Level 1: remembering.

Frequently used task words: define, list, label, name.

Can the student recall or remember the information?

Q

Define the term “molarity”.

i

This question simply requires you to provide a definition for the term “molarity”.

You don’t need to mention how the molarity is calculated or provide an example.

A

The molarity is the term used to describe the concentration of solution in moles per litre or mol L^{-1}.

Level 2: understanding.

Frequently used task words: describe, explain, identify & example.

Can the student explain ideas or concepts?

Q

A student has prepared a solution of sodium hydroxide by dissolving 4.000 g of NaOH pellets in water to give 1.000 L of solution.

The student's tutor has suggested that the NaOH solution should be standardised before it is used in a titration experiment.

In your own words, explain why the NaOH solution should be standardised. Your answer should specifically refer to NaOH.

i

This question is asking for the reason why some titration solutions need to be standardised AND wants you to specifically refer to NaOH in your answer.

In this case, it is presumed you already know what standardising a solution means. (I.e. the process of determining the exact concentration of a solution.)

To achieve full marks you need to address both parts of the question.

A

In order to have an accurate solution of NaOH, you must standardise the solution.

NaOH readily reacts with moisture in the air and therefore the measured weight may not be 100% NaOH.

Without knowing the exact concentration of the NaOH solution, the titration experiment will not produce accurate results.

Level 3: applying.

Frequently used task words: apply, illustrate, solve, use & demonstrate.

Can the student use information in a new way?

Q

A manufacturer makes lemon cordial by mixing flavouring, sugar syrup and citric acid. The concentration of the citric acid is determined by titration with NaOH.

To analyse the lemon cordial 50.00 mL of the cordial is diluted to 500.0 mL. Then 25.00 mL of the diluted solution is titrated with the NaOH solution to the phenolphthalein endpoint.

The concentration of the NaOH solution is 0.09746 mol L^{-1}

The titration volume of NaOH = 27.25 ml

The ratio of NaOH to citric acid = 3:1

Determine the concentration of citric acid in the lemon cordial.

i

Here is a classic mathematical question that asks you to demonstrate how well you understand the basic calculations associated with a titration experiment.

When answering this kind of question it's a good idea to put in some explanations of your logic, rather than just writing numbers down. That way, even if your numbers are incorrect, your marker can see how you are thinking and you might get some marks. It also makes the answers easier to interpret; therefore you are more likely to get marked fully and fairly.

Remember, if a marker can't understand what you are doing they will not give you marks for your answer. If you don't provide an explanation of what you are doing it is also very hard for you to challenge the way something was marked.

A

Concentration mol L^{-1} x Vol L

moles NaOH used = MV

= 0.09746 mol $L^{-1} \times$ 0.02725 L

= 2.656×10^{-3} mol

A

moles of citric acid = moles of NaOH / 3

= 8.853×10^{-4} mol

concentration of dilute solution = moles/volume

=8.853×10^{-4} mol / 0.025 L

= 0.0354 mol L^{-1}

concentration of original solution = $C_1V_1 = C_2V_2$

= $C_1 \times 0.05$ L = 0.5 L × 0.03541 mol L^{-1}

= C_1 x 0.05 L = 0.017705 mol L^{-1}

= C_1 = 0.017705 mol L^{-1} / 0.05 L

= 0.3541 mol L^{-1}

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Level 4: analysing.

Frequently used task words: analyse, compare, contrast, examine.

Can the student distinguish between different parts?

Q

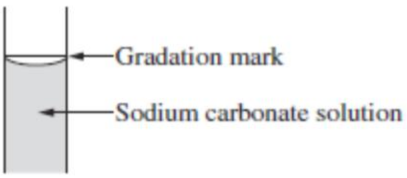
A student attempted to determine the concentration of a hydrochloric acid solution.

The following steps were performed.

Step 1. A conical flask was rinsed with water.

Step 2. A 25.0 mL pipette was rinsed with water.

Step 3. The student filled the pipette with a standard sodium carbonate solution to the level shown in the diagram.



Step 4. The standard sodium carbonate solution in the pipette was transferred to the conical flask. The student ensured that all of the sodium carbonate solution was transferred to the conical flask by blowing through the pipette. Three drops of an appropriate indicator were added to the conical flask.

