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THE ACID TEST

You are the salt of the earth (Matthew 5:13).

Rick, Josh, and Kelsey slip down the narrow stone stairway and through the heavy wooden door of their grandfather's laboratory unnoticed. Professor Seismo is crouched in front of a small portable blackboard. He has a perplexed look on his face.*

Kelsey: "HI, GAMPA!"

Dr. Seismo jumps up like a man who had just had ice put down his bare back.

Seismo: "Oh, hi, kids. You startled me!"

Josh: "Watcha doin', Grandpa?"

Seismo: "I'm studying acids and bases, and how they might reflect the attributes of our Lord Jesus."

Kelsey: "What are adda-boots?"

Seismo: "An **attribute** is...well...it's like God's personality. For instance, He's STRONG, and SMART, and..."

Kelsey: "And pretty?!"

Seismo: "Ahh, you could say that."

Josh: "What're all those letters and numbers on the blackboard, Grandpa?"

$$HCl + NaOH \longrightarrow NaCl + H_2O$$
$$CO_2 + H_2O \longrightarrow H_2CO_3$$
$$H_2CO_3 + CaO \longrightarrow CaCO_3 + H_2O$$

Seismo: "They're symbols for atoms and molecules, the tiny particles Jesus used to make you, me, and everything in the universe. H stands for hydrogen, O for oxygen, C for carbon, Ca for calcium, Na for sodium, and Cl for chlorine."

*In this fictitious story, Rick is ten, Josh is seven, & Kelsey, four years old. Seismo is pronounced SIZE - mo.

Rick: "What are acids and bases?"

Seismo: "They're chemicals which react in a special way with other chemicals, and they have unique properties. Here's a chart showing the differences between an acid and a base." Professor Seismo pulls a small card from the top pocket of his lab jacket.

ACID	**BASE**
sour	bitter
pH less than 7	pH greater than 7
turns litmus red	turns litmus blue
reacts with metal	slippery
stings	stings
conducts electricity	conducts electricity

"Acids are sour and bases are bitter. Try a piece of this lemon." The professor hands Rick, Josh, and Kelsey each a slice of fresh lemon. Kelsey's face turns red and her lips draw into a pucker as she tastes it.

Kelsey: "Oooo, that's spicy!"

Seismo: "We call that sensation 'sour.' A lemon is sour because it contains **citric acid**, an acid found in all citrus fruit: oranges, grapefruit, limes, lemons. Many acids are edible; that is, you can eat them, but there are some that are quite dangerous!"

Josh: "What other acids are safe to eat?"

Seismo: "Pickles! Pickles are soaked in vinegar, which is actually **acetic acid**. Carbonated drinks, like pop, have **carbonic acid**, and green peppers contain a lot of vitamin

Lemon (acid)

C or **ascorbic acid**."
Rick: "What are some of the dangerous acids, Grandpa Hans?"
Seismo: "**Hydrochloric acid**, **sulfuric acid**, and **nitric acid**, to name a few. You should NEVER taste an acid or a base that you don't know is safe!"
Kelsey: "Like in baseball?"
Seismo smiles and then gently explains.
Seismo: "Well, sweetheart, that kind of base is different than the bases we're talking about. **Bases** are chemicals that are slippery...ah, soap and detergents are bases. That stinky stuff that Mommy uses to clean the bathroom is called **ammonia**, and it's a base. Baking soda* is a base, and so is Milk of Magnesia, which is actually **magnesium hydroxide**. All these things can be found around your home."
Rick: "Are acids and bases found outside in nature?"
Seismo: "Yes! Volcanoes produce hydrochloric and sulfuric acids. Nitric acid is formed when lightning passes through the atmosphere and reacts with nitrogen in the air. Lye is **sodium hydroxide**, a very powerful base—it can burn your skin and eyes!"
Josh: "If some acids and bases are so dangerous, how come God made 'em?"
Seismo: "I believe that God reflects His holy character in strong acids and bases. We mustn't trifle with either—His holiness or the things that display His holiness!

"Acids and bases also demonstrate how He provides for us. We can make lots of things with them."
Josh: "Like what?"
Seismo: "Well, sulfuric acid is the most common chemical found in industry! It is used to refine petroleum and gasoline, produce fertilizers and plastics, make dyes and other chemicals. Car batteries contain sulfuric acid. Dynamite is made from nitric acid, as is nitroglycerin. And our stomachs secrete hydrochloric acid—it helps us digest the food we eat."

