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VCE Chemistry ½

Principles of Chromatography [1.10]

Homework Solutions

Homework Outline:

Section A: Compulsory Questions (52 Marks)

Sub-Section: Identify Which Substances Would Dissolve one Another Based on Miscibility and Polarity

Question 1 (4 marks)

For the following molecules, label their polarities and determine if they will dissolve in each other.

a. Water and HCl.

i. Polarity. (0.5 marks)

Both are polar.

ii. Miscibility. (0.5 marks)

Miscible

b. CH_4 and HF.

i. Polarity. (0.5 marks)

CH_4 - Non-polar, HF - Polar

ii. Miscibility. (0.5 marks)

Not miscible.

c. C_2H_5OH and CH_3F.

i. Polarity. (0.5 marks)

Both are polar.

ii. Miscibility. (0.5 marks)

Miscible

d. C_3H_8 and $C_{10}H_{22}$.

i. Polarity. (0.5 marks)

Both are non-polar.

ii. Miscibility. (0.5 marks)

Miscible

Question 2 (4 marks)

For the following molecules, state and identify whether they are soluble or miscible in each other.

a. NH_3 and H_2O. (1 mark)

Yes

b. CCl_4 and CH_3OH. (1 mark)

No

c. CH_3Cl and CO_2. (1 mark)

No

d. H_2S and HCl. (1 mark)

Yes

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Question 3 (4 marks)

For the following molecules, explain whether the following molecules are soluble in a non-polar, organic solvent.

a. Ethane, C_2H_6. (2 marks)

Yes, because ethane is also non-polar and as such they can form dispersion forces that are strong between each other and hence, dissolve.

b. Methanol, CH_3OH. (2 marks)

No, because methanol is polar and therefore, will not exhibit the same types of intermolecular bonds (and will not dissolve in each other).

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Sub-Section: Apply the Concepts of Adsorption and Desorption to Stationary and Mobile Phases

Question 4 (3 marks)

For the following pairs of items, identify which is the stationary phase and which is the mobile phase.

a. Water passing through a sponge. (1 mark)

Water – mobile, Sponge – stationary

b. Paper dipped into a solution of ink. (1 mark)

Paper – stationary, Ink - mobile

c. A glass tube and a solution of CH_3OH. (1 mark)

Glass tube – stationary, CH_3OH – mobile

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Question 5 (4 marks)

Explain how the following would affect a substance's speed and distance travelled along a stationary phase and mobile phase.

a. Substance adsorbing to the stationary phase. (2 marks)

This means that the substance will move slower through the mobile phase due to weaker desorption and stronger adsorption to the stationary phase, and therefore, will also travel a shorter distance.

b. Substance desorping to the mobile phase. (2 marks)

This means that the substance will move along with the mobile phase more so than adsorbing onto the stationary phase, and hence, will move faster and travel further.

Question 6 (4 marks)

For the following list of molecules,

$$C_2H_6, CH_3OH, CH_3Cl$$

a. Rank how far each of the substance would travel along a polar mobile phase and a non-polar stationary phase in a TLC setup. (2 marks)

Shortest: C_2H_6, CH_3Cl, CH_3OH (longest distance).

b. Explain the process by which the furthest molecule will travel. (2 marks)

The CH_3OH will strongly desorp into the polar mobile phase and adsorb weakly onto the stationary phase, hence, will spend more time travelling through the setup.

Sub-Section: Apply Chromatography Principles to Thin Layer Chromatography (TLC)

Question 7 (2 marks)

For each of the following, identify which is the stationary phase and which is the mobile phase.

a. A plastic plate coated with silica gel and a solvent mixture solution. (1 mark)

Silica Gel – stationary, Solvent mixture – mobile phase

b. A thin piece of paper suspended in a glass beaker with water inside the beaker. (1 mark)

Piece of paper – stationary phase, Water – mobile phase

Question 8 (3 marks)

Consider a TLC setup. If a substance had stronger adsorption to the stationary phase:

a. Would the component move faster or slower? Explain why. (2 marks)

It would move slower because then it would spend more time being attached onto the stationary phase and would desorp more weakly onto the mobile phase, making it slower.

b. Hence, would it be far along the stationary phase? (1 mark)

No, it would travel a short distance.

