Ch. 7 Notes ~ Covalent Bonding

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics.*

I. Compounds – a review

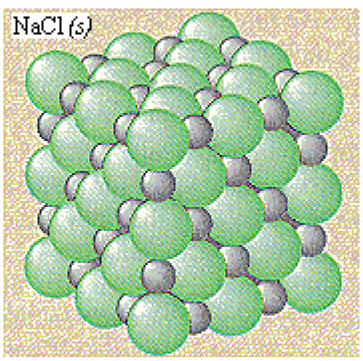
A. **compound** ("cmpd.")—*a substance formed from more than one element*

B. **molecule** or **molecular compound**—*a group of atoms with no net charge*

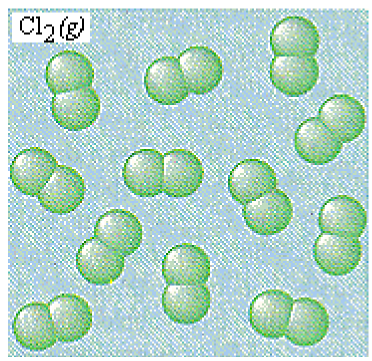
C. **molecular formula**—symbols representing the composition of a *molecular compound*

Comparison of molecular and ionic compounds

	Molecular compounds	***Ionic compounds***
Particles	Molecules	Formula units made of ions cations & anions
Elements	Nonmetals	Metals & nonmetals
Conductivity	Low "nonelectrolytes"	High (when molten or in aqueous solution) "electrolytes"
State at room temp.	Solid, liquid, or gas	Solid
Type of Bond	Polar or nonpolar covalent	Ionic (stronger)
Misc.	Covalent compounds	Salts



repeating formula units



molecules

II. Types of Covalent Bonds

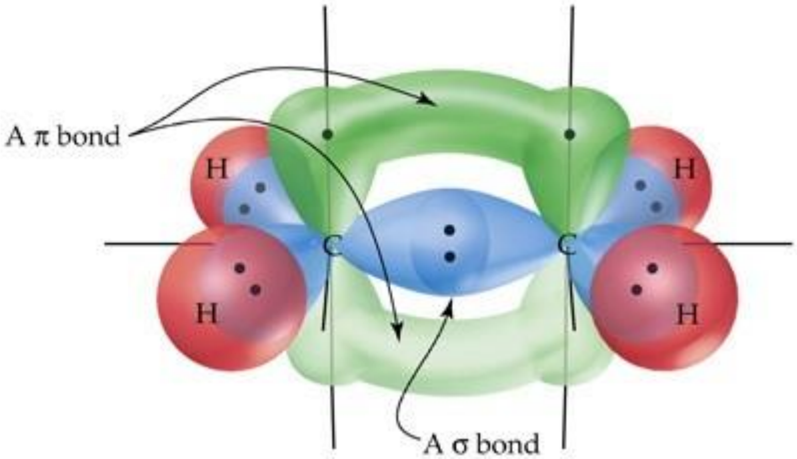
A. **covalent bonding**—*electron sharing between nonmetals*

1) **single covalent bond**—*a sharing of one pair of electrons between two atoms*
   a) weaker than an ionic bond
   b) weakest of all of the covalent bonds
   c) longest length of all of the covalent bonds
   d) sigma (σ) bond – overlapping orbital clouds between atoms

2) **double covalent bond**
   a) *sharing two pairs of electrons between two atoms*
   b) has one sigma bond
   c) has one pi (π) bond – indirect orbital overlap

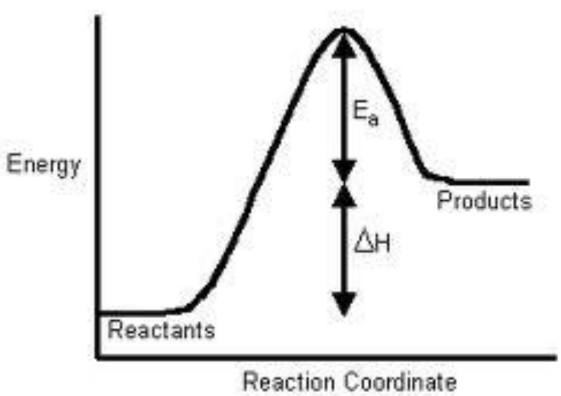
3) **triple covalent bond**
   a) *sharing three pairs of electrons between two atoms*
   b) strongest of all of the covalent bonds
   c) shortest length of all of the covalent bonds
   d) has one sigma bond
   e) has two pi bonds – indirect orbital overlap

