WORKSHEET 5.1: BONDING INTRODUCTION

NAME: ____________________ DATE: _____________________

1. Which groups of elements in the periodic table of elements will form
   a. network covalent compounds – compound made of C and Si

   b. metallic compounds – compound made of only metals (Na, alloy – Ni & Cu)

   c. ionic compounds – compounds made cation and anion

   d. molecular compounds – compounds made non-metals only

2. Predict whether the bonding between the atoms in the following substances will be *network, metallic, ionic or covalent*.

a. $KCl_{(s)}$ I	b. $Mg_{(s)}$ M	c. $CaO_{(s)}$ I
d. $O_{2(g)}$ C	e. $NO_{2(g)}$ C	f. $Ag_{(s)}$M
g. $BaCl_{2(s)}$I	h. $S_{8(s)}$ C	i. $SO_{2(g)}$C
j. $CsF_{(s)}$ I	k. $C_{4(s)}$ N	l. $SiC_{(s)}$ N

3. Define and give one characteristic for each of the following:
   a. A chemical bond: net attraction between the positive protons and negative electrons

   b. A covalent bond: attraction between shared electrons and the positive nuclei

   c. An ionic bond: attraction between cation and anion

   d. An metallic bond: attraction between sea of electrons and positive metal nuclei

   e. A network bond: attraction between a network of shared electrons and C or Si nuclei

