

# Reaction Types: Precipitation & Redox

**Academic Boot Camp**

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July 22, 2016

# Reading

Silberberg: §4.1, 4.3, 4.5.

# Overview

➤ \_\_\_\_\_  
➤ Formation of solid

➤ \_\_\_\_\_  
➤ Transfer of electrons

➤ Acid-Base  
➤ Arrhenius  
➤ Bronsted-Lowry  
➤ Lewis

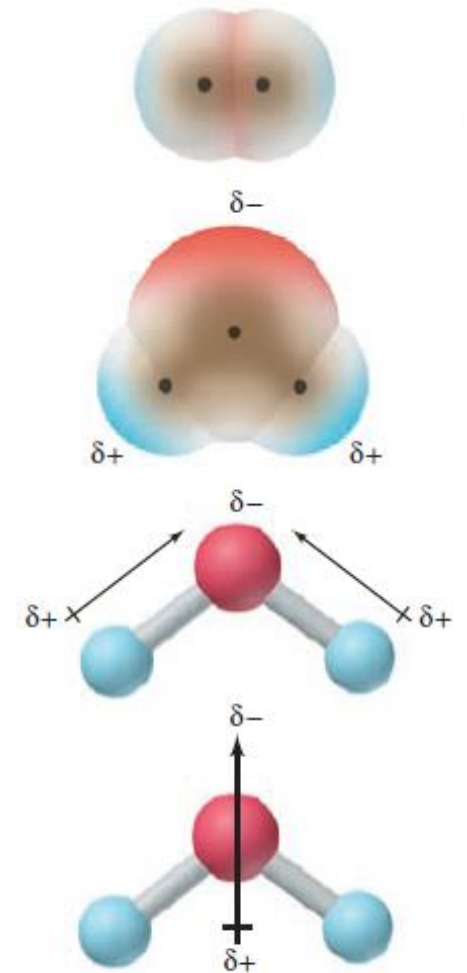
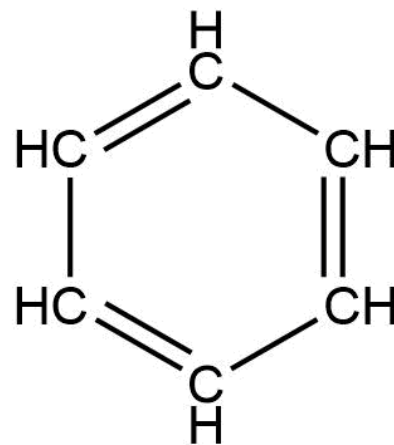
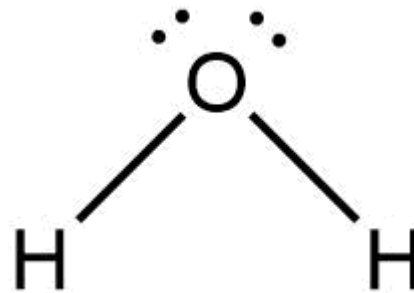
# Review: Solutions

- Solutions:
  - Solute: what dissolves in solvent
  - Solvent: what makes the solute dissolve



