Chapter 3 Review, pages 186–191

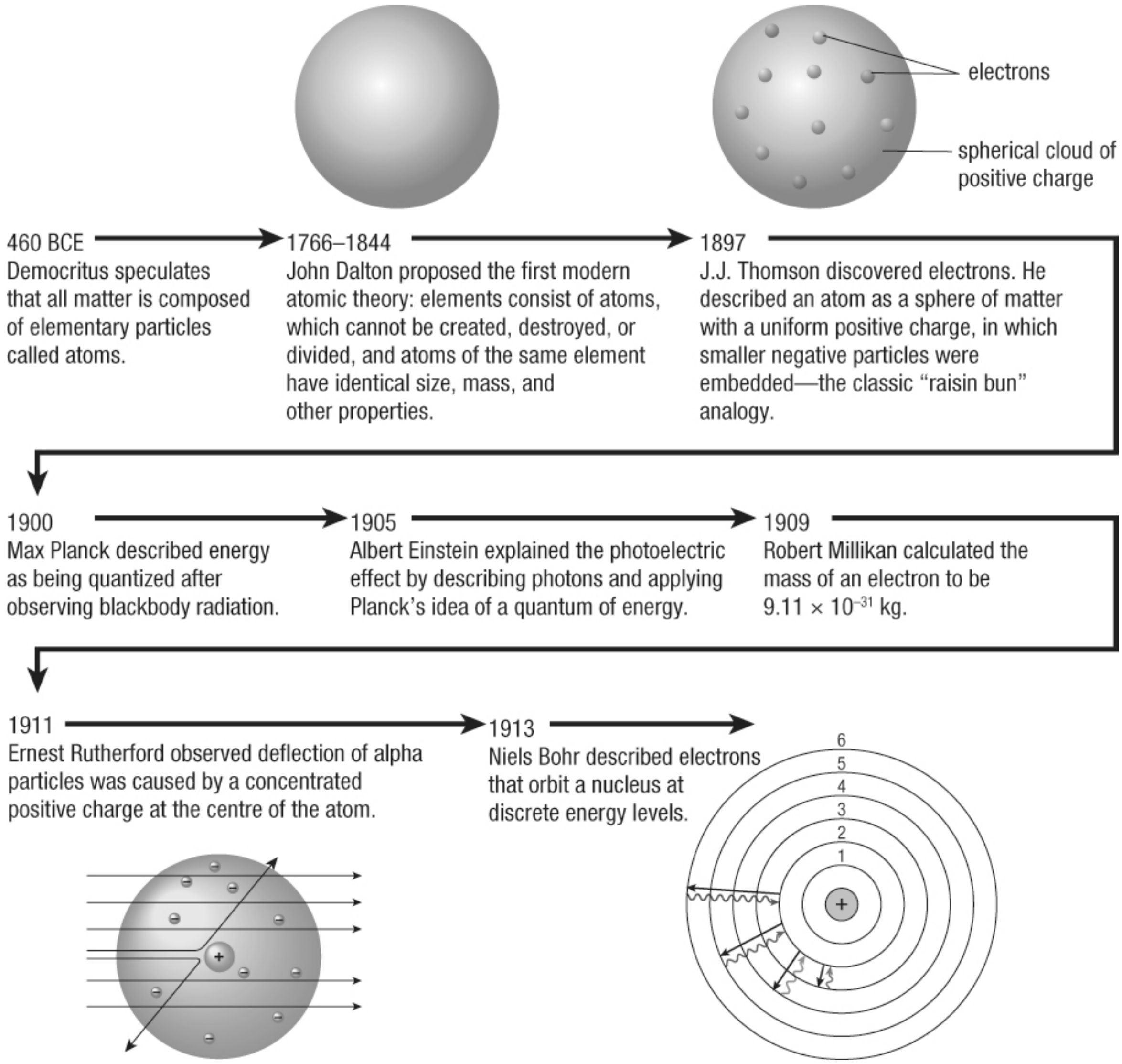
Knowledge

1. (d)
2. (b)
3. (a)
4. (d)
5. (a)
6. (d)
7. (d)
8. False. The chemical properties of an atom mainly result from its *electrons*.
9. True
10. False. Bohr's atomic model is *not* supported because it *does not* accurately describe most atoms.
11. True
12. False. Each atom can combine in *many ways*.
13. True
14. True
15. True

Understanding

16. The atomic number of an element is the number of protons that an atom of that element contains. The mass number is the number of protons and neutrons that an atom of that element contains.
17. Radioactivity is the release of matter or energy as an unstable nucleus undergoes decay.
18. The significance of the photoelectric effect is that it illustrates that electrons in an atom absorb only specific energies of electromagnetic radiation.
19. Rutherford interpreted the deflection of alpha particles travelling through a thin foil to mean that atoms had tiny, massive nuclei. Bohr interpreted the bright-line spectrum of hydrogen to mean that electrons exist only at specific energy levels. Both of these interpretations are key elements of the planetary model of the hydrogen atom, in which an electron orbits a massive nucleus, and can change energy levels.
20. A continuous spectrum contains all the wavelengths in a particular region of the electromagnetic spectrum. A line spectrum contains only thin lines of specific colours in a particular region of the electromagnetic spectrum.
21. The main flaw in Bohr's atomic model was that it did not make acceptable predictions for atoms larger than hydrogen.
22. There are more lines in the spectrum of xenon than in the spectrum of helium because xenon has more electrons than helium does, and they occupy more orbitals. As electrons move from one orbital to another in xenon, more changes in energy level are possible than are possible in helium. Each change of energy level results in a different colour emitted in the line spectrum.
23. The line spectra in Question 22 are emission spectra because the spectra contain mainly dark regions and a few bright lines. Absorption spectra would contain regions with most wavelengths and only a few dark bands where the light was absorbed.

