CHM1321 – Organic Chemistry I Laboratory (Z07)

Experiment1:Thin Layer Chromatography (TLC)

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TA (Demonstrator)'s Name: Nathan Lu

Date Experiment Performed: Thursday, January 09th, 2020

Date Experiment Submitted: Thursday, January 16th, 2020

Attach here (if required, indicate the appropriate document(s)):

Medical or other Acceptable Document: **NA**

Change of Lab Day Form: **NA**

Change of Lab Section Form: **NA**

Late Pass: **NA**

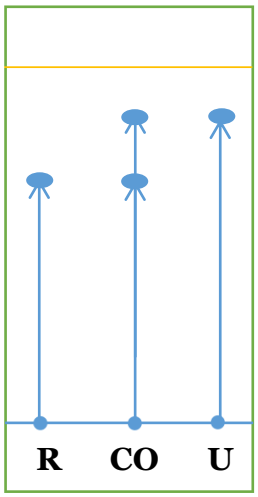
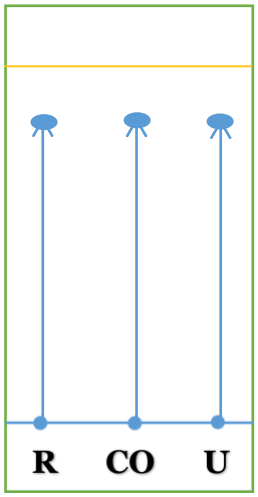
Procedure

Refer to lab manual ----- Experiment 1: Thin Layer Chromatography (page 1-6)

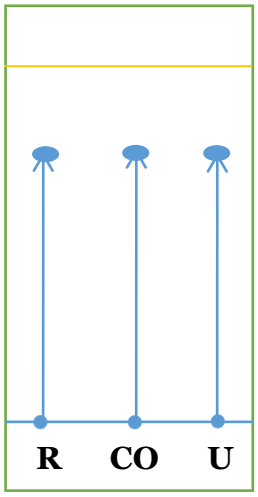
Qualitative Observations

- The TLC plate was composed of silica which was a white layer. The compounds were all spotted on the white silica layer.
- The unknown sample provided (#53) was composed of opaque white crystals. When dissolved in the transparent dichloromethane, the resulting unknown solution was also transparent.
- Both benzophenone and biphenyl were transparent solutions.
- 2:8 mixture of ethyl acetate (EtOAc) and hexanes was transparent solutions with a strong odor.
- 9:1 mixture of hexanes and ethyl acetate (EtOAc) was transparent solutions with a strong odor.
- m-bromonitrobenzene was a transparent, colorless liquid with a strong odor.
- o-bromonitrobenzene was a transparent, colorless liquid with a strong odor.
- p-bromonitrobenzene was a transparent, colorless liquid with a strong odor.

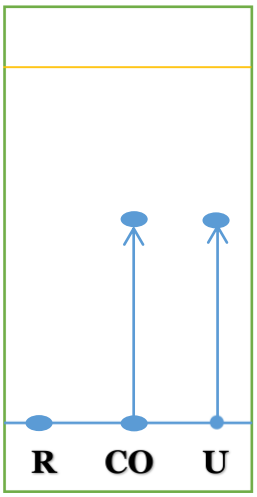
Part A (Unkown sample 53)

TLC 1. Benzophenone (Reference) Solvent: 2:8 EtOAc : hexanes	TLC 2. Biphenyl (Reference) Solvent: 2:8 EtOAc : hexanes
 Solvent System: 2:8 EtOAc : hexanes R:reference (benzophenone) CO:Co-spot (R+U) U: unknown #53	 Solvent System: 2:8 EtOAc : hexanes R:reference (biphenyl) CO:Co-spot (R+U) U: unknown #53
d1= 3.4cm (reference) d1= 3.4cm(L) & 4.2cm(T) (Co-spot) d1= 4.2cm (sample) ds= 4.8cm	d1= 3.6cm (reference) d1= 3.6cm (Co-spot:L+T) d1= 3.6cm (sample) ds= 4.1cm

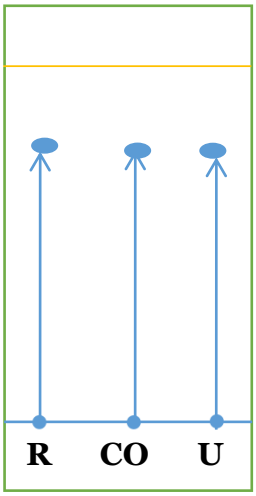
Part B (Unkown sample 53)

<table>
<tr><td>TLC 3. Benzophenone (Reference)
Solvent: ethyl acetate (EtOAc)</td><td>TLC 4. Benzophenone (Reference)
Solvent: hexanes</td></tr>
<tr><td> 

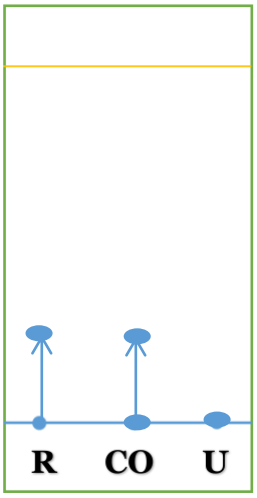
Solvent System:
Ethyl Acetate

R:reference
(benzophenone)
CO:Co-spot (R+U)
U: unknown #53
d1= 4.3cm (reference)
d1= 4.3cm (Co-spot:L+T)
d1= 4.3cm (sample)
ds= 4.9cm</td><td> 

Solvent System:
Hexane

R:reference
(benzophenone)
CO:Co-spot (R+U)
U: unknown #53
d1= 0cm (reference)
d1= 0cm(L) & 3.0cm(T) (Co-spot)
d1= 3.0cm (sample)
ds= 4.9cm</td></tr>
<tr><td>TLC 5. Biphenyl (Reference)
Solvent: ethyl acetate (EtOAc)</td><td>TLC 6. Biphenyl (Reference)
Solvent: hexanes</td></tr>
<tr><td> 