Step 5. A burette was rinsed with the hydrochloric acid solution and then filled with the acid. The student then carried out a titration to determine the concentration of the hydrochloric acid solution.

Examine steps 2, 3 and 4 of the procedure.

a) Identify the mistake the student made in step 4 and propose a change that would improve the validity of the result.

b) Identify and explain the effect of the mistakes made in steps 2 and 3 on the calculation of the concentration of the hydrochloric acid solution.

For this question, you need to analyse steps 2, 3 and 4 of the procedure and identify the mistakes.

For part a, in addition to identifying the mistake in step 4, you are asked to provide an alternative way of performing the procedure.

For part b, you are asked to identify the mistakes in steps 2 and 3 AND explain what impact they had on the calculation of the HCl solution.

This question is testing your knowledge of the basic steps in a titration procedure and whether you understand the reasons for performing steps in a particular manner. It is also asking you to think about how making mistakes can affect the outcome of an experiment.

A

a) Instead of blowing through the pipette, the student should have touched the end of pipette to the surface of flask to draw out the liquid.

b) In step 2, rinsing the pipette with water would decrease the number of moles of Na_2CO_3 it contains. This would be compounded by not filling to the mark made in step 3, resulting in the pipette having fewer moles of Na_2CO_3.

Hence, a lower volume of the HCl would be added from the burette, but the student would think that there were more moles of HCl in this volume. So, they will calculate the concentration of the acid solution to be higher than the actual value.

Level 5: evaluating.

Frequently used task words: justify, defend, argue, evaluate, assess

Can the student justify a stand or decision?

Q

There has been an increase in the concentration of the oxides of nitrogen in the atmosphere as a result of combustion.

Assess both the evidence to support this statement and the need to monitor these oxides.

i

This question is asking you to argue the reasons for monitoring the concentration of nitrogen oxides in the atmosphere.

You should try to outline your arguments in a logical manner, include specific examples of sources of atmospheric NOx (including relevant equations), and explain the detrimental effects of these oxides. Providing examples is essential to justify why the oxides need monitoring.

It's up to you to decide what examples you use to tell the story – there is no model answer.

A

The evidence of increasing concentrations of NO and NO2 in the atmosphere comes from direct measurement, knowledge of sources and measurement of effects. Thus there is clear factual evidence to support this statement. Monitoring is necessary due to detrimental environmental and health effects.

Combustion of fossil fuels in motor vehicles and in power stations results in the formation of NO

$N_2 (g) + O_2 (g) \rightarrow 2NO(g)$

In the lower atmosphere, in the presence of sunlight NO is oxidised to NO2

$2NO(g) + O_2 (g) \rightarrow 2NO_2 (g)$

Direct measurements are made by statutory bodies, such as NSW EPA, and also by scientists researching the atmosphere. Nitrogen oxides were found to be part of pollution generated over large cities from the onset of the industrial revolution and the use of the internal combustion engine. This was essentially unrestricted till the 1950s, when concerns grew from loss of life due to smog. Some reduction of NO was achieved by the introduction of catalytic converters in motor vehicles where

$2CO(g) + 2NO(g) \rightarrow N_2 (g) + 2CO_2 (g)$

A

This removes NO from the exhaust gas. However the increased number and use of motor vehicles has offset further major reductions.

Measurement of effects of NOx highlights both issues of quantities produced and detrimental effects which necessitates their monitoring.

One effect is production of photochemical smog. NOx is part of a complex set of chemical species which have several reactions in the presence of sunlight resulting in photochemical smog.

Another effect is the direct toxicity of NOx to people, affecting especially the respiratory tract and eyes. There is a need to monitor NOx in cities in order to warn people most susceptible to acute effects.

NOx are also contributors to acid rain:

$2NO_2\ (g) + H_2O(l) \rightarrow HNO_2\ (aq) + HNO_3\ (aq)$

$2HNO_2\ (g) + O_2\ (g) \rightarrow 2HNO_3(aq)$

The effects of acid rain are multiple:

- Lowering pH of natural waters affecting all biota in that water body.
- Acidic precipitation affecting vegetation by acid burning or defoliating plants.
- Acidic runoff from soils leaching some nutrients, specifically Ca^{2+}, Mg^{2+}.
- Acidic leaching of toxic species, e.g. Al^{3+}.
- Acidic attack on manmade structures, e.g. marble or limestone buildings.

