

Unit 4 – Chemical Bonding

At the end of this unit, you'll know that / be able to...

- ✓ Compounds can be differentiated by their chemical and physical properties
- ✓ Two major categories of compounds are ionic and molecular (covalent) compounds.
- ✓ Chemical bonds are formed when valence electrons are: transferred from one atom to another (ionic); shared between atoms (covalent); mobile within a metal (metallic).
- ✓ In a multiple covalent bond, more than one pair of electrons is shared between two atoms. Unsaturated organic compounds contain at least one double or triple bond.
- ✓ Molecular polarity can be determined by the shape and distribution of that charge.
- ✓ Symmetrical (nonpolar) molecules include CO₂, CH₄, and diatomic elements.
- ✓ Asymmetrical (polar) molecules include HCl, NH₃, and H₂O.
- ✓ When an atom gains one or more electrons, it becomes a negative ion and its radius increases. When an atom loses one or more electrons, it becomes a positive ion and its radius decreases.
- ✓ When a bond is broken, energy is absorbed. When a bond is formed, energy is released.
- ✓ Atoms attain a stable valence electron configuration by bonding with other atoms.
- ✓ Noble gases have stable valence electron configurations and tend not to bond.
- ✓ Physical properties of substances can be explained in terms of chemical bonds and intermolecular forces. These properties include conductivity, malleability, solubility, hardness, melting point, and boiling point.
- ✓ Electron-dot diagrams (Lewis structures) can represent the valence electron arrangement in elements, compounds, and ions.
- ✓ Electronegativity indicates how strongly an atom of an element attracts electrons in a chemical bond. Electronegativity values are assigned according to an arbitrary scale.
- ✓ The electronegativity difference between two bonded atoms is used to assess the degree of polarity in the bond.
- ✓ Metals tend to react with nonmetals to form ionic compounds. Nonmetals tend to react with other nonmetals to form molecular (covalent) compounds. Ionic compounds containing polyatomic ions have both ionic and covalent bonding.
- ✓ Determine the noble gas configuration an atom will achieve when bonding.
- ✓ Demonstrate bonding concepts, using Lewis dot structures, representing valence electrons: transferred (ionic bonding); shared (covalent bonding); in a stable octet.
- ✓ Distinguish between nonpolar and covalent bonds (two of the same nonmetals) and polar covalent bonds.

Term	Definition
Binary compound	compound containing 2 ELEMENTS (example: CO)
Bond	forces of attraction that hold atoms together in a molecule or compound
Compound	a substance composed of two or more atoms from different elements CHEMICALLY bonded together
Covalent Bond	chemical bond involving the SHARING of electrons between two nonmetal atoms; electronegativity difference between elements typically LESS than 1.7
Dipole	a difference in charge between 2 atoms in a bond
Dissociate	a process in which molecules separate or split into smaller particles such as ions, usually in a reversible manner.
Endothermic	energy is CONSUMED as a product of a chemical reaction
Exothermic	energy is RELEASED as a product of a chemical reaction
Intermolecular forces (IMF's)	weak forces between molecules that hold the molecules to one another; not actually chemical bonds
Ionic Bond	chemical bond involving the TRANSFER of electrons between a metal and nonmetal atom (metals lose, nonmetals gain); electronegativity difference between elements typically GREATER than 1.7
Molecule	a COVALENTLY bonded substance; can be atoms of the same element
Nonpolar molecules	a molecule with equal sharing of electrons; a symmetrical covalent molecule
Octet Rule	atoms bond together in order to have 8 electrons in their valence shell
Oxidation number	the "charge" an element has within a compound
Polar molecule	a covalent molecule with an unequal sharing of electrons; an asymmetrical covalent molecule
Polyatomic ions	atoms of two or more elements chemically bonded together and having a NET CHARGE
Stock system	system using Roman numerals (appearing in parentheses) after the element symbol to indicate the oxidation number of a TRANSITION METAL
Ternary compound	compound containing 3 ELEMENTS (example: C ₆ H ₁₂ O ₆)

Name _____

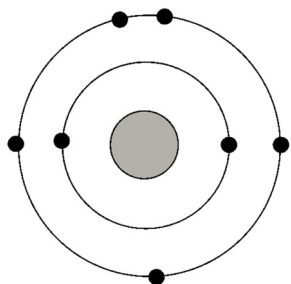
Date _____

Period _____

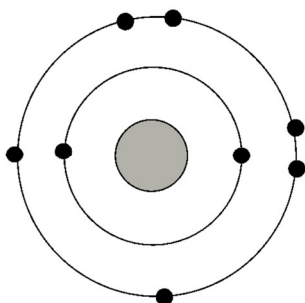
Electron Shells and Bonding

1. Give another name for an electron shell. _____

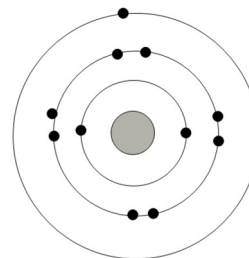
2. Identify the elements shown below.



A. _____



B. _____



C. _____

3. What is the name for an electron in the outer shell of an atom? _____

4. Name the type of bond being formed in each of the following reactions.

a. A sodium atom gives up its outer electron which is picked up by a fluorine atom. Sodium fluoride is formed. _____

b. Two chlorine atoms share a pair of electrons to form a chlorine molecule. _____

Name _____

Date _____

Period _____

- To break a chemical bond, energy must be
 - produced
 - absorbed
 - released
 - destroyed
- Which quantities must be conserved in all chemical reactions?
 - charge, volume, density
 - charge, volume, energy
 - mass, charge, energy
 - mass, charge, density
- Which statement describes a chemical change?
 - Water vapor forms snowflakes.
 - Table salt (NaCl) is crushed into powder.
 - Glucose (C₆H₁₂O₆) and oxygen produce CO₂ and H₂O.
 - Alcohol evaporates.
- Given the balanced equation representing a reaction:

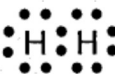
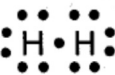
$$\text{Cl}_2 \rightarrow \text{Cl} + \text{Cl}$$
 What occurs during this reaction?
 - A bond is formed as energy is absorbed.
 - A bond is broken as energy is absorbed.
 - A bond is formed as energy is released.
 - A bond is broken as energy is released.
- Given the balanced equation representing a reaction:

$$\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g}) + \text{energy}$$
 Which statement describes the energy changes in this reaction?
 - Energy is absorbed as bonds are broken, and energy is released as bonds are formed.
 - Energy is released as bonds are broken, only.
 - Energy is absorbed as bonds are formed, and energy is released as bonds are broken.
 - Energy is absorbed as bonds are formed, only.
- What occurs when an atom of chlorine and an atom of hydrogen become a molecule of hydrogen chloride?
 - A chemical bond is broken and energy is absorbed.
 - A chemical bond is formed and energy is released.
 - A chemical bond is formed and energy is absorbed.
 - A chemical bond is broken and energy is released.
- In a gaseous system at equilibrium with its surroundings, as molecules of A(g) collide with molecules of B(g) without reacting, the total energy of the gaseous system
 - decreases
 - increases
 - remains the same
- The forces between atoms that create chemical bonds are the result of interactions between
 - electrons
 - protons and nuclei
 - nuclei
 - protons and electrons
- As energy is released during the formation of a bond, the stability of the chemical system generally will
 - decrease
 - increase
 - remain the same
- Which particles may be gained, lost, or shared by an atom when it forms a chemical bond?
 - protons
 - electrons
 - nucleons
 - neutrons
- As a chemical bond forms between two hydrogen atoms the potential energy of the atoms
 - decreases
 - increases
 - remains the same
- Which kind of energy is stored in a chemical bond?
 - potential energy
 - activation energy
 - kinetic energy
 - ionization energy

