Chemistry Q&A for *Skilletheads*

2021 Interview with Ashley L. Jones and
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Q1, Jones: I've contacted labs to see if they will run a test to see if products like Easy-off, Carbon-Off!, and Evapo-Rust remain in the pores of the pan after using them to restore the cast iron, but none has been willing to help me. Is this because the levels are expected to be so small or because most labs aren't equipped to test for these chemicals?

A1, Rosolina: Definitely the latter. These products contain uncommon compounds (e.g. Butyl carbitol (2-(2-Butoxyethoxy)ethanol) in Easy-off). Most labs will test for common contaminants in water (volatile organic compounds or heavy metals). Specialty compounds aren't worth labs creating an analytical method for unless there's a common need for (e.g. EPA ruling, public outcry, etc.)

Q2, Jones: From a chemist's perspective, would you expect the chemicals in Easy-off, Carbon Off!, and Evapo-Rust to rinse off completely or would some of the chemicals remain within the pores of the pan?

A2, Rosolina: First, let me put forth a disclaimer: the manufacturers should be consulted since they're the experts—my thoughts come solely from the chemical components that are listed in the SDSs.

However, based on the known physical properties of the ingredients in Easy-off, I would expect that they would rinse readily from the pan. 2-(2-Butoxyethoxy)ethanol is noted to be readily soluble in water, or even miscible in water (https://pubchem.ncbi.nlm.nih.gov/compound/2-_2-Butoxyethoxy_ethanol#section=Solubility). Anything that is readily soluble in water will rinse off well. There's nothing to me that suggests that it would sorb to the cast iron within the pores. Similarly, ethanolamine is also very soluble in water. I wouldn't expect it to stick around as long as the pan is rinsed well.

For Carbon Off! the main concerning components are dichloromethane (methylene chloride), toluene, and 2-butoxyethanol. All three are soluble in ethanol and are volatile enough to be driven off by 450 degrees F.

I can't comment on Evapo-Rust since they don't disclose the components. (They have one or more "proprietary ingredients.") They claim to be "super-safe," but they should be contacted directly in terms of using their product on potential cookware. From a technical standpoint, based on their description, they use a chelator (like EDTA) to bind iron oxides and pull them away from the iron surface, and then a sulfur-based compound pulls the iron away from the chelator (like a baton being passed in a relay race). But the final product is an iron sulfate salt that is water soluble. Although the chelating group should only pull the iron out of the iron oxides, I can't say that it won't bind to the iron (non-rusted) portions and stick around.

Q3, Jones: If some of the chemicals remain, how serious a problem is that? Are they really dangerous to your health, or are they like soap and not much of a health concern?

A3, Rosolina: It’s hard for me to say - the osha limit for ethanolamine is 3 parts per million (ppm) in air for 8 hours straight (https://nj.gov/health/eoh/rtkweb/documents/fs/0835.pdf). Even without knowing the concentration of ethanolamine in Easy-off, it would be difficult to be exposed to 3 ppm for 8 hours straight if I were to use it for cast iron restoration. This is even more true for 2-(2-Butoxyethoxy)ethanol which has an OSHA limit of 50 ppm for 8 hours (https://nj.gov/health/eoh/rtkweb/documents/fs/0275.pdf). That being said, there isn’t much information on acute (short term) toxicity. Personally, I don’t see a problem using something like Easy-off in the same way someone would use oven cleaner—finishing by heating it up in the oven. Obviously, care should always be taken when using any kind of cleaner not to directly breath it in.

Q4, Jones: Restorers recommend rinsing cast iron in very cold water to prevent flash rust. Would you recommend a special way to ensure Easy-off is removed from the pan? For example, should we wash with soap? Apply another product (like baking soda)? Heat the pan to a certain temperature before seasoning?

A4, Rosolina: I wouldn't use water at all to rinse off the Easy-off ingredients; instead I would recommend using ethanol. Both ethanolamine as well as Butyl carbitol are miscible in ethanol. So some good grain alcohol should be the safest way to rinse it and prevent flash rust. Acetone would work as well.

In the chemistry world we usually perform multiple rinses of an item to truly remove the previous chemicals. Especially since this is porous iron, I would recommend multiple (2-3) rinses of ethanol or acetone. I would make sure that the final rinse is ethanol (even if acetone was used initially) and then finish it off by heating the cast iron in an oven at 450 degrees F to remove the ethanol and any possible remaining butyl carbitol/ethanolamine. Obviously, all usual precautions should be taken if this is done indoors—don’t throw a cast iron full of alcohol into an oven that's already 450 degrees.

Q5, Jones: Restorers who don’t use chemicals usually use an electrolysis tank to remove rust and old seasoning. Although an E-tank uses water, it does not contribute to the rust or pit the pan. Can you describe what happens during electrolysis from a chemical standpoint?

A5, Rosolina: Sure! So, iron rusts because it oxidizes. Oxygen loves electrons enough that it takes the electrons from the iron when it forms iron oxide (rust). So by pumping electricity (electrons) into the system, you can reverse this by forcing the oxygen to give the electrons back to the iron.

