a. p^3 There are (6!)/(3!3!) = 20 microstates:

		M_S			
		–3/2	–1/2	1/2	3/2
	+2		$1^+\ 1^-\ 0^-$	$1^+\ 1^-\ 0^+$	
	+1		$1^+\ 1^-\ -1^-$ $1^-\ 0^-\ 0^+$	$1^+\ 1^-\ -1^+$ $1^+\ 0^-\ 0^+$	
M_L	0	$1^-\ 0^-\ -1^-$	$1^+\ 0^-\ -1^-$ $1^-\ 0^+\ -1^-$ $1^-\ 0^-\ -1^+$	$1^+\ 0^+\ -1^-$ $1^+\ 0^-\ -1^+$ $1^-\ 0^+\ -1^+$	$1^+\ 0^+\ -1^+$
	–1		$-1^+\ -1^-\ 1^-$ $-1^-\ 0^-\ 0^+$	$-1^+\ -1^-\ 1^+$ $-1^+\ 0^-\ 0^+$	
	–2		$-1^+\ -1^-\ 0^-$	$-1^+\ -1^-\ 0^+$	

Terms: $L = 0, S = 3/2$: ^{4}***S*** (ground state)
$L = 2, S = 1/2$: ^{2}***D***
$L = 1, S = 1/2$: ^{2}***P***

b. p^1d^1 There are $\dfrac{6!}{1!5!} \times \dfrac{10!}{1!9!} = 60$ microstates:

		M_S		
		–1	0	1
	3	$1^-\ 2^-$	$1^-\ 2^+,\ \ 1^+\ 2^-$	$1^+\ 2^+$
	2	$1^-\ 1^-$ $0^-\ 2^-$	$1^+\ 1^-,\ \ 1^-\ 1^+$ $0^-\ 2^+,\ \ 0^+\ 2^-$	$1^+\ 1^+$ $0^+\ 2^+$
	1	$1^-\ 0^-$ $0^-\ 1^-$ $-1^-\ 2^-$	$1^+\ 0^-,\ \ 0^+\ 1^-$ $1^-\ 0^+,\ \ 0^-\ 1^+$ $-1^-\ 2^+,\ \ -1^+\ 2^-$	$1^+\ 0^+$ $0^+\ 1^+$ $-1^+\ 2^+$
M_L	0	$1^-\ -1^-$ $0^-\ 0^-$ $-1^-\ 1^-$	$1^+\ -1^-,\ \ 1^-\ -1^+$ $0^-\ 0^+,\ \ 0^+\ 0^-$ $-1^+\ 1^-,\ \ -1^-\ 1^+$	$1^+\ -1^+$ $0^+\ 0^+$ $-1^+\ 1^+$
	–1	$-1^-\ 0^-$ $0^-\ -1^-$ $1^-\ -2^-$	$-1^+\ 0^-,\ \ 0^+\ -1^-$ $-1^-\ 0^+,\ \ 0^-\ -1^+$ $1^-\ -2^+,\ \ 1^+\ -2^-$	$-1^+\ 0^+$ $0^+\ -1^+$ $1^+\ -2^+$
	–2	$-1^-\ -1^-$ $0^-\ -2^-$	$-1^+\ -1^-,\ -1^-\ -1^+$ $0^+\ -2^-,\ \ 0^-\ -2^+$	$-1^-\ -1^+$ $0^+\ -2^+$
	–3	$-1^-\ -2^-$	$-1^-\ -2^+,\ -1^+\ -2^-$	$-1^+\ -2^+$

Terms: $L = 3, S = 1$ ^{3}***F*** (ground state) $L = 2, S = 0$ ^{1}***D***
$L = 3, S = 0$ ^{1}***F*** $L = 1, S = 1$ ^{3}***P***
$L = 2, S = 1$ ^{3}***D*** $L = 1, S = 0$ ^{1}***P***

The two electrons have quantum numbers that are independent of each other, because the electrons are in different orbitals. Because they have different l values, the electrons can have the same m_l and m_s values.

2 For p^3: $L = 0$, $S = 3/2$, the term ^4S has $J = 3/2$ only ($|L+S| = |L–S|$). Therefore, the ground state is $\mathbf{^4S_{3/2}}$.

For p^1d^1: $L = 3$, $S = 1$, the term ^3F has $J = 4, 3, 2$. Since both levels are less than half filled, the state having lowest J has lowest energy, and the ground state is $\mathbf{^3F_2}$.