Solvent System:
Ethyl Acetate

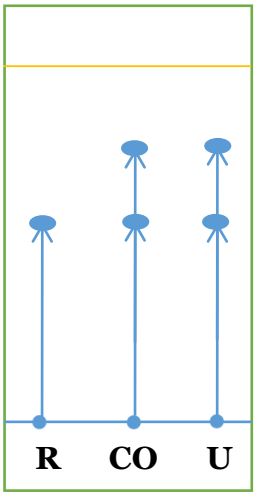
R:reference
(biphenyl)
CO:Co-spot (R+U)
U: unknown #53
d1= 4.6cm (reference)
d1= 4.4cm (Co-spot:L+T)
d1= 4.4cm (sample)
ds= 5.0cm</td><td> 

Solvent System:
Hexane

R:reference
(biphenyl)
CO:Co-spot (R+U)
U: unknown #53
d1= 1.1cm (reference)
d1= 0cm(L) & 1.1cm(T) (Co-spot)
d1= 0cm (sample)
ds= 4.5cm</td></tr>
</table>

Part C (Unknown I)

TLC 7. Meta-bromonitrobenzene (Reference)
Solvent: 9:1 hexanes : EtOAc

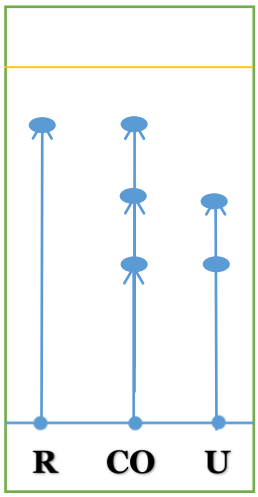


Solvent System:
9:1 hexanes : EtOAc

R:reference
M=meta-bromonitrobenzene)
CO:Co-spot (R+U)
U: unknown

d1= 2.7cm (reference)
d1= 2.7cm(L) & 3.3cm(T) (Co-spot)
d1= 2.7cm(L) & 3.3cm(T) (sample)
ds= 4.4cm

TLC 8. Para-bromonitrobenzene (Reference)
Solvent: 9:1 hexanes : EtOAc



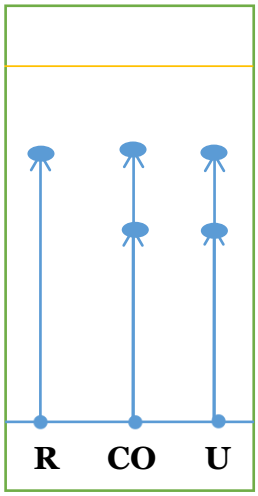
Solvent System:
9:1 hexanes : EtOAc

R:reference
P=para-bromonitrobenzene)
CO:Co-spot (R+U)
U: unknown

d1= 2.3cm (reference)
d1= 1.4cm(L) & 2.0cm(M) & 2.3cm(T) (Co-spot)
d1= 1.4cm(L) & 2.0cm(T) (sample)
ds= 4.4cm

VVVVVVVVVVVVVVVVVVVVVVVVVVVVV

TLC 9. Ortho-bromonitrobenzene (Reference)
Solvent: 9:1 hexanes : EtOAc



Solvent System:
9:1 hexanes : EtOAc

R:reference
O=ortho-bromonitrobenzene)
CO:Co-spot (R+U)
U: unknown

d1= 2.9cm (reference)
d1= 1.9cm(L) & 2.9cm(T) (Co-spot)
d1= 1.9cm(L) & 2.9cm(T) (sample)
ds= 5.0cm

Calculation

(R_f Value of sample)

TLC1

Reference:Benzophenone

Solvent: 2:8 EtOAc : hexanes

R_f Value = d1/ds

R_f Be,CO(L) = 3.4 cm /4.8 cm = 0.708

R_f CO(T),Un = 4.2 cm /4.8 cm = 0.875

Part A (Unknown #53)	R_f Value = d1/ds
TLC1 Reference:Benzophenone Solvent: 2:8 EtOAc : hexanes	R_f Be,CO(L) = 3.4 cm /4.8 cm = 0.708 R_f CO(T),Un = 4.2 cm /4.8 cm = 0.875
TLC2 Reference:Biphenyl Solvent: 2:8 EtOAc : hexanes	R_f Bi,CO(L&T),Un = 3.6 cm /4.1 cm = 0.878
Part B (Unknown #53)	R_f Value = d1/ds
TLC3 Reference: Benzophenone Solvent: Ethyl Acetate	R_f Be,CO(L&T),Un = 4.3 cm /4.9 cm = 0.878
TLC4 Reference: Benzophenone Solvent: Hexane	R_f Be,CO(L) = 0 cm /4.9 cm = 0 R_f CO(T),Un = 3.0 cm /4.9 cm = 0.612
TLC5 Reference: Biphenyl Solvent: Ethyl Acetate	R_f Bi = 4.6 cm /5.0 cm = 0.920 R_f CO(L&T),Un = 4.4 cm /5.0 cm = 0.880
TLC6 Reference: Biphenyl Solvent: Hexane	R_f Bi,CO(T) = 1.1 cm /4.5 cm = 0.244 R_f CO(L),Un = 0 cm /4.5 cm = 0
Part C (Unknown I)	R_f Value = d1/ds
TLC7 Reference: M=meta-bromonitrobenzene Solvent:9:1 hexanes : EtOAc	R_f M,CO(L) = 2.7 cm /4.4 cm = 0.614 R_f CO(T),Un(L&T) = 3.3 cm /4.4 cm = 0.750
TLC8 Reference: P=para-bromonitrobenzene Solvent:9:1 hexanes : EtOAc	R_f P,CO(T) = 2.3 cm /4.4 cm = 0.523 R_f CO(L),Un(L) = 1.4 cm /4.4 cm = 0.318 R_f CO(M),Un(T) = 2.0 cm /4.4 cm = 0.455
TLC9 Reference: O=ortho-bromonitrobenzene Solvent:9:1 hexanes : EtOAc	R_f O,CO(T),Un(T) = 2.9 cm /5.0 cm = 0.580 R_f CO(L),Un(L) = 1.9 cm /5.0 cm = 0.380

Discussion

Protocol justification:

-In the middle row of the TLC, also known as the co-spot, both reference and sample solution were spotted to compare the polarity

-Image J was used to calculate absorbance of bromonitrobenzene.

