

Objective 7

Single replacement reactions:
balancing,
apply Activity Series,
write net ionic equations to predict whether a
reaction occurs,
perform mole-mass and mole ratio calculations

Single Replacement Reactions are a Type of
Oxidation-Reduction Reactions
Electron transfer

batteries

Gold plating

combustion

A good relationship involves *Give and Take*

Acid-Base reaction involves giving and taking H^+ :

giver = acid, taker = base

Oxidation-Reduction reaction involves giving and taking electrons (e^-):

- oxidation = lose (give) electrons
- reduction = gain (take) electrons
- oxidizing agent oxidizes another substance but is reduced. Is an oxidizing agent a giver or taker?
- reducing agent reduces another substance but is oxidized. Is a reducing agent a giver or taker?
- every oxidizing agent has a partner reducing agent

Acid-base = H^+ transfer

Oxidation-reduction = e^- transfer

*Rusting (Corrosion) of Fe is an **Oxidation-Reduction** Reaction*



a. Write a chemical equation that represents the rust forming reaction.



b. What is the charge (oxidation number) of each element in each substance?

c. Which substance is oxidized? Which substance is reduced?

d. Which substance is the oxidizing agent? Which substance is the reducing agent?

Rusting (Corrosion) of Fe is an **Oxidation-Reduction** Reaction



Reactants: Fe charge in Fe element = 0
O charge in O₂ element = 0

Products: Fe charge in Fe₂O₃ = +3
O charge in Fe₂O₃ = -2

Fe is oxidized (0 charge to +3 charge means losing electrons)
O is reduced (0 charge to -2 charge means gaining electrons)

Fe is the reducing agent (it reduces O₂)
O₂ is the oxidizing agent (it oxidizes Fe)

Metals are _____ to form cations.

Non-metals are _____ to form anions.

Ionic Charge Is Determined From the Group Number

Metal ion charge = Metal group number. See Fig. 2.10, p. 39.

Non-metal ion charge = Non-metal group number - 8

- Group Letter (next to Roman numeral)

A = Main Group element

B = Transition element

- Period Number

Atomic orbitals occupied by valence electrons. See Chapter 7.

Element by Itself has the same number of protons and electrons so ...

Charge on an atom in an element = 0

In a Compound, an element can gain or lose electrons.

See Group Number (see Roman numeral) and Ionic Charge

a. Metals lose electrons to form **cations**.

Metal ion charge = Metal group number. See Fig. 2.10, p. 39.

b. Non-metals gain electrons to form **anions**.

Non-metal ion charge = Non-metal group number - 8

In H_2 , the H has a charge = 0

In H_2O , the H has a charge = 1, O has a charge = -2

In $NaCl$, Na charge = _____, Cl charge = _____

In Fe_2O_3 , Fe charge = _____, O charge = _____

Rust Costs a Lot of \$ -- Corrosion Protection Saves \$

Corrosion costs the U.S. economy \$276 billion per year, according to a 2002 report by the Federal Highway Administration. (CEN, 9/17/07, p. 20)

Lab 6

1. Allow a protective film, such as a metal oxide, to form naturally on the surface of the metal.
2. Galvanizing, or coating steel with zinc, a more active metal.
See <http://www.galvanizeit.org/hot-dip-galvanizing>
3. Apply a protective coating, such as paint.
4. Connect the metal directly to a “sacrificial anode”, a piece of another metal that is more active and is preferentially oxidized.
5. Plate the metal with a thin layer of a less easily oxidized metal.

Does Method 1 work for iron?

What metal could be used as a sacrificial anode to prevent iron from rusting in Method 4?

How could you use Method 5 for iron?

How is rust prevented on the hulls of boats? (see <http://www.kastenmarine.com/corrosion.htm>)

Decorative Coatings: \$39 billion business (2005)

Protective Coatings: \$5 billion business (2005)

The most important function of a protective coating is to prevent corrosion. (CEN, 9/17/07, p. 19)

3 layers: primer, intermediate coat, and top coat

Epoxy resins: 50% of coating business

Polyurethanes: 20-25%

Alkyds: 15-20%

Buildings and stadiums that are only 30 years old can potentially be torn down because of structural corrosion problems.

Self-Healing Paint would save military millions of \$/ year in repainting costs.



