

**Atomic Structure & Theory**

1. Can the number of protons in an element ever change?

- A. No, protons and neutrons are bound together in atomic nuclei, and neither can change.
  - B. Yes, isotopes of the same element have different numbers of protons.
  - C. No, if the number of protons changes, the element changes.
  - D. Yes, when different elements bond, they can share or transfer protons.
- 

**Atomic Structure & Theory**

2. All matter, both living and nonliving, is made up of tiny particles called \_\_\_\_\_.

- A. cells
  - B. atoms
  - C. dust
  - D. bacteria
- 

**The Periodic Table**

4. Which of the following is true of all the elements in group 2 on the periodic table?

- I. They are all metals.
  - II. They all have two electrons in their outermost shell.
  - III. They all tend to lose electrons and become positive ions.
  - IV. They all have similar chemical properties.
- A. II, III, and IV only
  - B. I, III, and IV only
  - C. I, II, III, and IV
  - D. III and IV only
-

## Molecular Interactions

6. An atom can best be described as
- A. the smallest part of a compound that retains the chemical and physical properties of that compound.
  - B. a substance that is composed of two elements linked by chemical bonds.
  - C. an element that is composed of charged particles linked by ionic bonds.
  - D. the smallest part of an element that cannot be broken down by ordinary chemical means.
- 

## The Periodic Table

7. Helium is placed in group 18 on the periodic table because
- A. it is a metal.
  - B. it has a full outer shell of electrons.
  - C. it has a valence of eight.
  - D. it is highly reactive.
- 

## Lab Tools & Safety

8. Doug wants to find out how increasing a gas's pressure can affect the gas's temperature. What tool will Doug need in order to conduct his experiment?
- A. light microscope
  - B. thermometer
  - C. spring scale
  - D. treadmill
- 

## Molecular Interactions

9. Based on the bonding between molecules, which of the following substances would be expected to have the lowest melting point?
- A. Cu

- B.  $\text{Ca}(\text{NO}_3)_2$
  - C.  $\text{C}_{12}\text{H}_{22}\text{O}_{11}$
  - D.  $\text{SiO}_2$
- 

### Atomic Structure & Theory

10. A neutral atom always contains the same number of

- A. protons and electrons.
  - B. protons, electrons, and neutrons.
  - C. electrons and neutrons.
  - D. protons and neutrons.
- 

### The Periodic Table

12. The reactivity of elements can be predicted based on the position of an element in the periodic table. Based on the periodic table, which of the following elements would be expected to be the least reactive?

- A. fluorine (F)
  - B. iodine (I)
  - C. chlorine (Cl)
  - D. bromine (Br)
- 

### Atomic Structure & Theory

13. Which of the following subatomic particles are closest in mass?

- A. proton and electron
  - B. proton and neutron
  - C. electron and ion
  - D. neutron and electron
- 

### Chemical Bonding

14. Metals are malleable, which means that they can be hammered into thin sheets. Which of the following statements best explains why this is possible?

- A. The arrangement of the atoms in a lattice allows stress to pass through the metal solid.
  - B. The atoms are not in fixed locations so layers of atoms can slide past each other.
  - C. The metallic bonding creates a magnetic force which makes the metal soft and flexible.
  - D. The sea of electrons surrounding the metal atoms protects the metal atoms from the force.
- 

### Scientific Inquiry

16. A scientist discovered a new antibiotic and wanted to know if it would be effective against group A *Streptococcus* bacteria. He designed a test experiment in a lab with ten different cultures of the bacteria. He introduced the antibiotic into five of the cultures, leaving the other five to grow without it. He recorded observations every three hours for a week.

What is the independent variable in this experiment?

- A. the reaction of the bacteria to the antibiotic
  - B. the total number of bacteria cultures
  - C. the presence of the *Streptococcus* bacteria
  - D. the presence of the new antibiotic
- 

### Electron Configuration

17. What happens when a hydrogen atom changes from the excited state to the ground state?

- A. The excess energy is released as light.
  - B. The excess energy is released as heat.
  - C. The excess energy is absorbed as light.
  - D. The excess energy is absorbed as heat.
- 

### The Periodic Table

19. Which of the following substances is an element?

- A. methane (CH<sub>4</sub>)
- B. carbon (C)
- C. brass (Cu + Zn)

- D. water (H<sub>2</sub>O)
- 

### The Periodic Table

20. Which of the following lists four elements from greatest electronegativity to least electronegativity?

- A. Ba, Fe, Al, He  
 B. Rn, Ge, Si, Ar  
 C. Fe, Co, Ni, Zn  
 D. Cl, Si, Mg, Na
- 

### The Periodic Table

21. The atomic number of an atom is always equal to the number of \_\_\_\_\_ in an atom.

- A. nucleons  
 B. protons  
 C. electrons  
 D. neutrons
- 

### Scientific Inquiry

22. Which of the following describes a way in which mathematics can be used in a scientific investigation?

- A. Jake graphs the results of his science experiment and determines the slope of the trend line.  
 B. Sarah determines the correct number of significant figures to report the mass of her sample.  
 C. Kayla calculates the molarity of the substance that she is using in her experiment.  
 D. all of these
- 

### Lab Tools & Safety

24. Strong acids are chemicals that can burn hands, clothes, and anything else with which they come into contact. When creating a solution of a strong acid and water, what order should the ingredients be added?

- A. Carefully pour the acid and the water into a beaker at the same time.
  - B. Carefully pour the acid into a beaker and then add water.
  - C. Carefully pour the water into the bottle of acid.
  - D. Carefully pour the water in the beaker and then cautiously add the acid.
- 

### Scientific Inquiry

25. Dr. Morris hypothesizes that if a new drug is given to rabbits, then the drug will increase their metabolic rates and cause them to lose weight. He designs an experiment to test his hypothesis.

Dr. Morris separates six rabbits into two equal groups and weighs them all individually. He gives the experimental group of rabbits the drug but does not give it to the control group. He keeps everything else about the rabbits' living environment the same, including the amount of food and water provided.

After three weeks, Dr. Morris reweighs the rabbits to see if they have lost weight. His results are shown in the table below.

Group	Original Rabbit Weight	Rabbit Weight After 3 Weeks
Control	2.3 lbs	2.4 lbs
Control	2.8 lbs	2.7 lbs
Control	3.5 lbs	3.7 lbs
Experimental	2.5 lbs	2.8 lbs
Experimental	3.4 lbs	3.9 lbs
Experimental	2.9 lbs	3.1 lbs

Based on the table, was Dr. Morris's hypothesis supported by his data?

