

Chemistry Review

Unit 4 - Chemical Bonding

The Nature of Chemical Bonding, Directional Nature of Covalent Bonds, Intermolecular Forces

Bonding

1. Chemical compounds are formed when atoms are bonded together.

- ✓ Breaking a chemical bond is an endothermic process.
- ✓ Forming a chemical bond is an exothermic process.
- ✓ Compounds have less potential energy than the individual atoms they are formed from.

2. Two major categories of compounds are ionic and molecular (covalent) compounds.

3. Compounds can be differentiated by their chemical and physical properties.

- ✓ Ionic substances have high melting and boiling points, form crystals, dissolve in water (dissociation), and conduct electricity in solution and as a liquid.
- ✓ Covalent or molecular substances have lower melting and boiling points, do not conduct electricity.
- ✓ Polar substances are dissolved only by another polar substance. Non-polar substances are dissolved only by other non-polar substances.

4. Chemical bonds are formed when valence electrons are:

- ✓ Transferred from one atom to another – ionic.
- ✓ Shared between atoms – covalent.
- ✓ Mobile in a free moving “sea” of electrons – metallic.

5. In multiple (double or triple) covalent bonds more than 1 pair of electrons are shared between two atoms.

6. Polarity of a molecule can be determined by its shape and the distribution of the charge.

- ✓ Polar molecules must have polar bonds.
- ✓ Polar molecules are asymmetrical.
- ✓ Nonpolar molecules are symmetrical and/or have no polar bonds.

7. When an atom gains an electron, it becomes a negative ion and its radius increases.

8. When an atom loses an electron, it becomes a positive ion and its radius decreases.

9. Atoms gain a stable electron configuration by bonding with other atoms.

- ✓ Atoms are stable when they have a full valence level.
- ✓ Most atoms need 8 electrons to fill their valence level.
- ✓ H and He only need 2 electrons to fill their valence level.
- ✓ The noble gasses (group 18) have filled valence levels. They do not normally bond with other atoms.

10. Electron-dot diagrams (Lewis structures) represent the valence electron arrangement in elements, compounds and ions.

- ✓ Electrons in Lewis structures are arranged by their orbitals.
- ✓ The first two electrons are placed together in the “s” orbital.
- ✓ The remaining electrons are spread among the 3 “p” orbitals.
- ✓ The “s” orbital must be filled first. Then each “p” orbital must have one electron before another “p” orbital gains a second.

11. Electronegativity indicates how strongly an atom of an element attracts electrons in a chemical bond. These values are based on an arbitrary scale.

Unit 4 - Chemical Bonding

12. The electronegativity difference between two bonded atoms can determine the type of bond and its polarity.

0.0 - 0.4 = non-polar covalent

0.4-1.7 = polar covalent

1.7+ = ionic

13. Bonding guidelines:

- ✓ Metals react with nonmetals to form ionic compounds.
- ✓ Nonmetals bond with nonmetals to form covalent compounds (molecules).
- ✓ Ionic compounds with polyatomic ions have both ionic and covalent bonds.

14. Intermolecular forces allow different particles to be attracted to each other to form solids and liquids.

- ✓ Hydrogen bonds are an example of a strong IMF between atoms.
- ✓ Hydrogen bonds exist between atoms of hydrogen and oxygen, fluorine, or nitrogen.
- ✓ Substances with hydrogen bonds tend to have much higher melting and boiling points than those without hydrogen bonds.

15. Physical properties of a substance can be explained in terms of chemical bonds and intermolecular forces.

These include conductivity, malleability, solubility, ductility, hardness, melting point and boiling point.