Name _____

Date _____

Period _____

13. A chemical bond results when two nuclei have a simultaneous attraction for
- A) protons B) electrons
C) neutrons D) nucleons
14. Which symbol represents an atom in the ground state with the most stable valence electron configuration?
- A) Ne B) Li C) O D) B
15. Which symbol represents a particle that has the same total number of electrons as S^{2-} ?
- A) O^{2-} B) Ar C) Si D) Se^{2-}
16. Given the Lewis electron-dot diagram:
- $$\begin{array}{c} \text{H} \\ \vdots \\ \text{H} : \text{C} : \text{H} \\ \vdots \\ \text{H} \end{array}$$
- Which electrons are represented by all of the dots?
- A) the hydrogen valence electrons, only
B) all of the carbon and hydrogen electrons
C) the carbon valence electrons, only
D) the carbon and hydrogen valence electrons
17. When a sodium atom reacts with a chlorine atom to form a compound, the electron configurations of the ions forming the compound are the same as those in which noble gas atoms?
- A) krypton and argon
B) krypton and neon
C) neon and argon
D) neon and helium
18. Which properties are characteristic of the Group 1 metals?
- A) low reactivity and the formation of stable compounds
B) low reactivity and the formation of unstable compounds
C) high reactivity and the formation of stable compounds
D) high reactivity and the formation of unstable compounds
19. Which electron-dot diagram represents H_2 ?
- A)  B) $H \cdot H$
C)  D) $H : H$
20. What is the most likely electronegativity value for a metallic element?
- A) 1.3 B) 2.7 C) 3.4 D) 4.0
21. Which element has an atom with the greatest tendency to attract electrons in a chemical bond?
- A) chlorine B) carbon
C) silicon D) sulfur
22. Which term indicates how strongly an atom attracts the electrons in a chemical bond?
- A) alkalinity B) electronegativity
C) activation energy D) atomic mass
23. Based on electronegativity values, which type of elements tends to have the greatest attraction for electrons in a bond?
- A) noble gases B) metalloids
C) nonmetals D) metals
24. If the electronegativity difference between the elements in compound NaX is 2.1, what is element X ?
- A) fluorine B) oxygen
C) bromine D) chlorine
25. Given the electron dot diagram:
- $$\text{H} : \ddot{\text{F}} :$$
- The electrons in the bond between hydrogen and fluorine are more strongly attracted to the atom of
- A) fluorine, which has the lower electronegativity
B) hydrogen, which has the higher electronegativity
C) hydrogen, which has the lower electronegativity
D) fluorine, which has the higher electronegativity

Name _____

Date _____

Period _____

26. Electronegativity is a measure of an atom's ability to
- attract the protons of another atom
 - attract the electrons in the bond between the atom and another atom
 - repel the electrons in the bond between the atom and another atom
 - repel the protons of another atom
27. Given the electron dot formula:
- $$\text{H} : \overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{X}}} :$$
- Which atom represented as *X* would have the *least* attraction for the electrons that form the bond?
- Br
 - I
 - Cl
 - F
28. Which element is most likely to form a compound with krypton?
- chlorine
 - fluorine
 - bromine
 - iodine
29. In which compound do the atoms have the greatest difference in electronegativity?
- AlCl_3
 - NaBr
 - LiI
 - KF
30. Base your answer to the following question on your knowledge of chemical bonding and on the Lewis electron-dot diagrams of H_2S , CO_2 , and F_2 below.
- $$\begin{array}{c} \text{H} : \overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{S}}} : \\ \text{H} \end{array} \quad \overset{\cdot\cdot}{\text{O}} :: \text{C} :: \overset{\cdot\cdot}{\text{O}} : \quad \overset{\cdot\cdot}{\text{F}} : \overset{\cdot\cdot}{\text{F}} :$$
- Which atom, when bonded as shown, has the same electron configuration as an atom of argon?

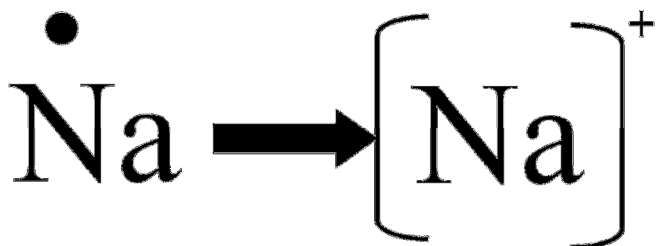
Name _____

Date _____

Period _____

Ionic Bonding

1. What is an ion? _____
2. Give 2 examples of ions. _____
3. Draw Lewis Dot Structures like the example shown to show the given elements becoming ions.



Sodium

Potassium

Fluorine

Aluminum

Magnesium

Chlorine

Calcium

Oxygen

Name _____

Date _____

Period _____

4. Will the charge on a metal ion be positive or negative? _____
5. Will the charge on a nonmetal ion be positive or negative? _____
6. Will the charge on a hydrogen ion be positive or negative? _____

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

- (1) CO₂ (3) KBr
(2) NH₃ (4) Cl₂

8. 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

9. 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, Cl₂. [1]

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

55



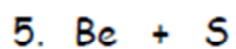
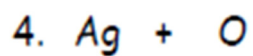
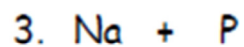
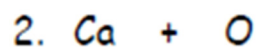
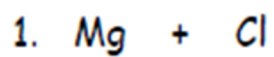
56

Name _____
Period _____

Date _____

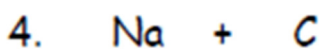
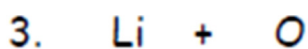
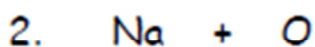
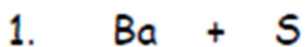
IONIC Lewis Dot Bonding

Draw Lewis dot bonding diagrams for the IONIC compounds below.