WORKSHEET 5.2: BASICS OF BONDING

1. Draw energy level diagrams for:

a) $_{11}Na^{23}$ and Na^+

1e-	**lost e**
8e-	**8e-**
2e-	**2e-**
11p, 12n	**11p 12n**

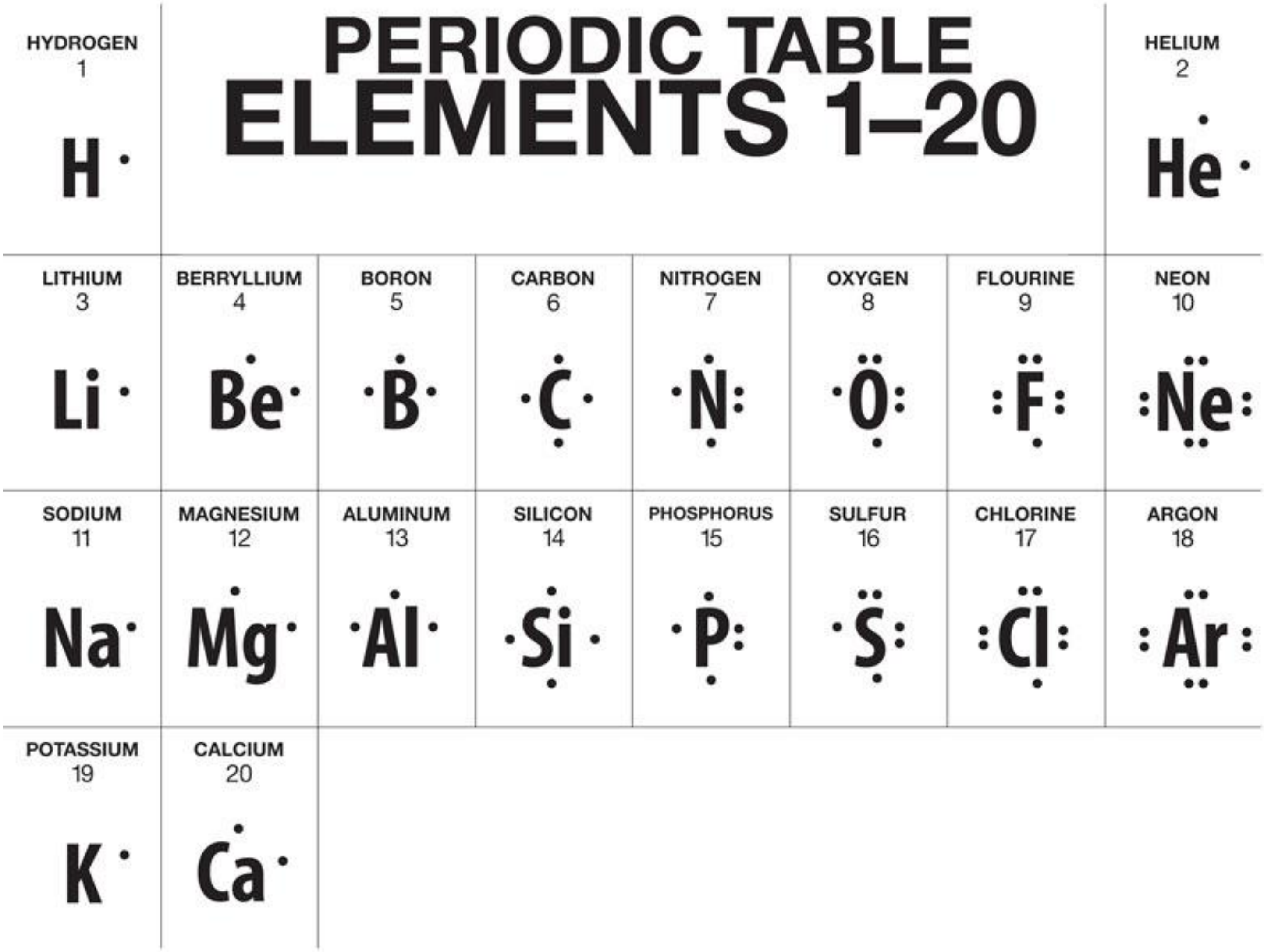
b) $_{8}O^{15}$ and O^{2-}

6e-	**6e- + 2e-**
2e-	**2e-**
8p, 7n	**8p, 7n**

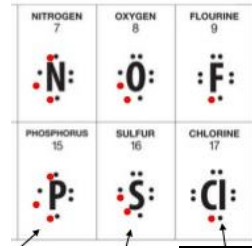
2. Predict and fill in the rest of the *valence shell* representations for the first 36 elements

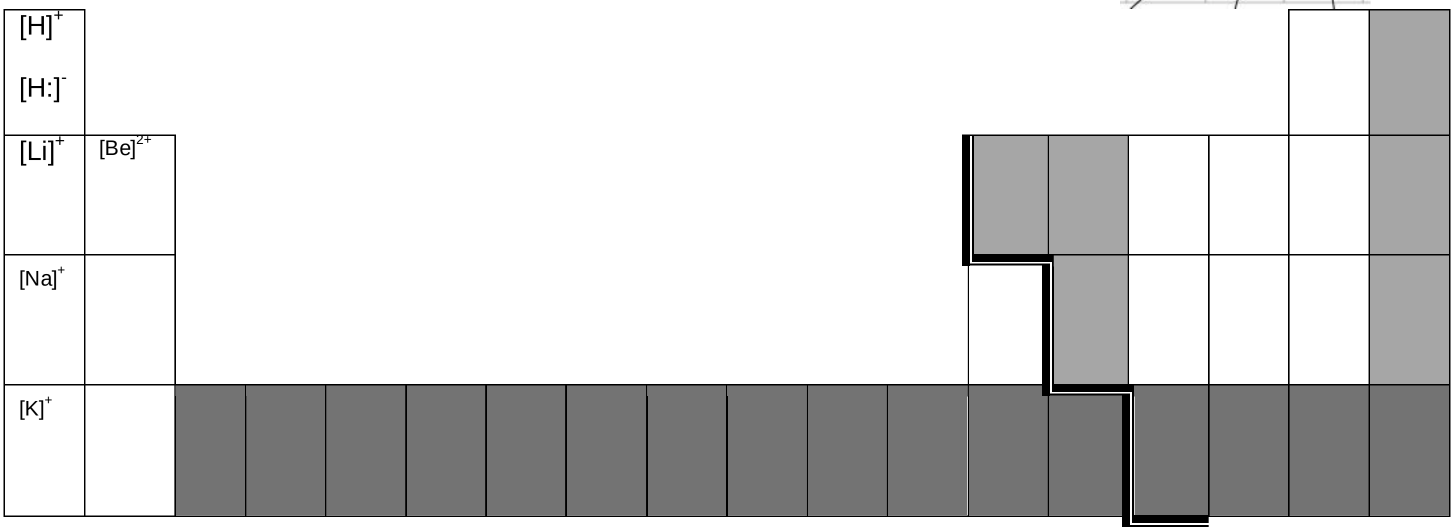
$1s^1$																	$1s^2$
$2s^1$	$2s^2$											$2s^2$ $2p^1$	$2s^2$ $2p^2$	$2s^2$ $2p^3$	$2s^2$ $2p^4$	$2s^2$ $2p^5$	$2s^2$ $2p^6$
$3s^1$	$3s^2$											$3s^2$ $3p^1$	$3s^2$ $3p^2$	$3s^2$ $3p^3$	$3s^2$ $3p^4$	$3s^2$ $3p^5$	$3s^2$ $3p^6$
$4s^1$	$4s^2$	$3d^1$ $4s^2$	$3d^2$ $4s^2$	$3d^3$ $4s^2$	$3d^4$ $4s^2$	$3d^5$ $4s^2$	$3d^6$ $4s^2$	$3d^7$ $4s^2$	$3d^8$ $4s^2$	3d s^2	$3d^{10}$ $4s^2$	$3d^{10}$ $4s^2$ $4p^1$	$3d^{10}$ $4s^2$ $4p^2$	$3d^{10}$ $4s^2$ $4p^3$	$3d^{10}$ $4s^2$ $4p^4$	$3d^{10}$ $4s^2$ $4p^5$	$3d^{10}$ $4s^2$ $4p^6$

