2016

6. Which one of the following sets of titres indicates a systematic error if the actual volume being measured is 85.2 mL?

(a)	85.1 mL,	85.1 mL,	85.3 mL,	85.5 mL
(b)	65.2 mL,	75.2 mL,	85.2 mL,	95.2 mL
(c)	85.2 mL,	85.3 mL,	85.1 mL,	85.1 mL
(d)	87.3 mL,	86.9 mL,	89.1 mL,	88.2 mL

2016

7. In an acid-base titration, which of the following is **least** likely to cause an error in the calculated concentration?

(a) using a funnel in the burette and leaving it in the same place for each titration
(b) measuring the volume at the bottom of the meniscus
(c) each member of the experimental team taking turns to measure the burette
(d) rinsing the burette with distilled water before the titration

2016

9. How many moles of a diprotic acid would be required to neutralise 1 mole of sodium hydroxide?

(a) 0.5
(b) 1.0
(c) 1.5
(d) 2.0

2016

10. Which one of the following represents a conjugate acid-base pair?

(a) N^{3-}/CN^-
(b) NH_3/NH_2^-
(c) CH_3CH_2OH/CH_3CHO
(d) H_3PO_4/PO_4^{3-}

2016

11. Which of the following equations **best** represents the self-ionisation of water according to the Brønsted-Lowry model?

(a) $H_2O(\ell) \rightleftharpoons H^+(aq) + OH^-(aq)$
(b) $H_2O(\ell) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$
(c) $2\,H_2O(\ell) \rightleftharpoons H_3O^+(aq) + 2\,OH^-(aq)$
(d) $2\,H_2O(\ell) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$

2016

12. The **best** definition of the equivalence point in an acid-base titration is the point at which the

(a) indicator changes colour.
(b) volume of acid equals the volume of base.
(c) pH of the solution is 7.
(d) mole ratio of acid to base is equal to their stoichiometric ratio.

2016

Question 31 **(6 marks)**

(a) Select **one** basic, **one** acidic and **one** neutral salt from the list below to complete the table. (3 marks)

KCN, NH_4Cl, $Mg_3(PO_4)_2$, $NaNO_3$, $KHCO_3$, $NaCH_3COO$, KCl

Acidic salt	Neutral salt	Basic salt

(b) Use the Brønsted-Lowry model to explain why the pH of ammonia solution is greater than 7.0 at 25 °C. Incorporate at least **one** appropriate equation in your answer. (3 marks)

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2016

Question 32 **(6 marks)**

(a) A buffer of carbonic acid (H_2CO_3)/hydrogencarbonate (HCO_3^-) is present in blood plasma to maintain a pH between 7.35 and 7.45. Write an equation to show the relevant species present in a carbonic acid/hydrogencarbonate buffer solution. (2 marks)

(b) Explain why 300.0 mL of 1.00 mol L^{-1} carbonic acid/hydrogencarbonate buffer does **not** change in pH significantly when 3 drops of 1.00 mol L^{-1} $HC\ell$ are added to it, yet when 3 drops of 1.00 mol L^{-1} $HC\ell$ are added to 300.0 mL of distilled water there is a significant change in pH? (4 marks)

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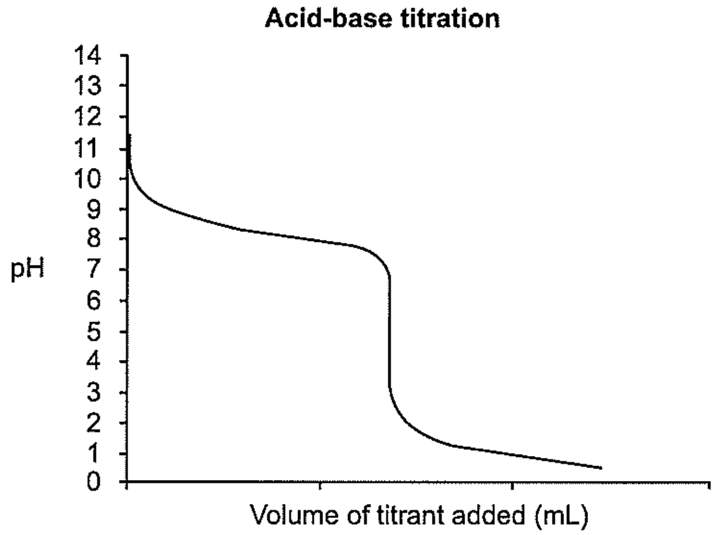
2016

Question 34 **(6 marks)**

The data below were collected from an acid-base titration.

(a) Label the equivalence point on the titration curve below using an arrow and record the pH value at this point. (2 marks)



pH value at equivalence point: ______________________

(b) Select an indicator from the table below that would be **best** for this titration and justify your choice. (4 marks)

Indicator	Low pH colour	Transition pH range	High pH colour
Methyl Yellow	red	2.1 – 3.3	yellow
Bromocresol Green	yellow	3.8 – 5.4	blue
Bromothymol Blue	yellow	6.0 – 7.6	blue
Phenolphthalein	colourless	8.3 – 10.0	pink
Alzarine Yellow R	yellow	10.2 – 12.0	red

Indicator: ______________________

Justification: ______________________

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2016

Question 42 **(26 marks)**

Acid rain is a significant issue in many industrialised areas of the world; particularly around power stations using fossil fuels. Legislation has been developed in Australia to minimise the formation of sulfur dioxide, SO_2(g), such as from the use of low-sulfur fuels in automobiles, which can cause acid rain. Normal rain has a pH of about 5.6; it is slightly acidic because carbon dioxide, CO_2(g) dissolves into it, forming weak carbonic acid. Rain with a pH less than 4.4 is usually classified as acid rain.

Testing was carried out on a rainwater sample taken near a coal-fired power station by titration, using sodium hydroxide solution, NaOH(aq). Standardisation of the sodium hydroxide solution was carried out before it was used in the titration. An anhydrous sodium carbonate, Na_2CO_3(s), primary standard was used to standardise a hydrochloric acid solution, $HC\ell$(aq) and subsequently used to standardise the NaOH(aq) solution.