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Question 9 (4 marks)

Consider a TLC setup that involves a polar stationary phase and a non-polar mobile phase.

a. Given a list of the following molecules, rank how far along they would travel. (2 marks)

$$HF, CH_4, H_2O, C_2H_6$$

Shortest: HF, H_2O, C_2H_6, CH_4 (longest distance).

b. Describe the movement of the most polar compound. (2 marks)

As HF is the most polar compound it would adsorb strongly onto the stationary phase and desorp weakly into the mobile phase, making it unlikely to move very far along the stationary phase.

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Sub-Section: Calculate Retardation Factor (Rf) Values for Components on a TLC Plate

Question 10 (3 marks)

Given the following data, calculate the R_f values of the following substances:

Substance	Distance Travelled (cm)
Solvent	11.00
Sample A	3.50
Sample B	6.00
Sample C	5.75

A – 3.50 / 11.00 = 0.318

B – 6 / 11 = 0.545

C – 5.75 / 11 = 0.523

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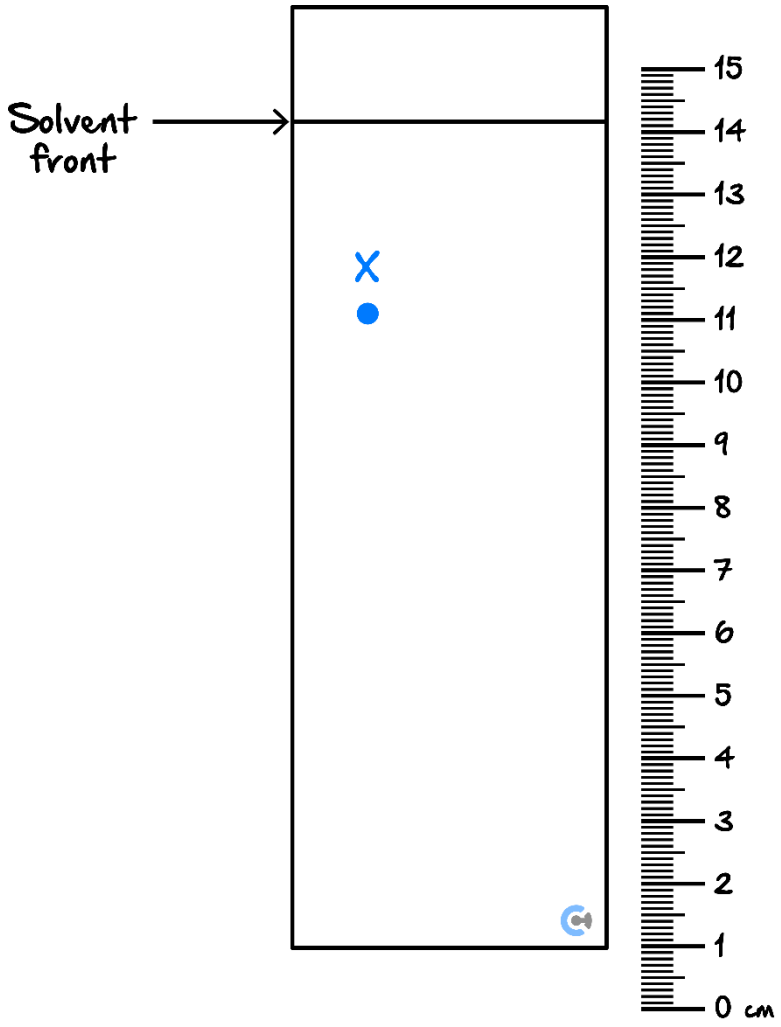
Question 11 (4 marks)

Consider the following paper chromatography setup.



a. Calculate the R_f value of component X. (2 marks)