From www.quora.com

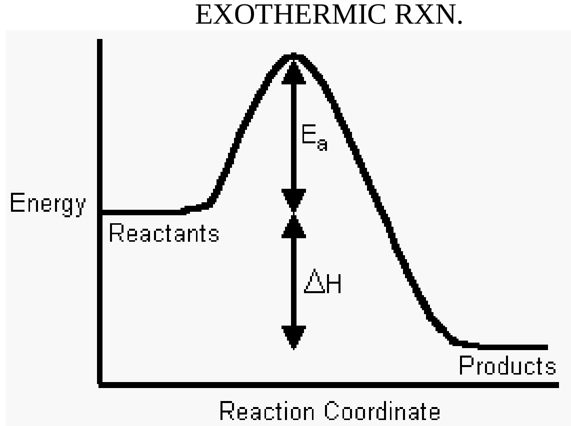


B. bonds and energy
   1) **endothermic reaction** – *absorbing heat*
      (new bonds are at a higher chemical energy than the old bonds)
   2) **exothermic reaction** – *giving off heat*
      (new bonds are at a lower chemical energy than the old bonds)

ENDOTHERMIC RXN.

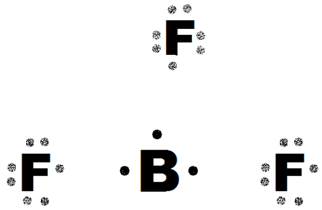


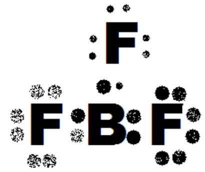
EXOTHERMIC RXN.



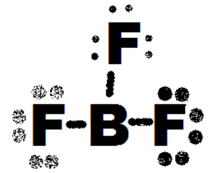
III. Covalent Compounds: Drawing Structures
   A. remember the octet rule (NO lone electron dots when finished!) – compounds must be neutral
   B. draw each electron dot diagram using the "A" group numbers
   C. make the compound by combining the individual structures

EXAMPLE 1) Draw the electron dot diagram for BF_3 .



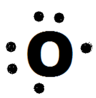


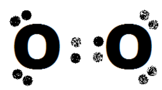
OR



single boron atom with three fluorines → boron trifluoride

EXAMPLE 2) Draw the electron dot diagram for O_2 .





OR

single O atom single O atom → diatomic oxygen molecule

EXAMPLE 3) Draw the electron dot diagram for N_2 .

OR

2 nitrogen atoms → diatomic nitrogen molecule

IV. Naming Molecules: Binary molecular (BM) compounds

A. **binary compound**—*composed of two elements*

B. **binary molecular compound**—("BM")— *nonmetal / nonmetal combination*

1) no ionic charges involved (no crisscross)
2) ending in *-IDE*
3) since there are no charges to determine the ration of symbols, *mandatory prefixes are used in naming:*

MONO-,	DI-,	TRI-,	TETRA-,	PENTA-,	HEXA-,	HEPTA-,	OCTA-,	NONA-,	DECA-
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

(mono- is not used on the first element)

EXAMPLE 4) Write the chemical formula for carbon tetrachloride. CCl_4

EXAMPLE 5) Name the compound P_2O_5. diphosphorus pentoxide

V. Acids – a preview

*** Chem 1H students responsible for knowing how to name any acid.
Chem 1 students learn the six major acids only.***

A. generic formula for an acid = *HX, where H is hydrogen and X is an anion*
HX → H^+ + X^-

B. **<u>acid</u>**—*an aqueous solution with components that donate H^+ ions when in* solution

C. common acids to know

1)	**acetic**	**$HC_2H_3O_2$ or CH_3COOH**
2)	**carbonic**	**H_2CO_3**
3)	**hydrochloric**	**HCl**
4)	**nitric**	**HNO_3**
5)	**phosphoric**	**H_3PO_4**
6)	**sulfuric**	**H_2SO_4**