-Capillary was used to spot because TLC required only small amount of solution, smaller than a drop.

Analysis

Part A

In this part of the experiment, we want to obtain the identity of sample # 53. Therefore, we performed two TLCs on the samples using two different known compounds as references. The two TLCs were TLC1; based on benzophenone, and TLC2; based on biphenyl. And we know that the R_f value is a measurement of the polarity of a substance, which is determined by the distance of how far the substance can move up the TLC plate ("Experiment 1: Thin-layer chromatography", 2020). Therefore, substances with similar or equal R_f values usually presents similar distances on the plate.

According to the data shown in TLC1, the composition of the unknown sample may not contain benzophenone, because in the TLC image, the co-spots of sample # 53 and benzophenone are shown as two disjoint spots, this means that the sample # 53 and benzophenone have different R_f values.

The R_f value of benzophenone in TLC1 is 0.708, lower than the Rf value of unknown samples 0.875, which means that benzophenone has a higher polarity than sample # 53 and biphenyl. The unknown sample # 53 component does not contain benzophenone.

According to the data shown by TLC2, sample #53 is most likely to be biphenyl because of the co-spot, where both sample and biphenyl was spotted, shows only one spot, meaning sample #53 and biphenyl had same R_f value of 0.878. There the unknown composition # 53 present must be biphenyl.

Through this part of the experiment, we learned the basic of thin layer chromatography and how to analyze its results

Part B

In this part of the experiment, we tested or demonstrated the effect of solvents on TLC. We performed TLCs for a total of four times; twice using ethyl acetate (EtOAc) as the eluent, and the other half (twice) using hexane as the eluent. When performing TLC, the distance (polar or non-polar) the compound moves depends not only on the polarity of the compound itself, but also on the polarity of the solvent system. The more polar the solvent is, the more it can destroy the intermolecular forces between the TLC plate (silica gel) and the compound ("Experiment 1: Thin-layer chromatography", 2020). This allows the compound to have higher mobility and cover longer distances, resulting in a larger R_f value.

This difference can be seen in TLC3 and TLC4. TLC3 represents the TLC of benzophenone and unknown samples in a solvent system made of ethyl acetate, and TLC4 represents the TLC of benzophenone and unknown samples in a solvent system of hexane. The Rf value of TLC3 is generally greater than the Rf value in TLC4. When comparing the experimental results of biphenyl and unknown samples in TLC5 (a solvent system made of ethyl acetate) and TLC6 (a solvent system made of hexane), the same experimental results were also observed.

The R_f value of a plate run in an eluent made of ethyl acetate is greater than the R_f value of a plate run in a hexane eluent, so ethyl acetate is a more polar solvent. This indicates that ethyl acetate is a more polar solvent. This makes sense because hexane is composed primarily of carbon and hydrogen, while ethyl acetate has oxygen that binds to hydrogen, making the material more polar.

But when using ethyl acetate as the eluent, benzophenone / biphenyl and sample # 53 seem insignificant due to the polarity of ethyl acetate. Similarly, using hexane as the eluent, hexane is non-trivial. Polar, so the difference between benzophenone / biphenyl and the # 53 sample is also insignificant.

Through this part of the experiment, we learned the importance of thin layer chromatography with eluents of appropriate polarity.

Part C:

In this part of the lab, an unknown sample I was provided and it's components needed to be determined using TLCs and three different references, o-bromonitrobenzene, m-bromonitrobenzene, and p-bromonitrobenzene. Three different TLCs were performed, one for each reference. A solvent system of Hexane:EtOAc (9:1) was used.

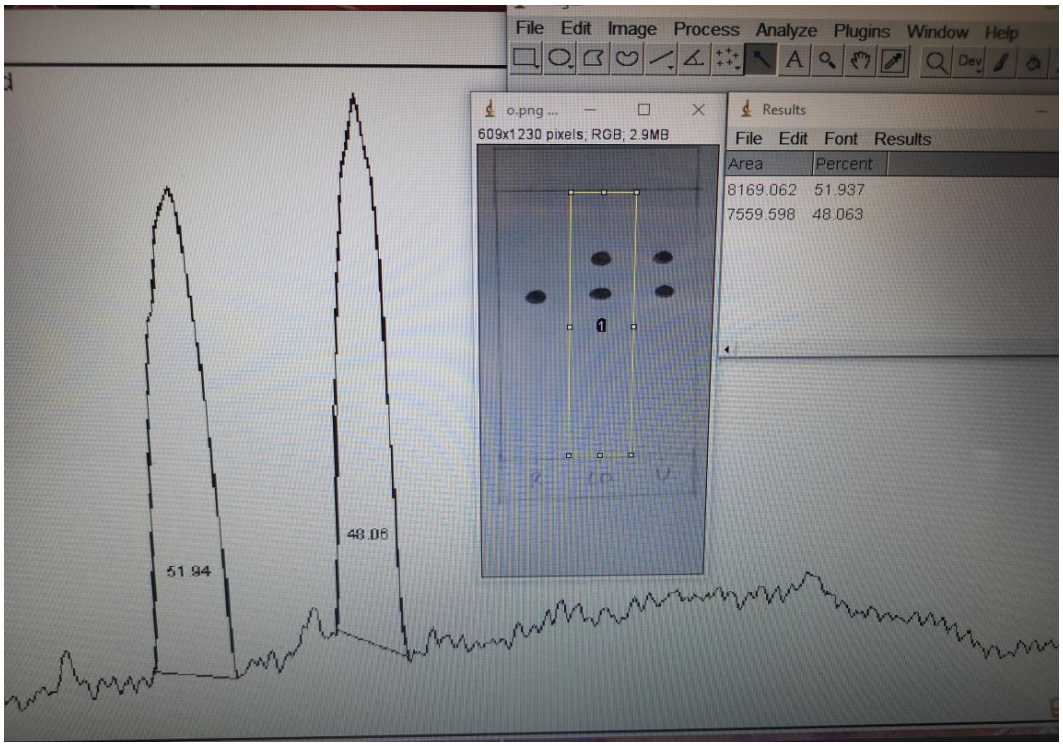
This ratio for the eluant was predetermined as indicated in the lab manual and was chosen because it yielded the optimal separation of spots on the TLC and had the optimal polarity as a solvent system ("Experiment 1 : Thin Layer Chromatography," 2020). This is most likely because the compounds used in this TLC were aromatics. These types of compounds are non-polar and so it would move faster along the TLC plate ("Experiment 1 : Thin Layer Chromatography," 2020).