- A. No; the data in the table does not support Dr. Morris's hypothesis.
  - B. No; Dr. Morris should not have used a control group in his experiment.
  - C. Yes; Dr. Morris designed the experiment correctly so his hypothesis must be correct.
  - D. Yes; the data in the table supports Dr. Morris's hypothesis.
- 

### Atomic Structure & Theory

27. Which of the following is true about the structure of an atom?

- A. Electrons, neutrons, and protons are the smallest structures in an atom and cannot be broken down into smaller parts.
  - B. Atoms are composed of tiny cells that make up all forms of matter.
  - C. An atom is not composed of smaller parts and cannot be broken down into smaller constituents.
  - D. Electrons, neutrons, and protons are made up of even smaller constituents, such as quarks and gluons.
- 

### Molecular Interactions

30. An atom has 33 protons, 41 neutrons, and 36 electrons. What is a correct description of the atom?

- A. an atom with an atomic mass of 33
  - B. an ion with a net charge of -3
  - C. an atom with an atomic mass of 36
  - D. an ion with a net charge of +3
- 

### Electron Configuration

33. When the electron of a hydrogen atom is in its lowest energy orbit, what is the state of the atom?

- A. minimal state
  - B. neutral state
  - C. ground state
  - D. negative state
- 

### Chemical Bonding

34. An atom's outermost electron arrangement determines how it interacts with other atoms. Which of the following atomic structures would be most likely to form an ionic bond?

- A. carbon with four outer electrons
  - B. fluorine with seven outer electrons
  - C. helium with two outer electrons
  - D. neon with eight outer electrons
- 

### Molecular Interactions

35. Which statement explains why metals are good conductors of electricity?

- A. Valence electrons cannot travel between the metal atoms.
  - B. Valence electrons can easily travel between the metal atoms.
  - C. Protons can easily travel between the metal atoms.
  - D. Protons cannot travel between the metal atoms.
- 

### Chemical Bonding

37. If a neutral atom gains electrons, what type of particle is formed?

- A. a negatively charged ion
  - B. a new element
  - C. a positively charged ion
  - D. an isotope
- 

### Chemical Bonding

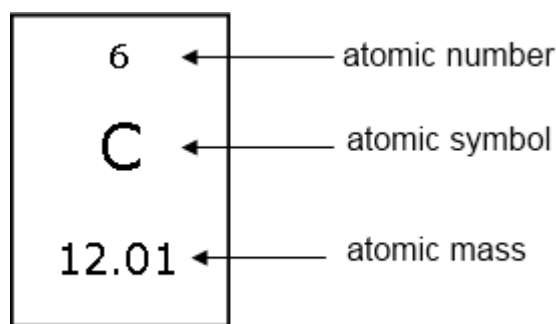
38. In the process of ionic bonding



- A. electrons are transferred from one atom to another.
  - B. protons are transferred from one atom to another.
  - C. electrons are shared between atoms.
  - D. protons are shared between atoms.
- 

### Atomic Structure & Theory

40. The image below shows the square that represents carbon on the periodic table.



Which of the following pieces of information given in this square is originally based on the research done by John Dalton?

- A. atomic mass
  - B. atomic number
  - C. atomic number and symbol
  - D. atomic symbol
- 

### Scientific Inquiry

41. Dr. Grey discovers a new drug that she hypothesizes will increase fat storage in rabbits. She designs an experiment to test her hypothesis.

Dr. Grey separates twelve rabbits into two equal groups and measures their body fat individually. She gives one group of rabbits the drug but does not give the drug to the other group. She keeps everything else about the rabbits' living environment the same, including the amount of water and food provided. After a month, she measures the body fat of the rabbits in both groups.

What is the control in Dr. Grey's experiment?

- A. the group of rabbits that are given the drug
- B. the group of rabbits that are not given the drug

- C. the quantity of experimental drug used
  - D. the body fat of the rabbits
- 

### Lab Tools & Safety

42. During a lab experiment, Mandy and her lab partner work with corrosive chemical substances. What is the proper way to dispose of these chemicals after the lab is completed?

- A. The chemicals should be poured in the trash can.
  - B. The chemicals should be mixed together and left unmarked in the lab area.
  - C. The chemicals should be washed down the sink with plenty of water.
  - D. The chemicals should be placed in marked waste containers.
- 

### Atomic Structure & Theory

43. The nucleus of an atom contains positively charged particles, called protons, and neutral particles, called neutrons.

How is the nucleus of an atom held together?

- A. Electric forces exist between the protons and neutrons in a nucleus, and the particles are attracted to one another by these electric forces.
  - B. Electric forces exist between the protons of the nucleus, and the protons are attracted to one another by these electric forces.
  - C. A strong force exists between the particles in a nucleus, and this force is usually stronger than the electric forces that would pull them apart.
  - D. A strong force exists between the particles of the nucleus, but this force is always much weaker than the electric forces that would pull them apart.
- 

### Atomic Structure & Theory

44. An atom is held together by

- A. electric forces between the nucleus and the electrons.
  - B. mechanical forces between the electrons of the atom.
  - C. electric forces between the protons and the neutrons.
  - D. mechanical forces between the protons and the nucleus.
- 

### Electron Configuration

45. When an electron moves up to a higher orbit, a quantum of light energy is absorbed. This quantum of light energy is also known as a(n) \_\_\_\_\_.

- A. alpha particle
  - B. neutron
  - C. quark
  - D. photon
- 

### Chemical Bonding

46. Sometimes a group of covalently bonded atoms can act like a single atom when combining with other atoms. These covalently bonded groups possess a charge and usually form ionic bonds with other atoms. These groups are otherwise known as...

- A. valence shell electrons.
  - B. polyprotic acids.
  - C. alpha particles.
  - D. polyatomic ions.
- 

### Scientific Inquiry

48. A scientific explanation for a natural phenomenon should be which of the following?

- I. logically consistent
  - II. based on previous scientific knowledge
  - III. supported by scientific evidence
  - IV. never questioned or modified
- A. I and IV only

- B. I, II, III, and IV
  - C. I, II, and III only
  - D. II only
- 

### Electron Configuration

49. According to Bohr's model, what can be said of the amount of energy that an electron absorbs when it is excited compared to the amount of energy that it releases when it returns to ground state?