3. Draw the electron dot diagrams for the first 20 elements.



4. Draw the electron dot diagrams for the first 14 ions. Hydrogen has two ions.





5. Complete the following table.

	Group #	Gain/Lose e^-	Name of Ion	Ion formula	Nobel Gas Most Like
sodium	**1**	**Lose 1e**	**Sodium ion**	Na^+	**Ne**
magnesium	**2**	**Lose 2e**	**Magnesium ion**	Mg^{2+}	**Ne**
sulfur	**16**	**Gains 2e**	**Sulfide ion**	S^{2-}	**Ar**
chlorine	**17**	**Gains 1e**	**Chloride ion**	Cl^{1-}	**Ar**

6. Name and draw the Lewis dot diagrams for 4 ionic compounds that could form from the table above.

Sodium sulfide: $[Na]^{1+}$-$[:\ddot{S}:]^{2-}$-$[Na]^{1+}$

Sodium chloride: $[Na]^{1+}$-$[:\ddot{Cl}:]^{1-}$

Magnesium sulfide $[Mg]^{2+}$-$[:\ddot{S}:]^{2-}$

Magnesium chloride: $[:\ddot{Cl}:]^{1-}$-$[Mg]^{2+}$-$[:\ddot{Cl}:]^{1-}$

7. Does carbon gain or lose electrons to achieve a stable electron configuration. HINT look at your periodic table. It does neither. It can't decide whether to gain 4 or lose 4e so it does neither. Instead is shares 4 electrons – over 80 of all molecular compounds contain carbon. (ORGANIC CHEMISTRY)

8. What observable evidence is there that the electron structure in Noble Gases is stable? Noble Gases are inert; shells are full of at least 8 electrons (octet rule); Exception is Helium

9. Define & give an example of

a. bonding electrons: 1 electron on the last shell

b. lone pair: pair of electrons that are not active (Paul's Exclusion)

c. ionic bond: transfer of electrons creating a cation and anion that are attracted to each other; NaCl

d. network covalent bond: sharing of electrons between Cs and/or Sis forming a network

e. metallic bond: sea of electrons attracted to metal positive nuclei

10. Based on electronegativity describe what type of bond would form between:
   a. Br_2: **3.0-3.0 = 0; covalent non-polar**
   b. CO: **2.6 – 3.5 = 0.9; covalent polar**
   c. Hydrogen phosphide: **H_3P 2.2–2.2=0; but it is pyramidal = covalent polar**
   d. Lithium nuclei – **Li; 1.0 – 1.0 = 0; metallic**
   e. Argon nuclei – Ar: no electronegativity = inhert (non-reactive and no bonds)
   f. Potassium sulfide **K_2S: 0.8 – 2.6 = 1.8; ionic**

WORKSHEET 5.3: IONIC COMPOUNDS

1. Silver sulfide tarnish (sulfur):
   a) Write a balanced simple composition reaction. Identify the type of reaction. Identify the element that is undergoing reduction and the element that is undergoing oxidation.