Name _____
Period _____

Date _____

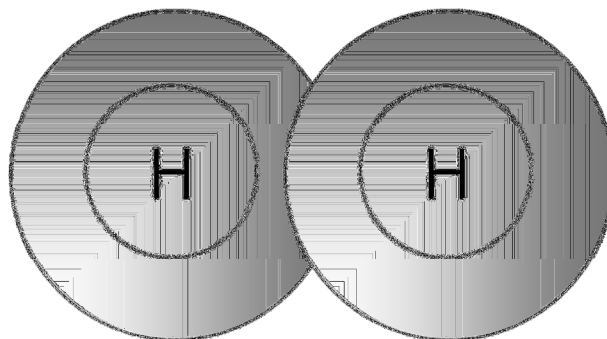
IONIC Lewis Dot Bonding*Draw Lewis dot bonding diagrams for the IONIC compounds below.*

Name _____
Period _____

Date _____

Covalent Bonding

1. What is a molecule? _____
2. What is the joining of two atoms together usually called? _____
3. A covalent bond involves two atoms sharing what? _____
4. Draw 2 dots to represent electrons in a single covalent bond.



5. Why do atoms share electrons? _____

6. Which group on the periodic table do other atoms try to “look like?” _____
7. How many more electrons does chlorine need to achieve a noble gas configuration? _____
8. Draw a chlorine molecule similar to the hydrogen molecule above. Include only the valence electrons.

9. Draw a molecule of carbon dioxide similar to the examples above.

Name _____
Period _____

Date _____

COVALENT Lewis Dot Bonding*Draw Lewis dot bonding diagrams for the COVALENT compounds below.*

Cl_2	CCl_4
O_2	CH_4
C_2H_4	PF_3
NH_3	HF

Name _____
Period _____

Date _____

Covalent Lewis Dot Bonding*Draw Lewis dot bonding diagrams for the COVALENT compounds below.*

H ₂	H ₂ O
CH ₃ I	CH ₂ O
F ₂	CO ₂
N ₂	HCN (<i>Bonus</i>)

Name _____
Period _____

Date _____

Ionic Substances

1. What is an ionic bond? _____
2. If an atom gains one electron, what charge does it have? _____
3. If an atom loses one electron, what charge does it have? _____
4. Why do sodium ions have a +1 charge? _____
5. Why do chloride ions have a -1 charge? _____
6. What charge would you find on a group 2 ion? _____
7. What charge would you find on a group 16 ion? _____
8. What is a cation? _____ an anion? _____
9. Draw a Lewis structure diagram showing what happens when a lithium atom reacts with a chlorine atom and name the compound formed.

10. Draw a Lewis structure diagram showing what happens when a magnesium atom reacts with 2 chlorine atoms and name the compound formed.

11. Why is sodium chloride neutral? _____
12. Draw a diagram to show the arrangement of sodium and chloride ions in a sodium chloride crystal.

Name _____

Date _____

Period _____

13. Give the formula for each of the following:

a. Magnesium oxide: _____

b. Sodium fluoride: _____

c. Sodium oxide: _____

d. Magnesium sulfate: _____

e. Sodium sulfate: _____

14. Name the following ions:

a. Na^+ : _____h. K^+ : _____b. Cl^- : _____i. Ca^{2+} : _____c. S^{2-} : _____j. Mg^{2+} : _____d. NO_3^- : _____k. PO_4^{3-} : _____e. SO_4^{2-} : _____l. H^+ : _____f. I^- : _____m. Ba^{2+} : _____g. F^- : _____n. H^- : _____15. Choose from the following to answer a-f: SO_4^{2-} Mg^{2+} Kr MgO CO_2

a. A gas containing single atoms: _____

b. A substance made from ions: _____

c. A substance made from molecules: _____

d. A compound: _____

e. An ion: _____

f. A molecular ion (a polyatomic ion) : _____

16. Which of the following are general properties of ionically bonded compounds? _____

a. High BP

d. Nonconductor when melted

b. Usually dissolve in water

e. Weak forces hold molecules together

c. Conductor when solid

f. noncrystalline

Name _____
 Period _____

Date _____

Covalent Substances

- Draw Lewis structures of the following molecules:
- Which of the following list are general properties of covalently bonded molecules? _____
 - Low BP
 - Soluble in water
 - Conducts electricity when melted
 - Does not conduct electricity when solid
 - Weak forces attract molecules to each other
 - Crystalline

- The table below lists properties of some substances. Choose from the following to fill in the substance.
 Diamond, Not a covalent substance, a simple molecular substance.

Substance	MP °C	Conducts electricity?	Soluble in water?
	3650	No	No
	-114	No	No
	804	Yes (when molten)	Yes

- Water is a covalent compound.
 - Draw a lewis structure diagram of water
 - Give one property of water that suggests it is a simple molecular structure _____

 - Diamond is also a covalent compound, Explain why water melts at 0°C and diamond at more than 3000°C. _____

Name _____
 Period _____

Date _____

Bonding: Lewis Structure

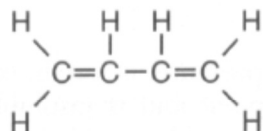
1. What is the total number of electron pairs shared between the two atoms in an O₂ molecule?

- A) 1 B) 2 C) 6 D) 4

2. The nitrogen atoms in a molecule of N₂ share a total of

- A) one pair of electrons
 B) one pair of protons
 C) three pairs of electrons
 D) three pairs of protons

3. Base your answer to the following question on Given the formula of a substance:



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

- A) 9 B) 22 C) 11 D) 6

4. Base your answer to the following question on What is the total number of electrons shared in the bonds between the two carbon atoms in a the molecule shown below?



- A) 6 B) 8 C) 2 D) 3

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

- A) fluorine B) carbon
 C) hydrogen D) oxygen

6. Multiple covalent bonds exist in a molecule of

- A) H₂ B) F₂ C) Br₂ D) N₂

7. Which is the correct electron-dot formula for a hydrogen molecule at STP?

- A) H· B) H·H C) H:H D) H:

8. Atoms of which element can bond to each other to form chains, rings, and networks?

- A) carbon B) fluorine
 C) hydrogen D) oxygen

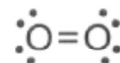
9. Which Lewis electron-dot diagram correctly represents a hydroxide ion?

