Magnet Junior High/High School Lesson Plan

COURSES: Integrated Physics and Chemistry, High School Chemistry (developed for Kealing Middle School's Integrated Physics and Chemistry course)

TOPIC: Understanding the Relationship Between Functional Groups and Polarity

TITLE: Organic Functional Groups and Thin Layer Chromatography

TEXAS ESSENTIAL KNOWLEDGE AND SKILLS

(Especially relevant parts of the TEKS are bolded and italicized)

Integrated Physics and Chemistry

(c) Knowledge and Skills

(1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:

(A) demonstrate safe practices during laboratory and field investigations; and

(B) demonstrate an understanding of the use and conservation and proper ***disposal*** or recycling of materials

(2) Scientific processes. The student uses ***scientific methods during laboratory*** and field investigations. The student is expected to:

(A) know the definition of science and understand that it ***has limitations***, as specified in subsection (b)(2) of this section;

(B) plan and ***implement investigative procedures, including asking questions, formulating testable hypotheses***, and selecting equipment and technology;

(C) ***collect data and make measurements with precision;***

(D) ***organize, analyze, evaluate, make inferences, and predict trends from data; and***

(E) communicate valid conclusions.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions. The student is expected to:

(A) in all fields of science, ***analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing***, including examining all sides of scientific evidence of those scientific explanations, ***so as to encourage critical thinking by the student***

(6) Science concepts. The student knows that relationships exist between structure and properties of matter. The student is expected to:

(A) examine differences in physical properties of solids, liquids, and gases as explained by the arrangement and motion of ***atoms,*** ions, or ***molecules*** of the substances and ***the strength of the forces of attraction between those particles;***
(B) ***relate chemical properties of substances to the arrangement of their atoms or molecules;***
(C) analyze physical and chemical properties of elements and compounds such as color, density, viscosity, buoyancy, boiling point, freezing point, conductivity, and ***reactivity;***
(D) ***relate the physical and chemical behavior of an element, including bonding*** and classification, to its placement on the Periodic Table; and

Chemistry

(c) Knowledge and Skills.

(1) Scientific processes. The student, for at least 40% of instructional time, conducts laboratory and field investigations using safe, environmentally appropriate, and ethical practices. The student is expected to:
(A) ***demonstrate safe practices during laboratory*** and field investigations, including the appropriate use of safety showers, eyewash fountains, ***safety goggles,*** and fire extinguishers;
(C) demonstrate an understanding of the use and conservation of resources and the ***proper disposal*** or recycling of materials.

(2) Scientific processes. The student uses scientific methods to solve investigative questions. The student is expected to:
(A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;
(B) know that ***scientific hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence.*** Hypotheses of durable explanatory power which have been tested over a wide variety of conditions are incorporated into theories;
(E) ***plan and implement investigative procedures, including asking questions, formulating testable hypotheses,*** and selecting equipment and technology, including graphing calculators, computers and probes, sufficient scientific ***glassware such as beakers,*** Erlenmeyer flasks, ***pipettes,*** graduated cylinders, volumetric flasks, safety goggles, and burettes, electronic balances, ***and an adequate supply of consumable chemicals;***
(F) ***collect data and make measurements with accuracy and precision;***
(G) ***express and manipulate chemical quantities using scientific conventions*** and mathematical procedures, including dimensional analysis, scientific notation, and significant figures;
(H) organize, analyze, evaluate, make inferences, and predict trends from data; and
(I) ***communicate valid conclusions supported by the data*** through methods such as lab reports, labeled drawings, graphs, journals, summaries, oral reports, and technology-based reports.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to:

(A) in all fields of science, ***analyze, evaluate,*** and critique scientific explanations ***by using empirical evidence, logical reasoning, and experimental and observational testing,*** including examining all sides of scientific evidence of those scientific explanations, so as to ***encourage critical thinking by the student;***

(7) Science concepts. The student knows how atoms form ionic, metallic, and covalent bonds. The student is expected to:

(C) construct electron dot formulas to illustrate ionic and ***covalent*** bonds;

DID YOU KNOW?

