



# W.O.W. – Waters of the World

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# First things smirst

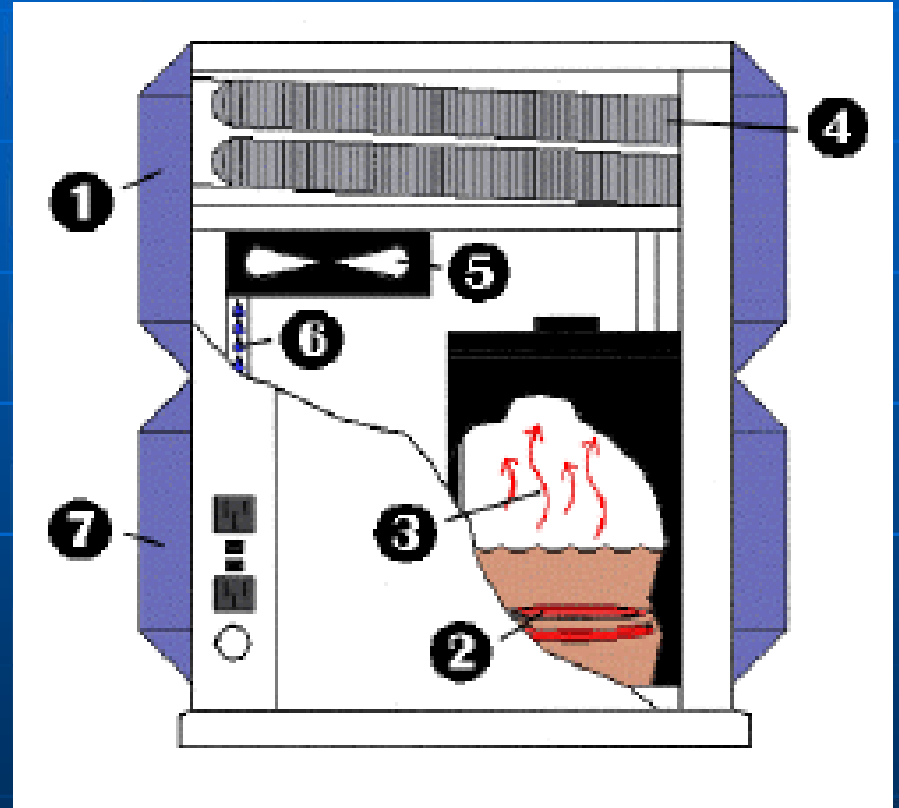
- ~95% beer is aqua
- Styles developed b/c of the water of the city

# Types-O-Aqua

- Tap water
- Spring water
- RO water
- Distilled water
- 'Heavy' water
  - Deuterium isotope – good for things like the Manhattan project NOT brewing

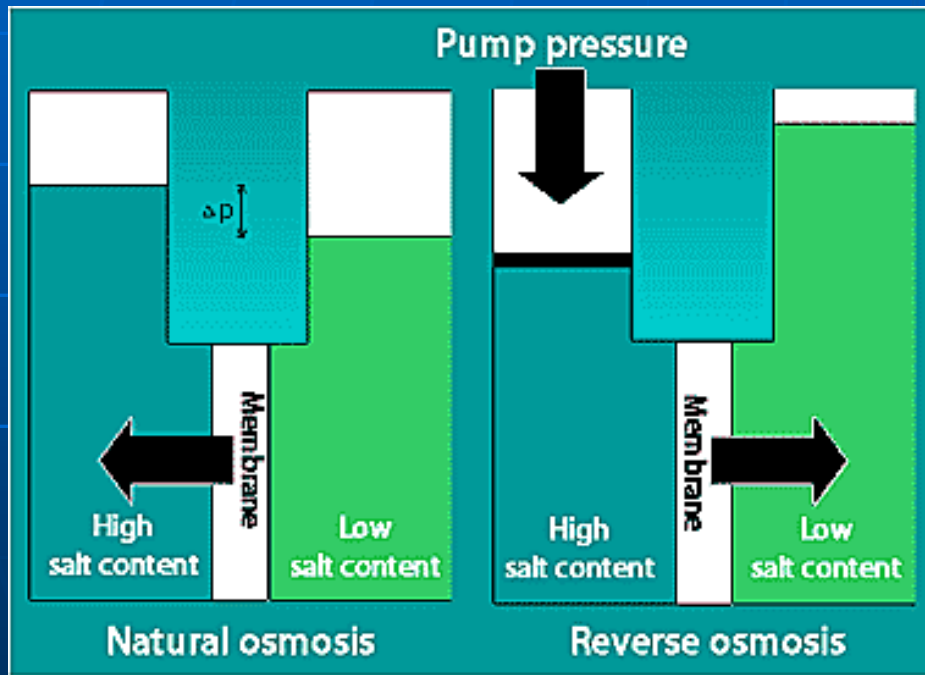
# Distilled Water

1. Contaminated water
2. Heat from the heating element
3. Evaporation of H<sub>2</sub>O molecules
4. Condenser
5. Cool air from fan
6. Distilled water
7. Distilled water storage

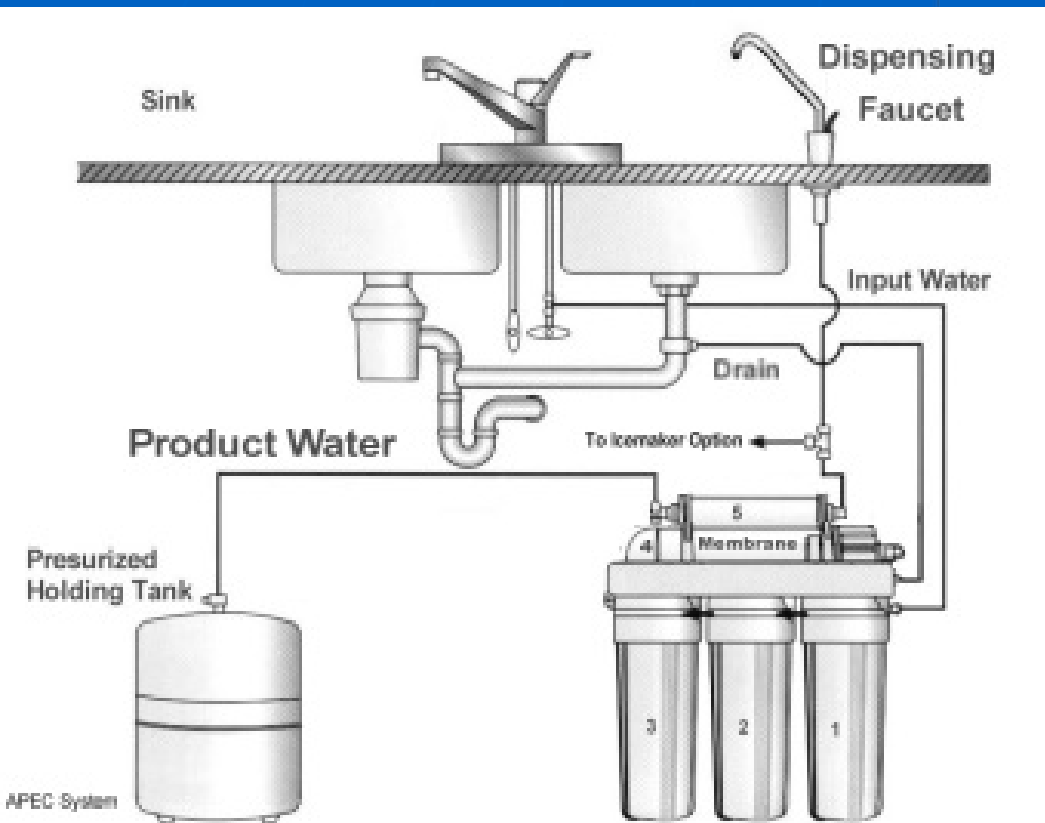


# RO Water

- A method of producing pure water by forcing saline or impure water through a semipermeable membrane across which salts or impurities cannot pass.