24.



25. Orbit and orbital are terms that both refer to the location of electrons within atoms. An orbit is a circular path in the Bohr–Rutherford model where the electron can be found. An orbital is a volume of space described in the quantum mechanical model where the probability of locating the electron is high.

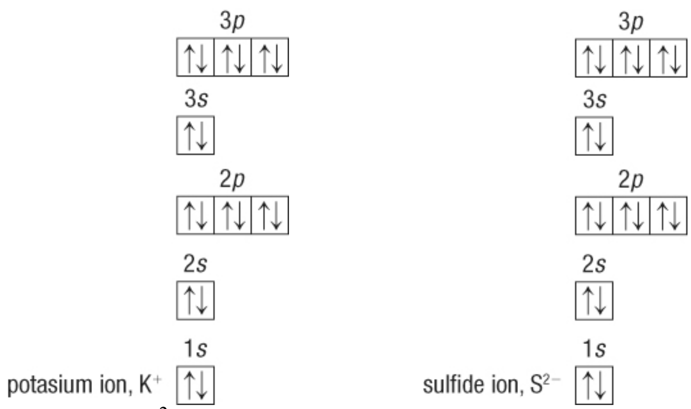
26. The energy levels in the Bohr model of the atom correspond with radial distance of the electron from the nucleus. The quantum mechanical model of the atom also contains energy levels. Each energy level contains a given number of orbitals.

27. (a) The lowest energy level that can have an *s* orbital is the first energy level ($n = 1$).

(b) The periodic table region including Groups 1 and 2 are designated as the *s* region.

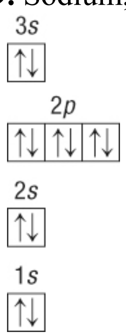
(c) The alkaline earth metals and the alkali metals comprise this region.

28. The fourth energy level includes: an *s* orbital that is spherical; three *p* orbitals, each having two lobes separated by the nucleus, and each orbital running along a different axis (x, y, z); five *d* orbitals; seven *f* orbitals. The fourth energy level can hold 32 electrons. An example of an element with its valence electrons in the fourth energy level is arsenic.
29. (a) The maximum number of electrons in an atom with $n = 1$ is 2.
(b) The maximum number of electrons in an atom with $n = 2$ is 10.
(c) The maximum number of electrons in an atom with $n = 3$ is 30.
(d) The maximum number of electrons in an atom with $n = 4$ is 70.
30. We can use the position of an element in the periodic table to predict its properties because the elements in any group on the periodic table all have atoms with the same valence electron configurations. Only the principal quantum number of the valence electrons changes within a group. Atoms with similar valence electron configurations will have similar properties.
31.

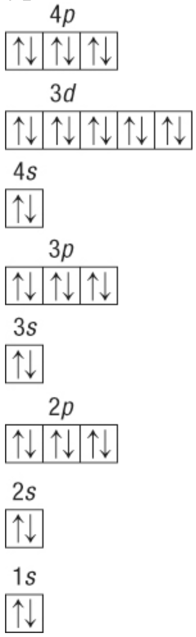


Both K^+ and S^{2-} have 18 electrons in orbitals. These ions have the same energy level diagram as the noble gas argon, Ar, which also has 18 electrons.
32. Ferromagnetism is a very strong magnetism that is exhibited by a material based on the alignment of the atoms with in the material. Paramagnetism is the weak magnetic field generated by unpaired electrons in an individual atom.
33. helium: atomic number 2, 2 electrons, electron configuration: $1s^2$; boron: atomic number 5, 5 electrons, electron configuration: $1s^22s^22p^1$; chlorine: atomic number 17, 17 electrons, electron configuration: $1s^22s^22p^63s^23p^5$; neon: atomic number 10, 10 electrons, electron configuration: $1s^22s^22p^6$; phosphorus: atomic number 15, 15 electrons, electron configuration: $1s^22s^22p^63s^23p^3$
34. (a) Mg has 12 electrons. Complete ground-state electron configuration for Mg: $1s^22s^22p^63s^2$
(b) Ar has 18 electrons. Complete ground-state electron configuration for Ar: $1s^22s^22p^63s^23p^6$
(c) O has 8 electrons. Complete ground-state electron configuration for O: $1s^22s^22p^4$
(d) Rb has 37 electrons. Complete ground-state electron configuration for Rb:
$1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^1$
(e) Au has 79 electrons. Complete ground-state electron configuration for Au:
$1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^66s^14f^{14}5d^{10}$
35. (a) S has 16 electrons. S^{2-} has 18 electrons. Complete ground-state electron configuration for S^{2-}: $1s^22s^22p^63s^23p^6$
(b) K has 19 electrons. K^+ has 18 electrons. Complete ground-state electron configuration for K^+: $1s^22s^22p^63s^23p^6$
36. (a) Si has 14 electrons. The noble gas immediately preceding Si is Ne, which has 10 electrons. Shorthand ground-state electron configuration for silicon: [Ne]$3s^23p^2$