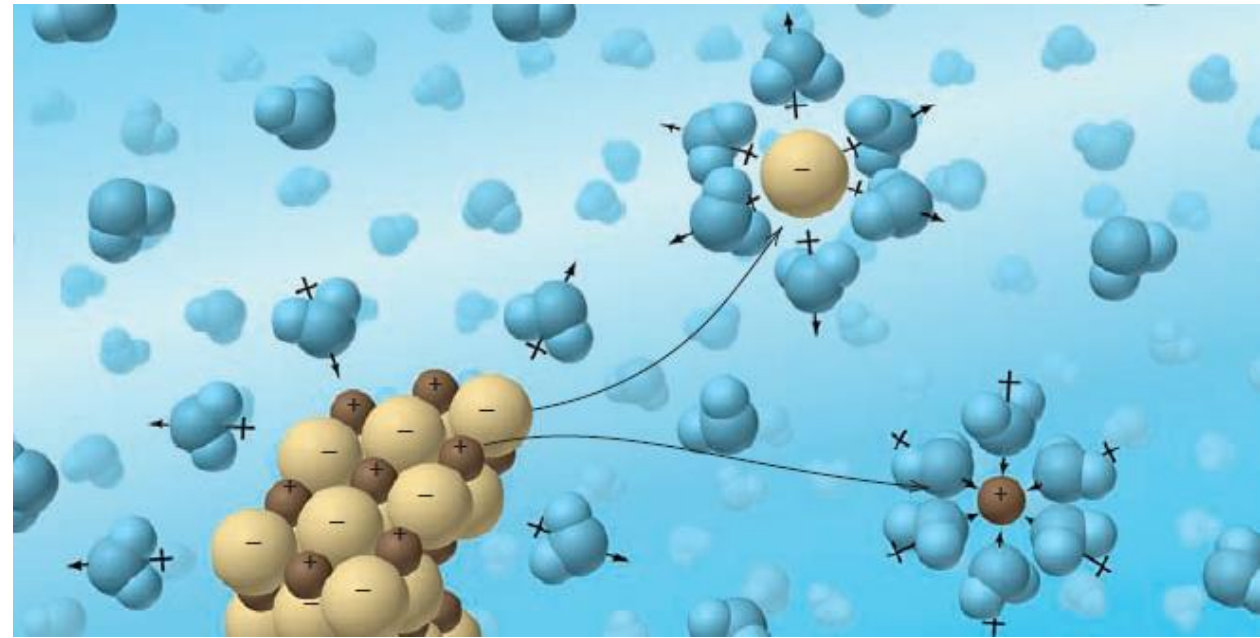
# Precipitation Reactions: Solvent

- Substance in which chemicals dissolve
- Water => "aqueous" (aq)
  - Polar compound
- Benzene => "organic"
  - Or nonpolar compounds like it



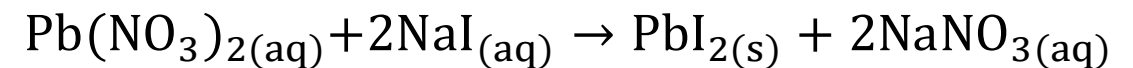
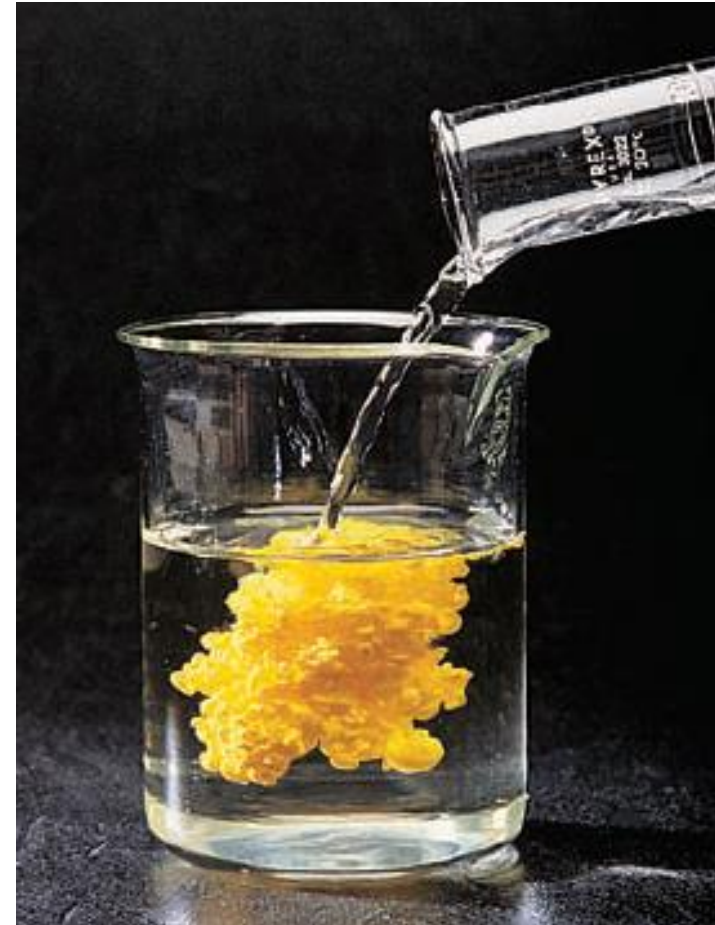
# Precipitation Reactions: Solubility

- Substance in which chemicals dissolve
- Water => "aqueous" (aq)
  - Polar compound
- Polarity causes molecular orientation
- Ability to dissolve in water dependent on strength of ionic bond
  - **Solubility**



