Chemistry Department

Christ Church Grammar School

Year 12

2022

Reaction of Alcohols

Investigation

Time allowed: 45 minutes

Instructions

Please ensure you enter your name and circle your teacher's initials below. Scientific calculators only.

Chemistry Data Sheet will be provided

Name: **SOLUTIONS**

_____

Teacher: (circle)

MXC NMO BLR

Mark:_____ **/ 40**

Question 1 - Planning **(5 marks)**

For the oxidation of alcohols with acidified potassium dichromate, a group of students wrote the following variables in their planning:

Independent Variable: Type of alcohol

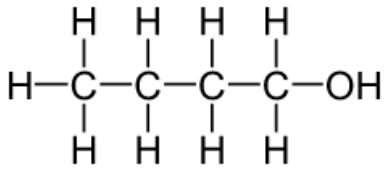
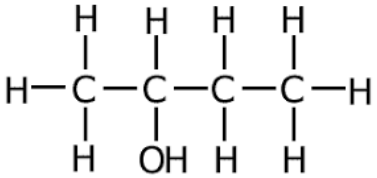
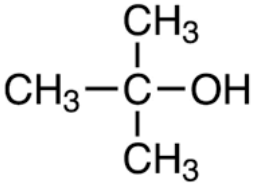
Dependent Variable: Observed colour.

a) Write two controlled variables in this part of the investigation. (2 marks)

Controlled Variables:

Description	Marks
Two appropriate controlled variables, i.e. • Same molecular formula • Same volume of alcohol • Same volume of acidified dichromate NOTE: must be appropriate to the experiment.	2
Total	2

b) Draw the structural formula for the three alcohols used in this investigation. (3 marks)

Compound	Structural Formula
butan-1-ol	 (1)
butan-2-ol	 (1)
methylpropan-2-ol	 (1)

Question 2 - Observations **(7 marks)**

Excess acidified potassium dichromate was added to each of the three alcohols.

a) Write appropriate observations for each test tube. (3 marks)

Compound	Observation
butan-1-ol	An orange solution is added to a colourless solution, and the solution turns deep green. (1)
butan-2-ol	An orange solution is added to a colourless solution, and the solution turns deep green. (1)
methylpropan-2-ol	No visible reaction. (1)

Sodium metal was added to each of the three alcohols.

b) Write an appropriate observation for when sodium metal was added to the test tube containing butan-1-ol. (2 marks)

Compound	Observation
butan-1-ol	A grey solid is added to a colourless liquid. The solid is consumed and bubbles are produced. (2) -1 mark for each underlined observation missing.

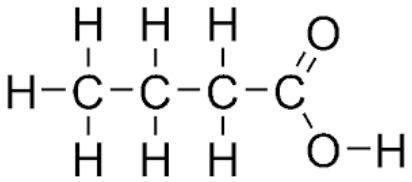
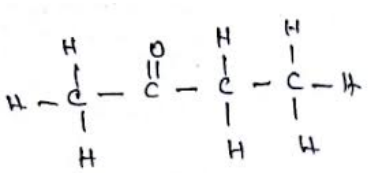
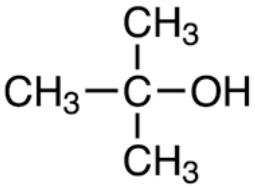
c) List the three alcohols in order of observed increasing reactivity to sodium metal. (2 marks)

methylpropan-2-ol < butan-2-ol < butan-1-ol (2)

1 mark for a correct position

Question 3 - Results **(8 marks)**

a) Draw the structural formula and name any organic species remaining in the test tube after the addition of excess acidified dichromate. (6 marks)

Compound	Structural Formula of remaining organic species	Name of remaining organic species
butan-1-ol	 (1)	butanoic acid (1)
butan-2-ol	 (1)	butanone (1) (accept: butan-2-one)
methylpropan-2-ol	 (1)	methylpropan-2-ol (1)

b) Write a balanced equation for the reaction of sodium metal and butan-1-ol.

(2 marks)

$2\ Na + 2\ C_4H_{10}O \rightarrow 2\ Na^+ + 2\ C_4H_9O^- + H_2$

$2\ Na + 2\ CH_3CH_2CH_2CH_2OH \rightarrow 2\ Na^+ + 2\ CH_3CH_2CH_2CH_2O^- + H_2$ (2 marks)

OR

$2\ Na + 2\ C_4H_{10}O \rightarrow 2\ NaC_4H_9O + H_2$

$2\ Na + 2\ CH_3CH_2CH_2CH_2OH \rightarrow 2\ NaCH_3CH_2CH_2CH_2O + H_2$ (2 marks)

-1 mark, minor error

Question 4 - Results **(11 marks)**

Butan-2-ol ($C_4H_{10}O$) was exposed to two different oxidising agents and the **same** organic product was formed in both circumstances.

a) Aqueous butan-2-ol was made to react with acidified potassium dichromate. Write the oxidation and reduction half equations and overall balanced equation for this reaction. Include state symbols in the overall reaction. (5 marks)