Unit 4 - Chemical Bonding

January 2008

- 12 Magnesium nitrate contains chemical bonds that are
- (1) covalent, only
 - (2) ionic, only
 - (3) both covalent and ionic
 - (4) neither covalent nor ionic
- 35 What is the total number of pairs of electrons shared between the carbon atom and the oxygen atom in a molecule of methanal?
- (1) 1
 - (2) 2
 - (3) 3
 - (4) 4
- 36 When sodium and fluorine combine to produce the compound NaF, the ions formed have the same electron configuration as atoms of
- (1) argon, only
 - (2) neon, only
 - (3) both argon and neon
 - (4) neither argon nor neon
- 37 In which compound is the ratio of metal ions to nonmetal ions 1 to 2?
- (1) calcium bromide
 - (2) calcium oxide
 - (3) calcium phosphide
 - (4) calcium sulfide

August 2007

- 13 Which formula represents an ionic compound?
- (1) H₂
 - (2) CH₄
 - (3) CH₃OH
 - (4) NH₄Cl
- 21 Given the balanced equation representing a reaction:
- $$\text{Cl}_2(\text{g}) \rightarrow \text{Cl}(\text{g}) + \text{Cl}(\text{g})$$
- What occurs during this change?
- (1) Energy is absorbed and a bond is broken.
 - (2) Energy is absorbed and a bond is formed.
 - (3) Energy is released and a bond is broken.
 - (4) Energy is released and a bond is formed.
- 38 Which group on the Periodic Table of the Elements contains elements that react with oxygen to form compounds with the general formula X₂O?
- (1) Group 1
 - (2) Group 2
 - (3) Group 14
 - (4) Group 18

June 2007

- 10 Given the balanced equation:
- $$\text{I} + \text{I} \rightarrow \text{I}_2$$
- Which statement describes the process represented by this equation?
- (1) A bond is formed as energy is absorbed.
 - (2) A bond is formed and energy is released.
 - (3) A bond is broken as energy is absorbed.
 - (4) A bond is broken and energy is released.
- 11 An oxygen molecule contains a double bond because the two atoms of oxygen share a total of
- (1) 1 electron
 - (2) 2 electrons
 - (3) 3 electrons
 - (4) 4 electrons

Unit 4 - Chemical Bonding

- 41 At STP, fluorine is a gas and bromine is a liquid because, compared to fluorine, bromine has
- (1) stronger covalent bonds
 - (2) stronger intermolecular forces
 - (3) weaker covalent bonds
 - (4) weaker intermolecular forces
- 42 The boiling point of a liquid is the temperature at which the vapor pressure of the liquid is equal to the pressure on the surface of the liquid. What is the boiling point of propanone if the pressure on its surface is 48 kilopascals?
- (1) 25°C
 - (2) 30°C
 - (3) 35°C
 - (4) 40°C
- 62 Explain, in terms of electronegativity, why a P-Cl bond in a molecule of PCl_5 is more polar than a P-S bond in a molecule of P_2S_5 . [1]