Sodium carbonate, Na_2CO_3(s) was heated at 110 °C in a drying oven for 1 hour before 6.08×10^{-4} g was dissolved in distilled water to make 2.00 L of the primary standard. Three 25.0 mL aliquots of $HC\ell$(aq) were titrated and an average titre of 16.4 mL was required for neutralisation.

(a) Demonstrate, by means of calculation, that the concentration of $HC\ell$(aq) solution is 3.76×10^{-6} mol L^{-1}. (5 marks)

(b) Outline **two** reasons why sodium hydroxide, NaOH(s) is **not** a suitable primary standard for this titration. (2 marks)

One:

Two:

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An average titre of 21.3 mL of the standardised (3.76 x 10^{-6} mol L^{-1}) HCℓ(aq) solution was required to neutralise 25.0 mL aliquots of NaOH(aq) solution.

(c) Calculate the concentration of the NaOH(aq) solution. (3 marks)

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The standardised NaOH(aq) solution was then used for the titration of a rainwater sample. A 100.0 mL sample of rain water was collected near a coal-fired power station and diluted to 250.0 mL with distilled water in a volumetric flask. 25.0 mL aliquots of the diluted rainwater were used in the titration.

(d) Complete the table below to state with what the following pieces of glassware should be rinsed for this titration. (3 marks)

Glassware	Final rinse
Burette	
Conical flask	
Pipette	

The titre values obtained for the rainwater sample are shown in the table below:

Titre volume of NaOH (mL)				Average titre volume (mL)
Trial 1	Trial 2	Trial 3	Trial 4	
21.81	19.64	19.67	19.66	

(e) Calculate the average titre volume and record it in the table above. (1 mark)

2016
Question 42 (continued)

(f) Calculate the pH of the undiluted rainwater sample. Determine if it would be classified as acid rain or not. (6 marks)

(g) If carbon dioxide, $CO_2(g)$ alone accounts for rain with a pH of 5.60, then calculate the volume of sulfur dioxide, $SO_2(g)$ at 16.0 °C and 97.2 kPa, that would also need to be dissolved to produce 0.100 L of an acid rain sample with a pH of 4.0. Use the equation below.

$$SO_2(g) + H_2O(\ell) \rightleftharpoons H_2SO_3(aq)$$

For this calculation, assume the complete ionisation of $H_2SO_3(aq)$. (6 marks)

End of questions

Suggested working time: 50 minutes.

2017
1. Which one of the following pairs contains a strong acid and a weak acid?

(a) $HC\ell$ and NaOH
(b) $MgCO_3$ and CH_3COOH
(c) NH_3 and KOH
(d) HNO_3 and H_2CO_3

DO NOT

2017
8. The indicator HIn is used in a titration between hydrochloric acid and magnesium hydroxide solutions. The following equation represents how the indicator works.

$$\underset{\text{green}}{HIn(aq)} \leftrightharpoons H^+(aq) + \underset{\text{purple}}{In^-(aq)}$$

The indicator is added to 20.0 mL of magnesium hydroxide solution in a conical flask and the hydrochloric acid is added via a burette until the end point is observed. The acidic and basic solutions are of similar concentrations and the flask is swirled continuously as the acid is added.

Which one of the following statements describes the expected observations for the colour of the solution in the conical flask?

(a) The solution starts green and turns purple after the addition of approximately 10 mL.
(b) The solution starts green and turns purple after the addition of approximately 40 mL.
(c) The solution starts purple and turns green after the addition of approximately 10 mL.
(d) The solution starts purple and turns green after the addition of approximately 40 mL.

DO NOT WRITE IN TH

2017
18. The acidification of oceans due to their increased concentrations of carbon dioxide decreases the rate and amount of calcification in some marine organisms, e.g. shellfish and coral reefs.

Which one of the following equations **best** represents the chemistry involved in decreasing the rate and amount of calcification?

(a) $2\,H^+ + CaCO_3 \rightarrow Ca^{2+} + H_2O + CO_2$
(b) $CO_2 + H_2O + CO_3^{2-} \rightarrow 2\,HCO_3^-$
(c) $4\,H^+ + 2\,CO_3^{2-} \rightarrow H_2CO_3 + H_2O + CO_2$
(d) $CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$

2017

Question 29 **(10 marks)**

In a beaker 12.00 mL of 0.0334 mol L^{-1} sulfuric acid solution, $H_2SO_4(aq)$, is added to 32.50 mL of 0.0288 mol L^{-1} potassium hydroxide solution, KOH(aq).

(a) Identify the limiting reagent in this reaction. Show **all** workings. (5 marks)

(b) Calculate the final concentration of the excess reagent. Show **all** workings. (3 marks)

(c) Calculate the pH of the final solution. Show **all** workings. (2 marks)

2017

Question 31 **(8 marks)**

Water is capable of self-ionisation.

(a) Write an equation for the self-ionisation of water. (2 marks)

(b) Write the equilibrium constant expression for the self-ionisation of water. (1 mark)

(c) The equilibrium constant for the self-ionisation of water K_w is 1.00×10^{-14} at 25 °C. What does this value indicate about this reaction? (1 mark)

The K values for the self-ionisation of water at 100.0 kPa are given here for a number of different temperatures.

Temperature (°C)	K value
0	0.114×10^{-14}
25	1.00×10^{-14}
50	5.48×10^{-14}
75	19.9×10^{-14}
100	51.3×10^{-14}

(d) Calculate the pH of water at 50 °C. (2 marks)

(e) Is water acidic, basic or neutral at 50 °C? State a reason for your answer. (2 marks)

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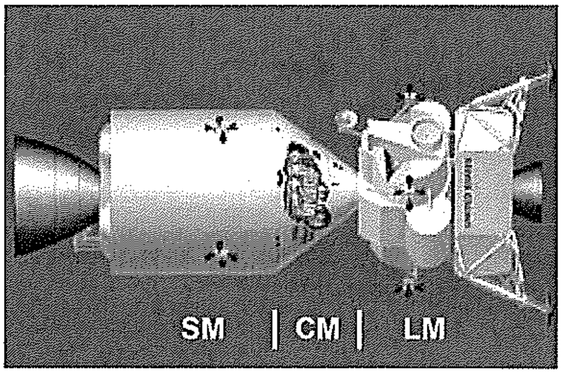
2017

Question 37 **(24 marks)**

In 1971, the seventh manned Apollo mission, Apollo 13, was launched and expected to land on the moon. Two days into the mission, one of the oxygen tanks exploded. The mission was aborted, but in order for the spacecraft to return to Earth safely, many problems needed to be solved. A number of them involved chemistry.



