TOTB 2024

Younger Paper

Answers

Question	Mark
Section A	
10	
11	
12	
TOTAL	

SECTION A General chemistry knowledge

1. **Figure 1** shows particle diagrams of different substances labelled **A**, **B**, **C** and **D**.

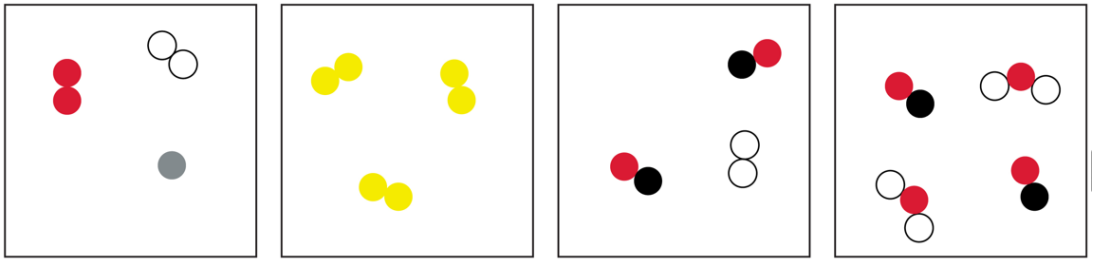


Figure 1

Choose the diagram (**A**, **B**, **C** or **D**) that best represents: [2]

a. a pure element **B**

b. a mixture of two different compounds **D**

2. Name the change of state when a **solid** turns directly into a **gas**. [1]

sublimation

3. Only two elements in the periodic table are liquids at room temperature.

Name any **one** of them. [1]

Either mercury *or* bromine

4. Name the compound formed when iron reacts with fluorine. [1]

Iron fluoride (*correct spelling required*)

5. When citric acid and sodium hydrogencarbonate react the temperature of the surroundings decreases.

Which term describes the reaction?

Choose from: [1]

[x] endothermic [ ] exothermic

6. Which element forms an alkaline solution when reacted with water?

Choose from: [1]

- [x] sodium
- [ ] copper
- [ ] iron
- [ ] sulfur

7. Balance the equation: [1]

$$6\ AgI + (1)\ Fe_2(CO_3)_3 \rightarrow 2\ FeI_3 + 3\ Ag_2CO_3$$

8. Name the gas that is found in the Earth's atmosphere in the highest percentage. [1]

nitrogen _____

9. 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?

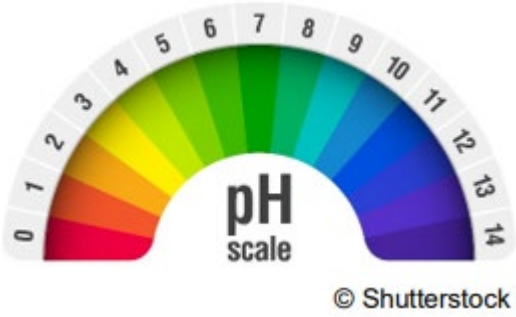
Choose from; [1]

- [ ] 1×10^{-3} m
- [x] 1×10^{-9} m
- [ ] 1×10^{-12} m

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

10. This question is about neutralisation reactions.

Water is a product of all neutralisation reactions.



a. When an acid and a base react a salt and water is produced.

i. Complete **Table 1** by naming the salt produced from the acid and base in each of the experiments **1-3**. [3]

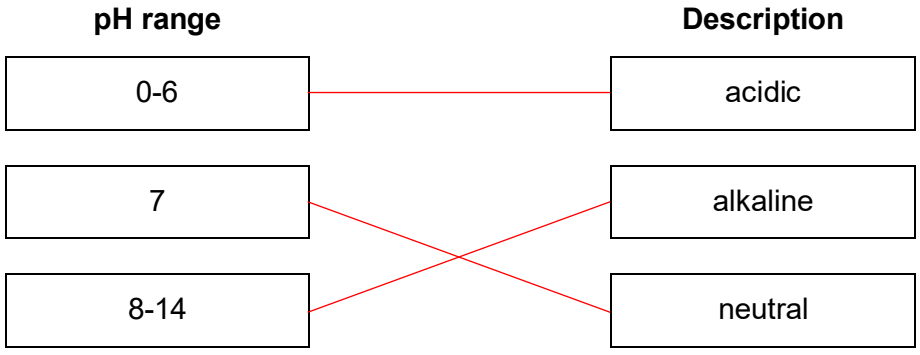
Experiment	Acid	Base	Salt formed
1	hydrochloric acid	lithium oxide	lithium chloride
2	nitric acid	sodium hydroxide	sodium nitrate
3	sulfuric acid	calcium carbonate	calcium sulfate

Table 1

ii. The pH scale shows how acidic a substance is.

