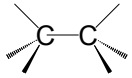
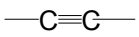
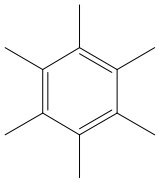
TOPIC 2. ORGANIC COMPOUNDS

OBJECTIVES

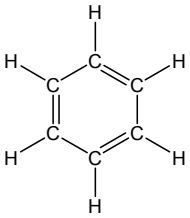
1. Describe the structure of N, O and halogen containing functional groups: formal charges, hybridization, VSEPR theory, polarity, resonance.
2. Develop relationships between structure and physical properties (b.p., solubility).

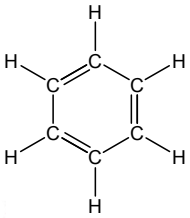
HYDROCARBONS

Molecules containing only C, H

		C-C bond length / Å	bond energy kcal/mol
alkanes		1.54	88
alkenes		1.34	152
alkynes		1.20	200
arenes		1.40	≈115

Molecular structure of benzene

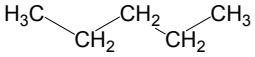




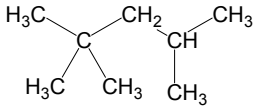
Validating resonance theory

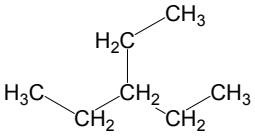
BRANCHED ALKANES, CLASSIFICATION OF CARBON ATOMS, ALKYL GROUPS

Linear alkane



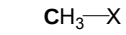
Branched alkanes

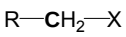


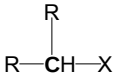


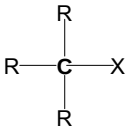
Classification of carbon atoms

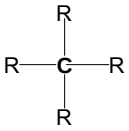
R = carbon, X ≠ C

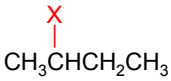
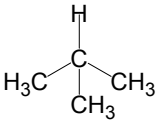
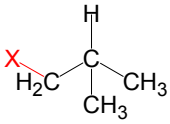
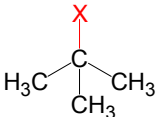


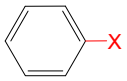




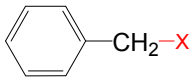




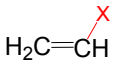
Alkane	Alkyl group	
CH_4 methane	X– CH_3	methyl, Me
CH_3CH_3 ethane	X– CH_2CH_3	ethyl, Et
$CH_3CH_2CH_3$ propane	X– $CH_2CH_2CH_3$	propyl, Pr, *n*-Pr, 1-propyl
	X– $CH(CH_3)_2$	isopropyl, *i*-Pr, 2-propyl
$CH_3CH_2CH_2CH_3$ butane	X– $CH_2CH_2CH_2CH_3$	butyl, Bu, 1-butyl
		*sec*-butyl, *s*-Bu, 2-butyl
 isobutane		isobutyl, i-Bu
		*tert*-butyl, t-Bu



phenyl, Ph, Φ



benzyl, Bn



vinyl

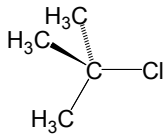
FUNCTIONAL GROUPS

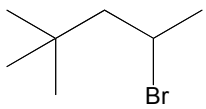
Alkyl Halides

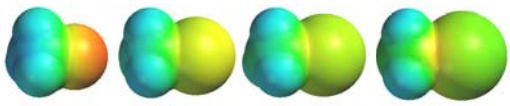
R—Hal

Classes of alkyl halides

ethylene dibromide
(banned pesticide)
chlorodane
(banned pesticide)
carbon tetrachloride
(banned dry cleaning agent)
methyl bromide
(banned fumigating agent)

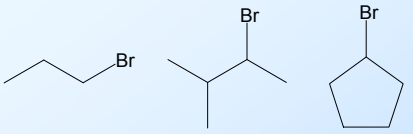






CH_3F CH_3Cl CH_3Br CH_3I

Which of the following are 2° bromoalkanes?