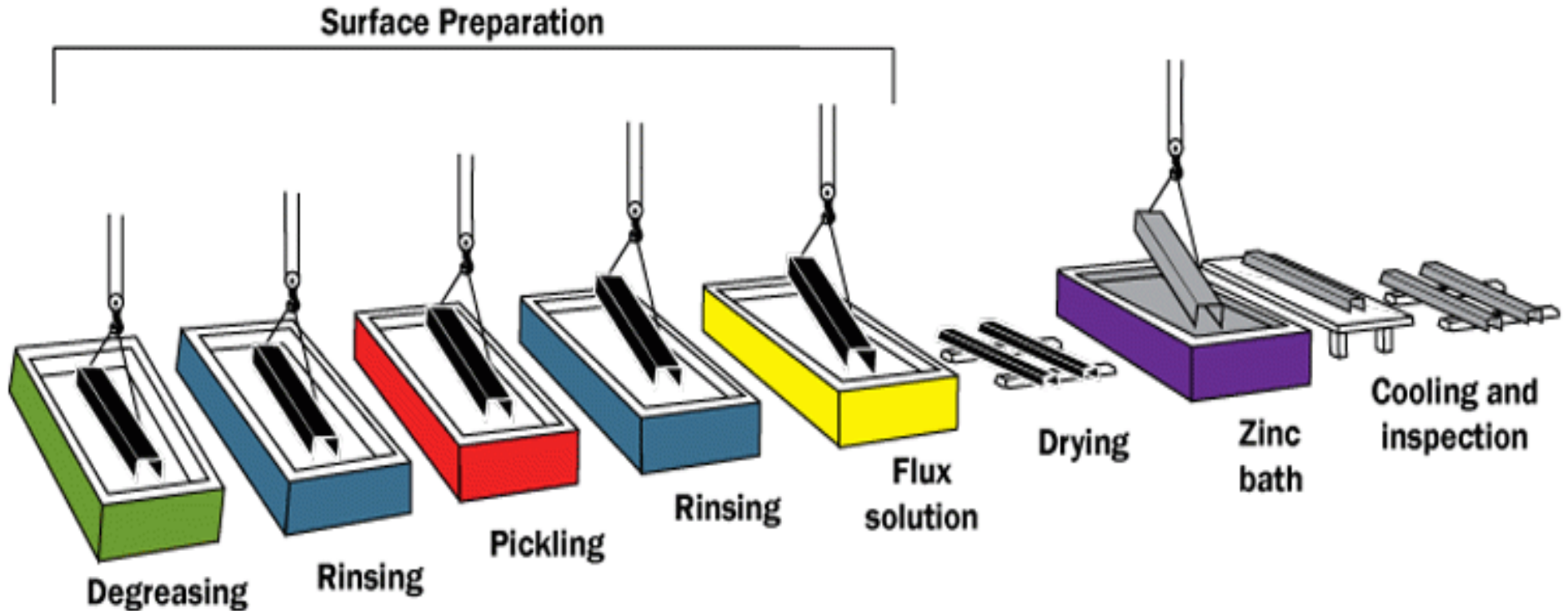
Microcapsules filled with clear, oily organosilane liquid is embedded in paint. It breaks when paint is scratched.

<http://cen.acs.org/articles/92/i28/Self-Healing-Paint-Chemical-Weapons.html>

The Galvanizing Process

<http://www.galvanizeit.org/hot-dip-galvanizing/what-is-hot-dip-galvanizing-hdg/hdg-process/>

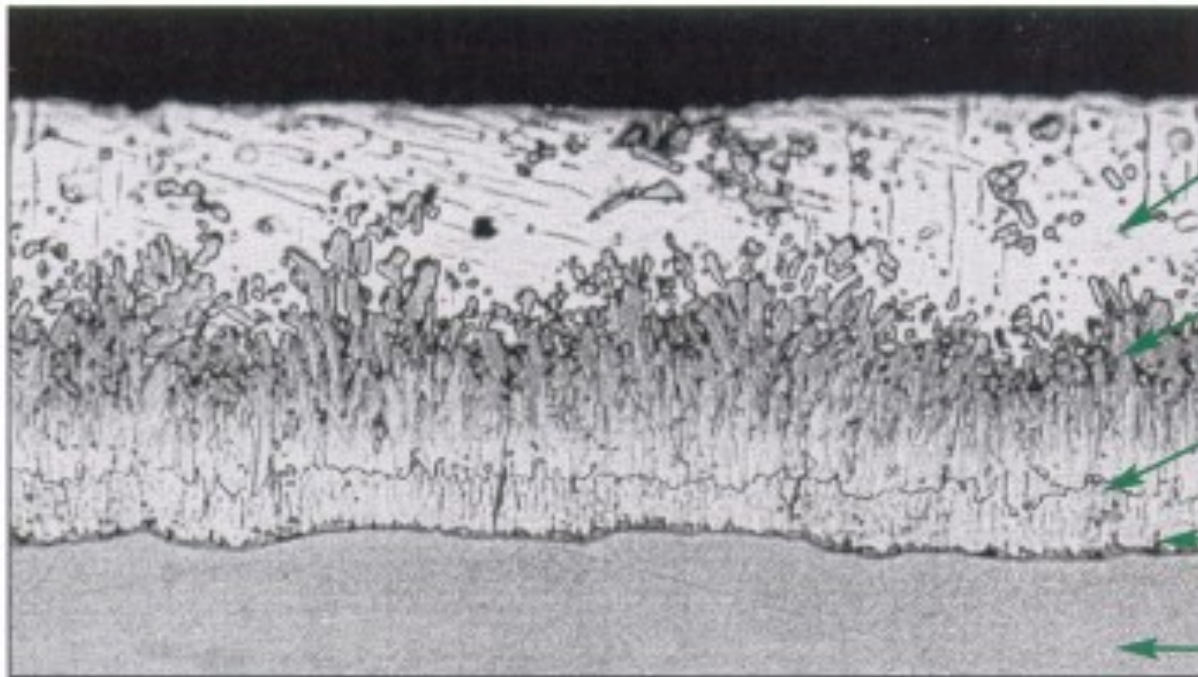
What is the purpose of each step?



Galvanized Steel

Maintenance free for decades

Corrosion resistance = 1/30 of bare steel



Eta

(100% Zn)
70 DPN Hardness

Zeta

(94% Zn 6% Fe)
179 DPN Hardness

Delta

(90% Zn 10% Fe)
244 DPN Hardness

Gamma

(75% Zn 25% Fe)
250 DPN Hardness

Base Steel

159 DPN Hardness

<http://www.galvanizeit.org/hot-dip-galvanizing/how-long-does-hdg-last/>

The Diamond Pyramid Number (DPN) is a progressive measure of hardness; the higher the number, the greater the hardness.

