

3

1. Atoms of which element have the greatest tendency to gain electrons?

- | | |
|-------------|-------------|
| 1. bromine | 3. fluorine |
| 2. chlorine | 4. iodine |

3 The tendency of an atom to gain electrons can be determined by inspecting the electronegativity value of the atom: the higher the electronegativity, the greater the tendency to gain electrons. See Reference Table *S*. Of the choices given, choice (3), fluorine, has the highest electronegativity value.

2

2. Which polyatomic ion contains the greatest number of oxygen atoms?

- | | |
|--------------|--------------|
| 1. acetate | 3. hydroxide |
| 2. carbonate | 4. peroxide |

2 See Reference Table *E*. Choice (2), the carbonate ion, CO_3^{2-} , contains 3 oxygen atoms, the greatest number of those given in the question.

Wrong Choices Explained:

- (1) The acetate ion, $\text{C}_2\text{H}_3\text{O}_2^-$, contains 2 oxygen atoms.
(3) The hydroxide ion, OH^- , contains 1 oxygen atom.
(4) The peroxide ion, O_2^{2-} , contains 2 oxygen atoms.

4

3. Which formula represents an ionic compound?

- | | |
|------------------|---------------------------|
| 1. H_2 | 3. CH_3OH |
| 2. CH_4 | 4. NH_4Cl |

4 The compound NH_4Cl is composed of NH_4^+ and Cl^- ions.

Wrong Choices Explained:

- (1) H_2 is the diatomic molecule of the element hydrogen.
(2), (3) CH_4 and CH_3OH are molecular (covalent) compounds.

2

4. An ion of which element has a larger radius than an atom of the same element?

- | | |
|-------------|--------------|
| 1. aluminum | 3. magnesium |
| 2. chlorine | 4. sodium |

2 When an atom forms a negative ion, the radius of the ion is larger than the radius of its parent atom. Of the choices given, only choice (2), chlorine, forms a negative ion.

3

5. Based on electronegativity values, which type of elements tends to have the greatest attraction for electrons in a bond?

- | | |
|---------------|----------------|
| 1. metals | 3. nonmetals |
| 2. metalloids | 4. noble gases |

3 Use the Periodic Table of the Elements and Reference Table S. The higher the electronegativity value of an atom, the greater its attraction for bonded electrons. Nonmetals typically have the highest electronegativity values and therefore the greatest attraction for bonded electrons.

3

6. What is the total number of different elements present in NH_4NO_3 ?

- | | |
|------|------|
| 1. 7 | 3. 3 |
| 2. 9 | 4. 4 |

3 There are three elements in the compound: N, H, and O.

Wrong Choice Explained:

(2) You counted the total number of atoms in the compound.

1

7. Given the balanced equation representing a reaction:

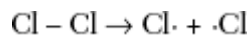


What occurs during this change?

- | | |
|---|---|
| 1. Energy is absorbed and a bond is broken. | 3. Energy is released and a bond is broken. |
| 2. Energy is absorbed and a bond is formed. | 4. Energy is released and a bond is formed. |

1 When a chlorine molecule (Cl_2) dissociates, the single bond is broken and a pair of chlorine atoms are formed: (see image)

Anytime a bond is broken, energy is absorbed.



3

8. What is the net charge on an ion that has 9 protons, 11 neutrons, and 10 electrons?

- | | |
|-------|-------|
| 1. 1+ | 3. 1- |
| 2. 2+ | 4. 2- |

3 Each proton contributes a charge of 1+, and each electron contributes a charge of 1-. Neutrons have no effect on the charge. The charge on the ion is 1- : $(9+) + (10-)$.

3

9. At standard pressure, a certain compound has a low boiling point and is insoluble in water. At STP, this compound most likely exists as

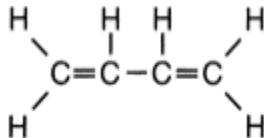
- | | |
|----------------------|-----------------------|
| 1. ionic crystals | 3. nonpolar molecules |
| 2. metallic crystals | 4. polar molecules |

3 Nonpolar molecules have low boiling points because the intermolecular forces among these molecules are weak. Moreover, nonpolar compounds are insoluble in polar liquids such as water because the intermolecular forces of both substances are too dissimilar.

1

10. Given the formula of a substance:

What is the total number of shared electrons in a molecule of this substance?



- | | |
|-------|------|
| 1. 22 | 3. 9 |
| 2. 11 | 4. 6 |

1 Each line in the formula represents a pair of shared electrons. Since there are 11 lines in the formula, a total of 22 electrons must be shared.

2

11. Which formula represents an ionic compound?

- | | |
|---------------------|--------------------|
| 1. H ₂ O | 3. NH ₃ |
| 2. KCl | 4. CH ₄ |

2 Ionic compounds are generally formed between metallic and non-metallic elements. The electronegativity difference is greater than or equal to 1.7. Of the choices given, only choice (2), KCl, meets these criteria.

3

12. An oxide ion (O²⁻) formed from an oxygen-18 atom contains exactly

- | | |
|--|---|
| 1. 8 protons, 8 neutrons, 10 electrons | 3. 8 protons, 10 neutrons, 10 electrons |
| 2. 8 protons, 10 neutrons, 8 electrons | 4. 10 protons, 8 neutrons, 8 electrons |

3 An *atom* of oxygen-18 contains 8 protons, 10, neutrons, and 8 electrons. An oxide ion (O₂²⁻) contains 2 more electrons than the atom. Therefore, the ion contains 8 protons, 10 neutrons, and 10 electrons.