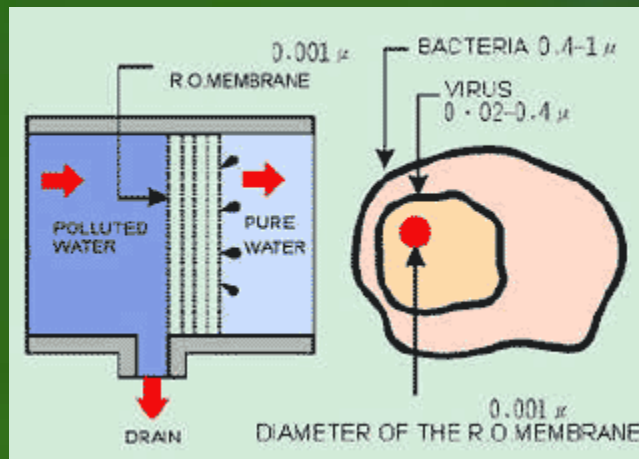


# RO – Under counter



- **Stage 1 - Sediment Prefiltration** - 1 micron cartridge that traps dirt, rust, mud, hair
- **Stage 2 - Chlorine Prefiltration** - 1 micron chemical removal cartridge to ensure no chemical deterioration of membrane from residual chlorine.
- **Stage 3 - Membrane Process**  
This is the primary component that can separate up to 98% of dissolved metals and minerals from ordinary tap water.

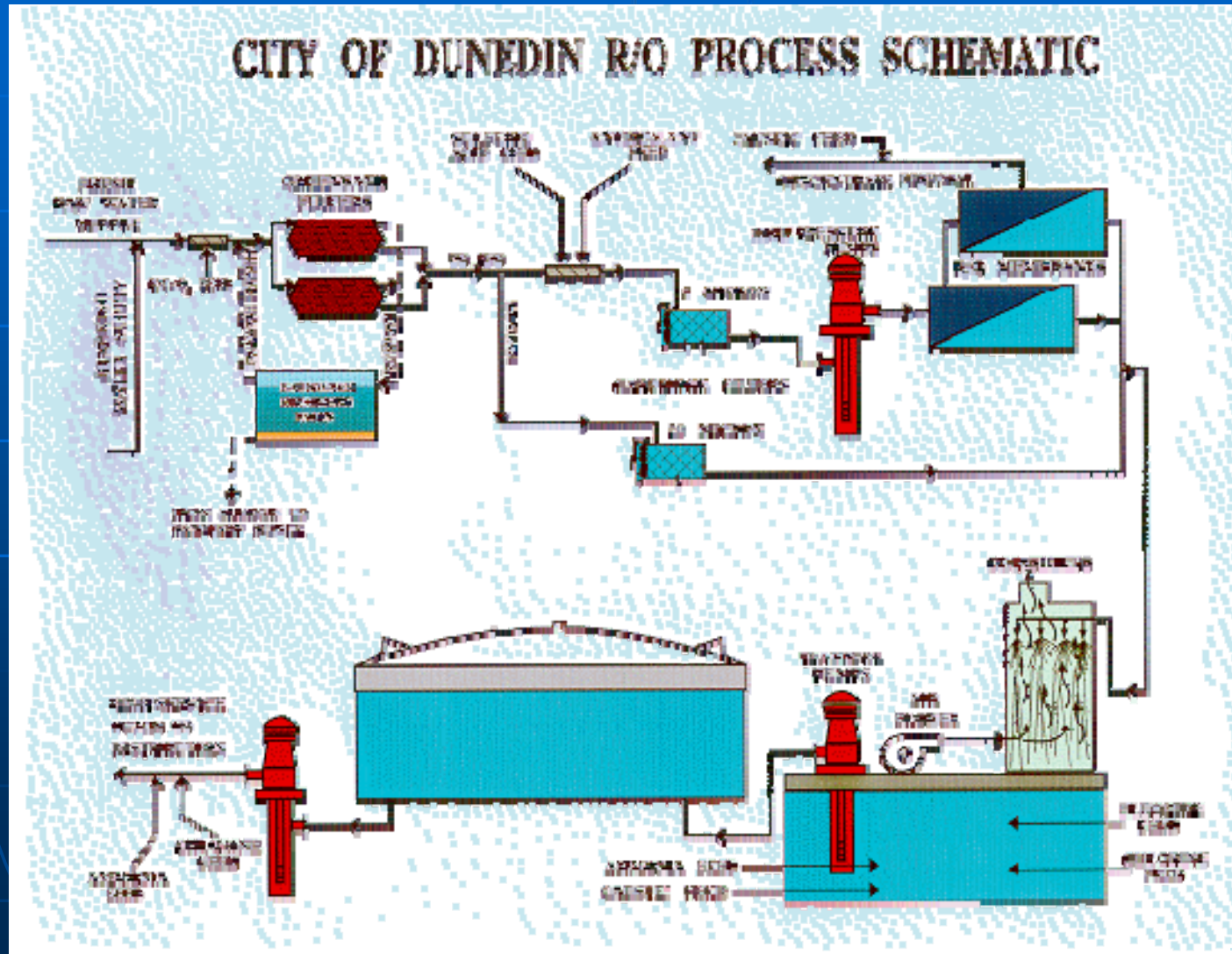
# RO - Membrane pore size



*Yeast 5-12u*



# RO – City Scale





# Spring Water

- Spring water is water that comes out of the ground on its own or is bottled near water that comes out of the ground on its own.
- Check ion content