The hardness of the inner layers protects against _____.

1. When something is oxidized, it

Gains electrons

Gains protons

Gains oxygen

Loses electrons

Loses protons

Loses oxygen

2. When something is reduced, it

Gains electrons

Gains protons

Gains oxygen

Loses electrons

Loses protons

Loses oxygen

3. The charge on H in H₂ is:

-2

-1

0

1

2

4. The charge on H in H₂O is:

-2

-1

0

1

2

Some Substances are *Better* e⁻ Givers;
Others are *Better* e⁻ Takers

A good e⁻ Giver is a:

- Strong Ox Agent
- Weak Ox Agent
- Strong Red Agent
- Weak Red Agent

A good e⁻ Taker is a:

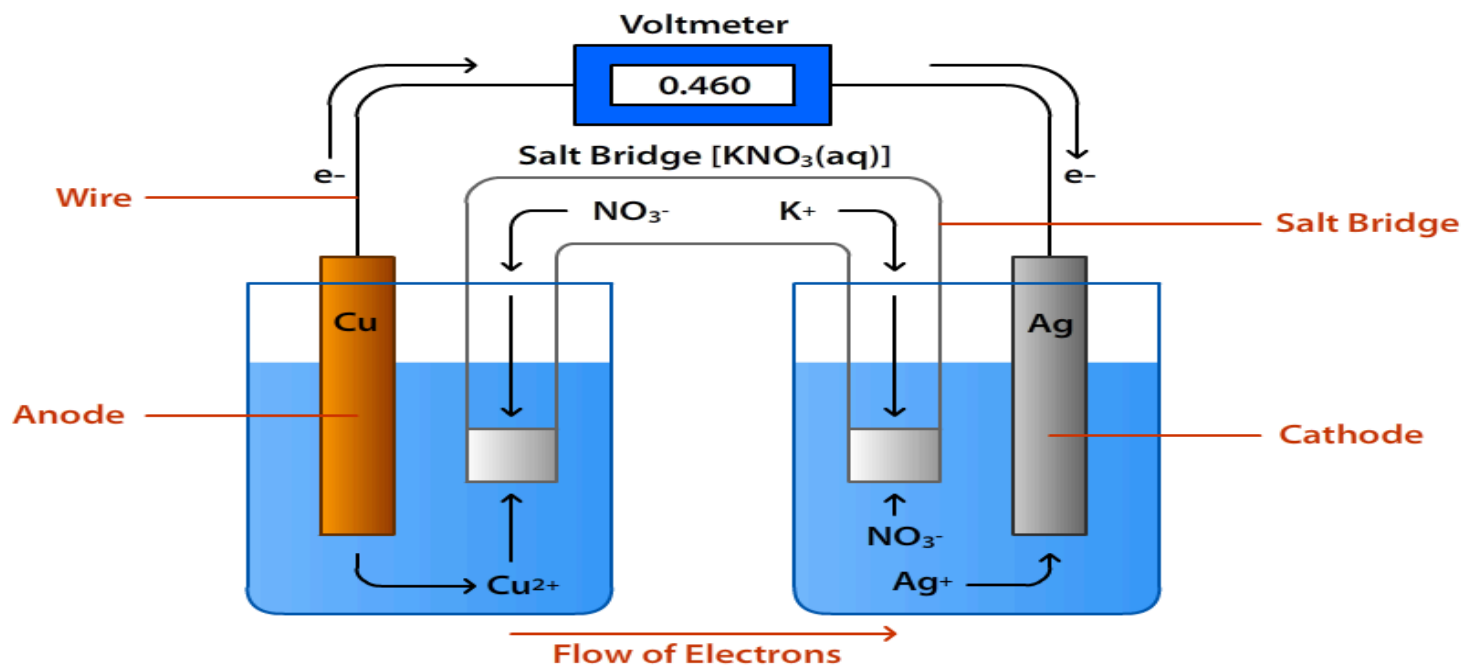
- a) Strong Ox Agent
- b) Weak Ox Agent
- c) Strong Red Agent
- d) Weak Red Agent

Poor e⁻ Givers Are _____

Poor e⁻ Takers Are _____

A Battery Involves an Oxidation-Reduction Reaction

Chemical energy is converted to electrical energy.
Two metals (electrodes) of different activity are used.



Graphic by Shamsheer Singh

http://chemwiki.ucdavis.edu/Analytical_Chemistry/Electrochemistry/Voltaic_Cells

- What happens when silver metal comes in contact with copper metal?
- How is this used in a battery?

An **Active Metal** is a Metal that ***Easily*** Gives Up (Loses) its e⁻.

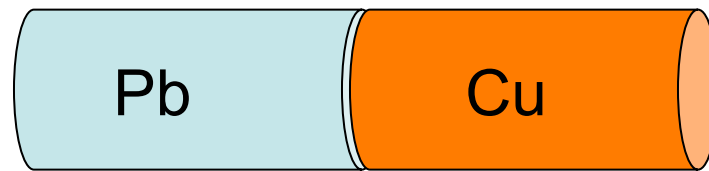
Using The *Activity Series of Metals* (Chang, Fig. 4.14, p. 114):

- Reducing agent has a partner Oxidizing agent
- Reducing agents are listed from strongest to weakest; Oxidizing agents are listed from weakest to strongest.
- A Reducing agent reacts with any Oxidizing agent below it or an Oxidizing agent reacts with any Reducing agent _____ it.
- Predict the products of an oxidation-reduction reaction.