   $16\ Ag_{(s)} + S_{8(s)} \rightarrow 8\ Ag_2S_{(s)}$ Formation

   BONUS: Write the reduction and oxidation reactions below.

   $Ag(s) \rightarrow Ag^{+}_{(aq)} + 1e$ Oxidation reaction

   $S_{8(s)} + 16\ e^- \rightarrow 8\ S^{2-}_{(aq)}$ Reduction reaction

   b) Write out the formula unit for silver sulfide using dot diagrams.

   $[Ag]^{+}$-[:S̤̈:] $^{2-}$- $[Ag]^{+}$

   c) Write any evidences of a reaction.
   New precipitate forms. Silver changes color

   d) How could the silver sulfide tarnish removed?
   Chemically with a polish or mechanically by rubbing it

2. Fertilizers are made of ammonium dihydrogen phosphate, ammonium nitrate and ammonium sulfate.

   a) Write the formula unit for each compound. Verify the formula unit by showing that the net charge is zero. Identify the cation and anion.
   $[NH_4]^{1+}[H_2PO_4]^{1-}$, $[NH_4]^{1+}[NO_3]^{1-}$, $[NH_4]_2^{1+}[SO_4]^{2-}$,

   b) Identify three physical properties that each of these compounds may have.
   Conduct electricity (electrolyte), colorful, solid at room temp, high melting point, soluble in water (aq)

3. Sodium chloride, found in the Lotsberg formation below Fort Saskatchewan is in a solid crystal form. The formation is too deep to be mined.

a) Write out a reaction for the formation of sodium chloride from its elements.

$2\ Na_{(s)} + Cl_{2(s)} \rightarrow 2\ NaCl_{(s)}$ Formation

b) What evidence is there that a reaction occurred?

New precipitate forms. Na changes from a silver to a white salt

c) What are the solubility, color and approximate melting point of sodium chloride?

Solubility: very soluble; Color: white; melting point is above 300C

d) Knowing that salt is very soluble in warm water, how could sodium chloride be removed from the ground?

Pump warm water into the ground, let the salt dissolve, and remove the salt water from the ground.

e) Why is iron (III) oxide not recovered the same way as sodium chloride. (Hint: Is iron (III) oxide soluble in water)

Iron(III) oxide is not soluble in water, therefore it needs to be mined.

Worksheet 3.4: Lewis Dot diagrams for Elements

1. Fill in the Table Below. The first one is done for you.

Name & Symbol	Total # of Valence Electrons	Electron Dot Diagram	Total # of Lone Pairs	# of Bonding Electrons in One Atom	Bonding Capacity or Shared Pairs	Electron Configuration of one atom
F **Fluorine**	7	•• : F : •	3	1	1	**$2s^2 2p^5$**
H **HYDROGEN**	1	H •	0	1	1	**$1s^1$**
He **HELIUM**	2	•• He	1	0	0	**$1s^2$**
Be **Beryllium**	2	• Be •	0	2	2	**$2s^2$**
Al	3	• Al • •	0	3	3	**$3s^2 3p^1$**
C	4	• • C • •	0	4	4	**$2s^2 2p^2$**
N_2	10	•• •• N:::N :N:::N: triple	2	3	3	**$2s^2 2p^3$**
O_2	12	•• •• :O::O: double	4	2	2	**$2s^2 2p^4$**

Cl_2	14	:Cl:Cl: single	6	1	1	$3s^23p^5$
S_8	48	:S:S:S: :S: :S: :S:S:S:	16	2	2	$3s^23p^4$

