

Cations and anions IV: The meaning of the superscripts

Yes, we mean it.

Well, sort of . . .

No, not really.

2	3	4	5	6	7	
He	Li ⁺	Be ²⁺	B ³⁺	C ⁴⁺	N ⁵⁺	
10	11	12	13	14	15	16
Ne	Na ⁺	Mg ²⁺	Al ³⁺	Si ⁴⁺	P ⁵⁺	S ⁶⁺
18	19	20	21	22	23	24
Ar	K ⁺	Ca ²⁺	Sc ³⁺	Ti ⁴⁺	V ⁵⁺	Cr ⁶⁺
36	37	38	39	40	41	42
Kr	Rb ⁺	Sr ²⁺	Y ³⁺	Zr ⁴⁺	Nb ⁵⁺	Mo ⁶⁺
54	55	56	57	72	73	74
Xe	Cs ⁺	Ba ²⁺	La ³⁺	Hf ⁴⁺	Ta ⁵⁺	W ⁶⁺
86	87	88	89	90	91	92
Ra	Fr ⁺	Ra ²⁺	Ac ³⁺	Th ⁴⁺	Pa ⁵⁺	U ⁶⁺

In our symbols used to identify chemical entities, we employ superscripts to identify charged forms of atoms. We thus know that Na^+ , Ca^{2+} , and O^{2-} indicate ions of atoms that, in uncharged elemental form, we would designate as Na, Ca, and O. In the case of Na^+ and Ca^{2+} , we take the superscripts to mean that these are ions with one and two fewer electrons, respectively, than the number of protons in each atom*. Studies of electron density support this view that Na^+ and Ca^{2+} have 10 and 18 electrons, as many electrons as would the noble gas to their left in the periodic table.

Mineralogists and geochemists commonly venture onto shakier ground in writing 4+, 5+, and 6+ as superscripts, arriving at C^{4+} , Si^{4+} , Ti^{4+} , and Zr^{4+} , N^{5+} , P^{5+} , and V^{5+} , and S^{6+} , Cr^{6+} , Mo^{6+} , and so on. They do so for at least two reasons. First, the progression of charge across the periodic table makes sense with our accounting of charge in chemical formulae. For example, in the formula for anhydrite (CaSO_4), assigning 2+ to the Ca, 2- to the four Os, and thus 6+ to the S yields a sum of zero and thus charge balance. Secondly, calculating ionic potential using the charges shown here yields patterns that predict geochemical and mineralogical behavior (as many other pages in this book show). It's thus conceptually useful to assign these higher charges as shown at left.

With that said, one should appreciate that studies of electron density do not support the use of these large values, and so not indicate that, for example, Si, P, and S ever achieve the outer-shell configuration of electrons of Ne. Thus our use of the large superscripted numbers at left may make our accounting work out well, but we might be more accurate to say that anhydrite balances with "Ca with a charge of at most 2, S with a charge probably a little over 3, and the four Os with charges that average something around $-1\frac{1}{3}$ ".

* If you're curious why we didn't say "we take these superscripts to mean that these are atoms that have lost one and two electrons, respectively . . .", see Part I of this series.