Answer to Essential Question 28.4: The atom should have an atomic number of at least 39. Following the twists and turns of Figure 28.9, we can count that there are 38 electron states up to and including the 5s subshell. Thus, the 39^{th} electron should go into the 4d subshell. Because the 4d subshell can contain as many as 10 electrons, the *x* in $4d^x$ is an integer between 1 and 10.

28-5 Understanding the Periodic Table

In the previous two sections, we have laid the groundwork for understanding the periodic table. An idealized periodic table is laid out in Figure 28.10. Table 28.2 and Figure 28.9 are repeated here from Section 28-4 so you can more easily see the connection between the diagram that goes with the aufbau principle (Figure 28.9) and the periodic table.

Value of ℓ	Letter (stands for)
0	s (sharp)
1	p (principal)
2	d (diffuse)
3	f (fundamental)
4	g (letter after f)
5	h (letter after g)
6	i (letter after h)

Table 28.2: Letters for various ℓ values.

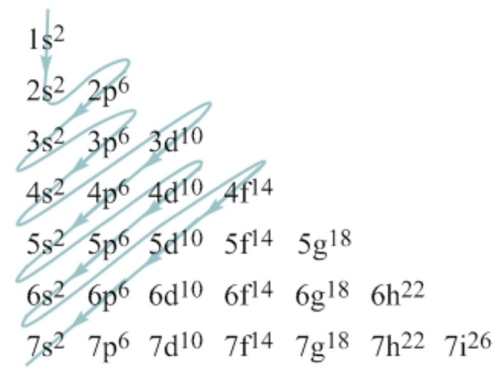

Figure 28.9: The order in which electrons fill the different subshells.

Figure 28.10 shows an idealized periodic table, showing the state of the last few electrons in each element's ground-state configuration. Atoms with completely filled subshells, or half-filled subshells, are particularly stable, and atoms with similar last-electron states generally have similar chemical properties. Note that the true ground-state configurations of elements with atomic numbers 105 and above are not yet known.

In reality, there are some deviations from the idealized behavior shown in Figure 28.10. These deviations can be quite instructive. Some of those deviations include:

- In column 11, the last two terms in the ground-state configurations for copper (Cu), silver (Ag), and gold (Au) are actually $4s^1\ 3d^{10}$, $5s^1\ 4d^{10}$, and $6s^1\ 5d^{10}$, respectively. Each of these configurations ends with a half-full s subshell and a full d subshell, rather than a full s subshell and an almost-full d subshell, demonstrating that full and half-full subshells are particularly stable (lower energy) states.
- In column 6, the last two terms in the ground-state configurations for chromium (Cr) and molybdenum (Mo) are actually $4s^1\ 3d^5$ and $5s^1\ 4d^5$, respectively. Each of these configurations ends with a half-full subshell and a half-full d subshell, rather than a full s subshell and partly-filled d subshell, demonstrating that half-full subshells are particularly stable (lower energy) states.
- The last two terms in the ground-state configurations for gadolinium (Gd, element 64) and curium (Cm, element 96) are actually $4f^7\ 5d^1$ and $5f^7\ 6d^1$, respectively. Each of these configurations has a half-full f subshell and one electron in a d subshell, rather than partly-filled f subshell, again demonstrating that half-full subshells are particularly stable (lower energy) states.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H $1s^1$																	2 He $1s^2$
3 Li $2s^1$	4 Be $2s^2$											5 B $2p^1$	6 C $2p^2$	7 N $2p^3$	8 O $2p^4$	9 F $2p^5$	10 Ne $2p^6$
11 Na $3s^1$	12 Mg $3s^2$											13 Al $3p^1$	14 Si $3p^2$	15 P $3p^3$	16 S $3p^4$	17 Cl $3p^5$	18 Ar $3p^6$
19 K $4s^1$	20 Ca $4s^2$	21 Sc $3d^1$	22 Ti $3d^2$	23 V $3d^3$	24 Cr $3d^4$	25 Mn $3d^5$	26 Fe $3d^6$	27 Co $3d^7$	28 Ni $3d^8$	29 Cu $3d^9$	30 Zn $3d^{10}$	31 Ga $4p^1$	32 Ge $4p^2$	33 As $4p^3$	34 Se $4p^4$	35 Br $4p^5$	36 Kr $4p^6$
37 Rb $5s^1$	38 Sr $5s^2$	39 Y $4d^1$	40 Zr $4d^2$	41 Nb $4d^3$	42 Mb $4d^4$	43 Tc $4d^5$	44 Ru $4d^6$	45 Rh $4d^7$	46 Pd $4d^8$	47 Ag $4d^9$	48 Cd $4d^{10}$	49 In $5p^1$	50 Sn $5p^2$	51 Sb $5p^3$	52 Te $5p^4$	53 I $5p^5$	54 Xe $5p^6$
55 Cs $6s^1$	56 Ba $6s^2$	*	72 Hf $5d^2$	73 Ta $5d^3$	74 W $5d^4$	75 Re $5d^5$	76 Os $5d^6$	77 Ir $5d^7$	78 Pt $5d^8$	79 Au $5d^9$	80 Hg $5d^{10}$	81 Tl $6p^1$	82 Pb $6p^2$	83 Bi $6p^3$	84 Po $6p^4$	85 At $6p^5$	86 Rn $6p^6$
87 Fr $7s^1$	88 Ra $7s^2$	**	104 Rf $6d^2$	105 Db $6d^3$	106 Sg $6d^4$	107 Bh $6d^5$	108 Hs $6d^6$	109 Mt $6d^7$	110 Ds $6d^8$	111 Rg $6d^9$	112 Uub $6d^{10}$	113 Uut $7p^1$	114 Uuq $7p^2$	115 Uup $7p^3$	116 Uuh $7p^4$	117 Uus $7p^5$	118 Uuo $7p^6$

