Acid-Base Chemistry
Redox Chemistry

Basic Inorganic Chemistry

Lesson 6, 2016.Q1

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SERIOUSLY BORING AHEAD!

Boring, but important..

Why people hate Chemistry?

- *Too many random facts*
  - Materials, reactions, ..

- *"What is happening?"* aka *"But why ??"*
  - Recipes
    Example: extract DNA from strawberries

GOOD NEWS:
THERE IS ACTUALLY A SYSTEM

Acid-base chemistry

Redox chemistry

We can influence how reactions, processes go!

Acid or base?

CH_3CH_2OH
Ethanol

NH_3
Ammonium

$FeCl_3$
Iron(III)-chloride

$Al(OH)_3$
Aluminum hydroxide

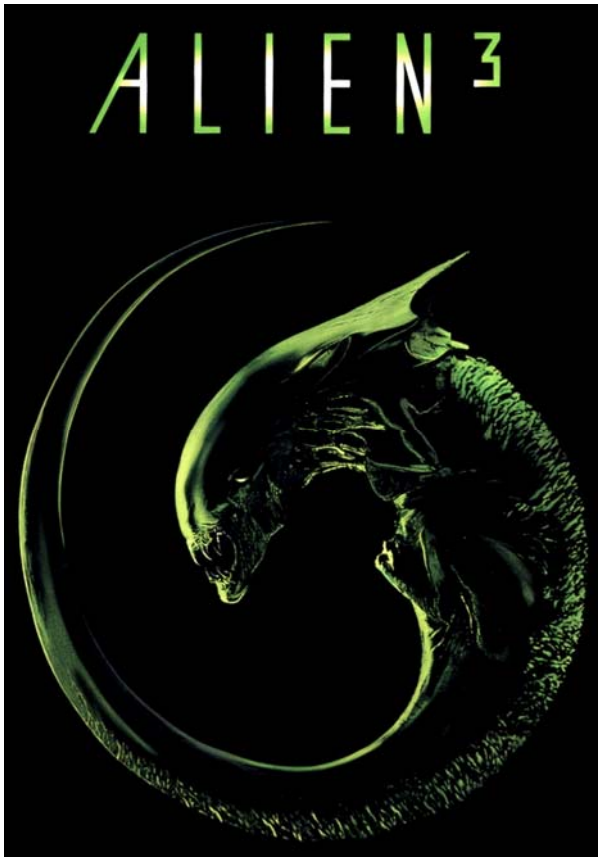
NaOH
Sodium hydroxide

CH_4
Methane

$NaHCO_3$
Sodium-bicarbonate

Acids and bases
HISTORY

Acids and bases nowadays



Weapon of mass destruction

Coca Cola dissolves	Hits
teeth	219,000
bone	114,000
nail	20,200
penny	122,000
human body	180,000
(kill) slugs	108,000

“phosphorous acid Lewis structure”: 81,200 hits

What is an acid / base?

$$HCl(g) \overset{H_2O}{\rightleftarrows} H^+(aq) + Cl^-(aq)$$

$$NaOH(s) \overset{H_2O}{\rightleftarrows} Na^+(aq) + OH^-(aq)$$

$$HCl(g) + H_2O \rightleftarrows H_3O^+(aq) + Cl^-(aq)$$

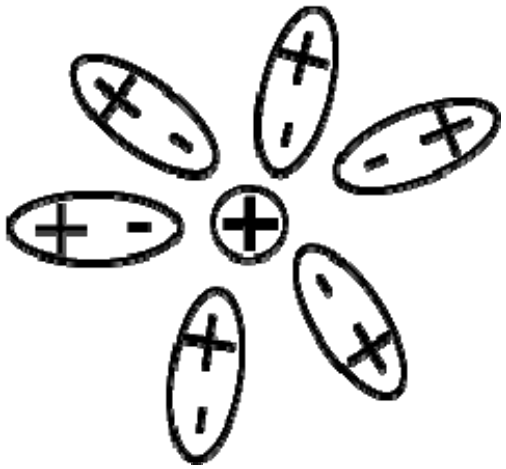
<u>Arrhenius theory (aqueous solutions)</u>

- Acid produces H^+ (H_3O^+, oxonium), base produces OH^-
- It is an equilibrium

One word about water and H^+

H^+ in solvent (water)

$$H^+ \text{ or } H_3O^+$$



Charge in a small place is instable!

