Using Specific Gravity To ID Mystery Alloy

Yesterday I was down at the industrial scrap recycling yard that has become my own little private gold mine. I found a newly arrived “gold deposit” that looked very much like tin metal. It was bright shiny new stuff that was in the form of easily bent 1/2-inch wide strips cut from thin sheets. Besides being easily bent, it was also light silver or aluminum-colored like tin is, too hard to scratch with my fingernail but still soft enough to be scratched with a penny just like tin. When I bent it, though, it did not squeak, crackle, or groan like tin does, which is the best way to identify tin when pure. Zinc will also make a crunching sound when bent, but the sound as well as the appearances of the two metals are quite different, zinc making a noise more like a pecan shell cracking than a squeak when bent as well as being a darker bluish colored metal with the typical gray color reminiscent of galvanized steel since zinc is what is used for galvanizing. However, just because some light silvery colored metal does not squeak and squeal when bent is not proof positive that the stuff in question does not contain a high concentration of tin metal since a small amount of alloying metal such as copper, silver, lead, antimony, bismuth, phosphorus, arsenic, etc, will prevent the phenomenon referred to as “tin cry”. The only way to tell for sure if an alloy has tin in it is to do a chemical test, which is actually not that difficult for tin, but the reagents needed are unfortunately no longer available without going to a chemical supply house, and those businesses will not sell to a stranger walking in from the street. But there is one test that will work in this particular case that is real easy and anyone who reloads or casts boolits already has all the right stuff to do it with just sitting there ready to go!

In this case, the only other thing my mystery metal could be is lead since it superficially resembles tin rather closely except for being softer. Freshly cut lead is very nearly the same silvery color as tin and the two can only be told apart after a few days when the lead begins to darken from the formation of lead rust, which is a dull dark gray, and tin does not rust. If alloyed to make solder or Babbitt with tin or any of the metals listed in the example above for tin “cry”, though, the color match is impossible to tell apart even after a few days since the alloying metals prevent the lead from rusting and keep it bright. The only means left to tell them apart very quickly at this point is to find their densities, or specific gravities, since lead is a substantially denser element compared to tin. Lead is 11.34 times as dense as water and tin is 7.265 times as dense.
To find the density of a sample of metal it is simply weighed while under water and then this weight is compared to its weight out of water. Theoretically the weight should be checked in a vacuum since air also supports and buoys-up all objects as well, but its buoying properties are tiny compared to water and for our purposes for extremely dense materials like metals it can be conveniently ignored. I tied one end of a six-inch length of fine sewing thread onto my piece of mystery metal and the other end onto the pan mount pivot of my 509.9-grain capacity Hornady-Pacific powder scale and weighed the piece with it dangling down below the top of my workbench. After weighing it I got a glass of water and carefully lifted the glass up underneath the piece of metal until I could see through the glass that it was totally submerged. I got a plastic drink straw and teased the air bubbles loose that were hanging onto the thread and then weighed the piece under water. I weighed it three times and the three wet weights all agreed, so I was done. All that was left to do was the math part, which is straightforward. The dry weight was 167.2 grains and the wet weight was 151.5 grains. Subtracting the two weights left 15.7 grains, which is the weight of water equivalent to the volume of the piece of metal. We want to find how many times more the weight of the metal is than the weight of its volume of water, so dividing the dry weight by the difference of the weights gives this number. The specific gravity of the piece is 167.2 divided by 15.7, which gives the number 10.64968. Rounding off that number to a legitimate value gives us a specific gravity of 10.65. Since it is a whole bunch more than 7.265 but pretty close to 11.34, it is a good educated guess that the mystery metal is mostly lead with a smidgen of something in it to make it harder than my fingernail, probably antimony, and judging from its shape and where I found it, its use was as tare weights for balancing some kind of aerospace devices. Since I get wheel weights free but this stuff was selling for $0.50 per pound, I left it.

On the specific gravity (SG) of lead, tin, antimony alloys
From "Reade", on the net-search under "specific gravity reade"

Metal	Symbol	SG
Antimony	Sb	6.68
Lead	Pb	11.34
Tin	Sn	7.29

To Use: EX: Under 0.5% Tin and 1% Antimony, see the highlighted **11.27**, the specific gravity of an alloy of those metals plus 98.5% lead.

