

11.1: Valence Electrons and the Periodic Table

Learning Objectives

- Explain the relationship between the chemical behavior of families in the periodic table and their valence electrons.
- Identify elements that will have the most similar properties to a given element.

The chemical properties of elements are determined primarily by the number and distribution of valence electrons. Since the groups on the periodic table were originally organized based on their chemical behavior, it should be no surprise that the individual members of each group have similar electron configurations of their valence electrons.

Section 4.9 described how Dmitri Mendeleev arranged the original periodic table so that elements with the most similar properties were placed in the same group. For example, the alkali metals (Group IA) are quite soft and may easily be cut apart using a dull knife. They also reacted in a similar manner with water to produce hydrogen gas. When they combined with oxygen, they were found to do so in a 2:1 ratio of atoms. Once quantum mechanics was developed in the 1920s, it was found that the alkali metals all had one valence electron, thereby explaining their similar reactions and the 2:1 atom ratio with oxygen.

The halogens (Group VIIA) were all observed to be colorful, reactive elements that combined with oxygen in a 7:2 atom ratio and with the alkali metals in a 1:1 atom ratio. As a gas or vapor, the halogens all had a pungent odor. After the development of quantum mechanics, it was shown that the halogens all had seven valence electrons, supporting their original placement into the same group on Mendeleev's periodic table.

Reihen	Gruppe I. — R ² O	Gruppe II. — RO	Gruppe III. — R ² O ³	Gruppe IV. RH ⁴ RO ²	Gruppe V. RH ⁵ R ² O ⁵	Gruppe VI. RH ² RO ³	Gruppe VII. RH R ² O ⁷	Gruppe VIII. — RO ⁴
1	H=1							
2	Li=7	Be=9.4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27.3	Si=28	P=31	S=32	Cl=35.5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	—
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	—
12	—	—	—	Th=231	—	U=240	—	— — — —

Figure 11.1.1: Periodic table by Dmitri Mendeleev, 1871. (NikNaks, Public domain, via Wikimedia Commons)

The Modern Periodic Table and Chemical Bonds

As described in Section 10.6, the modern periodic table is arranged based on an atom's valence electrons. But what does this tell us about how they form chemical bonds with each other? Why do sodium atoms and chlorine atoms combine in a 1:1 ratio, while sodium and oxygen atoms combine in a 2:1 ratio? Much of this was already described in Chapter 5 in our study of chemical nomenclature. At that time, it wasn't really explained why sodium atoms always form ions with a 1+ charge, why chlorine atoms form ions with a 1− charge, or why oxygen atoms form ions with a 2− charge. By the time you complete this chapter, you will have a much better idea.

	1 IA	2 IIA		3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 H 1.008																		2 He 4.003
2	3 Li 6.939	4 Be 9.012												5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31												13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08		21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62		39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc (99)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57-70 *	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89-102 **	103 Lr (262)	104 Rf (265)	105 Db (268)	106 Sg (271)	107 Bh (270)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (285)	112 Cn (285)	113 Nh (284)	114 Fl (289)	115 Mc (288)	116 Lv (293)	117 Ts (294)	118 Og (294)
				57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (147)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04		
				89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)		

Figure 11.1.2: The modern periodic table. An interactive periodic table may be found [here](#).

Summary

- All of the elements in the same group on the periodic table have the same number of valence electrons and similar chemical properties.

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