrencium (Lr). Mass numbers are provided for each element, with those in parentheses indicating the longest half-life isotope for elements without stable isotopes.



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





## Precipitation Reaction

## Evaporite deposits

Water removed through evaporation

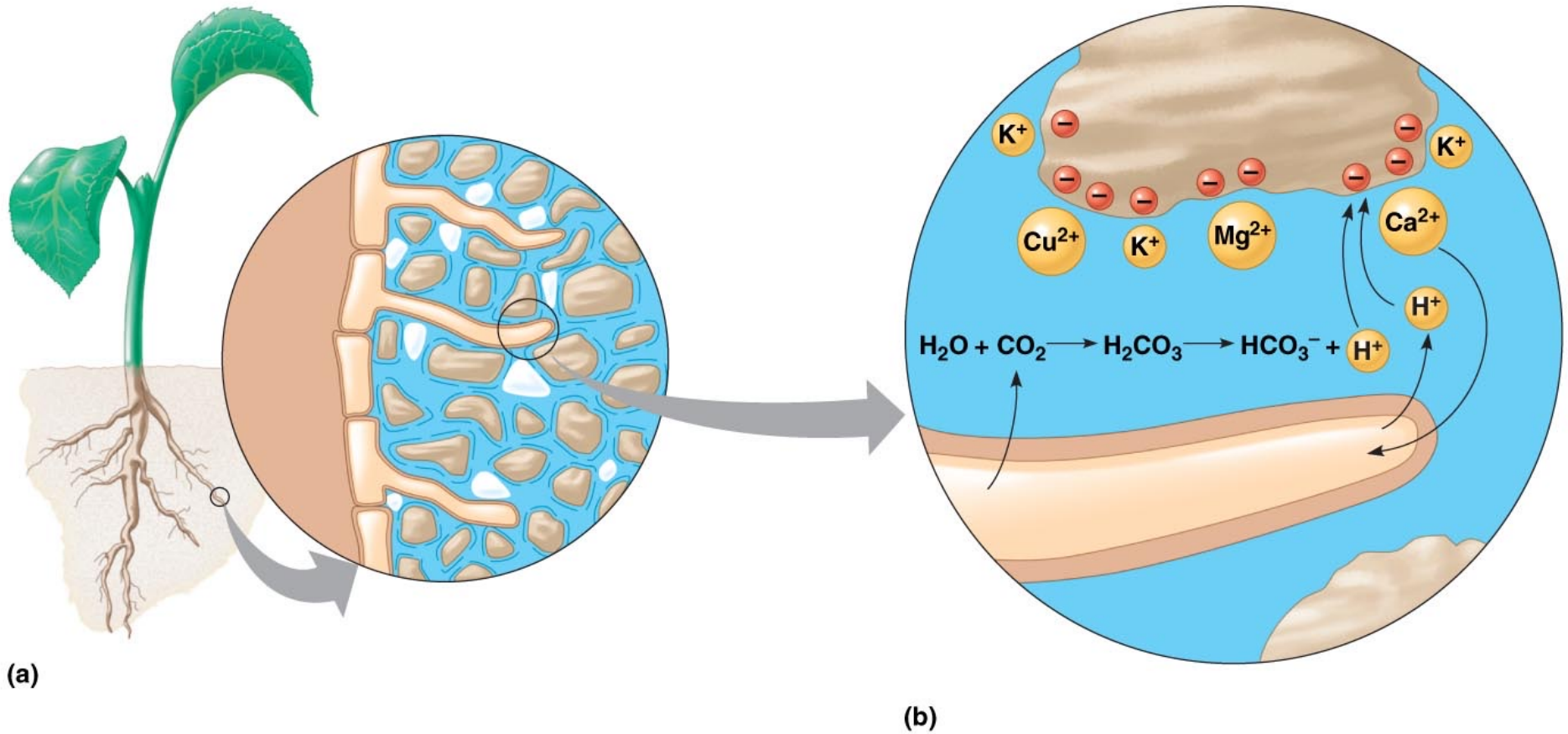


Pipe scaling

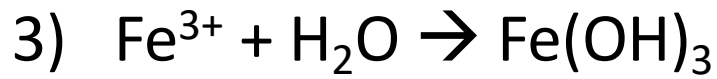
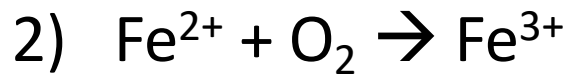
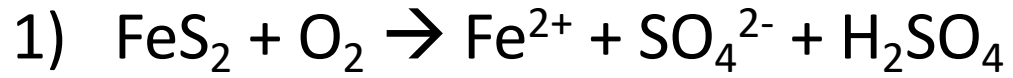
## Acid-base reaction



# Cation exchange in soils



# Redox reaction in acid mine drainage



What is oxidized and what is reduced in each reaction?

\*\*unbalanced reactions



# Global Carbon Cycle