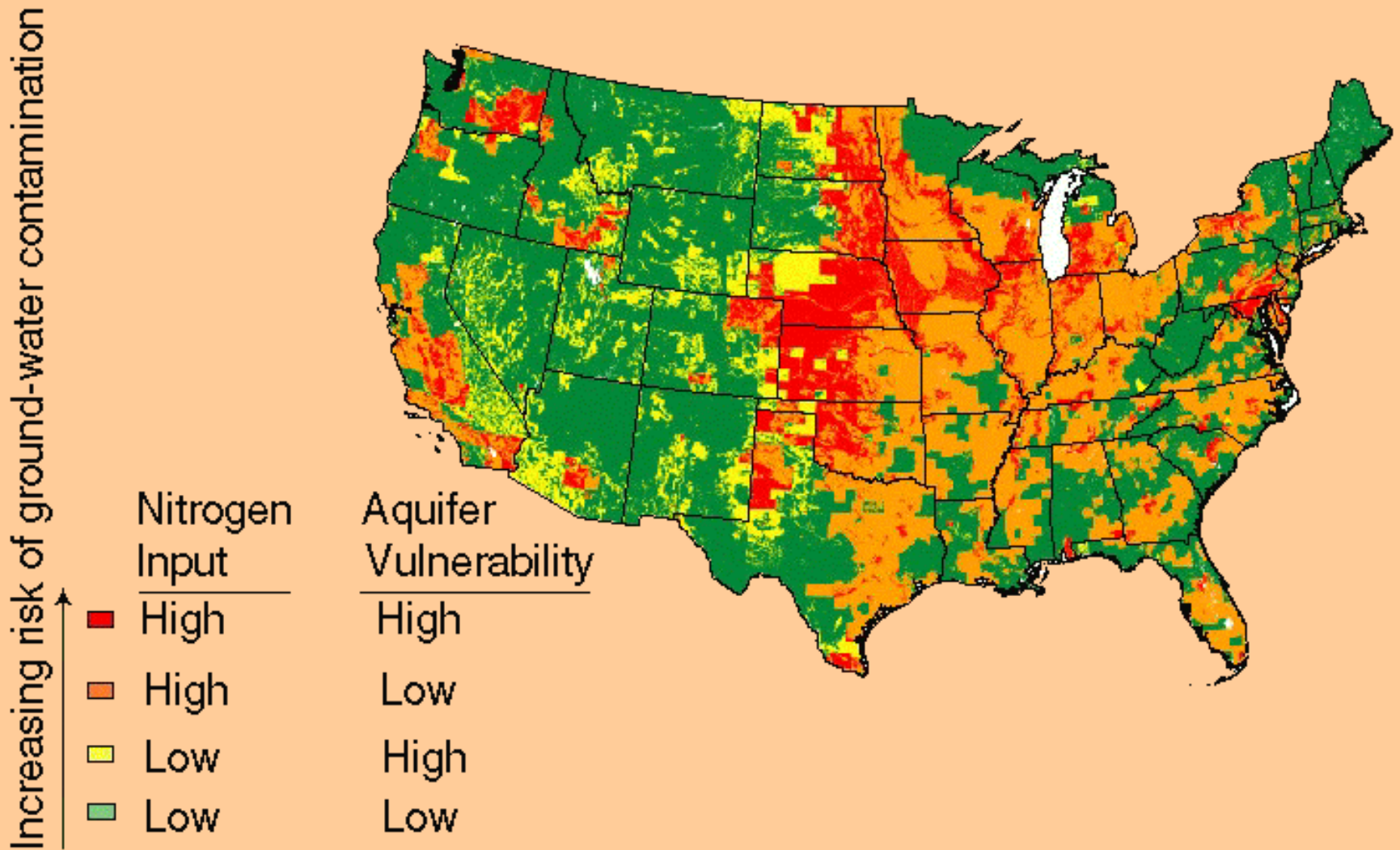
# Tap Water – The Bad

- 'Bad'
  - Non-potable
  - Chlorine and/or Chloramines
  - Sulfur
  - Nitrates – ummm...poop
  - Corn chips, old feet, etc

# Chlorine, borine!!!

- Chlorine gas
  - Used VERY little
  - Boils off easily
- Chloramines
  - Used most often
  - Need carbon filter to remove
    - Sulfate and UV bs
  - Boil only concentrates!!

# Nitrates = POO!



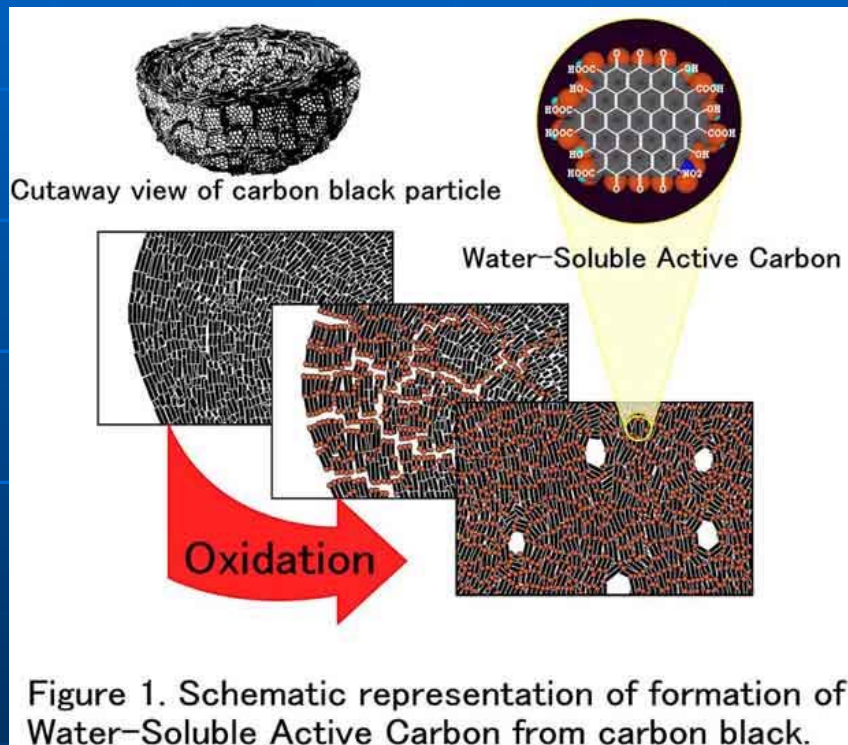
# Tap Water – The Good

- Good
  - Anything you can drink - potable water
  - Well water
  - NOT through 'softener'
  - Carbon filtered
    - Removes Cl and other nasty stuff

# Activated Carbon

## ■ Uses

- Air purification
- Water purification
- Booze purification
- Hospital

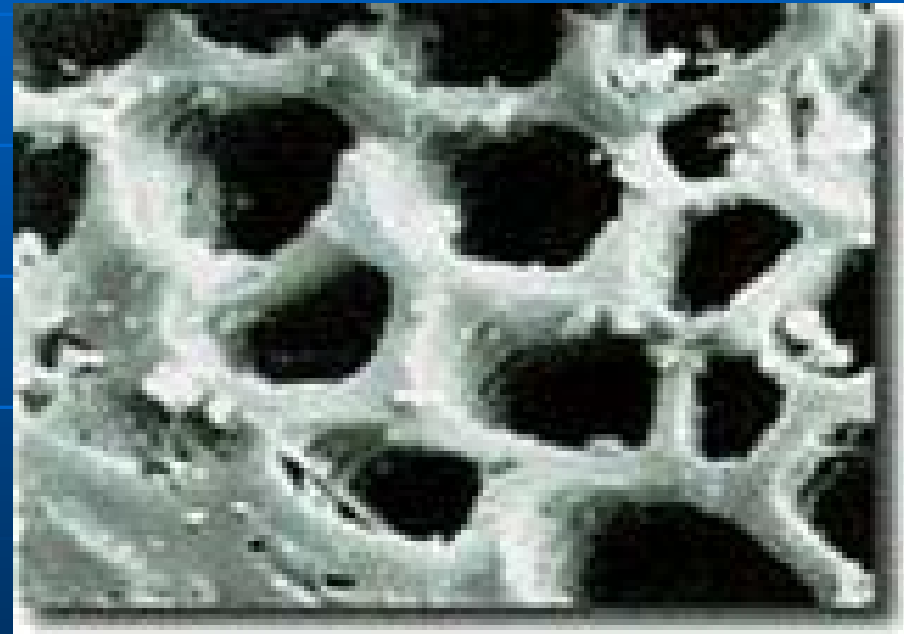
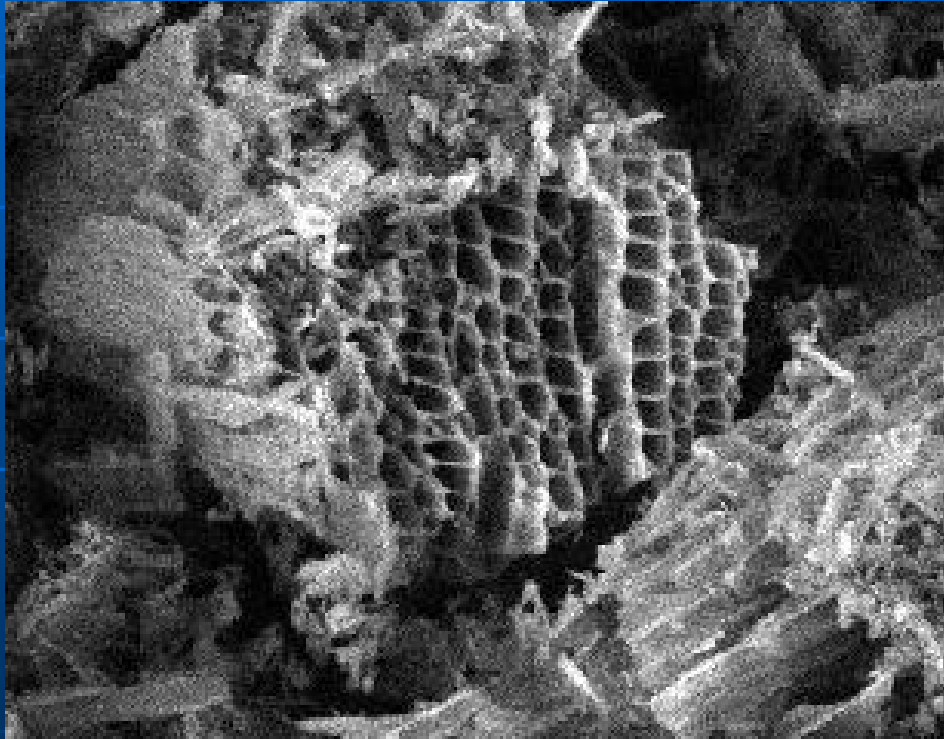


# Activated Carbon

- Charcoal that has been treated with **oxygen**
- 300-2,000 m<sup>2</sup>/g (3200-21500 ft<sup>2</sup>/g)
  - A tennis court is about 260 m<sup>2</sup> (2800ft<sup>2</sup>/g)
- Trap
  - Carbon-based contaminants – flavor and odorous stuff
  - Chlorine
- Pass
  - Sodium, Nitrates
- Good at trapping other carbon-based impurities ("organic" chemicals), as well as things like chlorine.
- Once all of the bonding sites are filled, an activated charcoal filter stops working.