Thus, a more non-polar solvent was used to counter this and ultimately yield a better separation. Like the first part of the lab, if a TLC had 3 spots with the same R_f value this would mean that the compound found in the sample is the same as the reference compound. This is because the R_f value of the sample would definitely be shared by the co-spot as it was also spotted with the sample and the only way that the Rf value of the reference could be the same as the sample is if the reference was the same as the sample. This provides a row of 3 spots to look out for when identifying the components of an unknown compound. This is in TLC7 and TLC9, a row of 3 spots is seen. In TLC8; however, this is not seen, therefore demonstrating that the sample has

nothing in common with the reference. This diagram in particular has 3 spots in the co-spot lane which is a representation of the separation of the reference and the other 2 compounds that the sample is composed of. In this case, it was determined that the unknown compound I contained o-bromonitrobenzene and m-bromonitrobenzene.

With reference to TLC 7, 8, and 9, we can conclude that the Unknown sample I contains ortho-bromonitrobenzene and meta-bromonitrobenzene, because the polarity of ortho-bromonitrobenzene and meta-bromonitrobenzene match with the sample.

Through this part of the experiment, we can conclude that the Unknown sample I contains ortho-bromonitrobenzene (51.937%) and meta-bromonitrobenzene (48.063%).



Source of possible error:

A few sources of error may have hindered the success of this experiment.

- The TLC plate preparing process is vastly delicate, and if rushed will not yield perfect results. An easy way to damage an already prepared TLC plate is to accidentally touch the silica side of the plate with one's fingers or palm. The skin is oily, coated in organic compounds, touching the silica will cloud the results of the molecules under analysis. This could be accounted for an experimental error.
- There were three capillaries, 1 for each solvent. It would only take one person in the lab to misplace the capillaries to damage all the TLC plates that were prepared using those capillaries. This would explain outliers seen in quantitative observations part C and other. The error can be avoided by being more careful and perhaps labeling the capillaries with some sort of marker to color coordinate it to each solvent.
- A large dot of reference or unknown is placed on the TLC plate then there will be less separation between the spots on the plate after the TLC has developed. The spots will appear smeared together and this can cause readings on image J to be inaccurate. In order to ensure this problem does not occur practice dots can be made in order to get a sense of how the capillary dispenses the substances.
- In TLC4, the R_f value of benzophenone was 0. The source of error could possibly be because the eluent touched by the benzophenone spot. This

source of error can be resolved by using less eluent or raising the base line of TLC plate.

Conclusion

Part A: The unknown #53 sample was found to be biphenyl.

Part B: The R_f value of a plate run in an eluent made of ethyl acetate is greater than the R_f value of a plate run in a hexane eluent, so ethyl acetate is a more polar solvent. This indicates that ethyl acetate is a more polar solvent.

Part C: The unknown I was a compound contains that ortho-bromonitrobenzene (51.937%) and meta-bromonitrobenzene (48.063%).

References

1. Durst, B. T., Scaiano, T., Flynn, A., & Focsaneanu, K. (2020). CHM 1321 Organic Chemistry Laboratory Manual 2020, 1–18.
2. Experiment 1: Thin Layer Chromatography. (2014), (September), 1–6.
3. Da Silva, Manuel A.V. Ribeiro, Ferreira, Ana I.M.C. Lobo, Santos, Ana Filipa L.O.M., & Rocha, InA*S M. (2010). Thermochemical study of the monobromonitrobenzene isomers. The Journal of Chemical Thermodynamics, 42(2), 169-176.

Question：

1. Why is it important to make co-spots last?

It is important to make co-spots last in TLC because TLC isn't always perfect, and the solvent front may not always run in a straight line.
If things go wrong, it can be very difficult to differentiate between RFS that are in separate lanes. Thus, having a lane where you spot both materials can be sort of a "reference" lane, where you can see where both spots elute in the same lane.That is why the importance of co-spots is very much in Thin Layer Chromatography.

2. How does increasing the polarity of the solvent system affect the results of a TLC?

In general, the adsorption capacity of compounds increases with increased polarity (i.e. the more polar the compound the stronger it binds to the adsorbent). The eluting power of solvents increases with polarity. The stronger a compound is bound to the adsorbent , the slower it moves up the TLC plate.

The factor that affects the Rf value of TLC is the polarity of the solvent. If the solvent is too polar, all of the compounds can run right up the plate resulting in poor separation.

