

so on. The water itself weighs 964.80 g, and if one were to evaporate the water from one kilogram of seawater there would be a pile of powder left over that would weigh 35.169 g. (Note: the reason there is still a small amount not accounted for in this example is that all the other ions in seawater weigh 0.031 grams).

No single salinity or specific gravity value is definitively correct for a marine aquarium. Instead, one should strive to maintain the salinity within a range of 27 to 33‰. However, one area where it is important to worry about the measuring concept is when comparing sea salts and trying to determine which is most economical to purchase. Two factors come into play when comparing sea salts (we're talking only about the amount of seawater made, not about the chemical makeup of the sea salts, which will be covered in a later episode). The factors are the total number of gallons one can make and the salinity of the final product. For years, a bag of sea salt for making 50 gallons of seawater contained 16 pounds of sea salt; this was the de facto standard. In the early 1990s, however, some manufacturers began to reduce the amount of salt in the bags—first to 15 pounds, then to 14, yet they still claimed the bag contained enough salt to make 50 gallons of water. How is this possible? It is possible because the salinity of the final product would be different. The salinity obviously will be less when only 14 pounds of salt are dissolved in 50 gallons of water, compared to 15 or 16 pounds.

Whether you maintain your marine aquarium at 27 or 33‰, therefore, you will get more salt water if you watch the bag labels and purchase by weight, and consider the reputation of the manufacturer and their devotion to quality control. The standard Instant Ocean 15-pound bag will produce 50 gallons of synthetic seawater with a salinity of about 30‰ or a specific gravity of 1.022 at a water temperature of 75°F (23.9°C).

Table 1. Mean Concentration of the Major Ions or Constituents of Natural Seawater and Instant Ocean® Synthetic Sea Salt

Ion	Natural Seawater	Instant Ocean
Sodium (Na ⁺)	10.781	10.780
Potassium (K ⁺)	0.399	0.420
Magnesium (Mg ⁺⁺)	1.284	1.320
Calcium (Ca ⁺⁺)	0.4119	.400
Strontium (Sr ⁺⁺)	0.00794	.0088
Chloride (Cl ⁻)	19.353	19.290
Sulfate (SO ₄ ⁻)	2.712	2.660
Bicarbonate (HCO ₃ ⁻)	0.126	.200
Bromide (Br)	0.0673	.056
Boric Acid (B(OH) ₃)	0.0257	—
Fluoride (F)	0.00130	.001



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Advancing the Hobby of the Marine Aquarist

What Does That Number Really Mean? Aquarium Water Testing Methods, Results and Interpretation.

by Mary Orr, MSc Biology, Researcher and Hobbyist

It is easy to assume that the results you obtain from an aquarium-water test kit are the answer to the question, “What is the level of this substance in my tank?” The value you get when you conduct any test is, however, almost never the true level. That is because all measurements are subject to some degree of error. Many variables influence the degree of error, which can range widely. To give an example of how this error occurs and how it must be considered when interpreting results, we will examine the testing of calcium levels in the marine aquarium.

Calcium testing methods for salt water range from complicated, expensive ion chromatography and ICP-MS (inductively coupled plasma mass spectroscopy) to simple drop-titration methods. All methods, even the most sophisticated, are subject to a number of sources of error, and these individual sources of error can add up to significant differences in values obtained. The most sophisticated methods applied with poor technique will give no better results than simpler methods carefully applied. Potential sources of error include: sample concentration errors including errors in measuring salt and water and errors in measuring salinity; dilution errors when samples must be diluted into the range of the instrument or errors introduced when the dilution water is not of high purity; calibration errors; errors due to technique; errors due to aging or contaminated reagents; and errors in calculations. In addition, the sensitivity of the test method must be considered.

Each of these errors can be considered in detail to get an idea of the accuracy that can be expected of a particular measurement method. By far the most common test method used by hobbyists is titration. It is a simple, reliable and reasonably accurate method, but one must consider the potential for error and the inherent accuracy of the test method when interpreting results. Some examples illustrate the accuracy that can be expected of tests of these types.