D. **<u>oxyacid</u>**—*an acid with oxygen in its anion*

E. naming rules for acids (Chem 1H):

1) *naming binary acids, ending in -IDE:* *hydro-STEM-ic acid*
(HBr = hydrobromic acid)

2) *naming oxyacids with an anion ending in –ATE:* *STEM-ic acid*
($HClO_3$ = chloric acid)

3) *naming oxyacids with an anion ending in –ITE:* *STEM-ous acid*
(H_2SO_3 = sulfurous acid)

NOTE: (STEM is the element name, other than H or O)

F. examples of naming acids:

EXAMPLE 6) Name the acid HI. hydroiodic acid (rule 1 above)
EXAMPLE 7) Name the acid H_3BO_3. boric acid (rule 2 above)
EXAMPLE 8) Name the acid $HClO_2$ chlorous acid (rule 3 above)

VI. Molecular Elements – a review

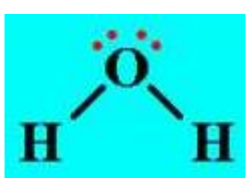
THE SEVEN DIATOMIC MOLECULES (“Super Seven”):
H_2 F_2 O_2 N_2 Cl_2 Br_2 I_2

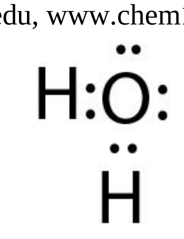
VII. Molecular Structures

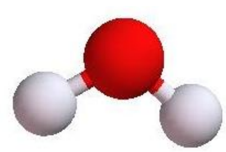
A. general terms

1) molecular formula—writing out the symbols and subscripts
2) structural formula—drawing lines connecting the symbols
3) Lewis structure—electron dot diagram
4) ball-and-stick model—uses spheres for atoms and sticks or springs for bonds
5) space-filling model—attaching the spheres together in a molecule
(images from www. eou.edu, www.chem110.collegescience.com)

H_2O





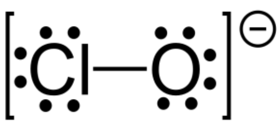


B. dot diagrams can be drawn for polyatomic ions and monatomic ions, as well as ionic compounds and molecular compounds

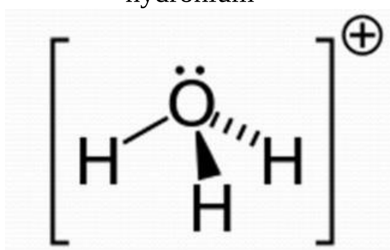
C. dot diagrams for polyatomic ions (Chem 1H)

1) the number of electrons must be adjusted to account for the charge of the ion
2) negative ions should have extra electron(s) placed in their Lewis structures according to the charge
3) positive ions should have fewer electron(s) in their Lewis structures, deleted according to the charge
4) examples (from lumenlearning, slideplayer)

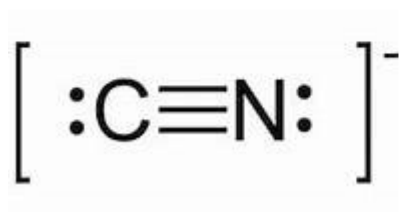
hypochlorite



hydronium

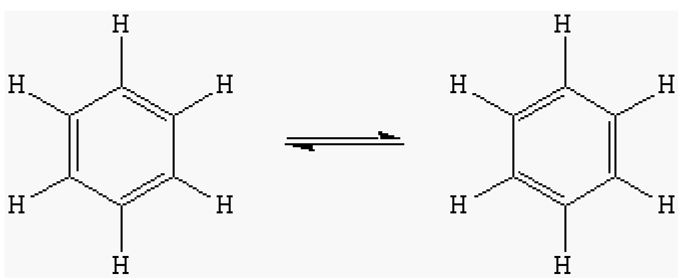


cyanide

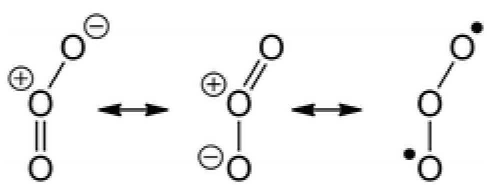


D. resonance structures (Chem 1H)

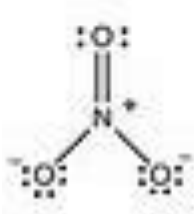
1) **resonance**—a bond that "flips" between two positions
2) the actual structure is a blend of the options
   (images from kentchemistry, libretext, rsc.org)
3) structures that show resonance:
   a) benzene - C_6H_6