3 **a.** s^1d^1 There are $\frac{2!}{1!1!} \times \frac{10!}{1!9!} = 20$ microstates:

M_L \ M_S	–1	0	+1
+2	$0^-\ 2^-$	$0^-\ 2^+$, $0^+\ 2^-$	$0^+\ 2^+$
+1	$0^-\ 1^-$	$0^-\ 1^+$, $0^+\ 1^-$	$0^+\ 1^+$
0	$0^-\ 0^-$	$0^-\ 0^+$, $0^+\ 0^-$	$0^+\ 0^+$
–1	$0^-\ {-1}^-$	$0^-\ {-1}^+$, $0^+\ {-1}^-$	$0^+\ {-1}^+$
–2	$0^-\ {-2}^-$	$0^-\ {-2}^+$, $0^+\ {-2}^-$	$0^+\ {-2}^+$

b. Terms: $L = 2, S = 1$: $\mathbf{^3D}$; $L = 2, S = 0$: $\mathbf{^1D}$

c. The $\mathbf{^3D}$, with the higher spin multiplicity, is the lower energy term.

4 **a.** d^1f^1 There are $\frac{10!}{1!9!} \times \frac{14!}{1!13!} = 140$ microstates:

M_L \ M_S	–1	0	+1
+5	$2^-\ 3^-$	$2^-\ 3^+$, $2^+\ 3^-$	$2^+\ 3^+$
+4	$2^-\ 2^-$ $1^-\ 3^-$	$2^-\ 2^+$, $2^+\ 2^-$ $1^-\ 3^+$, $1^+\ 3^-$	$2^+\ 2^+$ $1^+\ 3^+$
+3	$2^-\ 1^-$ $1^-\ 2^-$ $0^-\ 3^-$	$2^-\ 1^+$, $2^+\ 1^-$ $1^-\ 2^+$, $1^+\ 2^-$ $0^-\ 3^+$, $0^+\ 3^-$	$2^+\ 1^+$ $1^+\ 2^+$ $0^+\ 3^+$
+2	$2^-\ 0^-$ $1^-\ 1^-$ $0^-\ 2^-$ ${-1}^-\ 3^-$	$2^-\ 0^+$, $2^+\ 0^-$ $1^-\ 1^+$, $1^+\ 1^-$ $0^-\ 2^+$, $0^+\ 2^-$ ${-1}^-\ 3^+$, ${-1}^+\ 3^-$	$2^+\ 0^+$ $1^+\ 1^+$ $0^+\ 2^+$ ${-1}^+\ 3^+$
+1	$2^-\ {-1}^-$ $1^-\ 0^-$ $0^-\ 1^-$ ${-1}^-\ 2^-$ ${-2}^-\ 3^-$	$2^-\ {-1}^+$, $2^+\ {-1}^-$ $1^-\ 0^+$, $1^+\ 0^-$ $0^-\ 1^+$, $0^+\ 1^-$ ${-1}^-\ 2^+$, ${-1}^+\ 2^-$ ${-2}^-\ 3^+$, ${-2}^-\ 3^-$	$2^+\ {-1}^+$ $1^+\ 0^+$ $0^+\ 1^+$ ${-1}^+\ 2^+$ ${-2}^-\ 3^+$
0	$2^-\ {-2}^-$ $1^-\ {-1}^-$ $0^-\ 0^-$ ${-1}^-\ 1^-$ ${-2}^-\ 2^-$	$2^-\ {-2}^+$, $2^+\ {-2}^-$ $1^-\ {-1}^+$, $1^+\ {-1}^-$ $0^-\ 0^+$, $0^+\ 0^-$ ${-1}^-\ 1^+$, ${-1}^+\ 1^-$ ${-2}^-\ 2^+$, ${-2}^+\ 2^-$	$2^+\ {-2}^+$ $1^+\ {-1}^+$ $0^+\ 0^+$ ${-1}^+\ 1^+$ ${-2}^+\ 2^+$
–1	${-2}^-\ 1^-$ ${-1}^-\ 0^-$ $0^-\ {-1}^-$ $1^-\ {-2}^-$ $2^-\ {-3}^-$	${-2}^-\ 1^+$, ${-2}^+\ 1^-$ ${-1}^-\ 0^+$, ${-1}^+\ 0^-$ $0^-\ {-1}^+$, $0^+\ {-1}^-$ $1^-\ {-2}^+$, $1^+\ {-2}^-$ $2^-\ {-3}^+$, $2^-\ {-3}^-$	${-2}^+\ 1^+$ ${-1}^+\ 0^+$ $0^+\ {-1}^+$ $1^+\ {-2}^+$ $2^-\ {-3}^+$