	<u>Metal</u> (Reducing Agent)	---->	<u>Metal Ion</u> (Oxidizing Agent)	
Strongest	Li	---->	Li ⁺	Weakest
(Best giver)	Zn	---->	Zn ²⁺	
	Fe	---->	Fe ²⁺	
	H ₂	---->	H ⁺	
	Cu	---->	Cu ²⁺	
	Ag	---->	Ag ⁺	
Weakest	Au	---->	Au ⁺	Strongest (Best taker)

Flint, MI – high lead levels found in drinking water

Lead poisoning – neurological damage, affects learning
One solution: replace lead pipes with copper pipes.



Problem: partial replacement doubles lead levels in water; remains elevated for 6 months.

Connecting new copper pipes to lead pipes cause an electrochemical reaction that release lead ions into water flowing through them. (CEN, 7/18/16, p. 6)

Pb is **more active** than Cu → connecting Cu to Pb releases Pb^{2+} into H_2O .

Chem 1A Reactions: **predict products**

1. Double replacement

Precipitation

Acid-base

Gas forming

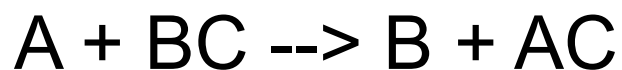
2. **Single replacement**

Oxidation-reduction

3. Combustion

A Single Replacement Reaction Is a Type of Oxidation-Reduction reaction.

It involves the reaction of an **element** and a **compound** to produce a new **element** and new **compound** .

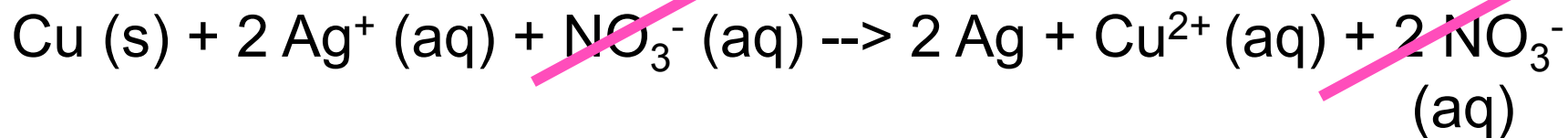


Example:



What is being oxidized? Reduced?

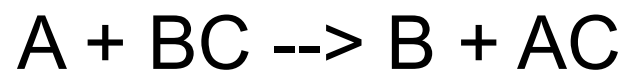
Write a net ionic equation.



YouTube video: http://www.youtube.com/watch?v=wBCmt_pJTRA

A Single Replacement Reaction Is a Type of Oxidation-Reduction reaction.

It involves the reaction of an **element** and a **compound** to produce a new **element** and new **compound** .



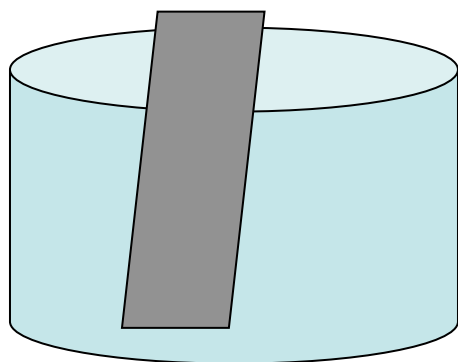
Example:



What is being oxidized? Reduced?

Write a net ionic equation.

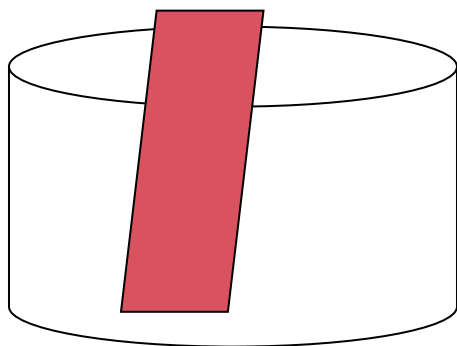
Use the Activity Series to Plate One Metal onto another Metal



What happens when silver metal is placed in a solution of CuSO_4 (aq)? If this reaction occurs, write a net ionic equation.

<u>Metal</u> (Reducing Agent)		---	<u>Metal Ion</u> (Oxidizing Agent)	
Strongest	Li	---	Li^+	Weakest
(Best giver)	Fe	---	Fe^{2+}	
	Cu	---	Cu^{2+}	
Weakest	Ag	---	Ag^+	Strongest (Best taker)

Use the Activity Series to Plate One Metal onto another Metal



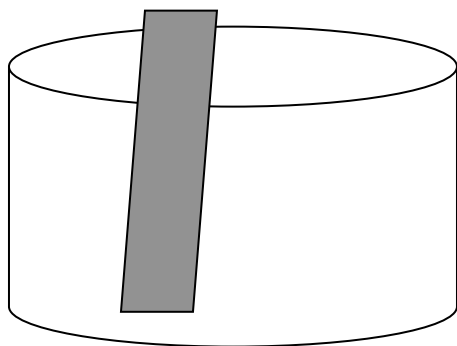
What happens when copper metal is placed in a solution of AgNO_3 (aq)?

If this reaction occurs, write a net ionic equation.

Metal (Reducing Agent) ---> Metal Ion (Oxidizing Agent)

Strongest	Li	--->	Li^+	Weakest
(Best giver)	Fe	--->	Fe^{2+}	
	Cu	--->	Cu^{2+}	
Weakest	Ag	--->	Ag^+	Strongest (Best taker)

Use the Activity Series to Plate One Metal onto another Metal



Lab 6: What metal could you plate onto Fe? (for corrosion protection)

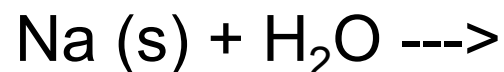
Write a molecular equation and net ionic equation.