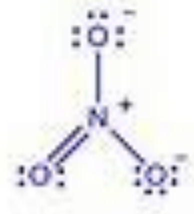


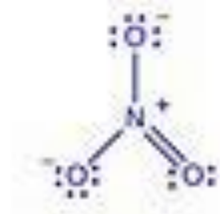
   b) ozone - O_3

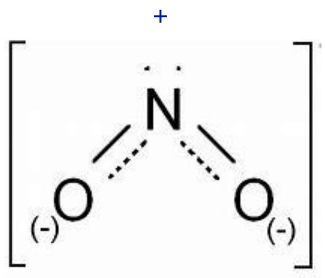


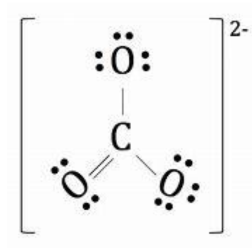
   c) polyatomic ions: nitrate, nitrite, sulfite, carbonate, phosphate

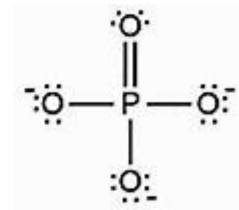






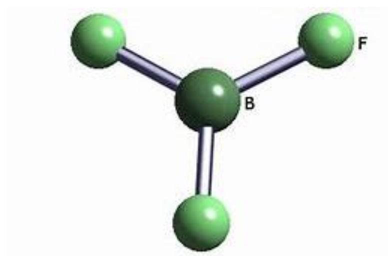




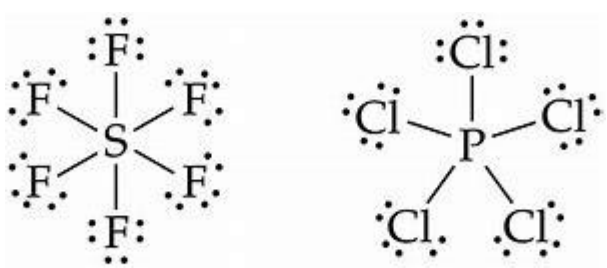


E. exceptions to the octet rule (Chem 1H)

1) odd number of valence electrons
2) *suboctets— stability with less than eight valence electrons*
   example: boron compounds, BF_3



3) expanded octets— more than eight valence electrons
   a) octahedral = sulfur hexafluoride
   b) trigonal bipyramidal = phosphorus pentachloride



4) **coordinate covalent bonds**—covalent bonds consisting of *two electrons donated by a single atom*