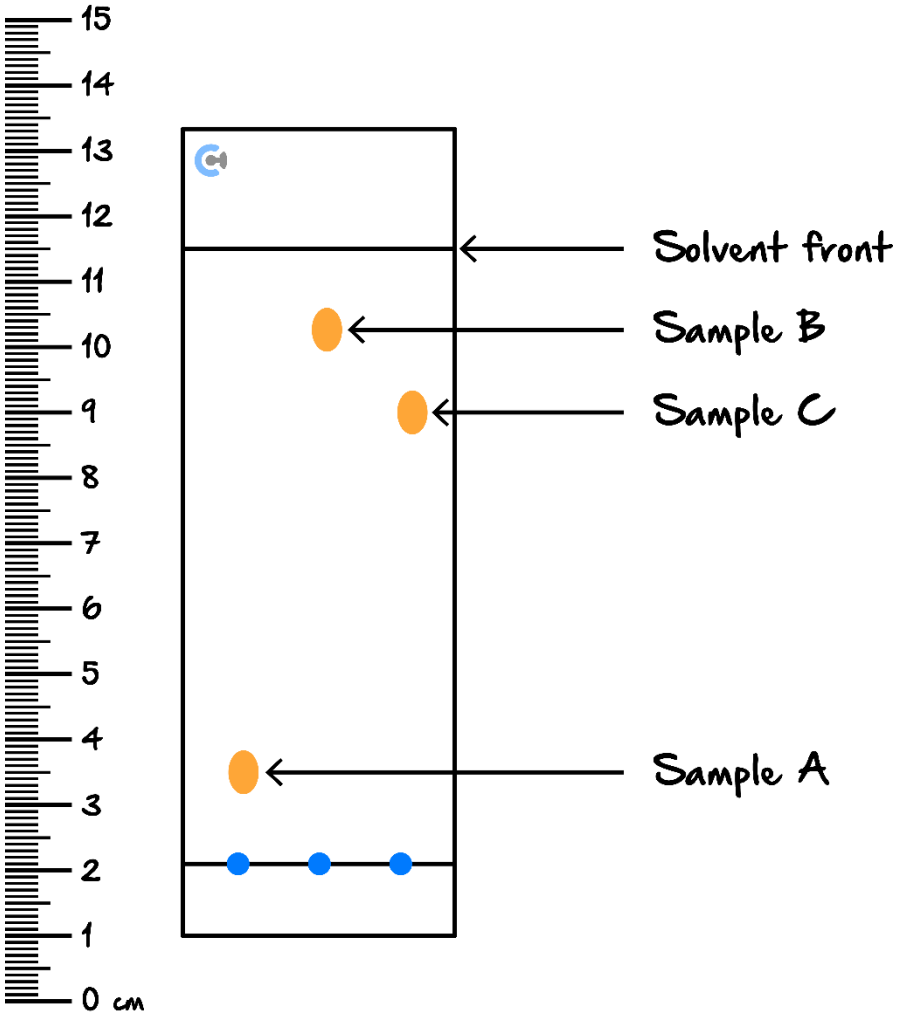
Solvent Front $-14.2-1=13.2\,cm$
$X\ R_f$: $(11-1)\ /\ 13.2 = 0.758$ (approx.)

b. Explain why the R_f value will always be less than one no matter what. (2 marks)

This is because the R_f is a measure of ratio between the solvent front and all other components, and as the solvent front will always be the one moving the furthest, as long as nothing moves past the solvent front, the ratio will always remain less than one.

Question 12 (5 marks)

The following TLC setup has a polar stationary phase and a non-polar mobile phase.



a. Calculate the R_f values of each of the samples. (2 marks)

Solvent Front: 9.5 cm
A – 1.5/ 9.5 = 0.158 (all approx. vals)
B – 8.5 / 9.5 = 0.895
C – 7 / 9.5 = 0.737

b. The following molecules were used for this experiment: CH_3OH, C_2H_6 and C_3H_8.

i. Identify the samples according to the molecules. (1 mark)

C_2H_6 – Sample C, C_3H_8 – Sample B, CH_3OH – Sample A

ii. Explain why Sample A is so low on the TLC plate, with reference to the molecules' bonding. (2 marks)

It is because methanol is a polar molecule and hence, will adsorb strongly onto the polar stationary phase, thus, will stay attached and not move that far.

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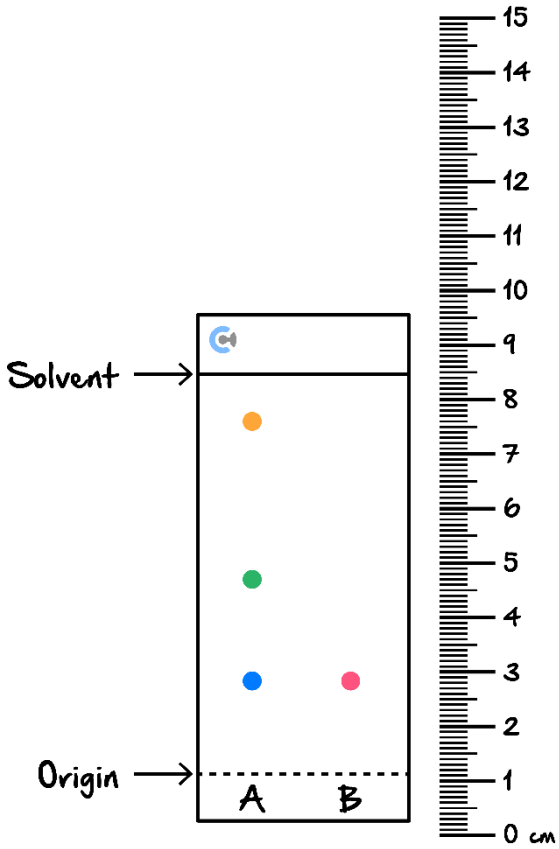
Sub-Section: The 'Final Boss'