4

13. Which bond is *least* polar?

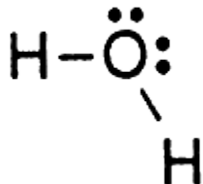
1. As-Cl
2. Bi-Cl

3. P-Cl
4. N-Cl

4 Use Reference Table S and calculate the electronegativity *difference* for each bond. Of the choices given, choice (4), N-Cl, has the smallest electronegativity difference and is the least polar.

3

14. Which pair of characteristics describes the molecule shown in the accompanying illustration?



1. symmetrical and polar
2. symmetrical and nonpolar
3. asymmetrical and polar
4. asymmetrical and nonpolar

3 Since the H₂O molecule is bent, it lacks symmetry. As a result, the molecule is polar.

3

15. An unknown substance, liquid X, is tested in the laboratory. The chemical and physical test results are listed below.

- Nonconductor of electricity
- Insoluble in water
- Soluble in hexane
- Low melting point as a solid
- Combustion produces only CO₂ and H₂O

Based on these results, a student should conclude that liquid X is

1. ionic and organic
2. ionic and inorganic
3. covalent and organic
4. covalent and inorganic

3 The conductivity, solubility, and melting point test results all indicate that the substance is *nonpolar*. The combustion results indicate that the substance contains either carbon and hydrogen, or carbon, hydrogen, and oxygen—that is, the substance is *organic*.

3

16. Which substance is correctly paired with its type of bonding?

1. NaBr--nonpolar covalent
2. HCl--nonpolar covalent
3. NH₃--polar covalent
4. Br₂--polar covalent

3 Refer to Reference Table S. The respective electronegativities of hydrogen (H) and nitrogen (N)

are 2.1 and 3.0. Therefore, each of the hydrogen-nitrogen bonds are polar covalent.

Wrong Choices Explained:

- (1) NaBr is ionic (the electronegativity difference is 2.1).
- (2) HCl is polar covalent (the electronegativity difference is 1.1).
- (4) Br₂ is nonpolar covalent (the electronegativity difference is 0.0).

4

17. Based on intermolecular forces, which of these substances would have the highest boiling point?

- 1. He
- 2. O₂
- 3. CH₄
- 4. NH₃

4 Intermolecular forces are strongest in polar covalent substances and weakest in nonpolar substances. Therefore, NH₃, a polar substance, will have the highest boiling point.

Wrong Choices Explained:

(1), (2), (3) Each of these substances is nonpolar and will have a relatively low boiling point.

1

18. Which type of bonding is found in all molecular substances?

- 1. covalent bonding
- 2. hydrogen bonding
- 3. ionic bonding
- 4. metallic bonding

1 In all molecules, the atoms are bonded by the sharing of electrons, that is, by covalent bonding.

Wrong Choices Explained: (2) Hydrogen bonding is an intermolecular attraction, not a bond between atoms. Not all molecular substances have hydrogen bonds.

(3), (4) Molecules do not exist in ionic or metallic substances.

4

19. What is the total number of electrons shared in a double covalent bond between two atoms?

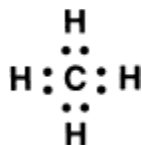
- 1. 1
- 2. 2
- 3. 8
- 4. 4

4 Multiple covalent bonds share multiple pairs of electrons. In a double covalent bond, two pairs of electrons, that is, 4 electrons, are shared by two atoms.

3

20. Given the Lewis electron-dot diagram:

Which electrons are represented by all of the dots?



- | | |
|---|--|
| 1. the carbon valence electrons, only | 3. the carbon and hydrogen valence electrons |
| 2. the hydrogen valence electrons, only | 4. all of the carbon and hydrogen electrons |

3 In a Lewis electron-dot diagram, the *valence* (outer-level) electrons of the relevant atoms are represented by one or more pairs of dots.

3

21. Which formula represents a nonpolar molecule?

- | | |
|---------------------|--------------------|
| 1. H ₂ S | 3. CH ₄ |
| 2. HCl | 4. NH ₃ |

3 Nonpolar molecules must have symmetrical electron distribution. Of the choices given, only choice (3), CH₄, has a symmetrical distribution of its electrons.

2

22. What occurs when an atom loses an electron?

- | | |
|---|---|
| 1. The atom's radius decreases and the atom becomes a negative ion. | 3. The atom's radius increases and the atom becomes a negative ion. |
| 2. The atom's radius decreases and the atom becomes a positive ion. | 4. The atom's radius increases and the atom becomes a positive ion. |

2 An atom has an equal number of protons and electrons. When an electron is lost, the atom becomes a positive ion. Since there is less repulsion among the outermost electrons, the radius of the ion is less than the radius of the parent atom.

4

23. Note: This question may require the use of the *Reference Tables for Physical Setting/Chemistry*. Based on Reference Table S, atoms of which of these elements have the strongest attraction for the electrons in a chemical bond?

- | | |
|-------|------|
| 1. Al | 3. P |
| 2. Si | 4. S |

4 An atom's attraction for electrons in a chemical bond is described by its electronegativity. Of the choices given, choice (4), S, has the highest electronegativity value (2.6).