3. A student is monitoring a reaction using TLC. The chemical reaction converts compound A into compound B, and she uses molecule A as her reference. Compound A has a Rf value of 0.45; while compound B has an Rf of

0.68 in the solvent system being used.

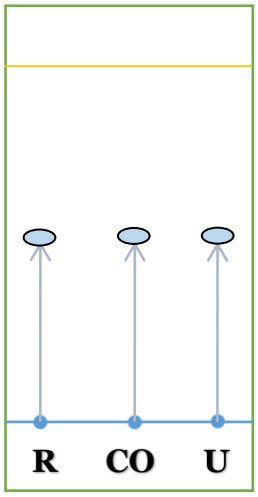
a. Draw a picture of her TLC plate at the beginning of the reaction.

b. Draw a picture of her TLC plate after 50% completion (50% of the A molecules have been converted to B molecules).

c. Draw a picture of her TLC plate at the end of the reaction (all of the A molecules have been converted to B molecules).

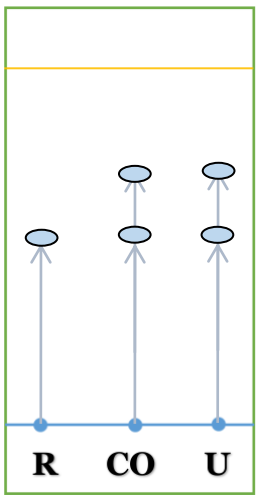
d. Why is it better to use a sample of molecule A rather than molecule B to follow the reaction?

a.



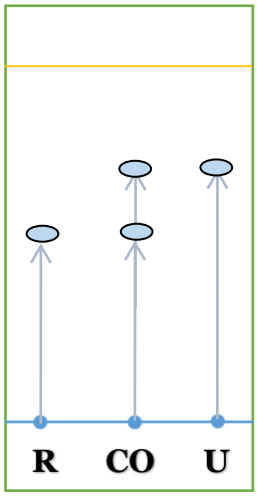
Reaction: A ⟶ B
Reference=Compound A point
Unknown Sample=Reaction mixture
Co-spot=R+U
R_f Value = d1/ds
R_f A = 0.45 R_f B = 0.68
In the first TLC plate where we only observe one spot which is for the compound A because there is not B formed at the beginning. So the R_fR&Co&Un = 0.45

b.



Reaction: A ⟶ B
Reference=Compound A point
Unknown Sample=Reaction mixture
Co-spot=R+U
R_f Value = d1/ds
R_f A = 0.45 R_f B = 0.68
At the half way of the reaction when 50 % of A molecules converted to B then we observe two spots which is for the compound A and B respectively.So theR_fR&Co(L)&Un(L)= 0.45, R_f Co(T)&Un(T)= 0.68

C.



Reaction： A ⟶ B
Reference=Compound A point
Unknown Sample=Reaction mixture
Co-spot=R+U
R_f Value = d1/ds
R_f A = 0.45 R_f B = 0.68
At the end of the reaction when all the A is converted to B then spot of the A is disappear and only we can see the spot of the B.So the R_f R&Co(L)= 0.45, R_f Co(T)&Un= 0.68

d.

It is important to use the compound A as the reference spot because if we use compound B as the reference, then we will not be able to confirm if the reaction is complete or not, because when A is completely converted to B, A will disappear completely, signaling the completion of the reaction.

This would tell that all the reactants have turned into products. Molecule B or any product is not a good reference because firstly, the reaction has to be complete to acquire the products and second, it makes the reaction harder to track. Instead of looking for a point that should eventually disappear, one would be looking for a point to become fixed on the TLC to match with the reference. This is counterintuitive and there is a potential for error. Furthermore, if the products were used instead of the reactants, then it would be harder to know that the reaction taking place is the correct reaction. Therefore, it is better to use the compound A as a reference than B.

4.A student is monitoring a reaction involving compounds C and D using TLC. Compound C has an Rf value of 0.43; compound D has an Rf of 0.40.

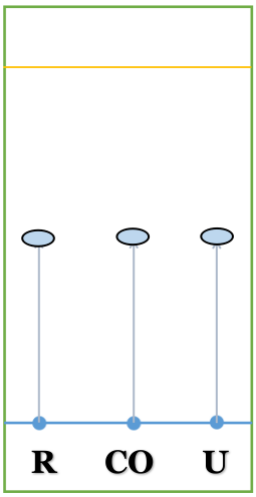
a. Draw a picture of the TLC plate at the beginning of the reaction.

b. Draw a picture of the TLC plate after 50% completion (50% of the C molecules have been converted to D molecules).

c. Draw a picture of the TLC plate at the end of the reaction (all of the C molecules have been converted to D molecules).

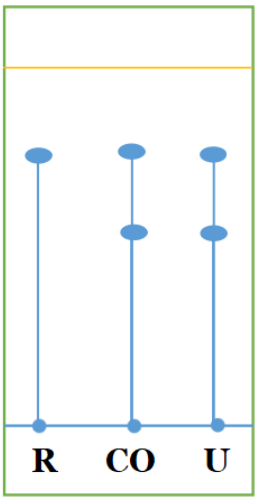
d. Why is it important to use a co-spot?

a.



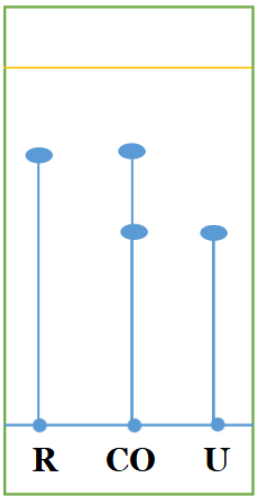
Reaction: C ⟶ D
Reference=Compound C point
Unknown Sample=Reaction mixture
Co-spot=R+U
R_f Value = d1/ds
R_f C = 0.43 R_f B = 0.40
In the first TLC plate where we only observe one spot which is for the compound C because there is not D formed at the beginning. So the R_f R,Co&Un= 0.43

b.