OR

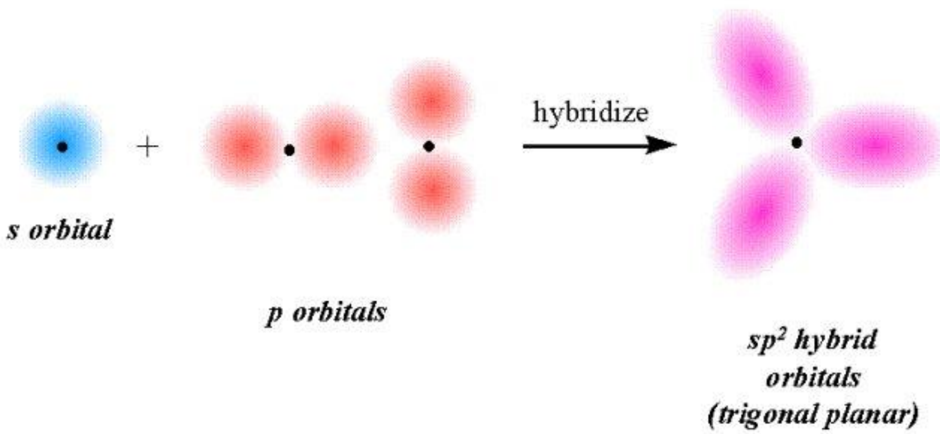
ammonia hydrogen ion → ammonium ion

VIII. Molecular Shape

A. **hybrid orbitals**—atomic orbitals mix to form blended, identical orbitals

1) single bond = sp^3
2) double bond = sp^2
3) triple bond = sp

From www.mikeblaber.org



B. **VSEPR** = *Valence Shell Electron Pair Repulsion* model

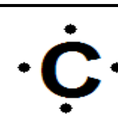
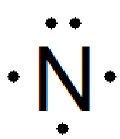
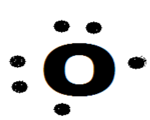
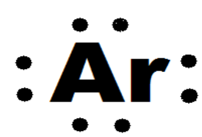
1) valence electrons repel themselves as far apart as possible
2) VSEPR predicts 3-D geometric shapes of molecules based on the numbers of bonding and nonbonding pairs on the central atom
3) a double or a triple bond is treated as one main bonding "arm"
4) electron dot diagrams (Lewis structures) are used to predict models' shapes

"right, left, up, down, top all the way around – (counterclockwise)"

3 5

2 **SYMBOL** **1**
6 **8**

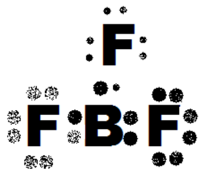
4 7

			
one unshared e- 1 bond can form	two unshared e- 2 bonds can form	three unshared e- 3 bonds can form	four unshared e- 4 bonds can form
			
three unshared e- one nonbonding pair 3 bonds can form	two unshared e- 2 nonbonding pairs 2 bonds can form	one unshared e- 3 nonbonding pairs 1 bond can form	NO unshared e- 4 nonbonding pairs NO bonds can form

VSEPR SHAPES

# BONDING PAIRS OF CENTRAL ATOM	# NONBONDING PAIRS OF CENTRAL ATOM	SHAPE	BOND ANGLE
2	0	linear	180°
2	1	angular (bent)	116°
2	2	angular (bent)	104.5°
3	0	trigonal planar (triangular planar)	120°
3	1	pyramidal (trigonal pyramidal)	107.3°
4	0	tetrahedral	109.5°
5	0	trigonal bipyramidal	90° & 120°
6	0	octahedral	90°

EXAMPLE 9) What is the shape of a BF_3 molecule?



The central atom is B, which has 3 bonding and 0 nonbonding pairs. (3,0) = trigonal planar

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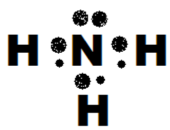
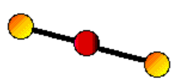
EXAMPLE 10) What is the shape of an NH_3 molecule?



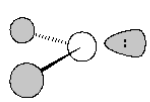
The central atom is N, which has 3 bonding pairs and 1 nonbonding pair. (3,1) = pyramidal

VSEPR MODELS



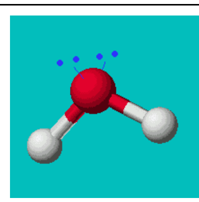
LINEAR

(2,0)



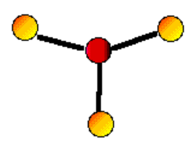
ANGULAR / BENT

(2,1)



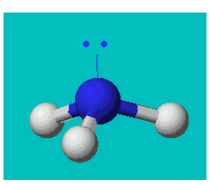
ANGULAR / BENT

(2,2)



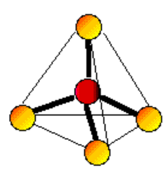
TRIGONAL PLANAR

(3,0)



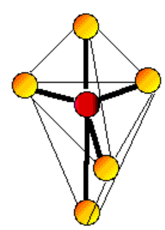
(TRIGONAL) PYRAMIDAL

(3,1)



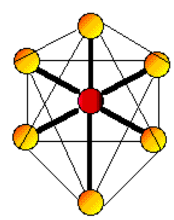
TETRAHEDRAL

(4,0)



TRIGONAL BIPYRAMIDAL

(5,0)



OCTAHEDRAL

(6,0)

IX. Electronegativity and Polarity

A. **<u>electronegativity</u>**—the *"greediness" of an atom for electrons when bonding*

B. group trends: electronegativity decreases from top to bottom

C. periodic trends: electronegativity increases from left to right

D. **Δ EN** (*electronegativity differences*) give more detailed information about bond strength than just generalizing BI, BM, TI, etc… but these are just guidelines

The guidelines vary slightly depending on sources. We will use the textbook numbers.