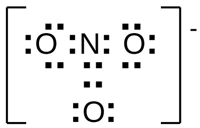
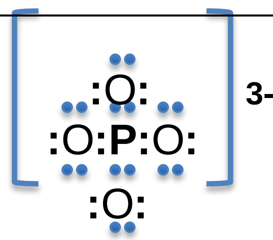
2. What is a covalent bond?
   Electrostatic attraction between the positive non-metal nuclei and the negative shared valence electrons
3. What elements form covalent bonds?
   Non-metals

4. Using electronegativity, how do I know if I have a covalent bond?
   Electronegativity is a measure of the atoms desire for electrons between 0 & 4.
   If you subtract the electronegativity and the number is less than 1.7 than the bond is considered to be covalent.
5. What determines the bond distance?
   The minimum energy required to keep atoms together determines the bond distance.

6. What are two differences between ionic and covalent bonds?
   Melting point above 300C
   Conductivity

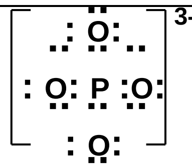
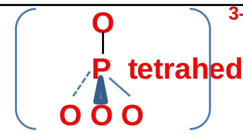
WORKSHEET 3.5: LEWIS DOT DIAGRAMS FOR COMPOUNDS

NAME	FORMULA	TOTAL # OF VALENCE ELECTRONS	ELECTRON DOT DIAGRAM	TOTAL # OF LONE PAIRS	# & TYPES OF BONDS (SINGLE, DOUBLE, TRIPLE, COORDINATE)
Ammonia	$NH_{3(g)}$	8	•• H :N: H H	1	3 single bonds
Bromine	$Br_{2(g)}$	14	•• •• :Br:Br: •• ••	6	1 single bond
Oxygen	$O_{2(g)}$		•• •• :O :: O:	4	1 double bond
Hydrogen cyanide (hydrocyanic acid)	HCN	10	H:C:::N:	1	1 single bond 1 triple bond
methane	$CH_{4(g)}$	8	H H :C: H H	0	4 single bonds
Dinitrogen tetrahydride	$N_2H_{4(g)}$	14	H H :N:N: H H	2	5 single bonds
nitrogen	N_2	10	•• •• N:::N	2	1 triple bond
Carbon dioxide	$CO_{2(g)}$	16	•• •• :O::C::O:	4	2 double bonds
ethane	C_2H_6	14	H H H:C:C:H H H	0	7 single bonds
Hydronium ion	H_3O^+	9 -1 = 8	[•• H :O: H H] +	1 (or 2 due to 1 coordinate)	2 single 1 coordinate

Acetylene	C_2H_2	10	H:C:::C:H	0	2 single 1 triple
Water	H_2O	8	•• H :O: H ••	2	2 single bonds
methanol	CH_3OH	14	H H:C:O:H H	2	5 single bonds
Nitrate ion	$NO_3^-{}_{(aq)}$	5 +18 +1 =24		8 (or 9 due to 1 coordinate)	1 double 1 single 1 coordinate
Phosphate ion	PO_4^{3-} (aq)	5 + 24 + 3 = 32		12 (or 13 due to 1 coordinate)	3 single 1 coordinate