Metal (Reducing Agent) ----> Metal Ion (Oxidizing Agent)

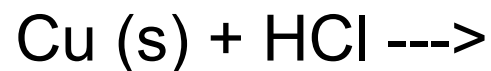
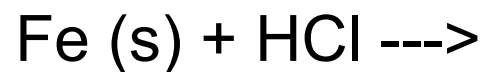
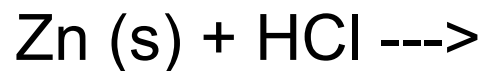
Strongest	Li	---->	Li ⁺	Weakest
(Best giver)	Fe	---->	Fe ²⁺	
	Cu	---->	Cu ²⁺	
	Ag	---->	Ag ⁺	
Weakest	Au	---->	Au ⁺	Strongest (Best taker)

Single Replacement Reactions Have Many Applications

Sodium metal reacts with water (see YouTube):



Which metal reacts with acids?



How is this reaction related to how elements get in our food?



http://en.wikipedia.org/wiki/Exothermic_welding

Thermite reaction is used to weld railroad tracks and in underwater welding. Predict the products.



Can a metal besides Al be used to make Fe?

The Hall process is used to make aluminum from aluminum ore (Al_2O_3).

Identify a substance that reacts with Al_2O_3 to produce Al. Write a chemical equation that represents this industrial reaction.



<http://www.eoearth.org/view/article/150013/>

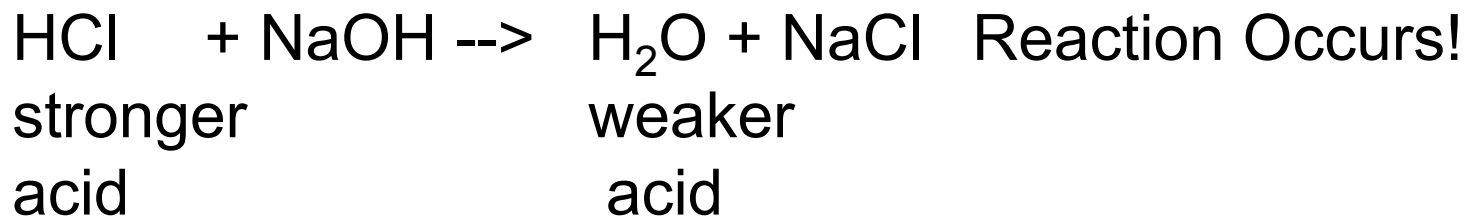


<http://www.sunhomecans.com/blog/uses-of-aluminum-cans/>

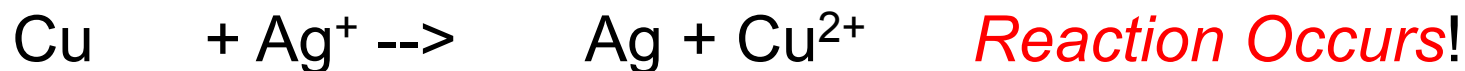
When exposed to air, Al metal becomes coated with an oxide layer whereas Au metal does not become coated with an oxide layer.

Explain this observation in terms of the Activity Series of the Elements.

A Reaction Can Tell You the Strength of an Acid/ Base or Oxidizing Agent/Reducing Agent



Which base is stronger?



Which reducing agent is stronger?

Which oxidizing agent is stronger?

(Taken from Fall 2001 Quiz 2)

You are given three metals, Metal A, Metal M, and Metal Z, and the corresponding metal ion solutions, A^+ (aq), M^+ (aq), and Z^+ (aq). You perform the following reactions and make these observations:

(i) $A (s) + Z^+ (aq) \rightarrow$ a reaction occurs

(ii) $Z (s) + M^+ (aq) \rightarrow$ no reaction occurs.

(iii) $A (s) + M^+ (aq) \rightarrow$ a reaction occurs

a. For the reactions that occur, determine the products that form.

b. Rank the metals in order of activity. Are the metals oxidizing agents or reducing agents?



<http://encap.net/lawn-mineral-nutrients/fast-acting-lime/>



NOT
this kind
of lime!

<http://www.internationalcitrusandproduce.com/products-by-line/10lb-euro-lime/954/>

Lime ($\text{Ca}(\text{OH})_2$) is used to increase the pH of soil in farming.
Why does the addition of lime increase pH?

When water is added to calcium metal, a gas evolves and a white, powdery solid forms. However, when HCl is added to calcium metal, a gas evolves and no solid forms.

