

Intro to Ionic Compounds

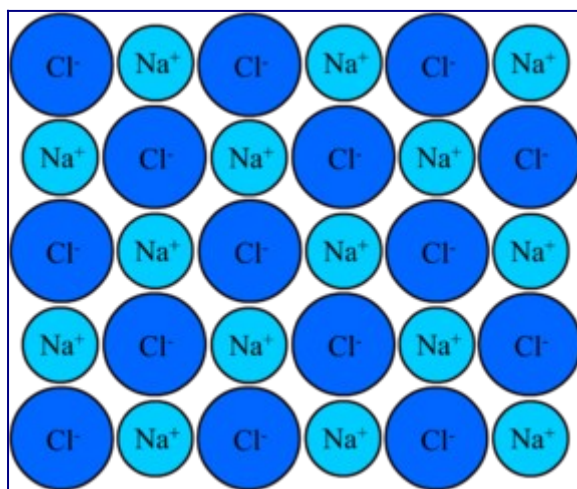
After all of this talk about electrons and such, you're probably wondering when you'll get to learn some actual chemistry. Well, you're in luck: It's time to learn about the wonders of ionic compounds. And yes, they are wonderful!



Pictured: Something wonderful

What are ionic compounds?

Ionic compounds are compounds in which ions are attracted to one another due to the fact that one sort of ion has a positive charge (the cation) and another has a negative charge (the anion).¹ Sodium chloride is an example of an ionic solid:



Each sodium cation attracts chlorine anions to it, and vice-versa. To maximize the number of interactions between cations and anions, the ions arrange themselves into a pattern like this one.

The attraction between each cation and anion is what people refer to when they call something an “ionic bond.” However, it should be noted that this interaction is not truly a bond in the literal sense, as the attraction involves no sharing of electrons. Still, if your teacher wants to call it an ionic bond, go with it.^{2 3}

How are ionic compounds made?

If you'll recall, the octet rule states that all elements want to be like the nearest noble gas. Put another way, all atoms want to have the same number of valence electrons (a.k.a. outer electrons) as the noble gas closest to it on the periodic table.

Let's look at the example of what happens when a sodium atom and a chlorine atom meet each other in a play called "Sodium Turns The Tables." Feel free to act out this play at home with your friends.

Sodium Turns The Tables: A Play in One Act

Curtain opens to show the stereotypical break room you can find at any large corporation. A half-filled water cooler is in the corner, and the refrigerator has a heavily edited sign on it that originally said “Remember that coffee break’s are a privilege and not a right.” Around the single table sit the perpetually happy Sodium, the perpetually grumpy Chlorine, and the dimwitted but loveable Neon and Helium.

Sodium: Hey chlorine.

Chlorine: What do you want?

Sodium: I was thinking...

Chlorine: I doubt that.

Sodium (ignores chlorine): ...that I could be happier.

Chlorine: I'd be happier if you went away.

Sodium (ignoring Chlorine's negativity): Take a look at this picture I made of us on the periodic table:

[illegible]

Chlorine: Why are you drawing pictures of me? That's creepy as hell.

Helium (*speaking to Neon*): Look, we're there, too!

Sodium: If you look at the table, you can see that if I lose one valence electron, I'll be as happy as Helium. And he's pretty happy.

Chlorine (*muttering under his breath*): That's because he's a moron.

Sodium: Chlorine, if you were to gain one electron, you'd be a lot happier, too. You see, that would make you just as happy as your neighbor, Neon, because you'd have a full valence shell.

Chlorine (*thoughtful*): Hmm... so what you're saying is...

Chlorine, realizing that Sodium has the extra electron he needs, grabs Sodium's outermost electron.

Chlorine (*triumphant*): Check it out, you idiot! I stole your electron and now have a filled valence shell! I may have a negative charge because of this extra electron, but now I can hang out with my buddy Neon! (*Neon looks around with a vacant look on his face and goes back to solving the newspaper's Kidz Krossword*).

Sodium: I think you forgot something, though.