- A. There is no relationship between the amount of energy that is absorbed and the amount of energy that is released.
  - B. The amount of energy that is absorbed is less than the amount of energy that is released.
  - C. The amount of energy that is absorbed is the same as the amount of energy that is released.
  - D. The amount of energy that is absorbed is greater than the amount of energy that is released.
- 

### Molecular Interactions

50. Diamond is a hard substance with a very high melting point. What type of solid is diamond?

- A. ionic
  - B. metallic
  - C. covalent-network
  - D. molecular
- 

### The Periodic Table

51. The atomic mass of an element is shown below.



How many neutrons does this element contain?

- A. 16
  - B. 10
  - C. 8
  - D. 9
- 

### Atomic Structure & Theory

53. In the electron cloud model, if you begin at the electron shell closest to the nucleus of an atom and move out, what is the number of electrons that each energy level or electron shell needs to fill the first four electron shells?

- A. 2, 8, 18, 32
  - B. 2, 6, 10, 14
  - C. 2, 8, 6, 2
  - D. 8, 8, 8, 8
- 

### Electron Configuration

55. Which of the following would have to happen in order for an electron in energy level 3 to move to energy level 4?

- A. The atom would have to absorb energy.
  - B. The atom would have to destroy energy.
  - C. The atom would have to create energy.
  - D. The atom would have to release energy.
- 

### Chemical Bonding

56. Common table salt has a chemical formula of NaCl. Please explain how the chemical reaction that forms table salt occurs.

- A. The negatively charged sodium atom attracts the positively charged chlorine atom.
  - B. Sodium donates an electron to chlorine.
  - C. The sodium atom takes an electron from the chlorine atom.
  - D. Chlorine donates an electron to sodium.
- 

### The Periodic Table

58. If an element is located in the middle of the periodic table, into what category would it most likely fit?

- A. nonmetal
  - B. metal
  - C. metalloid
  - D. noble gases
- 

### Chemical Bonding

59. Which of the following pairs of elements is most likely to form an ionic bond?

- A. phosphorous and bromine
  - B. carbon and chlorine
  - C. silicon and oxygen
  - D. potassium and chlorine
- 

### Lab Tools & Safety

62. Which of these best describes when splash goggles should be worn?

- A. when mixing acids with bases
  - B. when mixing any two liquids
  - C. when mixing highly reactive liquids
  - D. when mixing toxic liquids
- 

### Scientific Inquiry

**63.** Cindy hypothesizes that if she adds salt to a weak acid, then its pH will be lowered. She develops the following experiment to test her hypothesis. Which of the following steps could compromise the validity of her experiment?

1. Fill two beakers with 50 mL of the same weak acid.
2. Add salt to the first beaker.
3. Add water to the second beaker.
4. Measure the pH of the solution in each beaker.

- A. step 2
  - B. step 3
  - C. step 1
  - D. step 4
- 

### Scientific Inquiry

**64.** Which of the following is true about scientific inquiries?

- A. Scientific inquiries are never based on previous scientific research and data.
  - B. Scientific inquiries usually do not require accuracy or precision when gathering data.
  - C. Scientific inquiries never require any mathematical knowledge or the application of mathematics.
  - D. Scientific inquiries are usually guided by previous scientific principles and knowledge.
- 

### The Periodic Table

**65.** The atomic number of an element is equal to the number of protons that the element contains.

What is the atomic number of the element hydrogen?

- A. 1
  - B. 1.008
  - C. +1
  - D. IA
- 

### Electron Configuration

66. Atomic emission spectra are produced when the light emitted by an element passes through a prism. Which of the following statements is true regarding these spectra?

- A. All elements produce the same atomic spectra.
  - B. Elements produce continuous spectra.
  - C. Elements produce spectra with only a few distinct lines.
  - D. It is impossible to see atomic emission spectra.
- 

### Scientific Inquiry

67. The results of historical and current scientific research significantly influence which of the following?

- I. the results of new scientific research
- II. the design of new scientific investigations
- III. the evaluation of new scientific theories
- IV. the precision of new scientific data

- A. I, II, III, and IV
  - B. II and III only
  - C. I only
  - D. I, II, and IV only
- 

### The Periodic Table

68. An element forms an ion with a charge of +3. To which of the following families does the element most likely belong?

- A. transition metals
  - B. halogens
  - C. alkaline earth metals
  - D. noble gases
- 

### Chemical Bonding

71. Compounds are formed when the atoms of two or more elements are chemically combined.

What type of bond is formed if atoms donate electrons to other atoms when the elements are combined?



- A. metallic bond
  - B. hydrogen bond
  - C. ionic bond
  - D. covalent bond
- 

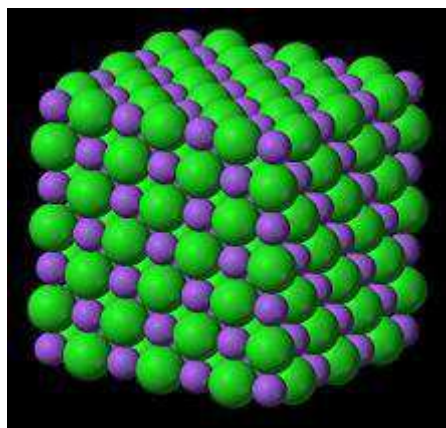
### The Periodic Table

72. What do all the elements in group 2 of the periodic table have in common?

- A. They all have the same number of protons.
  - B. They all have the same number of valence electrons.
  - C. They all have the same atomic number.
  - D. They all have the same number of electron shells.
- 

### Molecular Interactions

74. The following diagram represents a crystal of sodium chloride (table salt).



If the large green spheres represent chloride ions ( $\text{Cl}^-$ ) and the small purple spheres represent sodium ions ( $\text{Na}^+$ ), what type of bonding occurs in sodium chloride crystals?

- A. metallic bonding
  - B. ionic bonding
  - C. covalent bonding
  - D. nonmetallic bonding
- 

### Lab Tools & Safety

77. Gwen would like to find out the volume of a metal screw. What tool could Gwen use in order to measure the screw's volume?