# Precipitation Reactions

- " \_\_\_\_\_ " compounds:
  - Dissolve in water
- " \_\_\_\_\_ " compounds:
  - Do not dissolve in water
- Precipitation reactions:
  - Reactions between soluble compounds which form an insoluble product



# Precipitation Reactions

**Table 4.1** Solubility Rules for Ionic Compounds in Water

## Soluble Ionic Compounds

1. All common compounds of Group 1A(1) ions ( $\text{Li}^+$ ,  $\text{Na}^+$ ,  $\text{K}^+$ , etc.) and ammonium ion ( $\text{NH}_4^+$ ) are soluble.
2. All common nitrates ( $\text{NO}_3^-$ ), acetates ( $\text{CH}_3\text{COO}^-$  or  $\text{C}_2\text{H}_3\text{O}_2^-$ ), and most perchlorates ( $\text{ClO}_4^-$ ) are soluble.
3. All common chlorides ( $\text{Cl}^-$ ), bromides ( $\text{Br}^-$ ), and iodides ( $\text{I}^-$ ) are soluble, *except* those of  $\text{Ag}^+$ ,  $\text{Pb}^{2+}$ ,  $\text{Cu}^+$ , and  $\text{Hg}_2^{2+}$ . All common fluorides ( $\text{F}^-$ ) are soluble, *except* those of  $\text{Pb}^{2+}$  and Group 2A(2).
4. All common sulfates ( $\text{SO}_4^{2-}$ ) are soluble, *except* those of  $\text{Ca}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Ag}^+$ , and  $\text{Pb}^{2+}$ .

## Insoluble Ionic Compounds

1. All common metal hydroxides are insoluble, *except* those of Group 1A(1) and the larger members of Group 2A(2) (beginning with  $\text{Ca}^{2+}$ ).
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# Precipitation Reactions

- Given a reaction, consult solubility rules table
- If all compounds/ions involved are soluble, no precipitation occurs

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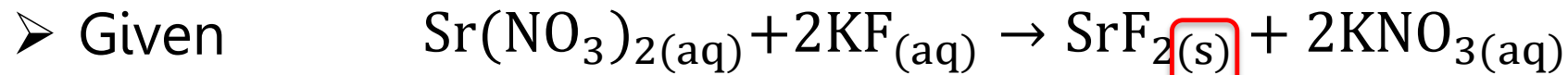
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# Precipitation Reactions: Example



➤ Does precipitation occur?

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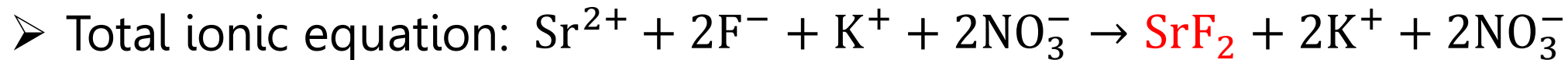
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# (Net) Ionic Equations



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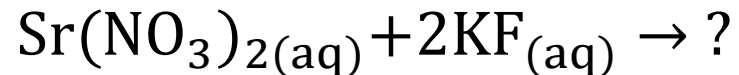
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# Precipitation Reactions: Prediction

➤ Given



➤ Does reaction occur? Does precipitation occur?

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# Oxidation States

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- For ionic compound, O.N. is just charge on ion
- For covalent compound, O.N. is what charge on atom would be if it was ionic

# Oxidation States

- Oxidation state (or oxidation number):
  - Number of electrons an atom would have (relative to ground state) if electrons were NOT shared in compound

- Rules in text: Table 4.3, p. 160

- Use context clues

- \_\_\_\_\_
- \_\_\_\_\_

- Use periodic table for prediction

**Table 4.3** Rules for Assigning an Oxidation Number (O.N.)

## General Rules

1. For an atom in its elemental form (Na, O<sub>2</sub>, Cl<sub>2</sub>, etc.): O.N. = 0
2. For a monatomic ion: O.N. = ion charge
3. The sum of O.N. values for the atoms in a molecule or formula unit of a compound equals zero. The sum of O.N. values for the atoms in a polyatomic ion equals the ion's charge.