Looking down at the chart Hans Seismo had previously handed his grandchildren, Rick queries, "What is pH, Grandpa Hans?"
Seismo: "The **pH** is a measure of how strong an acid or a base is. The pH scale goes from 0 to 14—here, let me show you." Professor Seismo strides back to the chalkboard and draws a scale of pH so the kids might understand what he's talking about. "Water is neutral—it is neither an acid nor a base. It has a pH of 7. Milk is weakly acidic and has a pH of about 6-1/2; coffee is pH 5.

pH scale

strong acid	0	sulfuric acid
	1	stomach acid
	2	soft drinks, lemons
	3	vinegar
	4	tomatoes
weak acid	5	coffee
	6	milk
neutral	7	tap water, blood
	8	sea water
weak base	9	baking soda
	10	Milk of Magnesia
	11	ammonia
	12	garden lime
	13	drain cleaner
strong base	14	sodium hydroxide

The stronger the acid, the closer and closer its pH approaches zero. The acid in your stomach is fairly powerful; it has a pH between 1 and 2. Laboratory-grade sulfuric and hydrochloric acids have a pH of 0—they're strong!

"Bases, on the other hand, are chemicals whose pH is greater than 7; the closer they are to pH 14, the stronger they are. Our blood has a pH of approximately 7-1/2, baking soda about 8-1/2, and ammonia, 11-1/2. Concentrated sodium hydroxide (lye) has a pH of 14. By

FOR THE EXTRA CURIOUS
DEFINITIONS OF ACIDS/BASES

Acids and bases can be defined in a number of ways. The most widely accepted definition was developed by a Danish chemist named Johannes Brönsted and an English chemist, Thomas Lowry, in 1923. The Brönsted-Lowry model of acids and bases states that acids are substances that donate, or give up, **protons** in solutions like water, while bases are chemicals that accept protons. An alternate definition was described by Sweden's Svante Arrhenius in 1880. He recognized that acids release hydrogen ions (H^+), or protons, in water; bases release hydroxyl ions (OH^-). A third theory of acids/bases came from American G.N. Lewis. He proposed that acids are electron acceptors and that bases are electron donors (the complementary view of the Brönsted-Lowry model).

2 Traditional Japanese origami permits the cutting as well as folding of paper.
3 Orogenesis is Greek for "mountain formation" (oros + genesis).

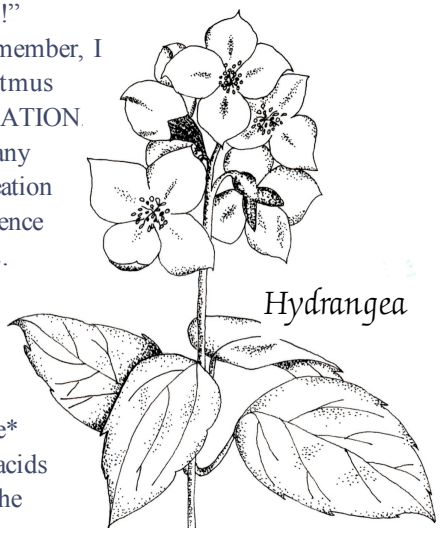
the way, drain cleaners and oven cleaners contain sodium hydroxide. They are dangerous and should be handled by an adult!

"The pH scale is constructed in a way that every time we move up or down the scale by one number, the concentration of the acid or base changes by a factor of ten." The kids look very confused, and give Dr. Seismo some of their famous blank stares. "Umm…tomatoes, with a pH of 4, are ten times more acidic than coffee, with a pH of 5. Soft drinks have a pH about 3 and are thus ten times ten, or one hundred times more acidic than black coffee. Household ammonia with a pH of 11-1/2, on the other hand, is ten times stronger as a base than Milk of Magnesia, pH of 10-1/2.

"We can test whether something is an acid or a base using **litmus** paper. Litmus paper contains chemicals obtained from **lichen**, and these chemicals are very sensitive to pH. Red litmus paper will turn blue if dipped in a base, and blue litmus paper will turn red if dipped in an acid. Oh my, now where did I put those samples of litmus paper? I can't seem to find them!" Professor Seismo hurriedly rifles through a mountain of loose papers strewn over one part of the lab floor. The children watch, wondering all the while how anyone could have SO MUCH PAPER!

Rick: "That's OK, Grandpa Hans, I'm sure you've got better things to do!"

Seismo: "Oh, I remember, I sent samples of litmus paper to HIS CREATION. Well, anyway, many things in God's creation can detect the presence of acids and bases. Hydrangea flowers (Hydrangea sp.) turn blue in acidic soil, but are pink in basic or alkaline* soil. In this way, acids and bases radiate the beauty of Christ!"



