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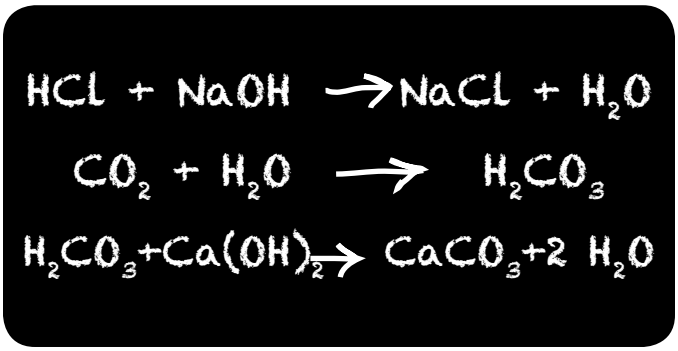
# The Acid Test

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

Rick, Josh, and Kelsey creep unnoticed down the narrow stone stairway and through the heavy wooden door leading to their grandfather's laboratory. Professor Hans Seismo is crouched in front of a small portable blackboard. He is deep in thought.[1]




**Kelsey:** "HI, GAMPA!"
Dr. Seismo jumps up like a man who just had ice water poured down his back.
**Seismo:** "Oh, hi kids. You startled me!"
**Josh:** "Watcha doin', Grandpa?"
**Seismo:** "I'm studying acids and bases, and how they reflect the attributes of our wonderful Lord Jesus."
**Kelsey:** "What are adda-boots?"
**Seismo:** "An *attribute* is . . . well . . . it tells us something about God's character. For instance, He's *strong*, and *wise*, and . . . ."
**Kelsey:** "And bootiful?"
**Seismo:** "Yes, Kelsey, He is more lovely than anyone or anything you've ever seen!"
**Josh:** "What're all those letters and numbers on the blackboard, Grandpa?"
**Seismo:** "They're symbols for atoms and molecules, the super-tiny pieces of matter Jesus skillfully uses 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."
**Rick:** "What are acids and bases?"
**Seismo:** "They're chemicals that react in a special way with other chemicals and materials, 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.

*Lemons contain citric acid.*

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

| 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 each child a slice of fresh lemon that he cut earlier in the morning. 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 or soda, contain carbonic acid, and green peppers have a lot of vitamin C, which is 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 'safe 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 Mommy uses to clean the bathroom, called ammonia, is a base. Baking soda[2] 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 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."[3]

### 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 the American, G.N. Lewis. In 1923, he proposed that acids are electron acceptors and that bases are electron donors (the complementary view of the Brönsted-Lowry model).

**Josh:** "If some acids and bases are so dangerous, how come Jesus made 'em?"
**Seismo:** "They help us understand that *God is holy* and that we must not trifle with Him."
**Josh:** "What does *trifle* mean?"
**Seismo:** "Not taking someone or something seriously—like carelessly handling a powerful acid with our bare hands. Many people handle God's Word in the same way. Yet, we must give great care to our Lord's commands, seeking to obey them all with love, fear, and trembling. This is how we show proper respect to God. Jesus is very kind to reveal the importance of these things. Acids and bases also demonstrate how He daily helps us. We can do lots of things with them."
**Josh:** "Like what, Grandpa?"
**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 in the form of 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 to 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 can see what he's talking about.


**Seismo:** "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 6½; coffee is pH 5. 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 really strong!

"Bases, on the other hand, are chemicals whose pH is greater than 7. The closer they come to pH 14, the stronger they are. Our blood has a pH of approximately 7½, baking soda about 8½, and ammonia 11½. Concentrated sodium hydroxide, or lye, has a pH of 14. By the way, drain cleaners and oven cleaners contain sodium hydroxide. They are dangerous and should only be handled by an adult!

"The pH scale is constructed in such 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 one 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 11½, on the other hand, is ten times stronger as a base than Milk of Magnesia, with a pH of 10½.

"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

2 Baking soda is sodium bicarbonate ($NaHCO_3$).

3 In the past, lye was obtained from wood ash.

have so much paper!
**Rick:** "That's OK, Grandpa Hans, I'm sure you've got better things to do."
**Seismo:** "Oh, I remember, here they are. 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.[4] In this way, these flowers radiate the beauty of Christ, their color determined by the pH He providentially makes the soil."