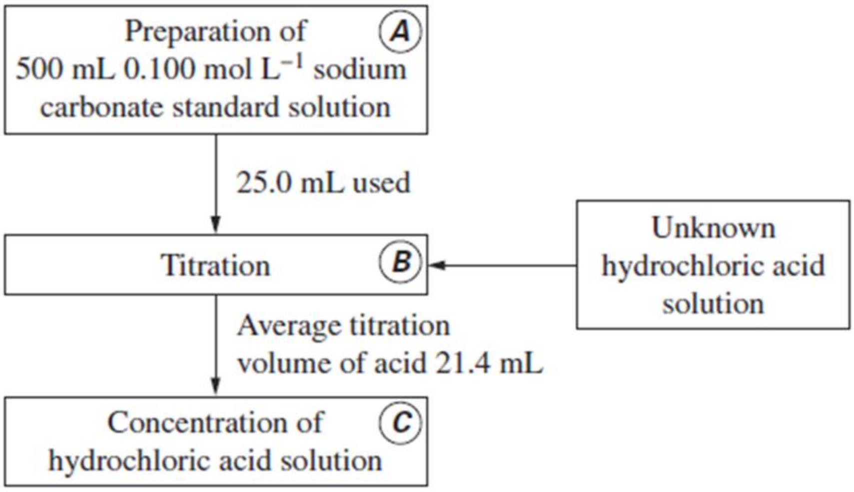
Level 6: creating.

Frequently used task words: create, design, develop, formulate, construct.

Can the student create a new product or point of view?

Q

The flowchart shown outlines the sequence of steps used to determine the concentration of an unknown hydrochloric acid solution.



Describe steps A, B and C including correct techniques, equipment and appropriate calculations. Determine the concentration of the hydrochloric acid.

This question is asking you create a protocol from the flow chart AND calculate the concentration of the hydrochloric acid.

This question relies on a good knowledge of the laboratory techniques and equipment used in a titration experiment.

Your protocol should be neatly arranged in numbered steps, rather than written in paragraphs – be kind to the person marking your work!

Think about how you would perform this experiment in the lab and then outline detailed steps that will allow someone to perform the experiment. The steps should include important details relating to specific techniques used in titration experiments.

The more information you provide (i.e. chemical formulas and balanced equations) the more likely it is that you will receive full marks.

A

1. STEP A: Na_2CO_3 (anhydrous) should be initially dried and stored in a desiccator.

2. Mass of Na_2CO_3 = 0.1 mol L^{-1} × 105.99 g/mol x 0.5 L

Dried Na_2CO_3 (anhydrous), 5.30 g, should be weighed out accurately (2 decimal places).

3. 500 mL volumetric flask cleaned and rinsed with distilled water. Weighed Na_2CO_3 (anhydrous) added to volumetric flask, using funnel and washed in using distilled water. Add distilled water to the flask to mark, with bottom of the meniscus.

4. STEP B: Clean, rinse, and fill a 50 mL burette with the unknown acid and place on a retort stand.

5. Clean a 250 mL conical flask and rinse with distilled water.

6. Clean a 25 mL pipette and rinse with 0.1 mol L^{-1} Na_2CO_3 solution. Fill pipette with Na_2CO_3 solution to mark with bottom of meniscus.

7. Add pipette volume into conical flask. Add suitable indicator to the conical flask. Place a white tile under the conical flask.

8. Slowly add acid solution from the burette into the conical flask. When the indicator changes colour, record the final volume. This initial titration should be taken as a rough test.

Three more titrations should be performed with the average titration being used for calculations.

9. STEP C: $2H^+ (aq) + CO_3^{2-} (aq) \rightarrow H_2CO_3 (aq) \rightarrow H_2O(l) + CO_2 (g)$

10. moles of Na_2CO_3 = 0.1 mol L^{-1} × 0.025 L

= 2.5×10^{-3} mol

11. moles of HCl = 2 × moles of Na_2CO_3

= 5×10^{-3} mol

Concentration of HCl = $\dfrac{\text{moles of HCl}}{\text{vol of HCl}}$

$$= \frac{5 \times 10^{-3}\ \text{mol}}{21.4 \times 10^{-3}\ \text{L}}$$

= 0.234 mol L^{-1}

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