The spacecraft consisted of three sections:

- the Service Module (SM)
- the Command Module (CM)
- the Lunar Module (LM).

The Lunar Module was designed to hold two astronauts for the short trip between lunar orbit and the moon's surface. On the trip back to Earth, the astronauts were required to spend more time than expected in the lunar module.

One of the problems encountered was how to remove the carbon dioxide breathed out by the astronauts from the atmosphere in the spacecraft. This was done by reacting it with lithium hydroxide, which was housed in canisters.

(a) Write an equation for the reaction between carbon dioxide gas and lithium hydroxide to form lithium carbonate and water. (2 marks)

(b) A typical lithium hydroxide canister contains 750.0 g of lithium hydroxide. What mass of carbon dioxide would be required to react completely with the lithium hydroxide in each canister? (3 marks)

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On returning to Earth, a partially-used canister was analysed to determine the percentage of lithium hydroxide remaining.

A 12.33 g sample of the canister contents was dissolved in distilled water and sufficient barium nitrate solution was added to precipitate the carbonate ions. The solution was filtered and transferred to a 500.00 mL volumetric flask, which was then filled to the mark. 20.00 mL aliquots of the solution were transferred to conical flasks and titrated against a standardised 0.116 mol L^{-1} solution of hydrochloric acid.

The following results were obtained from the titrations.

Volume (mL)	1	2	3	4
Final Volume	18.55	34.90	18.50	34.85
Initial Volume	1.50	18.55	2.20	18.50
Titre				

(c) Complete the results table above and calculate the percentage of lithium hydroxide remaining in the canister. (6 marks)

2017
Question 37 (continued)

(d) From the list of indicators given below, identify **two** that could be used in the titration between lithium hydroxide and hydrochloric acid. Explain why both indicators are appropriate choices for this titration. (4 marks)

Indicator	Low pH colour	Transition pH range	High pH colour
Methyl violet	yellow	0.0 – 1.6	blue
Bromothymol blue	yellow	6.0 – 7.6	blue
Phenolphthalein	colourless	8.3 – 10.0	pink
Thymolphthalein	colourless	9.4 – 10.6	blue

Indicator one: ______________________________

Indicator two: ______________________________

Explanation: ______________________________

____

____

____

____

Suggested working time: 50 minutes.

DO NOT WRITI

2018

1. An acid-base indicator is red in acid, green in base and yellow in neutral solutions. The indicator was originally in sodium hydroxide solution and excess nitric acid was added dropwise. Which of the following shows the order of colour that would be shown by the indicator?

(a) red only
(b) yellow, green, red
(c) green, yellow, red
(d) yellow, red

2018

3. Which of the following solutions has the **greatest** electrical conductivity?

(a) 0.010 mol L^{-1} methanoic acid, HCOOH(aq) ($K_a = 1.8 \times 10^{-4}$)
(b) 0.100 mol L^{-1} methanoic acid, HCOOH(aq) ($K_a = 1.8 \times 10^{-4}$)
(c) 0.010 mol L^{-1} hypochlorous acid, $HC\ell O$(aq) ($K_a = 3.5 \times 10^{-8}$)
(d) 0.100 mol L^{-1} hypochlorous acid, $HC\ell O$(aq) ($K_a = 3.5 \times 10^{-8}$)

See next page

2018

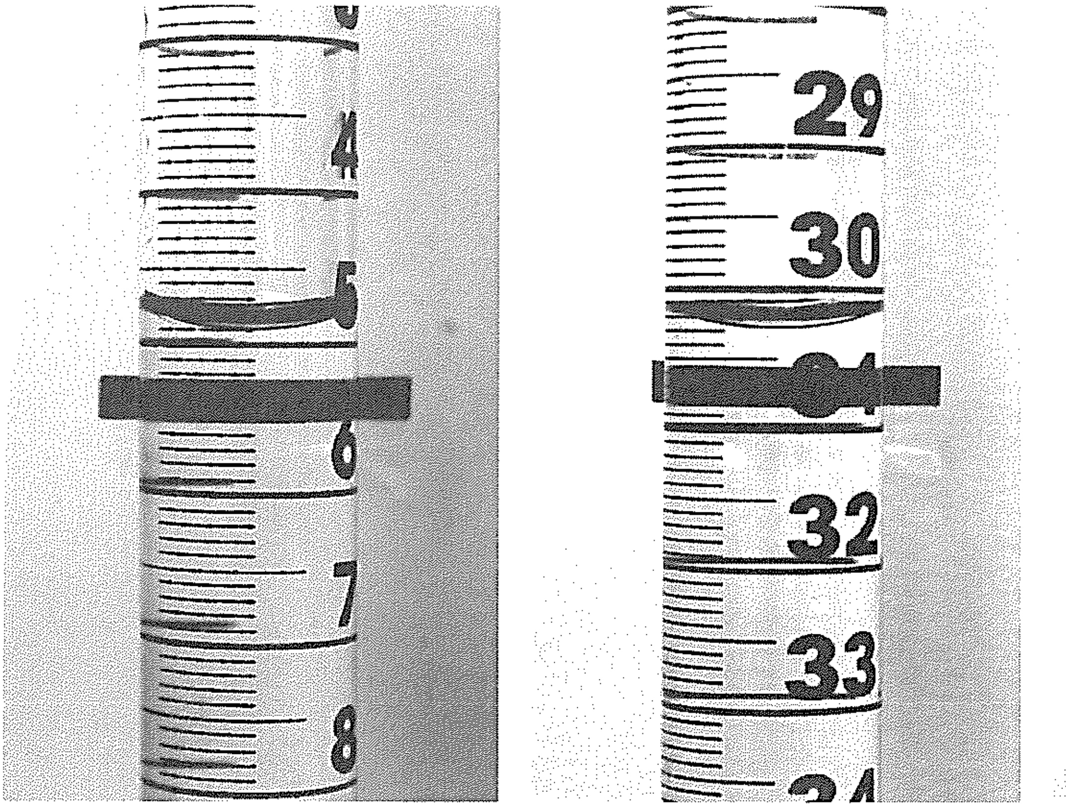
8. Consider the hydrolysis equation below.

$$CH_3NH_2(aq) + H_2O(\ell) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

Which of the following are conjugate acid-base pairs?