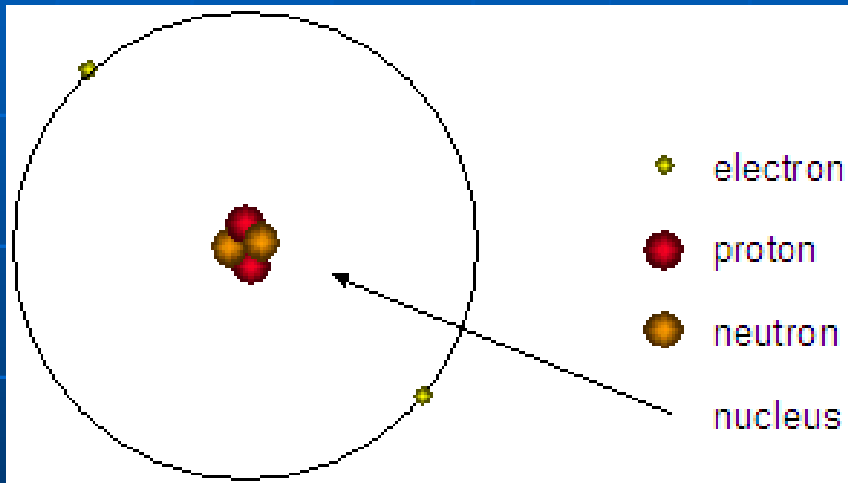


Ummm....honeycomb!



# Chemistry Primer

# Atoms



- Atoms are composed of protons, neutrons, and electrons.
- ***Protons*** and ***neutrons*** are located in a central area called the nucleus.
- ***Electrons*** move about the nucleus. The number of electrons is equal to the number of protons.
  - Electrons in cloud, not ring

# Periodic Table of the Elements

## Elementary my dear Watson!!

1 IA	New Original										13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA				
1 <b>H</b> Hydrogen 1.00794											5 <b>B</b> Boron 10.811	6 <b>C</b> Carbon 12.0107	7 <b>N</b> Nitrogen 14.00674	8 <b>O</b> Oxygen 15.9994	9 <b>F</b> Fluorine 18.9984032	10 <b>Ne</b> Neon 20.1797	K			
2 <b>Li</b> Lithium 6.941	3 <b>Na</b> Sodium 22.989770	4 <b>Be</b> Beryllium 9.012182	11 <b>Mg</b> Magnesium 24.3050											13 <b>Al</b> Aluminum 26.981538	14 <b>Si</b> Silicon 28.0855	15 <b>P</b> Phosphorus 30.973761	16 <b>S</b> Sulfur 32.066	17 <b>Cl</b> Chlorine 35.453	18 <b>Ar</b> Argon 39.948	K L
3 <b>Sc</b> Scandium 44.955910	21 <b>Y</b> Yttrium 88.90585	22 <b>Ti</b> Titanium 47.867	23 <b>V</b> Vanadium 50.9415	24 <b>Cr</b> Chromium 51.9961	25 <b>Mn</b> Manganese 54.938049	26 <b>Fe</b> Iron 55.8457	27 <b>Co</b> Cobalt 58.933200	28 <b>Ni</b> Nickel 58.6934	29 <b>Cu</b> Copper 63.546	30 <b>Zn</b> Zinc 65.409	31 <b>Ga</b> Gallium 69.723	32 <b>Ge</b> Germanium 72.64	33 <b>As</b> Arsenic 74.92160	34 <b>Se</b> Selenium 78.96	35 <b>Br</b> Bromine 79.904	36 <b>Kr</b> Krypton 83.798	K L M			
4 <b>K</b> Potassium 39.0983	37 <b>Rb</b> Rubidium 85.4678	38 <b>Sr</b> Strontium 87.62	39 <b>Y</b> Yttrium 88.90585	40 <b>Zr</b> Zirconium 91.224	41 <b>Nb</b> Niobium 92.90638	42 <b>Mo</b> Molybdenum 95.94	43 <b>Tc</b> Technetium (98)	44 <b>Ru</b> Ruthenium 101.07	45 <b>Rh</b> Rhodium 102.90550	46 <b>Pd</b> Palladium 106.42	47 <b>Ag</b> Silver 107.8682	48 <b>Cd</b> Cadmium 112.411	49 <b>In</b> Indium 114.818	50 <b>Sn</b> Tin 118.710	51 <b>Sb</b> Antimony 121.760	52 <b>Te</b> Tellurium 127.60	53 <b>I</b> Iodine 126.90447	54 <b>Xe</b> Xenon 131.293	K L M N	
5 <b>Rb</b> Rubidium 85.4678	55 <b>Cs</b> Cesium 132.90545	56 <b>Ba</b> Barium 137.327	57 to 71	72 <b>Hf</b> Hafnium 178.49	73 <b>Ta</b> Tantalum 180.9479	74 <b>W</b> Tungsten 183.84	75 <b>Re</b> Rhenium 186.207	76 <b>Os</b> Osmium 190.23	77 <b>Ir</b> Iridium 192.217	78 <b>Pt</b> Platinum 195.078	79 <b>Au</b> Gold 196.96655	80 <b>Hg</b> Mercury 200.59	81 <b>Tl</b> Thallium 204.3833	82 <b>Pb</b> Lead 207.2	83 <b>Bi</b> Bismuth 208.98038	84 <b>Po</b> Polonium (209)	85 <b>At</b> Astatine (210)	86 <b>Rn</b> Radon (222)	K L M N O	
6 <b>Cs</b> Cesium 132.90545	87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)	89 to 103	104 <b>Rf</b> Rutherfordium (261)	105 <b>Db</b> Dubnium (262)	106 <b>Sg</b> Seaborgium (266)	107 <b>Bh</b> Bohrium (264)	108 <b>Hs</b> Hassium (269)	109 <b>Mt</b> Meitnerium (268)	110 <b>Ds</b> Darmstadtium (271)	111 <b>Rg</b> Roentgenium (272)	112 <b>Uub</b> Ununbium (285)	113 <b>Uut</b> Ununtrium (284)	114 <b>Uuq</b> Ununquadium (289)	115 <b>Uup</b> Ununpentium (288)	116 <b>Uuh</b> Ununhexium (292)	117 <b>Uus</b> Ununseptium	118 <b>Uuo</b> Ununoctium	K L M N O P	

57 to 71

89 to 103

Atomic masses in parentheses are those of the most stable or common isotope.