4

24. Note: This question may require the use of the *Reference Tables for Physical Setting/Chemistry*. Which Lewis electron-dot diagram in the image shown is correct for a S²⁻ ion?



(1)

(3)



(2)

(4)

4 Use the Periodic Table of the Elements. An atom of sulfur (S) contains 6 valence electrons. An S^{2-} ion contains 8 electrons arranged in four pairs as illustrated in choice (4).

3

25. Which substance contains bonds that involved the transfer of electrons from one atom to another?

1. CO_2

3. KBr

2. NH_3

4. Cl_2

3 Ionic bonds involve the transfer of electrons from one atom to another. Use Reference Table S. An ionic bond results when the difference in the electronegativities of the bonding atoms is 1.7 or greater. In KBr, this difference is 2.2 (3.0 - 0.8).

Wrong Choices Explained:

(1), (2), (4) In each of these compounds, the difference in the electronegativities of the bonding atoms (C-O, N-H, and Cl-Cl) is less than 1.7.

3

26. What is the total number of pairs of electrons shared in a molecule of N_2 ?

1. one pair

3. three pairs

2. two pairs

4. four pairs

3 See the Periodic Table of the Elements. The electron configuration of a nitrogen (N) atom is 2-5; it has 5 valence electrons. Sharing 3 pairs of electrons in a molecule of N_2 assures that each nitrogen atom will be associated with 8 electrons. The Lewis structure for N_2 is shown in the accompanying diagram:



2

27. Which formula represents a nonpolar molecule containing polar covalent bonds?

1. H_2O

3. NH_3

2. CCl_4

4. H_2

2 A nonpolar molecule that contains polar covalent bonds must have a symmetrical electron distribution. Of the choices given, only choice (1), CCl_4 , meets both criteria.

Wrong Choices Explained:

- (1), (3) H_2O and NH_3 are molecules that contain polar covalent bonds, but their electron distributions are not symmetrical.
(4) H_2 is a nonpolar molecule that has a symmetrical distribution of electrons, but the bond between the hydrogen atoms is nonpolar covalent.

3

28. The degree of polarity of a chemical bond in a molecule of a compound can be predicted by determining the difference in the

- | | |
|---|--|
| 1. melting points of the elements in the compound | 3. electronegativities of the bonded atoms in a molecule of the compound |
| 2. densities of the elements in the compound | 4. atomic masses of the bonded atoms in a molecule of the compound |

3 Electronegativity measures an atom's attraction for bonded electrons. The difference in the electronegativities of the bonded atoms measures the polarity of the chemical bond.

3

29. Which compound contains both ionic and covalent bonds?

- | | |
|------------|-----------------------|
| 1. ammonia | 3. sodium nitrate |
| 2. methane | 4. potassium chloride |

3 Substances containing ionic and covalent bonds generally contain polyatomic ions. The substance KNO_3 contains K^+ and NO_3^- ions. Within the NO_3^- ion, the nitrogen and oxygen atoms are bonded covalently.

Wrong Choices Explained:

- (1), (2) NH_3 and CH_4 contain only covalent bonds.
(4) KCl contains only ionic bonds.

1

30. Which of the following elements has the highest electronegativity?

- | | |
|------|-------|
| 1. H | 3. Al |
| 2. K | 4. Ca |

1 Use Reference Table S. The element H has the highest electronegativity (2.1). You could have arrived at the answer without using the table. Metals have low electronegativities; only choice (1), H, is a *nonmetal*.

1

31. Which formula represents an ionic compound?

1. NaCl
2. N₂O
3. HCl
4. H₂O

1 An ionic compound consists of a metal and a nonmetal with a significant difference in electronegativity (≥ 1.7). Of the choices given, only choice (1), NaCl, meets these criteria.

4

32. Which species does *not* have a noble gas electron configuration?

1. Na⁺
2. Mg²⁺
3. Ar
4. S

4 Use the Periodic Table of the Elements. The element S has the configuration 2–8–6, which is not a noble gas (Group 18) configuration.

Wrong Choices Explained:

(1) An Na⁺ ion is formed by removing one electron from Na; its electron configuration is (2–8–1) – 1 = 2–8, which is the electron configuration of Ne, a noble gas.

(2) An Mg²⁺ ion is formed by removing two electrons from Mg; its electron configuration is (2–8–2) – 2 = 2–8, which is the electron configuration of Ne, a noble gas.

(3) Ar is a noble gas.

2

33. A barium atom attains a stable electron configuration when it bonds with

1. one chlorine atom
2. two chlorine atoms
3. one sodium atom
4. two sodium atoms

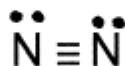
2 In order for a barium atom to have stable electron configuration, it must lose its 2 valence electrons. When a barium atom combines with 2 chlorine atoms, each chlorine atom will accept a single electron in order to complete its valence shell.

2

34. Which molecule contains a triple covalent bond?

1. H₂
2. N₂
3. O₂
4. Cl₂

2 Refer to the Periodic Table of the Elements. An atom of nitrogen has five valence electrons, and three of them are unpaired. In forming the N_2 molecule, three pairs of electrons are shared by both atoms. The Lewis electron-dot structure of N_2 is shown below:



Wrong Choices Explained:

- (1), (4) The atoms in H_2 and Cl_2 are joined by *single* bonds.
- (3) The atoms in O_2 are joined by a *double* bond.