Reaction: C ⟶ D
Reference=Compound C point
Unknown Sample=Reaction mixture
Co-spot=R+U
R_f Value = d1/ds
R_f C = 0.43 R_f D = 0.40
At the half way of the reaction when 50 % of C molecules converted to D then we observe two spots which is for the compound C and D respectively. So the R_f Co(L)&Un(L)= 0.40, R_fR&Co(T)&Un(T) = 0.43

c.



Reaction： C ⟶ D
Reference=Compound C point
Unknown Sample=Reaction mixture
Co-spot=R+U
R_f Value = d1/ds
R_f C = 0.43 R_f D = 0.40
At the end of the reaction when all the C is converted to D then spot of the C is disappear and only we can see the spot of the D.So the R_f Un&Co(L)= 0.40,
R_f R&Co(T)= 0.43

d. It is important to use a co-spot because it allows to get a clearer differentiation for compounds that have very similar R_f values. As in the above TLC's, compound C and D share very similar R_f values. This difference is only made visual by using a lane with a co-spot. This allows us to observe both the spots in the same lane and makes the differences in R_f values much clearer. If the co-spot was not made, then there is a high chance that it would not be known that the R_f values were different and it would seem as though the reaction is not occurring. This would be a major error but is easily preventable by the co-spot.

5.For each of the following sets of compounds perform the following:

a. Draw the line structure of each molecule.

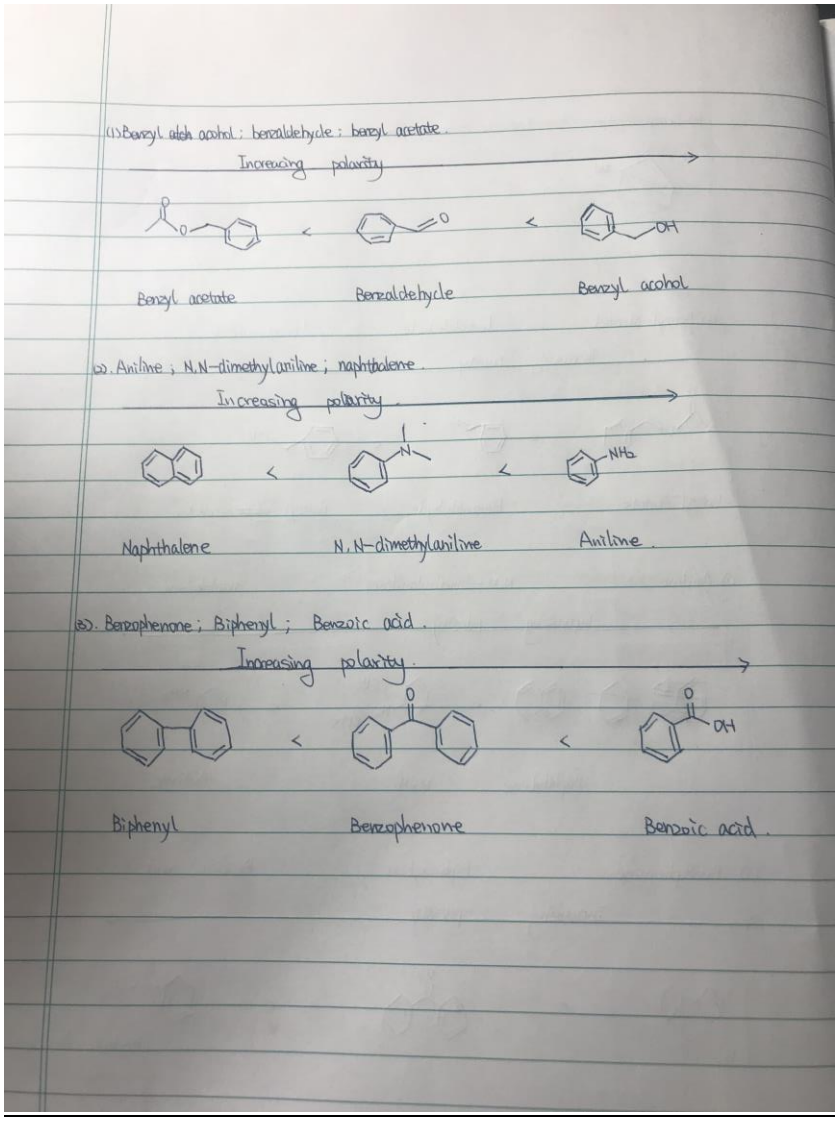
b. Arrange them in order of increasing polarity.

c. Explain your reasoning in part b.

i. Benzyl alcohol, benzaldehyde, benzyl acetate

ii. Aniline, N,N-dimethylaniline, naphthalene

iii. Benzophenone, Biphenyl, Benzoic acid



I.

- All three molecules are polar, some more than others.
- Benzyl alcohol can accept and donate hydrogen bonds therefore benzyl alcohol will have the lowest Rf value.

- Between benzyl acetate and benzaldehyde, benzaldehyde is more polar. The molecule is smaller, and has more hydrogen bonding potential with silica than benzyl acetate.

II.

- Naphthalene is a symmetrical molecule; therefore it is non-polar (least polar). It won't bind to silica, will have the highest Rf value.
- N,N-dimethylaniline and aniline are both polar, both have a nitrogen. The nitrogen on N,N-dimethylaniline is attached to two non polar methyl groups. The nitrogen on aniline is bonded with two hydrogens, creating an amino functional group which is polar. More hydrogen bonding potential. N,N-dimethylaniline has more atoms than aniline and is more heavy, this is also a reason for it to be less polar.
- Therefore aniline is more polar than N,N-dimethylaniline and will have the lowest Rf value.

III.