- A) $\left[\begin{array}{c} \cdot\cdot \\ \cdot\cdot \\ \text{O} \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \text{H} \\ \cdot\cdot \end{array} \right]^{-}$ B) $\left[\begin{array}{c} \cdot\cdot \\ \cdot\cdot \\ \text{O} \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \text{H} \\ \cdot\cdot \end{array} \right]^{-}$
 C) $\left[\begin{array}{c} \cdot\cdot \\ \cdot\cdot \\ \text{O} \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \text{H} \\ \cdot\cdot \end{array} \right]^{-}$ D) $\left[\begin{array}{c} \cdot\cdot \\ \cdot\cdot \\ \text{O} \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \text{H} \\ \cdot\cdot \end{array} \right]^{-}$

10. Which electron-dot diagram best represents a compound that contains both ionic and covalent bonds?

- A) $\text{Ca}^{2+} \left[\begin{array}{c} \cdot\cdot \\ \cdot\cdot \\ \text{O} \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \text{O} \\ \cdot\cdot \\ \cdot\cdot \\ \cdot\cdot \\ \text{O} \\ \cdot\cdot \\ \cdot\cdot \end{array} \right]^{2-}$ B) $\begin{array}{c} \cdot\cdot \\ \cdot\cdot \\ \text{H} \\ \cdot\cdot \\ \cdot\cdot \\ \text{S} \\ \cdot\cdot \\ \cdot\cdot \\ \text{H} \end{array}$
 C) $\text{K}^+ \left[\begin{array}{c} \cdot\cdot \\ \cdot\cdot \\ \text{Br} \\ \cdot\cdot \\ \cdot\cdot \end{array} \right]^{-}$ D) $\begin{array}{c} \cdot\cdot \\ \cdot\cdot \\ \text{Br} \\ \cdot\cdot \\ \cdot\cdot \\ \text{Br} \\ \cdot\cdot \\ \cdot\cdot \end{array}$

11. Base your answer to the following question on Given a formula for oxygen:



What is the total number of electrons shared between the atoms represented in this formula?

- A) 1 B) 2 C) 8 D) 4

12. The bond between Br atoms in a Br₂ molecule is

- A) ionic and is formed by the transfer of two valence electrons
 B) covalent and is formed by the transfer of two valence electrons
 C) covalent and is formed by the sharing of two valence electrons
 D) ionic and is formed by the sharing of two valence electrons

13. Which molecule contains a triple covalent bond?

- A) N₂ B) Cl₂ C) O₂ D) H₂

14. Which molecule will have a double covalent bond?

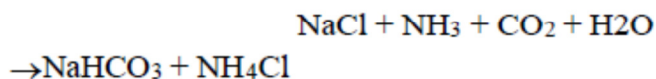
- A) O₂ B) Cl₂ C) F₂ D) N₂

Name _____
 Period _____

Date _____

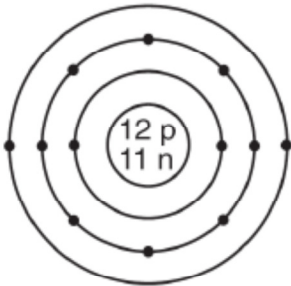
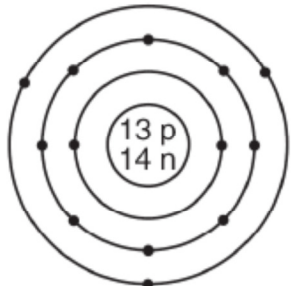
Base your answers to questions **15** and **16** on the information below.

In 1864, the Solvay process was developed to make soda ash. One step in the process is represented by the balanced equation below.



15. In the space draw a Lewis electron-dot diagram for the reactant containing nitrogen in the equation.
16. Write the chemical formula for *one compound in the equation that contains both ionic bonds and covalent bonds*.
- _____
17. What is the total number of electron pairs shared between the carbon atom and one of the oxygen atoms in a carbon dioxide molecule?
18. Base your answer to the following question on the information below.

Atomic Diagrams of Magnesium and Aluminum

Key • = electron	Element	Lewis Electron-Dot Diagram	Electron-Shell Diagram
	magnesium	Mg:	
	aluminum	Al:	

Explain why Lewis electron-dot diagrams are generally more suitable than electron-shell diagrams for illustrating chemical bonding.

Name _____
 Period _____

Date _____

19. Base your answer to the following question on the following information.

Carbon and oxygen are examples of elements that exist in more than one form in the same phase.

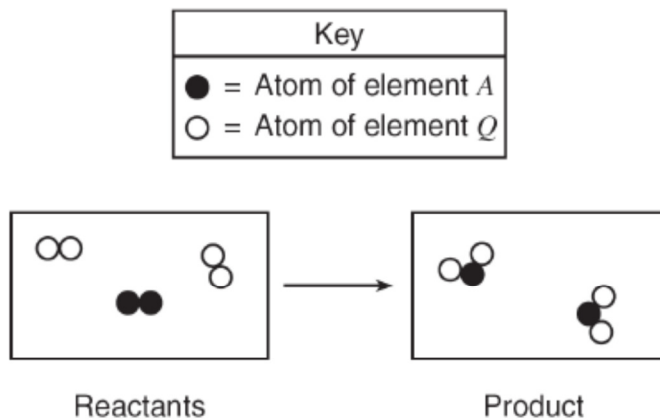
Graphite and diamond are two crystalline arrangements for carbon. The crystal structure of graphite is organized in layers. The bonds between carbon atoms within each layer of graphite are strong. The bonds between carbon atoms that connect different layers of graphite are weak because the shared electrons in these bonds are loosely held by carbon atoms. The crystal structure of diamond is a strong network of atoms in which the shared electrons are strongly held by the carbon atoms. Graphite is an electrical conductor, but diamond is not. At 25°C, graphite has a density of 2.2 g/cm³ and diamond a density of 3.51 g/cm³.

The element oxygen can exist as diatomic molecules, O₂, and as ozone, O₃. At standard pressure the boiling point of ozone is 161 K.

Explain, in terms of electrons, why graphite is an electrical conductor and diamond is *not*. Your response must include information about both graphite and diamond.

Base your answers to questions 20 through 22 on the information below.

The particle diagrams below represent the reaction between two nonmetals, A₂ and Q₂.



20. Compare the total mass of the reactants to the total mass of the product.
21. Identify the type of chemical bond between an atom of element A and an atom of element Q.
22. Using the symbols A and Q, write the chemical formula of the product.
-
23. Explain, in terms of valence electrons, why the bonding in magnesium oxide, MgO, is similar to the bonding in barium chloride, BaCl₂.

Name _____
 Period _____

Date _____

Metallic Structures

1. Describe how an atom of iron joins up to other atoms of iron in an iron bar. _____

2. Metals have “giant structures” of atoms. What is a “giant structure?” _____

3. What are mobile electrons? _____

Where do they originate? _____

4. Draw a diagram to show the metal atoms and free electrons in a giant structure.

5. Complete the table,

Metal Property	Reason
Strong	
Good conductor of heat	
Good conductor of electricity	
Malleable	
Ductile	

6. What is the name given to a bond in a metal? _____

7. What is an alloy? _____

Name _____

Date _____

Period _____

8. Use the info in the table below to choose a suitable metal for each of the following. Explain your choice.

Metal	MP °C	BP °C	Density in g/cm ³	Electrical conductivity	Reaction with water
A	659	2447	2.7	0.41	None
B	1083	2582	8.9	0.64	None
C	1539	2887	7.9	0.11	Slight
D	328	1751	11.3	0.05	None
E	98	890	0.97	0.20	Very reactive
F	183	2500	7.3	0.66	None
G	1063	2707	19.3	0.49	None
H	3377	5527	19.3	0.20	None