2

35. Which electron configuration is correct for a sodium ion?

- 1. 2-7
- 2. 2-8
- 3. 2-8-1
- 4. 2-8-2

2 Refer to the Periodic Table of the Elements. An Na^+ ion is formed by removing one electron from Na; its electron configuration is $(2-8-1) - 1 = 2-8$, which is the electron configuration of Ne, a noble gas.

2

36. Which type of bond is formed when electrons are transferred from one atom to another?

- 1. covalent
- 2. ionic
- 3. hydrogen
- 4. metallic

2 An ionic bond is formed as the result of a transfer of electrons between two atoms.

Wrong Choices Explained:

- (1) A covalent bond is formed as the result of the sharing of one or more pairs of electrons.
- (3) A hydrogen bond is a special type of *intermolecular* attraction.
- (4) A metallic bond is one formed between the positive ions of metal atoms and allows the valence electrons to move freely throughout the metallic structure.

4

37. Which Lewis electron-dot structure is drawn correctly for the atom it represents?



4 A Lewis electron-dot structure of an atom uses dots to represent the valence electrons of the atom. Of the choices given, only choice (4), Ne, correctly matches the structure with the 8 valence electrons present in the atom.

Wrong Choices Explained:

- (1) Nitrogen has 5 valence electrons; the structure shows only 4 electrons.
(2) Fluorine has 7 valence electrons; the structure shows 8 electrons.
(3) Oxygen has 6 valence electrons; the structure shows 7 valence electrons.

2

38. What occurs when an atom of chlorine forms a chloride ion?

- | | |
|---|---|
| 1. The chlorine atom gains an electron, and its radius becomes smaller. | 3. The chlorine atom loses an electron, and its radius becomes smaller. |
| 2. The chlorine atom gains an electron, and its radius becomes larger. | 4. The chlorine atom loses an electron, and its radius becomes larger. |

2 Chlorine (Cl, atomic number 17) has 7 valence electrons. When an atom of chlorine forms a chloride ion (Cl⁻), it gains an electron. Due to the increased repulsion of the valence electrons, the radius of the chloride ion is larger than the radius of the chlorine atom.

3

39. The bonds in the compound MgSO₄ can be described as

- | | |
|-------------------|-------------------------------|
| 1. ionic, only | 3. both ionic and covalent |
| 2. covalent, only | 4. neither ionic nor covalent |

3 MgSO₄ contains the ions Mg²⁺ and SO₄²⁻. Therefore it contains ionic bonds. However, within the SO₄²⁻ ion, the oxygen atoms are joined to the sulfur atom by covalent bonds. Therefore, this compound contains both ionic and covalent bonds.

2

40. As two chlorine atoms combine to form a molecule, energy is

- | | |
|-------------|--------------|
| 1. absorbed | 3. created |
| 2. released | 4. destroyed |

2 When a molecule is formed from two separate atoms, the formation of the bond always results in the release of energy.

4

41. Which particle has the same electron configuration as a potassium ion?

- | | |
|-----------------|---------------|
| 1. fluoride ion | 3. neon atom |
| 2. sodium ion | 4. argon atom |

4 Refer to the Periodic Table of the Elements. An *atom* of potassium (symbol K) has the electron configuration 2-8-8-1. When potassium forms a (positive) *ion*, it loses one electron. Therefore the electron configuration of a potassium ion (K⁺) is 2-8-8. Of the choices given only choice (4), argon atom, has an electron configuration of 2-8-8.

Wrong Choices Explained:

(1), (2), (3) A fluoride ion (F⁻), a sodium ion (Na⁺), and a neon atom (Ne) all have the electron

configuration 2-8.

4

42. Which compound contains only covalent bonds?

- | | |
|------------------------|------------------------|
| 1. NaOH | 3. Ca(OH) ₂ |
| 2. Ba(OH) ₂ | 4. CH ₃ OH |

4 The compound CH₃OH, known as methanol, is an organic compound in which all its atoms are bonded covalently.

Wrong Choices Explained:

(1), (2), (3) NaOH, Ba(OH)₂, and Ca(OH)₂ contain both ionic and covalent bonding. The metal ions (Na⁺, Ba²⁺, and Ca²⁺) form ionic bonds with the negatively charged OH⁻ ion. Within the OH⁻ ion, the O and the H atoms are bonded covalently.

3

43. Which substance represents a compound?

- | | |
|----------|-----------------------|
| 1. C(s) | 3. CO(g) |
| 2. Co(s) | 4. O ₂ (g) |

3 A compound consists of two or more elements in chemical combination. The compound CO(g) consists of molecules in which a carbon and an oxygen atom are bonded covalently.

Wrong Choices Explained:

(1), (2), (4) C(s), Co(s), and O₂(g) represent elements, not compounds.

3

44. Which characteristic is a property of molecular substances?

- | | |
|---------------------------------|-----------------------|
| 1. good heat conductivity | 3. low melting point |
| 2. good electrical conductivity | 4. high melting point |

3 Molecular substances have relatively weak *intermolecular forces*. As a result, they tend to be soft, have low melting and boiling points, and conduct electricity and heat poorly.

2

45. Which element has atoms with the greatest attraction for electrons in a chemical bond?

- | | |
|--------------|------------|
| 1. beryllium | 3. lithium |
| 2. fluorine | 4. oxygen |

2 The quantity that measures the attraction for electrons in a chemical bond is electronegativity. See Reference Table S. Of the choices given, choice (2), fluorine, has the highest electronegativity.