Chlorine: What? What could you possibly say that would make this moment any less awesome?

Sodium (*with a nasty smile*): You forgot that by taking an electron from me, you gave me the same electron configuration as Helium, which makes me happy. (*Helium gives Neon a high-five, though neither is following the conversation*).

Chlorine (*confused*): So?

Sodium: So you forgot the best part. When you took my valence electron, it didn't just turn you into an anion with negative charge... it turned me into a cation with positive charge.

Chlorine suddenly looks aghast.

Sodium: I see you figured it out. Now that I have positive charge and you have negative charge, we'll stay stuck together as an ionic compound. And we'll be friends for ever, and ever, and ever, and ever....

Stage lights go dark, to the sound of chlorine's screaming.

And that's how an ionic compound is made.

Properties of ionic compounds

The properties of ionic compounds are completely dependent on the fact that cations and anions are arranged in regular patterns. If you understand that these ions are tightly bound in a certain arrangement, you can pretty much figure out the rest on your own. We'll refer to this arrangement when talking about the properties of ionic compounds.

Ionic compounds form crystals: Crystals are groups of atoms or ions in which there is a regular, repeating pattern that involves huge numbers of particles – the smallest unit of this crystal is called a **unit cell**. In the case of an ionic compound like NaCl, the sodium and chloride ions stack together in an alternating pattern because if they didn't, you'd see ions with similar charges next to each other – this would cause repulsion instead of attraction. As a result, you can make huge crystals of sodium chloride.⁴



The cubic crystals of NaCl on the left reflect the way that the anions and cations stick together in salt's crystal structure.

Ionic compounds have high melting and boiling points: Compared to other compounds, ionic compounds have much higher melting and boiling points. The reason for this is simple: When you have a bunch of positive and negative ions all stacked together so that they have the maximum amount of positive-negative interactions, it takes a lot of energy to pull them apart again. To get a lot of energy takes a high temperature, which is why you have to heat these guys up quite a bit to make them melt and/or boil. As an example, carbon tetrafluoride (CF_4) has a melting point of -299 degrees Celsius, while the melting point of sodium fluoride (NaF) is 993 degrees Celsius.⁵

Ionic compounds are hard and brittle: Again, this goes back to the way that ionic compounds are held together, with opposing charges all lined up perfectly.

What happens if we throw a chunk of salt at your neighbor's head? Depending on how hard you throw it, it will either shatter, or it won't.

If the chunk of salt doesn't shatter, your neighbor will feel a great deal of pain because it is very hard. The reason for this hardness has to do with the structure of the salt: Because all of the anions and cations are lined up with one another, it takes a lot of energy to shift them around. Most likely, the energy with which the salt impacted your neighbor's head wasn't enough to do the trick.



You expect me to believe you hit me on the head for science? Damn kids...

If the salt shatters, you've demonstrated that the salt is brittle, as the tendency to shatter is the definition of brittleness. Though it takes a lot of energy to shift those ions around, it turns out that if you succeed in doing so, they probably won't end up in just the right places to maximize the positive-negative interactions. Because the crystal is no longer stabilized by these attractive forces, it breaks along the lines where the ions stop being lined up.



That's it "Mr. Scientist." I'm calling the cops.

Ionic compounds conduct electricity when they dissolve in water. When something dissolves in water, the water molecules pull the particles of that thing apart from one another, which is why it dissolves. If you dissolve an ionic compound, the same thing happens: The water molecules pull the cations and anions apart from one another and the compound dissolves.

Now, let's talk about electrical conductivity. If you want something to conduct electricity, you have to move charged particles from one place to another. Metals conduct electricity because metallic bonding allows electrons to move from one place to another (you've probably noticed that electrons are charged particles). Though ionic compounds don't have any moving electrons, the ions themselves have either positive or negative charge. As a result, if you can move the ions from one place to another, you'll see them conduct electricity.

