increases going down a group, more electrons lie between the nucleus and the electrons in the highest occupied energy levels. This partially shields the outer electrons from the effect of the nuclear charge. Together, these influences overcome the attraction of the electrons to the increasing nuclear charge.

extension

CROSS-DISCIPLINARY

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Keyword: HC6PERX

Removing Electrons from Positive Ions

With sufficient energy, electrons can be removed from positive ions as well as from neutral atoms. The energies for removal of additional electrons from an atom are referred to as *the second ionization energy* (IE_2), *third ionization energy* (IE_3), and so on.

Table 3 shows the first five ionization energies for the elements of the first, second, and third periods. You can see that the second ionization energy is always higher than the first, the third is always higher than the second, and so on. This is because as electrons are removed in successive ionizations, fewer electrons remain within the atom to shield the attractive force of the nucleus. *Thus, each successive electron removed from an ion feels an increasingly stronger effective nuclear charge (the nuclear charge minus the electron shielding).*

The first ionization energies in **Table 3** show that removing a single electron from an atom of a Group 18 element is more difficult than removing an electron from atoms of other elements in the same period. This special stability of the noble-gas configuration also applies to ions that have noble-gas configurations. Notice in **Table 3** the large increases between the first and second ionization energies of lithium, Li, and between the second and third ionization energies of beryllium, Be. Even larger increases in ionization energy exist between the third and fourth

TABLE 3 *Ionization Energies (in kJ/mol) for Elements of Periods 1–3*

	Period 1		Period 2							
	H	He	Li	Be	B	C	N	O	F	Ne
IE_1	1312	**2372**	520	900	801	1086	1402	1314	1681	2081
IE_2		5250	**7298**	1757	2427	2353	2856	3388	3374	3952
IE_3			11 815	**14 849**	3660	4621	4578	5300	6050	6122
IE_4				21 007	**25 026**	6223	7475	7469	8408	9370
IE_5					32 827	**37 830**	9445	10 990	11 023	12 178
			Period 3							
			Na	Mg	Al	Si	P	S	Cl	Ar
IE_1			496	738	578	787	1012	1000	1251	1521
IE_2			**4562**	1451	1817	1577	1903	2251	2297	2666
IE_3			6912	**7733**	2745	3232	2912	3361	3822	3931
IE_4			9544	10 540	**11 578**	4356	4957	4564	5158	5771
IE_5			13 353	13 628	14 831	**16 091**	6274	7013	6540	7238