"TOOTH" INFINITY.... AND BEYOND!

Tooth enamel is a layer (approximately 2mm in depth) of a chemical called hydroxyapatite: Ca10(PO4)6(OH)2 - the hardest substance in the body. (Do you recall the mineral "apatite" from the Moh's Scale of Hardness in Earth Science…?) As you know, your teeth can decay and the chief cause of tooth decay is due to demineralization of the hydroxyapaptite. The demineralization of the enamel is a complex cycle which impinges upon the fields of biology and chemistry, especially acid/base theory. There is good news though. Using acid/base theory and a replacement reaction you can inhibit the process of demineralization.

The demineralization of tooth enamel begins with the presence of one



strain of bacteria that makes plaque as a by-product of its life cycle. Plaque

is a thin sugary adhesive material. A ***second strain*** of bacteria,

*Streptococcus mutans,* lives off of this plaque and produces a weak acid

called lactic acid (C3H6O3 or CH3CH(OH)COOH ). And, this lactic acid

is the real problem. [Buell & Girard, Wilbraham et. al]

Your saliva plays an important role by keeping the plaque at a pH 6.8.

However, when the presence of lactic acid lowers the pH of plaque to 5.5 or

less, the benefit of saliva is lost and the tooth enamel can begin to break

down. [Wilbraham et. al.]

One of the reactions associated with demineralization is:

Ca10(PO4)6(**OH**)2(s) + CH3CH(OH)COO**H**(aq) → 10 Ca+2(aq) + 6 PO4-3(aq) + H2O(l) + CH3CH(OH)COO-1(aq)

**⮱ ⮰**  **⮱** lost by the enamel **⮱**becomes soluble and

(OH)-1 reacts with the "acidic" H+1 dissolves away

creating a soluble salt (demineralization)

Once the enamel is penetrated, dental caries, or cavities, result. The damage can progress to the underlying dentin and pulp, which contains blood vessels and nerves, and can cause a toothache. (Buell & Girard)

You can control the "kinetics" of tooth decay by removing one of the initial reactants, such as the plaque. This is done normally by removing the plaque with a cleaner and an abrasive (toothpaste). The nice thing about toothpaste is that at the same time you can strengthen the enamel. The toothpaste acts as the "cleaner and abrasive" as well as the delivery system for a reactant needed for the strengthening process. (Buell & Girard, Consumer Reports)

Fluoride is that needed reactant. Most toothpastes contain a compound of fluoride (often, NaF) and it is the fluoride ion (F1-) that is important. It's deposition into the tooth enamel strengthens the enamel by converting the hydroxyapatite into fluoroapatite. One of the reactions associated with ***strengthening the enamel*** is:

Ca10(PO4)6(OH)2(aq) + 2 NaF(aq) Ca10(PO4)6F2(s) + 2 Na+1(aq) + 2 OH-1(aq)

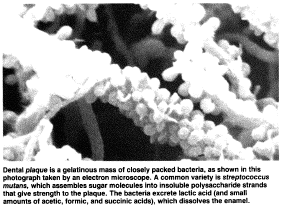
⮱ hydroxyapatite ⮱from ⮱ fluoroapatite

toothpaste

Fluoroapatite is denser and harder than hydroxyapatite. The presence of the fluoride ion even supresses the

ability of  *S. mutans* to generate acid. But, the really important bonus is that fluoroapatite, is **100 times more resistant to the attacts of acids than hydroxyapatite!** (Buell & Girard)

Since most Americans spend fewer than 60 seconds brushing their teeth the challenge for toothpaste manufacturers has been to create "super-efficient / super-fast" fluoride delivery systems. Some toothpastes are better than others at the delivery process. (Consumer Reports)



**As an aside:**

Do you ever experience that bitter taste of orange juice, right after you brushed your teeth? Well, I do…and so does 66% of the U.S. population.. In truth it may be another one of those pesky genetic issues. (DeCristofaro)

First, you must understand the "flavor" is a complex interaction, between taste (sour, bitter, sweet, salty) and smell (the aroma of food) and this interaction is mediated by your brain.

Taste begins with an ion or molecule docking in a receptor on the tongue or palate (kind of like that old lock & key idea for enzymes). The substances that trigger sweet and bitter tastes are usually large, complex organic molecules. It's just the opposite for salty and sour tastes. These are triggered by cations. (DeCristofaro)

Secondly, with respect to the taste of "bitterness", you need to realize that many of us have receptors for bitterness while some do not. These receptors may be controlled by various genes (DNA). If you have two genes for the receptors… you probably have many "bitterness" receptors. With one gene your bitterness receptors are fewer. No genes for this trait and you *might* have a tough time finding any receptors for detecting bitter taste. (DeCristofaro)

Now take a look at toothpaste. Sodium lauryl sulfate is the detergent (soap) found in toothpaste. (Buell & Girard, De Cristofaro) It also **suppresses** some receptors and **sensitizes** other the taste receptors. When you brush your teeth, the sodium lauryl sulfate goes to work on each of us, somewhat differently. One study found that the citric acid (found in orange juice) has its bitterness enhanced by about 10 times due to the sensitizing activity of sodium laurly sulfate! (DeCristofaro)

Thus, it seems to be the sodium lauryl sulfate of toothpaste which enhances a genetic pre-disposition towards detecting bitterness as you drink that morning orange juice.