4

46. What is the total number of electrons in a S²⁻ ion?

1. 10

3. 16

2. 14

4. 18

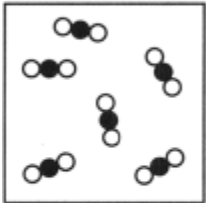
4 Refer to the Periodic Table of the Elements. The atomic number of sulfur (S) is 16: an atom of sulfur has a total of 16 electrons. An S^{2-} ion has two more electrons, or a total of 18 electrons.

4

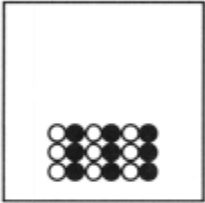
47. Given the key (see first diagram):

Which particle diagram represents a sample containing the compound $CO(g)$?

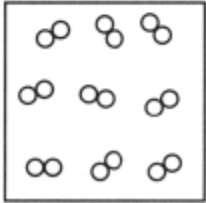
Key	
○	= Atom of oxygen
●	= Atom of carbon



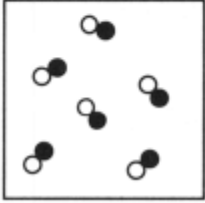
(1)



(3)



(2)



(4)

4 The particle diagram for a single molecule of CO (one atom of C and one atom of O) is (refer to image):

Since the CO is a gas, it must be able to fill the entire container. Of the choices given, only choice (4) meets both requirements.

Wrong Choices Explained:

(1) The diagram represents a container of CO_2 gas. (2) The diagram represents a container of O_2 gas. (3) The diagram represents a container of solid CO .

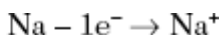


1

48. When an atom loses one or more electrons, this atom becomes a

- | | |
|--|--|
| 1. positive ion with a radius smaller than the radius of this atom | 3. negative ion with a radius smaller than the radius of this atom |
| 2. positive ion with a radius larger than the radius of this atom | 4. negative ion with a radius larger than the radius of this atom |

1 An atom forms a positive ion by losing one or more electrons. When an atom loses electrons to form an ion, it "loses" its valence level as well. The resulting ion has a smaller radius than its parent atom. The example shown in the accompanying diagram illustrates this concept:



electron configurations: 2-8-1 2-8

3

49. Which changes occur as a cadmium atom, Cd, becomes a cadmium ion, Cd²⁺?

- | | |
|--|--|
| 1. The Cd atom gains two electrons and its radius decreases. | 3. The Cd atom loses two electrons and its radius decreases. |
| 2. The Cd atom gains two electrons and its radius increases. | 4. The Cd atom loses two electrons and its radius increases. |

3 A positive ion is formed by the loss of one or more valence electrons by an atom. In this case, the Cd atom loses 2 electrons. When a positive ion is formed, the radius of the ion is less than the radius of its parent atom. Additionally, the Periodic Table of the Elements shows that the Cd atom's outermost electron shell has only 2 electrons. When both are lost to create the Cd²⁺ ion, the entire electron shell is lost, reducing the radius.

4

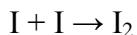
50. What is the name of the polyatomic ion in the compound Na₂O₂?

- | | |
|--------------|-------------|
| 1. hydroxide | 3. oxide |
| 2. oxalate | 4. peroxide |

4 See Reference Table E. Since each sodium ion has a charge of 1+, the O₂ ion in Na₂O₂ must have a charge of 2-. This polyatomic ion is known as the peroxide ion.

2

51. Given the balanced equation:



Which statement describes the process represented by this equation?

- | | |
|---|---|
| 1. A bond is formed as energy is absorbed. | 3. A bond is broken as energy is absorbed. |
| 2. A bond is formed and energy is released. | 4. A bond is broken and energy is released. |

2 When two iodine (I) atoms combine, they form a single bond by sharing a pair of electrons (see

image).

Any time a bond is formed, energy is released.



4

52. An oxygen molecule contains a double bond because the two atoms of oxygen share a total of

- | | |
|----------------|----------------|
| 1. 1 electron | 3. 3 electrons |
| 2. 2 electrons | 4. 4 electrons |

4 A double bond is always formed when two atoms share 2 pairs or a total of 4 electrons.

1

53. What is the total number of electrons in a Mg^{2+} ion?

- | | |
|-------|-------|
| 1. 10 | 3. 14 |
| 2. 12 | 4. 24 |

1 Use the Periodic Table of the Elements. The atomic number of Mg is 12. An atom of magnesium has 12 electrons. When the atom forms a $2+$ ion, it loses 2 electrons. Therefore, a Mg^{2+} ion has a total of 10 electrons.

3

54. Which element has an atom with the greatest attraction for electrons in a chemical bond?

- | | |
|-------|------|
| 1. As | 3. N |
| 2. Bi | 4. P |

3 See Reference Table S. Electronegativity measures the attraction of an atom for electrons in a chemical bond. Of the choices given, choice (3), N, has the highest electronegativity (3.0).