62 _____

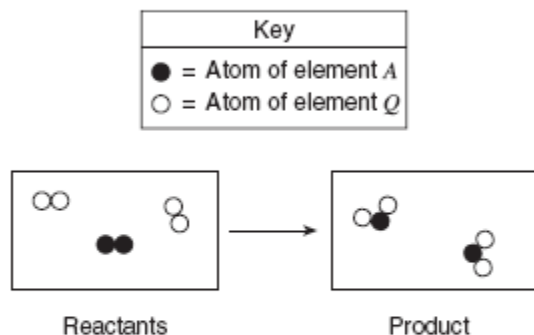
January 2007

- 12 Which two substances are covalent compounds?
- (1) $\text{C}_6\text{H}_{12}\text{O}_6(\text{s})$ and $\text{KI}(\text{s})$
 - (2) $\text{C}_6\text{H}_{12}\text{O}_6(\text{s})$ and $\text{HCl}(\text{g})$
 - (3) $\text{KI}(\text{s})$ and $\text{NaCl}(\text{s})$
 - (4) $\text{NaCl}(\text{s})$ and $\text{HCl}(\text{g})$
- 16 The balanced equation below represents a molecule of bromine separating into two bromine atoms.
- $$\text{Br}_2 \rightarrow \text{Br} + \text{Br}$$
- What occurs during this change?
- (1) Energy is absorbed and a bond is formed.
 - (2) Energy is absorbed and a bond is broken.
 - (3) Energy is released and a bond is formed.
 - (4) Energy is released and a bond is broken.
- 29 Which compound has hydrogen bonding between its molecules?
- (1) CH_4
 - (2) CaH_2
 - (3) KH
 - (4) NH_3
- 34 Element X reacts with iron to form two different compounds with the formulas FeX and Fe_2X_3 . To which group on the Periodic Table does element X belong?
- (1) Group 8
 - (2) Group 2
 - (3) Group 13
 - (4) Group 16
- 45 What is the oxidation number of chromium in the chromate ion, CrO_4^{2-} ?
- (1) +6
 - (2) +2
 - (3) +3
 - (4) +8
- 46 Given the balanced equation representing a reaction:
- $$\text{H}_2\text{SO}_4(\text{aq}) + 2\text{KOH}(\text{aq}) \rightarrow \text{K}_2\text{SO}_4(\text{aq}) + 2\text{H}_2\text{O}(\ell)$$
- Which type of reaction is represented by this equation?
- (1) decomposition
 - (2) neutralization
 - (3) single replacement
 - (4) synthesis

Unit 4 - Chemical Bonding

Base your answers to questions 55 through 57 on the information below.

The particle diagrams below represent the reaction between two nonmetals, A_2 and Q_2 .



55 Using the symbols A and Q , write the chemical formula of the product. [1]

56 Identify the type of chemical bond between an atom of element A and an atom of element Q . [1]

57 Compare the total mass of the reactants to the total mass of the product. [1]

55 _____

56 _____

57 _____

65 Explain, in terms of molecular structure or distribution of charge, why a molecule of methane is nonpolar. [1]

65 _____

66 A liquid boils when the vapor pressure of the liquid equals the atmospheric pressure on the surface of the liquid. Using Reference Table H , determine the boiling point of water when the atmospheric pressure is 90. kPa. [1]

66 _____ °C

Unit 4 - Chemical Bonding

Base your answers to questions 71 through 74 on the information below.

Have you ever seen an insect called a water strider “skating” across the surface of a calm pond? Have you ever “floated” a sewing needle on the water in a glass? If you have, then you’ve observed one of water’s many amazing properties.

Water’s surface tension keeps the water strider and the sewing needle from sinking into the water. Simply stated, the surface tension is due to the forces that hold the water molecules together. Without these intermolecular forces, the water strider and the sewing needle would sink below the surface of the water.

The surface tension of water at various temperatures is given in the data table below.

Surface Tension at Different Water Temperatures

Water Temperature (°C)	Surface Tension (mN/m)
10.	74.2
25	72.0
50.	67.9
75	63.6
100.	58.9