Question 13 (8 marks)

A normal phase TLC setup was done to analyse laundry detergent (sample *A*) which comprises of several components. The following chromatogram was obtained when comparing it to sample *B*, components of a dangerous compound.



a. Explain which component is the least polar in this setup from sample *A*. (2 marks)

As the mobile phase is non-polar, the yellow component will be the most non-polar from sample *A* because this means it would have formed stronger intermolecular bonds with the non-polar mobile phase and hence, desorped more strongly into the mobile phase, moving further.

b. If another component has an R_f value of 0.75, what is the distance that it has travelled? (2 marks)

$0.75 \times 7.5 = 5.625\ cm$

c. Sample B represents that of a dangerous compound that is not allowed in laundry detergent. Calculate its R_f value and state its relative polarity. (2 marks)

$R_f = (3-1)/7.5 = 0.267$ and it is relatively polar as it adsorbs strongly onto the polar stationary phase and hence, will not be that far.

d. Is this laundry detergent permitted to go on sale? Explain your answer. (2 marks)

No, because it contains the same dangerous compound as in sample B since one of its components has the same R_f as the sample B.

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Section B: Supplementary Questions (67 Marks)

Sub-Section: Identify Which Substances Would Dissolve one Another Based on Miscibility and Polarity

Question 14 (4 marks)

For the following substances, state their polarity and explain why.

a. HF. (2 marks)

Polar – Because F is electronegative and pulls electrons towards itself strongly.

b. NH_3. (2 marks)

Polar – Because the N is electronegative and pulls electrons from the H towards itself strongly, creating a dipole.

Question 15 (4 marks)

For the following molecules, state and identify whether they are soluble or miscible in each other.

a. SO_2 and H_2O. (1 mark)

Yes

b. C_6H_6 and H_2O. (1 mark)

No

c. CH_3OH and C_3H_8. (1 mark)

No

d. HCl and NH_3. (1 mark)

Yes

Question 16 (4 marks)

For the following molecules, explain whether they are soluble in a non-polar, organic solvent.

a. CH_3COOH. (2 marks)

Not soluble as CH_3COOH is a polar compound.

b. $C_7H_{15}OH$. (2 marks)

This molecule is soluble despite having a $-OH$ in its structure, this is due to the length and size of the molecule making it majorly non-polar, meaning it exhibits the same intermolecular bonding as the non-polar solvent.

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Question 17 (6 marks)

Consider a solvent that is comprised of benzene C_6H_6, a non-polar compound.

a. Why do we find that a compound of CH_4 dissolves well in benzene whereas H_2O does not? Explain, with reference to intermolecular bonding. (3 marks)

CH_4 dissolves well in benzene as both molecules are non-polar and will exhibit the same type of intermolecular bonding, and therefore, will dissolve but as H_2O is a very polar molecule it will not have the same types of intermolecular bonding that will allow it to be miscible with benzene.

b. A student suggests that C_4H_9Cl will not be miscible in benzene since it has a polar Cl compound which will cause it to be polar. Evaluate their statement. (3 marks)

They are incorrect as while Cl may be polar and the compound has a polar section, the majority of the compound is non-polar due to its sheer size, and hence, will exhibit the dispersion forces required to be miscible with benzene.

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Sub-Section: Apply the Concepts of Adsorption and Desorption to Stationary and Mobile Phases

Question 18 (3 marks)

For the following scenarios, identify which is the stationary phase and which is the mobile phase.

a. Air passing through an activated charcoal filter. (1 mark)

Air – mobile, Filter – stationary

b. A TLC plate with a solvent moving upward. (1 mark)

TLC plate – stationary, Solvent - mobile

c. Drinking coffee with a straw. (1 mark)

Coffee- mobile, Straw – stationary

Question 19 (4 marks)

Explain how the following factors influence the movement of substances in chromatography.

a. Increased attraction between a substance and the stationary phase. (2 marks)

This means the substance will be more strongly adsorbed onto the stationary phase and weakly desorped into the mobile phase, making it move slower and lesser distance in the setup.

b. Increased molar mass of a substance when the mobile phase is polar. (2 marks)

If the molar mass of a substance increases, its strength of dispersion forces increases. This will result in its desorption into the polar mobile phase weaker, and hence, adsorption onto the stationary phase stronger, making it move slower and lesser distance too as the size increases.