Oxidation half-equation	$C_4H_{10}O\ (aq) \rightarrow C_4H_8O\ (aq) + 2\ H^+\ (aq) + 2\ e^-$ **(1)** OR $CH_3CH(OH)CH_2CH_3\ (aq) \rightarrow CH_3COCH_2CH_3\ (aq) + 2\ H^+\ (aq) + 2\ e^-$
Reduction half-equation	$Cr_2O_7^{2-}\ (aq) + 14\ H^+\ (aq) + 6\ e^- \rightarrow 2\ Cr^{3+}\ (aq) + 7\ H_2O\ (l)$ **(1)**
Overall equation	$3\ C_4H_{10}O\ (aq) + Cr_2O_7^{2-}\ (aq) + 8\ H^+\ (aq) \rightarrow 3\ C_4H_8O\ (aq) + 2\ Cr^{3+}\ (aq) + 7\ H_2O\ (l)$ **(2)** OR $3\ CH_3CH(OH)CH_2CH_3\ (aq) + Cr_2O_7^{2-}\ (aq) + 8\ H^+\ (aq) \rightarrow 3\ CH_3COCH_2CH_3\ (aq) + 2\ Cr^{3+}\ (aq) + 7\ H_2O\ (l)$ **(2)** State symbols **(1)** NOTE: f.t. from incorrect half equation if minor error.

b) Aqueous butan-2-ol was made to react with pyridinium chlorochromate (PCC). The PCC reagent is orange in aqueous solution and forms a brown chromium containing precipitate in the reaction with alcohols. Write the oxidation half equation, overall balanced equation, and an observation for this reaction. The reduction of the PCC reagent has been provided. Include state symbols and record the observations for the overall reaction. (5 marks)

Oxidation half-equation	$C_4H_{10}O\ (aq) \rightarrow C_4H_8O\ (aq) + 2\ H^+\ (aq) + 2\ e^-$ OR $CH_3CH(OH)CH_2CH_3\ (aq) \rightarrow CH_3COCH_2CH_3\ (aq) + 2\ H^+\ (aq) + 2\ e^-$ (f.t. from above)
Reduction half-equation	**$[CrO_3C\ell]^-\ (aq) + 2\ H^+\ (aq) + 2\ e^- \rightarrow CrO(OH)_2\ (s) + C\ell^-\ (aq)$**
Overall equation	$C_4H_{10}O\ (aq) + [CrO_3C\ell]^-\ (aq) \rightarrow C_4H_8O\ (aq) + CrO(OH)_2\ (s) + C\ell^-\ (aq)$ **(2)** OR $CH_3CH(OH)CH_2CH_3\ (aq) + [CrO_3C\ell]^-\ (aq) \rightarrow CH_3COCH_2CH_3\ (aq) + CrO(OH)_2\ (s) + C\ell^-\ (aq)$ **(2)** State symbols **(1)** NOTE: f.t. from incorrect half equation if minor error.
Observation	An orange solution is added to a colourless solution. A brown solid is formed, and the solution turns colourless. -1 mark for each underlined observation missing. **(2)**

Question 5 - Discussion **(10 marks)**

a) Explain the trend in rate of reaction for the three alcohols and sodium metal (Question 2c), with reference to collision theory. (4 marks)

Description	Marks
The primary alcohol has the least hinderance around the -OH functional group (comment on structure of the primary, secondary and tertiary alcohols).	1
Greater frequency of collisions in the primary alcohol	1
And a greater frequency of collisions which reach the activation energy (successful collisions)	1
Therefore, the primary alcohol has the highest rate of reaction (tertiary alcohol lowest)	1
Total	4

Alcohols are useful as antiseptic agents in hand sanitation. Appropriate alcohols are soluble in water, such that non-hazardous diluted solutions of alcohols can be prepared for human use. All the alcohols tested in this investigation were soluble in water.

b) Describe, using your knowledge of intermolecular forces, why methylpropan-2-ol is soluble in water. (4 marks)

Description	Marks
In order for a substance to dissolve, the strength of intermolecular forces formed must be sufficient to disrupt the intermolecular forces between the solute molecules and between the solvent molecules.	1
The alcohol forms dispersion forces and hydrogen bonds with water	1
The strength of the hydrogen bonds formed are sufficient to overcome the hydrogen bonds (sum of IMFs) between the water molecules and the hydrogen bonds (sum of IMFs) between the alcohol molecules and so dissolution occurs.	2
Total	4

One group of students observed that their dichromate reaction mixture became a blue colour, which was different to the colour observed in reaction mixtures of their classmates.

c) State two ways in which the students might improve the **reliability** of their observed data. (2 marks)

Description	Marks
Students may repeat their experiment multiple times	1
To remove outlier (anomalous) observations if they occur.	1
Total	2

END OF INVESTIGATION

Additional Working Paper

Additional Working Paper