A B C

$(CH_3)_3CBr$ D

$CH_3CH_2CH_2C(CH_3)BrCH_3$ E

1 Only **B**

2 Only **B** and **C**

3 Only **A**, **B** and **C**

4 Only **B**, **C** and **E**

5 Only **B**, **D** and **E**

Carbon-Halogen Bonds

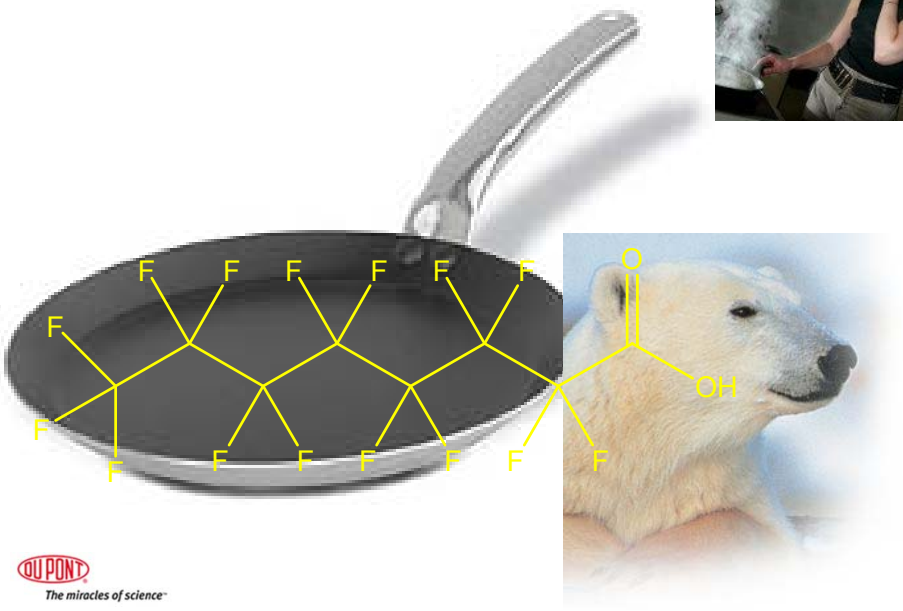
R—Hal

Halogen	C-Hal bond length / Å	C-Hal bond dipole / D	Bond energy kcal/mol
Fluorine	1.38	1.51	116
Chlorine	1.77	1.56	79
Bromine	1.94	1.48	66
Iodine	2.21	1.29	52

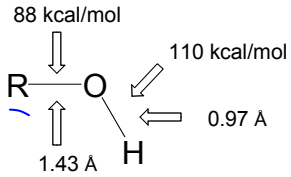
We will see later that in general the reactivity of alkyl halides increases in the order:

alkyl fluorides << alkyl chlorides < alkyl bromides < alkyl iodides

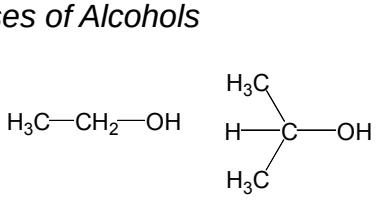
Why? A large part of the answer is bond strength

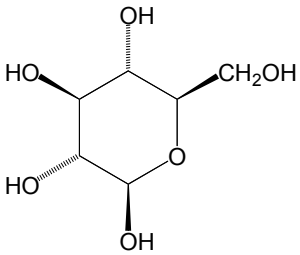


Alcohols



Classes of Alcohols



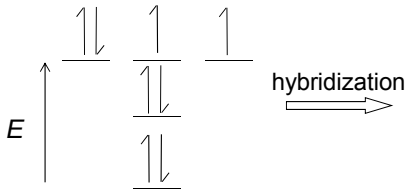


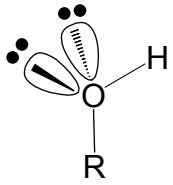
ethanol

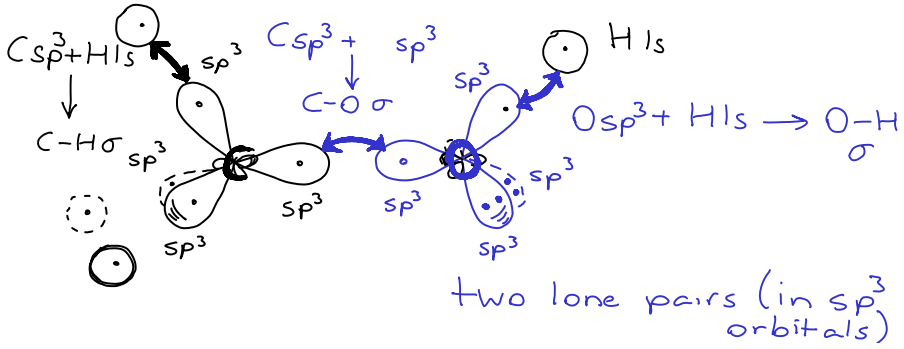
isopropanol
(rubbing alcohol)

glucose (5 OH groups)