If you dissolve an ionic compound, the ions are no longer stuck in one place and can migrate around, allowing them to conduct electricity. Likewise, if you were to melt an ionic compound, the ions that are present can also move and conduct electricity. If moving ions can conduct electricity, then anything that causes them to move (such as melting or dissolving) allows ionic compounds to conduct. Though ionic compounds don't conduct electricity at all when in the solid form, dissolving and melting let the ions move and the electrical magic happen.



Behold! The magic of electricity!

Try this at home!

If you're anything like me, you've been told that it's a bad idea to iron your clothes while you're taking a bath. Apparently, "the man" thinks that you'll electrocute yourself when the electric iron hits the water. I'm here to tell you that this isn't true.

Contrary to popular belief, water doesn't conduct electricity. Though it may seem like it does, that's only because tap water contains dissolved ions that cause it to be conductive. As a result, if you were to use an iron in water that has absolutely nothing dissolved in it, you should be just fine.

Here's an experiment you can do at home:

- 1) Scrub your tub to remove all traces of dissolved ionic compounds. You will probably need to do this several times to ensure it's totally clean.*
- 2) Coat the bathtub in thick plastic to ensure no further contamination.*
- 3) Obtain enough deionized water to fill the tub. It should go through this purification process several times to ensure complete purity.*
- 4) Take a shower in completely pure deionized water to remove all trace of dissolved compounds from your body. Don't use soap - just stand under the stream of DI water for four or five hours to ensure you're clean. Air dry to ensure the towel doesn't contaminate you with any dissolved salts it may contain.*
- 5) Spray yourself in thick plastic to ensure that your body doesn't accidentally sweat out anything ionic.*
- 6) Obtain an electric iron and subject it to the same purification process used above. The materials used to make irons may involve a lot of dissolved ionic compound, so this process may take several hours. When finished, coat all surfaces of the iron in plastic.*
- 7) Get in the bathtub and test the conductivity of the water with the most sensitive conductivity tester you can find. If the water conducts in the slightest, this indicates that your purification processes weren't strict enough. Go back and do steps 1-6 again.*
- 8) Get in the now non-conducting water and throw the iron in with you. See? It didn't electrocute you!*

See? With a little ingenuity, you now have a trick to impress your friends!

Editor's note: After testing this experiment several times with a focus group, we found that 100% of the people who tried this experiment were horribly electrocuted. Though Mr. Guch claims that this was because "those dumbasses didn't do it right", we at the Cavalcade o' Chemistry are forced to conclude that this experiment is unsafe and should not be performed by anybody, ever.

Footnotes:

1. The interaction between ions (and any charged particles, for that matter) is called an "electrostatic force." In an ionic compound, this electrostatic force is what is usually referred to as an "ionic bond."
2. It's not entirely true that there is no sharing of electrons between the ions in an ionic compound. All nuclei attract all electrons in an ionic solid – this goes for the electrons on the Cl^- ion and the nucleus of the Na^+ ion. However, because of the drastic difference in electronegativities between cations and anions, this is usually considered to be of negligible importance.

3. The electrostatic interaction between cations and anions is usually referred to as an “ionic bond” to indicate that it’s an interaction with comparable strength to the bonded atoms in other compounds. Though there is very little sharing of electrons, and nothing present that can be referred to as a discrete “molecule”, people use it anyway.
4. It’s important to note that just because something is a crystal doesn’t mean that it will look like one. For example, if you look closely at a grain of salt from a salt shaker, you can tell that it’s a little crystal. However, if you mash it up a lot, this crystal will turn into a white powder. When this happens, the structure of the salt has not changed – it’s still stacked the same way. It’s just that instead of being a crystal that’s big enough to see, the crystals in the powder are really, really small. Get a good microscope and you can see this for yourself.
5. Like all rules referred to as “general” rules, there are exceptions. For example, the covalent compound anthracene has a melting point 16 degrees above that of the ionic compound sodium acetate. For the most part, however, you’ll find that it’s true that, all else being equal, ionic compounds have higher melting and boiling points. (Source for temperatures: Wikipedia).