- A. balance
  - B. graduated cylinder
  - C. eyedropper
  - D. spring scale
- 

### Atomic Structure & Theory

78. Isotopes are atoms of the same element that have a different number of \_\_\_\_\_.

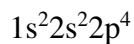
- A. nuclides
  - B. nucleoles
  - C. protons
  - D. neutrons
- 

### Electron Configuration

Electrons always fill orbitals in the same order. Each *s* orbital holds 2 electrons, each set of *p* orbitals holds 6 electrons, each set of *d* orbitals holds 10 electrons, and each set of *f* orbitals holds 14 electrons. The order in which orbitals are filled, from first to last, is:

1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d 7p

79. To what element does the following electron configuration correspond?



- A. fluorine: 9 electrons
  - B. oxygen: 8 electrons
  - C. sulfur: 16 electrons
  - D. neon: 10 electrons
- 

### Atomic Structure & Theory

80. A neutral atom could become a positively-charged particle through the loss of

- A. neutrons.
  - B. ions.
  - C. protons.
  - D. electrons.
- 

### Electron Configuration

81. The way in which one atom interacts with another atom is mostly influenced by the configuration of the

- A. electrons closest to the nucleus.
  - B. electrons farthest from the nucleus.
  - C. protons in the center of the nucleus.
  - D. protons on the outer edge of the nucleus.
- 

### Chemical Bonding

83. Polyatomic ions are a group of

- A. ionically bonded atoms that dissociate when dissolved in water or an acid.
  - B. covalently bonded atoms that act like a single atom when combining with other atoms.
  - C. elements that have a similar number of protons but a varying number of neutrons.
  - D. elements that have a similar number of neutrons but a varying number of protons.
- 

### Atomic Structure & Theory

84. An atom is composed of a nucleus surrounded by electron clouds of varying sizes. The nucleus contains protons and neutrons, while electrons move about the nucleus in the electron clouds.

Which of the following statements is also true of atoms?

- A. Even though the nucleus of an atom is very small, it contains most of the atom's mass.
- B. The nucleus of an atom is very large, and it contains most of the atom's mass.

- C. The nucleus of an atom is very small, so most of the atom's mass is in the electron clouds.
  - D. Even though the nucleus of an atom is very large, most of the atom's mass is in the electron clouds.
- 

### Nature of Science

**85.** A scientist doing research on plant hormones wants to go to a conference to present her data in one month. She rushes through her research, and is happy to see that her data matches her original hypothesis. However, because she rushed, all the experimental controls were not in place. What should the scientist do?

- A. Publish her findings and don't discuss the problems about the controls.
  - B. Ignore the problem with the controls and continue the experiments as is.
  - C. Hold off on the presentation of data until the experiments can be done correctly.
  - D. Present her findings at the conference.
- 

### Chemical Bonding

**87.** Which of the following is a common physical property of ionic compounds?

- A. conduct electricity when solid
  - B. high melting point
  - C. magnetic
  - D. insoluble in water
- 

### Atomic Structure & Theory

**90.** If an atom has 5 electrons outside of its nucleus, which combination of protons and neutrons would result in a neutral atom?

- A. 1 proton, 3 neutrons
  - B. 5 protons, 5 neutrons
  - C. 10 protons, 10 neutrons
  - D. 1 proton, 1 neutron
- 

### The Periodic Table

91. Most main group elements found within the same family on the periodic table tend to have

- A. the same electron affinity.
  - B. the same number of valence electrons.
  - C. the same atomic radius.
  - D. the same chemical activity.
- 

### Electron Configuration

93. Which electron orbiting the nucleus will have the lowest energy?

- A. the one farthest from the nucleus
  - B. the one moving toward the nucleus
  - C. the one closest to the nucleus
  - D. the one moving away from the nucleus
- 

### Chemical Bonding

95. Covalent bonds tend to form between \_\_\_\_\_.

- A. a metal and a metal
  - B. two or more nonmetals
  - C. a hydrogen atom and a nonmetal
  - D. a metal and a nonmetal
- 

### Electron Configuration

96.



The diagram above shows the line spectrum of hydrogen. The wavelength of each line is shown at the top of the line. What does each line of the spectrum represent?

- A. the energy of a photon
  - B. the number of electrons
  - C. the color of the atom
  - D. the distance between orbits
- 

### Molecular Interactions

98. The bonding of metals is based on the valence electrons of the metals that are delocalized throughout the solid. The \_\_\_\_\_ of the electrons explains why metals are good conductors of electricity.

- A. energy
  - B. mobility
  - C. charge
  - D. stability
- 

### Molecular Interactions

99. What is the difference between the Lewis model and the valence-shell electron pair repulsion (VSEPR) model?

- A. Only the VSEPR model can be used to explain intermolecular forces.
  - B. Only the VSEPR model shows the geometric shape of a molecule.
  - C. Only the Lewis model takes into account unbonded electrons.
  - D. Only the Lewis model shows the covalent bonds in a molecule.
- 

## Answers

1. C
2. B
3. A
4. C
5. A
6. D
7. B
8. B

9. C
10. A
11. C
12. B
13. B
14. B
15. A
16. D
17. A
18. D
19. B
20. D
21. B
22. D
23. A
24. D
25. A
26. D
27. D
28. B
29. D
30. B
31. B
32. C
33. C
34. B
35. B
36. D
37. A
38. A
39. B
40. A
41. B
42. D
43. C
44. A
45. D
46. D
47. B
48. C
49. C
50. C
51. C
52. B
53. A
54. B

- 55. A
- 56. B
- 57. D
- 58. B
- 59. D
- 60. B
- 61. C
- 62. B
- 63. B
- 64. D
- 65. A
- 66. C
- 67. B
- 68. A
- 69. D
- 70. A
- 71. C
- 72. B
- 73. C
- 74. B
- 75. D
- 76. A
- 77. B
- 78. D
- 79. B
- 80. D
- 81. B
- 82. A
- 83. B
- 84. A
- 85. C
- 86. A
- 87. B
- 88. D
- 89. B
- 90. B
- 91. B
- 92. C
- 93. C
- 94. A
- 95. B
- 96. A
- 97. A
- 98. B
- 99. B
- 100. A



# Explanations

1. The number of electrons in an element can change when it forms an ion or chemical bond. The number of neutrons in an element can change when it forms an isotope or goes through radioactive decay. However, **the number of protons in an element never changes**.

This is demonstrated by the fact that the periodic table is arranged in order of the elements' numbers of protons, otherwise known as the elements' atomic numbers. If the number of protons changes, the element changes.

2. All matter, both living and nonliving, is made up of tiny particles called **atoms**.

Living organisms, including bacteria, are made up of small parts called cells, but nonliving things do not contain cells.

Cells are made up of trillions of atoms.

3. The electron in orbit 4 can return directly to orbit 1. It can also move from orbit 4 to 3 and then to 1, from 4 to 2 and then to 1, or from 4 to 3 to 2 to 1. This shows that there are four possible return paths for the electron.