## Rules for Specific Atoms or Periodic Table Groups

1. For Group 1A(1): O.N. = +1 in all compounds
2. For Group 2A(2): O.N. = +2 in all compounds
3. For hydrogen: O.N. = +1 in combination with nonmetals  
O.N. = -1 in combination with metals and boron
4. For fluorine: O.N. = -1 in all compounds
5. For oxygen: O.N. = -1 in peroxides  
O.N. = -2 in all other compounds (except with F)
6. For Group 7A(17): O.N. = -1 in combination with metals, nonmetals (except O), and other halogens lower in the group



# Oxidation States

Periodic Table of the Elements

1 IA 1A												13 IIIA 3A		14 IVA 4A	15 VA 5A	16 VIA 6A	17 VIIA 7A	18 VIIIA 8A	
1 H Hydrogen 1.008												5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180		
3 Li Lithium 6.941	4 Be Beryllium 9.012											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948		
11 Na Sodium 22.990	12 Mg Magnesium 24.305	3 IIIB 3B	4 IVB 4B	5 VB 5B	6 VIB 6B	7 VIIB 7B	8 VIII 8	9 VIII 8	10 VIII 8	11 IB 1B	12 IIB 2B	13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948		
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.88	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.933	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.732	32 Ge Germanium 72.61	33 As Arsenic 74.922	34 Se Selenium 78.972	35 Br Bromine 79.904	36 Kr Krypton 84.80		
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.29		
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.967	80 Hg Mercury 200.59	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [209]	85 At Astatine 209	86 Rn Radon 222.018		
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinide Series	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [293]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown		
Lanthanide Series		57 La Lanthanum 138.906	58 Ce Cerium 140.115	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.24	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.966	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.50	67 Ho Holmium 164.930	68 Er Erbium 167.26	69 Tm Thulium 168.934	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967			
Actinide Series		89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]			

Atomic Number  
Oxidation States\*  
Symbol  
Name  
Atomic Mass

\*Oxidation States in Bold are most common. States in *italics* are predicted.

# Oxidation States

- Oxidation state (or oxidation number):
  - Number of electrons an atom would have (relative to ground state) if electrons were NOT shared in compound

➤ Example: CaO

➤ Ca:

- Valence electrons: 2

➤ O:

- Valence electrons: 6

hydrogen 1 H 1.0079																	helium 2 He 4.0026	
lithium 3 Li 6.941	beryllium 4 Be 9.0122											boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180	
sodium 11 Na 22.990	magnesium 12 Mg 24.305											aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948	
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	seleเนียม 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80	
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29	
caesium 55 Cs 132.91	barium 56 Ba 137.33	* 57-70	lanthanum 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	* * 89-102	actinium 103 Ac [227]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnilium 110 Uun [271]	unununium 111 Uuu [272]	ununbium 112 Uub [277]	ununquadium 114 Uuq [289]					

\* Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendeleevium 101 Md [258]	nobelium 102 No [259]

\* \* Actinide series

# Oxidation States

- Oxidation state (or oxidation number):
  - Number of electrons an atom would have (relative to ground state) if electrons were NOT shared in compound

➤ Assuming electrons are not shared:

➤ Example: CaO

➤  $EN_{Ca} < EN_O$

➤ Ca:

➤ Valence electrons: 2

➤ Ca:

➤ Valence electrons: 0

➤ Ca oxidation state: +2

➤ O:

➤ Valence electrons: 6

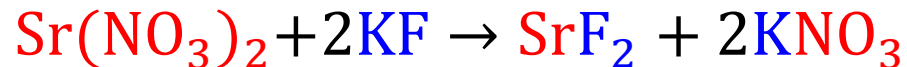
➤ O:

➤ Valence electrons: 8

➤ O oxidation state: -2

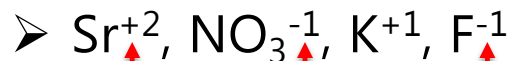
# Precipitation Reactions: Prediction

➤ Given



➤ Does reaction occur? Does precipitation occur?

➤ List of ions:



➤

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**Table 4.1 Solubility Rules for Ionic Compounds in Water**

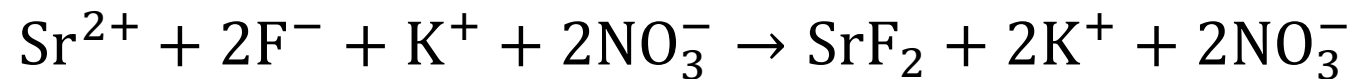
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4. All common sulfates ( $\text{SO}_4^{2-}$ ) are soluble, *except* those of  $\text{Ca}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Ag}^+$ , and  $\text{Pb}^{2+}$ .