- a. A filament for a light bulb _____

- b. A metal that could be used to make solder _____

- c. A metal used to make airplanes _____

- d. An overhead power cable _____

Name _____
 Period _____

Date _____

Polar Bonds

1. Explain what is meant by electronegativity. _____

2. What is the most electronegative element? _____ What group is it in? _____
3. Name 3 other elements which are strongly electronegative. _____
 _____ In which period(s) are they? _____
4. Why are some covalent bonds polar? _____

5. A hydrogen bromide molecule has a polar bond. Which of the two atoms in this molecule has the lower electronegativity? _____
6. Why are the covalent bonds in diatomic molecules such as H₂ nonpolar? _____

Give another example of a diatomic gas. _____

7. What is a dipole? _____
8. For each of the following, state which atom has the greatest electronegativity.
 - a. HCl _____
 - b. CO₂ _____
 - c. H₂O _____

9. The diagram below shows the polar bond between hydrogen and fluorine. Draw diagrams like the example above to show bonds between the following atoms.



- a. H and Cl
 - b. C and Br
 - c. F and F
10. List the following bonds in order from highest to least polarity. HF, HBr, HCl _____

Name _____
Period _____

Date _____

BOND POLARITY

1. What factor causes some combinations of atoms to form ions, and other combinations of atoms to form covalent bonds? Explain in detail. _____

2. What is a nonpolar covalent bond? _____

Explain the electronegativity differences attributed to this type of bond.

3. What is a polar bond? _____

Explain the electronegativity differences attributed to this type of bond. _____

4. Explain the relationship between electronegativity difference and polarity. _____

5. What is a dipole? _____

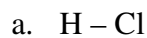
6. How do you determine which atom gets the partial negative charge? _____

Name _____

Date _____

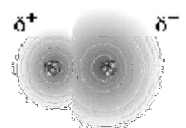
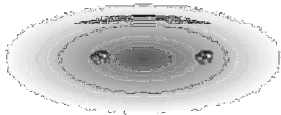
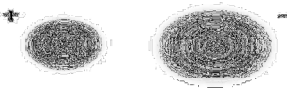
Period _____

7. Given the following indicate which atom will receive the partial negative charge and which atom will receive the partial positive charge. Place the partial charges in the upper right hand corner of the atom symbol:



8. Compare the degree (which compound is most polar, which is least polar) of polarity in HF, HBr, HCl, and HI. _____

9. Classify the type of molecule the diagrams below represent (Ionic, Polar Covalent, or Nonpolar Covalent), and explain your reasoning.

Electron Distribution Diagram	Type of Compound	Reason for Classification of Compound
		
		
		

Name _____
Period _____

Date _____

10. Write Lewis structures for each of the following molecules. Indicate any partial charges that may exist for polar bonds with + or -.

(a) PCl_3	(b) CBr_4
(c) CS_2	(d) H_2O
(e) CH_4	(f) NH_3

Name _____
 Period _____

Date _____

Intermolecular Forces

1. Which of the following will have the higher boiling point, NH_3 or N_2 ? _____

Explain your answer using intermolecular forces. _____

2. Why does dry ice (solid CO_2) evaporate before sodium chloride? _____

3. Why does gasoline (C_8H_{18}) exist in the liquid form while methane (CH_4), the gas we use to power our Bunsen burners, exists in the gas form even though both compounds are nonpolar? _____

4. Identify the intermolecular forces that exist in the following molecules.

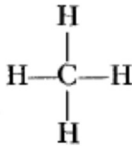
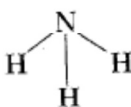
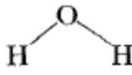
Compound	Type of IMF
H_2O	
N_2	
HCl	
LiCl	

5. Of the compounds in question 4, which has the strongest surface tension? _____

Name _____
 Period _____

Date _____

Polarity and IMF's

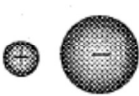



- Which formula represents a polar molecule?
 A) CO_2 B) CCl_4 C) H_2 D) H_2O
- Which substance is correctly paired with its type of bonding?
 A) Br_2 —polar covalent
 B) NH_3 —polar covalent
 C) NaBr —nonpolar covalent
 D) HCl —nonpolar covalent
- When two atoms form a chemical bond by sharing electrons, the resulting molecule will be
 A) polar, only
 B) nonpolar, only
 C) either polar or nonpolar
 D) neither polar nor nonpolar
- Which molecule is the most polar?
 A) H_2S B) H_2Te
 C) H_2Se D) H_2O
- Which of these substances has the strongest intermolecular forces?
 A) H_2O B) H_2Se
 C) H_2S D) H_2Te
- Which compound has hydrogen bonding between its molecules?
 A) KH B) CaH_2
 C) CH_4 D) NH_3
- The liquids hexane and water are placed in a test tube. The test tube is stoppered, shaken, and placed in a test tube rack. The liquids separate into two distinct layers because hexane and water have different
 A) pH values
 B) molecular polarities
 C) specific heats
 D) formula masses
- Which structural formula represents a nonpolar symmetrical molecule?
 A)  B) 
 C)  D) $\text{H}-\text{F}$
- Which is the formula of a nonpolar molecule containing nonpolar bonds?
 A) CO_2 B) H_2 C) NH_3 D) H_2O
- Two fluorine atoms are held together by a covalent bond. Which statement correctly describes this bond?
 A) It is polar and forms a polar molecule.
 B) It is nonpolar and forms a nonpolar molecule.
 C) It is polar and forms a nonpolar molecule.
 D) It is nonpolar and forms a polar molecule.
- Given the formula representing a molecule:

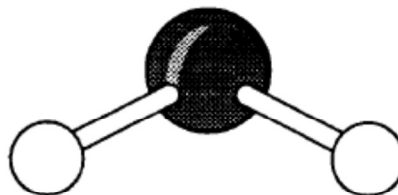
$$\text{H}-\text{C}\equiv\text{C}-\text{H}$$

 The molecule is
 A) symmetrical and polar
 B) asymmetrical and nonpolar
 C) asymmetrical and polar
 D) symmetrical and nonpolar
- Why is a molecule of CO_2 nonpolar even though the bonds between the carbon atom and the oxygen atoms are polar?
 A) The CO_2 molecule has a deficiency of electrons.
 B) The shape of the CO_2 molecule is asymmetrical.
 C) The shape of the CO_2 molecule is symmetrical.
 D) The CO_2 molecule has an excess of electrons.