4. Elements on the periodic table are arranged into vertical columns, known as groups or families, based on similarities in certain chemical and physical properties.

All of the elements in group 2, the alkaline earth metals, have the same number of electrons in their outermost shell (i.e., valence = 2). They are all fairly reactive and tend to lose electrons and become positive ions. Finally, they are all metals.

5. Science utilizes **logical arguments**, empirical standards, and skepticism to determine the best explanations for the natural world. Science is based upon facts only, and nothing in science should be accepted until it is proven correct.

6. All matter is made up of atoms. An atom can best be described as **the smallest part of an element that cannot be broken down by ordinary chemical means**. Atoms of a particular element possess all the physical and chemical properties of that element.

7. Group 18 on the periodic table is also known as the *noble gases*. These nonmetallic elements are grouped together because they all have **a full outer shell of electrons** and are thus nonreactive.

Helium differs slightly from the other noble gases in that it only has 2 electrons in its outermost shell (i.e., valence = 2 instead of 8). However, since helium only has one electron shell, which can hold a maximum of 2 electrons, it still has a full outer shell.

8. A thermometer is an instrument for measuring temperature. Typical thermometers have a graduated glass tube with a bulb containing a liquid, such as mercury or alcohol, which expands and rises in the tube as the temperature increases.

9. The melting point of a substance is determined by the type of attractions between molecules. Molecular solids have the lowest melting points.  $C_{12}H_{22}O_{11}$  is the only substance listed that is a molecular solid, so it would be expected to have the lowest melting point.  $SiO_2$  is a covalent-network solid,  $Ca(NO_3)_2$  is an ionic solid, and Cu is a metallic solid.

10. Neutral atoms have no charge. So, in order to be neutral, an atom must possess the same number of positively-charged **protons** and negatively-charged **electrons**.

Since neutrons have no charge, the number of neutrons has no effect on the overall charge of the atom.

11. The safest way to approach a new piece of equipment is to ask the teacher for a demonstration. It is unsafe to play with unfamiliar equipment or carry it around the lab.

12. Chemical properties describe a substance's potential to change into new substances. These properties depend on the elements that the substance contains, the arrangement of atoms within the substance, as well as the type of bonding that is present within the substance. Flammability, combustibility, and reactivity are all examples of chemical properties.

Reactivity generally decreases as you move down the periodic table. This occurs because the bonding electrons are further from the nucleus and so are not held as strongly. This trend means that iodine would be expected to be the least reactive of the four elements listed.

13. A proton has a mass of  $1.6726 \times 10^{-27}$  kg. The mass of a neutron is just slightly larger, at  $1.6749 \times 10^{-27}$  kg. Each of these particles is over 1,800 times the mass of an electron.

14. In metallic bonding, positive metal atoms are packed into a lattice and are surrounded by a sea of negatively charged electrons. Without fixed bonding, the layers of atoms can slide past each other. This explains why metals are malleable (able to be hammered into thin sheets). It also explains why metals are ductile (able to be drawn into thin wires).

15. Dispersion forces and dipole interactions are both weak molecular interactions that are collectively called **van der Waals forces**. These forces are named after the Dutch scientist J.D. van der Waals who first developed a theory regarding intermolecular forces in 1873.

16. In a scientific experiment, the independent or controlled variable is the factor that is manipulated by the person performing the experiment. In this case, the scientist controlled whether there was any antibiotic in each culture, so the independent variable was **the presence of the antibiotic**.

The dependent or responding variable was what the scientist wanted to measure--that is, the reaction of the bacteria to the antibiotic.

17. When an atom changes from the excited state to the ground state, the electron has moved from a high energy state to a low energy state. When this occurs, **the excess energy is released as light energy**. This explains why atoms emit light when they change from an excited state back to the ground state.

Also, since the amount of light emitted or absorbed by separate atoms or molecules has distinct energy values, it can be used to identify what the substance is.

18. Silver chloride is a salt. The intermolecular forces between silver chloride atoms are based on attractions between the positive and negative ions. These strong interactions give silver chloride a high melting point of 455\*deg;C.

19. An element consists of only one type of atom. Since **carbon** only contains carbon atoms, it is an element.

Water is a pure substance, methane is a compound, and brass is a mixture of metals (i.e., alloy).

20. Electronegativity refers to how strongly an atom attracts electrons toward itself in a chemical bond. It is directly related to an element's ionization energy and electron affinity. If an element has a large ionization energy and electron affinity, it will have a high electronegativity.

Electronegativity, therefore, generally increases from left to right across a period and from the bottom of a group to the top of that group. The only elements that correctly follow this trend are found in the choice that includes Cl, Si, Mg, and Na.

21. Protons give the identity, or *atomic number*, of an atom. They are unique to each element and never change. This is why the number of **protons** in an element is equal to the atomic number of that element.

22. Mathematics is essential in conducting scientific investigations. Mathematics can be used to ask questions; to gather, organize, and present data; and to form convincing explanations.

**All of the examples** (determining the correct number of significant figures, calculating molarity, and interpreting graphs) demonstrate ways in which mathematics can be used in scientific investigations.

23. Many medical researchers feel that their use of animals is justified by the fact that their research may lead to medical advancements that can save many lives. However, the use of animals for research is typically limited to medical research.

24. If water is poured into a container of acid, the mixture can produce heat and splatter. The safest procedure for mixing acid and water is to cautiously add the acid to the water in a beaker.

25. Dr. Morris hypothesized that the drug would increase the rabbits' metabolic rate and cause them to lose weight. The results show that the rabbits that were given the drug did not lose weight, but in fact gained weight. **Dr. Morris's data does not support his hypothesis.**

26. The energy released is equal to the difference in energy between the two levels. The energy level  $n = 3$  has an energy of  $-146 \text{ kJ}$ . The energy level  $n = 2$  has an energy of  $-328 \text{ kJ}$ . The difference between these two levels is **182 kJ**. Therefore, 182 kJ of energy would be released.

27. Scientists continue to investigate the structure of atoms under high-powered microscopes. Atoms are composed of electrons, neutrons, and protons. Scientists have discovered that **electrons, neutrons, and protons are made up of even smaller constituents, such as quarks and gluons.**

28. Scientific inquiry involves making judgments about the relevance of information.

The scientific question that Johnny's class is researching asks whether random mutations occur in plant cells during seed germination. Johnny found information about seed germination, but it is not relevant to the problem he has been given.

