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VCE Chemistry ½
Principles of Chromatography [0.9]
Workshop

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Section A: Recap

Learning Objective: [1.10.1] - Identify which substances would dissolve one another based on miscibility and polarity

- **Polar** objects will attract more to the [polar] / [non-polar] phase as they form [dispersion forces] / [dipole-dipole bonds].
- **Non-polar** objects will attract more to the [polar] / [non-polar] phase as they form [dispersion forces] / [dipole-dipole bonds].

Learning Objective: [1.10.2] - Apply the concepts of adsorption and desorption to stationary and mobile phases

Stationary Phase	Mobile Phase
Component which [stays still] / [moves].	Component which [stays still] / [moves].
Substances [adsorb] / [desorb] to this phase.	Substances [adsorb] / [desorb] to this phase.
More attracted to this phase → substance travels a [shorter] / [longer] distance & has a [quicker] / [slower] rate of travel.	More attracted to this phase → substance travels a [shorter] / [longer] distance & has a [slower] / [quicker] rate of travel.

Learning Objective: [1.10.3] – Apply chromatography principles to Thin Layer Chromatography (TLC)

- Chromatography is used to separate mixtures.
- It does so based on each component's polarity
- TLC stands for thin layer chromatography
- TLC involves a glass plate being covered in a thin layer of silica or alumina
- Silica gel is [polar] / [non-polar].
- Consequently, the solvent used in TLC is typically [polar] / [non-polar].

Learning Objective: [1.10.4] – Calculate Retardation Factor (R_f) values for components on a TLC plate

$$R_f = \frac{\textit{distance travelled by component}}{\textit{distance travelled by solvent}}$$

- Substances which are more strongly **adsorbed** to the stationary phase will have a [higher] / [lower] R_f value.
- Substances which are more strongly **desorbed** to the mobile phase will have a [higher] / [lower] R_f value.
- As the solvent will always travel the longest distance, the R_f value will always be less than one
- The units for a R_f value are N/A, as the R_f value is merely a ratio.

Question 1 Walkthrough.

The red component for a particular chromatogram travelled 1.8 *cm* from the origin, whereas the solvent had travelled 6.5 *cm*. What is the R_f value for the red dye?

R_f (red dye) $= \frac{1.8}{6.5} \rightarrow 0.28$

Space for Personal Notes

Section B: Warm Up (17 Marks)

INSTRUCTION: 17 Marks. 11 Minutes Writing.

Question 2 (4 marks)

For the following substances, state whether they can dissolve in water or in organic non-polar solvent.

a. CCl_4. (1 mark)

np

b. CH_3Cl. (1 mark)

water

c. CO_2. (1 mark)

np & water

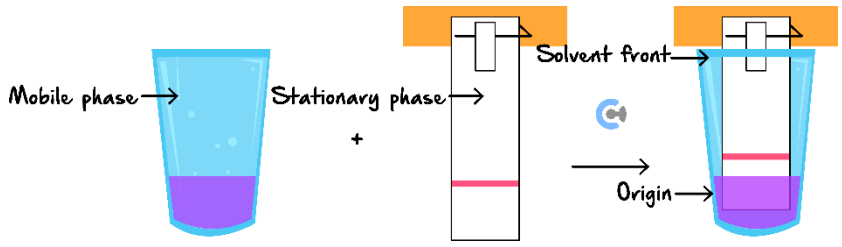
d. $NaNO_3$. (1 mark)

water

Question 3 (2 marks)

Label the following diagram with the following points:

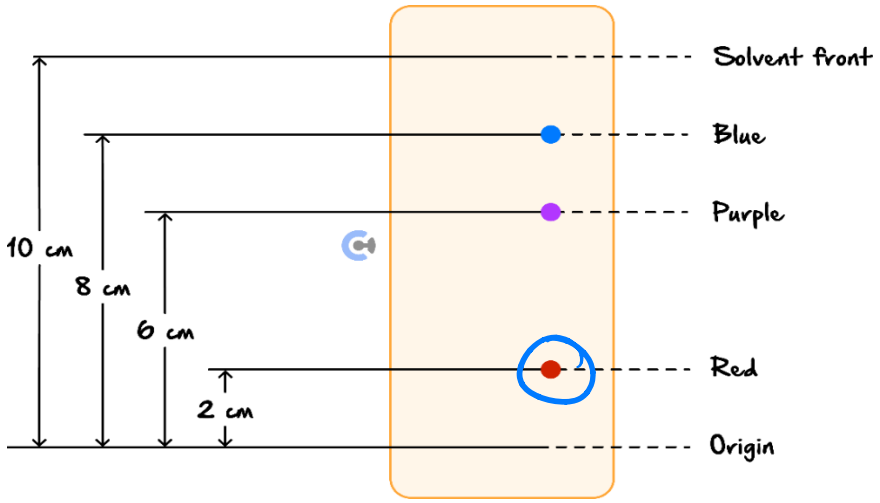
- Stationary phase
- Mobile phase
- Origin
- Solvent front



Question 4 (3 marks)

mp → non-polar

Wanting to separate the individual components of her favourite dye, Kanta places a drop onto a piece of paper and dips the base of this paper into a solution of hexane. The results of her experiment are shown below:



a. Identify the most polar component. (1 mark)

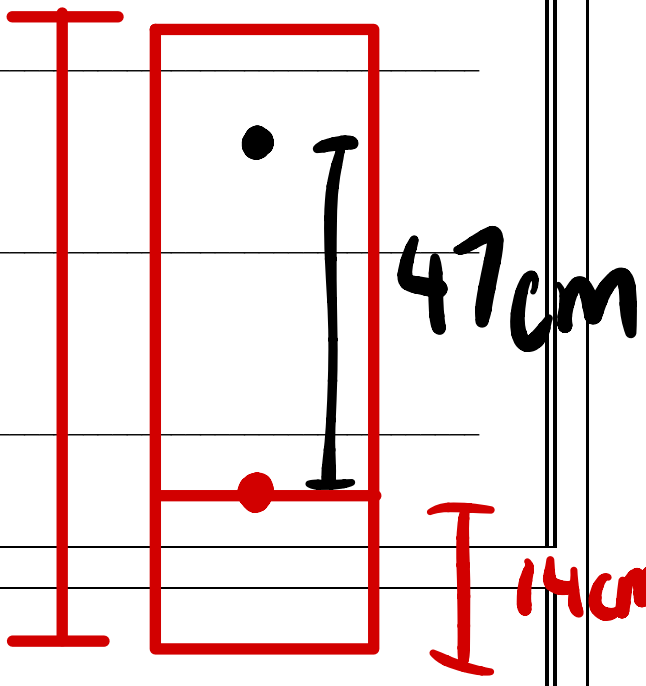
red

b. What would the polarity of the stationary phase be? (1 mark)

polar

c. Calculate the retardation factor of the blue component. (1 mark)

8/10 = 0.8



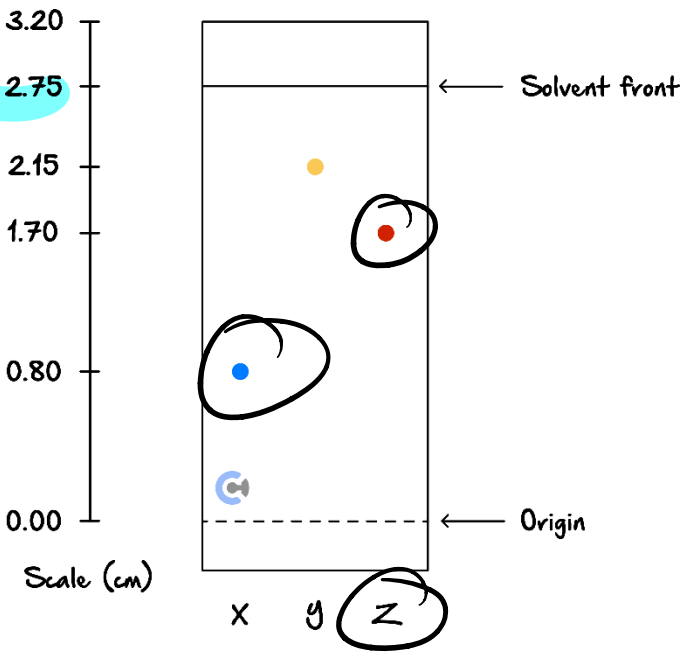
Question 5 (2 marks)