Molecules are comprised of atoms forming bonds, either ionic or covalent. For covalent bonds, we know that due to differences in electronegativity lead to the electrons within the bonds not always being evenly shared throughout the molecule. When a covalent bond shares electrons unevenly, it is called a polar covalent bond (i.e. water). When the molecules are shared more or less evenly, that is called a nonpolar covalent bond (i.e. a hydrocarbon, like oil). So we can draw trends about molecules, we tend to refer to clusters of atoms that are covalently bound with similar properties as functional groups. Typically functional groups are bound to a chain comprised of carbons and hydrogens (called a "hydrocarbon"), which is denoted as "R" or the "rest of the molecule." This property, polarity, is extremely useful as a strategy to examine, separate, and identify unknown molecules. One strategy to do this is called chromatography. The type of chromatography used in class today is called "thin layer chromatography" where the degree to which the molecule is attracted to a polar surface indicates how polar the substance is.

Examples of functional groups include: alcohols, aldehydes, ketones, carboxylic acids, esters, amides, amines, and ethers

Terms that you encounter in chromatography include:

Stationary phase: in this experiment, the TLC plate, or silicon dioxide attached to a glass or plastic backing. Silica is a polar surface, so molecules with polar functional groups are attracted to the surface of silica.
Mobile phase: The solvent solution used to migrate the compounds up the TLC plate. In this experiment it is 3 parts ethyl acetate: 1 part hexanes
Baseline: The bottom of the TLC plate, where the compounds are "spotted," or placed with a micropipettor
Solvent Front: How far the solvent migrated
Retention Factor (R_f): The distance the compound migrated over the distance the solvent migrated (this is easiest to show visually, using the diagram of the TLC plate shown on attachment).

LEARNING EXPERIENCE:

GENERAL TIME FRAME: 1.5 hours

Description: Students will run a thin layer chromatography (TLC) plate with four different compounds, benzoic acid, methyl benzoate, N-phenyl acetamide, and phenol. These compounds each have a different functional group appended to them, but the same "R" group, a phenyl ring. They will make predictions about the elution order and the polarity of the molecules. Then they will run a TLC plate and calculate and retention factor to test this hypothesis.

Materials:
1. Beakers—one for each group
2. Aluminum foil to cover the top of the beaker
3.The following chemicals (only a tiny amount of the four chemicals for samples are needed, so if you can find smaller quantities that will be sufficient):

Compound	CAS #	Vendor	Typical Price
Benzoic acid	65-85-0	Sigma Aldrich	$24.60/ 25 grams
Phenol	108-95-2	TCI America	$25/ 25 grams
Methyl Benzoate	93-58-3	Sigma Aldrich	$28.70/ 25 grams
N-phenyl acetamide	103-84-4	Alfa Aesar	$22.50/ 100 grams

4. The solvents ethyl acetate and hexanes (100 mL bottles will be more than sufficient)
5. Short wave UV lamp
6. TLC plates (plastic backed is cheaper than glass backed and easier to handle; vendors include Alfa Aesar, VWR, and Fisher)
7. Pencils
8. Small vials for samples
9. Rulers
10. Micropipette tubes

Advanced Preparation:
1. Prepare the TLC samples by adding a small amount (~5 milligrams) in ~1 mL of

ethyl acetate
2. Prepare the mobile phase in a bottle, 50% ethyl acetate, 50% hexanes
3. Cut TLC plates into rectangles (~1 inch by 2 inches)

Procedure:

(A worksheet is attached, which may be used in class)

Before the class runs their TLC plates:
1. Review functional groups. Use a complex molecule (such as Taxol) to illustrate the importance of breaking up molecules into functional groups, and label the functional groups.
2. Demo a running TLC plate on a dot cam.