Seismo: "When a molecule of acid or base is mixed with water, it breaks apart into **ions**, that is, pieces with positive or negative charge. Hydrochloric acid (HCl) mixed with water forms hydrogen ions (H^+) and chloride ions (Cl^-)." The professor quickly scribbles on the board.

*The term "alkali" is synonymous with the term "base."

FOR THE EXTRA CURIOUS—pH

pH is a measure of the hydrogen ion (proton) concentration in a solution. pH is an abbreviation for the French term, **puissance d'hydrogene**, which translated, means, "the power of hydrogen," though it might be better to call it "the power of God!" The pH of an acid or a base can be determined from the following formula:

$$pH = -\log [H+]$$

pH is found by taking the logarithm* of the hydrogen ion concentration [H+] and then multiplying by negative one (-1).

$$HCl \longrightarrow H^+ + Cl^-$$

"As we know, H is the symbol for hydrogen, and Cl the symbol for the chlorine atom. A strong acid or base is a chemical that splits apart completely in water. In other words, all of the molecules break up to form ions. When hydrochloric acid is placed in water, all of it breaks apart to form hydrogen and chloride ions; there are practically no HCl molecules left! Carbonic acid, a much weaker acid, loses only a few of its hydrogen ions."

$$H_2CO_3 \text{ (carbonic acid)} \longrightarrow H^+ + HCO_3^-$$

"So when we add carbonic acid to water, most of it remains H_2CO_3. The pH of hydrochloric acid is therefore much lower than that of carbonic acid because hydrochloric acid produces many more hydrogen ions (H^+)."

Rick: "What happens if we mix an acid with a base?"

Seismo: "We get **salt**!" With excitement, Professor Seismo again erases the blackboard and starts to write. Chalk dust seems to fly in all directions! "When you first snuck into the lab, I had this formula written down:

$$\underset{\text{acid}}{HCl} + \underset{\text{base}}{NaOH} \longrightarrow \underset{\text{salt}}{NaCl} + \underset{\text{water}}{H_2O}$$

"HCl is hydrochloric acid, and NaOH stands for sodium hydroxide, a strong base. If we were to mix them together, we would get table salt (which is NaCl or sodium chloride), and water. It's very interesting that we can combine a dangerous acid with a dangerous base and

*The log of a number can be obtained from a logarithm table found in a math book.

get the same salt Grandma uses for cooking! This is called a **neutralization reaction**; the acid and base **neutralize** each other. This is also why ordinary soap can damage your hair; your hair is acidic and, as we said, soap is a base. Soap neutralizes your hair and changes its structure."*

Seismo: "Salts remind us that God is our Great Provider! Jesus employs many different kinds of salt in order to provide plants, animals, and people with essential minerals. He also uses salts in combination with acids and bases to show us His compassion. Most living things need a fairly **neutral and stable pH** in order to survive. Our blood, for instance, is a very mild base. If the pH of our blood changes even a little, we could become sick and die. Fish are also sensitive to the different pH levels of the water in which they live. Most lakes and rivers have a pH between 5 and 6, while ocean water has a pH around 8. If these pH values change much, the fish living there will perish. The mystery is that our Lord placed His creatures, including us, in a world full of acids and bases!"

Rick: "So how does He prevent the pH of our blood and the pH of lakes from changing?"

Seismo: "Buffers!"

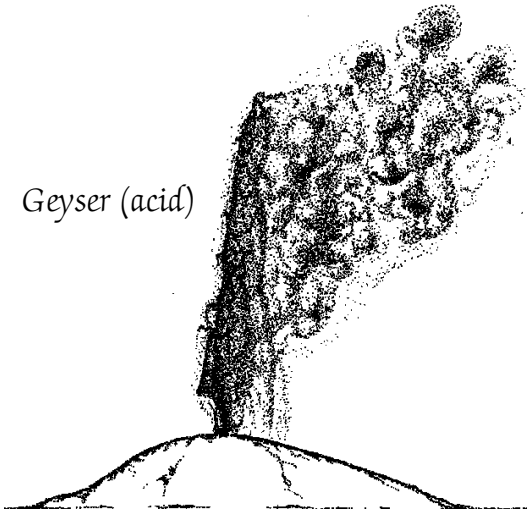
Kelsey: "Buffys?" Seismo gives his granddaughter another kind smile.

Seismo: "No, sweetheart, buffers. **Buffers** are a group of chemicals that God adds to our blood, sea water, lakes and streams, to protect them from foreign acids and bases that might change their pH."

Josh: "Where'd the acids and bases come from, Grandpa?"