(i) CH_3NH_2 and H_2O
(ii) CH_3NH_2 and $CH_3NH_3^+$
(iii) H_2O and OH^-
(iv) $CH_3NH_3^+$ and OH^-

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



2018

12. The photographs above show a Class A burette before (left) and after (right) a titration. Use these photographs to determine the titre volume used in this titration.

(a) 25.3 ± 0.05 mL
(b) 25.33 ± 0.05 mL
(c) 25.39 ± 0.10 mL
(d) 26.6 ± 0.1 mL

2018

13. The table below shows the volumes added from a burette during a titration.

Titre (mL)					
1	2	3	4	5	6
19.23	19.94	19.98	19.94	20.02	19.94

What value should be used in the titration calculations?

(a) 19.84 mL
(b) 19.94 mL
(c) 19.95 mL
(d) 19.96 mL

2018

18. Which of the following sets of equations corresponds correctly to the acid-base theory of the chemist/s who proposed it?

	Chemist/s	Equations
(a)	Johannes Brønsted and Thomas Lowry	$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
	Humphry Davy	$HNO_3(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + NO_3^-(aq)$
	Svante Arrhenius	$HC_2H_3O_2(aq) + H_2O(\ell) \rightleftharpoons C_2H_3O_2^-(aq) + H_3O^+(aq)$
(b)	Johannes Brønsted and Thomas Lowry	$HC_2H_3O_2(aq) + CH_3OH(aq) \rightleftharpoons CH_3OH_2^+(aq) + C_2H_3O_2^-(aq)$
	Humphry Davy	$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$
	Svante Arrhenius	$NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
(c)	Johannes Brønsted and Thomas Lowry	$HC\ell(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + C\ell^-(aq)$
	Humphry Davy	$H_3O^+(aq) + OH^-(aq) \rightarrow 2\ H_2O(\ell)$
	Svante Arrhenius	$HNO_3(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + NO_3^-(aq)$
(d)	Johannes Brønsted and Thomas Lowry	$NH_3(aq) + CH_3OH(aq) \rightleftharpoons CH_3O^-(aq) + NH_4^+(aq)$
	Humphry Davy	$2\ HC\ell(aq) + Mg(s) \rightarrow H_2(g) + Mg^{2+}(aq) + 2C\ell^-(aq)$
	Svante Arrhenius	$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

See next page

Section Two: Short answer

35% (79 Marks)

This section has **9** questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

2018

Question 26

(10 marks)

Solid copper(II) hydroxide is added to excess 0.100 mol L^{-1} carbonic acid solution.

(a) Write the balanced equation, with appropriate state symbols, for the reaction that takes place between the copper(II) hydroxide and carbonic acid. (3 marks)

(b) Predict **all** visible changes that would be observed, if any, while the reactants are mixed together and afterwards. (3 marks)

(c) Predict **two** observations that would be different if excess 0.100 mol L^{-1} hydrochloric acid was used instead of the 0.100 mol L^{-1} carbonic acid. (2 marks)

One: ______

Two: ______

(d) State **two** personal safety measures the experimenter should take when conducting these experiments. (2 marks)

One: ______

Two: ______

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2018

Question 27 **(12 marks)**

Phosphoric acid, $H_3PO_4(aq)$, is a weak, triprotic acid.

(a) Write the ionisation equation for phosphoric acid in water which shows the **second** proton of the acid being released into solution. (2 marks)

Magnesium carbonate, $MgCO_3(s)$, is an ingredient of a commonly-used antacid.

(b) Other than water, list **three** species (elements, compounds, ions) that would be found in the reacting vessel open to the atmosphere at the completion of the reaction between excess solid magnesium carbonate and an aqueous solution of phosphoric acid. (3 marks)

One: ______________________________

Two: ______________________________

Three: ______________________________

Sodium hydroxide solution, NaOH(aq), was used in a titration to determine the concentration of phosphoric acid.

(c) Other than it having too low a molar mass, state **two** reasons why the concentration of the sodium hydroxide solution cannot be reliably determined by weighing out an amount of solid sodium hydroxide and dissolving it in a known volume of distilled water. (2 marks)

One: ______________________________

____

____

Two: ______________________________

____

____

The table below lists some acid-base indicators and the colour that each appears over a pH range.

Indicator	Colour		pH range
	Acid	Base	
Universal indicator	red	violet	1.0 – 14.0
Methyl orange	red	yellow	3.2 – 4.4
Bromocresol green	yellow	blue	3.8 – 5.4
Litmus	red	blue	4.5 – 8.3
Methyl red	yellow	red	4.8 – 6.0
Bromothymol blue	yellow	blue	6.0 – 7.6
Phenol red	yellow	red	6.8 – 8.4
Phenolphthalein	colourless	magenta	8.2 – 10.0

(d) Select the acid-base indicator from the table above that would be most suitable for the titration between phosphoric acid, $H_3PO_4(aq)$, and sodium hydroxide solution, $NaOH(aq)$. Justify your choice of indicator, including **one** relevant equation. (5 marks)

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2018

Question 29 **(15 marks)**

Wines and other alcoholic drinks can spoil when the alcohol (ethanol) they contain oxidises to acetic acid (ethanoic acid). An acidity regulator, monosodium citrate, is often added to drinks to prevent the formation of acetic acid. The monosodium citrate does this by acting as a buffer.

A citric acid/dihydrogen citrate ion buffer can be prepared from citric acid, $H_3C_6H_5O_7$ and monosodium citrate, $NaH_2C_6H_5O_7$.