Ionic product of water

$$H_2O \rightleftarrows H^+ + OH^-$$

$$2H_2O \rightleftarrows H_3O^+ + OH^-$$

$$[H^+][OH^-] = K \approx 10^{-14}$$

$$pH = -\log_{10}([H^+])$$

$$pOH = -\log_{10}([OH^-]) = 14 - pH$$

UNITS ?

It is not the H^+, but giving the H^+!

Conjugate pair (1)

ACID **BASE** **ACID** **BASE**

$$HCl(g) + H_2O \rightleftarrows H_3O^+(aq) + Cl^-(aq)$$

Conjugate pair (2)

<u>Bronsted-Lowry theory</u>

- There is no acid without base.
- The stronger the acid, the weaker the conjugate base.
- The strongest acid in water is H_3O^+ (same for base / OH^-)!!

Acid or base?

CH_3CH_2OH
Ethanol

NH_3
Ammonium

$FeCl_3$
Iron(III)-chloride

$Al(OH)_3$
Aluminium hydroxide

Depending on the circumstances!

NaOH
Sodium hydroxide

CH_4
Methane

$NaHCO_3$
Sodium-bicarbonate

Chemical equilibrium: strong and weak acids

$$HA \rightleftarrows H^+ + A^-$$

$$HA + B \rightleftarrows H^+ + HB^-$$

$$K_{HA} = \frac{[H^+][A^-]}{[HA]}$$

$$pK = -\log(K)$$

UNITS ?

Strong acid: dissociation is complete

Weak acid: dissociation varies

Strong acid in water

- Where the H^+ comes from?

$$HA \rightarrow H^+ + A^-$$

$$[H^+] = c_{HA}$$

- Dissociation is full, even in high concentration
- Examples:
- HCl, H_2SO4, HNO_3

Weak acid in water

- Where the H^+ is coming from?

$$HA \rightleftarrows H^+ + A^-$$

$$[H^+] = ?$$

$$K_{HA} = \frac{[H^+][A^-]}{[HA]}$$

$$pK = -\log(K)$$

- The dissociation is limited
- Examples:
- HF, H_2CO_3, H_2S, AcOH

Weak acid in water

Example:

$$HAc = H^+ + Ac^-$$

$$H_2O = H^+ + OH^-$$

$$[H^+] = [H^+]_{HAc} + \cancel{[H^+]_{H_2O}}$$

$$[H^+] \approx [H^+]_{HAc}$$

$$x := [H^+]_{HAc} = [Ac^-]$$

$$K_{HAc} = \frac{[H^+][Ac^-]}{[HAc]}$$

$$K_{HAc} \approx \frac{x^2}{c_{HAc} - x}$$

Why is pK (pK_a) useful?

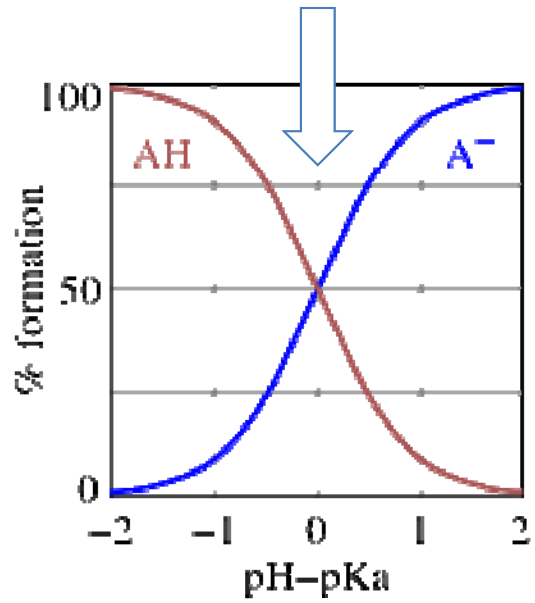
$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$pK = -\log(K_a)$$