A substance travelling through a TLC setup has a mark indicating the origin at the 14 cm mark and the solvent travelled 94 cm from the edge of the thin layer strip. Given the substance has travelled 47 cm, calculate the R_f value of this component.

$R_f = \frac{47}{80} = 0.5875$

Question 6 (4 marks)

Consider the following TLC plate of compounds X, Y, Z developed using a suitable mobile phase on a polar stationary phase:



a. What is the measure of the solvent front? (1 mark)

2.75cm

b. What is the R_f value for component Z? (1 mark)

1.7 / 2.75 = 0.618

c. Which component is the most polar out of the three? Explain your answer. (2 marks)

- X
- X is most adsorbed onto the SP → ∴ it is also polar

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Section C: Ramping Up (9 Marks)

INSTRUCTION: 9 Marks. 7 Minutes Writing.

Question 7 (9 marks)

Vivian wants to separate a mixture of ethanol (C_2H_5OH) and ~~propanol~~ butanol (C_4H_9OH) using a chromatography setup in her garage. To do this, she prepares a sheet of paper and a solvent.

a. Vivian's friend says that she should use TLC instead of paper chromatography. Explain two reasons why TLC may be better. (2 marks)

- Paper has low accuracy due to a lack of structural consistency
- TLC higher rates of RD & DE & SA:V

b. Would ethanol or ~~propanol~~ butanol be more polar? (1 mark)

ethanol

c. Given that the solvent used is polar, which one of the components would move further up the paper? (1 mark)

ethanol

d. What would happen if a less polar solvent was used? (1 mark)

less separation → weaker attraction to mobile phase

e. Using the words "adsorption" and "desorption" explain how ethanol would move up a paper chromatography setup which utilises a polar mobile phase. (2 marks)

- ethanol readily desorbs to the mobile phase, with limited adsorption to the SP.

f. Vivian's friend also undertakes a chromatography setup to separate ethanol and ~~propan~~butan-1-ol. What are some considerations which Vivian's friend would have to have before comparing their results. (2 marks).

- Gas conditions → temp
- Same mp & bp
- run time

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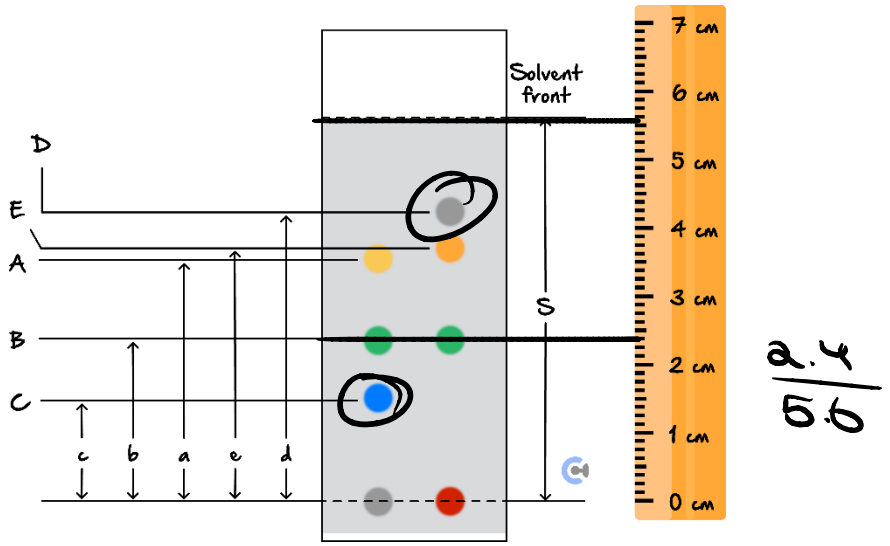
Section D: Getting Trickier I (11 Marks)

INSTRUCTION: 11 Marks. 9 Minutes Writing.