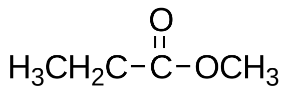
Student Procedure:

1. Measure 1 cm from the bottom of the plate. This is your baseline.
2. Spot the compound with a micro capillary tube at the frontline. Make sure to write down which lane contains with compound
3. Place the TLC plate in a beaker with the mobile phase. **Make sure the baseline is above the solvent level!!!!**
4. Allow the mobile phase to run up the plate until there is approximately 1 cm left of the plate that is dry.
5. Mark your solvent front.
6. Visualize the TLC plate with a UV lamp. Circle your spots so you can calculate the R_f

Data to collect:
1. Identify the functional groups
2. Measure the retention factor
3. Collect the class data on retention factors so you can see how reproducible these results are.

Post Lab Questions:

1. Which of the compounds is the most polar? Which is the least?
2. Which of the functional groups used in today's lab would you call (a) relatively non-polar functional group(s)? Which is/are (a) relatively polar functional group?
3. The mobile phase is made up of the solvents ethyl acetate and hexanes (in a 1:3 ratio). I have the structures drawn below. Which functional groups are present in the solvent? Which molecule is more polar?



$CH_3CH_2CH_2CH_2CH_2CH_3$

Extension:

Have the students figure out what happens to the retention factor when you vary the mobile phase polarity. This will require more TLC plates and time, but it is a good exercise.

Concepts To Discuss Post-Lab:

1. Use resonance to rationalize how polar the amide functional group is
2. Discuss differences in electronegativity; why is the carboxylic acid more polar than the ester
3. Discuss how this is a real technique used in organic chemistry labs to monitor reactions and purify compounds

Resources:

Guide to R_f and illustrations of TLC plates:
http://www.chemguide.co.uk/analysis/chromatography/thinlayer.html

Preparative TLC (a technique to purify compounds in chemistry, and it looks cool):
http://i1.ytimg.com/vi/xURJ3xKDKm0/hqdefault.jpg

Youtube video:
http://www.youtube.com/watch?v=F-QPmm5tJoM

Organic Functional Groups and Thin Layer Chromotography

So far, we have learned about various sorts of bonds, ionic and covalent. For covalent bonds, we know that due to ***differences in electronegativity***, the electrons are not always shared equally between the atoms.

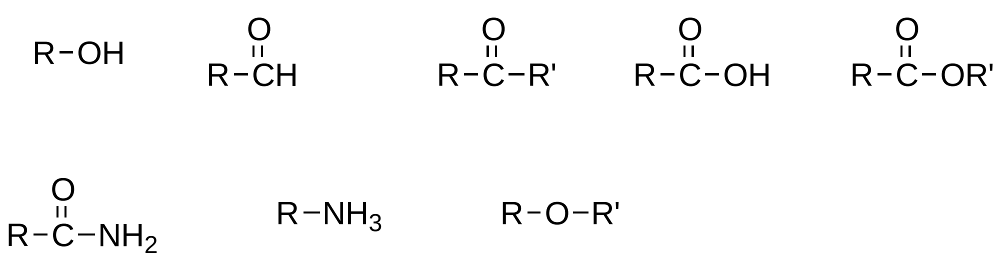
Types of covalent bonds:

Polar:

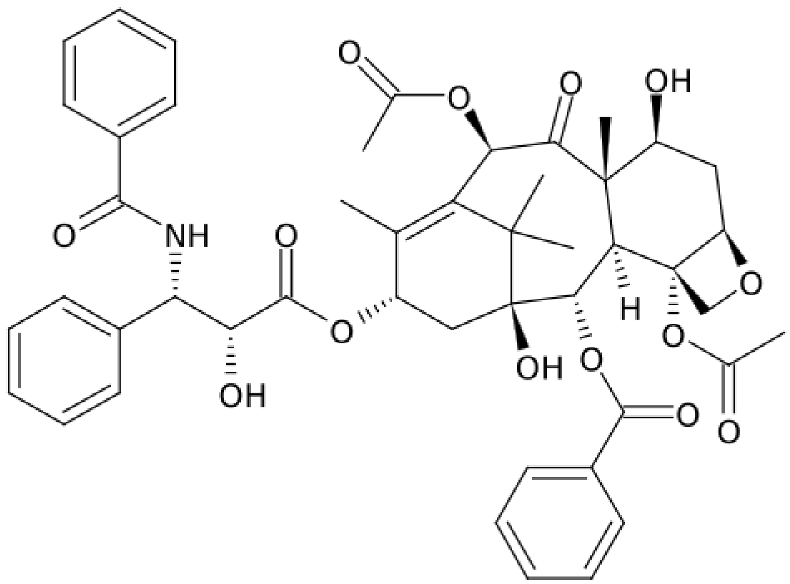
Nonpolar:

So we can draw trends about molecules, we tend to refer to groups of covalently bound atoms that have similar properties as ***functional groups***. Typically, functional groups are bound to a chain comprised of carbons and hydrogens (called a "hydrocarbon"), which is denoted as "R" (you can think of it as "the rest of the molecule"). An example of an "R group" would be, for example $-CH_3$.

Common Functional Groups:

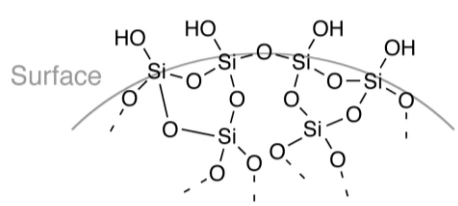


An example of functional groups in a real molecule, the anticancer drug Taxol:



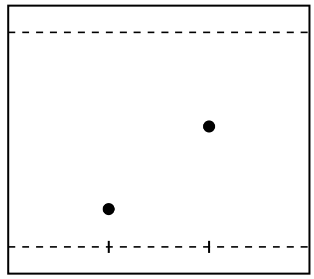
Thin Layer Chromotography

Thin layer chromatography is a technique that allows for the separation of molecules by **polarity**. The surface of the TLC plate is coated with silicon dioxide, which looks like this:

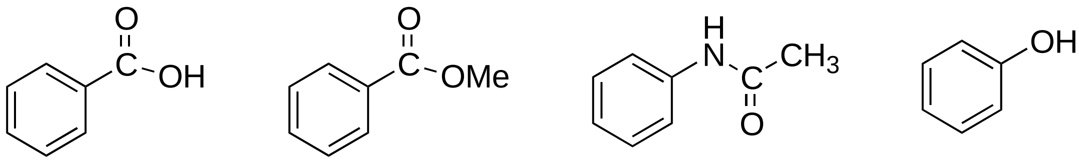


Silicon dioxide is a **polar** substance, so the more polar a compound is, the more it will interact with the silica. The silica is what is called your **"stationary phase."**

To get the compounds to migrate up the plate, you will use a **"mobile phase."** The mobile phase is a solvent. In this case, we will use 1 part ethyl acetate to 3 parts hexanes (1:3 ethylacetate: hexanes).



In this lab you have four compounds with different functional groups. The thin layer chromatography will allow you to compare the relative polarities of the four compounds.



Benzoic Acid   Methyl Benzoate   N-phenyl acetamide   Phenol

HYPOTHESIS: Rank the molecules by polarity and how far they will migrate up the plate. Which is the most polar? Which is the least?

Procedure:

7. Measure 1 cm from the bottom of the plate. This is your baseline.
8. Spot the compound with a micro capillary tube at the frontline. Make sure to write down which lane contains with compound
9. Place the TLC plate in a beaker with the mobile phase. **Make sure the baseline is above the solvent level!!!!**
10. Allow the mobile phase to run up the plate until there is approximately 1 cm left of the plate that is dry.
11. Mark your solvent front.
12. Visualize the TLC plate with a UV lamp. Circle your spots so you can calculate the R_f

Compound	Type of Functional Group In the Molecule	R_f
Benzoic Acid		
Methyl Benzoate		

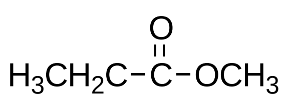
N-phenyl acetamide		
Phenol		

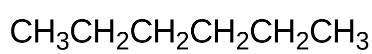
Questions:

4. Which of the compounds is the most polar? Which is the least?

5. Which of the functional groups used in today's lab would you call (a) relatively non-polar functional group(s)? Which is/are (a) relatively polar functional group?