(a) Write an equation for the buffer system ($H_3C_6H_5O_7$ / $H_2C_6H_5O_7^-$) containing citric acid, $H_3C_6H_5O_7$ and monosodium citrate, $NaH_2C_6H_5O_7$. (2 marks)

Buffers that contain equal concentrations of both components are most effective. This buffer solution is prepared by mixing 100.0 mL of citric acid solution with 100.0 mL of monosodium citrate solution. The citric acid solution, $H_3C_6H_5O_7(aq)$, has a concentration of 0.200 mol L^{-1}.

(b) Calculate the mass of sodium citrate, $NaH_2C_6H_5O_7$, that would need to be dissolved in 100.0 mL of distilled water to make the most effective buffer solution. (3 marks)

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(c) If a citric acid buffer was prepared to a pH of 3.5, what would be the concentration of the hydroxide ion at 25.0 °C? (3 marks)

(d) Explain why only a small change in pH is observed in this buffer solution when a small amount of sodium hydroxide solution is added, compared to adding a similar amount of sodium hydroxide solution to a system that is not a buffer solution. Your answer should refer to the buffer equilibrium in part (a). (4 marks)

(e) Increasing the concentration of this buffer solution will increase its buffering capacity. Explain this statement. (3 marks)

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2018
Question 31 **(6 marks)**

Arsenic acid, $H_3AsO_4(aq)$, is a weak, triprotic acid that can be produced from the element directly through the reaction with water and ozone, $O_3(g)$. This reaction can be represented by the equation below.

$$2\,As(s) + 3\,H_2O(\ell) + 5\,O_3(g) \rightleftharpoons 2\,H_3AsO_4(aq) + 5\,O_2(g)$$

(a) Write the equilibrium constant expression for this reaction. (2 marks)

(b) The arsenate ion, $HAsO_4^{2-}(aq)$, is amphoteric, meaning it can act as an acid and as a base.

(i) With the aid of equations, describe the amphoteric nature of $HAsO_4^{2-}$ in this aqueous solution. (3 marks)

(ii) State why an aqueous solution containing $HAsO_4^{2-}$ is found to have a pH>7 at 25 °C. (1 mark)

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2018

Question 32 **(4 marks)**

Many marine animals have shells that consist mainly of calcium carbonate. These shells are built from dissolved calcium and carbonate ions.

As the amount of atmospheric carbon dioxide increases, more carbon dioxide dissolves in the ocean. There is increasing concern that as more carbon dioxide dissolves, it will be more difficult for calcium carbonate to form.

Use the following equations to explain why an increasing concentration of atmospheric carbon dioxide will decrease the formation of calcium carbonate.

$CO_2(g)$	$\rightleftharpoons$	$CO_2(aq)$	Equation 1
$CO_2(aq) + H_2O(\ell) + CO_3^{2-}(aq)$	$\rightleftharpoons$	$2\ HCO_3^-(aq)$	Equation 2
$Ca^{2+}(aq) + CO_3^{2-}(aq)$	$\rightleftharpoons$	$CaCO_3(s)$	Equation 3

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Suggested working time: 50 minutes.

2019

1. Boric acid, which is a weak acid, was titrated with standardised sodium hydroxide solution.

Which one of the indicators listed below would be the **most** suitable to use in this titration?

	Indicator	Range of colour change (pH)
(a)	thymol blue	1 – 3
(b)	bromocresol green	3.8 – 5.4
(c)	cresolphthalein	8 – 10
(d)	alizarin yellow	10 – 12

2019

8. A distinguishing feature of strong acids is that they

(a) produce high concentrations of hydronium ions (H_3O^+) in solution.
(b) have high acidity constants.
(c) contain loosely-held hydrogen ions (H^+) in solution.
(d) ionise rather than dissociate in water.

2019

12. The United Nations Kyoto Protocol and the Intergovernmental Panel on Climate Change aim to secure a global commitment to reducing greenhouse gas emissions over the next few decades.

Which of the following equations shows the production of a greenhouse gas?

(i) $O_2 + O \rightarrow O_3$
(ii) $C + O_2 \rightarrow CO_2$
(iii) $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$
(iv) $CO_2 + 4\,H_2 \rightarrow CH_4 + 2\,H_2O$
(v) $NH_4NO_3 \rightarrow 2\,H_2O + N_2O$

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

2019

16. Which one of the following statements about an aqueous solution with a pH less than zero at 25.0 °C is true?

(a) Such a solution cannot exist at 25.0 °C.
(b) There are no $OH^-(aq)$ ions present.
(c) The concentration of $H^+(aq)$ ions is much greater than the concentration of $OH^-(aq)$ ions.
(d) There are no $H^+(aq)$ ions present as they have formed water molecules through the process of neutralisation.

2019

24. Which one of the following underlined species is acting as an acid?

(a) $\underline{CH_3CH_2CH_2CH_2NH_2} + CH_3COOH \rightleftharpoons CH_3CH_2CH_2CH_2NH_3^+ + CH_3COO^-$
(b) $HSO_3^- + NH_3 \rightleftharpoons \underline{SO_3^{2-}} + NH_4^+$
(c) $NH_4^+ + CH_3COO^- \rightleftharpoons \underline{NH_3} + CH_3COOH$
(d) $\underline{[Fe(H_2O)_6]^{3+}} + H_2O \rightleftharpoons [Fe(OH)(H_2O)_5]^{2+} + H_3O^+$

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The following information relates to Questions 19, 20 and 21.

A group of Year 12 Chemistry students wanted to know whether increasing ocean acidity increases the rate at which sea shells, $CaCO_3$, dissolve. They went to a beach to collect seawater and sea shells. In their school laboratory they crushed the sea shells and added 2.00 g of the resulting powder to five clean 250 mL beakers, each of which had been placed on top of its own electronic balance.

They split the seawater into five portions and bubbled carbon dioxide gas into four of the portions for different amounts of time. This gave the students 'natural' seawater plus four seawater samples of different pH. The various seawaters (150 mL portions) were then added to the beakers, with the weight of each beaker and its contents being recorded at timed intervals.

