

Victorian Certificate of Education

CHEMISTRY 2026 Unit 1

SAC 1 AOS 1 Outcome 1

Reading time: 5 minutes

Writing time: 60 minutes

Directions to students

Student's Name: _____

Teacher: _____

Structure of booklet

Section	Question to be answered	Total marks
Multiple choice	20	20
Short answer	4	44
	Total	64

Materials

- Students are permitted to bring into the examination room: pencils, highlighters, erasers, sharpeners, rulers, and an approved scientific calculator.
- Students are NOT permitted to bring into the examination room: white out liquid/tape, phones or electronic devices, including smart watches.
- Students are provided with the following: Question and answer book of 17 pages and VCAA Data booklet.

The task

- Please ensure that you write your name and teacher's name on this booklet. This paper consists of short answer questions and 20 multiple choice questions.
- There are a total of 64 marks available.
- Be sure to include states with all chemical equations.
- All numerical answers need to be quoted to the correct number of significant figures.
- All working out must be shown in the space provided.

1. Which element has the highest first ionization energy?

- a) Sulfur
- b) Phosphorus
- c) Chlorine
- d) Argon

First ionization energy increases across a period (left → right) due to increasing nuclear charge, and decreases down a group as the distance between the valence electrons and nucleus increases. Among sulfur, phosphorus, chlorine, and argon (all in Period 3), argon is a noble gas with a full valence shell, making it the hardest to remove an electron from.

2. Which species has the largest atomic radius?

- a) Na
- b) Na⁺
- c) Cl
- d) Cl⁻

Cations (Na⁺) are smaller than their neutral atoms. Anions (Cl⁻) are larger than their neutral atoms. Atomic radius decreases across a period. Na⁺ is very small (lost an electron). Na > Cl (neutral comparison across period). Cl⁻ is largest because it has extra electron repulsion

3. Which species has the smallest electronegativity difference with hydrogen?

- a) Fluorine
- b) Chlorine
- c) Oxygen
- d) Nitrogen

Using the periodic table given in the data book students should be able to arrive at the answer that N has the smallest difference in electronegativity when compared with hydrogen. Electronegativity of each element is given in the periodic table.

4. Which option below has the elements in order of increasing reactivity from left to right, where left is the lowest and right has the highest reactivity.

- a) Be, Mg, Sr, Ra
- b) Cs, Rb, Na, Li
- c) Ra, Ba, Ca, Be
- d) K, Ca, Mg, Be

*Reactivity for group 1 and group 2 metals increases down the group because valence electrons are further from the nucleus, therefore, easier to lose electrons (lower ionization energy)
Correct increasing order: Be < Mg < Sr < Ra*

5. Consider the subshell electronic configurations of the neutral elements shown below?

- i. $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5, 4s^1$
- ii. $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^1$
- iii. $1s^2, 2s^2, 2p^6, 3s^1, 3p^2$
- iv. $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6, 4s^2$
- v. $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6, 4s^1, 4p^1$

Which of the above are in an excited state not at ground state?

- a) i, ii and iv only
- b) i, ii, iii, iv and v
- c) i, ii and v only
- d) v and iii only

*$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5, 4s^1$ This is chromium (Cr) known exception where half full subshells are more stable than partly filled. Same goes for copper where $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^1$. A full d subshell and half filled 4s is more stable. Both Cu and Cr are at ground state. $1s^2, 2s^2, 2p^6, 3s^1 3p^2$ should be $3s^2 3p^1$ (Aluminium ground state) so this is excited state.
iv. is at ground state
v. with $4s^1 4p^1$ should be $4s^2$ so this is in an excited state*

6. Below are the electronic configurations of 4 ions.

- i. $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$
- ii. $1s^2, 2s^2, 2p^6$
- iii. $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$
- iv. $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^9$

Which option below best relates the ion to the electronic configuration.

- a) i belongs to Ar^{2+}
- b) ii. belongs to Al^{2+}
- c) iii. belongs to Mg^+
- d) iv. belongs to Cu^{2+}

$1s^2 2s^2 2p^6 3s^2 3p^6$ total number of electrons = 18. This is the same as argon (Ar), Ar^{2+} would have 16 electrons, not 18
ii. $1s^2 2s^2 2p^6$ total electrons = 10. This is not Al^{2+} 11 electrons, not 10.
iii. $1s^2 2s^2 2p^6 3s^2 3p^6$. Again 18 electrons, where as Mg^+ has 11 electrons, not 18
iv. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$. Total number of electrons = 27 Cu^{2+} has = 27 electrons. This is correct

The information below relates to questions 7 - 9
Consider the four molecular substances listed below.