2

55. As a bond between a hydrogen atom and a sulfur atom is formed, electrons are

- | | |
|-----------------------------------|--|
| 1. shared to form an ionic bond | 3. transferred to form an ionic bond |
| 2. shared to form a covalent bond | 4. transferred to form a covalent bond |

2 In ionic bonds, electrons are transferred; in covalent bonds, electrons are shared. The polarity of a bond is determined by the difference in the electronegativities of the two bonded atoms. A difference less than 1.7 is usually classified as a covalent bond. A difference of 1.7 and above is usually classified as an ionic bond. See Reference Table S. The electronegativity difference between hydrogen and sulfur is 0.5 (2.6 - 2.1). Therefore, the bond between hydrogen and sulfur is covalent, in which a pair of electrons is shared by both atoms.

4

56. Which formula represents a polar molecule?

- | | |
|------------------|------------------|
| 1. Br_2 | 3. CH_4 |
|------------------|------------------|

2. CO₂

4. NH₃

4 Polar molecules must contain at least one polar covalent bond and must not be symmetrical. Of the choices given, only choice (3), NH₃, meets both criteria.

3

57. What can be concluded if an ion of an element is *smaller* than an atom of the same element?

1. The ion is negatively charged because it has fewer electrons than the atom.

3. The ion is positively charged because it has fewer electrons than the atom.

2. The ion is negatively charged because it has more electrons than the atom.

4. The ion is positively charged because it has more electrons than the atom.

3 When an atom loses electrons, it becomes a positive ion and its radius decreases.

1

58. What is the total number of electrons in a Cu⁺ ion?

1. 28

3. 30

2. 29

4. 36

1 According to the Periodic Table of the Elements, the atomic number of Cu is 29. Therefore, a neutral atom of Cu contains 29 protons and 29 electrons. A Cu⁺ ion contains one less electron than an atom of Cu, or 28 electrons.

4

59. Covalent bonds are formed when electrons are

1. transferred from one atom to another

3. mobile within a metal

2. captured by the nucleus

4. shared between two atoms

4 The sharing of one or more pairs of electrons by two atoms is known as a covalent bond.

Wrong Choices Explained:

(1) The transfer of electrons forms an *ionic bond*.

(2) Electron capture by a nucleus is a type of *nuclear reaction*.

(3) The existence of mobile electrons within a metal is the basis of the *metallic bond*.

3

60. Which type of molecule is CF₄?

1. polar, with a symmetrical distribution of charge

3. nonpolar, with a symmetrical distribution of charge

2. polar, with an asymmetrical distribution of charge

4. nonpolar, with an asymmetrical distribution of charge

3 Refer to Reference Table S. The respective electronegativities of carbon (C) and fluorine (F) are 2.6 and 4.0. Therefore, each of the carbonfluorine bonds are polar. However, the CF₄ molecule has

a tetrahedral shape and is entirely symmetrical. As a result, the entire molecule is nonpolar.

1

61. Which substance contains metallic bonds?

- | | |
|---------------------------------|--|
| 1. Hg(<i>l</i>) | 3. NaCl(s) |
| 2. H ₂ O(<i>l</i>) | 4. C ₆ H ₁₂ O ₆ (s) |

1 Metallic bonds are found in metallic substances. The presence of metallic bonds confers good conductivity, malleability, and luster on the substance. Of the choices given, only choice (1), Hg(*ℓ*), is a metallic substance. The phase of the mercury (liquid) is not important in answering this question.

Wrong Choices Explained:

(2), (4) H₂O and C₆H₁₂O₆ are covalently bonded compounds and do not possess metallic properties.

(3) NaCl is an ionic compound and does not possess metallic properties.

3

62. Which change occurs when a barium atom loses two electrons?

- | | |
|--|--|
| 1. It becomes a negative ion and its radius decreases. | 3. It becomes a positive ion and its radius decreases. |
| 2. It becomes a negative ion and its radius increases. | 4. It becomes a positive ion and its radius increases. |

3 When any atom loses electrons, it becomes a positive ion. Refer to the Periodic Table of the Elements. The electron configuration of an atom of barium is 2-8-18-18-8-2. The electron configuration of a Ba²⁺ ion is 2-8-18-18-8. The loss of the sixth shell reduces the size of the ion. Therefore, the radius of Ba²⁺ is smaller than the radius of Ba.

4

63. Conductivity in a metal results from the metal atoms having

- | | |
|---------------------------|---|
| 1. high electronegativity | 3. highly mobile protons in the nucleus |
| 2. high ionization energy | 4. highly mobile electrons in the valence shell |

4 The characteristic of a metallic bond is the presence of mobile valence electrons. This mobility accounts for the conductivity of metallic substances.

3

64. Which of these elements has the least attraction for electrons in a chemical bond?

- | | |
|-------------|-------------|
| 1. oxygen | 3. nitrogen |
| 2. fluorine | 4. chlorine |

3 The attraction of an atom for electrons in a chemical bond is measured by the electronegativity of the atom. Refer to Reference Table S. Of the choices given, choice (3), nitrogen, has the smallest

electronegativity, 3.0.

1

65. The bonds between hydrogen and oxygen in a water molecule are classified as

- | | |
|----------------------|-------------|
| 1. polar covalent | 3. ionic |
| 2. nonpolar covalent | 4. metallic |

1 Refer to Reference Table S. The respective electronegativities of hydrogen (H) and oxygen (O) are 2.1 and 3.4. Therefore, each of the hydrogen-oxygen bonds are polar covalent.