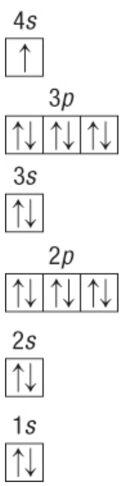
(b) Mn has 25 electrons. The noble gas immediately preceding Mn is Ar, which has 18 electrons. Shorthand ground-state electron configuration for manganese: [Ar]$4s^2 3d^5$
(c) The noble gas immediately preceding $_{73}$Ta is Xe, which has 54 electrons. Shorthand ground-state electron configuration for $_{73}$Ta: [Xe]$6s^2 4f^{14} 5d^3$
(d) Br has 35 electrons. The noble gas immediately preceding Br is Ar, which has 18 electrons. Shorthand ground-state electron configuration for bromine: [Ar]$4s^2 3d^{10} 4p^5$
(e) The noble gas immediately preceding $_{98}$Cf is Rn, which has 86 electrons. Shorthand ground-state electron configuration for $_{98}$Cf: [Rn]$7s^2 5f^{10}$
37. (a) The charge of the common ion of phosphorus is –3. P^{3-} has 15 + 3 = 18 electrons. The noble gas immediately preceding P is Ar, which also has 18 electrons. Shorthand ground-state electron configuration for phosphorus: [Ar].
(b) The charge of the common ion of beryllium is +2. Be^{2+} has 4 – 2 = 2 electrons. The noble gas immediately preceding Be is He, which also has 2 electrons. Shorthand ground-state electron configuration for beryllium: [He].
(c) The charge of the common ion of nickel is +3. Ni^{3+} has 28 – 3 = 25 electrons. The noble gas immediately preceding Ni is Ar, which has 18 electrons. Shorthand ground-state electron configuration for nickel: [Ar]$4s^2 3d^5$.
38. (a) Yttrium has 39 electrons. The noble gas immediately preceding Yttrium is Kr, which has 36 electrons. Shorthand electron configuration for yttrium: [Kr]$5s^2 4d^1$
(b) Antimony has 51 electrons. The noble gas immediately preceding Sb is Kr, which has 36 electrons. Shorthand electron configuration for antimony: [Kr]$5s^2 4d^{10} 5p^3$
(c) Ba^{2+} has 56 – 2 = 54 electrons. The noble gas immediately preceding Ba is Xe, which also has 54 electrons. Shorthand electron configuration for barium ion: [Xe]
39. Sodium, Na, has 11 electrons. Ground state electron configuration for Na:



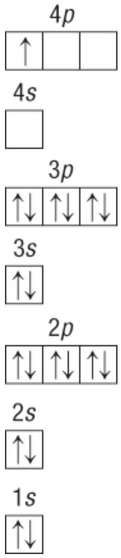
Krypton, Kr, has 36 electrons. Ground state electron configuration for Kr:



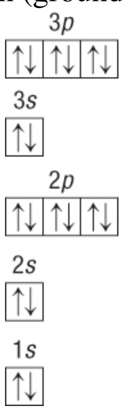
40. (a) Potassium atom in the ground state, K, has 19 electrons. Energy-level diagram for potassium atom (ground state), K:



(b) Potassium atom in the excited state, K^*, has 19 electrons. Energy-level diagram for potassium atom (excited state), K^*:



(c) Potassium ion in the ground state, K^+, has 18 electrons. Energy-level diagram for potassium ion (ground state), K^+:



(d) All three of K, K^* and K^+ have the 1*s*, 2*s*, 2*p*, 3*s*, and 3*p* orbitals filled. K and K^* have one additional electron that is found in the 4*s* orbital for K and in the 4*p* orbital for K^*.

41. (a) The electron configuration $1s^22s^22p^1$ shows 5 electrons. The neutral element with the electron configuration $1s^22s^22p^1$ is boron.

(b) The electron configuration $1s^22s^2$ shows 4 electrons. The neutral element with the electron configuration $1s^22s^2$ is beryllium.

(c) The electron configuration $1s^22s^22p^63s^23p^5$ describes a natural element in period 3, with 5 electrons in its 3*p* orbital. The neutral element with the electron configuration $1s^22s^22p^63s^23p^5$ is chlorine.

(d) The electron configuration $1s^22s^22p^63s^23p^4$ describes a natural element in period 3 with 4 electrons in its 3*p* orbital. The neutral element with the electron configuration $1s^22s^22p^63s^23p^4$ is sulfur.

(e) The electron configuration $1s^22s^22p^63s^23p^64s^23d^3$ describes a natural element in period 4 with 3 electrons in its 3*d* orbital. The neutral element with the electron configuration $1s^22s^22p^63s^23p^64s^23d^3$ is vanadium.