7. Which compound has the lowest boiling temperature

- a) CH_3NH_2
- b) CO_2
- c) NH_3
- d) HCl

Compare intermolecular forces
 CH_3NH_2 → hydrogen bonding + dispersion
 NH_3 → hydrogen bonding + dispersion
 HCl → dipole-dipole + dispersion
 CO_2 → London dispersion only (nonpolar)
Weakest forces = lowest boiling point as it takes less energy to overcome these forces. So CO_2 is the answer

8. Which are symmetrical molecules?

- a) CH_3NH_2 and NH_3 only
- b) CO_2 only
- c) NH_3 and CO_2 only
- d) HCl and CO_2 only

9. Liquid propane ($CH_3CH_2CH_3$) can dissolve fully in:

- a) $CH_3NH_2(l)$
- b) $CO_2(l)$
- c) $NH_3(l)$
- d) $HCl(l)$

Solutes dissolve in solvents that have similar intermolecular forces. Propane is a hydrocarbon (non-polar) and has dispersion forces only as the intermolecular force. CO_2 also is non-polar and hence dispersion forces only hence a likely match and the two substances can interact with each other via dispersion forces.

13. The following unknown element has three isotopes. The isotopic mass and the percentage abundance are given below.

Isotope	Isotopic mass (amu)	Percentage abundance
X	45	20
Z	47	65
Y	53	15

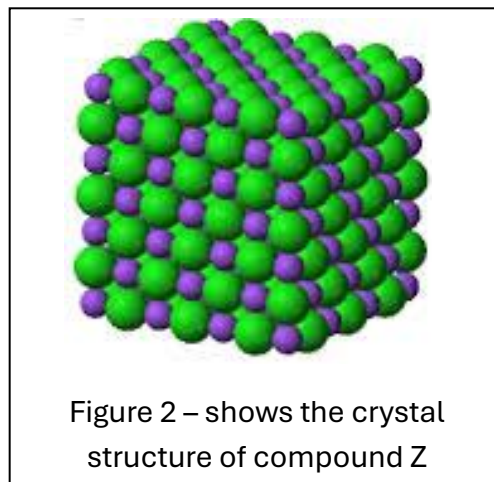
The average atomic mass is

- a) 49.6 amu
- b) 51.5 amu
- c) 47.5 amu
- a) 52.3 amu

$$\text{Average atomic mass} = ((45 \times 20) + (47 \times 65) + (53 \times 15)) / 100 = 47.5$$

14. Consider the crystal structure of compound Z as shown in fig. 2 on the right.

Which one of the following statements is true regarding the compound.



- a) It will conduct electricity, in the solid state only, as it is composed of ions.
- b) It will have a low melting point as ions will move such that similar charged ions will repel each other.
- c) It will be malleable in the solid state and able to be hammered into different shapes.
- d) Compound Z exists as a liquid only at relatively high temperatures due to strong electrostatic forces of attraction that exist between particles in the lattice.

Compound Z is an ionic substance. As such it is brittle due to directional forces and conducts electricity only in the liquid and aqueous states. Ionic substances generally have relatively high melting points due to the strong electrostatic forces of attraction within the ionic lattice.

The information below is relevant to questions 15-16

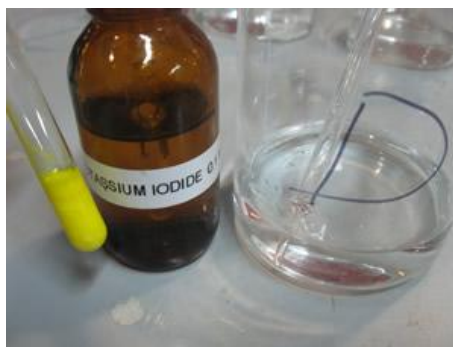


Figure 3 – A yellow precipitates is formed between potassium iodide and a clear solution.

15. Which of the following contaminants is most likely present in the clear solution?

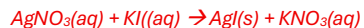
- a) Ammonium nitrate
- b) Sodium phosphate
- c) Potassium nitrate
- d) Lead(II) nitrate

Lead nitrate is the only reactant that can produce a precipitate. All other options produce compounds that are soluble eg have ammonium, sodium, nitrate or potassium in the name which makes them soluble.