$$\text{if } pK = pH$$

$$\frac{[A^-]}{[HA]} = 1$$

Percent ionization=50%



Polyprotic acids

Example

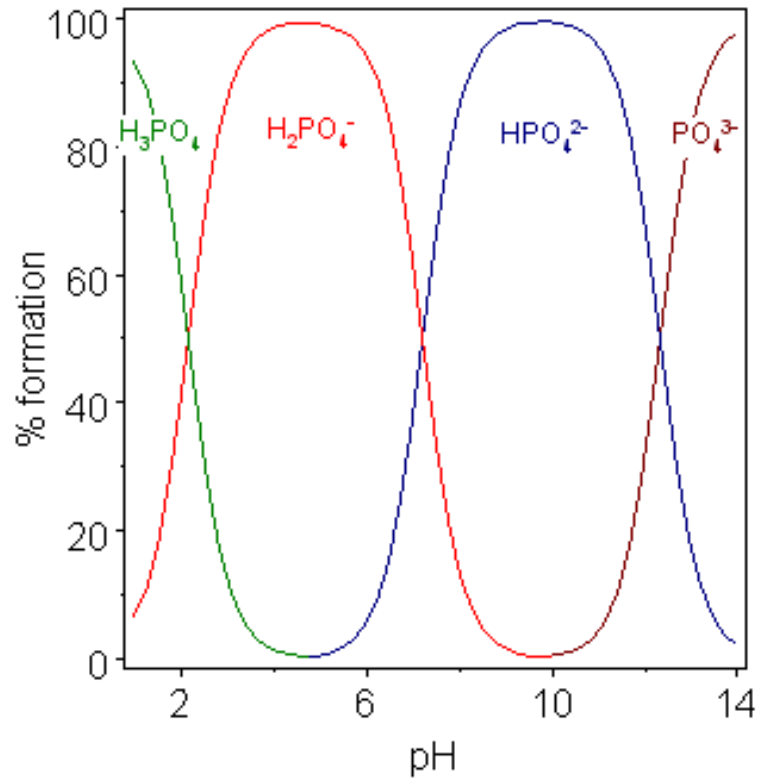
$$H_3PO_4 \Leftrightarrow H_2PO_4^- + H^+$$

$$H_2PO_4^- \Leftrightarrow HPO_4^{2-} + H^+$$

$$HPO_4^{2-} \Leftrightarrow PO_4^{3-} + H^+$$

- That sounds difficult…
- pK ??

Actual concentrations



Mixture of acids

$$HA_1 \rightleftarrows H^+ + A_1^-$$

$$HA_2 \rightarrow H^+ + A_2^-$$

$$[H^+] = ?$$

Le Chatelier's principle

- Any change will trigger a shift that partially counteracts the change.

<u>Result:</u>

- Stronger acid will protonate the weaker one / the dissociation is pushed back
- Often it is enough to consider only one equilibrium!

Using it : superacids

$$HA \rightleftarrows H^+ + A^-$$

$$A^- + X \rightleftarrows AX^-$$

$$HF \rightleftarrows H^+ + F^-$$

$$SbF_5 + F^- \rightleftarrows [SbF_6]^-$$

- It doesn't work much in water!
- Note: HF is actually a weak acid!

What makes an acid strong?

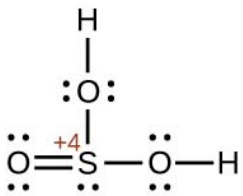
Size does matter!