6. The mobile phase is made up of the solvents ethyl acetate and hexanes (in a 1:3 ratio). I have the structures drawn below. Which functional groups are present in the solvent? Which molecule is more polar?





Organic Functional Groups and Thin Layer Chromatography (TEACHER KEY)

So far, we have learned about various sorts of bonds, ionic and covalent. For covalent bonds, we know that due to ***differences in electronegativity***, the electrons are not always shared equally between the atoms.

Types of covalent bonds:

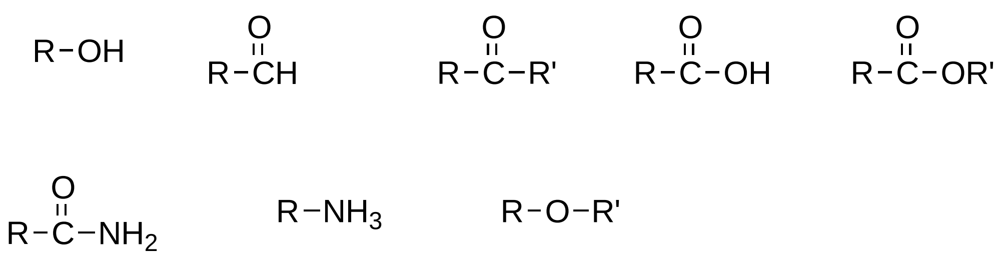
Polar: A covalent bond that shares electrons unequally (i.e. water) –Draw diagram of water with partial charges here

Nonpolar: A covalent bond that shares electrons **more or less** equally (i.e. methane) due to a small difference in electronegativity –Draw a hydrocarbon here

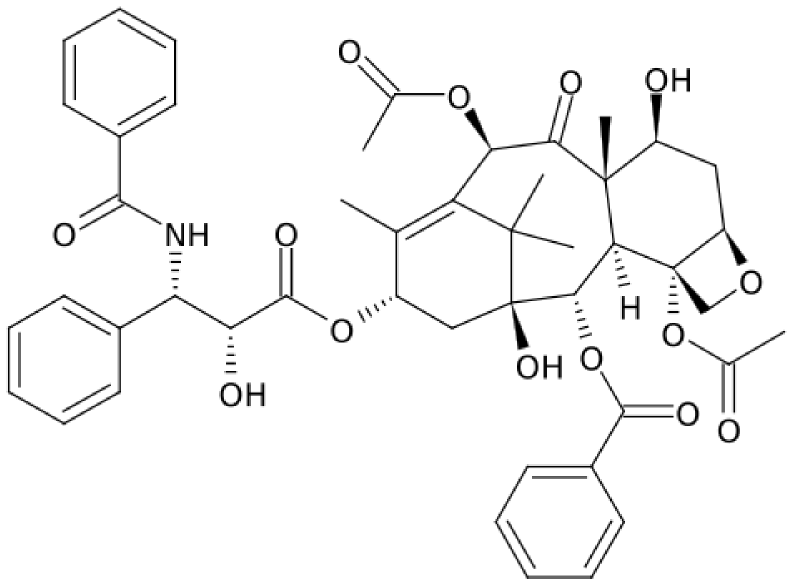
So we can draw trends about molecules, we tend to refer to groups of covalently bound atoms that have similar properties as ***functional groups***. Typically, functional groups are bound to a chain comprised of carbons and hydrogens (called a "hydrocarbon"), which is denoted as "R" (you can think of it as "the rest of the molecule"). An example of an "R group" would be, for example $–CH_3$.