Example 1 — Joe uses a bottle-dropper type of titration test kit to measure the calcium level in his aquarium. The actual (true) calcium level is 400 ppm. He carefully measures a vial full of the water to be tested, adds the correct reagents in the correct order and mixes them properly. He titrates with the dropper bottle, carefully counting the drops, but he does not realize that the drop size varies considerably, depending on whether the bottle is held vertically or at an angle. He titrates with the bottle at an angle and each drop contains about 0.48 grams (with some variability). If the same bottle is held vertically, the drop size

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Part 4: Science Behind Synthetic Sea Salts

From the Labs of Instant Ocean

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is very consistently 0.38 to 0.39 grams. If the bottle is held correctly, 27 drops are required before the color changes. Joe sees a color change in 22 drops. Based on this number of drops, he calculates his calcium to be 330 ppm.

Example 2 – Laura uses a syringe type of titration test kit to measure the calcium level in her aquarium. The actual (true) calcium level is 400 ppm. She follows all directions carefully, but does not see that there is air in the tip of the titrant syringe, because she inadvertently pulled the syringe out of the titrant as she was pulling up the last of the titrant. Because the air is in the narrow tip, it is difficult to see. This small amount of air displaces 0.05 ml of the titrant, leading to a reading 25 ppm lower than the true calcium level. If Laura had also stopped the titration when the solution turned from pink to purple, rather than titrating to reach the true blue, indicating full reaction, she would have had a reading that is another 20 ppm lower, giving a final reading of 355 ppm. Figure 1 shows the range of colors seen during titration to an endpoint.

Figure 1



Example 3 – David starts a new aquarium by mixing a synthetic sea salt in his tank. The manufacturer claims a calcium concentration of at least 400 ppm at 34 ppt salinity. David fills his 40-gallon aquarium with RO water and adds the amount of synthetic salt specified to make 40 gallons. He then measures the calcium level to see if it meets the manufacturer's claim, and the measurement reads 365 ppt. David has not yet checked his salinity. If he had done so, he would have found that it was 31 ppt. This has happened because the actual volume of water in the tank

and other reservoirs was 43.5 gallons (tank volumes are not precise, and the volume of water in large hang-on filters, canister filters and sumps add to the total water volume). If David had checked his salinity, but there was an error in the salinity measurement device of +/- 1 ppt, he would also have an inaccurate calcium reading by about 11 ppm. Table 1 illustrates the pronounced effects of salinity on calcium concentrations in seawater.

Table 1

Specific Gravity (15/4 scale) (salinity in ppt)	Natural Seawater*	
	Calcium	Magnesium
1.019 (25.9)	305	950
1.02 (27.2)	320	998
1.021 (28.5)	335	1046
1.022 (29.8)	351	1093
1.023 (31.1)	366	1141
1.024 (32.4)	381	1187
1.025 (33.7)	397	1236
1.026 (35)	412	1284

* Data for seawater values taken from *An Introduction to the Chemistry of the Sea*. 1998. M.E.Q. Pilson

These examples illustrate how easy it can be to make small errors that greatly affect test results. While this degree of error may be frustrating to the hobbyist, one must keep in mind that even sophisticated methods are subject to error. An examination of the literature shows that even expensive methods conducted in professional laboratories can result in fairly large errors. One calcium-containing sample was analyzed by 44 laboratories using the EDTA titration method. The relative standard deviation was 9.2%. ICP-MS methods give relative standard deviations in the 5-10% range, depending on the element.

So how do you deal with the potential for error? It is very important to understand how multiple small errors

can compound to give highly erroneous readings. The preceding examples show the results of single or multiple errors. Common errors include:

- Salinity determination and calculation errors
- Technique errors
- Equipment or reagent (chemical) problems
- Endpoint color interpretation

The following steps can help to minimize errors:

First, read and carefully follow all instructions for the test kit you use. Check the age and expiration dates of reagents.