<u>Δ EN VALUES</u>	
0.0	nonpolar covalent
0.01 – 0.40	(mostly) covalent
0.40 – 1.70	polar covalent
> 1.70	(mostly) ionic

Electronegativity Values

H 2.20																	**He** n.a.
Li 0.98	**Be** 1.57											**B** 2.04	**C** 2.55	**N** 3.04	**O** 3.44	**F** 3.98	**Ne** n.a.
Na 0.93	**Mg** 1.31											**Al** 1.61	**Si** 1.90	**P** 2.19	**S** 2.58	**Cl** 3.16	**Ar** n.a.
K 0.82	**Ca** 1.00	**Sc** 1.36	**Ti** 1.54	**V** 1.63	**Cr** 1.66	**Mn** 1.55	**Fe** 1.83	**Co** 1.88	**Ni** 1.91	**Cu** 1.90	**Zn** 1.65	**Ga** 1.81	**Ge** 2.01	**As** 2.18	**Se** 2.55	**Br** 2.96	**Kr** 3.00
Rb 0.82	**Sr** 0.95	**Y** 1.22	**Zr** 1.33	**Nb** 1.60	**Mo** 2.16	**Tc** 1.90	**Ru** 2.20	**Rh** 2.28	**Pd** 2.20	**Ag** 1.93	**Cd** 1.69	**In** 1.78	**Sn** 1.96	**Sb** 2.05	**Te** 2.10	**I** 2.66	**Xe** 2.60
Cs 0.79	**Ba** 0.89	**La** 1.10	**Hf** 1.30	**Ta** 1.50	**W** 2.36	**Re** 1.90	**Os** 2.20	**Ir** 2.20	**Pt** 2.28	**Au** 2.54	**Hg** 2.00	**Tl** 1.62	**Pb** 2.33	**Bi** 2.02	**Po** 2.00	**At** 2.20	**Rn** n.a.
Fr 0.70	**Ra** 0.89	**Ac** 1.10	**Rf** n.a.	**Db** n.a.	**Sg** n.a.	**Bh** n.a.	**Hs** n.a.	**Mt** n.a.	**Ds** n.a.	**Rg** n.a.	**Uub** n.a.	—	**Uuq** n.a.	—	—	—	—

EXAMPLE 11) NaCl – Classify the bond between Na and Cl based on electronegativity differences.

3.16 – 0.93 = 2.23 ionic

EXAMPLE 12) Fe_2O_3 – Classify the bond between Fe and O based on electronegativity differences.

3.44 – 1.83 = 1.61 polar covalent

X. Polar Bonds and Polar Molecules

A. **<u>polar bond</u>** (**<u>polar covalent bond</u>**)—a covalent bond with *unequal sharing* of electrons (unequal "pull" or preference)

1) a **<u>polar molecule</u>** has an *asymmetrical* molecular shape
2) *partially positive* = δ+ *partially negative* = δ-
3) because of the two ends, a polar molecule is also called a **<u>dipole</u>**

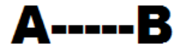
B. **<u>nonpolar covalent bond</u>**—*a covalent bond with equal sharing of electrons*

1) examples: diatomic molecules
2) symmetrical molecular shape

C. Every element has an electronegativity value assigned to it.

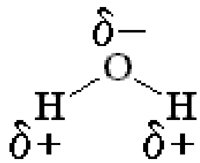
Electronegativity differences determine bond strength.

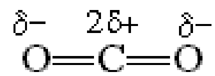
POLAR molecule (dipole)

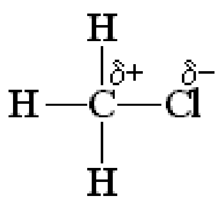


NONPOLAR molecule

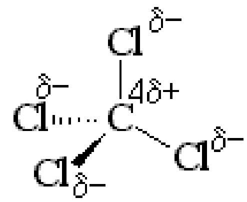
from www.webchem.net:







overall polar



overall non-polar

D. IMF – intermolecular forces

1) *London / van der Walls forces* - attractions btw nonpolar molecules
2) *Dipole-dipole forces* – attractions between polar molecules

From Chemistry 301: dipole-dipole forces