**Rick:** "That's the opposite of litmus paper."
**Seismo:** "Yes, it is Rick, great observation!"


*Hydrangea*

**Seismo:** "The pH of a substance depends on how much it breaks apart in water. In water, an acid or a base forms *ions*—that is, tiny pieces of matter with either a positive or negative charge."
**Rick:** "Boy, Grandpa Hans, this is really hard to understand."
**Seismo:** "Yes, Rick, it is. But what it reveals about our amazing Creator *is worth all the effort* we make to comprehend it! Hebrews 1:10 says that everything in the universe—including acids and bases—are the works of Christ's hands. Shouldn't we be eager to study deeply all that Jesus has created so that we can know Him better?

"Hydrochloric acid (HCl) mixed with water forms positive hydrogen ions ($H^+$) and negative chloride ions ($Cl^-$)." The professor quickly scribbles on the board.

$$HCl\ (\text{hydrochloric acid}) \rightarrow \underset{\text{(ions)}}{H^+ + Cl^-}$$

"If you remember, 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 in water. In other words, almost all of the molecules break up to form ions. When hydrochloric acid is placed in water, virtually all of it breaks apart to form hydrogen and chloride ions; there are practically no HCl molecules left.

"Carbonic acid is much weaker and loses only a few of its hydrogen ions."

$$H_2CO_3\ (\text{carbonic acid}) \rightarrow \underset{\text{(ions)}}{H^+ + HCO_3^-}$$

"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+)."

### 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'hydrogène, 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 (log)[5] of the hydrogen ion concentration $[H^+]$ and then multiplying by negative one (-1).

4 The term "alkaline" is synonymous with the term "basic."

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



**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:"

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

"Acids and bases neutralize each other, changing their molecular structure. If we were to mix together hydrochloric acid (HCl) and sodium hydroxide (NaOH), we get table salt (NaCl or sodium chloride) and water. It's fascinating to me that a dangerous acid can be combined with a dangerous base and we get the same salt Grandma uses to season food. Earlier, we talked about how God should be feared, for He does make many great and perilous things. But this now reveals that *He is as good as He is great*. Through the formation of salt, God is able to alter dangerous chemicals in nature to provide much-needed minerals in our diet. Salts remind us that God is our great Provider! Jesus employs many different kinds of salt in order to supply plants, animals, and people with essential minerals.

"The ability of acids and bases to neutralize each other is also why ordinary soap can damage your hair. Your hair is acidic and, as we said, soap is a base. Soap will neutralize your hair and, in so doing, change its God-given structure and appearance. That's why we use shampoo instead; it is pH neutral."[6]

6 Sodium hydroxide (NaOH), a powerful base contained in drain cleaner, is effective at breaking up hair (an acid) that is clogging a sink.

### 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 that 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 usually have a pH of 7, and are thus neutral, because the acid and base that formed them cancel each other out. Some salts can be somewhat 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 a weak acid will produce a salt with the properties of a base. Salts can also radiate the incomparable beauty of Christ. It is the salt, chromium oxide, that gives emeralds their striking green color, and rubies their beautiful red hue.


*Ruby*

**Seismo:** "God also uses salts in combination with acids and bases to reveal *His compassion* to us. Most living things need a fairly neutral or stable pH in order to survive. Our blood, for instance, is a very mild base. If the pH of our blood were to change, even a little, we could become sick and die. Fish are also very sensitive to the different pH levels of

the water in which they live. Most lakes and rivers have a pH that hovers between 5 and 6, while ocean water has a pH around 8. If these pH values were to change much, the fish living there would perish. By placing His creatures in a world full of acids and bases we begin to realize how utterly important Christ's continual care is!"

**Rick:** "So how does He prevent the pH of lakes from changing?"

**Seismo:** "Buffers!"

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

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

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

**Seismo:** "Oh, they come from lots of places. In Yellowstone National Park, acids percolate up through the ground. Hot springs and geysers there have a pH 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 healthy buffering systems—to neutralize the incoming acids.

"In the case of our bloodstream, we daily introduce all kinds of acids and bases into our body through the food we eat, like tomatoes. But we don't have to worry, because Jesus has put three different buffers into our bloodstream to prevent the pH from changing."

*Geyser*

### FOR THE EXTRA CURIOUS—BUFFERS

Buffers are a mixture of a weak acid or base and its corresponding salt. By itself, a weak acid or base does little to protect a body of water or our bloodstream—it must be united to a 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 more calcium carbonate (the chemical that shells are made from) and thus tends to have a pH that 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 bloodstream. Isn't God's care incredible?!