Question 20 (4 marks)

A chromatogram under analysis has a polar mobile phase, and a non-polar stationary phase. H_2S is passed through the chromatogram to analyse it.

a. Is H_2S polar? Explain. (2 marks)

Polar – Because F is electronegative and pulls electrons towards itself strongly.

b. Which phase of the chromatogram will H_2S be more attracted to? Explain. (2 marks)

Polar – Because the N is electronegative and pulls electrons from the H towards itself strongly, creating a dipole.

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Question 21 (6 marks)

Two objects *X* and *Y* are analysed using chromatography. *X* and *Y* have differing strengths of attraction to the phases of the chromatogram.

a. If object *Y* is seen to travel further along than *X* given the same amount of time, then explain its attraction to a phase in the chromatogram. (2 marks)

Y is then more attracted to the mobile phase and hence, it will desorb more strongly to the mobile phase and be adsorbed less onto the stationary phase.

b. As such, describe the motion for object *X* in the chromatogram. (2 marks)

X travels less than *Y* and hence, it will be more attracted to the stationary phase of the chromatogram, and it will adsorb more onto the stationary phase and will desorb less into the mobile phase compared to object.

c. If object *X* was analysed in the chromatogram using a different solvent to object *Y*, then can results still be comparable? Justify your answer. (2 marks)

Results can only be comparable if the conditions in which the chromatograms were obtained are the same. So, if they are done with different solvent, they will not be comparable since it is not the same conditions.

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Sub-Section: Apply Chromatography Principles to Thin Layer Chromatography (TLC)

Question 22 (2 marks)

In a TLC experiment that has a non-polar mobile phase, if a substance has a high polarity, describe its movement along the TLC setup.

If a substance has high polarity, that means it will have weak intermolecular bonding to the non-polar mobile phase and therefore, will adsorb strongly onto the stationary phase instead, and will not travel far up the TLC plate.

Question 23 (2 marks)

Consider a TLC experiment using a polar stationary phase. Rank the following compounds based on how far they will travel.

C_2H_5OH, CH_2O, CH_4

Shortest Distance: C_2H_5OH, CH_2O, CH_4: Longest Distance

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Question 24 (6 marks)

During normal phase TLC, a mixture which consists of CH_4, CH_3Cl and CH_3OH was used.

a. Which substance is expected to travel the shortest distance? (2 marks)

CH_3OH will travel the shortest distance as it is the most polar, and in normal phase TLC, the mobile phase is non-polar and the stationary phase polar. Therefore, CH_3OH will adsorb strongly onto the stationary phase and hence, will travel not very far.

b. Which substance is expected to travel the longest distance? Explain. (2 marks)

CH_4 will travel the furthest as it is the most non-polar, meaning it will form the strongest intermolecular bonds with the non-polar mobile phase, making it travel further.

c. If a different TLC set-up was used where the polarities were swapped than regular TLC, do you expect your answers to be the same? Justify your answer. (2 marks)

No, the answers would be the exact opposite as the mobile phase would encourage polarity and vice versa.

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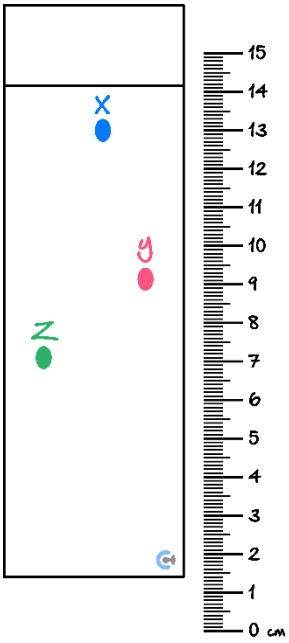
Question 25 (6 marks)

A TLC setup was utilised to examine three compounds, CH_3OH, C_2H_5OH and $C_6H_{12}O_6$. Consider the following results.



a. Rank the compounds in terms of decreasing polarity. (2 marks)

Most Polar: $C_6H_{12}O_6$, C_2H_5OH, CH_3OH :Least Polar

b. Identify what chemical is most likely substance *Y* and explain your answer. (2 marks)

Substance *Y* is most likely C_2H_5OH as it is in the middle in terms of polarity.

c. Which compound travels the fastest through the TLC setup? Explain. (2 marks)

As methanol is the least polar and in normal phase TLC, the mobile phase is non-polar, that means methanol will desorp the strongest into the mobile phase and hence, travel through it the fastest.