16. A student suggested that silver nitrate may be present in the clear solution. Which option represents the reaction taking place if silver nitrate was present?

- a) $\text{Ag}(\text{NO}_3)(\text{aq}) + \text{KI}(\text{s}) \rightarrow \text{AgI}(\text{aq}) + \text{KNO}_3(\text{aq})$
- b) $\text{AgNO}_3(\text{aq}) + \text{KI}(\text{s}) \rightarrow \text{AgI}(\text{aq}) + \text{KNO}_3(\text{aq})$
- c) $\text{AgNO}_3(\text{aq}) + \text{KI}(\text{aq}) \rightarrow \text{AgI}(\text{s}) + \text{KNO}_3(\text{aq})$
- d) $\text{AgNO}_3(\text{aq}) + \text{KI}(\text{s}) \rightarrow \text{AgI}(\text{s}) + \text{KNO}_3(\text{aq})$

Reactants must be aqueous and AgI needs to be a solid.



Data booklet should be used to see if a compound is soluble or insoluble. AgI is insoluble.

17. Magnesium nitrate solution is mixed with a solution of sodium phosphate. Which option below represents the net ionic equation for this reaction?

- a) $3\text{Mg}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Mg}_3(\text{PO}_4)_2(\text{s})$
- b) $\text{Mg}^{2+}(\text{aq}) + \text{PO}_4^{2-}(\text{aq}) \rightarrow \text{MgPO}_4(\text{s})$
- c) $2\text{Mg}^{2+}(\text{aq}) + \text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Mg}_2\text{PO}_4(\text{s})$
- d) $3\text{Mg}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{s}) \rightarrow \text{Mg}_3(\text{PO}_4)_2(\text{s})$

Equation should only show the ions along with their state that take part in the reactions and their charge. It should be balanced for ions and charge. Data booklet should be used to see if a compound is soluble or insoluble.

18. Consider the density toy shown on the right in fig. 4. Which two liquids can be used for this toy to work as it does?

- a) C_6H_{14} and H_2O
- b) C_9H_{20} and C_8H_{18}
- c) NH_3 and H_2O
- d) HCl and H_2O

Substances with similar intermolecular forces will interact with each other and mix. Option B has both substances with dispersion forces only as the intermolecular force present. Option C both have H-bonding as the dominant force, whilst options d both are polar molecules with similar dipole-dipole interactions (HCl) and H-bonding(H_2O) that can interact with each other. Option a is the only one that will not mix as their intermolecular forces are totally different in strength. C_6H_{14} has dispersion forces only whilst H_2O has H-bonding as the dominant force.



Figure 4 – A density toy

19. Consider the table of reactive metals shown in fig. 5. Which one of the following options is a practical metal to use as a sacrificial anode to protect an iron nail from rusting when placed in water?

- a) Zn
- b) Fe
- c) Tin
- d) Na

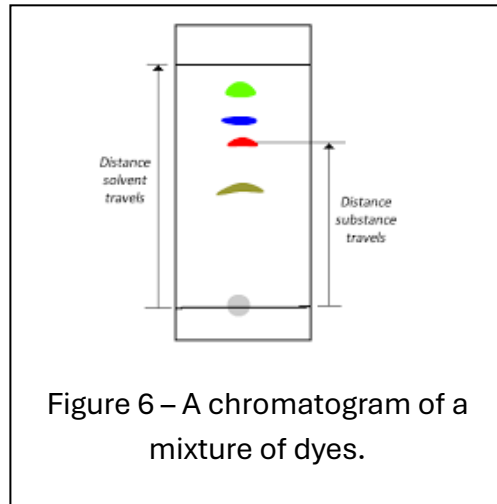
A more reactive metal than Fe can be used. The word "practical" in the stem of the question negates the use of Na. As this metal is highly reactive with water and produces H_2 gas.

	Very Reactive	Li	Lithium
	K	Potassium	
	Ba	Barium	
	Ca	Calcium	
	Na	Sodium	
	Mg	Magnesium	
	Al	Aluminum	
	C	Carbon	
	Zn	Zinc	
	Fe	Iron	
	Ni	Nickel	
	Sn	Tin	
	Pb	Lead	
	H	Hydrogen	
	Cu	Copper	
	Hg	Mercury	
Very Unreactive	Ag	Silver	
Au	Gold		
Pt	Platinum		

Figure 5 – Table of reactive metals.