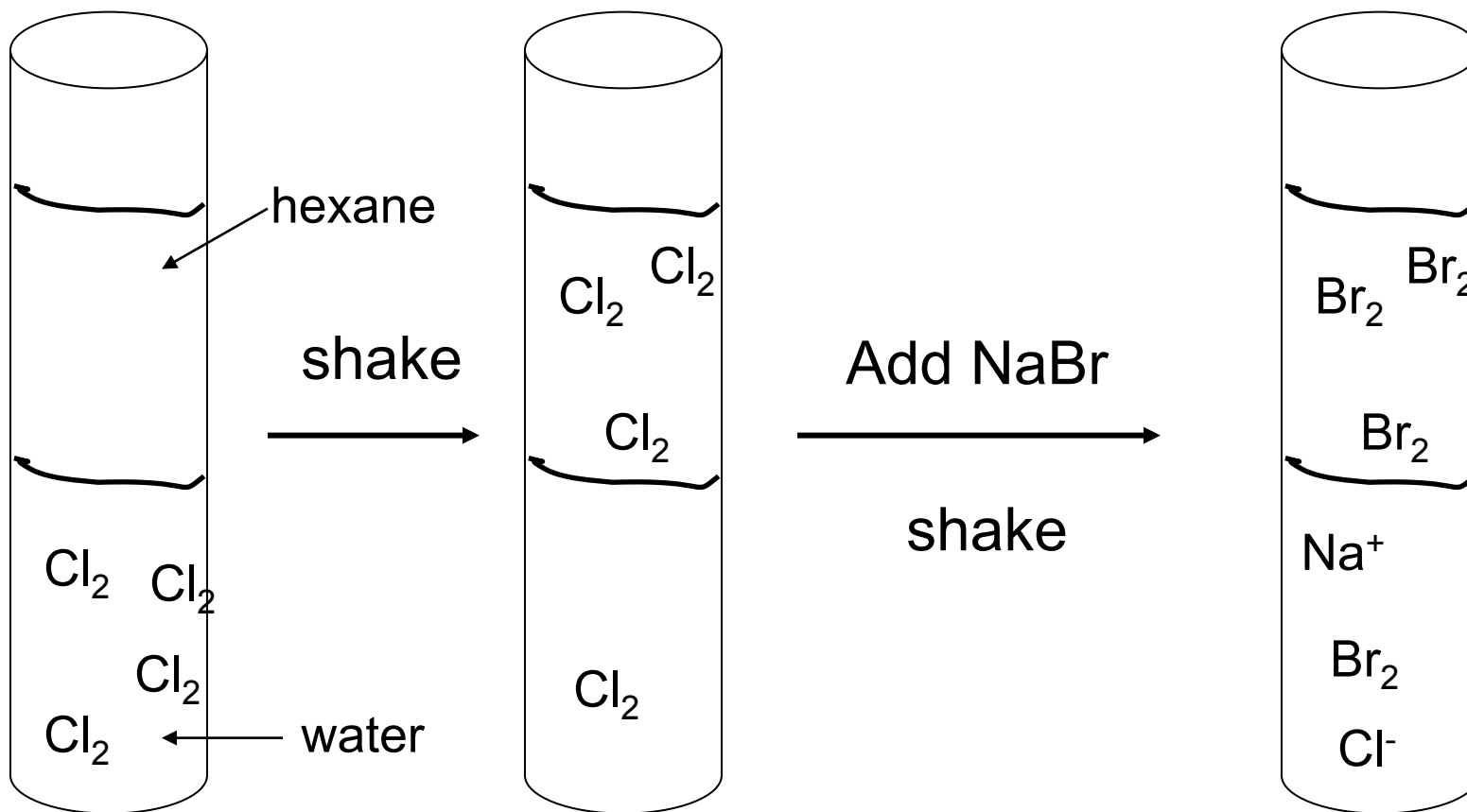
Write net ionic equations for these reactions and explain why a solid is formed with water and not with HCl.

Which reaction is used to make lime?

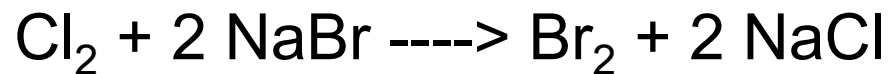
When exposed to air, silver tarnishes because the silver reacts with hydrogen sulfide in the air to form a layer of black silver sulfide. The tarnish can be chemically removed by using a solution of baking soda and aluminum foil. In this electrochemical process, electrons move from the aluminum atoms to the silver ions in the tarnish, reducing the silver ions to silver atoms while the aluminum atoms are oxidized to aluminum ions. The baking soda provides an electrolyte solution for the flow of electrons and also helps remove the aluminum oxide coating from the surface of the aluminum foil. This method of cleaning silverware is better than using polish because the tarnish is restored to silver on the silverware. Polish removes the Ag_2S , including the silver it contains. (Reference: Moore et al., "The Chemical World", 2nd ed., p. 840)

- a. Write a balanced chemical equation that represents the tarnish removing reaction.
- b. Explain why aluminum is used in this reaction.
- c. What other metal could be used besides aluminum? Give reasons.

Lab 6: Which Halogen is the Best Bleach?



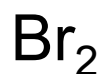
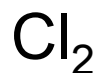
Cl_2 is more attracted to hexane than water



Which is the stronger ox agent?

Lab 6 results: Oxidizing strength of Halogens

Non-Metal
(Oxidizing Agent)



Non-Metal Ion
(Reducing Agent)



Where would you place F_2 in this list?

Why isn't F_2 bleach sold?

An acid and reducing agent are similar in that both substances donates something it has to another substance.

True

or

False?

Chlorine Bleach is Used to Disinfect (Kill Bacteria)

Water Purification:

Orange County Water District recycles 70 million gal of water every day.

3 steps: 1. microfiltration,
2. reverse osmosis, and
3. ultraviolet light with hydrogen peroxide

People worry about the water's safety when they learn that its source is sewage: “**yuck factor.**”

CA recycles 200 billion gallons of water each year

CA plans to recycle 325 billion gallons water/yr by 2020

(State Water Resources Board)



(<http://cen.acs.org/articles/89/i17/Challenges-Water-Reuse.html>)

http://www.nytimes.com/2015/05/12/science/recycled-drinking-water-getting-past-the-yuck-factor.html?partner=rss&emc=rss&_r=0

“Water Flowing from Toilet to Tap May be Hard to Swallow”



<http://cen.acs.org/articles/89/i35/Using-Bacteria-Clean-Water.html>

8/29/11, CEN, p. 34 Using Bacteria To Clean Water

Biodenitrification: as water passes through soil, bacteria removes contaminants, e.g., nitrate, perchlorate, and chlorinated organic compounds.