19. Which one of the following proposes a suitable hypothesis for the investigation?

(a) As the seawater becomes more acidic, the sea shell powder will dissolve faster.
(b) The sea shell powder will dissolve fastest in the most acidic seawater.
(c) Adding carbon dioxide to seawater changes the pH of the seawater.
(d) More of the sea shell powder will dissolve as time progresses.

20. Which one of the following pairs of statements on the validity and reliability of the investigation is correct?

	Validity	Reliability
(a)	It is valid because the investigation allows them to determine if seawater pH affects the rate of sea shell dissolution.	It is reliable because the trials were performed in a laboratory.
(b)	It is not valid because the investigation was simulated in a laboratory and not performed in a real ocean.	It is not reliable because only one trial was performed at each different pH value.
(c)	It is not valid because the investigation was simulated in a laboratory and not performed in a real ocean.	It is reliable because trials were performed at five different pH values.
(d)	It is valid because the investigation allows them to determine if seawater pH affects the rate of sea shell dissolution.	Its reliability could be improved by conducting multiple trials at each different pH value.

21. Which of the following reactions is/are likely to be occurring within the beakers during the investigation?

(i) $CaCO_3(s) + 2\,H_3O^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + 3\,H_2O(aq)$
(ii) $CaCO_3(s) + CO_2(aq) + H_2O(\ell) \rightleftharpoons Ca^{2+}(aq) + 2\,HCO_3^-(aq)$
(iii) $Ca(OH)_2(s) + 2\,H_3O^+(aq) \rightleftharpoons Ca^{2+}(aq) + 4\,H_2O(g)$
(iv) $HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$

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

See next page

Section Two: Short answer **35% (106 Marks)**

This section has **10** questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

2019

Question 26 **(9 marks)**

Dilute hydrochloric acid, $HC\ell(aq)$, is added to three labelled test tubes.

(I) Excess copper metal, Cu(s), is added to the first test tube.
(II) Excess copper(II) oxide, CuO(s), is added to the second test tube.
(III) Excess copper(II) carbonate, $CuCO_3(s)$, is added to the third test tube.

(a) Describe the contents of the first and second test tubes once **any** reactions are complete. (4 marks)

Test Tube	Description
(I)	
(II)	

(b) Write the balanced equation, with appropriate state symbols, for the reaction that takes place between the copper(II) oxide and the hydrochloric acid. (3 marks)

(c) If the labels of test tubes (II) and (III) became smudged, describe **all** the observations that could be used to distinguish between these test tubes once **any** reactions are complete. (2 marks)

2019

Question 27 **(13 marks)**

Calcium hypochlorite, $Ca(OC\ell)_2(s)$, is used for the treatment of water in swimming pools and is sold as 'pool chlorine'.

(a) Explain why a basic solution is produced when 'pool chlorine' is dissolved in the pool water. Include an equation in your answer. (4 marks)

Equation

A pool chemical used to counteract the basicity of the pool water is hydrochloric acid, $HC\ell(aq)$. It is sold as 'pool acid'.

(b) State what happens to the pH of the pool water when 'pool acid' is added to the pool water. Include an equation to illustrate your statement. (3 marks)

Equation

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'Pool chlorine' and 'pool acid' must be stored separately from each other because calcium hypochlorite can react explosively on contact with hydrochloric acid. The equation for this reaction is given below.

$$Ca(OC\ell)_2(s) + 4\,HC\ell(aq) \rightarrow CaC\ell_2(aq) + 2\,H_2O(\ell) + 2\,C\ell_2(g)$$

(c) Sketch a clearly-labelled energy profile diagram illustrating the reaction between the 'pool chlorine' and the 'pool acid'. (6 marks)

A spare grid is provided at the end of this Question/Answer booklet. If you need to use it, cross out this attempt and indicate clearly that you have redrawn it on the spare page.

2019

Question 32 **(9 marks)**

From a measuring cylinder, 34.0 mL of 0.114 mol L^{-1} nitric acid, $HNO_3(aq)$, is added to a flask containing 44.5 mL of 0.0556 mol L^{-1} solution of calcium hydroxide, $Ca(OH)_2(aq)$. Determine the pH of the final solution.

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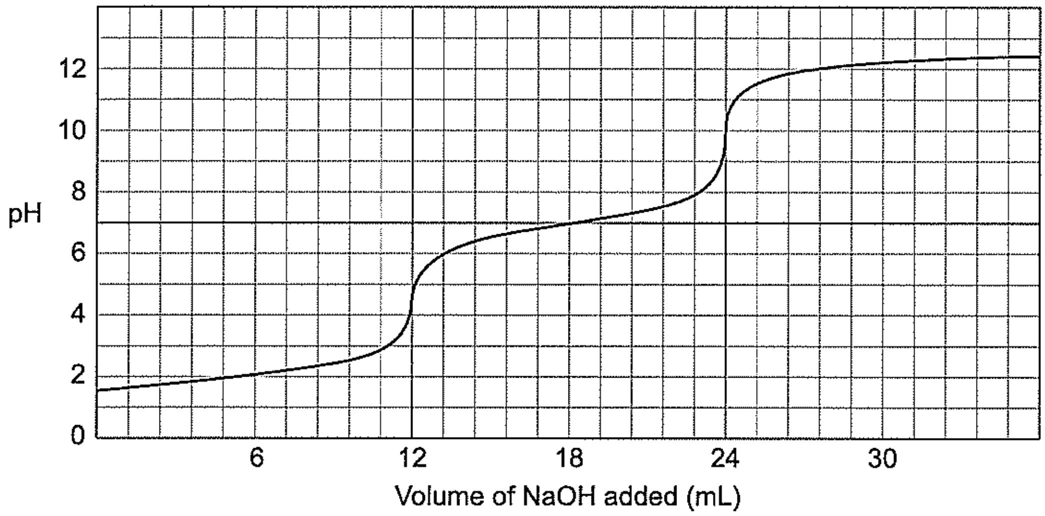
2019

Question 35 **(8 marks)**

Consider the following acid-base titration curve that is produced by the addition of 0.166 mol L^{-1} sodium hydroxide solution to 20.00 mL of an approximately 0.1 mol L^{-1} diprotic acid.