20. Consider the chromatogram shown in fig. 6 of a mixture of dyes. The chromatogram was developed using water as a solvent. What does the chromatogram reveal about the molecules of each dye?

- a) The molecules of the blue dye do not dissolve in water
- b) The red dye has the most polar molecules
- c) The red dye has the most non-polar molecules
- d) The green dye has the most polar molecule



The dye that is most soluble in the solvent (H₂O) will move up the paper the greatest distance. Having similar intermolecular forces means it can interact with the solvent mobile phase (H₂O) and be carried along with the solvent up the paper. Dyes that do not have similar intermolecular forces with the mobile phase will spend less time in the solvent and more time adsorbing (sticking) to the stationary phase, which is the paper.

Section B

1. Consider the four molecules SO_3 , NH_3 , CH_4 and C_2H_6 .
- a. Place the molecules in order of increasing boiling temperature (BP) and give an explanation as to why SO_3 is placed at the top of the list with the highest BP.
- Low _____, _____, _____, _____ SO_3 _____ High

1-----mark for correct order (CH_4 , C_2H_6 , NH_3 , SO_3)

1-----mark for correctly stating the different intermolecular forces at play.

1-----mark for correctly stating the difference in size of non-polar molecules which lead to greater strength dispersion forces to differentiate between CH_4 and C_2H_6 .

- b. Complete the table below by circling the correct response

5 marks

	SO_3	CH_4	NH_3	O_2
Intermolecular forces	<u>Dispersion forces</u>	<u>Dispersion forces</u>	<u>Dispersion forces</u>	<u>Dispersion forces</u>
	Dipole-dipole interactions	Dipole-dipole interactions	Dipole-dipole interactions	Dipole-dipole interactions
	Hydrogen bonding	Hydrogen bonding	<u>Hydrogen bonding</u>	Hydrogen bonding
Intramolecular bonding	<u>Polar covalent</u>	<u>Polar covalent</u>	<u>Polar covalent</u>	Polar covalent
	Non-polar covalent	Non-polar covalent	Non-polar covalent	<u>Non-polar covalent</u>
	Ionic	Ionic	Ionic	Ionic

- c. Using the molecules HCl and Cl_2 , explain how polar and non-polar covalent bonds form, and include diagrams of each molecule.

1-----mark for mentioning non-metal atoms with different electronegativities form polar covalent bonds unequally.

1-----mark for drawing each of the two molecules correctly

1-----mark with HCl having the correct permanent dipoles on each atom and Cl_2 not showing any permanent dipoles.

- d. In the box below clearly draw a labelled diagram of the structure of a Cu metal lattice and use the diagram to explain three properties of metals, malleability, high melting temperatures and heat conductivity.

1-----mark for drawing a lattice composed of cations (Cu^{2+}), clearly shown, in a sea of delocalized electrons. Delocalised electrons clearly labelled.

1-----mark for correctly identifying non-directional force of attraction between cations and sea of delocalized electrons as a strong force that enables metals to be hammered into different shapes and have high melting temperatures.

1-----mark for correctly stating the delocalized electrons as a vehicle for transferring heat across the metal.

- e. Aluminium oxide melts at $2072\text{ }^{\circ}\text{C}$ whilst NaCl melts at $801\text{ }^{\circ}\text{C}$. Explain the difference in melting temperatures between the two compounds.

1-----mark for correctly assigning charges to the ions of each compound.

1-----mark for correctly stating the higher charge leads to greater electrostatic force of attraction between the cations and anions.

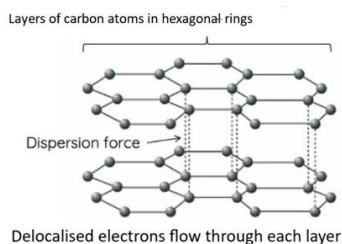
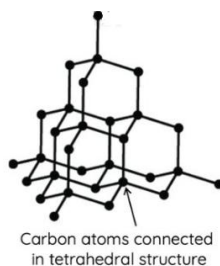
- f. CO_2 is a small molecule that turns from a solid to a gas (sublimes) at around $-75\text{ }^{\circ}\text{C}$, whilst SiO_2 melts at $1713\text{ }^{\circ}\text{C}$. Explain why?

