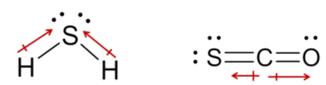
CHM 112 Experiment #2. Intermolecular Forces and Lewis Structures

The shape (also known as geometry) of a molecule influences its properties. Symmetrical shapes lead to electrons being evenly distributed throughout the molecule and are called non-polar. Asymmetrical shapes lead to molecules with more electrons on one side than the other. This imbalance leads to a partial positive and negative within the molecule known as a dipole. Molecules with dipoles are known as polar molecules. Polar molecules are attracted to magnetic and electric fields.

Determining Polarity of Molecules

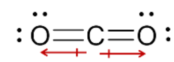
A covalent bond is polar if there is a difference in electronegativity between the bonded atoms. An entire molecule will be polar if the bond dipoles do not cancel. Polar molecules have a positive and a negative end and behave like tiny magnets. The shape of the molecule determines if dipoles cancel or not.

Polar molecules – bond dipoles do not cancel.
Have a lone pair on the central atom OR different outer atoms.



dipoles don't cancel

Non-polar molecules – bond dipoles cancel.
Have no lone pairs on the central atom AND have all outer atoms the same.



dipoles cancel

Intermolecular Forces (IMFs)

IMFs hold molecules together into solids and liquids. The stronger the IMFs, the higher the boiling and melting point of a compound. The forces between covalent compounds are relatively weak, so covalent molecules tend to have low boiling and melting points. IMFs are summarized in the table below.

	IMFs	Found in	Description	Examples
found in covalent compounds ***strongest***	hydrogen bonds	molecules with H-F, H-O, or H-N bonds	extreme case of dipole-dipole, occurs with small, highly electronegative atoms	H_2O, NH_3
□	dipole-dipole forces	polar molecules	attraction between δ + and δ-	CH_2Br_2, PH_3
weakest	dispersion forces	all molecules (only force in non-polar molecules)	attraction between temporary dipoles	CH_4, CO_2

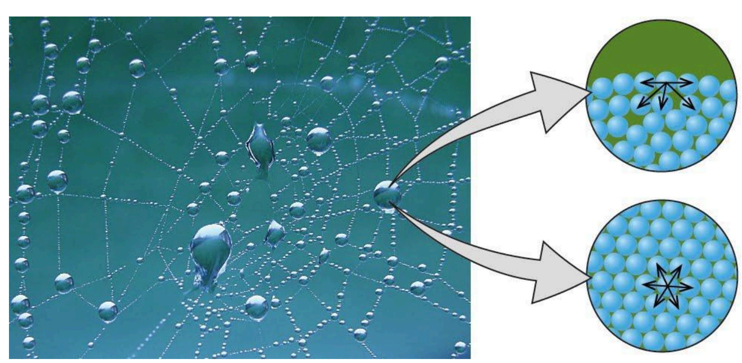
Intermolecular forces are the glue that holds covalent molecules together, the stronger they are, the stickier the molecules are. As a result, these intermolecular forces influence many properties of substances:

Stronger IMFs result in:

- Higher boiling and melting points
- Increased surface tension
- Lower evaporation rates and lower vapor pressure

Surface Tension

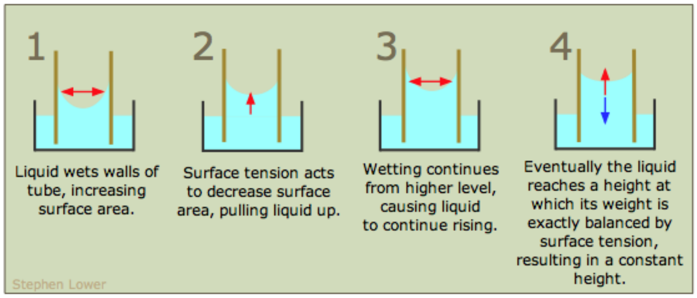
Surface tension is the amount of energy required to stretch or increase the surface of a liquid. Molecules at the surface are less stable because they are only held together by molecules on one side. Surface tension results from the need to minimize the amount of surface to a liquid. The stronger the IMFs, the higher surface tension.



(credit photo: OpenStax Chemistry modification of work by "OliBac"/Flickr)

Capillary Action

Capillary action is the flow of liquid up a narrow tube against the force of gravity. It depends on both the IMFs between the liquid molecules (cohesive forces) and the IMFs between the liquid and the tube surface (adhesive forces). As liquid spreads on the tube surface it creates more surface area, the liquid then rises to reduce the surface area. This continues until a balance is reached between gravity pulling liquid down and surface tension pulling it up. The final height depends upon the surface tension of the liquid, the attraction between the liquid and tube surface, and the tube diameter.