1

66. As a chlorine atom becomes a negative ion, the atom

- | | |
|---|---|
| 1. gains an electron and its radius increases | 3. loses an electron and its radius increases |
| 2. gains an electron and its radius decreases | 4. loses an electron and its radius decreases |

1 Atoms form ions by gaining or losing electrons. When a chlorine atom becomes a negative ion, it does so by gaining a single electron. The presence of this additional electron causes the radius of the ion to be larger than the radius of its parent atom.

1

67. Based on Reference Table S, the atoms of which of these elements have the strongest attraction for electrons in a chemical bond?

- | | |
|-------|-------|
| 1. N | 3. P |
| 2. Na | 4. Pt |

1 Electronegativity is defined as the attraction for electrons in a chemical bond. The higher the electronegativity, the stronger the attraction. According to Reference Table S, choice (1), N, has the highest electronegativity (3.0) of the four choices given.

4

68. Which symbol represents a particle that has the same total number of electrons as S^{2-} ?

- | | |
|-------------|--------------|
| 1. O^{2-} | 3. Se^{2-} |
| 2. Si | 4. Ar |

4 An atom of S has 16 electrons, so the S^{2-} ion has 18 electrons. Of the choices listed, only choice (4), Ar, has 18 electrons.

WRONG CHOICES EXPLAINED:

- (1) O^{2-} has 10 electrons.
- (2) Si has 14 electrons.
- (3) Se^{2-} has 36 electrons.

4

69. Which element is malleable and can conduct electricity in the solid phase?

- | | |
|---------------|-----------|
| 1. iodine | 3. sulfur |
| 2. phosphorus | 4. tin |

4 Metallic elements are malleable and can conduct electricity in the solid phase. Of the choices given, only choice (4), tin, is a metallic element.

2

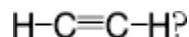
70. Which type of bond results when one or more valence electrons are transferred from one atom to another?

- | | |
|--------------------|-----------------------------|
| 1. a hydrogen bond | 3. a nonpolar covalent bond |
| 2. an ionic bond | 4. a polar covalent bond |

2 An ionic bond results when one or more valence electrons are transferred from one atom to another.

1

71. What is the total number of electrons shared in the bonds between the two carbon atoms in a molecule of ... ? (see accompanying diagram)



- | | |
|------|------|
| 1. 6 | 3. 3 |
| 2. 2 | 4. 8 |

1 In the structural formula shown, each horizontal line represents a pair of electrons that are shared between two neighboring atoms. Since the formula shows three horizontal lines between the 2 carbon atoms, 3 pairs of electrons (i.e., 6 electrons) are shared by the carbon atoms.

1

72. Which formula represents a nonpolar molecule?

- | | |
|--------------------|---------------------|
| 1. CH ₄ | 3. H ₂ O |
| 2. HCl | 4. NH ₃ |

1 Nonpolar molecules must have a symmetrical electron distribution. Of the choices given, only choice (1), CH₄--a tetrahedral molecule--has a symmetrical distribution of its electrons.

2

73. Which electron-dot symbol correctly represents an atom of its given element?

- | | |
|--|--|
| (1) $\overset{\cdot\cdot}{\underset{\cdot}{\text{S}}}$ | (3) $\overset{\cdot\cdot}{\text{Li}}\cdot$ |
| (2) $\overset{\cdot\cdot}{\text{Al}}\cdot$ | (4) $\cdot\overset{\cdot\cdot}{\underset{\cdot}{\text{B}}}\cdot$ |

2 Use the Periodic Table of the Elements. Al is located in Group 13 and has 3 electrons in its outermost (valence) shell. Of the choices given, only choice (2), $\overset{\cdot\cdot}{\text{Al}}\cdot$, displays the proper number of valence electrons.

Wrong Choices Explained:

- (1) S has 6 valence electrons.
- (3) Li has 1 valence electron.
- (4) B has 3 valence electrons.

3

74. Which statement explains why H₂O has a higher boiling point than N₂?

- 1. H₂O has greater molar mass than N₂.
- 2. H₂O has less molar mass than N₂.
- 3. H₂O has stronger intermolecular forces than N₂.
- 4. H₂O has weaker intermolecular forces than N₂.

3 The boiling point of a molecular substance depends on the strength of the forces between the molecules; the stronger the forces, the higher the boiling point.

4

75. The ability of carbon to attract electrons is

- 1. greater than that of nitrogen, but less than that of oxygen
- 2. less than that of nitrogen, but greater than that of oxygen
- 3. greater than that of nitrogen and oxygen
- 4. less than that of nitrogen and oxygen

4 Use Reference Table S to compare the electronegativity values of carbon (2.6), nitrogen (3.0), and oxygen (3.4). Electronegativity measures the ability of an atom to attract electrons. The higher the electronegativity, the greater the ability to attract electrons.

2

76. Which statement best describes the substance that results when electrons are transferred from a metal to a nonmetal?

- 1. It contains ionic bonds and has a low melting point.
- 2. It contains ionic bonds and has a high melting point.
- 3. It contains covalent bonds and has a low melting point.
- 4. It contains covalent bonds and has a high melting point.

2 The *transfer* of electrons between atoms leads to the formation of an ionic bond. Because these bonds are quite strong in nature, the ionic substance will have a high melting point.