Calculated Specific Gravity of Lead-Tin-Antimony Alloys

	Tin%>>													
Ant%	0	0.5	1	2	3	4	5	6	7	8	9	10	11	12
0	11.34	11.32	11.30	11.26	11.22	**11.18**	11.14	11.10	11.06	11.02	10.98	10.94	10.89	10.85
1	11.29	**11.27**	11.25	11.21	**11.17**	11.13	11.09	11.05	11.01	10.97	10.93	10.89	10.85	10.81
2	11.25	11.23	11.21	**11.17**	11.13	11.08	11.04	11.00	10.96	10.92	10.88	10.84	10.80	10.76
3	11.20	**11.18**	**11.16**	11.12	11.08	11.04	11.00	10.96	10.92	10.88	10.84	10.80	10.75	10.71
4	11.15	11.13	11.11	11.07	11.03	10.99	10.95	10.91	10.87	10.83	10.79	10.75	10.71	10.67
5	11.11	11.09	11.07	11.03	10.99	10.95	10.90	10.86	10.82	10.78	10.74	10.70	10.66	10.62
6	11.06	11.04	11.02	10.98	10.94	10.90	10.86	10.82	10.78	10.74	10.70	10.66	10.61	10.57
7	11.01	10.99	10.97	10.93	10.89	10.85	10.81	10.77	10.73	10.69	10.65	10.61	10.57	10.53
8	10.97	10.95	10.93	10.89	10.85	10.81	10.76	10.72	10.68	10.64	10.60	10.56	10.52	10.48
9	10.92	10.90	10.88	10.84	10.80	10.76	10.72	10.68	10.64	10.60	10.56	10.52	10.48	10.43
10	10.87	10.85	10.83	10.79	10.75	10.71	10.67	10.63	10.59	10.55	10.51	10.47	10.43	10.39
11	10.83	10.81	10.79	10.75	10.71	10.67	10.62	10.58	10.54	10.50	10.46	10.42	10.38	10.34
12	10.78	10.76	10.74	10.70	10.66	10.62	10.58	10.54	10.50	10.46	10.42	10.38	10.34	10.29
13	10.73	10.71	10.69	10.65	10.61	10.57	10.53	10.49	10.45	10.41	10.37	10.33	10.29	10.25
14	10.69	10.67	10.65	10.61	10.57	10.53	10.49	10.44	10.40	10.36	10.32	10.28	10.24	10.20
15	10.64	10.62	10.60	10.56	10.52	10.48	10.44	10.40	10.36	10.32	10.28	10.24	10.20	10.16
16	10.59	10.57	10.55	10.51	10.47	10.43	10.39	10.35	10.31	10.27	10.23	10.19	10.15	10.11
17	10.55	10.53	10.51	10.47	10.43	10.39	10.35	10.30	10.26	10.22	10.18	10.14	10.10	10.06
18	10.50	10.48	10.46	10.42	10.38	10.34	10.30	10.26	10.22	10.18	10.14	10.10	10.06	10.02
19	10.45	10.43	10.41	10.37	10.33	10.29	10.25	10.21	10.17	10.13	10.09	10.05	10.01	9.97
20	10.41	10.39	10.37	10.33	10.29	10.25	10.21	10.17	10.12	10.08	10.04	10.00	9.96	9.92

Calculating Specific Gravity When Making Your Own Alloy

When making a new boolit alloy, having doubts about whether or not the volumes of the metals will still add up the same after mixing together as before mixing them is a quite legitimate concern. That is because lots of things out there in the real world don't add up the same afterward as before mixing, good examples of that inequality are ethanol and water, or sodium chloride (good old table salt) and water, which do not. In fact with salt and water, as long as the salt is given time to become totally dissolved into the water, the volume of water does not change noticeably even when a considerable amount of salt is dissolved into it, making it greatly different from metals. Adding a whole saltshaker of salt to a nearly full glass of water without any ice in it at the table in a restaurant is an old magician's trick that has earned those folks who know about such things a bit of pocket change or a few free dinners by collecting on bets! Don't try it at home, though, it usually gets the owner of the saltshaker accused of rigging the bet by having "trick salt" in the saltshaker.

Metals behave totally different, though, and with few exceptions, when alloyed the volumes of metals WILL ADD UP nearly the same afterward as before. The only times when the before and after metal volumes do not add up pretty close to the same are a few very definite cases when the crystal systems of the two constituent metals are different, such as one being in the hexagonal system and the other being in the face-centered or body-centered cubic systems. Fortunately for tin and most other commonly used alloy constituents that are in the hexagonal system, their volumes add up very nearly equally with the metals of the two cubic system.