Sub-Section: Calculate Retardation Factor (Rf) Values for Components on a TLC Plate

Question 26 (2 marks)

Given the following data, calculate the R_f values of the following substances:

Substance	Distance (cm)
Solvent	10.50
Sample X	4.25
Sample Y	7.10
Sample Z	6.00

$X-\ 0.405, Y-\ 0.676, Z-\ 0.571$

Question 27 (2 marks)

How does the polarity of a substance affect its R_f value if the chromatography setup involved a polar stationary phase? Explain.

If a substance is more polar in this setup, that means it will adsorb more strongly onto the stationary phase and travel less of a distance. Therefore, when we calculate its R_f value it will be smaller.

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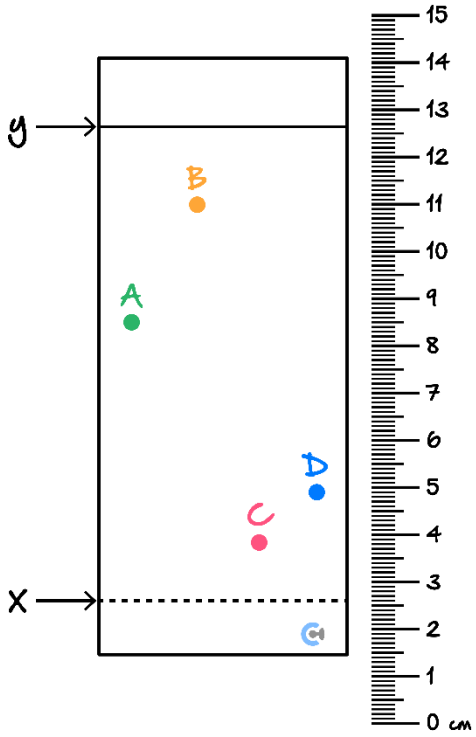
Question 28 (4 marks)

Consider the following reverse phase TLC setup involving a substance with three known components.



a. Calculate the R_f value of component A. (2 marks)

Solvent front – $12.8 - 1.5 = 11.3$

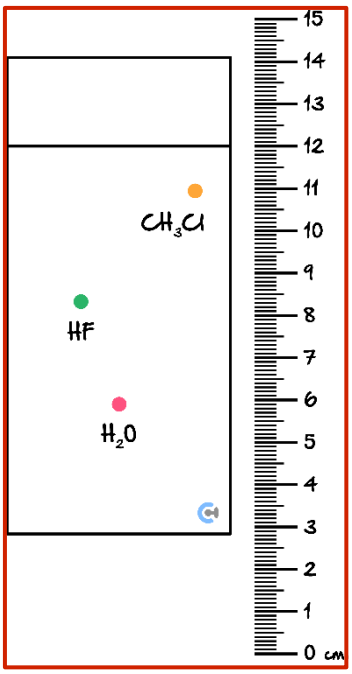
A – $(8.5 - 1.5)/11.3 = 0.619$

b. If the potential components the substance could be made of were either $CH_4, C_2H_6, CH_3Br, CH_3OH$, identify what component A would be and why? (2 marks)

As this is reverse phase, the mobile phase is polar, and therefore, the second most polar component here would be CH_3Br. As component A travels the second furthest, this means CH_3Br would desorp relatively strongly into the mobile phase and hence, travel further.

Question 29 (8 marks)

Consider the following normal phase TLC setup involving a mixture of three substances: HF, H_2O and CH_3Cl. The following results are observed.



a. Label the points on the chromatogram above with their respective compounds. (2 marks)

b. If a compound of HCl was also added into the mixture, where we would observe it on the chromatogram? (2 marks)

Mark it somewhere between HF and CH_3Cl.

c. A student suggested that we can just predict where the spots are on a chromatogram in normal phase TLC just by knowing the molar masses of the compounds involved, saying that the bigger the molecule, the further it will travel along the mobile phase. Evaluate their statement. (4 marks)

This student is incorrect because in some cases a large molecule can also be extremely polar as well, for example $C_6H_{12}O_6$ is a large molecule with high polarity due to the six oxygen groups. Hence, it will not travel far but if we only look at molar mass we would think it travels further just because of its high molar mass.

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