Name _____
 Period _____

Date _____

13. The four single bonds of a carbon atom in CH_4 are directed toward the corners of a
- A) parallelogram B) rectangle
 C) square D) tetrahedron
14. Which statement explains why low temperature and high pressure are required to liquefy chlorine gas?
- A) Chlorine molecules have strong covalent bonds.
 B) Chlorine molecules have weak covalent bonds.
 C) Chlorine molecules have strong intermolecular forces of attraction.
 D) Chlorine molecules have weak intermolecular forces of attraction.
15. At STP, fluorine is a gas and bromine is a liquid because, compared to fluorine, bromine has
- A) weaker covalent bonds
 B) weaker intermolecular forces
 C) stronger covalent bonds
 D) stronger intermolecular forces
16. Which diagram best represents a polar molecule?
- A)  NaCl B)  HCl
- C)  Cl_2 D)  H_2
17. Which of the following compounds has the highest boiling point?
- A) H_2O B) H_2Te
 C) H_2S D) H_2Se
18. In a nonpolar covalent bond, electrons are
- A) shared unequally by two atoms
 B) shared equally by two atoms
 C) transferred from one atom to another
 D) located in a mobile "sea" shared by many atoms
19. The degree of polarity of a chemical bond in a molecule of a compound can be predicted by determining the difference in the
- A) densities of the elements in the compound
 B) atomic masses of the bonded atoms in a molecule of the compound
 C) melting points of the elements in the compound
 D) electronegativities of the bonded atoms in a molecule of the compound
20. Two atoms of element A unite to form a molecule with the formula A_2 . The bond between the atoms in the molecule is
- A) ionic
 B) polar covalent
 C) nonpolar covalent
 D) electrovalent
21. At STP, fluorine is a gas and iodine is a solid. This observation can be explained by the fact that fluorine has
- A) stronger intermolecular forces of attraction than iodine
 B) lower average kinetic energy than iodine
 C) weaker intermolecular forces of attraction than iodine
 D) higher average kinetic energy than iodine
22. Which molecule is polar and contains polar bonds?
- A) N_2 B) CCl_4
 C) NH_3 D) CO_2
23. The diagram below represents a water molecule.



This molecule is best described as

- A) polar with nonpolar covalent bonds
 B) polar with polar covalent bonds
 C) nonpolar with nonpolar covalent bonds
 D) nonpolar with polar covalent bonds

Name _____
 Period _____

Date _____

24. In aqueous solution, a chloride ion is attracted to which end of the water molecule?
- A) the hydrogen end, which is the negative pole
 B) the hydrogen end, which is the positive pole
 C) the oxygen end, which is the positive pole
 D) the oxygen end, which is the negative pole
25. Base your answer to the following question on the number of the substance, chosen from the table below, that best answers that question.

Substance	Melting Point °K.	Boiling Point °K.
(1) sodium chloride	1,074	1,686
(2) helium	1	4
(3) diamond	3,773	4,473
(4) water	273	373

Which substance forms a molecular solid made up of polar molecules?

- A) 1 B) 2 C) 3 D) 4
26. Which electron-dot structure represents a non-polar molecule?
- A) $\begin{array}{c} \text{H} : \ddot{\text{O}} : \\ | \\ \text{H} \end{array}$ B) $\begin{array}{c} \text{H} \\ | \\ \text{H} : \ddot{\text{C}} : \text{H} \\ | \\ \text{H} \end{array}$
- C) $\begin{array}{c} \text{H} : \ddot{\text{C}} : \\ | \\ \text{H} \end{array}$ D) $\begin{array}{c} \text{H} : \ddot{\text{N}} : \text{H} \\ | \\ \text{H} \end{array}$
27. Which terms describe a substance that has a low melting point and poor electrical conductivity?
- A) ionic and molecular
 B) covalent and metallic
 C) ionic and metallic
 D) covalent and molecular

28. Molecules in a sample of $\text{NH}_3(\ell)$ are held closely together by intermolecular forces
- A) caused by unequal charge distribution
 B) existing between electrons
 C) existing between ions
 D) caused by different numbers of neutrons
29. Which compound has molecules that form the strongest hydrogen bonds?
- A) HI B) HBr C) HCl D) HF
30. Hexane (C_6H_{14}) and water do *not* form a solution. Which statement explains this phenomenon?
- A) Hexane is ionic and water is polar.
 B) Hexane is polar and water is nonpolar.
 C) Hexane is nonpolar and water is ionic.
 D) Hexane is nonpolar and water is polar.
31. Which phrase describes the distribution of charge and the polarity of a CH_4 molecule?
- A) symmetrical and polar
 B) asymmetrical and polar
 C) symmetrical and nonpolar
 D) asymmetrical and nonpolar
32. In which material are the particles arranged in a regular geometric pattern?
- A) $\text{NaCl}(\text{aq})$ B) $\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s})$
 C) $\text{CO}_2(\text{g})$ D) $\text{H}_2\text{O}(\ell)$

Name _____
Period _____

Date _____

IMF's and BP/MP

1. In terms of the forces of attraction holding them together, explain why a NaCl crystal has a melting point of 800°C while an ice cube of pure water has a melting point of 0°C . _____

2. Predict the relative melting points of CO_2 and SiO_2 based on their attractive forces and the information given in question one. Explain your reasoning. (Hint: SiO_2 is a covalent **network**) _____

3. List the noble gases from highest to lowest boiling point. Explain your answer based on intermolecular forces of attraction. _____

4. Explain why I_2 is a solid, Br_2 is a liquid but Cl_2 and F_2 are gases even though they are all Halogens. _____

5. List the following substances from highest to lowest melting point, KCl , Cl_2 , CH_4 , H_2S , SiO_2 and H_2O _____
_____ Use attractive force to justify your answers. _____

Name _____
 Period _____

Date _____

Relative Melting Point (m.p.)/Boiling Point (b.p.)

NaCl C(diamond) H₂Se H₂S O₂ CO₂ H₂O MgO

Group the above compounds according to the type of bonding present.

Covalent network	Ionic	Polar covalent/IMF's	Nonpolar covalent/IMF's

6. Which of the compounds would you expect to have the highest melting point? _____

7. Which of the compounds would you expect to have the lowest melting point? _____

HBr CCl₄ MgCl₂ SiO₂(network) NH₃ N₂ HCl LiBr

Group the compounds above according to the type of bonding present.

Covalent network	Ionic	Polar covalent/IMF's	Nonpolar covalent/IMF's

8. Which of the compounds would you expect to have the highest melting point? _____

9. Which of the compounds would you expect to have the lowest melting point? _____

Name _____
 Period _____

Date _____

Bonding Review

1-7 are True/False

1. A group of atoms united by ionic bonds is called a molecule. _____
2. A covalent bond is formed by a shared pair of electrons. . _____
3. A double covalent bond consists of two shared electrons. . _____
4. Dipole-dipole interactions are the only IMF's that exist in nonpolar molecules. . _____
5. Polar molecules always have a higher M.P./B.P. nonpolar molecules. . _____
6. In nonpolar covalent bonds, the electrons are shared unequally between two atoms. . _____
7. Hydrogen bonds are basically a specific, very strong version of dipole-dipole interactions. . _____
8. Carbon tetrachloride has polar bonds between the atoms but the overall molecule is nonpolar. Explain why the bonds are polar and why the molecules are nonpolar. _____

9. For each of the bonds below, determine the electronegativity difference (SHOW ALL WORK) and the type of bond that results (ionic, polar covalent, or nonpolar covalent).