## Insoluble Ionic Compounds

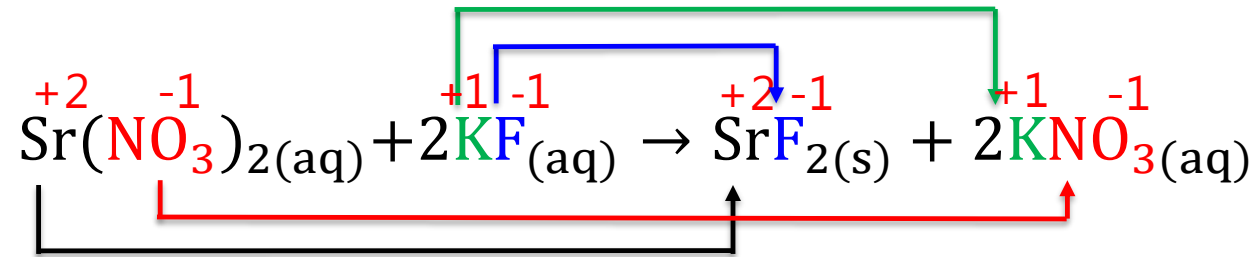
1. All common metal hydroxides are insoluble, *except* those of Group 1A(1) and the larger members of Group 2A(2) (beginning with  $\text{Ca}^{2+}$ ).
2. All common carbonates ( $\text{CO}_3^{2-}$ ) and phosphates ( $\text{PO}_4^{3-}$ ) are insoluble, *except* those of Group 1A(1) and  $\text{NH}_4^+$ .
3. All common sulfides are insoluble *except* those of Group 1A(1), Group 2A(2), and  $\text{NH}_4^+$ .

# Redox Reactions



- A reaction caused by the transfer of electrons to and from atoms
- Oxidation state of at least 1 atom changes

# Redox Reactions

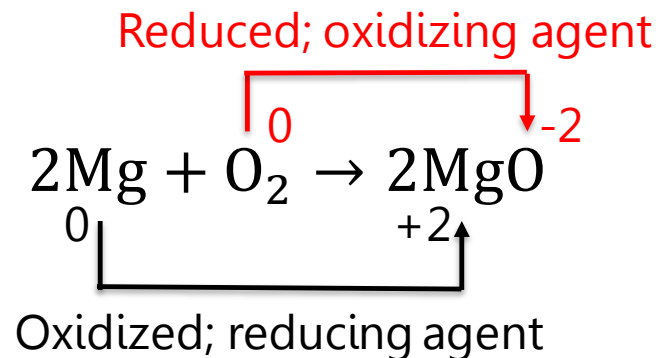


- A reaction caused by the transfer of electrons to and from atoms
- Oxidation state of at least 1 atom changes
- Above is **NOT** a redox reaction... no oxidation states change

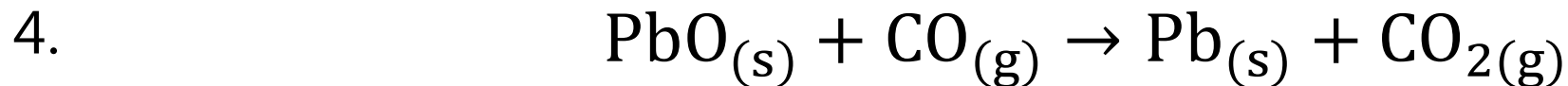
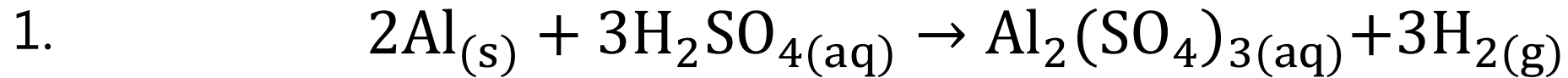
# Redox Reactions

- “Redox” is short for “Reduction-Oxidation” reactions
- : gaining electrons
  - “Reducing agent” reduces another atom. The agent itself is oxidized
- : losing electrons
  - “Oxidizing agent” oxidizes another atom. The agent itself is reduced

- Example:



# Reaction Examples





# Questions?

- Next time:
  - Reaction types:
    - Review
    - Acid-base
- Homework #3:
  - *Due Wednesday, July 27*