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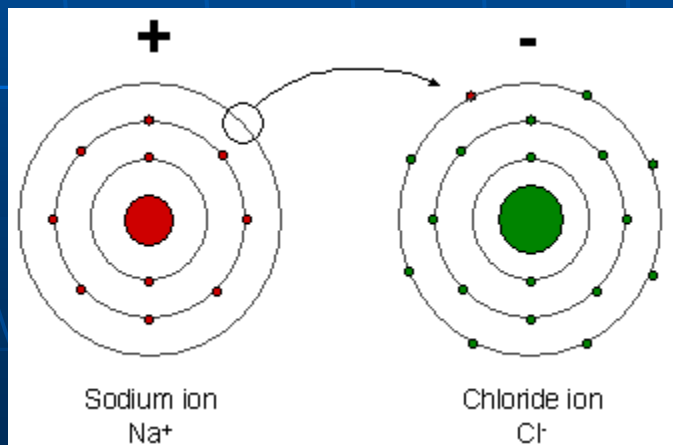
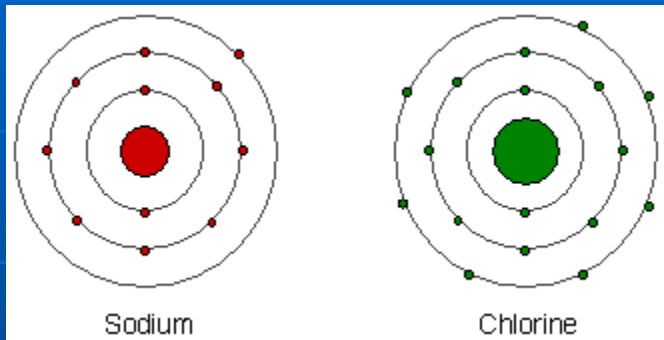
Note: The subgroup numbers 1-18 were adopted in 1984 by the International Union of Pure and Applied Chemistry. The names of elements 112-118 are the Latin equivalents of those numbers.

57 <b>La</b> Lanthanum 138.9055	58 <b>Ce</b> Cerium 140.116	59 <b>Pr</b> Praseodymium 140.90765	60 <b>Nd</b> Neodymium 144.24	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 158.92534	66 <b>Dy</b> Dysprosium 162.500	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 173.04	71 <b>Lu</b> Lutetium 174.967
89 <b>Ac</b> Actinium (227)	90 <b>Th</b> Thorium 232.0381	91 <b>Pa</b> Protactinium 231.03688	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)

# Compounds

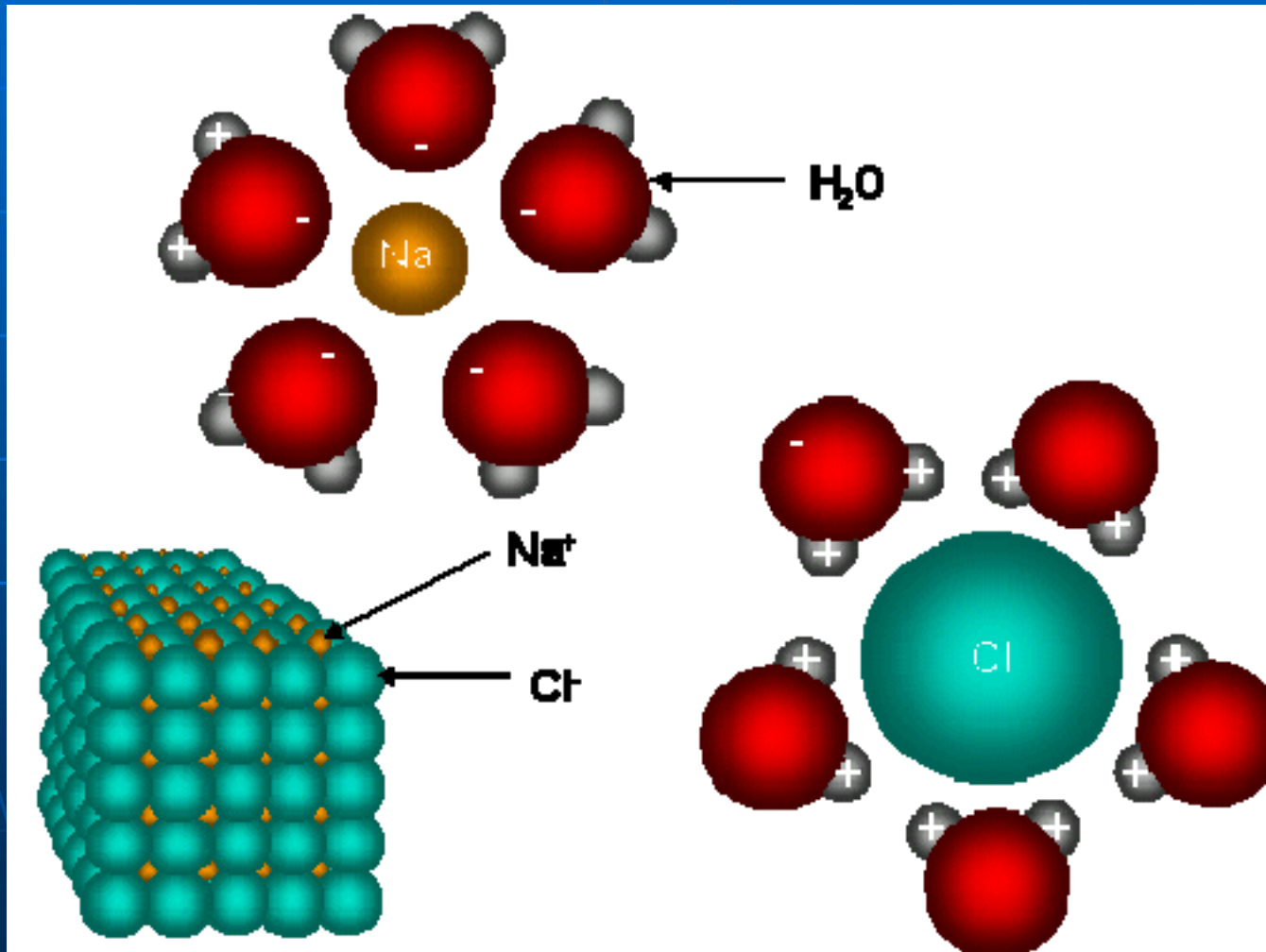
- Elements cannot be broken down into substances with different properties.
- Substances that are composed of two or more elements are called *compounds*.
- For example, water (H<sub>2</sub>O) is not an element because it can be broken down into hydrogen (H) and oxygen (O).

# Ionic Compound



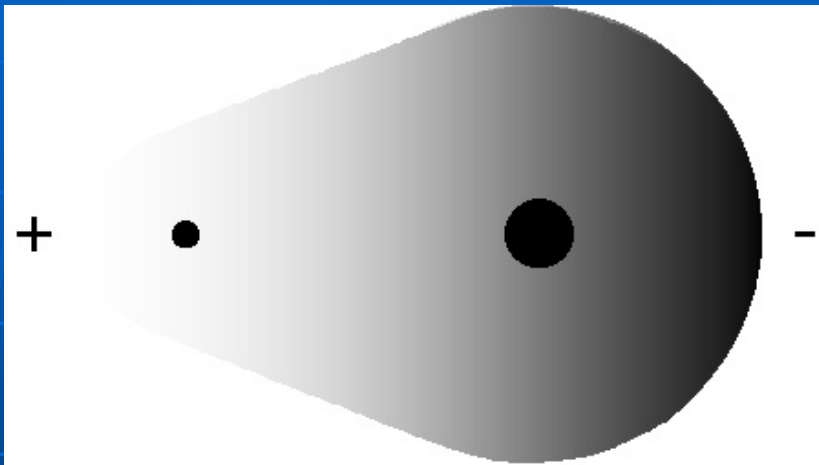
- Ionic bonding is the transfer of electrons from one atom to another.
- Atoms that have lost or gained electrons are called *ions*.
  - + = Cations
  - - = Anions

