CHAPTER 3 SELF-QUIZ

(Page 219)

1. False: The region in space where an electron is most likely to be found is called an orbital.
2. False: Electron configurations are often condensed by writing them using the previous noble-gas core as a starting point. In this system, [Ar] $3d^34s^2$ would represent vanadium.
3. False: The *f* sublevel is thought to have seven orbitals.
4. True
5. True
6. False: Rutherford knew the nucleus had to be very small because very few alpha particles were deflected when fired through a layer of gold atoms.
7. False: Electrons shifting to lower levels, according to Bohr, would account for emission spectra.
8. True
9. True
10. True
11. False: The Pauli exclusion principle states that no more than two electrons may occupy the same orbital, and that they must have opposite spins.
12. (b)
13. (d)
14. (a)
15. (c)
16. (c)
17. (b)
18. (b)
19. (d)

CHAPTER 3 REVIEW

(Page 220)

Understanding Concepts

1. (a) Rutherford interpreted the deflection of alpha particles travelling through a thin foil to mean that atoms had tiny, massive nuclei.
   (b) Bohr interpreted the bright-line spectrum of hydrogen to mean that electrons exist only at specific energy levels.
2. The Rutherford model explained nothing about the nature of electrons. The Bohr model did not make acceptable predictions for atoms larger than hydrogen.
3. Orbit and orbital are terms that both refer to electrons within atoms. An orbit is a simplistic representation of a small particle in a circular path, used in the Bohr–Rutherford model. An orbital is a probability density for a wave function that "occupies" a volume of space, used in the visualizing of the quantum mechanical model.
4. The main kind of experimental work used to develop the concepts of quantum mechanics was spectroscopy, specifically the analysis of bright-line spectra.
5. (a) Quantum is a term referring to a smallest unit or part of something.
   (b) Orbital is a term describing a volume of space that is "occupied" by an electron.
   (c) Electron probability density describes the calculated likelihood of locating an electron at any point within a given volume of space.
   (d) Photon is a quantum of electromagnetic energy— a smallest "piece" or "package" of light.
6.

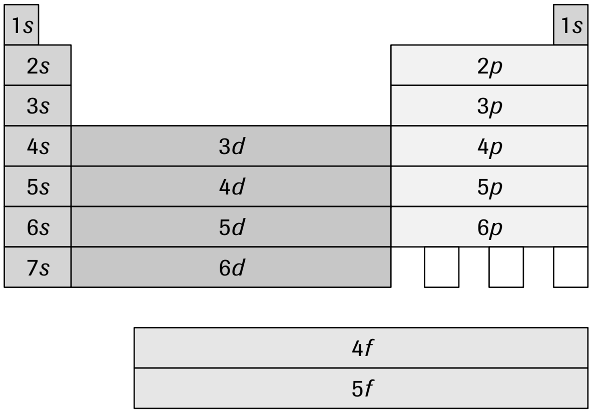
2*p* $\underline{\uparrow\downarrow}$ $\underline{\uparrow\ }$ $\underline{\uparrow\ }$
2*s* $\underline{\uparrow\downarrow}$

1*s* $\underline{\uparrow\downarrow}$
oxygen atom, O

(a) the main/principal energy level is the first number: 1,2, ...
(b) the energy sublevel (subshell) is the letter following: *s*, *p*, ...
(c) the orbital orientation (*x*, *y*, or *z* axis) is the respective __ line
(d) the spin of the electron (up or down) is the arrow: $\uparrow$ or $\downarrow$

7. The idea of electron spin comes from observations of line spectra influenced by a magnetic field as well as evidence from different kinds of magnetism.

Copyright © 2003 Nelson

8. 

9. According to quantum mechanics, an element's properties relate to its position in the periodic table because its position is directly related to the orbital configuration of its atoms.

10.

potassium ion, K^+	sulfide ion, S^{2-}
3p ↑↓ ↑↓ ↑↓	3p ↑↓ ↑↓ ↑↓
3s ↑↓	3s ↑↓
2p ↑↓ ↑↓ ↑↓	2p ↑↓ ↑↓ ↑↓
2s ↑↓	2s ↑↓
1s ↑↓	1s ↑↓

An atom of the noble-gas argon, Ar, has the same electron orbital energy-level diagram as do these two ions.