Seismo: "From the food we eat; and sometimes, as in the case of Yellowstone National Park, they come from the ground. The hot springs and geysers there have pH values as low as 2! The acidic water from these geothermal formations* eventually spills over into nearby creeks and streams located in the park. That's why it's important for these waterways to have a healthy 'buffering' capacity—to neutralize the incoming acids!"

Kelsey: "Ohhh!" Kelsey pretends to understand.



Seismo: "In the eastern United States and Canada, as well as in Europe, there is something called '**acid rain**.' Now, 'acid rain' is a misnomer because most rain is slightly acidic, with a pH value of 6. Cars, trucks, and factories in industrialized nations release chemicals into the atmosphere that become sulfuric and nitric acid, and add to the acidity of rain. In some areas, rain can have a pH as low as 3—which means it is 1,000 times more acidic than normal rain water! If this rain falls into lakes or streams with sufficient buffers, there won't be a

FOR THE EXTRA CURIOUS—SALT

There are many different kinds of salts—NaCl (table salt) is only one type. **Calcium carbonate** ($CaCO_3$) is the salt from which seashells are created. **Ammonium carbonate**, known as "smelling salts," is a chemical doctors place under the nose of patients in order to revive them after fainting. And **sodium nitrite** is used to preserve meat, like bacon. If the acid used to form a particular salt is sulfuric acid, then the salt is known as a **sulfate**; if nitric acid, then the salt is called a **nitrate**; and if hydrochloric acid is involved, the salt is known as a **chloride**. Salts frequently have a pH of 7, and are thus neutral, because the acid and base that formed them cancel each other out. Many salts are acidic or basic, however, depending on what acids and bases were used to create them. If a **strong acid**, for instance, is mixed with a **weak base**, the resulting salt will be acidic. Conversely, a **strong base** plus with a **weak acid** will produce a salt with the properties of a base. Salts also radiate the rare beauty of Christ! It is the salt **chromium oxide** that gives emeralds their striking green color, and rubies their beautiful red hue.

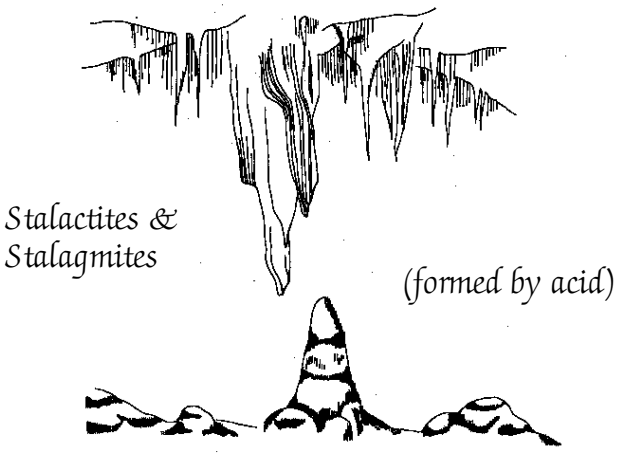
*Please see the September/October 1994 issue of ***CREATOR***.

problem. Some bodies of water, however, have very little buffering capacity and are easily overwhelmed by 'acid rain.' If the pH of the water goes below 4, most fish will die—this obviously becomes a serious problem for people relying on fishing as a living, and for wildlife. 'Acid rain' has also been known to affect plants, buildings, and statues." Professor Seismo takes a deep breath and then lets it out slowly as a big sigh.

FOR THE EXTRA CURIOUS—BUFFERS

Buffers are a mixture of a **weak acid or base** and its corresponding **salt**. The buffer that protects lakes and oceans from wide fluctuations in pH is the carbonic acid/calcium bicarbonate/calcium carbonate system—carbonic acid (H_2CO_3) and its salts, calcium bicarbonate ($Ca(HCO_3)_2$) and calcium carbonate ($CaCO_3$). Lakes are mildly acidic because there is more acid than salt as a part of the buffering mechanism. Sea water is in contact with much calcium carbonate and thus tends to have a pH which is mildly basic. Both ecosystems demonstrate Christ's compassion and the ingenious way He protects His creations! Human blood needs to have an extremely stable pH and that's why God installed no less than **three** separate buffering systems in our blood -stream! Isn't God's love incredible?!

Seismo: "Acids and bases can be destructive, but as we saw before, they are also a source of great beauty. Acid in rain water percolates through areas of the world where limestone is abundant, dissolving some of the calcium carbonate in the limestone as it passes through the ground. If this calcium-rich water reaches an underground cave, the calcium carbonate often deposits itself in the form of fascinating **stalactites** and **stalagmites**. Here we have Christ's beauty displayed as a hidden treasure deep in the earth!"
Kelsey: "What else can acids and bases do, Gampa?"
Seismo: "Acids react with metals, such as iron or zinc, to produce hydrogen gas. Acids also eat away at metal. Come over here kids." Dr. Seismo leads the three children to his cluttered desk. On top of a pile of papers sits a two-week-old, partially-eaten portion of lasagna in an aluminum dish.