Question 8 (2 marks)

One of the main reasons for undertaking paper chromatography is to undertake qualitative analysis of components in a mixture.

Take the following example of a chromatography setup which revealed the following separation.



a. What is the R_f value of the green component B? (1 mark)

0.43

b. Given that the solvent used is water, rank components A-E in terms of increasing polarity. (1 mark)

C, B, A, E, D

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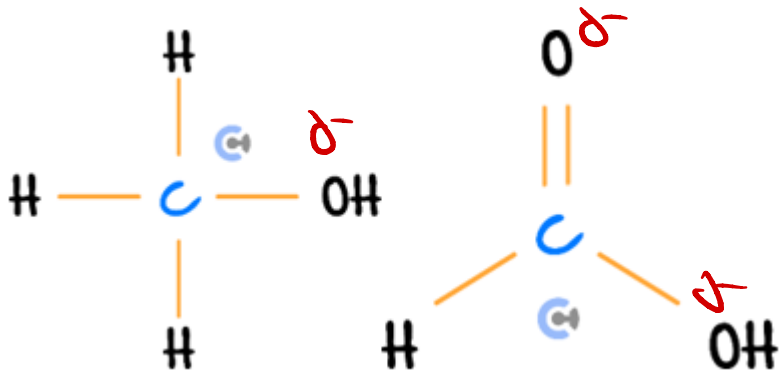
Question 9 (3 marks)

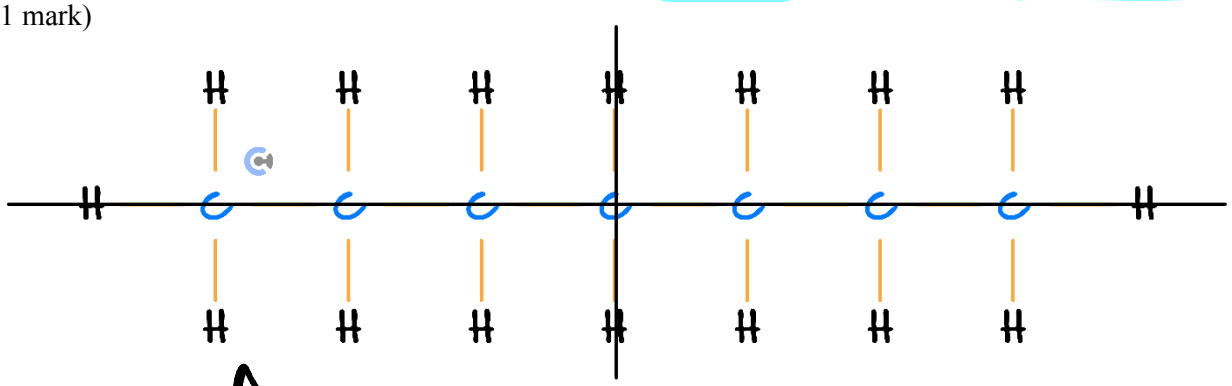
Below are two compounds, *A* (on the left) and *B* (on the right).



a. Which one of these compounds would be expected to be more polar? (1 mark)

B

b. Thus, which of these would have a greater attraction to a mobile phase comprised of the following chemical? (1 mark)



A

c. What is one way in which the rate of separation could be accelerated in a paper chromatograph setup? (1 mark)

use more polar (non-polar phase

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Question 10 (6 marks)

Emily wishes to setup a TLC in order to see what components she may have inside of an oil mixture that she has at home.