42. The 5*p* subshell is highlighted in the periodic table in Figure 2.

43. A multi-electronic atom is different from a hydrogen atom because electron-electron repulsions can occur which contributes to the difference in energy of different types of orbitals within the same energy level. For example, the *2s* orbital is slightly lower in energy than the *2p* orbitals.

44. The aufbau principal is based on the electron configuration of an atom. It states that an atom is built up by the addition of electrons filling orbitals in the order 1*s*, 2*s*, 2*p*, 3*s*, etc. The periodic table is also arranged in order of the electron configuration. The elements in the first period have electrons that fill the 1*s* subshell, the elements in the second period have electrons that fill the 2*s* and 2*p* subshells, and so on. In this way, the aufbau principal can be mapped on to the periodic table and can be used to explain its structure.

45. (a) Atom A has 3 electrons in its 4*p* orbital. Atom A is an arsenic atom, As.

(b) Atom Z is in period 6 and has 11 electrons in its 4*f* orbital. Atom Z is a holmium atom, Ho.

(c) Ion X^+ is in period 4 and has 6 electrons in its 4*p* orbital. Ion X^+ has the same electron configuration as krypton, Kr. Since Ion X^+ is a positive ion, it has one fewer electrons than it would as an atom. Ion X^+ is a rubidium ion, Rb^+.

(d) Ion D^- is in Period 5 and has 6 electrons in its 5*p* orbital. Ion D^- has the same electron configuration as xenon, Xe. Since Ion D^- is a negative ion, it has one more electrons than it would as an atom. Ion D^- is an iodide ion, I^-.

46. Hund's rule states that any unpaired electrons in the same set of orbitals will have the same parallel spins. This means that the electrons in a subshell will be found in separate orbitals until each orbital in the subshell contains one electron. For example, if there are 3 electrons in the 2*p* subshell, they will each be in a separate orbital and their spins would be parallel.

47. (a) Both sodium and chlorine atoms have unfilled electron energy levels. When an electron transfers from a sodium atom to a chlorine atom, both attain the electron configuration of a noble-gas atom. The noble gases are quite unreactive, which is thought to be due to their completely filled electron energy levels. This makes the ions in sodium chloride inert.

(b) The occupied and empty orbitals for lithium and sodium are quite different. Therefore, the electron transitions that occur when these elements are heated would also be different, producing different colours. (It is not possible to explain or predict the specific colours in this course.)

(c) Both sodium and silver atoms can obtain a more stable electron arrangement of filled electron orbitals if one electron is removed from an atom to form a 1+ ion. A sodium ion has the electronic configuration [Ne] and a silver ion has the electronic configuration [Kr] $4d^{10}$. Since both elements form a stable 1+ ion, they should also combine with a chloride ion to produce stable compounds with similar formulas.

(d) A tin atom has the electron configuration [Kr] $5s^2 4d^{10} 5p^2$. This atom could lose its $5p^2$ electrons to form a 2+ ion or lose both the $5s^2$ electrons and the $5p^2$ electrons to form a 4+ ion. As a result, tin forms two different chloride compounds, $SnCl_2$ and $SnCl_4$.

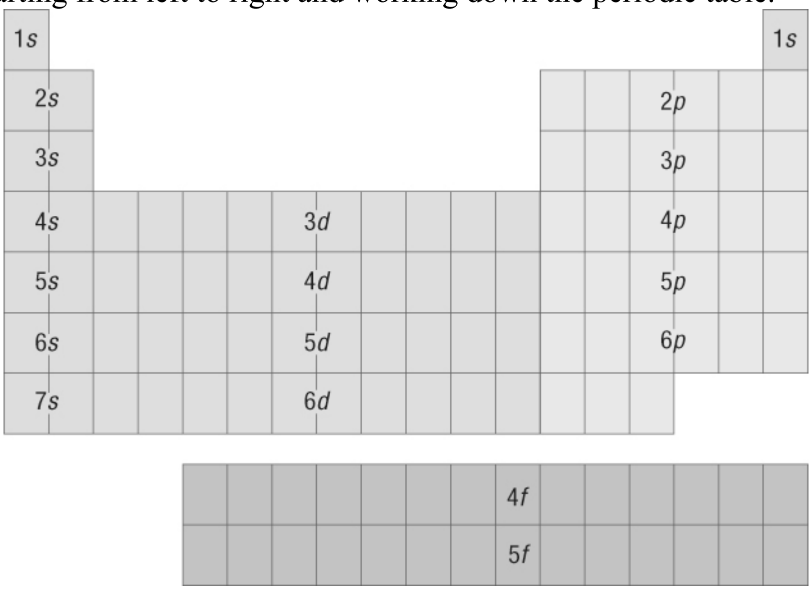
48. (a) Element 20 is the second element in Period 4. There are 2 valence electrons in element 20, found in the 4*s* orbital.

(b) O is in Period 2, the fourth element in the block where the *p* orbitals are being filled. There are 6 valence electrons in O, found in the 2s and 2*p* orbitals.

(c) Element 117 is in Period 7, the fifth element in the block where the p orbitals are being filled. There are 7 valence electrons in element 117, found in the 7s and 7*p* orbitals.

(d) In is in Period 5, the first element in the block where the *p* orbitals are being filled. There are 5 valence electrons in In, found in the 5*s* and 5*p* orbitals.