HI > HBr > HCl > HF

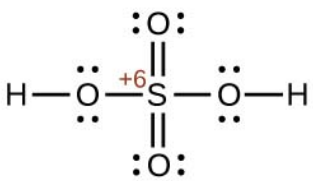
Stability: I^- > .. > F^-

Oxidation number

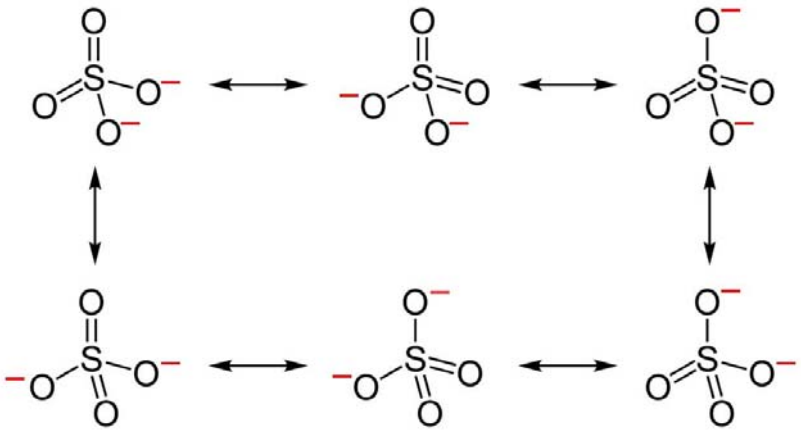
Sulfurous acid



Sulfuric acid



Hybridization of the anion



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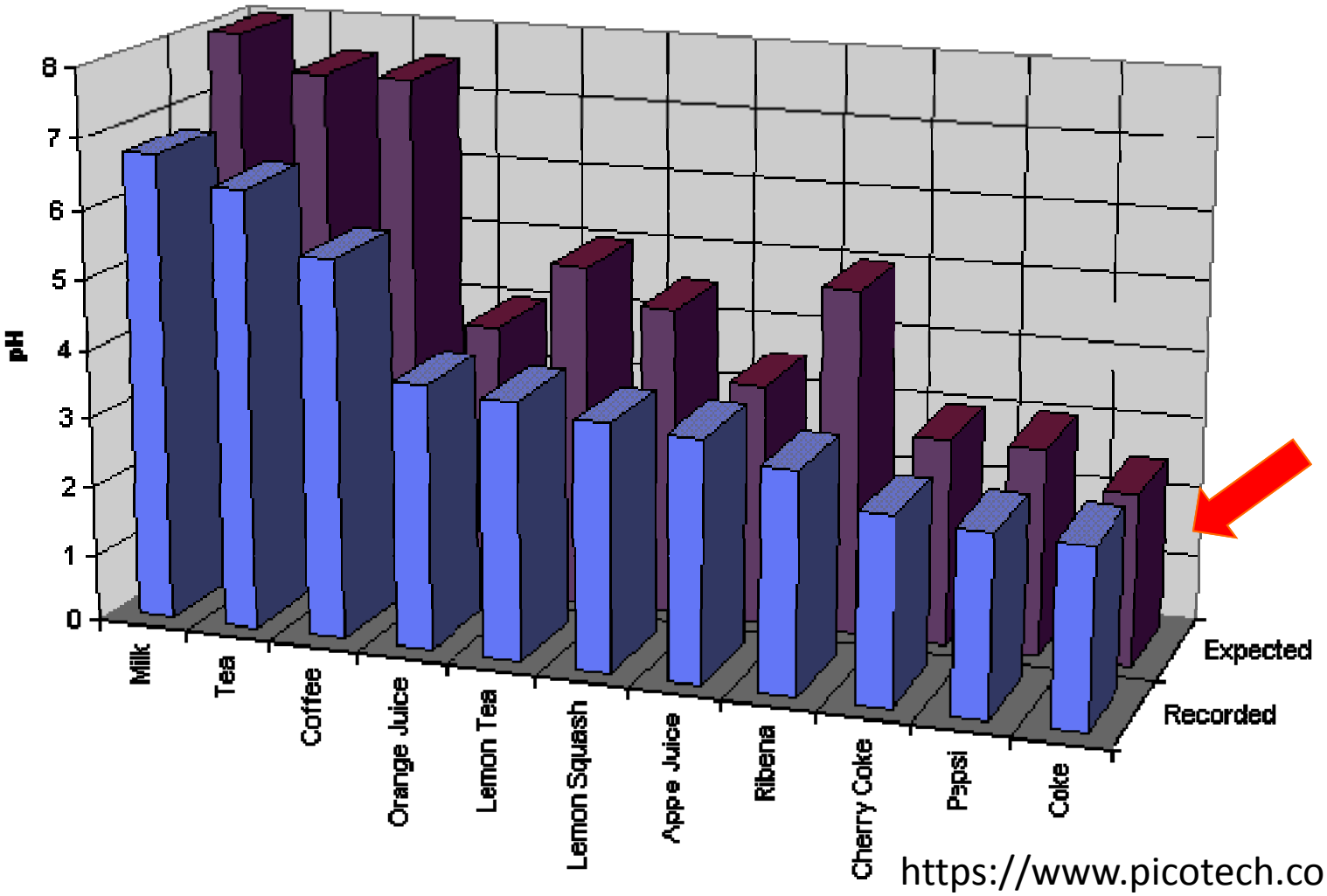
WHAT IS MORE IMPORTANT?