Bond	Electronegativity Difference	Bond Type
H---O		
C---C		
K---F		
N---H		
Na---F		
H---H		

Name _____
Period _____

Date _____

10. Draw Lewis Dot Structures for the following compounds. Indicate the type of bond by using either brackets and charges (ionic) or dashes (covalent).

1. NH_3	2. PCl_3
3. H_2	4. CCl_4
5. MgCl_2	6. KBr

Multiple Choice - 2 pts. each

- 1) Which of the following bonds exhibits the *greatest* ionic character?
a) H - F b) H - I c) H - Br d) H - Cl
- 2) Generally, how many valence electrons are needed for atoms to be *most* stable?
a) 8 b) 6 c) 32 d) 18
- 3) Which type of bonding is characteristic of a substance that has a high melting point and electrical conductivity only in the liquid phase?
a) ionic b) metallic c) nonpolar covalent d) polar covalent
- 4) Which compound is ionic?
a) CaCl_2 b) N_2O c) HCl d) SO_2
- 5) In which compound do the atoms have the greatest difference in electronegativity?
a) AlCl_3 b) NaBr c) KF d) LiI
- 6) What type of bonds are present in a strip of magnesium ribbon?
a) metallic b) covalent c) ionic d) London dispersion
- 7) Which particles are gained, lost, or shared by an atom when it forms a chemical bond?
a) nucleons b) neutrons c) protons d) electrons
- 8) Two atoms with an electronegativity difference of 0.4 form a bond that is
a) ionic, because electrons are transferred
b) covalent, because electrons are shared
c) ionic, because electrons are shared
d) covalent, because electrons are transferred
- 9) Which type of bonds are formed when calcium atoms react with oxygen atoms?
a) hydrogen b) coordinate covalent c) polar covalent d) ionic
- 10) Which type of bond is formed by the transfer of electrons from one atom to another?
a) an ionic bond c) a covalent bond
b) a hydrogen bond d) a coordinate covalent bond
- 11) Which atoms are most likely to form covalent bonds?
a) nonmetal atoms that share electrons
b) metal atoms that share protons
c) nonmetal atoms that share protons
d) metal atoms that share electrons

12) Which compound contains *both* covalent and ionic bonds?



13) Oxygen, nitrogen, and fluorine bond with hydrogen to form molecules. These molecules are attracted to each other by

a) coordinate covalent bonds

c) ionic bonds

b) electrovalent bonds

d) hydrogen bonds

14) The bond between hydrogen and oxygen in a water molecule is classified as

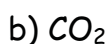
a) covalent and nonpolar

c) ionic and polar

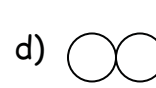
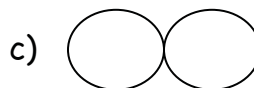
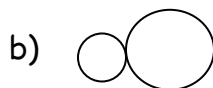
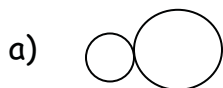
b) ionic and nonpolar

d) covalent and polar

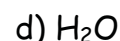
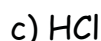
15) Which is a nonpolar molecule containing a nonpolar covalent bond?



16) Which diagram *best* represents a polar covalent molecule?



17) Which molecule is nonpolar due to a symmetrical distribution of charge?



18) The unusually high boiling point of water is due to the

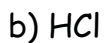
a) network bonds between the molecules

b) nonpolar character of the molecules

c) hydrogen bonds between the molecules

d) linear structure of the molecules

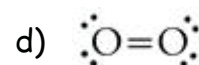
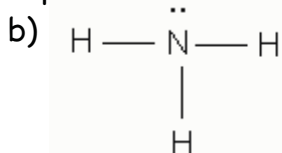
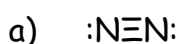
19) Which substance will conduct electricity in *both* the solid phase and the liquid phase?



20) Which formula represents a molecular substance?



21) Which molecule contains a polar covalent bond?



22) The electrons in a bond between two iodine atoms (I_2) are shared

- unequally, and the resulting bond is polar
- equally, and the resulting bond is polar
- unequally, and the resulting bond is nonpolar
- equally, and the resulting bond is nonpolar

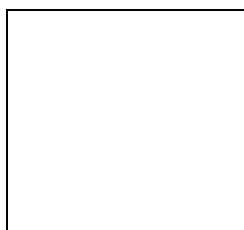
23) Which of the following solid substances contains positive ions immersed in a sea of mobile electrons?

- a) O_2 b) Cu c) CuO d) SiO_2

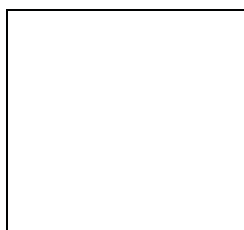
Short Answer Questions:

24) In the boxes below, draw a correct Lewis electron-dot structure for: (3 pts.)

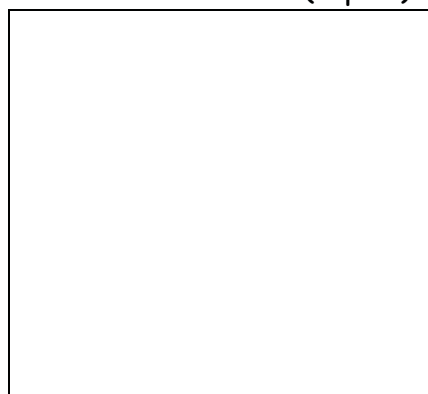
- an atom of hydrogen
- an atom of oxygen
- a molecule of water (H_2O)



(1) hydrogen

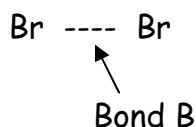
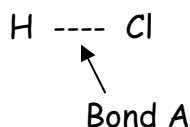


(2) oxygen

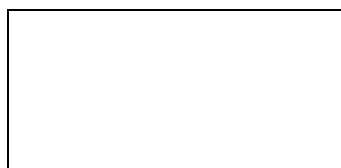


(3) water

25)



- State *one* way in which bond A and bond B (above) are the same and *one* way in which they are different. (2 pts.)
- Draw the Lewis electron-dot diagrams for the two molecules above. Label any partial charges. (2 pts.)



HCl



Br_2

- Is HCl a polar or nonpolar molecule? [Explain why.] (2 pts.)

26) Write the correct IUPAC chemical formula for the following compounds (1 pt. each)

1) barium chloride _____

2) iron (III) bromide _____

3) dihydrogen monoxide _____

4) magnesium nitrate _____

5) sodium bromide _____

27) Write the correct IUPAC chemical names for the following compounds (1 pt. each)

1) CF_4 _____

2) N_2S_3 _____

3) MgO _____

4) NaOH _____

28) Metals like copper are often used in electrical wiring.

a) Name *two* properties of metals that makes them useful in electrical wiring (2 pts.)

b) Explain how metallic bonding between copper atoms can account for each of these properties (1 pt.)