(e) Ar is in Period 3, the sixth element in the block where the *p* orbitals are being filled. There are 8 valence electrons in Ar, found in the 3*s* and 3*p* orbitals.
(f) Bi is in Period 6, the third element in the block where the *p* orbitals are being filled. There are 5 valence electrons in Bi, found in the 6*s* and 6*p* orbitals.
49. Energy level diagrams have an advantage over electron configurations because they display information about the relative energies of the orbitals. They also have a disadvantage compared to electron configurations because energy level diagrams take up a lot of space.
50. The diagram below shows how the periodic table is arranged in the order the orbitals fill, starting from left to right and working down the periodic table.



51. Li has 3 electrons. The ground state electron configuration of Li is $1s^2 2s^1$. Lithium has 1 unpaired electron, so it would be paramagnetic.
N has 7 electrons. The ground state electron configuration of N is $1s^2 2s^2 2p^3$. Since the 2*p* orbital has a capacity of 6 electrons, N has 3 unpaired electrons, so it would be paramagnetic.
Ni is the eighth element in the 3*d* block. The ground state electron configuration of Ni is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$. Since the 3*d* orbital has a capacity of 10 electrons, Ni has 2 unpaired electrons, so it would be paramagnetic.
Te is the fourth element in the 5*p* block. Since the 5*p* block has a capacity of 6 electrons, Te has 2 unpaired electrons, so it would be paramagnetic.
Ba is the second element in the 6*s* block. Since the 6*s* block has a capacity of 2 electrons, Ba has no unpaired electrons, so it would not be paramagnetic.
Hg is the tenth element in the 5*d* block. Since the 5*d* block has a capacity of 10 electrons, Hg has no unpaired electrons, so it would not be paramagnetic.
52. Answers may vary. Sample answer: Applications of quantum technologies in daily life include: laser scanners used at the grocery store checkout; quantum sensors used in making accurate atomic clocks; and semiconductors used in computers and other digital devices.
53. Lasers raise many electrons to a higher energy level by causing them to absorb energy.
$\downarrow$
They stimulate the electrons to drop to a lower energy level all at once.
$\downarrow$
The emission of a very large number of photons occurs that correlates to part of the emissions spectrum, which contains the colour of the light the laser will produce.

Analysis and Application

54. (a) If the nucleus were very large and took up most of the space in the atom then most of the alpha particles would have been deflected and only a small portion would have passed through the foil.

(b) If the alpha particles had a negative charge it may have interacted with the negatively charged electrons, diverting the alpha particles and making data collection impossible.

(c) If the nucleus of the atom were negatively charged the positively charged alpha particles would likely have crashed into the nuclei.

55. (a) Element 63 is europium, Eu. Since the ion has 3 fewer electrons than protons, it has a 3+ ionic charge. The number of neutrons is added to the number of protons to obtain the atomic mass, which is recorded at the top left of the symbol. The atomic symbol for the ion with 63 protons, 60 electrons and 88 neutrons is $^{151}_{63}Eu^{3+}$.

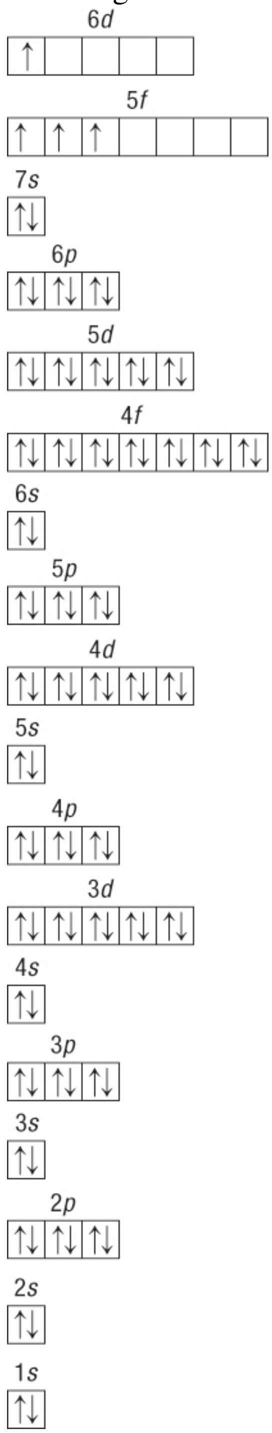
(b) Element 50 is tin, Sn. Since the ion has 2 fewer electrons than protons, it has a 2+ charge. The number of neutrons is added to the number of protons to obtain the atomic mass, which is recorded at the top left of the symbol. The atomic symbol for an ion with 50 protons, 68 neutrons, and 48 electrons is $^{118}_{50}Sn^{2+}$

56. (a) Answers may vary. Sample answer: Br^{-}, Rb^{+}, and Sr^{2+} are isoelectronic with a neutral krypton atom.

(b) When these atoms become ions, Br gains a 4*p* electron, Rb loses one 5*s* electron, and Sr loses two 5*s* electrons.

57. Since both atoms have 20 protons, they are calcium, Ca. These atoms are ^{44}Ca and ^{40}Ca isotopes; the difference in mass number is due to the different numbers of neutrons.