So when pure iron is exposed to water and oxygen, it becomes oxidized from Fe(0) to Fe(III). By forcing the electrons back (reduction), it turns the rust to Fe(II) in the form of iron hydroxides—this is the black material that's formed during electrolysis which can often be scraped off or rubbed off. The Fe(III) can also go all the way back to Fe(0) depending on the voltage, but regardless, the rust is removed as Fe(II) or completely transformed back to pure iron.

So this is why, even though an E-tank uses water, the water doesn't contribute to rust. Because we're putting energy into reversing the process.

Q6, Jones: Does stainless steel, used as anodes in an etank, really create hexavalent chromium? Is this something to be avoided?

A6, Rosolina: Yes. Stainless steel, by requirement, contains a certain percentage of chromium. The electrons that are used to reduce the cathode (the cast iron pan) must come from the sacrificial anode—essentially you're choosing to oxidize one thing so that you can reduce another. By oxidizing stainless steel, you turn Cr(0) into Cr(III) and then Cr(VI). I love chromium because it demonstrates the extreme difference that oxidation states can play. Cr(VI) is carcinogenic, but Cr(III) is an essential trace element for humans!

The amount of Cr(VI) produced compared to Cr(III) is really dependent on the setup. If you can control the voltage in your E-tank, you may be able to keep it at a voltage below what is required to produce Cr(VI). In general, it's really unlikely that a home setup will produce Cr(VI) in a high enough amount to be a serious human health or environmental threat, but I say it's safest to just use a plain steel anode or a graphite carbon anode.

Q7, Jones: There are a lot of warnings online saying not to use copper wires or brushes when cleaning cast iron and not to let copper wires dip into the water in E-tanks or it can "contaminate" the skillet and water. What exactly does the copper do to cast iron?

A7, Rosolina: Different metals have different preferences towards electrons. In the case of copper and iron, copper prefers electrons more than iron and so, similar to oxygen, copper will steal the electrons from iron which results in iron being oxidized (rust). In order for this to happen, there needs to be water and some kind of electrolyte (basically a water solution of charged particles like Na^+, Cl^-, K^+, OH^-, Ca^{2+}, etc.) so that the electrons can pass from one metal to another. Electrolytes are required in E-tanks for the same reason, so if copper ends up in an E-tank, or if it's used to scrub cast iron using water, it can result in this exchange of electrons which is called galvanic corrosion.

Q8, Jones: Can you give me any insight into carbonization and why some people would claim it's necessary?

A8, Rosolina: Like you, I'm having a hard time finding more info on the polymerization/carbonization process. In chemistry, when we talk about carbonization it's usually in terms of a much more dramatic environment.

For example, a lot of my PhD work revolved around glassy carbon electrodes. The glassy carbon that make up the sensor is created by a similar process as cast iron seasoning; carbon-based resins are "cured" (polymerized) and then carbonized—but the carbonization happens between 600 and 2000 degrees C.

For both processes the idea is the same—polymerization is when the polymer is initially formed (and carbon chains stick to the iron and line up together to form a natural plastic); carbonization is essentially burning it after it's all lined up and organized so that it's harder and more resistant to acidity, for example.
For cast iron seasoning I don't think it has to be a perfect science. Here are my thoughts (mostly from experience):

1. As we both know, polymerizing at *too* low of a temperature can be more of a pain than a help and produce brown, sticky polymer films in splotches.
2. However, I don't think I have ever needed to heat our cast irons past the smoke point when performing a classic seasoning (by which I mean a non-recipe based seasoning because there is an exception below). I think that once it's polymerized that continued cooking will help the carbonization process over time, it may just not be as efficient. It probably means that re-seasoning will need to happen more often compared to those who heat it up past the smoke point during the seasoning process.
3. I want to comment on your concern for carcinogens—obviously anytime something burns, smoke is produced, which is inherently carcinogenic. However, with a good hood vent it shouldn't be a problem. Remember that grilling and smoking foods is also inherently carcinogenic, so it's worth adding that context and weighing those risks. Overall, as long as you're not directly breathing in the smoke for long periods of time, the health risk is very low. (This also applies to standing around campfires.)

I will say that the most effective (and delicious) way that we tend to re-season is baking a cornbread. We use my wife's mother's recipe which requires placing the cast iron with oil in it into the oven while it's preheating. When the cast iron and oil are screaming hot (425 F, above the smoke point—we usually use grapeseed oil which has a smoke point of 420), we add the batter. So I think by letting it heat up in the cast iron it's polymerizing and when it reaches temp it's carbonizing which explains why it's always been a great method for us. We've never actually had much smoke form from this process though. Probably because we immediately add the batter which absorbs a bit of the heat and so the energy in the oil goes into crisping up the edges of the cornbread rather than burning. It's a pretty nice middle-ground for those who want to follow the carbonization recommendations and want to avoid a smoky kitchen.

User Notes:

Please feel free to reference or link to this material but provide credit to Ashley L. Jones, author of *Skilletheads*, and Sam Rosolina, PhD in Analytical Chemistry from University of Tennessee, Knoxville.