Top of the Bench 2024
Older Paper

Name:

School:

School year:

Answer all questions in the spaces provided.

You are provided with a Periodic table.

You may use a scientific calculator.

Write your answers clearly. Show all working.

Section A contains questions about general chemical knowledge.

Section B contains questions about this year's theme: Water

The total marks allocated to the paper are 40 marks (Section A 10 marks, Section B 30 marks)

The time allocated to the paper is 40 minutes.

Question	Mark
Section A	
8	
9	
10	
TOTAL	

SECTION A General chemistry knowledge

1. Give the number of protons, neutrons and electrons in an atom of $^{40}_{18}Ar$. [1]

protons _____ neutrons _____ electrons _____

2. Place each of the compounds below into the correct columns in **Table 1** based on the type of bonding present in each. [3]

CH_4 K $CaCl_2$ NH_3 NaBr Mg

Ionic bonding	**Covalent bonding**	**Metallic bonding**

Table 1

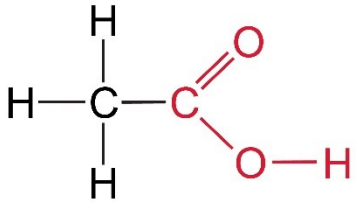
3. When chlorine is reacted with sodium bromide a displacement reaction occurs.
Complete the balanced symbol equation for the reaction**.** [2]

__ Cl_2 + __ NaBr → _____

4. A student adds sodium chloride to water to form a solution. Name the **solute** in the process. [1]

_____

5. Identify the functional group highlighted in red in the molecule in **Figure 1**. [1]



Functional group

_____

Figure 1

6. Aluminium reacts with chlorine to form aluminium chloride.

The equation for the reaction is;

$$2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$$

Calculate the mass of aluminium chloride formed from the reaction of 0.6 mol of aluminium with an excess of chlorine.

Give your answer in grams.

The relative formula mass of $AlCl_3$ is 133.5 [1]

_____

_____

7. The Nobel Prize in Chemistry this year rewarded the discovery and development of quantum dots. These are nanoparticles so tiny that their size determines their properties.

How big is one nanometre in metres?

Give your answer in standard form. [1]

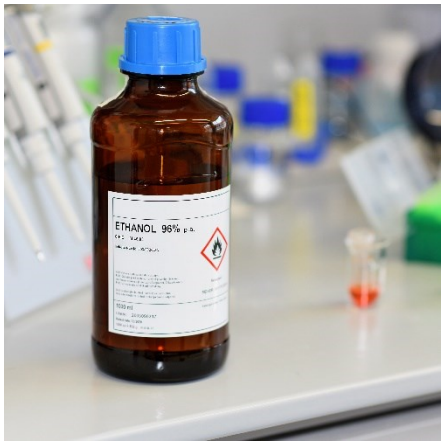
_____

Turn over for Section B

SECTION B Questions linked to this year's theme of Water

8. This question is about the use of water in the production of ethanol.

Ethanol is used as an important solvent in cosmetics such as aftershave and deodorants. It is also used in the manufacture of drugs, detergents, inks and coatings.



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Ethanol is a member of the alcohol family.

Table 2 gives the name and formula of the first four members of the alcohol family.

Name	Molecular formula
methanol	CH_3OH
ethanol	C_2H_5OH
propanol	C_3H_7OH
butanol	C_4H_9OH

Table 2

a. i. Which option gives the correct general formula for an alcohol? [1]

- ☐ $C_nH_{2n}OH$
- ☐ $C_nH_{2n+1}OH$
- ☐ $C_nH_{2n+2}OH$
- ☐ $C_{2n}H_{n+2}OH$

ii. The **displayed formula** of an organic compound shows every atom and every bond in the molecule.

Draw the **displayed formula** of ethanol in the box below. [1]

Both ethanol and water have an -OH group.

This means ethanol reacts with group one metals in a similar way to water.

b. i. Suggest the name of the gas produced when ethanol reacts with sodium. [1]

_____

ii. Complete the balanced symbol equation for the reaction. [2]

$$2C_2H_5OH + 2Na \rightarrow \_\_\_\_\_ + \_\_\_\_$$

Ethanol is produced industrially by the hydration of ethene.

$$C_2H_4(g) + H_2O(g) \leftrightharpoons C_2H_5OH(g)$$

The conditions used are 300 ºC, 65 atm pressure and a phosphoric acid catalyst.

c. i. Why are catalysts used in chemical reactions? [1]

_____

_____

ii. Phosphoric acid is a triprotic weak acid.