1-----mark for stating that CO_2 is molecular substance held together, in the solid state, by dispersion forces only.

1----- mark SiO_2 is a 3D covalent lattice which has strong covalent bonds holding the atoms in the lattice. Mark also awarded if diagram was used to explain rather than written response.

1-----mark - far more energy is required to break the covalent bonds in SiO_2 , giving it a much higher melting point than the dispersion forces between CO_2 molecules.

- g. Graphite and diamond are made of carbon atoms covalently bonded to each other. Both substances occur naturally. Diamond is extremely strong, used to drill through hard rock whilst graphite is a lubricant for heavy machinery and unlike diamond conducts electricity in the solid state. Explain the difference in properties. Use a diagram in the box provided to assist your explanation.



1-----mark for correct shape of diamond eg. Tetrahedral arrangement around each carbon and correctly identifying non-polar covalent bonds.

1-----mark correctly drawing a hexagonal layered structure for graphite clearly labelling dispersion forces between layers and delocalized electrons within layers.


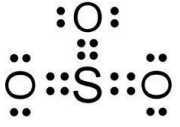
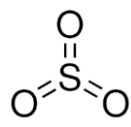
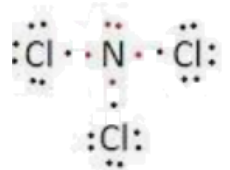
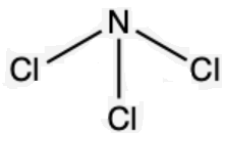

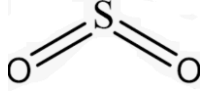
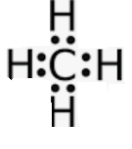
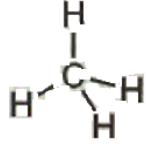
1-----mark for correctly attributing properties at least one, to diamond based on its structure. For example, very high melting point (under high pressures), does not conduct, this is due to strong covalent bonds in 3D and no delocalized electrons present. No need to mention high pressure for MP to get the mark.

1-----mark for correctly attributing at least one property of graphite with an explanation. For example lubricant due to sliding layers due to dispersion forces and conducts electricity in the solid state due to delocalized electrons.

2. In the table below, correctly fill the remaining cells.

6 marks

½----- mark for each correct answer

Formula	Lewis dot diagram	Structural formula	Shape	Symmetry
Cl ₂		$Cl - Cl$	<i>Linear</i>	Symmetrical Asymmetrical
SO ₃			<i>Trigonal planar</i>	Symmetrical Asymmetrical
NCl ₃			<i>Triangular pyramid</i>	Symmetrical Asymmetrical
SO ₂			<i>V-shape</i>	Symmetrical Asymmetrical
CH ₄			<i>Tetrahedral</i>	Symmetrical Asymmetrical

3. Two solutions are mixed as per fig. 8. A red precipitate is formed.

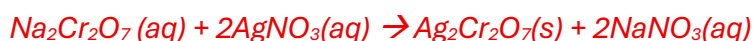
a. Name the precipitate that is shown in fig.8.

Silver dichromate 1 mark

b. Give the chemical formula of the precipitate.

Ag₂Cr₂O₇ 1 mark

c. Give the overall chemical equation for this reaction. States included



1-----mark correct formulae

1-----mark correct states

1-----mark balanced for elements

d. Give the net ionic equation for the reaction taking place.



1-----mark for correct ions with states

1-----mark balanced for charge

e. In another experiment, two solutions, potassium phosphate and aluminium nitrate are mixed.

i. With reference to your 2026 data booklet suggest why a precipitate is likely to form.

1-----mark aluminium phosphate is insoluble

ii. Give the name and formula of the precipitate



Figure 8 – The precipitate formed when silver nitrate is mixed with sodium dichromate

Name _____ *aluminium phosphate* _____ 1 mark

Formula _____ $Al_2(PO_4)_3$

1-----mark for correct ions

1-----mark for correct use of brackets

iii. Identify the spectator ions

Potassium (K^+) nitrate (NO_3^-)