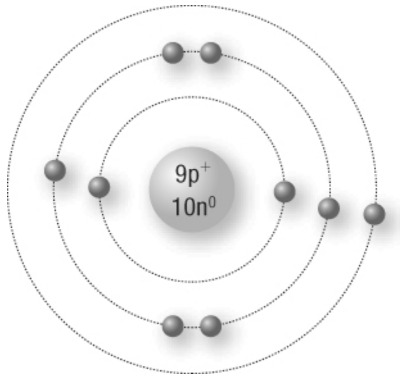
58. Uranium has 92 electrons.
Orbital diagram of uranium:



59. Chemists at the company could use emission and absorption spectroscopy to determine the types of elements and substances that are found in the substance.
60. (a) Each line in the line spectrum of the hydrogen atom represents the photon emission by an electron moving from higher energy orbitals into a lower energy orbital.

(b) A line spectrum is like a fingerprint because the energy differences between orbitals is unique for every element and produces a unique pattern that can be used to identify the element just as a fingerprint is unique and can be used to identify a person.

61.



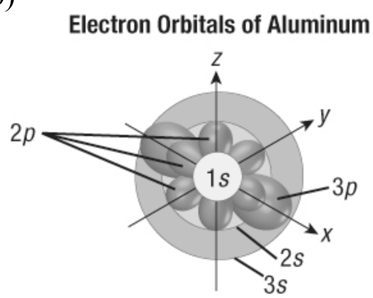
fluorine atom excited, F

62. Answers may vary. Sample Answer: If an atom is like a building where the nucleus is the ground. An orbital is like a room in that building. Some rooms are on different levels, and each level has different sizes of rooms that can hold varying numbers of people.

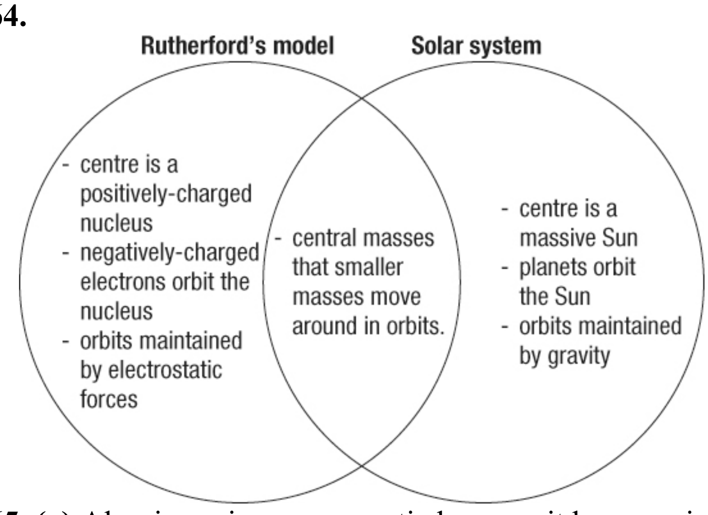
63. (a) Aluminum has 13 electrons. The electron configuration for aluminum is

Al: $1s^22s^22p^63s^23p^1$

(b)



64.



65. (a) Aluminum is paramagnetic because it has unpaired electrons in the 3p orbital, $1s^22s^22p^63s^23p^1$.

(b) Beryllium is not paramagnetic because it does not have unpaired electrons, $1s^22s^2$.

(c) Titanium is paramagnetic because it has unpaired electrons in the 3d orbital, $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$.
(d) Mercury is not paramagnetic because it does not have unpaired electrons, $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10}$.
66. Fe^{2+}: [Ar] $3d^6$ forms because iron loses 2 electrons from the $4s^2$ orbital; Fe^{3+}: [Ar]$3d^5$ forms because iron loses 2 electrons from the $4s^2$ orbital, then gains additional stability by having only one electron in each of the $3d$ orbitals.
67. (a) Electron configuration for a calcium atom in the ground state, Ca: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$
(b) Electron configuration for a calcium atom in the excited state, Ca*: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 4d^1$
(c) Electron configuration for a calcium ion, Ca^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6$
68. (a) Answers may vary. Sample answer: The electron configuration of an atom can be determined by dividing the periodic table into orbital blocks, e.g., *s* block, *p* block, *d* block, and an *f* block The electron configuration can be found by starting with the 1*s* block and adding electrons until you reach the desired element.
(b) We learned that electrons are organized into orbitals and tend to form the lowest energy configuration possible. Because of the Pauli exclusion principle we know that no two electrons can occupy the same quantum state and two electrons can share an orbital based on spin pairing. The aufbau principal explains that electrons fill orbitals starting with the lowest energy.
(c) Electron configurations are important tools for chemists because they allow predictions to be made about the reactivity of an atom and the types of ions it is likely to form.
69. (a) The atomic number for the molybdenum atom, Mo, is 42.
(b) The electron configuration for Mo using the chapter rules is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^4$.
(c) The actual electron configuration for Molybdenum is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1 4d^5$. The periodic table electron configuration is different from the predicted electron configuration because 1 electron from the 5*s* orbital went into the 4*d* orbital instead. This likely gives the atom additional stability because the 4*d* orbitals are half-filled.
70. (a) Lead can form a 2+ ion by losing 2 electrons from the 6*p* orbital. Lead can also form a 4+ ion by losing an additional 2 electrons from the 6*s* orbital.
(b) Nickel can form a 2+ ion by losing both electrons from the 4*s* orbital. Nickel can form a 3+ ion by losing three electrons from the 3*d* orbitals so that these orbitals are half-filled.
71. Potassium oxide: K_2O
Rubidium oxide: Rb_2O
Cesium oxide: Cs_2O
These were predicted using the periodic valence electron configuration of the elements. Elements form compounds with filled orbitals, so the periodic valence electron configuration of an element can be used to determine which element it is likely to form a compound with and how many of each atom will be present in one molecule of the compound.
72. Iron is element 26, so $^{53}Fe^{2+}$ has 26 protons. It has 53 – 26, or 27 neutrons. Since it is a 2+ ion, it has 26 – 2 = 24 electrons.
73. Answers may vary. Sample answer: The address system would indicate the position on the periodic table by associating the street name with the principal quantum number, *n*, e.g., *n* = 1 is first, *n* = 2 is second. The street type would be associated with the type of orbital, e.g., *s* blocks are streets, *p* blocks are paths, *d* blocks are drives, and *f* blocks are steps leading to the house. The street numbers would indicate how many other electrons are in the orbital already. So the element carbon would have the street address 2 Second Path corresponding to the valance orbital $2p^2$.