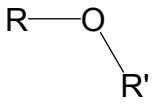
Hybridization of Oxygen in Alcohols

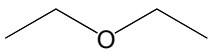




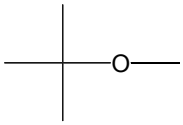


Ethers





diethyl ether
(old anesthetic)



methyl *tert*-butyl ether
(MTBE, *controversial fuel additive)*

ethylene oxide
(monomer for polymer in gel caps)

http://www.childsdoc.org/spring2000/stamps.asp

EMORY UNIVERSITY SYSTEM OF HEALTH CARE
CRAWFORD LONG HOSPITAL

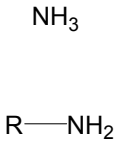
CNN.com

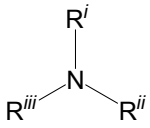
MTBE is not a carcinogen, California rules

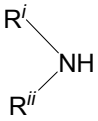
Amines

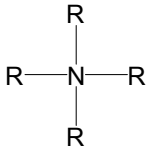
Classes of Amines: Classified by number of substituents *on the nitrogen atom* (*NOT* the attached carbon atom)

caffeine
nicotine









Problem: Using the concepts from topic 1….

- What is the geometry around the nitrogen of an amine

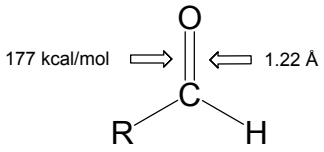
- What is the hybridization of the nitrogen of an amine

- What is the hybridization of the orbital containing the lone pairs of electrons on the nitrogen atom of amines?

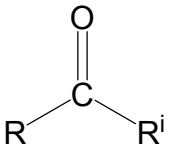
What is the hybridization of the orbital containing the lone pairs of electrons on the nitrogen atom of amines?

1 *s*
2 *p*
3 *sp*
4 sp^2
5 sp^3

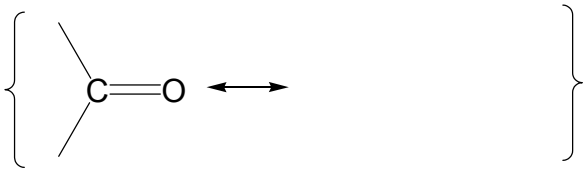
Aldehydes and Ketones



aldehyde



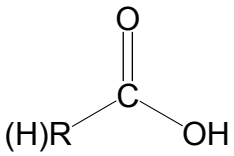
ketone



Formaldehyde
(biological preservative)
Benzaldehyde
(almond flavoring)
Acetone
(solvent)
Cortisone
(antiinflammatory)

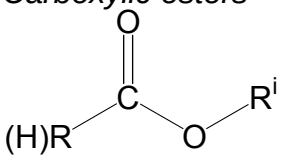
Carboxylic Acids and Derivatives (Esters and Amides)

Carboxylic acids



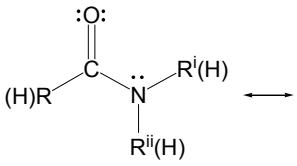
acetic acid
(vinegar)
acetylsalicylic acid
(aspirin)

Carboxylic esters



isoamyl acetate
(banana oil)
methyl salicylate
(wintergreen oil)

Amides



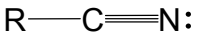
Validating resonance theory 

The above resonance structures ***predict*** partial double bond character for the carbonyl–nitrogen bond.

Experimental studies ***show***

1. The four atoms attached to the carbonyl carbon and the nitrogen atoms are close to being planar
2. There is very slow rotation about the carbonyl carbon–nitrogen bond

Nitriles (cyanides)



laetrile - amygdalin
(cyanogen sugar in bitter almonds, peach and apricot seeds)
Methyl cyanoacrylate
(monomer in Superglue)

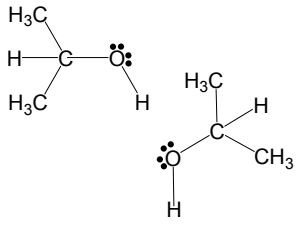
INTERMOLECULAR FORCES AND PHYSICAL PROPERTIES

Intermolecular Forces: Hydrogen Bonding; Dipole-Dipole Interactions; London Dispersion Forces (Van Der Waals Forces)

1. Hydrogen Bonding

Electrostatic attraction between lone pairs (e.g., on N, O, S, F, Cl, …) and a hydrogen atom bonded to an electronegative atom (e.g., on N, O, S, F, Cl,…)

- Hydrogen is $\delta+$ because of dipole
- Heteroatom has lone pair(s) of electrons