Josh: "Eewww, Grandpa, that looks gross!"

Seismo: "I know! Grandma Seismo didn't appreciate that I let her delicious lasagna go bad, but I'm performing an experiment."
Josh: "An experiment on lasagna?"
Seismo: "Well, actually, an experiment on the aluminum pan under the lasagna." Seismo uses a credit card to carefully scrape away some of the lasagna from the bottom of the dish. (Seismo doesn't much care for credit cards and hadn't used this one in a long time anyway.) "Do you see the discoloration of the aluminum?" All the children peer into the pan with great interest.
Kelsey: "Ya, Gampa, I see it!"
Seismo: "The tomato sauce in the lasagna has a pH of about 4, and is thus fairly acidic. The tomato acid has literally eaten away at the aluminum, changing its appearance."
Rick: "Kinda like Mom's cooking!"
Seismo: "Uh-hmm!" Seismo gives Rick a stern look and Rick's manner becomes sheepish. "Acids and bases can also sting if you accidentally get them on a cut in the skin."
Rick: "Yeah, I've got a cut on my finger and it really stung when I touched the lemon you gave me!"
Seismo: "That's also the reason bee and wasp stings hurt! The chemical in a bee sting is an acid, and the substance of a wasp sting is a base.* Both produce a burning sensation."
Josh: "I'll say! I was stung by a Yellow Jacket this summer and it smarted. Mom put some baking soda on it to make the pain go away."
Seismo: "Did it?"

*The sting of an ant also burns. Many ants inject **formic acid** into their victims.

Wasp sting (base)

Josh: "Well, not exactly."
Seismo: "Remember, baking soda is a base. A Yellow Jacket is a wasp and its sting is basic. So applying baking soda, a base, to a wasp sting won't neutralize the poison, only make it worse! If Mom uses vinegar on a wasp sting, the acetic acid of the vinegar will help neutralize the chemical base injected by the wasp and make it feel better. Baking soda is used on bee stings, because bee stings are acidic. Josh, I'll talk with your mom about it."
Rick: "Please don't say anything about her cooking!" Seismo smiles.

FOR THE EXTRA CURIOUS
CHRIST'S ATTRIBUTES

We have seen that acids and bases mirror Christ's holiness, power, beauty, provision, and compassion! And they show us that He is truly a remarkable God! In a way, we might say that ALL of God's attributes are reflected in acids and bases. Often, people describe acids as being opposite of bases. In reality, however, acids and bases exist as a **spectrum** of chemicals ranging in pH from 0 to 14. Unfortunately, people sometimes characterize God's holiness or His justice or His wrath in the same way—as being opposite of His tenderness, kindness, and love. Many individuals and churches cannot understand how God can be both loving and just at the same time. "How can He send someone to hell, and allow others into heaven?" people ask. Christ's attributes, like acids and bases, cannot be viewed as opposites, as either/or. Like the sting of a bee or a wasp, Christ's holiness will burn all those who reject Him. Yet, His is also a holy love and He saves sinners from eternal torment. God calls us to believe in His Son, Jesus Christ—who died on a cross for the sins of His people.

God must punish sin (Romans 6:23)—there is no way around it. The question then becomes, "Do *we* want to take on that punishment or let Jesus endure the wrath of His Father?" There are no other options! If we believe in Jesus, He becomes our infinite and glorious Buffer, neutralizing and eliminating our sins forever. And we become the repository of His divine attributes—that is, we can reflect His character in a finite way here on earth and in heaven. Maybe this is why Jesus said that those who believe in Him become the **salt of the earth** (Matthew 5:13)! Like an acid mixed with a base, He places His wonderful character in our lives that we may receive ALL the fruit of His Holy Spirit (Galatians 5:22-23), not just a part. It then becomes our job, through His Spirit, to display these fruits in our lives and be the "salt" He wants us to be. This is the "acid test!"

"Oh, Father in Heaven, I confess that I have lived my life in rebellion against You, and that this is foul sin before You. Please wash me clean by the blood of Your Son, Jesus, and forgive me because of His death on the cross—not because of anything I have done. King Jesus, please come into my heart right now. I embrace You as my all-powerful God, my sweet Savior, and my Eternal Life. Show me how to live the way You want me to live, so that I might express a wonderful aroma of worship before You for all eternity! In Your name, Lord Jesus Christ, I pray. Amen." ❑

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