A triprotic acid has 3 hydrogen ions (H^+) that can be donated for each molecule of acid.

The ionisation occurs in steps, with each step resulting in the release of one H^+ ion.

Step 1 is given below.

Complete the equations in **step 2** and **step 3** to show the successive ionisations. [2]

Step 1: $H_3PO_4 \leftrightharpoons H^+ + H_2PO_4^-$

Step 2: $H_2PO_4^- \leftrightharpoons H^+ + \_\_\_\_\_$

Step 3: $\_\_\_\_\_ \leftrightharpoons H^+ + \_\_\_\_\_$

[Total: 8 marks]

9. This question is about the analysis of impurities in water using test tube reactions.

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The presence of ions in water can be identified using precipitation reactions.

a. Which option correctly describes a **precipitation** reaction? [1]

- ☐ substances in solution are mixed and a soluble product is made.
- ☐ substances in solution are mixed and an insoluble product is made.
- ☐ insoluble reactants are mixed and a soluble product is made

The tests for some different anions and cations in solution are shown in **Table 3**.

Anion		**Test**	**Positive result**
Sulfate ion, SO_4^{2-}		Add HCl followed by $BaCl_2$ solution.	A white precipitate of $BaSO_4$ forms.
Halide ions	Cl^-	Add H_2SO_4 followed by $AgNO_3$ solution.	A white precipitate of AgCl forms
	Br^-		A cream precipitate of AgBr forms
	I^-		A yellow precipitate of AgI forms

Cation	**Test**	**Positive result**
Copper, Cu^{2+}	Add a few drops of sodium hydroxide solution	Blue precipitate of $Cu(OH)_2$
Iron, Fe^{2+}		Green precipitate of $Fe(OH)_2$
Iron, Fe^{3+}		Red-brown precipitate of $Fe(OH)_3$
Aluminium, Al^{3+}		White precipitate of $Al(OH)_3$*
Magnesium, Mg^{2+}		White precipitate of $Mg(OH)_2$*

Table 3

* Al^{3+} and Mg^{2+} both form a white precipitate when a few drops of sodium hydroxide solution are added. However the white precipitate of $Al(OH)_3$ redissolves in excess NaOH to form a colourless solution.

A student analyses five samples of water known to be contaminated.

The results are shown in **Table 4**.

Sample	Observation on adding NaOH solution	Observation on adding $HNO_3/AgNO_3$	Observation on adding $HCl/BaCl_2$
A	Blue precipitate	No change	White precipitate
B	White precipitate that redissolves in excess	White precipitate	No change
C	No change	Yellow precipitate	No change
D	Brown precipitate	Cream precipitate	White precipitate
E	Green precipitate	White precipitate	White precipitate

Table 4

b. Identify the anion present in **sample A**. [1]

_____

c. Identify the salt dissolved in **sample B**. [1]

Give the cation and the anion.

_____

d. Explain how the results for **sample E** show that the sample must be contaminated by more than one salt. [2]

_____

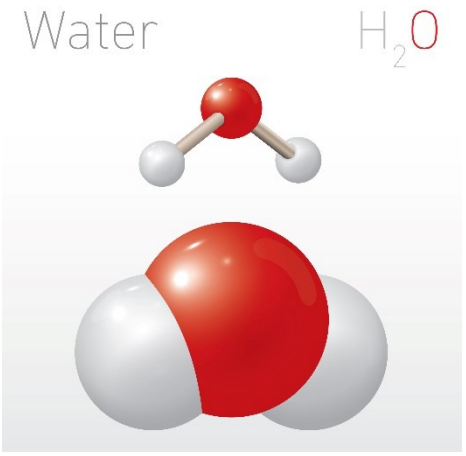
_____

_____

_____

[Total: 5 marks]

10. This question is about pure water.



a. Water exists as individual molecules consisting of two hydrogen atoms and an oxygen atom covalently bonded.