Physical Properties

Boiling Points

$CH_3CH_2CH_2CH_3$
butane, mw = 58
bp = –1°C

$CH_3CH_2CH_2NH_2$
propylamine, mw = 59
bp = 48 °C

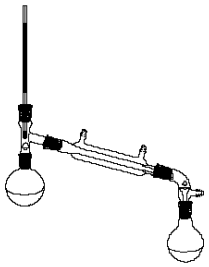
$CH_3CH_2CH_2OH$
1-propanol, mw = 60
bp = 97 °C

$CH_3CH_2CH_2F$
1-fluoropropane, mw = 62
bp = -3 °C

$(CH_3)_3N$
trimethylamine, mw = 59
bp = 3 °C

$CH_3CH_2OCH_3$
ethyl methyl ether, mw = 60
bp = 11 °C

CH_3CO_2H
acetic acid, mw = 62
bp = 118 °C



These differences in boiling point allow for the separation of compounds by distillation

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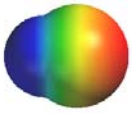
2. Dipole-Dipole Interactions

<u>Bond Dipoles</u>

Dipoles occur when two atoms with different electronegativity are bonded to one another.

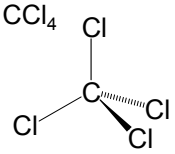
H—H 

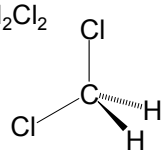
H—F 

<u>Dipole Moments</u>

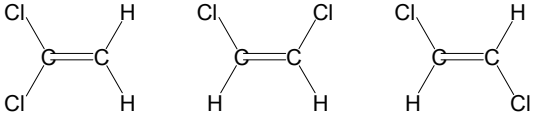
Add bond dipole vectors. C-H bonds are not polar (C and H have similar electronegativity), so they do not contribute much to polarity.

Chlorinated methanes

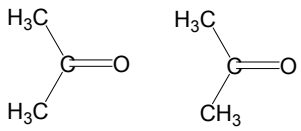
CCl_4 

CH_2Cl_2 

Dichloroethenes



Electrostatic attraction between permanent dipoles



3. Van der Waals (London) Forces

Electrostatic attraction between momentary dipoles and induced dipoles

Intermolecular forces determine a compound's physical properties.

Solubility

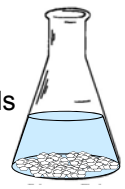
"Like dissolves like"

Polar solvents dissolve polar molecules and salts. Hydrogen bonding solvents dissolve hydrogen-bonding solutes.

- Soluble with water:
  - *Salts:* NaCl, NaOH
  - *Alcohols:* Methanol, CH_3OH, up to propanol, $CH_3CH_2CH_2OH$
  - *Acids:* Acetic acid, CH_3COOH, up to butanoic acid, $CH_3CH_2CH_2COOH$

- *Insoluble* in water
  - *Hydrocarbons:* Alkanes, alkenes
  - *Relatively non-polar functional molecules:* Alkyl halides, ethers, etc

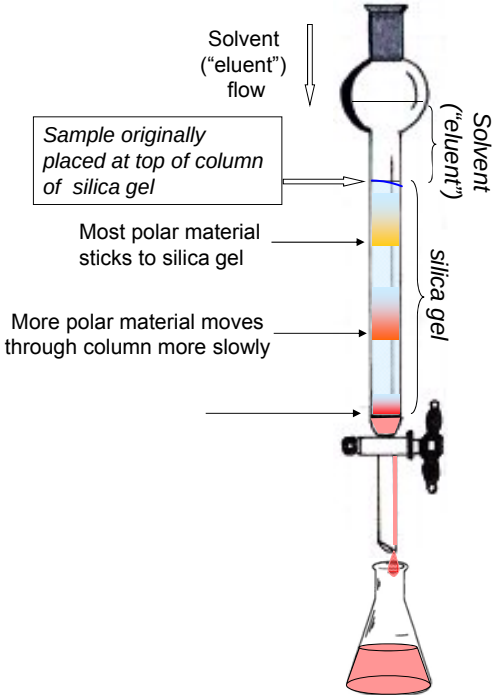
Differences in solubility allows for the separation of organic compounds by recrystallization and extraction (see later – Acids and Bases)



Polarity

Differences in polarity allows for the separation of organic compounds by *chromatography*.

Polar compounds stick to polar solids, non-polar compounds are eluted more rapidly



TOPIC 2

Types of Questions

- Describe various types of alkanes, alkyl groups, and carbons (primary, secondary, tertiary).
- Identify functional groups, geometry (bond lengths, angles), hybridization of atoms.
- Identify different types of intermolecular forces between molecules based on structure. Describe how these forces relate to physical properties of the compound