* Lanthanides	57 La $4f^1$	58 Ce $4f^2$	59 Pr $4f^3$	60 Nd $4f^4$	61 Pm $4f^5$	62 Sm $4f^6$	63 Eu $4f^7$	64 Gd $4f^8$	65 Tb $4f^9$	66 Dy $4f^{10}$	67 Ho $4f^{11}$	68 Er $4f^{12}$	69 Tm $4f^{13}$	70 Yb $4f^{14}$	71 Lu $5d^1$
** Actinides	89 Ac $5f^1$	90 Th $5f^2$	91 Pa $5f^3$	92 U $5f^4$	93 Np $5f^5$	94 Pu $5f^6$	95 Am $5f^7$	96 Cm $5f^8$	97 Bk $5f^9$	98 Cf $5f^{10}$	99 Es $5f^{11}$	100 Fm $5f^{12}$	101 Md $5f^{13}$	102 No $5f^{14}$	103 Lr $6d^1$

Alkali metals	Transition metals	Non-metals	Halogens
Alkaline earth metals	Poor metals	Metalloids	Noble gases

Figure 28.10: This figure lays out an idealized version of the periodic table, to show the predicted term in the ground-state configuration for each element. When viewed this way, one gets a better understanding of why the table is laid out as it is. In a given column, for instance, the elements have similar chemical properties because they have similar electron configurations. In the 17th column, for instance, these elements (known as halogens) have similar properties because in their ground-state configurations, each of the elements has 5 electrons in a p orbital, that p orbital being the highest-energy orbital that contains electrons for those elements. For most of the elements, the last term in their ground-state configurations match what is shown here, but some elements differ from the idealized version shown here, as detailed on the previous page. Also, note that helium is generally shown in the 18th column, because it is just as unreactive as the other noble gases, but you could make a strong argument for helium belonging at the top of column 2, based on its ground-state configuration.

Related End-of-Chapter Exercises: 55, 56, 59.

Essential Question 28.5: In Figure 28.10, the final term in the ground-state configuration of the element with the chemical symbol Po (element 84) is shown to be $6p^4$. What is the common name for this element? What is the complete ground-state configuration for this element, showing all the terms?