# Ionization

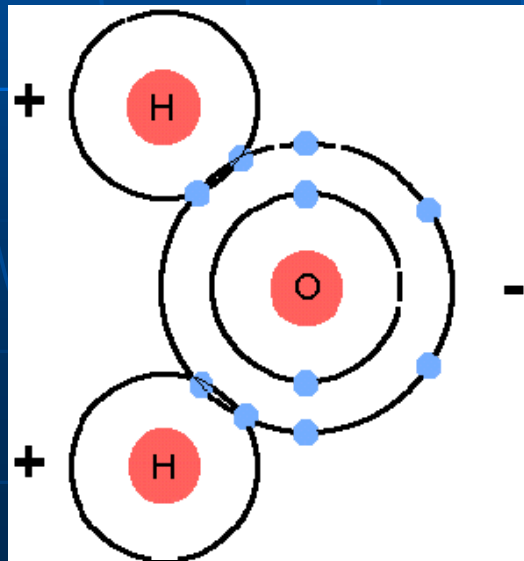




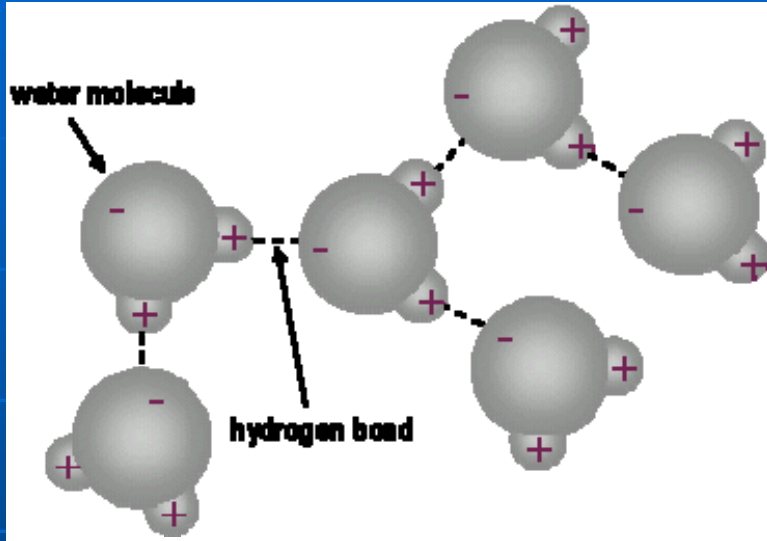
# H-Deuce-O



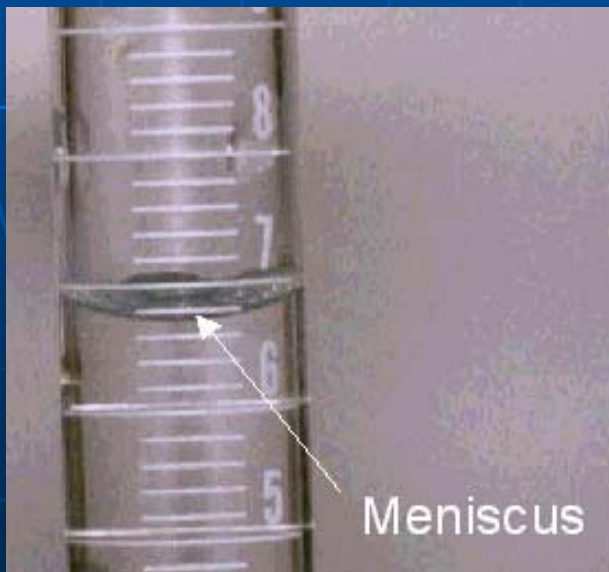
- Polar
- Covalent
  - Shares electrons, doesn't lose or gain
- Molecule



# Big prop's



- Solvent
- High surface tension
- 'Water bugs'
- Action is independent of volume



# Sorry, Its not that simple...

- Review
  - Water types
  - Water properties
  - Solutes – bits in the water

# Cations – Positive

- Most widely occurring cations in water
  - $\text{Ca} \gg \text{Mg} > \text{Na} \gg \text{K} \gg \text{Mn}$
- Ca
  - *Principle mineral hardness*
  - ↓ mash pH, enzyme activity, protein digestion, lauter runoff
  - Neutralizes toxic substances in yeast: Peptone & Lecithin
  - inverts malt phosphate to pp alkaline phosphate
- Mg
  - 2ndary mineral in hardness
  - accentuates bitterness
- Na
  - Accentuates beer flavor

# Anions - Negative

## Strong vs Weak Buffers

$\text{CO}_3 \gg \text{SO}_4 \gg \text{Cl}$

- $\text{CO}_3^{2-}$  - Carbonate
  - *Contributes most of alkalinity*
- $\text{CO}_3^{2-} + \text{H}_2\text{O} \rightarrow \text{HCO}_3^- + \text{OH}^-$ 
  - Pulls  $\text{H}^+$  from  $\text{H}_2\text{O} = \text{OH}^-$
  - STRONG alkaline buffer = neutralizes acids
    - Resists ↓ mash pH
  - ↓  $\alpha$ -amylase activity, cold break,
  - >200ppm = NEEDED dark roast grains to buffer
- $\text{SO}_4^{2-}$  - Sulfate
  - Weak buffer
  - >150ppm = cleaner, more pleasant bitter
- $\text{Cl}^-$  - Chloride
  - Very weak buffer

# Complicated??

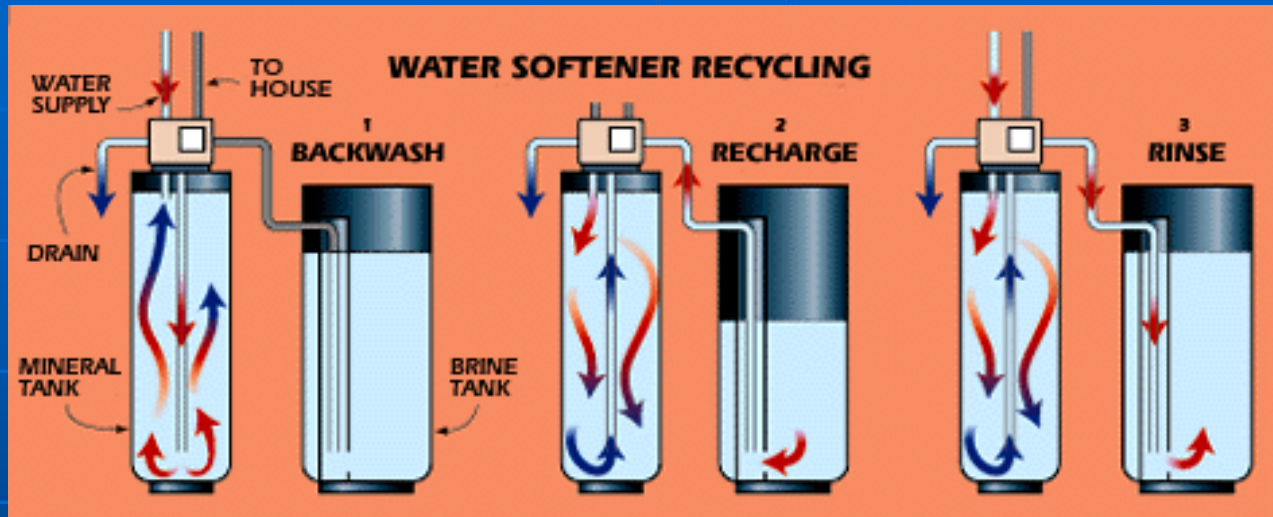
- Ca – ↓ mash pH
- CO<sub>3</sub> – buffers mash pH
  - resists changes in mash pH
  - neutralizes acid

# Hard vs Soft: The other definition

- Old Skizool nomenclature: Ability to form a lather with a bar of soap??
  - Hard: Buncha stuff
  - Soft: notta so much stuff



# Water Softener



- Exchanges Na for Ca and Mg
  - Ca/ Mg precipitate out in pipes
  - 'Scale' or 'Beer Stone'
- Bypass!!!