- Biphenyl is a symmetrical molecule; therefore it is non-polar (least polar). It won't bind to silica, will have the highest Rf value.
- Benzophenone and benzoic acid are both polar.
- Benzoic acid is more polar due to having two electronegative oxygen atoms, while benzophenone only has one. The acid has a hydroxyl group and therefore will have potential to create hydrogen bonding with silica.

Benzoic acid would bind to silica faster than benzophenone resulting in a smaller Rf value and therefore will show to be most polar.

Appendix:

Raw Data

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January 9th, 2020

Thin Layer Chromatography (534)

~~Fractl~~. Part A (2:8 EtOAC: hexanes

d_1 = ds 3.4 (Reference 4.2cm (Sample) (Co).

ds = 4.8 cm

Rf = d_1 / ds Rf R(Be) & Co(L) = $\frac{3.4}{4.8}$ = 0.88 Rf Co(T) & U = $\frac{4.2}{4.8}$ = 0.875

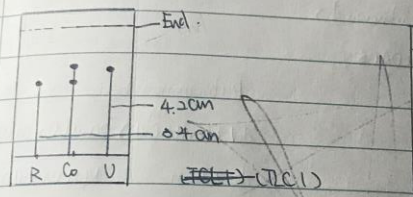
R: Benzophenone

d_1 = 3.6 (Reference & Sample) (Co)

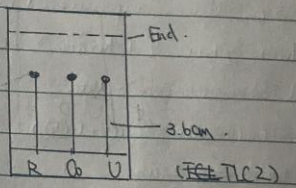
ds = 4.1 cm

Rf = d_1 / ds. Rf R(Be) & Co & U = $\frac{3.6}{4.1}$ = 0.878.

R: Biphenyl



~~(TCL1)~~ (TLC1)



(~~TCL~~ TLC2)

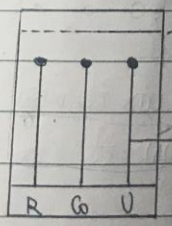
Part B.

Benzo (~~Ethy~~)

d_1 4.3 cm (R & U & Co).

d_3. 4.9 cm

Rf = d_1 / ds Rf R(Be) & Co & U = $\frac{4.3}{4.9}$ = 0.878



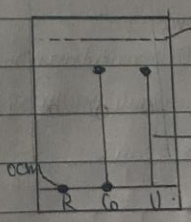
(TLC3)

Benzo (hexa).

d_1 = 0 (R) Co(L) & 3cm (S + Co(T)).

ds = 4.9cm.

Rf Be Co(L) = $\frac{0}{4.9}$ = 0 Rf Co(T) & U = 0.612.



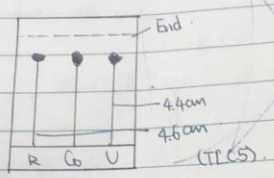
(TLC4)

Biphenyl (Ethy)

d_1 = 4.6 (R) 4.4 cm (Co + U).

d_s = ~~4.6cm~~ 5.0cm

$R_f = \frac{d_1}{d_s} \Rightarrow R_f = \frac{4.6}{5.0}$

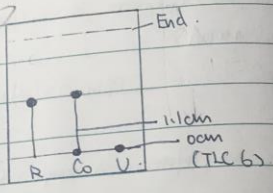


(TLC 5).

Biphenyl (Hexa.)

d_1 = 0cm (Co + Co(L)) 1.1cm (Co(T) + R).

d_s = 4.5cm



(TLC 6)

Part C New compound (Unknown I).

Solvent System: 9:1 hexanes : EtOAc

M. (bromonitrobenzene) — Meta.

d_1 = 2.7cm (R + Co(L)) 3.3cm (U + Co(T)).

d_s = ~~5.0cm~~ 4.4cm

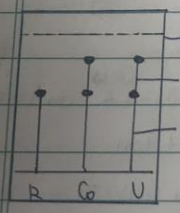
$R_f = \frac{d_1}{d_s} \Rightarrow R_f$(Co(L)) = $\frac{2.7}{4.4}$ = 0.614 R_f(Co(T)+U) = $\frac{3.3}{4.4}$ = 0.750

P (bromonitrobenzene) — Para.

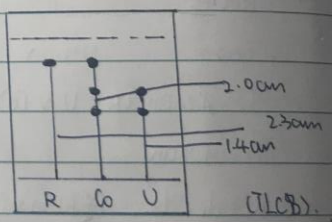
d_1 4.0cm (U + Co(L)) 2.0cm (U(T) + Co(M)) 2.3cm (R + Co(M))

d_s = 4.4cm. R_f(U(T) + Co(M)) = $\frac{2.0}{4.4}$

$R_f = \frac{d_1}{d_s} \Rightarrow R_f$(U(L) + Co(L)) = $\frac{1.4}{4.4}$ = 0.318



~~TLC~~ (TLC T)

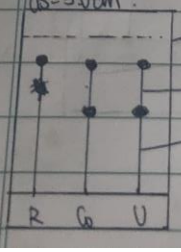


(TLC B).

O (bromonitrobenzene) — Ortho.

d_1 = 1.9cm (U(L) + Co(L)) 2.9 cm ((U(T) + Co(T) + R)