**Kelsey:** "Ohhh!" Wide-eyed, Kelsey pretends to understand.

**Seismo:** "In the eastern United States and Canada, eastern Europe, and southeastern China and Taiwan there is something called 'acid rain.'[7] Now, the term *acid rain* is a misnomer because rain is normally acidic, with a pH value of 6. Cars, trucks, and factories in industrialized nations, however, 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—that's 1,000 times more acidic than normal rain water.

7 Acid rain occurs elsewhere in the world, but these are the regions most affected.



"If this rain falls into lakes or streams with sufficient buffers, there won't be a 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 lake fish will die—this obviously becomes a serious problem for people relying on fishing as a living, and for wildlife. Acidic 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.

**Seismo:** "Acids and bases can be destructive, but 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."

*Stalactites & Stalagmites (formed by acid)*

**Kelsey:** "What else can acids and bases do, Gampa?"

**Seismo:** "Well, acids react with metal, such as iron or zinc, to produce hydrogen gas; at the same time, they eat away at the 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 pan.

**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. (He doesn't much care for credit cards and hasn't used this one in a long time.)

"Do you see the discoloration of the aluminum? It's much darker and less shiny than normal?" All the children peer into the pan with great interest.

**Kelsey:** "Yeah, 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. Acids and bases can also sting if you accidentally get them in a cut on your 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 one of the reasons bee stings hurt. The chemical in a bee sting is acidic, and it causes a burning sensation. The sting of an ant also burns because many ants inject *formic acid* into their victims."

**Josh:** "Grandpa, all this talk about food has made me hungry."

**Seismo:** "Me too, Josh. Say, I saw Grandma picking some fresh tomatoes this morning. Let's go have some with lunch!"

**Rick:** "Okay, but can we please do more experiments with acids and bases after lunch?"

*You can find the experiments Professor Seismo did with his grandchildren on the back side of kids' kreation #95.*

# The Salt of the Earth

We have seen that acids and bases reveal the attributes of Christ's holiness, greatness, power, beauty, goodness, wisdom, provision, kindness, and compassion—all to the glory of His Heavenly Father. We have also discovered that weak acids and bases, by themselves, are ineffective in preventing the pH of our blood, or the pH of a river, from fluctuating wildly. But unite them to their corresponding salt and they become powerful buffers.

*People are like these weak acids and bases;* on our own, *we are unable to overcome the trials of life.* If we are united to our Creator, however, our lives become a powerful "buffer" in the midst of this dangerous world. Christ then is the *Salt of Life* and the power of God's truth working in us. So, if we are united to Jesus, who is Truth (John 14:6), we are made strong. If we attempt to live life apart from the gracious wisdom and power of God in Christ Jesus (1 Corinthians 1:24), we will be unable to withstand the evil of this world and, more importantly, the coming wrath of God. As sinners, we are not holy in ourselves and are thus unfit for Heaven. But if we receive Christ and are found in Him—*the Salt of our salvation*—His saving power will be made perfect in our weakness (2 Corinthians 12:9). The all-important question then becomes: "Are we increasing in the sweet knowledge and the indefatigable power of Christ?" If so, then we are becoming more and more like our Master, and are as salt in a dying world (Matthew 5:13). Any attempt at living life on our own, without Christ's strength and the truth of His Word, causes us to lose our saltiness and our effectiveness for His kingdom.

Our lives are often flooded with sour and bitter trials (Acts 14:22). God uses trials to test us, much like the 19th century chemist used strong acids to test the value or worth of a metal. In chemistry, this is known as the "acid test." Acids could be used, for instance, to see if the metal in question was pure gold or a counterfeit.

By testing us, God proves the value of our faith (James 1:2-3 NIV) and reveals whether or not we are truly joined to Christ. If we are in Christ, there is joy in the midst of our difficulties because His wonderful character always shines before us (Hebrews 12:2).

If you are not united to Christ, then we beg you to repent of your sins and believe that Jesus died on a cross for those sins, and rose from the dead to give you the free offer of eternal life in Himself. If you do know Christ, then please allow us to encourage you to press on to know Him better (Hosea 6:3), see His glory all around you (Isaiah 6:3), and become more like Him (2 Corinthians 5:17)!

*"My grace is sufficient for you, for My power is made perfect in weakness" (2 Corinthians 12:9).*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