# hAHDness

## CaCO<sub>3</sub> Hardness

Soft 50ppm → Hard 300ppm

- Ca & Mg in water
  - Inhibit lather of soap = 'hard'
  - Slightly acidic = weak bonds
  - Combine with  $\text{CO}_3^{2-}$ ,  $\text{SO}_4^{2-}$ 
    - PP as insoluble mineral salts
- Temporary vs. Permanent
  - Temp = carbonate hardness
    - part of hardness that will pp after boiling
  - Permanent
    - Ca/Mg w/ non-carbonate ions

# *Alkalinity*

## *Alkalinity*

- buffering capacity of dissolved *anions*
- $\text{HCO}_3^-$  (bicarbonate)  $\sim$   $\text{CO}_3^{2-}$   $\rightarrow$  ONLY significant factor

# *Accepted standard – CaCO<sub>3</sub>??*

- expresses hardness and alkalinity together
- Ca – primary mineral of hardness
- CO<sub>3</sub> – principle cause of alkalinity

# ***MEHHHH!!??***

- Alkalinity > hardness → hardness is TEMPORARY
- Hardness > alkalinity → PERMANENT  
SO<sub>4</sub> hardness

# Rho to the H!!

Concentration of Hydrogen ions compared to distilled water		Examples of solutions at this pH
10,000,000	pH = 0	Battery acid, Strong Hydrofluoric Acid
1,000,000	pH = 1	Hydrochloric acid secreted by stomach lining
100,000	pH = 2	Lemon Juice, Gastric Acid Vineger
10,000	pH = 3	Grapefruit, Orange Juice, Soda
1,000	pH = 4	Tomato Juice, Acid rain
100	pH = 5	Soft drinking water, Black Coffee
10	pH = 6	Urine, Saliva
1	pH = 7	"Pure" water
1/10	pH = 8	Sea water
1/100	pH = 9	Baking soda
1/1,000	pH = 10	Great Salt Lake, Milk of Magnesia
1/10,000	pH = 11	Ammonia solution
1/100,000	pH = 12	Soapy water
1/1,000,000	pH = 13	Bleaches, Oven cleaner
1/10,000,000	pH = 14	Liquid drain cleaner

## pH

- Measure of acid ( $H^+$ ) to alkaline ( $OH^-$ ) ratios of a solution
- pH values run from 1 to 14
  - negative  $\log_{10}$  of  $[H^+]$
  - 0 (highly acidic) to 14 (highly basic), 7 neutral

BEER!!!

# *Das pH boot camp*

- Log scale
  - $\text{pH} = -\log_{10} [\text{H}^+]$
  - By 10's
  - Calculation
    - Change pH from 7 to 5
    - $10^{-7} \rightarrow 10^{-6} \rightarrow 10^{-5}$ 
      - $10^2 = 10 \times 10 = \text{increase } [\text{H}^+] = 100 \text{ fold}$
- **HCl(aq)  $[\text{H}^+] = 0.01 = \text{pH} 2$**
- **Distilled H<sub>2</sub>O(l)  $[\text{H}^+] = 0.0000001 = \text{pH} 7$**
- **NaOH(aq)  $[\text{H}^+] = 0.0000000000000001 = \text{pH} 14$**
- **The more acidic the solution, the lower the pH value;**
- **Conversely: the pH value rises as the solution becomes more alkaline.**



# pH in Brewing

- *pH in Brewing*
- prerequisite of brewing cycle!!
  - Enzyme activity, kettle break, yeast performance, hop extraction, clarification (flocculation)
- *Target pH*
  - pH 5.2 – 5.5 – sacchrification
  - pH 5.0 = protein degradation
  - pH 5.5 = amylase
  - pH 6.0 = reduce enzymatic activities, *extracts tannins*

# Malt pH

- Distilled H<sub>2</sub>O = NO ions
  - 100% base = pH 5.7 - 5.8
  - Caramel/crystal = pH 4.5 - 4.8
  - Chocolate = pH 4.3 - 4.5
  - Black/RB = pH 4.0 - 4.2

# Water Treatment

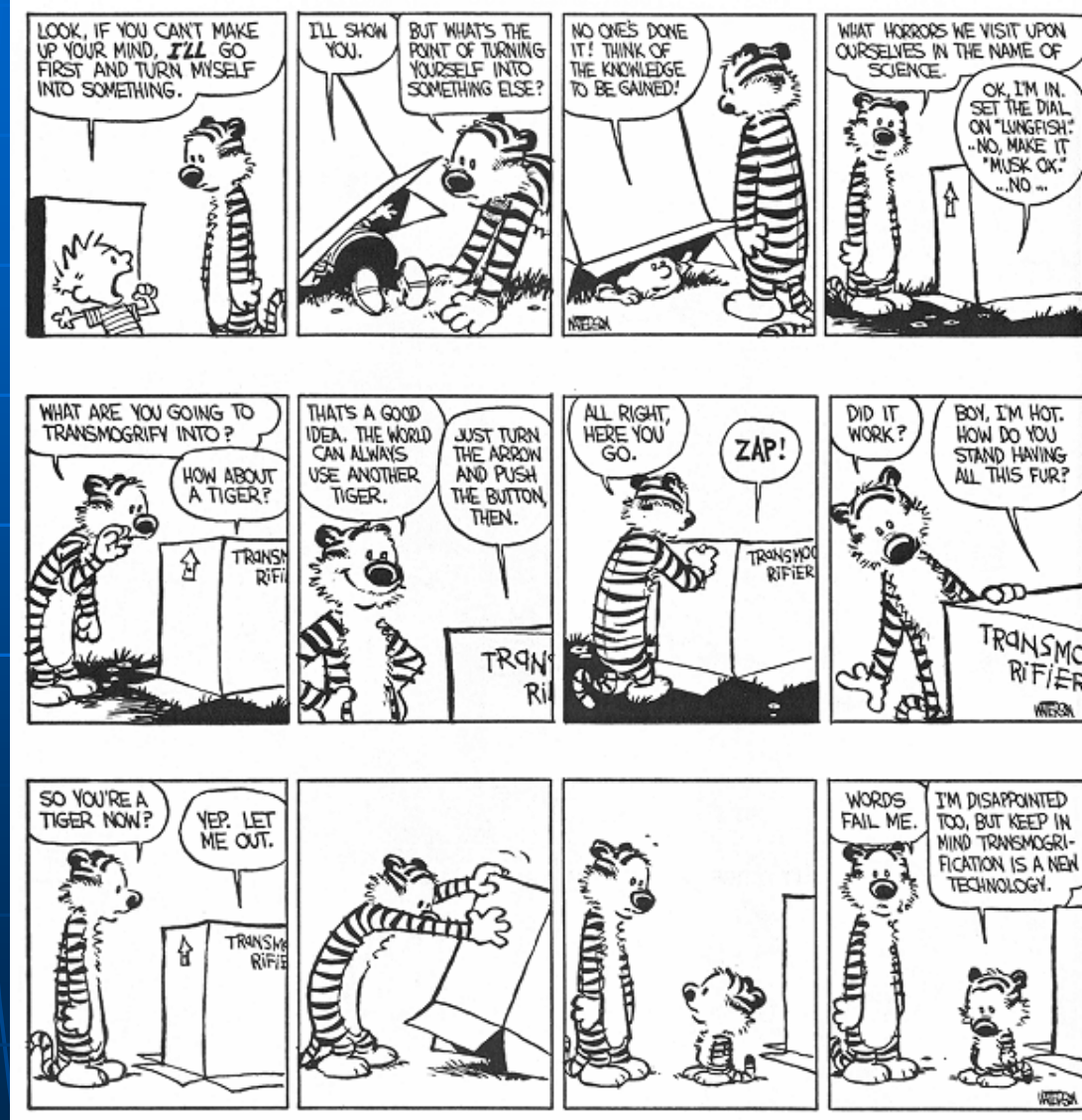
- ↓ pH = MOST common
- ↓ HCO<sub>3</sub>??
  - Boil
    - PP out organic salts in boil
    - $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3$
    - $\text{H}_2\text{CO}_3 \rightleftharpoons \text{HCO}_3^- + \text{H}^+$
  - Roast malts
    - Acid is created over high kiln temperatures
    - Dublin
  - Add acid
    - Phosphoric acid
      - $\text{H}_3\text{PO}_4 + \text{CaCO}_3 \rightarrow \text{H}_2\text{CO}_3 + \text{CaHPO}_4 \text{ pp}$
    - Lactic acid
      - $2\text{C}_3\text{H}_6\text{O}_3 + \text{CaCO}_3 \rightarrow \text{H}_2\text{CO}_3 + \text{Ca}(\text{C}_3\text{H}_5\text{O}_3)_2 \text{ pp}$

# Summarizationizzal

- IMPORTANTE!!!!
- Types aqua
- Chemistry
- Ions
- pH
  - Adjustments

# Transmogrification

- Brewing centers
- Specific water
- Salt Additions
- Recreations!!



# Brewing Capitals

How much do you  
know???