a. Given that the stationary phase is non-polar, give an example of an appropriate solvent that can be used as the mobile phase. (1 mark)

POLAR

H_2O

b. After 10 minutes, the oil in the mixture separates into three components across the glass sheet. Explain what can be said about the "highest" component and why with reference to the principles of chromatography. (3 marks)

- Polar
- It is most dissolved in the mobile phase
- Since the mobile is polar ∴ highest compound also has to be polar.

c. Emily believes that if a component moves up very high, it undergoes only desorption, whereas if a component does not move, it undergoes only adsorption. Explain whether or not Emily is correct. (2 marks)

- No!
- Adsorption & desorption happen in a cycle

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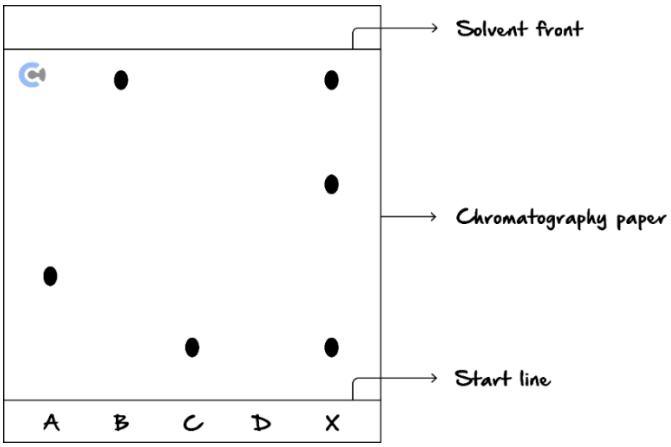
Section E: Getting Trickier II (9 Marks)

INSTRUCTION: 9 Marks. 8 Minutes Writing.

Question 11 (4 marks)

Take the following chromatography setup in which four reference chemicals (A, B, C, D) and an unknown mixture (X) have been placed in a solution of water.



a. What can be said about chemical A? (1 mark)

Chemical A is not present in the unknown mixture X.

b. What can be said about chemical B or C? (1 mark)

Chemical B and C are present in the unknown mixture X.

c. Adam believes that the mixture X only has 3 components inside of it, where as his Peter believes that there is at least three. Explain who is correct and how we could find out. (2 marks).

It contains at least three. There could be another component that still hasn't separated, and thus, one of the black dots could contain more components. We can find out by simply running the experiment for longer, using different MP/SP.

Question 12 (5 marks)

Revising for his upcoming test on Chromatography, Harry is confused on several principles regarding the topic and wishes to brush up on his knowledge. Harry remembers a term called "retardation factor" and wonders how the distance a component travel will affect it.

a. Explain the trends in how retardation factor changes, and the distance of the component changes. (1 mark)

If a component travels longer, the retardation factor gets bigger, and if a component travels less, the retardation factor gets smaller.

b. What is the solvent front? (1 mark)

The maximal distance traveled by the mobile phase on the stationary phase.

c. Given that a component has a retardation factor of 0.8 but has only travelled a distance of 6 cm, how far has the solvent front moved? (1 mark)

7.5

d. Can the retardation factor for the same component ever be different? Explain why with reference to rates of adsorption and desorption. (2 marks)

Yes. It depends on the type of stationary phase or mobile phase which is being used. This is because if a different stationary phase or mobile phase is being used (or even different conditions) components have a different level of adsorption/desorption.

Let's take a BREAK!

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Section F: VCAA-Level Questions I (13 Marks)

INSTRUCTION: 13 Marks. 30 Seconds Reading. 12 Minutes Writing.

Question 13 (7 marks)

The following information about a few components of a molecule is known.