Bioreactor

NO_3^- (MCL=44 mg/L) can cause oxygen deprivation in infants and is associated with several cancers

3 steps:

1. Biological treatment reactor
2. Filter
3. Disinfect with Cl_2 (bleach)

Ion-exchange and reverse osmosis:

1. Energy intensive
2. Produces waste streams (brine) - \$\$ to remove

Western Municipal WD (Riverside) and West Valley Water District (Rialto) are developing full-scale plants to target nitrate and perchlorate.

Americans spent \$21 billion in 2009 on 8.4 billion gal of bottled water.

U.S. water systems leak about 7 billion gal of water a day, he notes, “so the water pipes supplying our homes leak more drinking water in thirty hours than we buy at stores in a year.”

We spend about \$29 billion a year maintaining our entire water system in the United States—the drinking water treatment plants, the pump stations, the pipes in the ground, the wastewater treatment plants.

Charles Fishman, “The Big Thirst: The Secret Life and Turbulent Future of Water”

<http://cen.acs.org/articles/89/i27/Water-Water.html>

7/4/11 CEN, p. 3 Editorial

How Much Water Do We use?

<http://www.ocwd.com/ConservationEducation/WaterFacts.aspx>

- Taking a bath or shower: average is 9-12 gallons per person
- Americans combined use each day for showers: more than 2.7 billion gallons of water
- Watering the lawn: 180 gallons
- Washing dishes by machine: 13-19 gallons
- Washing clothes: 35-50 gallons
- Washing the car: 50 gallons
- Brushing your teeth: 2-5 gallons
- Cooking: 5-10 gallons
- Flushing the toilet (once): 4-7 gallons
- Leaking toilet (per day): 60 gallons

How Much Water Does it Take?

<http://www.ocwd.com/ConservationEducation/WaterFacts.aspx>

- 2,072 gallons to make four new tires
- 20 gallons of water per glass of beer
- 101 gallons of water to make one pound of wool or cotton
- 2,110 gallons of water for one pair of leather shoes
- 900 gallons of water for one pair of blue jeans
- 36 gallons of water per egg
- 60 gallons of water per serving of corn
- 18 gallons of water per apple
- 3 gallons of water per tomato
- 2.6 gallons of water per sheet of paper
- 37 gallons of water per cup of coffee
- 11 gallons of water per slice of bread
- 32 gallons of water per glass of wine
- 1,083 gallons of water for one cotton shirt
- 468 gallons of water per pound
- 616 gallons of water per 4 oz. hamburger
- 1,232 gallons of water per 8 oz. steak
- 39,090 gallons of water are used to manufacture a new car, including tires

Traditional Urinals typically produce 40,000 gal of contaminated water each year.

Waterless Urinals use gravity to channel urine into a cartridge located at their base. Urine inside the cartridge passes through a liquid sealant composed in part of a long-chain fatty acid and antibacterial terpenoids. The sealant's density of 0.97 ensures that it floats to the top of the cartridge and locks in odor, while urine, which has a slightly higher density, moves downward and makes its way to the drain.

Water from flushing promotes the growth of bacteria as well as the creation of unpleasant odors. The "urine smell" is ammonia gas when water is mixed with urine.

<http://cen.acs.org/articles/89/i19/Fresher-Urinals-Cancer-sniffing-Dog.html> (CEN, 5/9/11, p. 56)



Waterless urinal:
Environmentally friendly and odor-free.
Credit: Falcon Waterfree Technologies

<http://cen.acs.org/articles/89/i37/Scoop-Airborne-Bacteria-Reinventing-Toilet.html>

“Reinvent the Toilet” Challenge (2011)

Bill & Melinda Gates Foundation

http://www.youtube.com/watch?feature=player_embedded&v=fdwvuTrycYU

Growing global need for waste sanitation.

2.6 billion people don't have access to basic sanitation services.

> 1 million children die from diarrheal disease each year.

Design an innovative toilet that can work in communities that don't have access to sufficient running water, sewers, or electricity.

Must cost less than 5 cents per person per day.

Process human waste within 24 hours.

8/20/12 “Reinventing the Toilet” Challenge winners

<http://www.gatesfoundation.org/media-center/press-releases/2012/08/bill-gates-names-winners-of-the-reinvent-the-toilet-challenge>

1st prize: \$100,000: Solar powered toilet that generates hydrogen and electricity (Cal Tech)

2nd prize: \$60,000: toilet that produces biological charcoal, minerals, and clean water (Loughborough University, UK)

3rd prize: \$40,000: toilet that sanitizes feces and urine and recovers resources and clean water (Univ. of Toronto)

Slight Problem: the solar powered toilet costs \$1,000
“*the economics of such a solution remain uncertain.*”

(http://www.nytimes.com/2013/11/19/opinion/bill-gates-cant-build-a-toilet.html?_r=1&)

1. An acid and reducing agent are similar in that both substances donate something it has to another substance.

True

or

False?