# Beer central

1. Pilsen
2. Munich
3. London
4. Dublin
5. Edinburgh
6. Köln

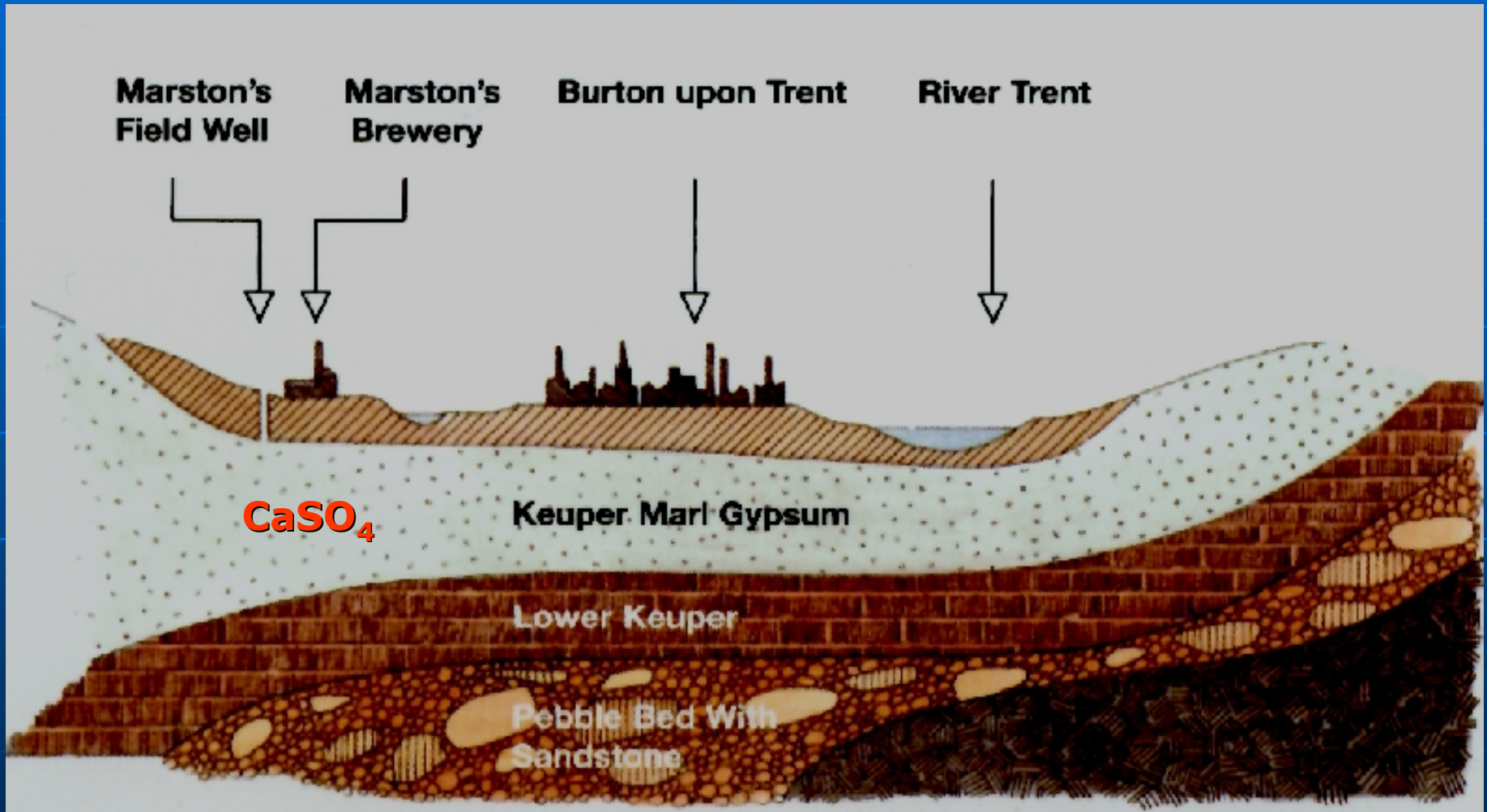
1. Softest brewing water – pale and clean beers
2. High Carbonates – low hops, high color and malt
3. High Carbonates – smooth dark ales
4. VERY VERY high Carbonate levels – acidic dark malts needed for mash pH
5. similar to London's, more bicarbonate and sulfate, lends heavier malt body
6. Soft, low levels of calcium, magnesium, bicarbonates. Lends delicate impression.



# Rock Formations

- Non-reactive
  - Granite, Sandstone
    - ~90% Silica ( $\text{SiO}_2$ )
- Reactive
  - Lime Stone ( $\text{CaCO}_3$ )
  - Dolomite ( $\text{CaMg}(\text{CO}_3)_2$ )
  - Gypsum ( $\text{CaSO}_4$ )

# Specific locations



# Blessed waters

- Brewing city, check! ...specific water???

# Water Salts: Stick the what in the where now??

	Pilsen	Munich	London	Vienna	Dublin	Dortmund	Burton
Calcium	7	75	52	200	118	225	268
Magnesium	2	18	16	60	4	40	62
Sodium	2	7	99	8	12	60	54
Chloride	5	10	60	12	19	60	36
Sulfate	5	10	77	125	54	120	638
Alkalinity	14	152	156	120	319	180	200



# Exact!?

- Only worry is solubility!
- Don't have to be exactly accurate
- Mother Nature
  - Not same stuff we have

# Stick the what in the where now??

## ■ *Key ideas*

- WEIGH, WEIGH, WEIGHT - DON'T use volumes e.g. NO tsp
- Add to water then to mash, NOT directly
- $\text{CaCO}_3$  – Calcium carbonate (chalk)
  - Buffers mash acidity
  - Partly pp in kettle
- $\text{CaSO}_4$  – Gypsum
  - $\downarrow$  pH = pp  $\text{CaPO}_4$
- $\text{MgSO}_4$  – Epsom salts
  - $\uparrow$  Mg &  $\text{SO}_4$
- $\text{Ca(OH)}_2$  – Slaked lime
  - $\uparrow$  pH = pp  $\text{CaCO}_3$

# Tasting!!!

- Taste the water
  - Get a 'feel' for it
  - Slosh it around
- Sip distilled water for rinse
- Taste the beer
  - Think about the 'flavor', mouthfeel
- Repeat
- Compare the water with the beer

# Order

1. Edinburgh
  1. Balhaven Scottish
2. Köln
  1. Reissdorf kölsch
3. Munich
  1. Hacker-Pschorr Ofest
4. London
  1. Fullers London Pride
5. Plzeň
  1. Pilsner Urquel
6. Dublin
  1. Guinness



# Water Analysis

SOURCE	Ca	Mg	Na	CO3	SO4	Cl
Antwerp [DeKonick]	90	11	37	76	84	57
Beerse region [Westmalle]	41	8	16	91	62	26
Brugse [Brugs Tarwebier]	132	13	20	326	99	38
Brussels region	100	11	18	250	70	41
Burton-upon-Trent 1	268	62	-	280	638	36
Burton-upon-Trent 2	270	60	30	200	640	40
Burton-upon-Trent 3	295	45	55	300	725	25
Burton-upon-Trent 4	268	62	54	200	638	36
Dortmund 1	225	40	60	180	120	60
Dortmund 2	250	25	70	550	280	100
Dublin 1	119	4	12	156	53	19
Dublin 2	118	4	12	319	54	19
Düsseldorf	40	-	25	-	80	45
Edinburgh 1	140	60	80	140	96	34
Edinburgh 2	120	25	55	225	140	20
Edinburgh 3	100	18	20	160	105	45
Köln (Cologne)	104	15	52	152	86	109
London Well 1	52	32	86	104	32	34
London Well 2	50	20	100	160	80	60
Munich 1	75	18	2	150	10	2
Munich 2	109	21	2	171	79	36
Munich 3	75	18	-	152	10	2
Pilsen	7	2	2	15	5	5
San Francisco [Anchor]	24	15	28	104	39	39
Vienna 1	200	60	8	120	125	12
Willebroek/Rumst [Duvel]	68	8	33	143	70	60