Component	R_f
A	0.673
B	0.280
C	0.483

The following chromatogram was produced when a sample was tested for its composition:

a. The stationary phase used was a non-polar solvent. Explain what the component with the highest R_f value means. (2 marks)

- component A → travelled furthest
- mobile phase is polar → A is dissolved to MP ∴ its also polar.

b. If the solvent front was measured to be 1.90 *cm*, calculate the distance each component travelled in the chromatogram. (2 marks)

$\frac{A}{1.9} = 0.673$ ∴ A = 1.28

B = 0.532

C = 0.917

c. If this molecule was again analysed using TLC, but this time, a different stationary phase and polar phase was used. The following R_f values were obtained.

Component	R_f
A	0.173
B	0.782
C	0.347

i. Is there any reasonable assumption that you can make with what changes were made to the TLC setup? (2 marks)

Rf values were switched → previously A was attracted to me, now it's attracted to SP ∴ polarities of phase have swapped

ii. In an experiment, would the units you use to measure the R_f values matter? (1 mark)

No → ratio

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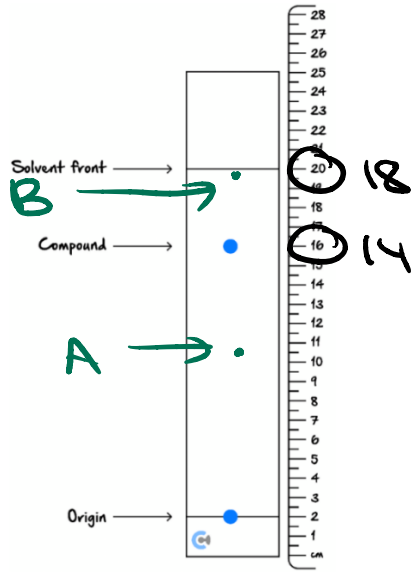
Question 14 (6 marks)

The following chromatogram was obtained for a certain compound.



a. Calculate the R_f value for the compound. (2 marks)

14/18 = 0.78

b. If the solvent used in this TLC setup was H_2O, then what can you conclude about the relative polarity of the compound? Justify your answer. (2 marks)

- compound is attracted to mp
- mp here is pola (H2O)

∴ compound has a high polarity.

c. Consider that subsequent compounds were analysed under the same conditions. Mark on the chromatogram where these components should be located.

i. Compound *A* has an R_f value of 0.35. (1 mark)

A/18 = 0.35 → 6.3

ii. Compound *B* has an R_f value of 0.89. (1 mark)

B/18 = 0.89 ∴ B = 16

Section G: VCAA-Level Questions II (14 Marks)

INSTRUCTION: 14 Marks. 30 Seconds Reading. 13 Minutes Writing.

Question 15 (7 marks)

Consider the following table generated from a column chromatography experiment. Silica gel was used as the stationary phase.

Component	~~Retention Time (seconds)~~
X	~~143~~ 0.4
Y	~~164~~ 0.3
Z	~~129~~ 0.5
W	~~178~~ 0.2

a. Identify and explain which component is the most polar. (2 marks)

- W
- W has the lowest Rf → most adsorbed to the polar stationary phase.

b. Rank the components in increasing polarity. (2 marks)

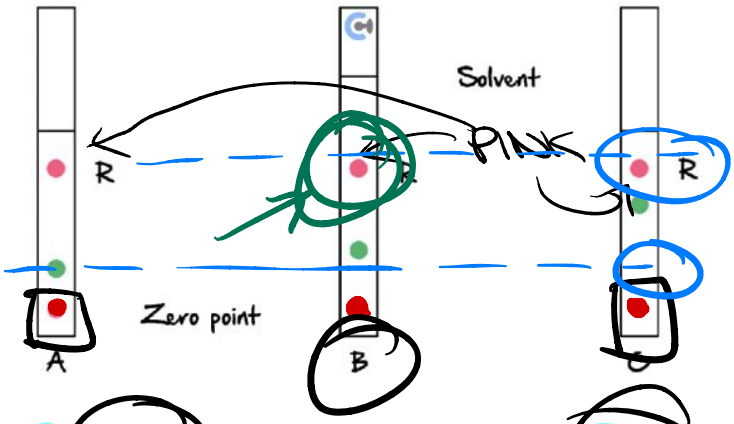
Z, X, Y, W

c. Compare the movement of component *X* and component *Z* through the column, with reference to the phases of chromatography. (3 marks)

- X & Z both undergo adsorption & desorption
- Z however, undergoes a higher rate of desorption
- X undergoes higher rates of adsorption

Question 16 (7 marks)

Paper chromatography was used to investigate certain red dyes used in candies. Three separate chromatograms are shown below.