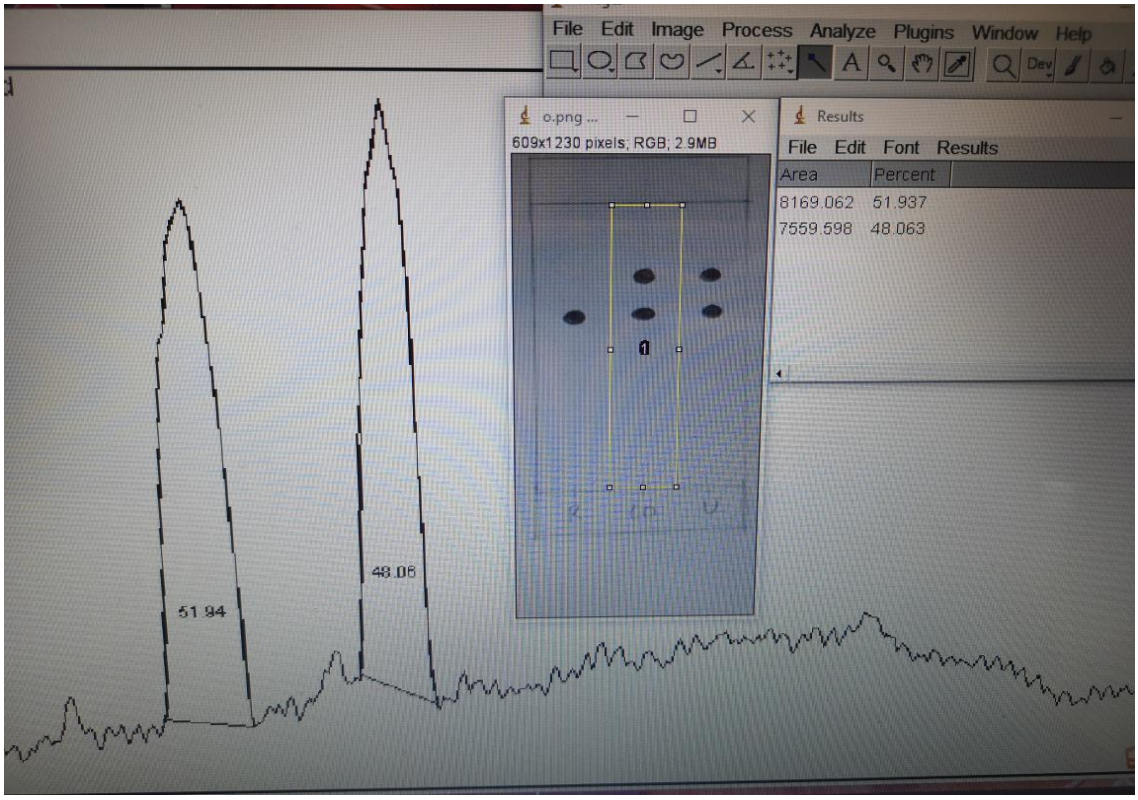
d_s = 5.0cm.



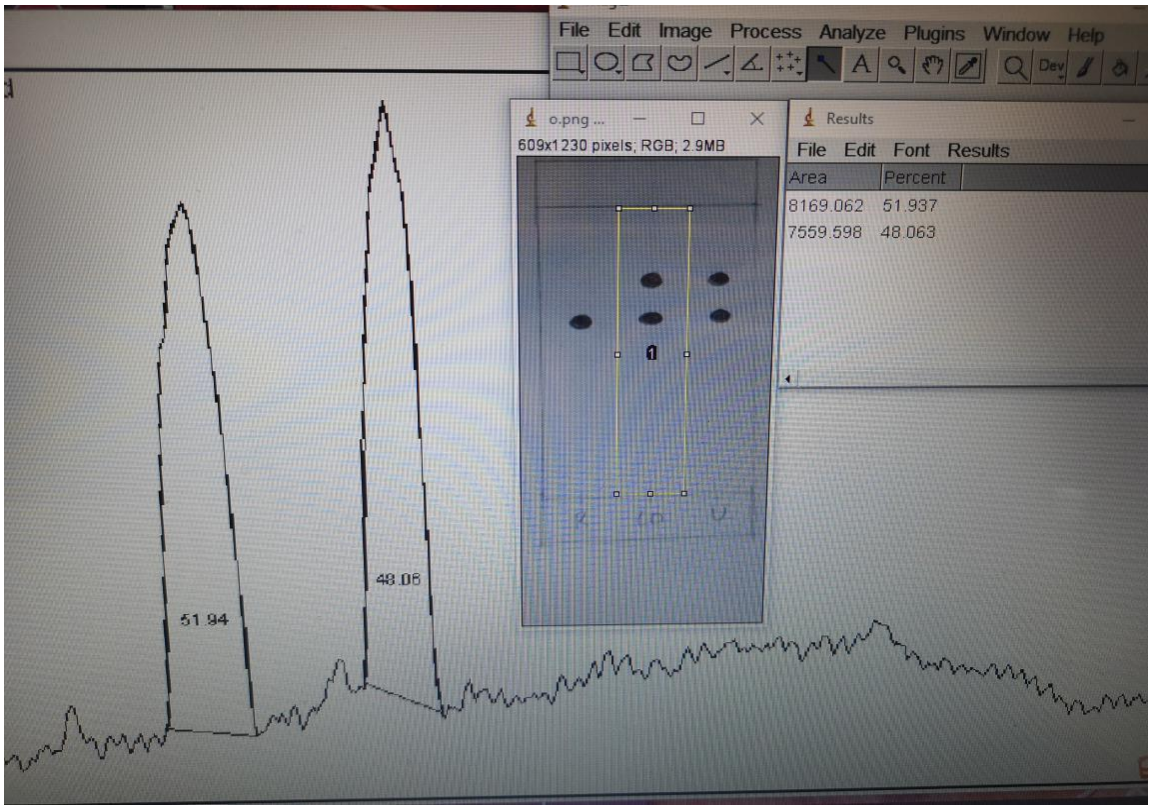
R_f (R + Co(T), U(T)) = $\frac{2.9}{5.0}$ = 0.580

R_f (Co(L), U(L)) = $\frac{1.9}{5.0}$ = 0.380

Additional Data



Additional Graphs



Sample Calculations

TLC1

Reference:Benzophenone

Solvent: 2:8 EtOAc : hexanes

R_f Value = d1/ds

R_f Be,CO(L) = 3.4 cm /4.8 cm = 0.708

R_f CO(T),Un = 4.2 cm /4.8 cm = 0.875