2. A _____ gains electrons and behaves like a _____ agent.

metal

non-metal

oxidizing

reducing

3. A _____ loses electrons and behaves like a _____ agent.

metal

non-metal

oxidizing

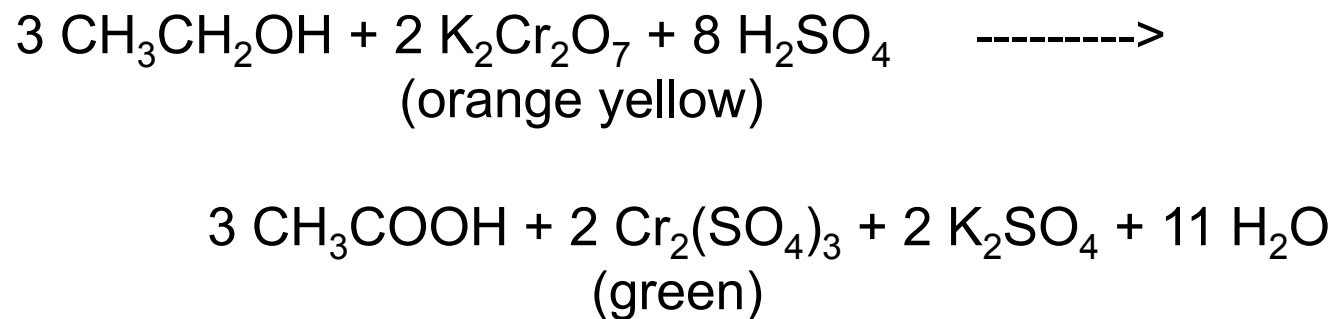
reducing

You are trying to prevent an iron drain pipe from rusting. Your high school chemistry teacher, who usually teaches PE, suggests wrapping the iron pipe in copper foil whereas your grandmother tells you to wrap the iron pipe in magnesium foil.

Which person's advice will you follow? Give reasons.
(Pick one or the other. Do not say neither.)

Don't Let This Happen to You!

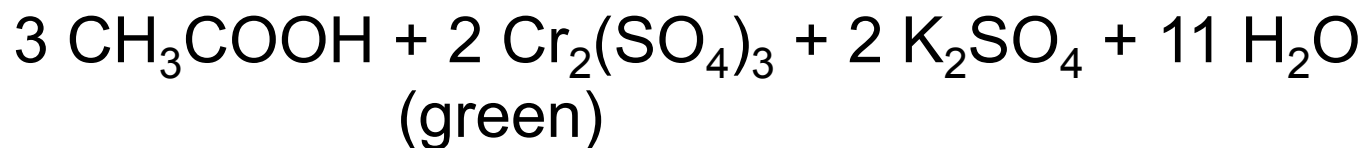
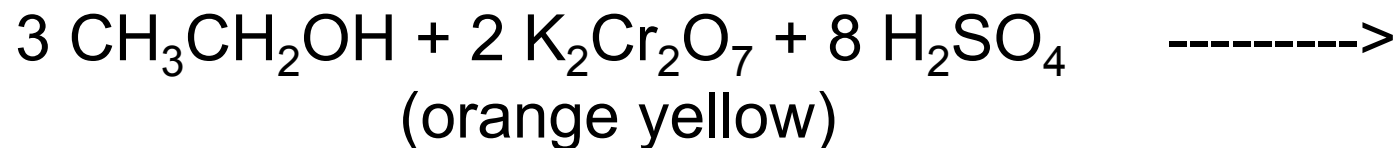
A ***breath analyzer*** is often used by law enforcement officials to test drivers suspected of being drunk. The chemical basis of this device is an oxidation-reduction reaction. A sample of the driver's breath is drawn into the breath analyzer where it is treated with an acidic solution of potassium dichromate. The alcohol (ethanol) in the breath is converted to acetic acid:



In this reaction, the ethanol is oxidized to acetic acid and the _____ in the _____ is reduced to the _____.

The driver's blood alcohol level can be determined readily by measuring the degree of the green color change (read from a calibrated meter on the instrument). The current legal limit of blood alcohol content in the U.S. is 0.08 % by mass.

Breath Analyzer



The current legal limit of blood alcohol content (BAC) in the U.S. is 0.08 % by mass.

One breath = 0.5 liters = 0.02 moles of air = 0.6 g air

Calculate the mass of $\text{CH}_3\text{CH}_2\text{OH}$ in one breath for a 0.08% BAC .

The concentration of $\text{K}_2\text{Cr}_2\text{O}_7$ is 0.0050 M. Calculate the volume of $\text{K}_2\text{Cr}_2\text{O}_7$ that reacts with $\text{CH}_3\text{CH}_2\text{OH}$.

Coca-Cola can be used to remove rust.
What substance in Coke removes rust?
Write a chemical equation that represents this reaction.
Is this an oxidation-reduction reaction?



<https://www.facebook.com/cocacola>

Reactions go in **ONE** direction: Reactants \rightarrow Products

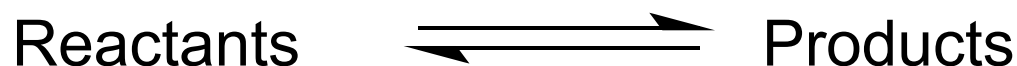
Some reactions go **BACKWARDS** (in reverse):
Products \rightarrow Reactants



Washington D.C. digs out.

[http://sc6.blogspot.com/
2010_02_01_archive.html](http://sc6.blogspot.com/2010_02_01_archive.html)

Reactions that occur in the forward and reverse directions are called reversible reactions or Equilibrium reactions



Will % yield for an equilibrium reaction be higher, lower, or the same as for a reaction that goes in the forward direction only?