continued

−2	$-2^-\ 0^-$ $-1^-\ -1^-$ $0^-\ -2^-$ $1^-\ -3^-$	$-2^-\ 0^+$, $-2^+\ 0^-$ $-1^-\ -1^+$, $-1^+\ -1^-$ $0^-\ -2^+$, $0^+\ -2^-$ $1^-\ -3^+$, $1^+\ -3^-$	$-2^+\ 0^+$ $-1^+\ -1^+$ $0^+\ -2^+$ $1^+\ -3^+$
−3	$-2^-\ -1^-$ $-1^-\ -2^-$ $0^-\ -3^-$	$-2^-\ -1^+$, $-2^+\ -1^-$ $-1^-\ -2^+$, $-1^+\ -2^-$ $0^-\ -3^+$, $0^+\ -3^-$	$-2^+\ -1^+$ $-1^+\ -2^+$ $0^+\ -3^+$
−4	$-2^-\ -2^-$ $-1^-\ -3^-$	$-2^-\ -2^+$, $-2^+\ -2^-$ $-1^-\ -3^+$, $-1^+\ -3^-$	$-2^+\ -2^+$ $-1^+\ -3^+$
−5	$-2^-\ -3^-$	$-2^-\ -3^+$, $-2^+\ -3^-$	$-2^+\ -3^+$

b. Terms: $L = 5, S = 1$: ^{3}***H***; $L = 5, S = 0$: ^{1}***H***; $L = 4, S = 1$: ^{3}***G***; $L = 4, S = 0$: ^{1}***G***; $L = 3, S = 1$: ^{3}***F***; $L = 3, S = 0$: ^{1}***F*** ; $L = 2, S = 1$: ^{3}***D***; $L = 2, S = 0$: ^{1}***D***; $L = 1, S = 1$: ^{3}***P***; $L = 1, S = 0$: ^{1}***P***

c. The lowest energy term is the ^{3}***H***. For this term, J has the values 6, 5, and 4. Because the subshells are less than half full, the lowest value of J provides the lowest energy: $^3\boldsymbol{H}_4$.

5.

a. s^1f^1 There are $\frac{2!}{1!1!} \times \frac{14!}{1!13!} = 28$ microstates:

		M_S		
		−1	0	1
	3	$0^-\ 3^-$	$0^-\ 3^+$, $0^+\ 3^-$	$0^+\ 3^+$
	2	$0^-\ 2^-$	$0^-\ 2^+$, $0^+\ 2^-$	$0^+\ 2^+$
	1	$0^-\ 1^-$	$0^-\ 1^+$, $0^+\ 1^-$	$0^+\ 1^+$
M_L	0	$0^-\ 0^-$	$0^-\ 0^+$, $0^+\ 0^-$	$0^+\ 0^+$
	−1	$0^-\ -1^-$	$0^-\ -1^+$, $0^+\ -1^-$	$0^+\ -1^+$
	−2	$0^-\ -2^-$	$0^-\ -2^+$, $0^+\ -2^-$	$0^+\ -2^+$
	−3	$0^-\ -3^-$	$0^-\ -3^+$, $0^+\ -3^-$	$0^+\ -3^+$

b. Terms: $L = 3, S = 1$ ^{3}***F*** (ground state)
$L = 3, S = 0$ ^{1}***F***

c. The ^{3}***F*** term, with the higher spin multiplicity, has the lower energy. This term has $J = 2, 3, 4$; the lowest energy term, including J, is $^3\boldsymbol{F}_2$.

6.

a. ^2D has $L = 2$ and $S = 1/2$, so $M_L = -2, -1, 0, 1, 2$ and $M_S = -1/2, 1/2$

b. ^3G has $L = 4$ and $S = 1$, so $M_L = -4, -3, -2, -1, 0, 1, 2, 3, 4$ and $M_S = -1, 0, 1$

c. ^4F has $L = 3$ and $S = 3/2$, so $M_L = -3, -2, -1, 0, 1, 2, 3$ and $M_S = -3/2, -1/2, 1/2, 3/2$

7.

a. ^2D with $J = 5/2, 3/2$ fits an excited state of d^3, $^2D_{3/2}$

b. ^3G with $J = 5, 4, 3$ fits an excited state of d^4, $^3G_3$

c. ^4F with $J = 9/2, 7/2, 5/2, 3/2$ fits the ground state of d^7, $^4F_{9/2}$