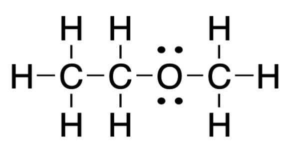
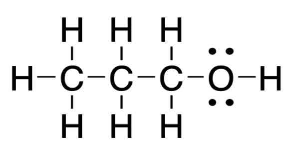
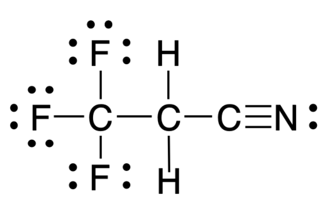


(image: Stephen Lower via chem.libretexts.org)

For a review of Drawing Lewis structures, see

Condensed Structural Formulas

Organic (carbon-based) molecules can contain chains of several central atoms. Condensed formulas are often used to indicate how the atoms are connected. To draw a Lewis structure from a condensed structure, connect any elements that are not hydrogens or halogens in a chain in the order written. Connect the hydrogens and halogens with single bonds to the atom they are written next to. Count valence electrons and add lone pairs and double/triple bonds to complete octets as needed.

Molecular Formula	**Condensed Formula**	**Lewis Structure**
C_3H_8O	$CH_3CH_2OCH_3$	
C_3H_8O	$CH_3CH_2CH_2OH$	
$C_3H_2NF_3$	CF_3CH_2CN	

Materials: buret with water, buret with hexane, balloons, paper towels, acetone dropper, ethanol dropper, isopropanol, beakers, Pennies

Procedure

A. Lewis structures

1. Complete the table.

B. Polarity of Liquids

2. Turn on burets of water and hexane to allow a fine stream of liquid. Rub a balloon on your hair or shirt, bring it near each liquid and record your observations.

C. Evaporation Rate

3. Put two drops of acetone and two drops of ethanol on either end of a paper towel and observe their evaporation.

D. Surface Tension

3. Get two dry pennies and lay them face up. Count how many drops of isopropanol you can add to the top of one penny before the liquid spills onto the table surface. Count drops of water you can add to the top of the other penny before it spills on the surface. This works best when the dropper is close to the penny.
4. Dry the pennies and repeat the experiment with each other group member.

E. Capillary action

5. Measure and pour 3 mL of water into a small beaker. Measure and pour 3 mL of acetone in to another small beaker.
6. Put a capillary tube in each beaker and compare the heights of the liquids.

Periodic Table of Elements

Period \ Group	1A 1	2A 2	3	4	5	6	7	8	9	10	11	12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc (97)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3	71 Lu 175.0	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	103 Lr (262)	104 Rf (267)	105 Db (270)	106 Sg (269)	107 Bh (270)	108 Hs (270)	109 Mt (278)	110 Ds (281)	111 Rg (281)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (293)	118 Og (294)

Period														
6	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0
7	89 Ac (227)	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)

Name___________________________

Team Name ________________________

CHM112 Lab – IMFs

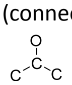
To participate in this lab you must have splash-proof goggles, proper shoes and attire.

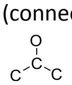
Criteria	Points possible	Points earned
Lab Performance		
Safety and proper waste disposal procedures observed. Actively participates.	3	
Lab Report		
Part A (table correct and complete)	5	
Part B –E. Complete explanations citing polarity and IMFs	6	
Post lab table	5	
Total	20	

Subject to additional penalties at the discretion of the instructor.

A. Complete the following table

	Water (H_2O) valence e- =	**Hexane ($CH_3CH_2CH_2CH_2CH_2CH_3$)** valence e- =
Lewis structure		(all carbons connected in a chain)
Polar? Y/N		
IMFs		

	Acetone (CH_3COCH_3) valence e- =	**Ethanol (CH_3CH_2OH)** valence e- =
Lewis structure	(connectivity is) 	(connectivity is C – C –O–H)
Polar? Y/N		
IMFs		

	Isopropanol ($CH_3CHOHCH_3$) valence e- =
Lewis structure	(connectivity is) 
Polar? Y/N	
IMFs	

B. Polarity of liquids

1. a) What happened when the charged balloon was brought near water?

   b) What happened when the charged balloon was brought near hexane?

2. Using the properties in table A, explain why the liquids behaved differently.

C. Evaporation rate.

3. Which liquid has a faster evaporation rate, acetone or ethanol? _______________

b) Using the properties in table A, explain why one evaporated faster.

D. Surface Tension

Group member	#isopropanol drops	# water drops

4. a) Which has more surface tension, water or isopropanol? _____________

b) Using the properties in table A, explain why it had more surface tension.

E. Capillary Action

5. a) Which liquid reached a greater height, water or acetone? _____________

b) Given that glass is highly polar, and the properties in table A, explain the height difference.

Complete the following table.

Formula	Lewis Structure	Polar? Y/ N	IMFs
PCl_3			
HOBr (O is central)			
CH_3OCH_3			
CH_2O			
NH_2F			