How can you solve the problem? For one, don't drink orange juice right after brushing your teeth. Give a rest period of 20 minutes to 30 minutes in between the two activities.

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An adaptation of information from:

Buell and Girard. Chemistry: An Environmental Perspective; Prentice Hall 1994 p 82

DeCristofaro. Chemmatters April 1995 p 14

Wilbraham et al. Chemistry; Addison-Wesley 2002 p603

Consumer Reports

NAME \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Graded: An Everyday Chemistry Issue: Chemical Reactions

SCORE: 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

DIRECTIONS: Use the reading and your smarts to complete each of the following questions. The last few do not deal with the reading, but with the last set of lectures.

\_\_\_1) Most commonly, tooth decay is caused by

a) sugar b) lactic acid c) fluoride d) sodium lauryl sulfate

2) Should toothpaste be classified as a substance or a mixutre? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Defend your reasoning: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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3) Is the demineralization of tooth enamel a physical change or a chemical reaction? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Defend your reasoning: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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4) Is the strengthening of enamel by the application of fluoride compounds considered to be a physical change

occurring to the enamel or a chemical reaction occurring to the enamel? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Defend your reasoning: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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5) List one reason as to why many feel fluoroapatite is superior to hydroxyapatite. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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6) Given the pH scale: 0 7 14

ACID RANGE neutral BASE RANGE

Identify saliva's pH and lactic acid's pH

Is lactic acid MORE acidic or Less acidic than saliva?

7) Which ion is associated most closely with what is meant by an acid?

a) O-2 b) Na+1 c) H+1 d) F-1

8) Which describes a neutral solution?

a) The concentration of H1+ is less than the concentration of (OH)1-

b) The concentration of H1+ is equal to the concentration of (OH)1-

c) The concentration of H1+ is greater than the concentration of (OH)1-

d) The concentration of water is equal to the concentration of sodium ion

For questions 9 – 11 use the following diagram of the pH scale and the pH values of various mixtures and substances.

0 1 2 3 4 5 6 **7** 8 9 10 11 12 13 14

Tap water

Baking soda

Egg white

Pure water

DRANO

Orange juice

Black coffee

Vinegar

TUMS

9) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Of the listed substances and mixtures, which is the most acidic?

10) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Which is 100 times more acidic than pure water?

11) \_\_\_\_\_\_\_\_ Egg *yolks* are 100 times **more** acidic than egg whites, but 10 times less acidic than black coffee.

What is the pH of egg yolks?

12) What can TUMS do to excess stomach acid, with a pH of about 2?

a) oxidize it b) neutralize it c) synthesize it d) polymerize it

13) Three of the following are classified as alcohols. Only one is classified as an Arrhenius base. Which of

the following is the Arrhenius base?

a) CH3OH b) C4H9OH c) C2H5OH d) NaOH

14) Which of these compounds has chemical properties most similar to the chemical properties of

acetic acid (ethanoic acid)?

a) C3H7COOH c) C2H5COOC2H5

b) C2H5OH d) C2H5OC2H5

15) Which statement correctly describes a solution with a pH of 9?

a) It has a higher concentration of H+1 than OH-1 and causes litmus to turn blue

b) It has a higher concentration of OH-1 than H+1 and causes litmus to turn blue

c) It has a higher concentration of H+1 than OH-1 and causes methyl orange to turn yellow

d) It has a higher concentration of OH-1 than H+1 and causes methyl orange to turn red

16) Which pH indicates a basic solution?

a) 1 c) 7

b) 5 d) 12

17) Which compound is an Arrhenius base?

a) CH3OH c) LiOH

b) CO2 d) NO2

18) Solution “A” has a pH of 3 and solution “Z” has a pH of 6. How many times greater is the

hydrogen ion (H1+) concentration in solution “A” than the hydrogen ion (H1+) concentration in

solution “Z”?

a) 100 c) 3

b) 2 d) 1,000

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19) Your child comes home and tells you that their coach says that sweating on the field is a good thing.

According to your child; “Coach says that sweating helps to cool me down. I don’t get that”.

Write an explanation you give your child...but make it a solid one using the chemistry you have learned.

Use that jargon. Use those formulae...Use that theory. Your kid is bright...

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READ THIS! For questions 20-21, **more than one answer may be correct**. Using your understanding of chemistry decide which of the responses is (are) correct. Then choose:

1) if only I is correct

2) if only II is correct

3) if only I and II are correct

4) if only II and III are correct

5) if only I, II and III are correct

20) Given the reaction: 2 K(s) + Cl2(g)  2 KCl(s) + 873.6 kJ

The reaction:

I) is exothermic

II) produces a new solid

III) represents a physical change, not a chemical reaction

21) Glucose is dissolved in water according to the equation: C6H12O6(s) + H2O(l) + 15 kJ → C6H12O6(aq)

I) This is a chemical reaction.

II) This is endothermic

III) Old bonds are broken and new bonds are made.