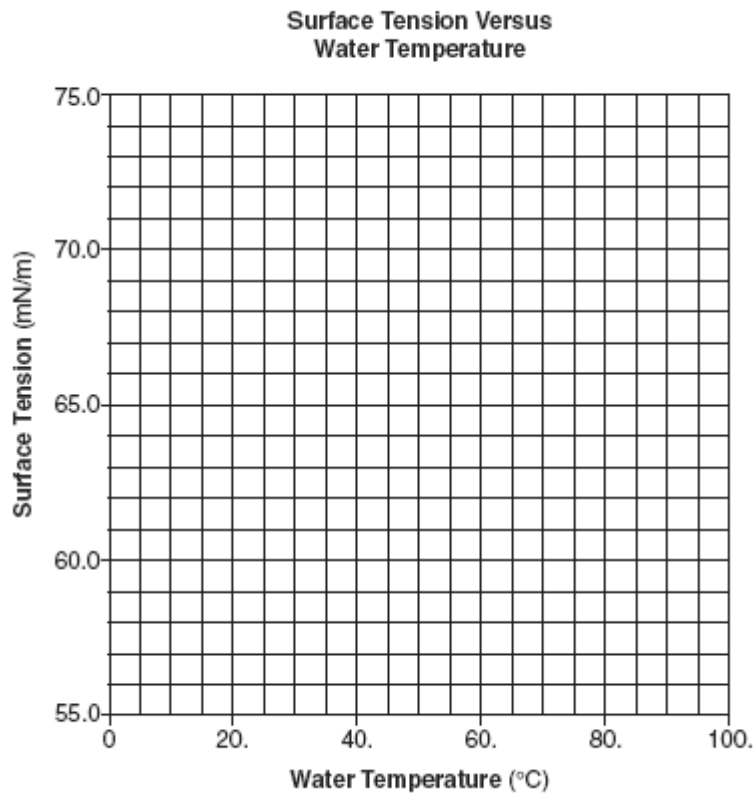
- 71 On the grid in your answer booklet, plot the data from the data table. Circle and connect the five points. [1]



- 72 According to your graph, what is the surface tension of water at 60.°C? [1]
- 73 State the relationship between the surface tension and the temperature of water. [1]
- 74 The surface tension of liquid tetrachloromethane, CCl_4 , at 25°C is 26.3 millinewtons/meter (mN/m). Compare the intermolecular forces between molecules of CCl_4 to the intermolecular forces between molecules of water, H_2O , at 25°C. [1]

Unit 4 - Chemical Bonding

71



72 _____ mN/m

73 _____

74 _____

Unit 4 - Chemical Bonding

August 2006

- 8 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
- 10 Which formula represents a nonpolar molecule containing polar covalent bonds?
- (1) H_2O (3) NH_3
(2) CCl_4 (4) H_2
- 11 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
(2) densities of the elements in the compound
(3) electronegativities of the bonded atoms in a molecule of the compound
(4) atomic masses of the bonded atoms in a molecule of the compound
- 47 Based on bond type, which compound has the highest melting point?
- (1) CH_3OH (3) CaCl_2
(2) C_6H_{14} (4) CCl_4

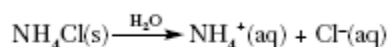
June 2006

- 5 Which statement correctly describes two forms of oxygen, O_2 and O_3 ?
- (1) They have identical molecular structures and identical properties.
(2) They have identical molecular structures and different properties.
(3) They have different molecular structures and identical properties.
(4) They have different molecular structures and different properties.
- 8 Which list includes three types of chemical reactions?
- (1) condensation, double replacement, and sublimation
(2) condensation, solidification, and synthesis
(3) decomposition, double replacement, and synthesis
(4) decomposition, solidification, and sublimation
- 9 Which type of bond results when one or more valence electrons are transferred from one atom to another?
- (1) a hydrogen bond
(2) an ionic bond
(3) a nonpolar covalent bond
(4) a polar covalent bond
- 10 What is the total number of electrons shared in the bonds between the two carbon atoms in a molecule of $\text{H}-\text{C}\equiv\text{C}-\text{H}$?
- (1) 6 (3) 3
(2) 2 (4) 8
- 11 Which formula represents a nonpolar molecule?
- (1) CH_4 (3) H_2O
(2) HCl (4) NH_3

Unit 4 - Chemical Bonding

Base your answers to questions 57 and 58 on the information below.