The solvent for samples *A* and *C* is water, whilst the solvent for sample *B* is hexane. Each red dye produces a pink spot that has been marked with an *R*.

a. Is the red dye used in the sample *C* likely to be the same as that from the sample *A*? Justify your answer. (2 marks)

- NO
- Green components have different Rf ∴ different chemicals.

b. Is the red dye used in the sample *A* likely to be the same as that from the sample *B*? Explain your answer. (3 marks)

- NO
- Solvent front is at different points
- A & B use different solvents

c. In sample *B*, which component out of the ones present is likely to be the least polar? Explain your answer. (2 marks)

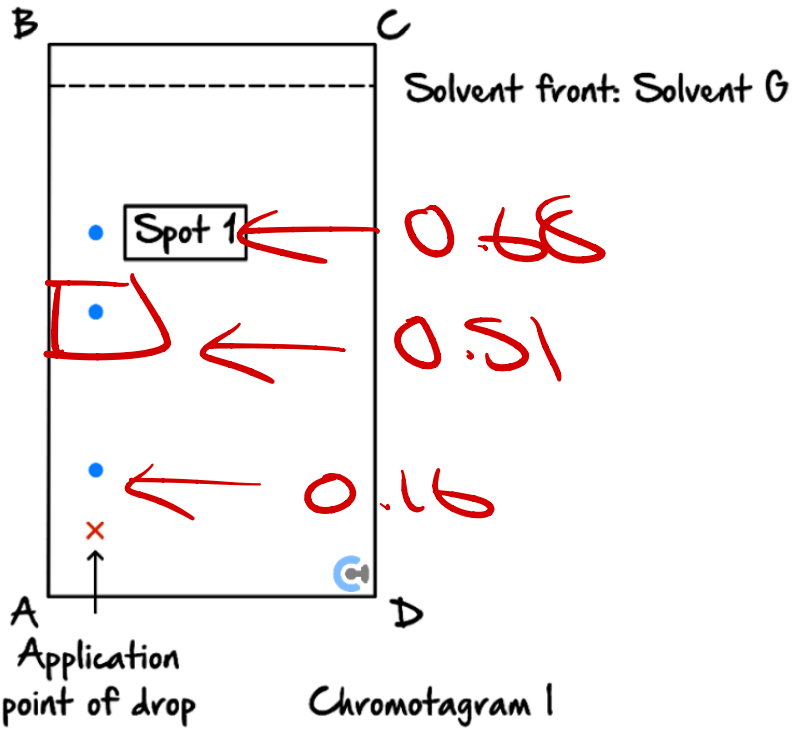
- Pink
- Travelled furthest → most dissolved ∴ most nonpolar.
  - to the nonpolar MP

Section H: VCAA-Level Questions III (4 Marks)

INSTRUCTION: 4 Marks. 30 Seconds Reading. 4 Minutes Writing.

Question 17 (4 marks)

A drop that contains a mixture of four amino acids was applied to a thin-layer chromatography plate. The plate was placed in a solvent *G* and the following chromatogram was obtained.



The R_f values for each of the amino acids in the solvent *G* are provided in Table 1 below.