74. Laser light is monochromatic because all the electrons are being excited to similar states. The emitted light is continually absorbed and reemitted by multiple electrons of different atoms.
75. Answers may vary. Sample answer: Lasers are used in scanning devices such as bar code scanners or CD drives. Lasers are used for surgical applications such as correcting lens tissue in eyes. Lasers are also used as industrial precision cutters for sheet metal and other materials.
76. Answers may vary. Sample answer: Some laser pointers may produce high-energy lasers that can damage retinal tissue and cause eye problems if shone into a person's eye.
77. (a) I would recommend the MRI because it is a high resolution non-invasive scan that does not use ionizing radiation.
(b) MRIs are expensive and may require some time to secure a scan. X-rays do not provide a 3- dimensional image. Both X-rays and CAT scans use ionizing radiation that can cause damage to the structure of DNA molecules and lead to genetic mutations.
78. Answers may vary. Sample answer: Because nanoparticles are so small, if they were released into the air it would be difficult to control where they went. The dangers would depend on the type of particles that were released: particles related to medicine could poison individuals or cause illness, particles related to building construction may spontaneously form structures on what ever they land on.
79. Nanochemicals are added to fabric and textiles to provide stain resistance and eliminate odours.
80. Answers may vary. Posters should illustrate and describe a variety of benefits that occur when using nanoparticles, e.g., stain resistance, odour elimination, strengthening, and waterproofing.
81. Answers may vary. Sample answer: Nanotechnology could be used as a weapon by engineering nanoparticle delivery systems that release endocrine disrupters or other poisons into the waters supply of a city or territory.
82. Answers may vary. Sample answer: If a nano-cancer drug attacked the wrong cells the drug could cause pathology in the cells it attacked. This could result in a variety of conditions from liver failure to diabetes depending on the type of cell attacked.

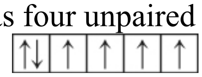
Evaluation

83. (a) J. J. Thomson applied high voltage to a partially evacuated tube with a metal electrode at each end. He observed that a ray was produced that started from the negative electrode, or cathode, and that the negative pole of an applied electric field repelled the ray. J. J. Thomson concluded that the ray was composed of a stream of negatively charged particles, which we now know to be electrons and that an atom was a sphere of matter with a uniform positive charge, in which smaller negative particles were embedded—the classic "raisin bun" analogy.
(b) Thomson's model was the first model to allow ionization of atoms because his was the first to include particles of negative charge, electrons that can be removed or added to produce ions.
(c) The figure is wrong because it contains positively charged particles that are mixed with the negatively charged electrons. Thomson's model describes a sphere of diffuse positive charge that has electrons embedded in it.
84. The photoelectric effect changed classical theory of light, which had assumed that the intensity of the light interacting with electron determined the energy of the emitted electron. Hertz's experiment demonstrated that the colour of the light was more important in determining the energy of the emitted electron.
85. (a) Answers may vary. Sample answer: The analogy is good in the sense that there are certain, fixed steps like quantized energy levels. However, the analogy fails in two ways.

Electron energy levels are not evenly spaced although stairs are, and quantum mechanics does not describe a particle such as an electron physically moving from one location to another.
(b) The computer simulation can be useful to illustrate some characteristics suggested by the quantum mechanical model if using a probability interpretation, not a wave model. Nevertheless, a computer program that is based on some simplified view of quantum mechanics cannot be used to test the theory. Only experimental evidence can provide this kind of a test.
86. (a) The student will not be able to detect the infrared spectrum without additional equipment. Perhaps he or she can use a spectrometer with an electronic visible and infrared detector.
(b) The student will not be able to pick out individual colours and should use a spectroscope to identify the mixture in the flame.
(c) The student will not be able to detect the force between the magnet and any iron present because there is not enough iron in the cereal to have a visible effect. A better design would be to monitor the mass of the cereal using a precise scale and lower the magnet near the cereal to observe any effect.
(d) The student should use pure Ca metal instead of calcium sulfate because the compounded Ca in calcium sulphate will not have unpaired electrons available to exhibit paramagnetism.
87. (a) Some elements display weak magnetic properties because they only have a single unpaired electron, e.g., Al only has one unpaired electron in its valence *p* orbital.