1-----mark given for either name or formula with correct charge

4. Consider the results of a metal displacement experiment conducted in class, shown in

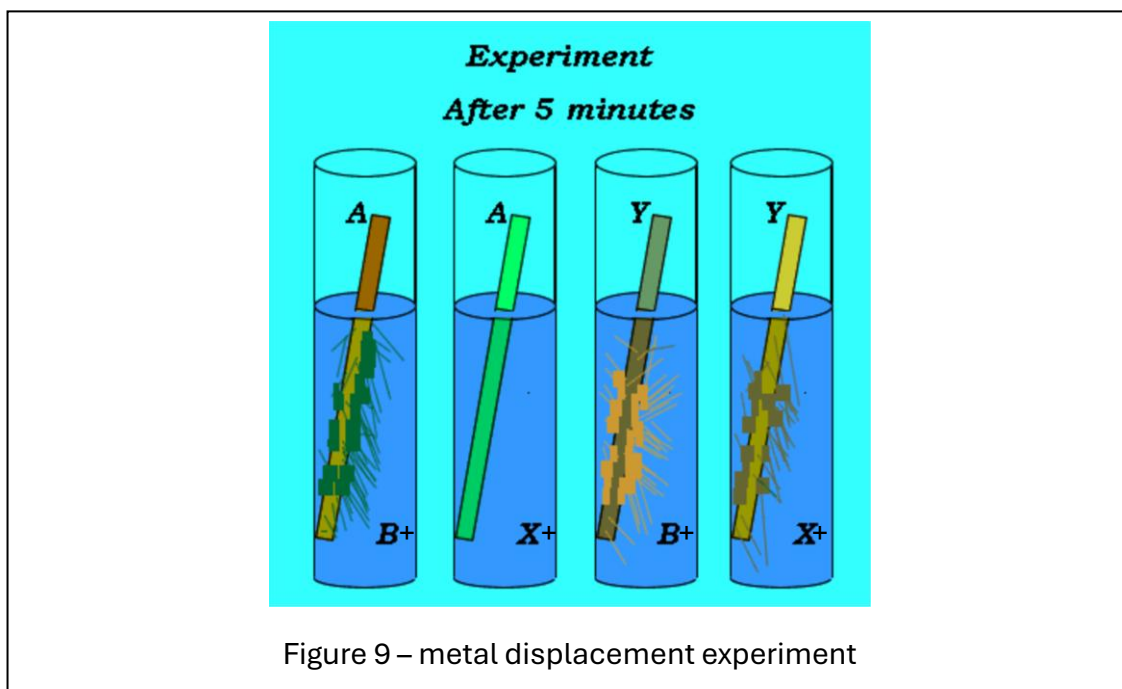


fig. 9. It involves metals A, X, B and Y.

a. Place the metals in order of increasing reactivity.

1 mark

Low _____ *B* _____, _____ *A* _____, _____ *X* _____, _____ *Y* _____, High

b. A bridge is made of metal X. The bolts holding the beams together are made of metal X. Overtime the bridge is in need of repair. Explain how the bolts will be impacted and give an explanation based on the experimental results shown in fig. 9.

1-----mark suggesting that both bridge and bolts are made from the same metal therefore no reactivity difference.

1-----mark for stating no change or both metal forming the bridge and bolts will rust at the same rate.

1-----no electrons will be exchanged between the bolts and the metal forming the bridge.

5. Consider the two chromatograms shown below in fig. 10. Water was used as the mobile phase. Chromatogram A and B were made from two different brands of black texta.