29. People who disagree with the use of animals in scientific experiments believe in the sanctity of life for all organisms, not just for humans. They believe that what is unethical to perform on humans is also unethical to perform on any organism with a nervous system.

30. The number of protons and electrons that an atom has determines its net charge. Since the atom has 33 protons and 36 electrons, it is an ion with a net charge of  $-3$ .

31. A flammable substance is a substance that burns easily or is ignited easily. Flammable substances must be kept away from any source that could ignite the substance. This includes **open flames**, electrical sparks, and any source of heat.

32. For FDA approval, the drug must first be tested on animal subjects and then human volunteers before being introduced into the market. However, it can take many years and even decades of research before the FDA gives approval for the drug to be tested on human volunteers.

33. When an electron is in the orbit closest to the nucleus, it is in its lowest energy state. This state is referred to as the **ground state**.

34. **Fluorine** has seven electrons in its outermost shell and is most likely to form ionic bonds. An element is most stable when its outermost electron shell is full. Since the addition of just one electron would fill fluorine's outermost shell, fluorine is a common participant in ionic bonding.

Full shells include 2 electrons for hydrogen and helium, and 8 electrons for the other elements, including fluorine. Elements like helium and neon have full outermost electron shells and rarely form bonds. Carbon, with four outer electrons, most often bonds in covalent bonding patterns.

35. The electron-sea model of metallic bonding explains that metal cations exist in a sea of electrons. The electrons are able to easily travel between metal atoms. This explains why metals are good conductors of electricity.

36. If those that flossed daily (Jamal, Brandy, and Travis) are compared with Kendra, the dentist's hypothesis is supported. However, if they are compared with Stephanie, the dentist's hypothesis is not supported. Therefore, **further research is necessary** before a conclusion can be reached.

37. Atoms are made up of three main subatomic particles:

- positively-charged protons,
- negatively-charged electrons
- neutrons, which have no charge.

Neutral atoms have the same number of protons and electrons. If a neutral atom gains or loses electrons, an **ion** is formed. If electrons are lost, the atom will have more protons than electrons and be positively charged. If electrons are gained, the atom will have more electrons than protons and be negatively charged.

*Isotopes* are atoms of an element that have the same number of protons but a different number of neutrons.

The number of protons in an element's atoms is equal to its *atomic number*, so this number never changes for an individual element.

38. Ionic bonds tend to form between metals and nonmetals. Since metals have low electron affinity, they give electrons to atoms with high electron affinity (i.e. nonmetals). Thus, in the process of ionic bonding, **electrons are transferred from one atom to another**.

39. Scientific ethics include the principle of communalism, or the idea that scientific knowledge is public property. This principle is behind the idea that scientists must publish the results of all their research.

40. John Dalton was one of the first scientists to attempt to calculate the **atomic masses** of different elements. Today, each element's atomic mass is written below the element's chemical symbol on the periodic table.

41. In a scientific investigation that attempts to determine the affect that one factor has on a group of organisms, two virtually identical experiments are conducted. In one of the experiments, a group of organisms receives the factor being tested. This is the experimental group. In the other experiment, a group of organisms does not receive the factor being tested. This is the control.

At the end of an experiment, the control group is compared to the experimental group in order to determine if the factor had the hypothesized effect.

In Dr. Grey's experiment, the control is **the group of rabbits that are not given the drug**.

42. After an experiment is complete, **chemical waste should be placed in marked waste containers**. Corrosive chemicals should never be washed down the sink or thrown in the trash can because they can be dangerous. Also, chemicals should never be mixed together or left unmarked in the lab area.

43. **A strong force exists between the particles in a nucleus. This force is usually stronger than the electric forces that would pull them apart.**

A strong force is only evident at nuclear distances, and it holds the nucleus together against the electrical repulsion that exists between the positively charged protons.

44. An atom is held together by **electric forces between the nucleus and the electrons**.

Protons in the nucleus are positively charged. Electrons are negatively charged. The protons in the nucleus attract the electrons outside of it, causing the electrons to orbit around the nucleus. These electric forces hold the electrons close to the nucleus.

45. A quantum of light energy is a discrete or definite amount of energy and is also known as a **photon**.

Photons are absorbed when electrons move from low energy states to high energy states and released when electrons move from high energy states to low energy states.

46. **Polyatomic ions** are made up of covalently bonded atoms that tend to stay together as if they were a single atom. Polyatomic ions are charged particles that usually form ionic bonds with other atoms. The ammonium ion ( $\text{NH}_4^+$ ), the hydroxide ion ( $\text{OH}^-$ ), and the sulfate ion ( $\text{SO}_4^{+2}$ ) are all examples of polyatomic ions.

47. Microscopes are tools that can be used to view structures, such as cells, that are too small to be seen with the naked eye. The major components of a microscope include:

1. The coarse adjustment knob makes large adjustments when focusing specimens.
2. The fine adjustment knob **makes minor adjustments when focusing specimens**.
3. The objective lenses change the magnification of the specimens.
4. The stage is the site where slides or specimens are placed.

48. A scientific explanation should be

- logically consistent,
- supported by scientific evidence,
- open to questions and modifications
- based on historical and current scientific knowledge.

A scientific explanation should be **I, II, and III only**.

49. In Bohr's model, electrons are positioned in specific levels outside of the nucleus. In order to move from a lower level to a higher level, an electron must absorb energy and be excited. When the electron returns to its original level, or its ground state, it releases the **same** amount of energy.

50. Diamond is a **covalent-network** solid. This means that the solid is held together by a network of covalent bonds. The network structure gives diamond a very high melting point and makes it a hard solid.

51. Atomic mass is composed of the sum of neutrons and protons. Protons give the **identity**, or **atomic number**, of an atom and never change.

Shown below is the element oxygen:



Oxygen has an atomic mass number of 16 and an atomic number of 8.  
 $16 - 8 = 8$ , the number of neutrons in an oxygen atom.

52. An electron in hydrogen emits energy as it moves from an excited state to a lower energy level. This energy can be recorded by a spectrometer and translated into five different series of lines based on their ranges within the electromagnetic spectrum.

The different series within the hydrogen spectrum can also be defined by the fact that the electron **transitions of different series end at different energy levels**. As shown in the diagram, the Lyman series ends at  $n=1$ , the Balmer series ends at  $n=2$ , the Paschen series ends at  $n=3$ , the Beckett series ends at  $n=4$ , and the Pfund series ends at  $n=5$ .