p- orbital filling of Al

Elements with more unpaired electrons will display stronger magnetic properties.
(b) Fe, Ni, and Co have multiple unpaired electrons, e.g., Fe
has four unpaired electrons in its valence *d* orbital.



d-orbital filling of Fe

This makes these elements more strongly magnetic.
(c) Elements with multiple unpaired electrons, such as Fe, Ni, and Cos are termed ferromagnetic and can be arranged into permanent magnets. Elements that have few unpaired electrons and have a weak attraction to magnets at an atomic level are termed paramagnetic.
88. Answers may vary. Sample answer: Medical diagnosis has benefited from an improved understanding of atomic structure through the development of various non-invasive scanning methods like MRI, X-ray, and CAT scans, through the development of new materials, and through new computer powers.
89. Answers may vary. Sample answer: Governments should continue support for research into atomic structure because advancements in the field lead to more productive technology increasing economic productivity, the discoveries have increased the quality of life by improving diagnostics and introducing new technologies, and an understanding of the atomic nature of the universe has scientific value because atomic understanding affects the scientific perspective of all things. Government should not support atomic research because funding of "pure" research is expensive; and the area does not include a profit or "payback" component, e.g., particle accelerators are multibillion-dollar projects, the practical applications are hard for laypeople to perceive, and the entire scientific community constantly lobbies for funding for research to satisfy the desire to know, whereas other research may aid humanity more directly.

90. (a)

Nanoparticles	
Advantages	Disadvantages
-advancements in medical technology -improved materials -improved process	-expensive -needs more research -potentially adverse reactions.

(b) Answers may vary. Sample answer: I think work to develop new nanoparticles should be continued because it holds a lot of promise of revolutionizing many fields like material science.

Reflect on Your Learning

91. Answers may vary. Students' answer should make connections with topics and knowledge from outside of this course. Reflection on the topic should present a curiosity about recent developments related to these topics.
92. Answers may vary. Sample answer: I gained an appreciation for the dynamic nature of electronic interactions and a new perspective that helps me understand how light and matter interact.
93. Answers may vary. Sample answer: I now see applications of quantum mechanics in a variety of optics and computational devices. Also, I can see how quantum mechanics allows plants to generate organic energy, resulting in the foundation of life.
94. Answers may vary. Students' answer should include an effort to link concepts and see the grand continuity of science.

Research

95. Answers may vary. Sample answer: Everything there is to learn about quantum mechanics has not been discovered. Though there have been many astonishing and theory-altering discoveries made throughout the 20th century and into the 21st, we have not achieved a grand unified model of the universe and the atomic models are not useful in the practical modelling of a quantum universe. In the coming years, researchers will be investigating the implications of information processing using quantum generalizations. If they are successful, useful models of the quantum universe will allow us to explore quantum mechanics to a greater extent than current experimentation will allow.
96. (a) The LeRoy radius was based on the observation that in high-energy states compounds will reach a point where the electronic wave functions of the two atoms can be neglected and the atoms interact according to "classical" mechanics.
(b) The *m*-dependent LeRoy radius is a general version of the LeRoy radius that can be used in non-S-state atomic systems.
97. Answers may vary. Student's answer should examine the physicist's career and make meaningful connections between work not mentioned in this text and the current scientific understanding of quantum mechanics.
98. Answers may vary. Students' answer may include that Bose-Einstein condensate is special because all the atoms are the same, giving scientists more control over their activities. Examples of applications may be the use of Bose-Einstein condensate in ultra sensitive measurement instruments.

99. Answers may vary. Students' answer might include information about real technologies such as the following: Ion cannons are a type of particle cannon that shoot charged particles. Scientists can fire beams of charged particles in a stream. However the ions are charged and interact with charged particles in the atmosphere that cause the beam to have an unpredictable firing pattern.
100. Answers may vary. Sample answer: Nanotechnologies must be evaluated and approved for use in medical applications and for use in environments where a risk of exposure would cause physical harm to individuals using or working with such technologies. Approval must be sought through a new branch of Health Canada, which will outline acceptable risk and applications. Upon a new technology being approved, companies will have to apply for licensing through the Canadian Food Inspection Agency on a case-by-case basis and will need to renew the license every 2 years; all license details are subject to review on a case-by-case basis every 5 years.
101. Answers may vary. Students' answer may mention that infrared spectroscopy can be used to identify unknown substances found at a crime scene or to match evidence to a sample from a suspect. Answers should include references to actual cases in which infrared spectroscopy was used in a forensic investigation.
102. Answers may vary. Sample answer: Mass spectrometry advances our understanding of the structure of chemicals by investigating the fractioning patterns that occur when a chemical is bombarded with ionizing radiation. Mass spectrometers have allowed us to identify novel natural products and processes associated with medical benefits, e.g., peptide sequencing techniques. Mass spectrometers can be used for isotope studies.