The scale ranges from 0-14.

Draw **one line** from each pH range to the correct description. [1]



b. A student uses a neutralisation reaction to make a sample of the salt **sodium chloride**.

They react sodium hydroxide with hydrochloric acid.

This is the method used:

Step 1. Measure 15 cm^3 of hydrochloric acid into a conical flask.

Step 2. Carefully add sodium hydroxide dropwise until the solution is just neutral.

i. Name a suitable piece of apparatus the student should use to measure 15 cm^3 of hydrochloric acid in **step 1**. [1]

Measuring cylinder. *Allow (graduated) pipette.*

ii. The bottle of sodium hydroxide has the hazard symbol shown in **Figure 2**.

Figure 2

What is the meaning of the hazard symbol?

Tick **one** option. [1]

x	**Irritant**		**Flammable**		**Corrosive**

iii. Describe how the student could find out that the solution is exactly neutral in **step 2**. [2]

M1 After each addition test the solution with Universal indicator paper

M2 If the paper turns green the solution is neutral

allow

M1 use a pH meter

M2 when the meter reads pH 7 the solution is neutral

iv. The method described produces a solution of sodium chloride.

Describe how the student could produce a **pure**, **dry sample of solid sodium chloride** from the solution produced in **step 2**.

Include the name of any scientific equipment they should use. [4]

M1 Place the solution in an evaporating basin / dish

M2 Gently heat until crystals just start to form

M3 Leave to cool

M4 Decant any remaining liquid and pat crystals dry

Place the solution in an evaporating basin and heat to evaporate the water / leave for the water to evaporate scores 2

[Total: 12 marks]

Questions continue on the next page

11. This question is about sea water.

Sea water is a solution of sodium chloride.

Rain water dissolves minerals in rocks which are then carried to the sea by rivers.

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a. **Table 2** gives the mass of sodium chloride per 100 cm^3 in different bodies of water.

Name	**Mass of sodium chloride found in 100 cm^3 of water**
Dead sea	33.7
Mediterranean sea	3.8
Black sea	2.30-1.30
Caspian sea	1.25

Table 2

i. A 500 cm^3 sample of salt water is found to contain 19.6 g of salt.

Which body of water is the sample most likely to have been collected from?

Use the information in **Table 2**. [2]

M1 19.6 g ÷ 5 = 3.92 g per 100 cm^3

M2 Mediterranean sea (*allow ecf from incorrect calculation*)

ii. Calculate the volume of water from the Caspian sea that contains the same mass of salt as 250 cm^3 of water from the Dead sea. [2]

M1 Mass of salt in 250 cm^3 of Dead sea = 2.5 × 33.7 = 84.25 g

M2 Volume of Caspian sea water needed = (84.25 g ÷ 1.25) × 100

= 6740 cm^3

Alternative method

M1 Dead sea is 33.7 ÷ 1.25 = 26.98 times more concentrated than the Caspian sea

M2 Volume of Caspian sea water needed = 26.98 × 250 cm^3 = 6740 cm^3

(Correct answer with no working = 2 marks)

Pure water can be obtained from salt water using distillation.

b. A student sets up the distillation apparatus in **Figure 3**

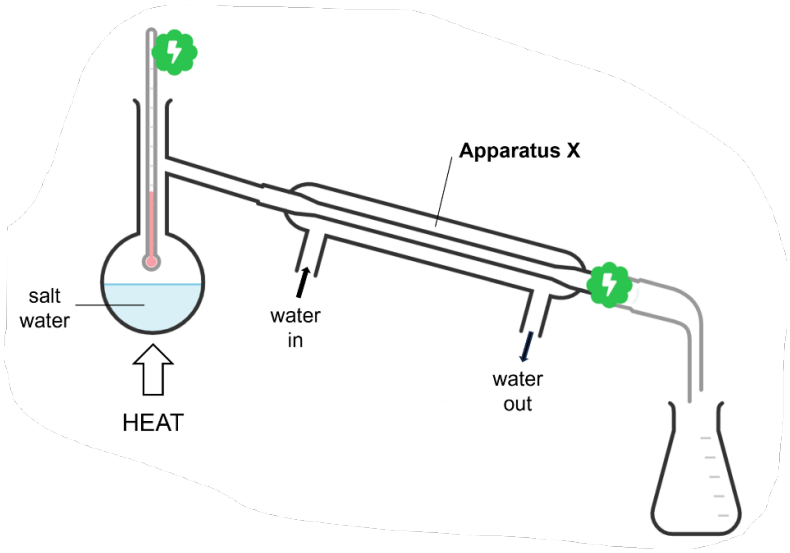

Figure 3

i. Give the name for the piece of equipment labelled **Apparatus X.** [1]

(Liebig) condenser _____

ii. Identify two errors in the way the equipment is set up which would mean the distillation would be unsuccessful.