(a) (i) Indicate whether the diprotic acid is most likely to be sulfuric acid, $H_2SO_4(aq)$ or sulfurous acid, $H_2SO_3(aq)$, by **circling** your choice below. (1 mark)

Sulfuric acid Sulfurous acid

(ii) Making reference to the titration curve shown above, give **two** reasons for your answer. (2 marks)

One: ___

___

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Two: ___

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(b) Predict the effect (increase, decrease or no change) on the calculated concentration of the acid for the following two systematic errors that can occur in a titration and justify your choice. (4 marks)

Systematic Error		Effect on calculated concentration of acid (circle)	Justification
I	Only rinsing the pipette with distilled water before use	increase decrease no change	
II	Using an indicator with an end point of pH = 4.5	increase decrease no change	

(c) State **one** reason why these errors are classified as systematic errors rather than random errors. (1 mark)

End of Section Two

Section Three: Extended answer **40% (109 Marks)**

This section contains **six** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures and include appropriate units where applicable.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

2019

Question 36 **(20 marks)**

The ideal pH of human blood is 7.4. If the pH of a person's blood varies too much from this value, a serious condition can develop. If the pH is too low, it is called acidosis; if the pH is too high, it is called alkalosis. Death may occur if the pH drops below 6.8 or rises above 7.8.

One buffer system for maintaining acid-base balance in blood is the carbonic acid-hydrogencarbonate buffer.

During exercise, the muscles need more oxygen to produce energy. They produce carbon dioxide, CO_2, and hydronium ions, H_3O^+, which move from the muscles to the blood.

The relevant equilibrium equations for the carbonic acid-hydrogencarbonate buffer system are shown as follows.

Equation 1 $H_3O^+(aq) + HCO_3^-(aq) \rightleftharpoons H_2CO_3(aq) + H_2O(\ell)$

(a) Identify the **two** conjugate acid-base pairs on Equation 1 above, indicating clearly which is the acid and which is the base in each pairing. (2 marks)

2019 Q36 cont

(b) Write the equilibrium constant expression for Equation 1. (2 marks)

Carbonic acid further reacts to form water and carbon dioxide as shown in Equation 2.

Equation 2 $H_2CO_3(aq) \rightleftharpoons H_2O(\ell) + CO_2(aq)$

(c) Combine Equations 1 and 2, to create an overall equation that shows the relationship between $HCO_3^-(aq)$ and $CO_2(aq)$. (2 marks)

(d) Identify the effect on the blood's pH when each of the following components are removed: carbon dioxide and hydrogencarbonate ions. (2 marks)

Component removed	**Effect on pH** (circle your answer)		
carbon dioxide	increase	decrease	no effect
hydrogencarbonate ions	increase	decrease	no effect

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2019
Question 36 (continued)

The buffering capacity of the carbonic acid-hydrogencarbonate is greatest when the pH is between 5.1 and 7.1.

(e) State **two** conditions in terms of concentration that are necessary for this buffering capacity to be optimal. (2 marks)

One: ____

____

____

Two: ____

____

____

When the pH of the blood is too high, the kidneys can remove hydrogencarbonate ions, HCO_3^-, from the blood.

(f) Use Le Châtelier's Principle to demonstrate that the kidneys' action can help to prevent excessively high blood pH. (3 marks)

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When inhaling, oxygen is taken into the lungs and transferred to the blood; when exhaling, carbon dioxide is expelled.

During hyperventilation (very rapid and deep breathing) more carbon dioxide is being expelled from the body than it can produce. This upsets the oxygen/carbon dioxide balance and can cause dizziness and fainting. Hyperventilating results in lowering the carbon dioxide concentration in the blood, which can affect the pH of the blood.

The equation shown below illustrates the formation of hydronium ions within the blood system.

$$2\,H_2O(\ell) \;+\; CO_2(aq) \;\rightleftharpoons\; H_3O^+(aq) \;+\; HCO_3^-(aq)$$

A first-aid treatment for hyperventilation is the 'paper-bag treatment' whereby the patient breathes into a paper bag and so breathes back in the expelled breath, which contains a higher concentration of carbon dioxide.

(g) State the effect of the 'paper-bag treatment' on the pH of the blood and explain why it is an effective treatment for hyperventilation. (3 marks)

Another contributor to a potential imbalance of blood pH is the formation of lactic acid. The chemical name for lactic acid is 2-hydroxypropanoic acid, $C_3H_6O_3$.

(h) Draw the structural formula for lactic acid with **all** its functional groups circled and labelled. (4 marks)

2019
Question 39 **(13 marks)**

Herbicides are chemicals that kill plants, including weeds. The label of a commercially-available herbicide concentrate is shown below.

Generic Weed Killer

SUPER CONCENTRATE

Fast, effective, easy to apply.
Recommended by professional gardeners.

Ingredients:

155 g/L ± 5.00% sodium chloride
295 g/L ± 5.00% acetic (ethanoic) acid

A chemist was given the task of verifying the concentrations of sodium chloride and acetic (ethanoic) acid stated for this herbicide.

The sodium chloride content of the herbicide was analysed. It was found to be consistent within the tolerance of ± 5.00% of the stated concentration. The chemist then performed a series of titrations with sodium hydroxide to measure the acetic (ethanoic) acid concentration.

The herbicide solution used in the titrations was prepared by pipetting 5.00 mL of the concentrate into a 250.0 mL volumetric flask. The solution in the flask was then made up to the mark with distilled water.

A 20.00 mL sample of the diluted herbicide was pipetted into a conical flask and a few drops of a suitable indicator were added. This solution was then titrated with standardised 0.0947 mol L^{-1} NaOH solution.

After an initial 'rough titration', a further four titrations were performed. The results are shown in the following table.