1

77. Which statement explains why the radius of a lithium atom is larger than the radius of a lithium ion?

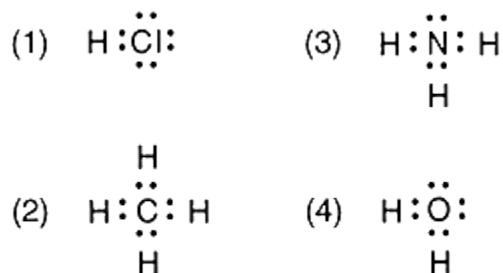
1. Metals lose electrons when forming an ion.
2. Metals gain electrons when forming an ion.

3. Nonmetals lose electrons when forming an ion.
4. Nonmetals gain electrons when forming an ion.

1 Metals have small numbers of valence electrons; they *lose* electrons when forming ions. The loss of the valence electrons causes the ion to be smaller than its corresponding atom.

2

78. Which electron-dot structure represents a nonpolar molecule?



2 A nonpolar molecule must be symmetrical in nature. Of the choices given, only choice (2), CH_4 , exhibits symmetry.

1

79. which bond is most polar?

- | | |
|----------|----------|
| 1. H--F | 3. H--Br |
| 2. H--Cl | 4. H--I |

1 Use Reference Table S, to compare the electronegativity *differences* between each pair of elements. Of the choices given, choice (1), H—F, has the greatest electronegativity difference and is the most polar bond.

4

80. Which formula represents a compound that is formed primarily by sharing electrons?

- | | |
|--------------------|--------------------|
| 1. KCl | 3. CrCl_3 |
| 2. CaCl_2 | 4. CCl_4 |

4 Compounds consisting of metals and nonmetals tend to be ionic, that is, they bond by transferring electrons. Compounds consisting of nonmetals tend to be covalent, that is, they bond by sharing electrons. Of the choices given, only choice (4), CCl_4 , is composed of two nonmetallic elements. One could also refer to Reference Table S and compare the electronegativity differences of the four choices. The electronegativity difference between C and Cl is the smallest ($3.2 - 2.6 = 0.6$), indicating the most covalent bond.

1

81. When a chemical bond is broken, energy is

1. absorbed, only
2. released, only
3. both absorbed and released
4. neither absorbed nor released

1 A chemical bond is formed because it gives stability to the substance; that is, the substance contains *less energy* than the individual atoms forming the bond. In order to break that bond, energy must be *absorbed* by the system.

3

82. Which compound contains ionic bonds?

1. NO
2. NO₂
3. CaO
4. CO₂

3 An ionic bond exists between two atoms when one atom is a metal, the other atom is a nonmetal, and the difference in the electronegativities of the atoms is large. In CaO, calcium is the metallic atom and oxygen is the nonmetallic atom. According to Reference Table S, the electronegativity difference between oxygen and calcium is $(3.4 - 1.0) = 2.4$, which is quite large.

Wrong Choices Explained:

(1), (2), (4) All of the atoms in these choices are nonmetallic, and the bonds in these compounds are all covalent.

2

83. Compared to the radius of a chlorine atom, the radius of a chloride ion is

1. larger because chlorine loses an electron
2. larger because chlorine gains an electron
3. smaller because chlorine loses an electron
4. smaller because chlorine gains an electron

2 Chlorine contains 7 valence electrons. In order to complete its octet, the atom *gains* an electron and becomes a negatively charged chloride ion. The increased electron–electron repulsion causes the ion to be larger in size than its parent atom.

4

84. Which of the following atoms has the greatest tendency to attract electrons?

1. barium
2. beryllium
3. boron
4. bromine

4 The tendency of an atom to attract electrons is measured by the electronegativity of the atom; the higher the electronegativity the stronger the attraction for electrons. Use Reference Table S to compare the electronegativities of each of the choices:

Atom	Electronegativity
barium (Ba)	0.9
beryllium (Be)	1.6
boron (B)	2.0
bromine (Br)	3.0

Since bromine has the highest electronegativity, it has the strongest attraction for electrons.

3

85. As an atom becomes an ion, its mass number

1. decreases
2. increases
3. remains the same

3 The mass number is defined as the sum of the protons and neutrons contained in the nucleus. Since the formation of an ion involves either the loss or gain of *electrons*, the mass number is not affected by the process.

4

86. Which type of chemical bond is formed between two atoms of bromine?

1. metallic
2. hydrogen
3. ionic
4. covalent

4 Use the Periodic Table of the Elements. Bromine (Br, element number 35) has seven valence electrons. When two atoms of bromine combine, a single pair of electrons is shared equally between the atoms. This is known as a (nonpolar) covalent bond.

3

87. Which of these formulas contains the most polar bond?

1. H-Br
2. A-Cl
3. H-F
4. H-I

3 Use the electronegativity values found on Reference Table S. The bond with the greatest electronegativity difference will be the most polar bond. Choice (3), H-F, has an electronegativity difference of 1.9 (4.0 – 2.1); it is the largest electronegativity difference of the four choices given in this question.

4

88. Which element has atoms that can form single, double, and triple covalent bonds with other atoms of the same element?

1. hydrogen

3. fluorine

2. oxygen

4. carbon

4 Of the choices given, only choice (4), carbon, can form single, double, or triple bonds with another carbon atom.

Wrong Choices Explained:

(1), (3) Two atoms of hydrogen or two atoms of fluorine can form only single covalent bonds between themselves.

(2) Two atoms of oxygen can form either single or double covalent bonds between themselves.