Second, be sure you know the salinity of the sample you are testing. To get an accurate sample, mix and aerate the solution well, preferably for 24 hours. Be sure the refractometer is temperature-calibrated or be sure the hydrometer is free of bubbles and on a level surface.

If the value you get seems unusual or if you have doubts about the accuracy, double check your calculations and review the test instructions. If you find no problems, repeat the test one or more times to determine whether your results are consistent.

Finally, keep in mind that the value you get, no matter what the test method, is a "more-or-less" value. Fortunately, while many test kits and references give a single "best" value for a water parameter, rarely is an exact value required for a healthy aquarium. It is far less frustrating to work to keep your aquarium in a healthy range around a desirable average than it is to fight to maintain a precise value. For example, if you wish to keep your calcium level at an average of 400 ppm, you can keep the calcium readings in the 360 to 440 ppm range, with the goal of averaging around 400 ppm over time, without worrying about normal test error.

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4. Chemical Composition of Natural Seawater

A remarkable feature of seawater is that its chemical composition is essentially similar throughout the World Ocean. This has been sometimes called Marcet's Principle or, more formally, the Principle of Constant Composition (Pilson 1998). Simply put, the salinity and the chemical composition of the major ions in seawater is constant from one ocean to another and from the surface to the extreme depths. The mean salinity of the World Ocean is 34.72 parts per thousand, which is usually abbreviated ppt or by the symbol ‰ (see sidebar Salinity, Specific Gravity and Units for a more in-depth discussion). 90% of the total volume of the seawater in the World Ocean is within 1.1% of this mean value (Pilson 1998). This is quite a small range and it is important to marine aquarists for two reasons. First, the chemical stability of the Ocean means that many of the animals living in it are not programmed evolutionarily to cope with chemical values outside this small range. In addition, many chemicals in the sea are present in very small amounts (they are referred to as trace elements). The measurement of these elements even with modern analytical instruments is particularly challenging. An upcoming episode of this article (section 6) will deal with the importance of this difficulty.

The constancy of seawater is good news for hobbyists and manufacturers, in that it means one SSS formula will suffice for organisms from nearly every oceanic region. Of course, there are exceptions, such as the Red Sea (which has a salinity of nearly 40 ppt, compared to Caribbean Sea's salinity of about 30 ppt), and one might wish to add extra amounts of certain elements, such as calcium and strontium, that are "consumed" in aquaria due to biological processes.

Table 1 presents the typical chemical composition of NSW, with the 11 major ions adapted from Pilson (1998). At first glance, this chart may seem strange because there is no listing for such chemical compounds as sodium chloride or magnesium chloride. The reason is that these and other compounds do not exist in seawater in the compound form. Rather, they have dissolved or dissociated into cations (positively charged ions) and anions (negatively charged ions). This fact is important because powdered sea salt mixtures are made of many compounds which, when added to water, dissolve into cations and anions at concentrations that mimic natural sea water (NSW). However, the formulator of the sea salt has the discretion of deciding which compounds to use in order to obtain the desired levels of each ion.

For instance, as Table 1 shows, NSW has the ions calcium, magnesium, sulfate and chloride. One could use calcium sulfate and calcium chloride in the sea salt to produce the calcium, sulfate and chloride levels of NSW. Alternatively, one could choose to use magnesium chloride and magnesium sulfate instead. If the formulator is trying to mimic NSW, however, then s/he has to take into account the total amount of each ion in the final product. For example, if there is too much calcium or magnesium in the mixture, it will not only deviate from NSW but also may be difficult to dissolve, and a precipitate may form in the aquarium when kalkwasser or other chemicals that affect the water pH are added. This is only one example of the potential problems that one faces when developing a synthetic sea salt formula.

The values in Table 1 are in grams per kilogram (g/kg). In this format, one kilogram of liquid seawater will contain, on average, 10.781 grams (g) of sodium (Na⁺), 1.284 g of magnesium (Mg⁺⁺), and