Table 1. R_f values in solvent *G*

Amino acid	R_f (solvent *G*)
Alanine	0.51
Arginine	0.16
Threonine	0.51
Tyrosine	0.68

a. Name the amino acid that corresponds to the spot 1. (1 mark)

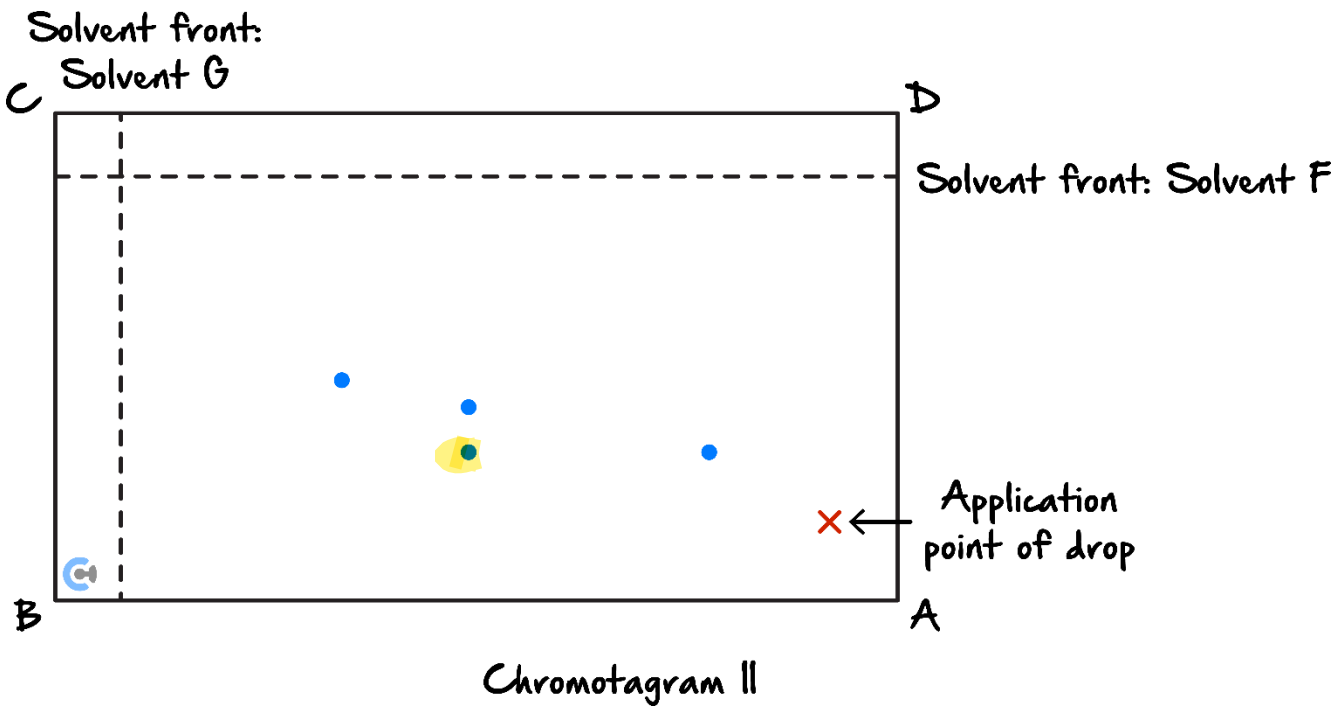
Tyrosine → highest Rf → furthest distance.

The plate was dried, rotated through 90° in an anticlockwise direction and then placed in solvent *F*. The R_f values for each of the amino acids in the solvent *F* are provided in Table 2 below.

Table 2. R_f values in solvent *F*

Amino acid	R_f (solvent *F*)
Alanine	0.21
Arginine	0.21
Threonine	0.34
Tyrosine	0.43

The following chromatogram was obtained:



Chromotagram II

b. Circle the spot on the chromatogram II that represents alanine. (1 mark)

c. Explain, in terms of the data provided, why only three spots are present in the chromatogram I while four spots are present in the chromatogram II. (2 marks)

- Chromatogram 1 → solvent didn't have a strong polarity ∴ meaning it couldn't separate which had similar polarities they didn't separate.
- Chromatogram 2 → strong solvent ∴ more separation to occur.

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