29) Describe the role of valence electrons in: (1 pt. each)

1) an ionic bond

2) a covalent bond

3) a metallic bond

30) In the laboratory, a student compares the properties of two unknown solids. The results of his experiment are reported in the data table below.

	Substance A	Substance B
Melting Point	low	high
Solubility in Water	nearly insoluble	soluble
Hardness	soft, waxy crystals	hard crystals
Electrical Conductivity	poor conductor in both solid and aqueous states	poor conductor in the solid state, but good conductor in the aqueous state

Predict the type of bonding in substance A. (1 pt.)

31) Given the binary compound formed from magnesium and chlorine:

- Write the correct IUPAC name for this compound (1 pt.)
- Write the correct chemical formula for this compound (1 pt.)
- What type of bond forms between magnesium and chlorine? [*Give one reason to support your answer.*] (2 pts.)
- In the boxes below, draw the Lewis electron-dot structures for the elements Mg and Cl. (2 pts.)

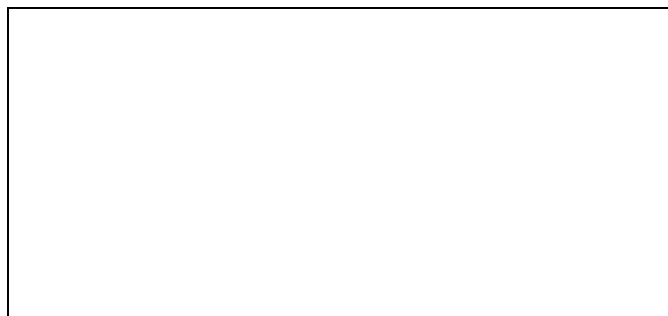


magnesium



chlorine

- In the box below, draw the Lewis electron-dot structure for the compound formed from magnesium and chlorine. [*Include any charges or partial charges.*] (1 pt.)



32) Explain, in terms of electronegativity, why an H-F bond is expected to be more polar than an H-I bond. (2 pts.)

33) Given the reaction: $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$

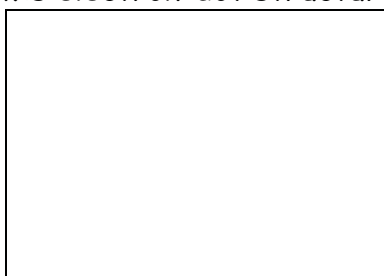
Which statement best describes the energy change as bonds are formed and broken in this reaction?

- a) The forming of the H-Cl bond releases energy
- b) The forming of the H-Cl bond absorbs energy
- c) The breaking of the H-H bond releases energy
- d) The breaking of the Cl-Cl bond releases energy

34) When phosphorus and chlorine atoms combine to form a molecule of PCl_3 , 6 electrons will be

- a) shared equally b) shared unequally c) lost d) gained

35) In the box below, draw a Lewis electron-dot structure for a molecule of hydrogen.

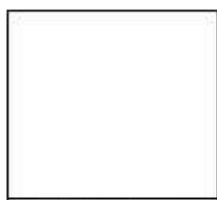


Hydrogen

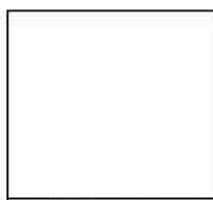
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____
21. _____
22. _____
23. _____

24) In the boxes below, draw a correct Lewis electron-dot structure for: (3 pts.)

- (1) an atom of hydrogen
- (2) an atom of oxygen
- (3) a molecule of water (H_2O)



(1) hydrogen



(2) oxygen



(3) water

25)



Bond A



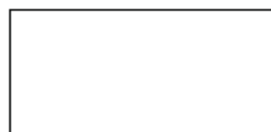
Bond B

a) State *one* way in which bond A and bond B (above) are the same and *one* way in which they are different. (2 pts.)

b) Draw the Lewis electron-dot diagrams for the two molecules above. Label any partial charges. (2 pts.)



HCl



Br₂

c) Is HCl a polar or nonpolar molecule? [Explain why.] (2 pts.)

26) Write the correct IUPAC chemical formula for the following compounds (1 pt. each)

1) barium chloride _____

2) iron (III) bromide _____

3) dihydrogen monoxide _____

4) magnesium nitrate _____

5) sodium bromide _____

27) Write the correct IUPAC chemical names for the following compounds (1 pt. each)

1) CF_4 _____

2) N_2S_3 _____

3) MgO _____

4) NaOH _____

28) Metals like copper are often used in electrical wiring.

a) Name *two* properties of metals that makes them useful in electrical wiring (2 pts.)

b) Explain how metallic bonding between copper atoms can account for each of these properties (1 pt.)

29) Describe the role of valence electrons in: (1 pt. each)

1) an ionic bond

2) a covalent bond

3) a metallic bond

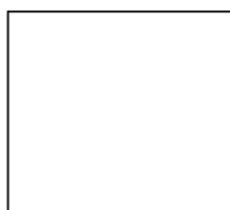
30) In the laboratory, a student compares the properties of two unknown solids. The results of his experiment are reported in the data table below.

	Substance A	Substance B
Melting Point	low	high
Solubility in Water	nearly insoluble	soluble
Hardness	soft, waxy crystals	hard crystals
Electrical Conductivity	poor conductor in both solid and aqueous states	poor conductor in the solid state, but good conductor in the aqueous state

Predict the type of bonding in substance A. (1 pt.)

31) Given the binary compound formed from magnesium and chlorine:

- Write the correct IUPAC name for this compound (1 pt.)
- Write the correct chemical formula for this compound (1 pt.)
- What type of bond forms between magnesium and chlorine? [Give one reason to support your answer.] (2 pts.)
- In the boxes below, draw the Lewis electron-dot structures for the elements Mg and Cl. (2 pts.)



magnesium



chlorine

- In the box below, draw the Lewis electron-dot structure for the compound formed from magnesium and chlorine. [Include any charges or partial charges.] (1 pt.)



32) Explain, in terms of electronegativity, why an H-F bond is expected to be more polar than an H-I bond. (2 pts.)

33) Given the reaction: $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$

Which statement best describes the energy change as bonds are formed and broken in this reaction?

- a) The forming of the H-Cl bond releases energy
- b) The forming of the H-Cl bond absorbs energy
- c) The breaking of the H-H bond releases energy
- d) The breaking of the Cl-Cl bond releases energy

34) When phosphorus and chlorine atoms combine to form a molecule of PCl_3 , 6 electrons will be

- a) shared equally
- b) shared unequally
- c) lost
- d) gained

35) In the box below, draw a Lewis electron-dot structure for a molecule of hydrogen.



Hydrogen