(a) Complete the table and determine the average titre. (2 marks)

Titration number	Burette readings (mL)		
	Initial	Final	Titre
1	1.28	20.75	
2	20.75	40.19	
3	1.48	21.82	
4	21.82	41.21	
		Average titre	

(b) Identify with what solution each of these pieces of glassware should be rinsed prior to their use in these titrations. (3 marks)

Glassware item	Rinse solution
5.00 mL pipette	
20.00 mL pipette	
250.0 mL volumetric flask	

(c) Demonstrate whether or not the experimentally-determined value of the acetic (ethanoic) acid concentration matches the value given on the herbicide label, bearing in mind that a difference of ± 5.00% is considered acceptable. Show **all** workings and reasoning. (8 marks)

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2020

2. Which of the following classifies the given acids as monoprotic or polyprotic?

	Monoprotic	Polyprotic
(a)	HCl	CH_3COOH
(b)	CH_3CH_2COOH	H_2SO_4
(c)	CH_3COOH	CH_3CH_2COOH
(d)	H_2SO_4	HCl

2020

5. Which of the following statements about pure water are correct?

(i) Pure water is a weak electrolyte that undergoes self-ionisation.
(ii) The equilibrium constant for the ionisation of pure water at 25 °C is 1.00×10^{-14}.
(iii) Pure water ionises completely at 25 °C, hence $[H^+] = [OH^-]$.
(iv) The ionisation of pure water produces twice as many hydrogen ions as hydroxide ions.

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

2020

15. The reaction of aniline ($C_6H_5NH_2$) with water is an equilibrium process:

$$C_6H_5NH_2(\ell) + H_2O(\ell) \rightleftharpoons C_6H_5NH^-(aq) + H_3O^+(aq)$$

A conjugate acid-base pair in this process is

(a) $C_6H_5NH^-$ and H_2O
(b) $C_6H_5NH_2$ and $C_6H_5NH^-$
(c) $C_6H_5NH^-$ and H_3O^+
(d) H_3O^+ and $C_6H_5NH_2$

2020

25. A chemist performed an acid-base titration. The acid was in a burette and a pipette was used to deliver a known quantity of the base into a conical flask. Which of the following gives the final rinse solution for each of these pieces of equipment?

	Final rinse solution		
	Burette	Pipette	Conical flask
(a)	acid	water	base
(b)	acid	base	water
(c)	water	base	water
(d)	water	water	base

End of Section One

See next page

2020

17. Acid-base indicators

(a) are oxidising or reducing agents.
(b) change colour at a specific pH value.
(c) are strong acids or bases.
(d) are weak acids or bases.

2020

18. A chemist prepares solutions of nitrous acid and hydrocyanic acid that have the same concentration.

The K_a values of these acids are:

- nitrous acid (HNO_2) is 4.6×10^{-4}
- hydrocyanic acid (HCN) is 6.17×10^{-10}.

Which of these two acids is the stronger and which has the higher pH?

	Stronger acid	Higher pH
(a)	nitrous acid	nitrous acid
(b)	nitrous acid	hydrocyanic acid
(c)	hydrocyanic acid	hydrocyanic acid
(d)	hydrocyanic acid	nitrous acid

See next page

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Question 31 **(9 marks)**

The amount of carbon dioxide in the Earth's atmosphere is increasing, leading to more carbon dioxide dissolving in the oceans and hence ocean acidification.

(a) Complete the following sequence of equations to show what happens to carbon dioxide when it dissolves in water. (3 marks)

$$CO_2(g) + H_2O(\ell) \rightleftharpoons \boxed{\qquad\qquad}$$

$$\boxed{\qquad\qquad} + H_2O(\ell) \rightleftharpoons \boxed{\qquad\qquad} + H_3O^+(aq)$$

$$\boxed{\qquad\qquad} + H_2O(\ell) \rightleftharpoons \boxed{\qquad\qquad} + H_3O^+(aq)$$

(b) Other than death, state **two** consequences of the above sequence of equations on marine organisms with shells. (2 marks)

One: ____

____

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Two: ____

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(c) Use Le Châtelier's Principle and the sequence of equations in part (a) to predict what might happen, in relation to ocean acidification, if the United Nations Kyoto Protocol is discarded. Explain your reasoning. (4 marks)

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2020
Question 37 (17 marks)

A student standardised an approximately 0.1 mol L^{-1} sodium hydroxide solution with a standard 0.0958 mol L^{-1} hydrochloric acid solution. The student pipetted 20.00 mL of the sodium hydroxide solution into a conical flask, added 2 drops of indicator and titrated to the end point with the hydrochloric acid. Five titrations were performed.

(a) Below is a table of the student's results. Determine the average titre. (1 mark)

Titration number	Burette readings (mL)		
	Initial	Final	Titre
Rough	1.35	22.45	21.10
1	21.45	41.50	20.05
2	3.50	23.65	20.15
3	23.65	43.05	19.40
4	2.75	22.85	20.10
		Average titre	

(b) Show that the concentration of the sodium hydroxide solution is 0.0963 mol L^{-1}, correct to three significant figures. (3 marks)

The student used the standardised sodium hydroxide solution to determine the percentage by mass of phosphoric acid (H_3PO_4) in a commercial brand of rust remover.

The student weighed a sample of the rust remover into a small beaker and then transferred it to a 250.0 mL volumetric flask. The beaker was rinsed several times with distilled water and each time the wash water was added to the volumetric flask. The volumetric flask was then made up to the mark with more distilled water. The student titrated 10.00 mL aliquots of the diluted rust remover with the standardised sodium hydroxide solution.

The student's results were as follows:

- mass of undiluted rust remover = 10.05 g
- average titre of standardised sodium hydroxide solution = 24.45 mL.

(c) Calculate the percentage, by mass, of phosphoric acid in the original, undiluted rust remover. Express your answer to the appropriate number of significant figures. Assume that the rust remover contains no other substances that react with sodium hydroxide. (8 marks)

2020
Question 37 (continued)

The following table provides some information about three different acid-base indicators.

Indicator	pH range	Acid colour	Base colour
methyl orange	3.2 – 4.4	red	yellow
bromothymol blue	6.0 – 7.6	yellow	blue
phenolphthalein	8.3 – 10.0	colourless	pink

(d) Which of these indicators should the student use when titrating phosphoric acid with sodium hydroxide? Justify your choice with the aid of a relevant balanced chemical equation. (5 marks)