Worksheet 3.6: VSEPR Diagrams

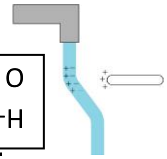
Name	Formula	Total Valence Electrons	Electron Dot Diagram	VSEPR Diagram & Shape(s)
Hydrogen cyanide	*$HCN_{(l)}$*	*10*	*H:C:::N:*	*H-C-N or H-C=N/ linear*
Iodine	$I_{2(s)}$	14	:I:I:	I – I linear
Carbon dioxide	$CO_{2(g)}$	16	O ::C:: O	O – C – O OR O=C=O linear
Carbonate ion	CO_3^{2-}	24	[O ::C:O: :O:] 2-	O trigonal planar C = O 2- O
Hydronium	H_3O^+	8	[H:O:H H] 1+	O pyramidal H H H 1+
Carbon Monoxide	CO	10	:C:::O:	C – O linear OR C ≡ O linear
Ethyne (acetylene)	C_2H_2	10	H:C:::C:H	H – C ≡ C – H (tetratomic) linear
ethanol	C_2H_5OH	20	H H H:C:C:O:H H H	H O – H bent (V-shaped) C – C 2 tetrahedrals H H H H
Ethane	C_2H_6	14	H H H:C:C:H H H	H H C – C 2 tetrahedrals H H H H
Ethanoic acid	CH_3COOH	24	H :O: H:C: C:O: H H	tetrahedral H O trigonal C – C planar H H O-H v-shape
hydrogen sulfide (dihydrogen sulfide)	H_2S	8	H: S:H	S – H H bent (v shape)
Water	H_2O	8	H H:O:	O – H H bent(v shape)
methanol	CH_3OH	14	H H:C:O:H H	O – H bent C tetrahedral H H H
Nitrite Ion	NO_2^-	18	[:O::N:O:] 1-	O V–shaped (bent) N 1- O

Phosphate	PO_4^{3-}	32		 tetrahedral

Worksheet 3.7: Polarity

1. Water exposed to a positive glass rod bends towards the glass rod. Draw a water molecule turned in the right position towards the positive glass rod below.

H O
-H



2. Draw the bond dipole using both delta notation & vector notation for the bonds below. Indicate which has the strongest bond dipole.

a) S – O (2.6, 3.4) δ^+ → δ^{--}
b) F – F (4.0, 4.0) **no dipole**
c) C – H (2.6, 2.2) δ^{--} ← δ^+
d) N – Br

3. Circle the following molecules that are polar. What characteristics helped you determine if they where polar?

hydrogen chloride, ***hydrogen sulfide***, ***ammonia***, ***methane***, ***hydrogen peroxide***
different atoms, bent & different atoms, pyramidal, tetrahedral, bent

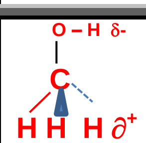
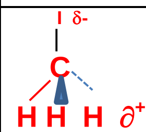
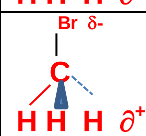
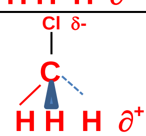
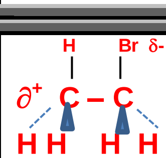
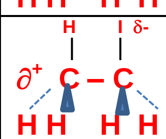
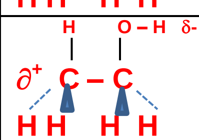
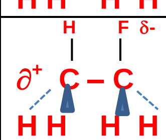
4. Fill in the Table Below. The first one is done for you.

Name & Formula	Lewis Dot Diagram	Structural Diagram with Electronegativity	VSEPR Diagram & Shape(s) with overall bond dipoles if polar (any notation)	Polar or Nonpolar Molecule
Hydrogen cyanide $HCN_{(l)}$	*H:C:::N:*	*2.1 2.5 3.0* ***H – C ≡ N***	δ^+ δ^{--} ***H – C – N linear***	***Polar***
Nitrogen, $N_{2(g)}$	:N:::N:	3.0 3.0 N≡N	N-N OR N≡N linear	Non polar
Phosphorus trihydride, $PH_{3(g)}$	H:P:H H	2.2 2.2 H – P – H 2.2 | H2.2	δ^+ P pyramidal H H H δ^-	POLAR
Dibromethane $CH_2Br_{2(g)}$	H H:C:Br: :Br:	H 2.2 C=2.6 H-C-Br 3.0 Br	H δ^+ C tetrahedral H Br δ^-Br	Polar
Hydronium ion $H_3O^+_{(aq)}$	[H:O:H H]1+	3.4 [H – O – H 2.2 | H]	δ^- O pyramidal H H H δ^+	Polar
carbon monoxide; CO	:C:::O:	2.6 C≡O 3.4	δ^+ C – O δ^- linear	Polar
ethyne C_2H_2 acetylene	H:C:::C:H	H – C ≡ C – H 2.6 2.2	H – C ≡ C – H linear	nonpolar
ethanol $C_2H_5OH(l)$	H H H H:C:C:O: H H	H H H C=2.6 H-C-C-O 3.4 H H 2.2	H O – H bent δ- δ^+ C – C 2 tetrahedrals H H H H	polar

ethene C_2H_4	**H H** **C::C** **H H**	H H C = C 2.6 H H 2.2	**O O** **C = C** **O O trigonal planar**	**nonpolar**
Water **H_2O**	**H** **H:O:**	**H – O** **H**	**H – O** δ^- δ^+ **H bent (v-shaped)**	**polar**