Given the balanced equation for dissolving $\text{NH}_4\text{Cl}(s)$ in water:



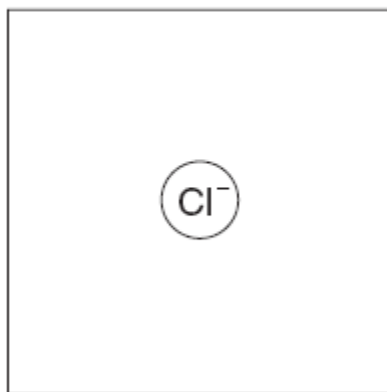
57 A student is holding a test tube containing 5.0 milliliters of water. When a sample of $\text{NH}_4\text{Cl}(s)$ is placed in the test tube, the test tube feels colder to the student's hand. Describe the direction of heat flow between the test tube and the hand. [1]

58 Using the key in your answer booklet, draw at least two water molecules in the box, showing the correct orientation of each water molecule when it is near the Cl^- ion in the aqueous solution. [1]

57

58

Key	
●	= Hydrogen atom
○	= Oxygen atom
●●○	= Water molecule

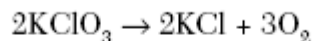


January 2006

12 Which type of bond is found in sodium bromide?

- (1) covalent (3) ionic
(2) hydrogen (4) metallic

37 Given the balanced equation:



Which type of reaction is represented by this equation?

- (1) synthesis
(2) decomposition
(3) single replacement
(4) double replacement

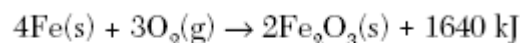
38 A solid substance was tested in the laboratory. The test results are listed below.

- dissolves in water
- is an electrolyte
- melts at a high temperature

Based on these results, the solid substance could be

- (1) Cu (3) C
(2) CuBr_2 (4) $\text{C}_6\text{H}_{12}\text{O}_6$

40 Given the balanced equation:



Which phrase best describes this reaction?

- (1) endothermic with $\Delta H = +1640 \text{ kJ}$
(2) endothermic with $\Delta H = -1640 \text{ kJ}$
(3) exothermic with $\Delta H = +1640 \text{ kJ}$
(4) exothermic with $\Delta H = -1640 \text{ kJ}$

Unit 4 - Chemical Bonding

August 2005

11 Which type of bonding is found in all molecular substances?

- (1) covalent bonding (3) ionic bonding
(2) hydrogen bonding (4) metallic bonding

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

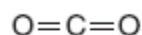
- (1) 1 (3) 8
(2) 2 (4) 4

14 Which formula represents a nonpolar molecule?

- (1) H_2S (3) CH_4
(2) HCl (4) NH_3

June 2005

40 Which molecule contains a nonpolar covalent bond?



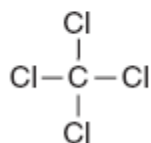
(1)



(3)

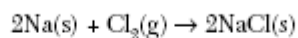


(2)



(4)

Base your answers to questions 55 and 56 on the balanced equation below.



55 In the box in your answer booklet, draw a Lewis electron-dot diagram for a molecule of chlorine, Cl_2 . [1]

56 Explain, in terms of electrons, why the bonding in NaCl is ionic. [1]

55



56

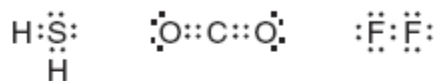
Unit 4 - Chemical Bonding

January 2005

11 Which compound contains both ionic and covalent bonds?

- (1) CaCO_3 (3) MgF_2
(2) PCl_3 (4) CH_2O

Base your answers to questions 51 through 53 on your knowledge of chemical bonding and on the Lewis electron-dot diagrams of H_2S , CO_2 , and F_2 below.



51 Which atom, when bonded as shown, has the same electron configuration as an atom of argon? [1]

52 Explain, in terms of *structure* and/or *distribution of charge*, why CO_2 is a nonpolar molecule. [1]

53 Explain, in terms of *electronegativity*, why a C=O bond in CO_2 is more polar than the F-F bond in F_2 . [1]

51 _____

52 _____

53 _____

August 2004

5 Which compound contains only covalent bonds?

- (1) NaOH (3) $\text{Ca}(\text{OH})_2$
(2) $\text{Ba}(\text{OH})_2$ (4) CH_3OH

9 Which characteristic is a property of molecular substances?

- (1) good heat conductivity
(2) good electrical conductivity
(3) low melting point
(4) high melting point