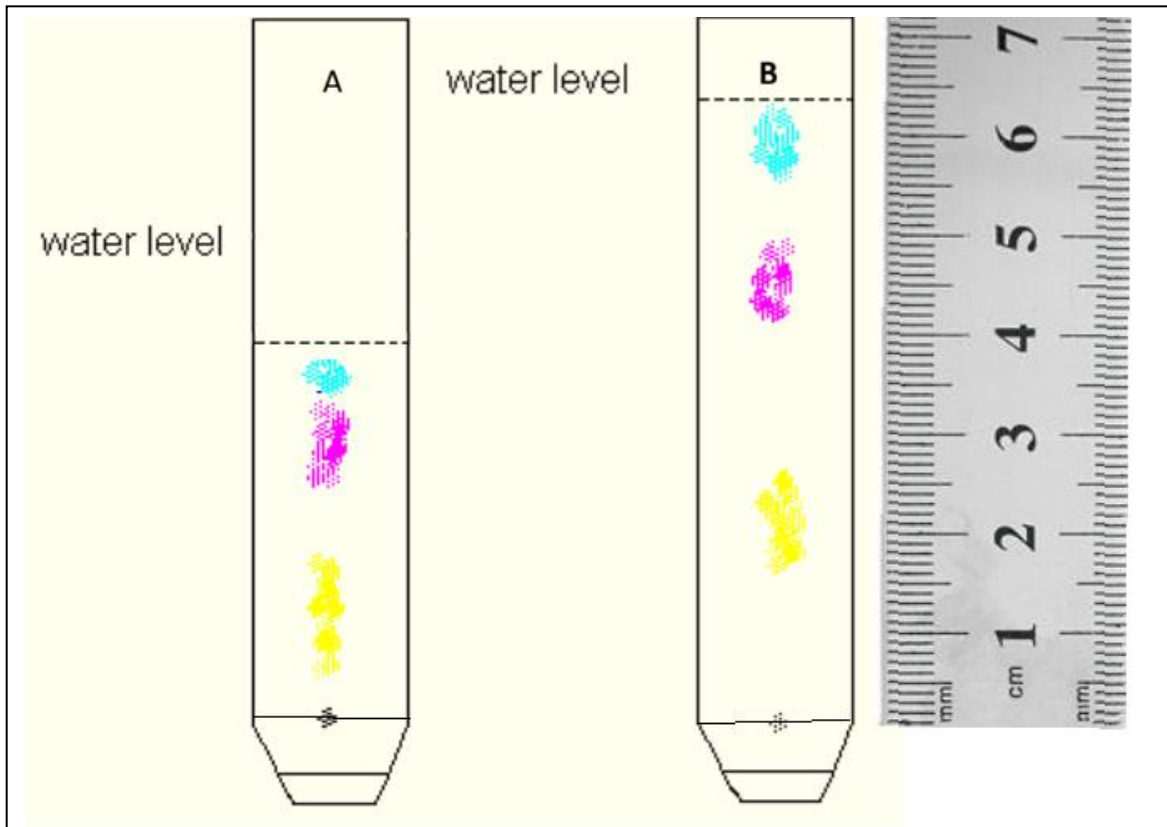


Figure 10 – chromatograms of two different brands of black texta, produced under identical conditions

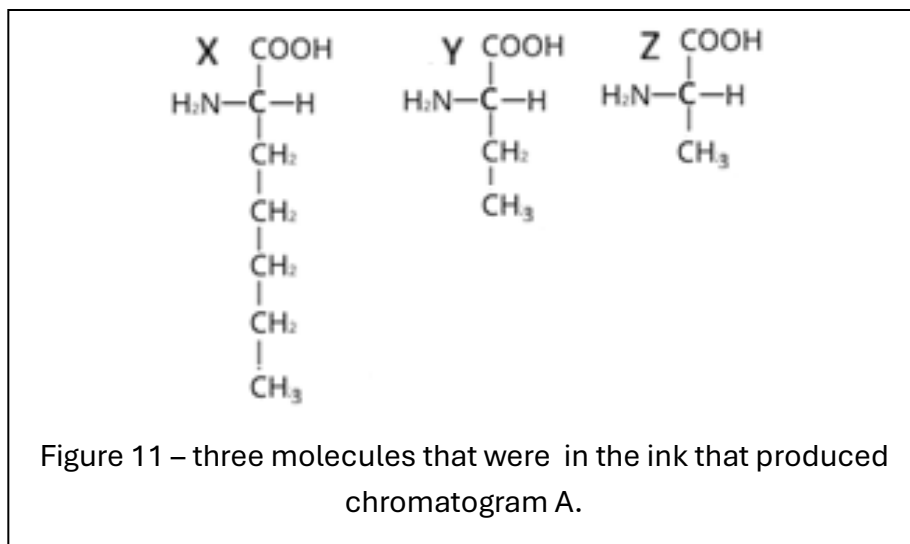
- a) Which colour, if any, appears to be used in both brands of texta. Justify your answer.

1-----mark for selecting a colour with an R_f

1-----mark for a calculation of R_f

1-----mark for equating the same colour with the same R_f value at each chromatogram

b)



Associate each molecule in fig. 11 to a colour and justify your answer.

1-----mark for relating polarity with solubility in water (more soluble the greater the polarity of the molecule, longer the carbon chain the lower the solubility in water)

1-----mark for linking the length of the carbon chain with the solubility in water.

1-----mark for correct association of colour . blue = z red = y, yellow = X.

End of assessment.