pH or K?

So will Coke kill all humanity?



https://www.picotech.com/

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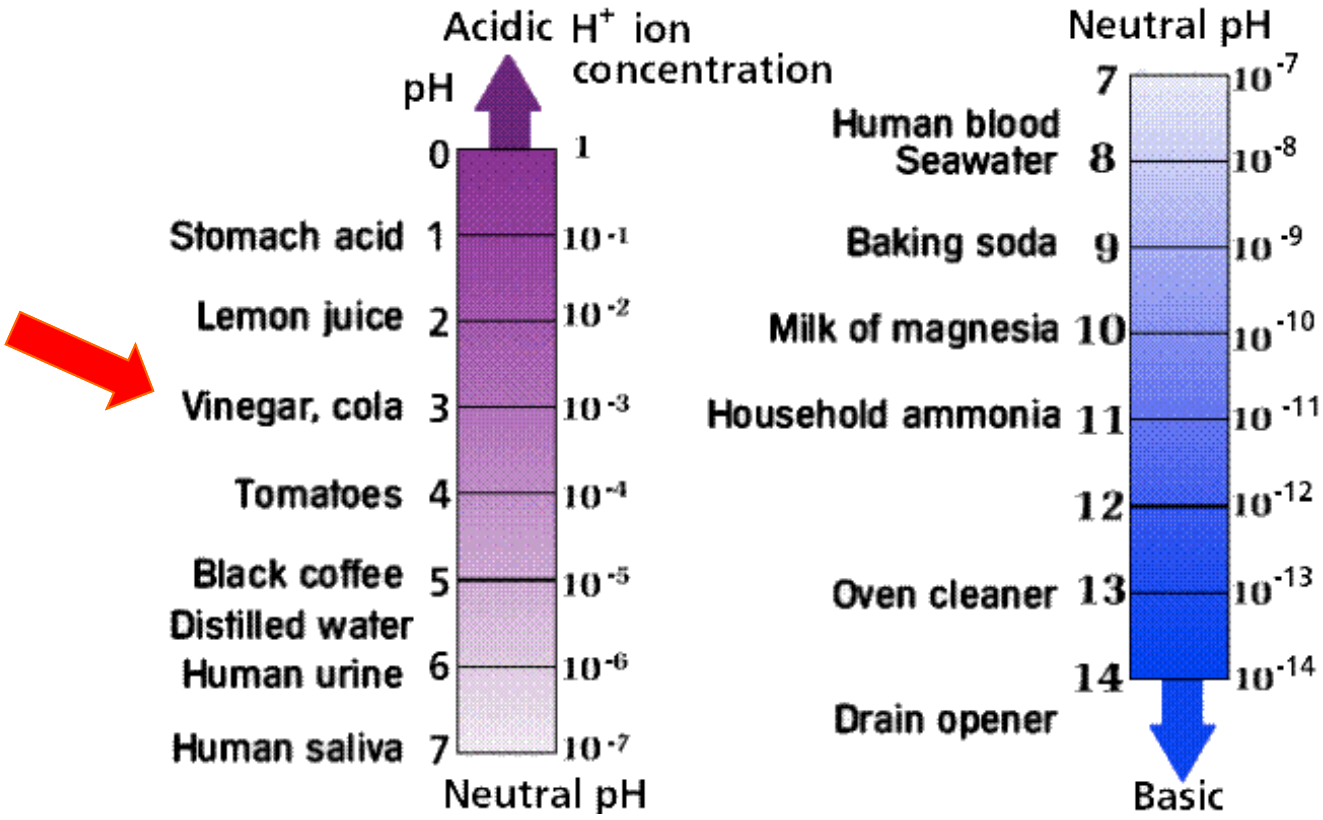
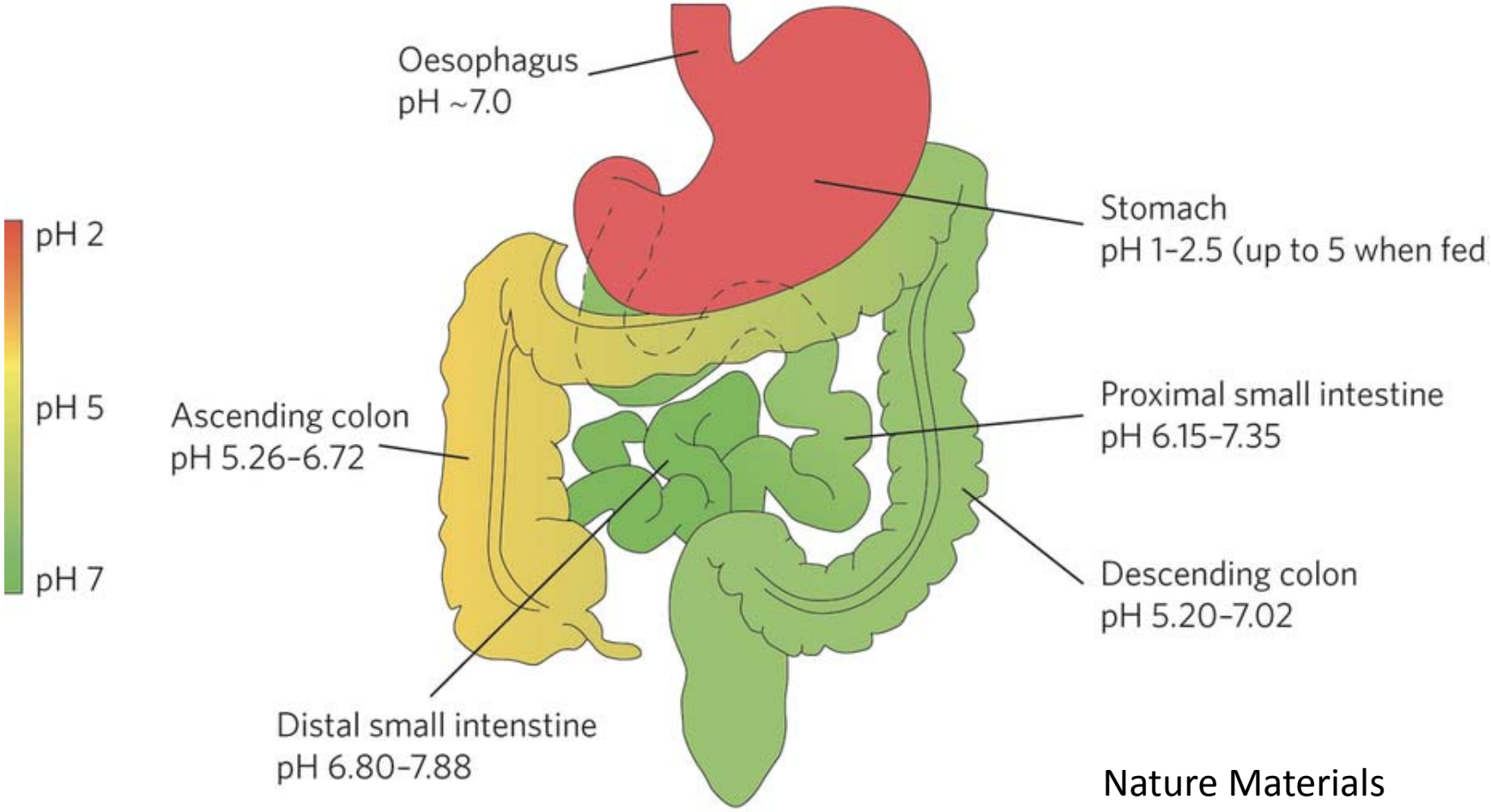
pH range of everyday substances