Worksheet 3.8: Bonding Review

1. Complete the following table. (* 1 is strong and 4 is weak)

Chemical Formula & name	Polarity & number of e-	Melting Point	Boiling Point	VSEPR Diagram With bond dipoles if polar	Types of Intermolecular Forces	Rank Inter-molecular strength*
$F_{2(g)}$	nonpolar 18 e	-220	-188	F-F	LD	4
$I_{2(s)}$	nonpolar 106 e	-7	59	I-I	LD	1
$Cl_{2(g)}$	nonpolar 34 e	-114	-184	Cl-Cl	LD	3
$Br_{2(l)}$	nonpolar 70 e	-101	-35	Br-Br	LD	2
$ICl_{(g)}$	polar 70 e	14	97	δ+ I-Cl δ-	LD, DD	1
$BrF_{(g)}$	polar 44 e	-33	-20	δ+ Br-F δ-	LD, DD	3
$ClF_{(g)}$	polar 26 e	-154	-101	δ+ Cl-F δ-	LD, DD	4
$BrCl_{(g)}$	polar 52 e	-66	5	δ+ Br-Cl δ-	LD, DD	2
$CH_3OH_{(l)}$ $CH_3OH_{(l)}$	polar 18 e	-10	65		LD, DD,HB	1
$CH_3I_{(l)}$	polar 62 e	-66	43		LD, DD	2
$CH_3Br_{(g)}$	polar 44 e	-94	4		LD, DD	3
$CH_3Cl_{(g)}$	polar 26 e	-98	-24		LD, DD	4
$C_2H_5Br_{(l)}$	polar 52 e	-119	38		LD, DD	3
$C_2H_5I_{(l)}$	polar 70 e	-108	72		LD, DD	2
$C_2H_5OH_{(l)}$	polar 26 e	-114	78		LD, DD, HB	1
$C_2H_5F_{(g)}$	polar 26 e	-138	12		LD, DD, HB	4

2. Rank the following in order of increasing melting point. Give reasons to support your answer.

RANK (1 is low; 8 is high) REASONS(bond type, intermolecular forces, # of e-)

_**6**_ Sodium chloride: 801C **Ionic**
_**5**_ Water: O C **Covalent, LD, DD, HB (Water has the strongest HB)**
_**2**_ Methane: -182C **Covalent, LD, 10e**
_**3**_ Hydrogen chloride: -114C **Covalent, LD, DD**
_**1**_ Hydrogen gas: -259C **Covalent, LD, 2e**
_**4**_ Methanol: -98C **Covalent, LD, DD, HB**
_**8**_ Silicon carbide:2730C **Network**
_**7**_ Iron metal: 1538C **Metalic**

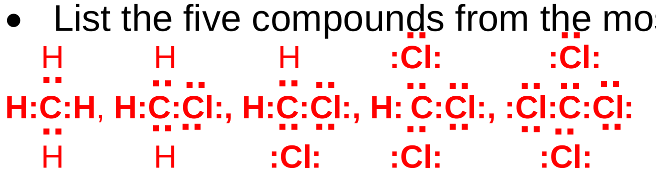
3. Use the observations about five solids below to fill in the table that follows.