i. Complete the dot and cross diagram in **Figure 2** to show the bonding in a molecule of water. [2]

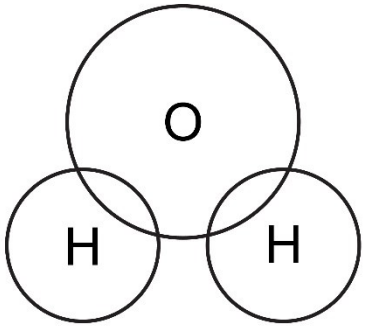


Figure 2

ii. Explain how a covalent bond holds two atoms together. [2]

_____

_____

_____

_____

iii. **Figure 3** shows the bond lengths and bond angles in a molecule of water.

pm = 1 picometre = 1×10^{-12} m

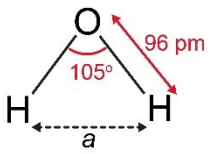


Figure 3

Use **Figure 3** to determine the horizontal distance between the two hydrogen atoms in picometres.

This is labelled '*a*' on the diagram. [3]

Distance '*a*' = _____ pm

b. i. Calculate the number of water molecules in 1 cm^3 of liquid water.

The density of liquid water is 1.0 g / cm^3.

1 mole of a covalent compound contains 6.02×10^{23} molecules. [2]

_____

_____

_____

ii. Calculate the volume occupied in cm^3 by 1 molecule of H_2O in liquid water. [1]

Use your answer to part (i).

_____

_____

_____

iii. Water expands when it is frozen.

This can lead to water pipes bursting when the water inside them freezes.

Calculate the change in volume when 1 dm^3 of water at 18 °C is cooled to -5 °C.

Assume;

The density of water at 18 °C is 0.999 g / cm^3

The density of ice at -5 °C is 0.917 g / cm^3. [3]

_____

_____

_____

_____

_____

Question continues on the next page

Pure water is slightly ionised.

An equilibrium is established between H_2O molecules and H^+ and OH^- ions.

$$H_2O(l) \leftrightharpoons H^+(aq) + OH^-(aq)$$

Figure 4 shows how the concentration of H^+ ions in a sample of pure water changes with temperature.

The higher the concentration of H^+ ions the more acidic a solution.

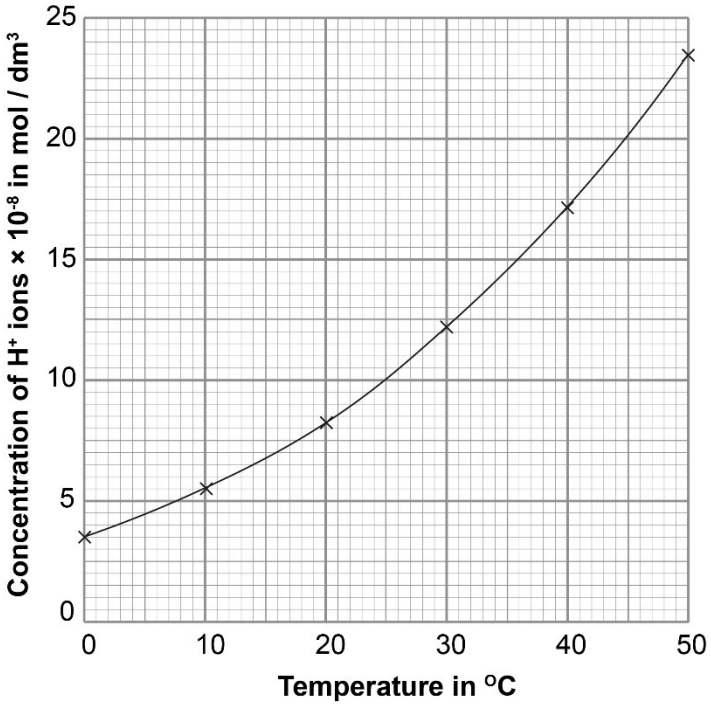


Figure 4

c. i. Describe the trend shown by **Figure 4**. [1]

_____

_____

ii. Suggest how the pH of pure water changes as the temperature is increased. [2]

_____

_____

iii. Give one reason why pure water is still neutral at all temperatures. [1]

_____

_____

[Total: 17 marks]