http://www2.estrellamountain.edu/

pH range of gastrointestial track



Nature Materials

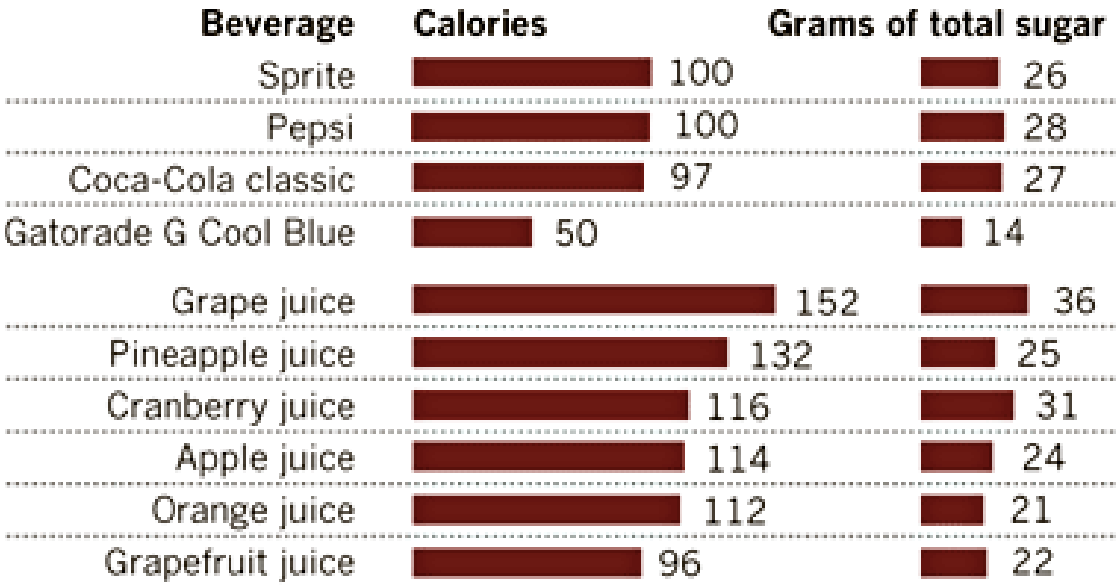
Just for the record: sugar

Fruit juice vs. soft drinks

Juice enjoys the reputation of a health food, but critics say its calorie and sugar content are on a par with soda and other more vilified beverages.