The formula for determining the specific gravity of an alloy from its constituent specific gravities is quite straightforward, and those of us who are familiar with electronics formulas will immediately recognize it as being derived from the same mathematical principle as the formula for determining resistance *R* and inductance *L* in parallel circuits, and capacitance *C* in series circuits. Besides metallurgy and electronics, the basic principle is also used in other areas of physics and chemistry for determining the specific heats of mixtures of materials. It has a lot of uses! The formula is as follows:

The reciprocal of the specific gravity of the new alloy is equal to the reciprocal of the specific gravity of the first metal times its decimal part of the weight of the alloy + the reciprocal of the specific gravity of the second metal times its decimal part of weight of the alloy + the reciprocal of the specific gravity of the third metal times its decimal part of the weight of the alloy + the reciprocal of the specific gravity of the fourth metal times its decimal part of the weight of the alloy + the reciprocal of the specific gravity of the fifth metal times its decimal part of the weight of the alloy + etc, carried out as many times as there are different metals in the resulting new alloy.

If there are only two metals in the new alloy then the formula is:

The reciprocal of the specific gravity of the new alloy is equal to the reciprocal of the specific gravity of the first metal times its decimal part of the weight of the alloy + the reciprocal of the specific gravity of the second metal times its decimal part of the weight of the alloy.

For an example I'll use the values for a common lead-based Babbitt or bearing alloy, that age-hardens, quenches, and also works okay for hard cast projectiles.

Because a lot of our younger members are still in school I will try to make the math as easy as possible so everybody can have a shot at being able to use this or at least get an idea of what is going on.

The alloy test sample weighs 1672 grains and was made from 1521.52 grains lead (chemist's symbol Pb) with 150.48 grains antimony (chemist's symbol Sb). Taking 1521.52 grains divided by 1672 grains gives me 0.910 decimal parts lead in 1.00 decimal part of the alloy. Taking 150.48 grains divided by 1672 grains gives 0.090 decimal parts antimony per 1.00 decimal part of the alloy.

The specific gravity of lead is 11.34 and its reciprocal is 1/11.34 or 0.0881834 in decimal form.
The specific gravity of antimony is 6.68 and its reciprocal is 1/6.68 or 0.1497 in decimal form.

The reciprocal of a number is found by simply taking 1 and dividing it by that particular number, for example the reciprocal of 5 is 1/5, or one fifth, and it is 0.2 in decimal form or decimal numbers. Another example is the reciprocal of 6 is 1/6, or one sixth, and it is 0.16666666666 etc in decimal form or decimal numbers, but quite often just rounded off to 0.167 to keep it simple.

Now we use the following formula:

Reciprocal of the specific gravity = (reciprocal of the specific gravity of lead times decimal parts of lead in the alloy) + (reciprocal of the specific gravity of antimony times decimal parts of antimony in the alloy)

When the math instructions are inside of a pair of () it means that all the adding, subtracting, multiplying, dividing, and exponential operations inside them have to be done first before anything else outside of them can be added or subtracted to or from those numbers because if not done that way the answer will be totally wrong.

Using actual math terms:

1/spgrv = (1/spgrv Pb x dec parts Pb in alloy)+(1/spgrv Sb x dec parts Sb in alloy)

Plugging in the actual numbers gives us:

1/spgrv = (1/11.34 x 0.910) + (1/6.68 x 0.090)

Now turning the “math crank” it grinds out

1/spgrv = (0.0881834 x 0.910) + (0.1497 x 0.090)

turning the “math crank” again it grinds out

1/spgrv = 0.080247 + 0.013473

turning the “math crank” one more time it grinds out

1/spgrv = 0.09372

At this point we still don’t have the answer yet because we have the reciprocal of the number we are trying to get to. To get the reciprocal just take 1 and divide the above number into it.

So we have 1/ 0.09372, which turning the “math crank” one more time makes it grind out the value of 10.6700848. Rounding this off to a significant number of places beyond the decimal point so it means something real gives us a specific gravity of 10.67 for this alloy. This jibes awful darned close to the specific gravity found by weighing the test sample under water to find the weight of its volume of water and then dividing the dry weight by the weight of its water volume. The calculations for that were in the earlier thread, but the test results were found to be 10.65 and that is 99.8% of the theoretical specific gravity of 10.67 that was just calculated.

With just two metals in an alloy it CAN be used for determining the percentages of those metals when the specific gravities of the alloy as well as both metals in it are known, but not their amounts. That is done by equating all values in the equation to one particular “like term” and then solving for the unknown. I don’t have time right now to rearrange the equation to solve for that, but if anyone who is a math whiz wants to do that and post it, go right ahead since it would be quite useful.

As already pointed out by garandsrus with the table he so kindly posted for us, this formula will not work using it backwards to discover the percentages of a metal in an alloy when there are THREE OR MORE metals in it. That is because by varying the amounts of three metals in an alloy it can still give one specific gravity just by varying the ratios of the ingredients over a rather wide range! But working forward like I did up above it is dead-on accurate for finding the RESULTING specific gravity when the amounts and specific gravities of all the constituents are known.