Common Functional Groups:

Label them underneath

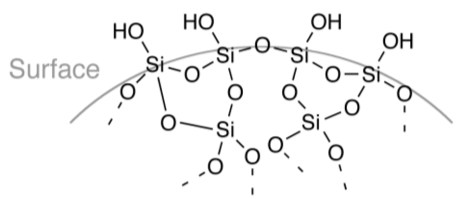


An example of functional groups in a real molecule, the anticancer drug Taxol:
Label functional groups in here—comment that it is a really complicated molecule that can be broken down in terms of functional groups. Also use this an example to point out line drawing for carbon and benzene rings, which comes up later in class for the TLC plates.



Thin Layer Chromotography

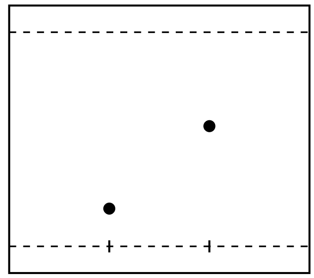
Thin layer chromatography is a technique that allows for the separation of molecules by **polarity**. The surface of the TLC plate is coated with silicon dioxide, which looks like this:



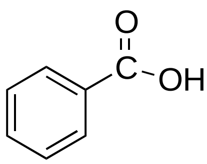
Silicon dioxide is a **polar** substance, so the more polar a compound is, the more it will interact with the silica. The silica is what is called your **"stationary phase."**

To get the compounds to migrate up the plate, you will use a **"mobile phase."** The mobile phase is a solvent. In this case, we will use 1 part ethyl acetate to 3 parts hexanes (1:3 ethylacetate: hexanes).

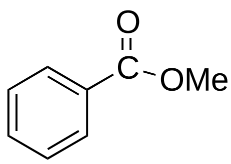
Use this diagram to illustrate the more polar substance is the bottom spot. Also use it to diagram baseline, solvent front, and R_f, or retention factor. Define baseline, solvent front, and R_f on the side. I can also use the dot cam to illustrate what it really looks like on a real TLC plate.



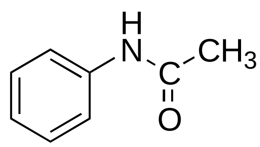
In this lab you have four compounds with different functional groups. The thin layer chromatography will allow you to compare the relative polarities of the four compounds.



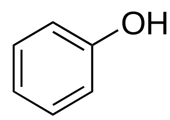
Benzoic Acid



Methyl Benzoate



N-phenyl acetamide



Phenol

HYPOTHESIS: Rank the molecules by polarity and how far they will migrate up the plate. Which is the most polar? Which is the least?

Procedure:

(I'll demo this on the dot cam)

13. Measure 1 cm from the bottom of the plate. This is your baseline.
14. Spot the compound with a micro capillary tube at the frontline. Make sure to write down which lane contains with compound
15. **Place the TLC plate in a beaker with the mobile phase. Make sure the baseline is above the solvent level!!!!**
16. Allow the mobile phase to run up the plate until there is approximately 1 cm left of the plate that is dry.
17. Mark your solvent front.
18. Visualize the TLC plate with a UV lamp. Circle your spots so you can calculate the R_f

Compound	Type of Functional Group In the Molecule	R_f
Benzoic Acid		
Methyl Benzoate		

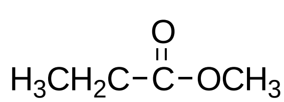
N-phenyl acetamide		
Phenol		

Questions:

7. Which of the compounds is the most polar? Which is the least?

8. Which of the functional groups used in today's lab would you call (a) relatively non-polar functional group(s)? Which is/are (a) relatively polar functional group?

9. The mobile phase is made up of the solvents ethyl acetate and hexanes (in a 1:3 ratio). I have the structures drawn below. Which functional groups are present in the solvent? Which molecule is more polar?



$CH_3CH_2CH_2CH_2CH_2CH_3$