11. (a) All of the alkali metals are soft, metallic solids with low melting and boiling points. They have high chemical reactivity, readily forming +1 ions.
   (b) We explain properties, using their electron configurations. All have a single *s* electron in the highest energy orbital, which is easily removed by the attraction of other atoms. The nearly empty valence shell creates the metallic properties—conductivity, shininess, and so on.
12. (a) $1s^2\ 2s^2\ 2p^6\ 3s^2$
   (b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
   (c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
   (d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^1$
   (e) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^1\ 4f^{14}\ 5d^{10}$
13. (a) [Kr] $5s^2\ 4d^1$
   (b) [Kr] $5s^2\ 4d^{10}\ 5p^3$
   (c) [Xe] Ba^{2+}
14. Aluminum and titanium should be paramagnetic because these two atoms have unpaired electrons. Beryllium and mercury have atoms with filled orbitals.
15. (a) arsenic atom, As
   (b) rubidium ion, Rb^+
   (c) iodide ion, I^-
   (d) holmium atom, Ho
16. (a) $2e^-$
   (b) $8e^-$
   (c) $18e^-$
   (d) $32e^-$
17. A $2p_x$ orbital is identical to the $2p_y$ and $2p_z$ orbitals, except for orientation. It lies at 90° to the other two.
18. (a) Max Planck explained that electromagnetic energy could be released only in smallest given amounts, which he called "quanta," with the amount determined by the frequency of the radiation.
   (b) Louis de Broglie suggested that particles could have properties and characteristics of waves, and that this effect would be significant for tiny, fast-moving particles like electrons.

Copyright © 2003 Nelson

(c) Albert Einstein proposed that light (electromagnetic energy) actually travels as quanta, which he called “photons,” and he used this concept to explain the evidence of the phenomenon called the photoelectric effect.
(d) Werner Heisenberg hypothesized that electron behaviour cannot ever be exactly described, but only discussed as a probability system, within limits imposed by his “uncertainty principle.”
(e) Erwin Schrödinger explained electron behaviour within the atom structure as a wave phenomenon, described by a wave mechanical equation.

19. (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 same electron configuration as a noble-gas atom. The noble gases are quite unreactive, which is thought to be due to their completely filled electron energy levels.
(b) The occupied and empty energy levels for lithium and sodium are quite different. Therefore, electron transitions would 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 and it forms a 1+ ion. A sodium ion becomes [Ne] and a silver ion becomes [Kr] $4d^{10}$. Combined with a chloride ion (1–), the formulas are therefore similar.
(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.

Applying Inquiry Skills

20. Evidence is the basis of the scientific process. Careful evaluation of evidence is crucial, since poor evidence may lead to incorrect support of a theory, law, or generalization. Good-quality evidence can also show an existing concept to be false.
21. Useful techniques would likely include spectroscopy—possibly visible, ultraviolet, and/or infrared.
22. (a) The design is basically good but you cannot visually observe the infrared spectrum using a hand-held spectroscope. It is also questionable whether the quality of a hand-held spectroscope will be adequate. The spectrum should be photographed with a good-quality spectroscope and suitable photographic film.
(b) This design is inadequate to identify the components of a mixture. A flame test could suggest some components, particularly certain metal ions. A qualitative analysis scheme would be necessary to identify other components.
(c) A better design would be to crush the cereal and insert the magnet directly into the cereal. This would be more likely to attract any small bits of iron present.
(d) The calcium in calcium sulfate is in the form of calcium ions, not calcium metal. The test with a strong magnet should be done on calcium metal.
23. (a) 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 and quantum mechanics has no picture of 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 mechanics if using a probability interpretation, not a wave model. Nevertheless, the 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.

Making Connections

24. (a) Some examples of benefits to medical diagnosis might include light spectroscopy, which is used to identify substances present in the body; MRI scanning, which allows examination of the interior of the body; and lasers, which allow illumination and examination of the body interior through fibre-optic devices.
(b) Some possible answers and perspectives might include:
Economically, government funding of “pure” research is expensive; and the area does not include a profit or “payback” component.
Socially, the benefits to society from increased knowledge inevitably advance our standard of living in our understanding of the atom.
Scientifically, the entire scientific community constantly lobbies for funding for research to satisfy the *desire to know*.
25. (a) Rutherford won the Nobel Prize for Chemistry in 1908, for the concept of the nuclear atom, for the theory of radioactive disintegration, and for determining the nature of the alpha particle. Soddy won the Nobel Prize for Chemistry in 1921, for the discovery of (explaining the nature of) isotopes of elements.
(b) Every aspect of modern technological society that has to do with radioactivity or nuclear energy in any form is to some extent directly dependent on work done by Rutherford and Soddy. This includes nuclear power generators, radioisotope uses in industry, research, analysis, and medicine, and our understanding of geologic processes, among many others.

Copyright © 2003 Nelson