For each error explain the outcome of the error. [4]

Any two with matching reason from;

Error	**Outcome**
System open at top	Any vapours would escape and not pass down the condenser
Thermometer bulb too low / not next to side arm	Recorded boiling point for distillate would be inaccurate
Water in / out wrong way round	Condenser would not cool the water vapour sufficiently / not all vapour would condense.

c. Which option correctly describes all the changes of state that occur during a distillation? [1]

- [x] liquid → gas → liquid
- [ ] gas → liquid → gas
- [ ] liquid → gas

[Total: 10 marks]

12. This question is about hard and soft water.

The water in some parts of the country is soft, while the water in other parts of the country is hard.

Hard water contains dissolved magnesium ions (Mg^{2+}) and calcium ions (Ca^{2+}).

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a. Magnesium and calcium are both in Group 2 of the periodic table.

Table 3 gives some information about atoms of the elements in Group 2.

Element	Atomic radius in nm	Atomic structure		
		Number of protons	Number of neutrons	Number of electrons
beryllium	0.125	4	5	4
magnesium	0.160	12	12	12
calcium	?	20	20	20
strontium	0.191	38	50	38
barium	0.198	56	81	56

Table 3

i. Predict the atomic radius in nm of calcium. [1]

Actual value 0.174 nm (allow anywhere in range between 0.190 and 0.161) _____

ii. Positive ions such as Mg^{2+} are formed when an atom reacts and loses electrons.

The size of the positive charge on the newly formed ion is determined by the number of electrons lost.

Give the number of electrons in a Mg^{2+} ion. [1]

10 _____

b. One type of hard water is formed when **calcium sulfate** rock dissolves in rain water.

What is the formula of calcium sulfate? [1]

- [x] $CaSO_4$
- [ ] Ca_2SO_4
- [ ] $CaSO_3$
- [ ] Ca_2SO_3

c. Another type of hard water is formed when rain water and carbon dioxide from the air react with calcium carbonate in chalk and limestone.

A solution of calcium hydrogen carbonate is formed.

Write a word equation for this reaction. [1]

calcium carbonate + (*rain*) water + carbon dioxide → calcium hydrogen carbonate (*solution*)

Ignore inclusion of rain and solution

Soap can be used to **test how hard a sample of water** is.

Soft water lathers well when mixed with soap, but hard water does not.

In hard water the calcium and magnesium ions react with the soap to form a solid called scum.

Only once the soap has reacted with all of the ions is the rest of the soap able to form a lather.

The more soap needed before a lather forms, the harder the water sample.

Figure 4 shows what is meant by a lather.

Figure 4

d. A student investigates the hardness of five samples of water.

This is the method used:

1. Measure 5 cm^3 of the water and place it in a boiling tube.
2. Whilst shaking the boiling tube, add the soap solution one drop at a time.
3. Record the volume of soap needed to make a lather.

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

	Volume of soap needed to form a lather in cm^3			
	Run 1	**Run 2**	**Run 3**	**Mean**
Sample A	5.2	4.1	4.7	4.7
Sample B	9.1	8.9	9.2	?
Sample C	15.4	14.6	15.1	15.0
Sample D	1.4	1.7	1.8	1.6
Sample E	12.1	12.4	12.2	12.2

Table 4

i. Calculate the mean volume of soap needed to form a lather with **sample B**.

Give your answer to 1 decimal place. [2]

9.1 + 8.9 + 9.2 = 27.2

27.2 ÷ 3 = 9.06…. (**M1**)

Mean volume = 9.1 cm^3

*(**M2** for rounding answer to 1 dp. Allow ecf from incorrect mean)*

(Correct answer with no working = 2 marks)

ii. Which sample is the hardest?

Explain how the results support this conclusion. [1]

Sample C

Because it needs the most soap before it forms a lather

Both correct sample and supporting reason needed for the mark

iii. The **uncertainty** in a set of measurements is the amount of error the measurements might have.

The larger the **range** the more uncertainty there is in the results.

For which sample is the uncertainty in the results the greatest? [1]

Sample A

[Total: 8 marks]