37 A substance that does not conduct electricity as a solid but does conduct electricity when melted is most likely classified as

- (1) an ionic compound
(2) a molecular compound
(3) a metal
(4) a nonmetal

38 Which substance is correctly paired with its type of bonding?

- (1) NaBr —nonpolar covalent
(2) HCl —nonpolar covalent
(3) NH_3 —polar covalent
(4) Br_2 —polar covalent

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

- (1) He (3) CH_4
(2) O_2 (4) NH_3

Unit 4 - Chemical Bonding

June 2004

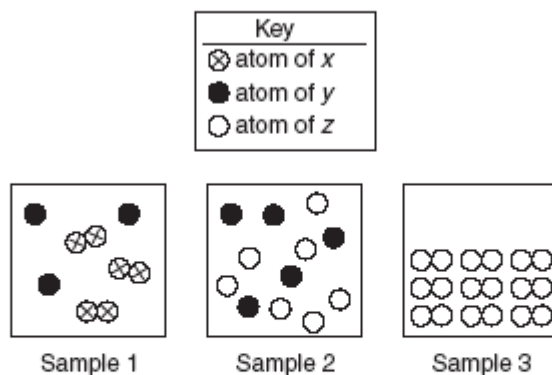
- 9 Covalent bonds are formed when electrons are
- (1) transferred from one atom to another
 - (2) captured by the nucleus
 - (3) mobile within a metal
 - (4) shared between two atoms
- 10 Which type of molecule is CF_4 ?
- (1) polar, with a symmetrical distribution of charge
 - (2) polar, with an asymmetrical distribution of charge
 - (3) nonpolar, with a symmetrical distribution of charge
 - (4) nonpolar, with an asymmetrical distribution of charge
- 17 At STP, the element oxygen can exist as either O_2 or O_3 gas molecules. These two forms of the element have
- (1) the same chemical and physical properties
 - (2) the same chemical properties and different physical properties
 - (3) different chemical properties and the same physical properties
 - (4) different chemical and physical properties
- 39 The bonds between hydrogen and oxygen in a water molecule are classified as
- (1) polar covalent
 - (2) nonpolar covalent
 - (3) ionic
 - (4) metallic

January 2004

- 7 The bond between Br atoms in a Br_2 molecule is
- (1) ionic and is formed by the sharing of two valence electrons
 - (2) ionic and is formed by the transfer of two valence electrons
 - (3) covalent and is formed by the sharing of two valence electrons
 - (4) covalent and is formed by the transfer of two valence electrons
- 9 What occurs when an atom of chlorine and an atom of hydrogen become a molecule of hydrogen chloride?
- (1) A chemical bond is broken and energy is released.
 - (2) A chemical bond is broken and energy is absorbed.
 - (3) A chemical bond is formed and energy is released.
 - (4) A chemical bond is formed and energy is absorbed.
- 20 Which of the following compounds has the highest boiling point?
- | | |
|--------------------------|---------------------------|
| (1) H_2O | (3) H_2Se |
| (2) H_2S | (4) H_2Te |
- 38 Given the reaction:
- $$\text{Mg}(s) + 2 \text{AgNO}_3(aq) \rightarrow \text{Mg}(\text{NO}_3)_2(aq) + 2 \text{Ag}(s)$$
- Which type of reaction is represented?
- (1) single replacement
 - (2) double replacement
 - (3) synthesis
 - (4) decomposition

Unit 4 - Chemical Bonding

Base your answers to questions 65 through 67 on the particle diagrams below, which show atoms and/or molecules in three different samples of matter at STP.