53. In the electron cloud model of an atom, electrons found within electron shells travel around the nucleus in unpredictable patterns. Although every atom basically has an infinite number of shells for the electrons to move around in, the electrons tend to stay in the electron shell that has the lowest energy and is closer to the nucleus.

Electron shells are named K, L, M, N, O, P (from the shell closest to the nucleus moving outward). To fill the electron shells: K needs **2** electrons, L needs **8** electrons, M needs **18** electrons, N needs **32** electrons, O needs 18 electrons, and P needs 4 electrons. The last electron shell of an atom usually will contain no more than eight electrons.

54. For most scientific experiments involving humans, the humans must be volunteers, have signed consent statements, and have been informed of all of the known consequences of the experiment. However, observation of human behavior in public areas does not require the subjects to volunteer since the humans will be in no way affected by the experiment. They will only be observed.

55. If an electron moves from energy level 3 to energy level 4, **it would have to absorb a photon of energy** to promote the electron to the higher energy orbit.

56. Atoms of an element wish to have a full and stable outer electron shell. In order to reach this goal, each atom has a number of electrons to donate or receive. Sodium has one electron in its outer shell and wishes to donate the electron. Chlorine has seven electrons in its outer shell and would like to gain one electron. In order to make NaCl, Sodium donates one electron to Chlorine.

57. Carbon dioxide is a molecular solid. The CO<sub>2</sub> molecules are held together by weak interactions between the molecules. This gives CO<sub>2</sub> a low melting point and explains why it is a gas at room temperature.

58. The majority of the periodic table is made up of **metals**, which are found in the middle and left side of the periodic table.

59. Ionic bonds usually occur when a metal cation donates electrons to a nonmetal anion. So, an ionic bond is most likely to form between the metal **potassium** and the nonmetal **chlorine**.

All of the other answer choices are pairs of nonmetals and are likely to form covalent bonds.

60. Glass is made up of silicon dioxide (SiO<sub>2</sub>). Water is made up of hydrogen and oxygen atoms. **Hydrogen bonds** are able to form between these two substances, so the water can climb up the sides of the glass tubing.

61. Currently, many different species of organisms have been cloned both in the United States and other countries. In most countries, though, it is illegal for a scientist to attempt to clone a human being due to ethical considerations. Most scientists are against human cloning because there are still problems with animal cloning. Many religious groups are also ethically opposed to human cloning.

62. **When mixing any two liquids**, there is always a risk of the liquids splashing. There is a greater risk of eye damage occurring when mixing acids and bases, highly reactive liquids, and toxic liquids, but there is still a risk of splashing causing eye damage in any case. For this reason, protective eyewear should be worn when mixing any two liquids.

63. **Step 3** would compromise the experiment because by manipulating a second variable (water), she has invalidated the controlled experiment. Controlled experiments should only change one variable at a time. In this case, that variable is salt. All other factors (the volumes used, the type of beakers used, the type of acid used, etc.) must remain the same.

64. Scientific inquiries can be used to learn more about the natural world. They are usually based on previous scientific research and data, always require precision and accuracy when gathering new data, and often require mathematical knowledge.

**Scientific inquiries are usually guided by conceptual principles and knowledge learned from previous research.**



65. Elements on the periodic table are organized in order of their atomic numbers. Since the atomic number is equal to the number of protons, this number is always a whole number.

According to the periodic table, the atomic number of the element hydrogen is **1**.

66. When white light passes through a prism, it emits a continuous spectrum. That is, even though the white light separates into individual colors, the edges blend together.

Elements, however, do not produce continuous spectra. Instead, they produce a series of distinct lines that are unique to each element. These lines can often be easily viewed using a spectroscope.

67. Historical and current scientific knowledge significantly influence

- the design of new scientific investigations
- the interpretation of new scientific data
- the evaluation of new scientific theories

The results of new scientific research and the precision of new scientific data are not controlled by the results of previous research.

Thus, **only II and III** are significantly influenced by the results of historical and current scientific research.

68. Transition metals usually form ions with charges of +1, +2, or +3. Halogens form ions with charges of -1. Alkaline earth metals form ions with charges of +2. Noble gases do not usually form ions. Therefore, an element that forms an ion with a charge of +3 is most likely to be a transition metal.

69. In order to make accurate measurements, it is necessary to ensure that the equipment being used is in the proper condition.

Prior to using a triple beam balance, it is necessary to

- make sure that the pan is clean and dry
- make sure that the riders are all set to zero
- make sure that the balance is calibrated to zero

70. It is illegal in the United States to buy or sell a human cadaver. Any human cadavers used in experiments must come from families that have given their express consent that the body of their family member could be used for medical research.

71. There are two main ways in which atoms combine to form compounds.

In a covalent bond, the atoms share electrons. In an ionic bond, atoms donate electrons to other atoms.

72. The elements in group 2 of the periodic table are Be, Mg, Ca, Sr, Ba, and Ra. All of these elements have 2 valence electrons in their outer shell.

73. The study of biochemistry **evolved from the disciplines of biology and chemistry**.

Advances in science and technology often lead to new questions that combine various scientific fields. Newer disciplines, such as biochemistry and geophysics, are created by combining older disciplines.

74. Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns.

Sodium chloride is an example of an ionic solid. In sodium chloride crystals, the positive ( $\text{Na}^+$ ) and negative ( $\text{Cl}^-$ ) ions are arranged in a three-dimensional alternating and repeating pattern, so the ions are held together by **ionic bonds**.

When ionic solids become molten or dissolve in water to form ions, the liquids they create are electrically conductive. Ionic compounds generally do not conduct electricity when they are in the solid phase.

75. Idriss wants to record 5 minutes worth of data, so the data table needs to only have entries from the start time to five minutes later. The entries should be spaced according to the recording interval. The recording interval that Idriss is using is one-minute long.

76. Hypotheses are written as statements rather than as questions. So, any answers written in the question form cannot be valid hypotheses.

For a hypothesis to be valid, it does not have to be correct, but it must be testable. Statements which are not testable, such as statements based on opinions, cannot be hypotheses.

77. A graduated cylinder is typically used to measure liquid volume, but it can also be used to measure the volume of solid objects.

To use a graduated cylinder to measure the volume of solids, first fill the graduated cylinder with a set amount of a liquid. Next, place the solid object in the cylinder, making sure there is enough liquid to cover the object. The difference between the liquid's volume with the solid object and the liquid's original volume is the volume of the object.