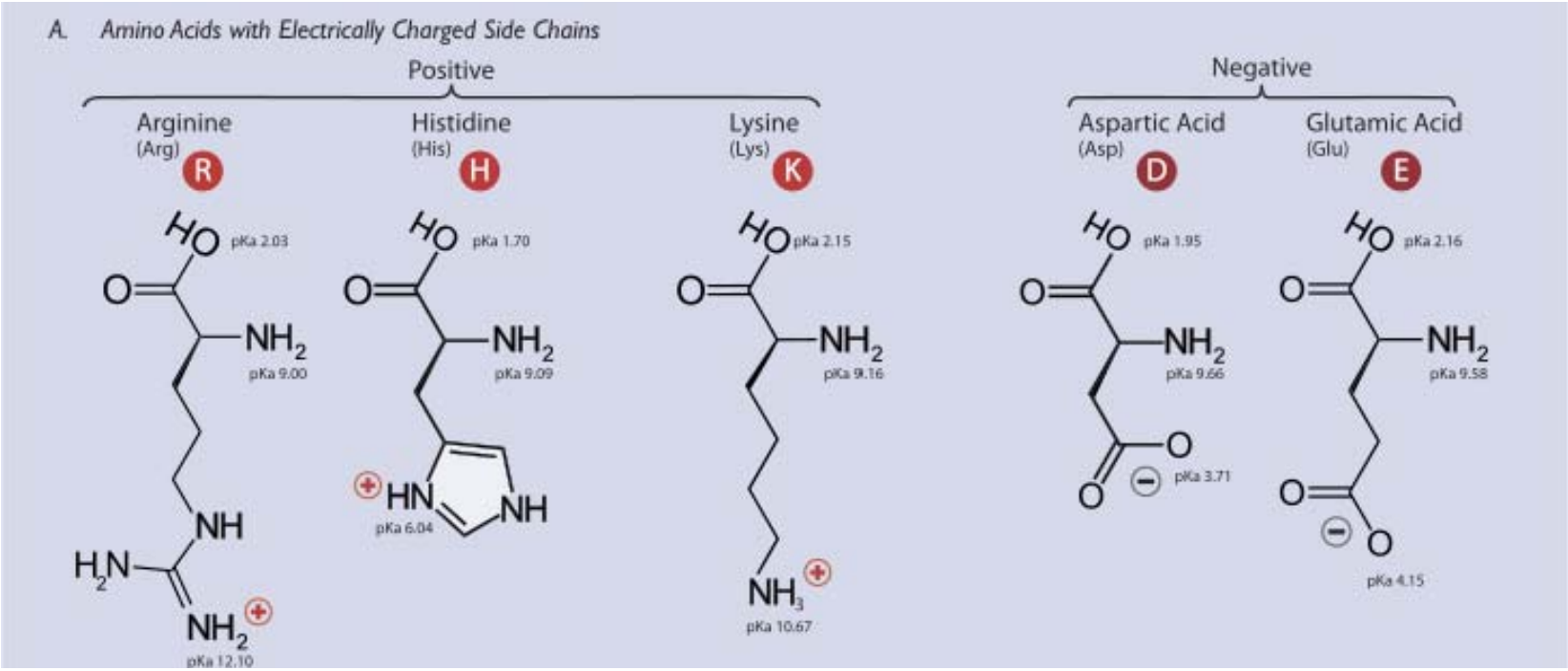
Calorie and sugar counts of selected beverages

(Per 8-ounce serving; all juices are unsweetened)



Sources: U.S. Department of Agriculture Nutrient Data Laboratory; company information
Graphics reporting by KAREN KAPLAN

Can we use this acid-base thing for something?



pKa 12.10 pKa 6.04 pKa 10.67 pKa 3.71 pKa 4.15

- Now we know why enzymes are pH sensitive…
- Also, we can extract amino acids!

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Typical reactions of acid

- Dissolving salts and oxides:

$$CaCO_3 + HCl = CaCl_2 + H_2O + CO_2$$

K matters

$$2FeOOH + 6HCl = 2FeCl_3 + 4H_2O$$

$$2FeOOH + 3H_2ox = Fe_2(ox)_3 + 4H_2O$$

Complex formation!

- Coca Cola dissolving teeth , penny…

Typical reactions of acids

- Dissolving metals

$2HCl + Zn = ZnCl_2 + H_2$

$HCl + Cu = ??$

K doesn't matter
Not even acid-base!

Redox reaction: H^+

$3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4\ H_2O$

Redox reaction: NO_3^-

Oxidizing acids

pH + anion matters

(a) Time = 0 seconds (b) Time = 15 seconds (c) Time = 60 seconds

H_2SO_4, HNO_3..

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Aqua regia (royal water) and similar animals

Redox reaction
Complex formation

$$Au + 3HNO_3 + 4HCl \Leftrightarrow [AuCl_4]^- + 3NO_2 + H^+ + 3H_2O$$

$$Au + HNO_3 + 4HCl \Leftrightarrow [AuCl_4]^- + NO + H^+ + 2H_2O$$

REDOX REACTIONS

Next week…