SOLID	COLOR	ODOR	HARDNESS	OTHER
A	**Yellow**	Slight	Moderate	Melts over flame
B	**White**	None	**Hard (I or M**	**Dissolves** in water & conducts electricity
C	White	Strong	Soft	Melts over a flame
D	Grey	None	**Very hard**	None
E	**Silver**	None	**Hard (I or M**	None

Letter, Name & Formula	Type of Intra-& Interbonds /forces	Explain how you identified the substances
sodium chloride Formula: **$NaCl_{(s)}$** Letter: **B**	Ionic & LD (electronegativity <1.7)	Salt is white color, hard, only one that dissolves in water
silicon carbide Formula: **$SiC_{(s)}$** Letter: **D**	Network & LD	Only one that is very hard
iron Formula: **$Fe_{(s)}$** Letter: **E**	Metallic & LD	Metals are silver and hard
Sulfur Formula: **$S_{8(s)}$** Letter: **A**	Covalent & LD	Sulfur is yellow and soft solid; has a rotten egg smell
dichlorobenzene Formula: $C_6H_4Cl_{2(s)}$ Letter: **C**	Covalent & LD, DD	Last one left, soft solid

4. A person is analyzing the five compounds below. Answer the questions that follow.
CH_4, CH_3Cl, CH_2Cl_2, $CHCl_3$, CCl_4

- Draw the Lewis diagrams
- List the five compounds in order of increasing boiling points.
- List the five compounds from the most non-polar to the most polar compounds



Increasing boiling points: $CH_{4(LD)}$, $CCl_{4(LD)}$, $CH_3Cl_{(LD,DD)}$, CH_2Cl_2, $CHCl_{3(LD,DD,most\ e)}$

Increasing polarity: CH_4, CCl_4, CH_3Cl, CH_2Cl_2, $CHCl_3$ (based on electronegativity difference & elec)

5. Complete the following table

Formula & Name	Lewis Diagram	VSEPR Shape	Polarity	Type of Bonds/Forces
$NH_{3(g)}$ ammonia	H:N:H H	N pyramidal H H H	polar	Covalent, LD, DD, HB
CBr_4 tetrabromomethane	:Br: :Br:C:Br: :Br:	Br tetrahedral C Br Br Br	Non-polar	Covalent, LD
H_2S hydrogen sulfide	H :S:H	H bent or v shape S – H	polar	Covalent, LD, HB
PCl_3–phosphorus trichloride	:Cl:P:Cl: :Cl:	N pyramidal H H H	polar	Covalent, LD, DD, HB
BCl_3- boron trichloride	:Cl:B:Cl: :Cl:	Cl B – Cl Cl trigonal planar	Non-polar	Covalent, LD
NH_4^+ - ammonium ion	[H H:N:H H] 1+	H tetrahedral N H H H 1+	Non-polar inside (ion outside)	*Covalent, LD, Ionic
HBr - hydrogen bromide	H:Br:	H-Br linear	polar	Covalent, LD, DD
Carbon dioxide - CO_2	O::C::O	O=C=O linear	Non-polar	Covalent, LD
Nitrogen triiodide - NI_3	:I:N:I: :I:	N pyramidal H H H	polar	Covalent, LD, DD
Sulfate ion – SO_4^{2-}	[:O: :O:S:O: :O:] 2-	O tetrahedral S O O O 2-	Non-polar inside (polar outside)	*Covalent, LD, Ionic
Sulfur dibromide - SBr_2	:Br: :S:Br:	Br bent S – Br	polar	Covalent, LD, DD
Germanium tetra hydride - GeH_4	H H:Ge:H H	H tetrahedral Ge H H H	Non-polar	Covalent, LD
dihydrogen telluride - H_2Te	H :Te:H	H bent or v shape Te–H	polar	Covalent, LD, DD
nitrogen trifluoride – NF_3	: F :N: F : : F :	N pyramidal F F F		Covalent, LD, DD
dihydrogen selenide - H_2Se	H :Se:H	H bent or v shape Se–H		Covalent, LD, DD
Tin (IV) bromide - $SnBr_4$	[:Br:]$^-$ [:Br:]$^-$-[Sn]$^{4+}$-[:Br:]$^-$ [:Br:]$^-$	crystal lattice	Ions are charged	Ionic
Sulfite ion – SO_3^{2-}	(:O:S:O: :O:) 2-	S pyramidal O O O	Polar inside the ion	*Covalent, LD, Ionic