78. Most elements have two or more isotopes. Isotopes are atoms of the same element that contain the same number of protons but a different number of **neutrons**. Also, since the number of neutrons is different, isotopes of an element have different masses.

*Nuclides* are the set of all isotopes for an element.

79. The electron configuration of an element shows how electrons are arranged around the nuclei of its atoms in their ground state. Electrons always fill the lowest energy levels first.

So, the element **oxygen** corresponds to the electron configuration  $1s^22s^22p^4$ .

80. Electrons are negatively-charged subatomic particles that are found outside of an atom's nucleus. If a neutral atom loses an electron, then the atom will have more protons than electrons. Thus, the atom will have a positive charge.

81. An atom interacts with other atoms in such a way as to fill up its outermost electron shell. An atom can do this by taking electrons from another atom, losing electrons to another atom, or sharing electrons with another atom.

The way in which one atom interacts with another atom is mostly influenced by the configuration of the **electrons farthest from the nucleus** of an atom, also known as the *valence electrons*. In general, the number of valence electrons affects the chemical properties of an element.

82. The melting point of a substance depends on how strongly its molecules are attracted to each other. The attraction between molecules is also influenced by how well molecules can pack together. **Benzene is a planar molecule and so molecules can pack together well.** This causes benzene's melting point to be higher than toluene's.

83. Polyatomic ions are a group of **covalently bonded atoms that act like a single atom when combining with other atoms.**

The sulfate ion ( $\text{SO}_4^{2-}$ ), the hydroxide ion ( $\text{OH}^-$ ), and the phosphate ion ( $\text{PO}_4^{3-}$ ) are some examples of polyatomic ions.

84. An atom's protons and neutrons are held together tightly in the nucleus by strong forces. These strong forces cause the nucleus of an atom to be both small and dense (i.e., there is a large mass contained within a small volume).

Even though electron clouds take up the majority of the space or volume of an atom, they have a relatively small mass. This is because electrons have a much smaller mass than protons and neutrons. In fact, each electron only has 1/1836 the mass of a proton or a neutron.

85. An ethical scientist, whether or not an experiment confirms his or her hypothesis, should always attempt to perform an experiment as accurately as possible. If the scientist is not able to perform the experiment with all controls in place, but still wants to publish the experiment, the scientist should be careful to discuss the problem in the publication.

86. In order to prevent unnecessary waste in the lab, students should carefully measure out only the amount of a substance that they need for the experiment. If a student makes a mistake and needs more of a specific chemical later, they can always get more from the instructor. Extra materials should never be poured back into stock bottles, so any extra chemicals that a student takes and does not use will have to be discarded.

Kyle is practicing the proper use and conservation of lab materials when he **weighs out exactly the amount of baking soda that he needs for an experiment before taking it to his lab area.**

87. Ionic compounds are usually composed of metal cations (positively charged ions) and nonmetal anions (negatively charged ions). Ionic compounds contain strong ionic bonds which occur as a result of the attraction between the oppositely charged ions. At room temperature, ionic compounds also tend to be crystalline solids. In this arrangement, not only are the cations and anions attracted to each other within a particular ionic molecule, the cations in one ionic molecule are also attracted to the anions in another ionic molecule. This creates very stable structures with high melting points.

88. Knowledge is shared among many different branches of science to help advance scientific understanding.

Our understanding of how the human body breaks down food to produce energy is rooted in principles of biology, chemistry, and physics.

89. A lab coat is used to protect the skin from chemical and dyes. If Tina does not have the proper safety equipment she must discuss it with her teacher. The teacher will instruct her on the safest way to address her missing lab coat. If she wears a coat that is too big, it may accidentally catch fire or be dipped in chemical due to its looseness. A ski coat is not appropriate protective clothing for the laboratory.

90. In order to have a neutral atom, the number of protons must be equal to the number of electrons. If an atom has more electrons than protons, it has a negative charge. If an atom has more protons than electrons, it has a positive charge. Neutrons are neutral and do not affect the overall charge of an atom.

Since the atom has 5 electrons, it must also have **5 protons** in order to be considered neutral. It is possible for the number of neutrons to also equal the number of electrons, but they are not required to be equal for the atom to be neutral.

91. The columns of the periodic table are grouped by common properties into groups, or families. One common property is that main group elements (i.e., non-transition metals) in the same family tend to have **the same number of valence electrons.**

A notable exception to this trend is helium which only has two valence electrons, while other elements within the same family have eight.

92. Only certain kinds of problems can be solved through scientific investigations. In order to solve a problem through a scientific investigation, you must be able to form a testable hypothesis about the problem. Questions that can only be answered by opinions are not testable through scientific investigations.

93. The energy of an electron is determined by the location of its orbit. The orbit with the smallest radius (**the one closest to the nucleus**) is the orbit with the lowest energy. The orbit with the largest radius (the one farthest from the nucleus) is the orbit with the highest energy.

94. A spring scale is a device that determines the force of gravity's pull on an object. This force, which is determined by the object's mass and gravity's force, is known as an object's weight. When the lead ball is submerged in water, the water will apply a buoyant force to counteract the ball's weight. Therefore, a **spring scale** is the best tool to use for his experiment.

95. Covalent bonds tend to form between two or more atoms that easily attract electrons (have high electron affinities). Since nonmetals easily attract electrons, covalent bonds tend to form between **two or more nonmetals**.

96. The line spectrum of hydrogen shows the different **photon energies** that are released from a hydrogen atom when electrons move from higher energy orbitals to lower energy orbitals.

Each photon has a different energy which is represented by a specific wavelength that corresponds to particular colors. The *lower* the energy of the photon, the *higher* the wavelength will be.

97. All facilities using laboratory animals covered under the Animal Welfare Act must register with and be inspected by the United States Department of Agriculture's enforcement arm, the Animal and Plant Health Inspection Service (APHIS).

98. In metal solids, the valence electrons of the metal atoms are delocalized throughout the solid. These electrons are **mobile** and are able to line up and move when a current is passed through the metal. This explains why metal solids are good conductors of electricity.

99. The VSEPR model is used to predict the geometric shape of a molecule. This model is based on the idea that electron pairs are best arranged when forces of repulsion are minimized.

The Lewis model is used to determine the number and types of bonds between atoms in a compound, but it does not describe the geometric shape of a molecule.

100. In order to prevent accidents, it is the safest and best practice to refrain from using laboratory glassware as containers for food or beverages. Even if a beaker is new or the lab does not use chemicals, there is still the risk of contamination and mistakes that could result in biological poisoning and other dangerous situations.