65 Which sample represents a pure substance? [1]

66 When two atoms of *y* react with one atom of *z*, a compound forms. Using the number of atoms shown in sample 2, what is the maximum number of molecules of this compound that can be formed? [1]

67 Explain why xx does *not* represent a compound. [1]

65 _____

66 _____

67 _____

August 2003

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

- (1) covalent (3) hydrogen
(2) ionic (4) metallic

26 The bonds in the compound MgSO_4 can be described as

- (1) ionic, only
(2) covalent, only
(3) both ionic and covalent
(4) neither ionic nor covalent

41 Which equation represents a double replacement reaction?

- (1) $2 \text{Na} + 2 \text{H}_2\text{O} \rightarrow 2 \text{NaOH} + \text{H}_2$
(2) $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$
(3) $\text{LiOH} + \text{HCl} \rightarrow \text{LiCl} + \text{H}_2\text{O}$
(4) $\text{CH}_4 + 2 \text{O}_2 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O}$

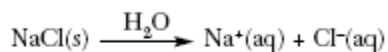
34 As two chlorine atoms combine to form a molecule, energy is

- (1) absorbed (3) created
(2) released (4) destroyed

Unit 4 - Chemical Bonding

Base your answers to questions 67 through 69 on the information below.

Given the equation for the dissolving of sodium chloride in water:



- 67 Describe what happens to entropy during this dissolving process. [1]
- 68 Explain, in terms of *particles*, why $\text{NaCl}(s)$ does *not* conduct electricity. [1]
- 69 When $\text{NaCl}(s)$ is added to water in a 250-milliliter beaker, the temperature of the mixture is lower than the original temperature of the water. Describe this observation in terms of *heat flow*. [1]

67 _____

68 _____

69 _____

June 2003

- 12 Which type of chemical bond is formed between two atoms of bromine?
- (1) metallic (3) ionic
(2) hydrogen (4) covalent
- 13 Which of these formulas contains the most polar bond?
- (1) H-Br (3) H-F
(2) H-Cl (4) H-I
- 42 Hexane (C_6H_{14}) and water do *not* form a solution. Which statement explains this phenomenon?
- (1) Hexane is polar and water is nonpolar.
(2) Hexane is ionic and water is polar.
(3) Hexane is nonpolar and water is polar.
(4) Hexane is nonpolar and water is ionic.

January 2003

- 10 The strength of an atom's attraction for the electrons in a chemical bond is the atom's
- (1) electronegativity (3) heat of reaction
(2) ionization energy (4) heat of formation
- 35 Which of the following solids has the highest melting point?
- (1) $\text{H}_2\text{O}(s)$ (3) $\text{SO}_2(s)$
(2) $\text{Na}_2\text{O}(s)$ (4) $\text{CO}_2(s)$

Unit 4 - Chemical Bonding

39 A chemist performs the same tests on two homogeneous white crystalline solids, A and B. The results are shown in the table below.

	Solid A	Solid B
Melting Point	High, 801°C	Low, decomposes at 186°C
Solubility in H ₂ O (grams per 100.0 g H ₂ O at 0°C)	35.7	3.2
Electrical Conductivity (in aqueous solution)	Good conductor	Nonconductor

The results of these tests suggest that

- (1) both solids contain only ionic bonds
- (2) both solids contain only covalent bonds
- (3) solid A contains only covalent bonds and solid B contains only ionic bonds
- (4) solid A contains only ionic bonds and solid B contains only covalent bonds

Base your answers to questions 57 through 60 on the information below.

Each molecule listed below is formed by sharing electrons between atoms when the atoms within the molecule are bonded together.

Molecule A: Cl₂

Molecule B: CCl₄

Molecule C: NH₃

57 In the box provided in *your answer booklet*, draw the electron-dot (Lewis) structure for the NH₃ molecule. [1]

58 Explain why CCl₄ is classified as a nonpolar molecule. [1]

59 Explain why NH₃ has stronger intermolecular forces of attraction than Cl₂. [1]

60 Explain how the bonding in KCl is different from the bonding in molecules A, B, and C. [1]

57

58

59

60
