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NZQA | Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 2 Chemistry 2025

91166 Demonstrate understanding of chemical reactivity

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of chemical reactivity.	Demonstrate in-depth understanding of chemical reactivity.	Demonstrate comprehensive understanding of chemical reactivity.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table and other reference material are provided in the Resource Booklet L2–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–16 in the correct order and that none of these pages is blank.

Do not write in any margins (⁝⁝⁝). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Achievement TOTAL 12

QUESTION ONE

Ocean acidification occurs due to carbon dioxide in the atmosphere dissolving into seawater and forming various acids.

One step of this process is shown below:

$$H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq) \qquad K_c = 4.30 \times 10^{-7}$$

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

$$K_c = \frac{[HCO_{3(aq)}][H_3O_{(aq)}]}{[H_2CO_{3(aq)}][H_2O_{(\ell)}]}$$

(ii) The value of the equilibrium constant is 4.30×10^{-7}.

Explain what this indicates about the ratio of products and reactants.

There is significantly more products than reactants in the solution

(iii) Global oceanic temperatures have been increasing since the industrial revolution.

Predict the impact on the position of equilibrium as temperature increases, if the enthalpy of this reaction is $\Delta_r H = -3.85$ kJ mol^{-1}.

In your answer:

- describe the effect of temperature on the forward and reverse reactions
- explain any changes that would occur to the value of K_c.

You do not need to perform any calculations.

exothermic releases energy ΔH -

The forward reaction is exothermic since $\Delta_r H$ is negative, and therefore the backward reaction is endothermic.

(b) (i) Calculate the pH of a 0.25 mol L^{-1} solution of hydrochloric acid, HCl.

$-\text{Log } 0.25$

$= 0.6$

(ii) Calculate the concentration of hydroxide ions, OH^-, in a solution of hydrochloric acid, HCl, with a pH of 1.3.

$c = \frac{n}{v}$

$10^{-1.3}$

$= 0.050 \text{ mol L}^{-1}$

(iii) Compare the pH and conductivity of hydrochloric acid, HCl and carbonic acid, H_2CO_3.

	Hydrochloric Acid, HCl	**Carbonic Acid, H_2CO_3**
Acid Strength	Strong	Weak
pH	1.0	4.7
Concentration	0.10 mol L^{-1}	0.10 mol L^{-1}

In your answer, include:

- definitions for strong and weak acids
- an explanation of the pH for each solution (HCl and H_2CO_3) and relevant equations
- a definition for conductivity
- an explanation for the conductivity of each solution (HCl and H_2CO_3).

~~Strong and weak~~ acids become stronger the more completely they dissociate in solution, with week acids only partially dissociating. ~~Stronger acids also~~ concentrated acids ~~the~~ are ~~strong~~ more potent and have a higher ~~PH~~ pH, which can be calculated using the formula $pH = -\log[acid]$. ~~pH = -log[H_2CO_3]~~ $-\log[0.1] = 1$, the pH for HCl comes to 1, which is it's actual pH level, however H_2CO_3, an acid with the same concentration, comes to a less acidic pH level of 4.7. This is because the strength of the acid (how completely it dissociates) has an impact on the pH, with H_2CO_3 being weaker means it only partially dissociates, and therefore has a lower pH. Conductivity can be cond from delocalised, free flowing ions. HCl ~~has many free flowing~~ and H_2CO_3 solutions have such freeflowing ions, and as such are conductive, with HCl having more dissociation it is more conductive with having more freeflowing ions.

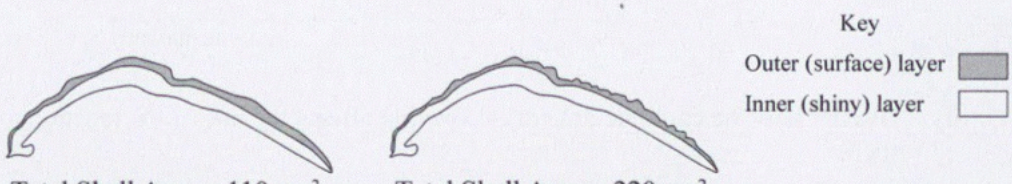
QUESTION TWO

Pāua are a species of marine organism, which form their shells from layers of calcium carbonate, $CaCO_3$, and proteins. This layering leads to a very strong shell structure with a dull, pitted outer layer and smooth, shiny inner layer. Unfortunately, the calcium carbonate reacts with acid in the oceans leading to degradation of their shells.

(a) (i) Describe the chemical observations made when the calcium carbonate shells react with acid in the ocean.

Dull, pitted shell when ~~reacts~~ acid reacts, shell degrades, revealing smooth, shinier layer.

(ii) Cross-sectional views of two different pāua shells are shown below.



Total Shell Area = 110 cm^2 — **Pāua Shell A**

Total Shell Area = 220 cm^2 — **Pāua Shell B**

Explain which pāua shell is more vulnerable to the effects of ocean acidification.

In your answer, include concepts of:

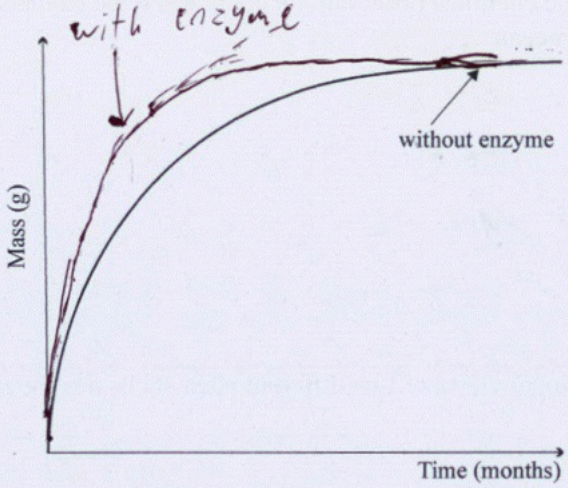
- collision theory
- rate of reaction.

Collision theory states that a larger surface ~~area~~ area will increase the rate of reaction as more particles of the substance is open to collision, and therefore can react with the other reactant(s) easier. Pāua shell B has a much higher surface area thanks to it's rough outer shell shape, compared to shell A which is flatter with a lower surface area. Following collision theory, pāua shell B is more vunruble to the effects of ocean acidification.

(b) Pāua use enzymes like carbonic anhydrase to help form their shells. Enzymes are biomolecules that act as catalysts for specific reactions.

The graph shows the change in the mass of the pāua shell over time without the use of an enzyme to build the shell.

(i) Add a second line to the graph to predict the change in mass over time when using the enzyme.



(ii) Discuss how the carbonic anhydrase enzyme affects the rate of the reaction to form pāua shell.

In your answer, refer to:

- the role of a catalyst
- collision theory
- activation energy.

Collision theory states that for reactants to collide succesfully, they must collide with enough energy to overcome the activation energy in the reaction. The role of a catalyst is to give a diffirent path to the product, in this case the carbonic anhydrase ~~[illegible]~~ helps the reaction occur, by ~~[illegible]~~ bringing the reactants together ~~[illegible]~~ with the correct orientation and enough energy to overcome the activation energy, making the reactants collide succesfully more often, therfore increasing the rate of reaction.

help the reaction occur

slash

(c) Calcium hydroxide, $Ca(OH)_2$, calcium chloride, $CaCl_2$, and calcium ethanoate, $Ca(CH_3COO)_2$, are soluble calcium compounds.

(i) Write an equation to show the complete dissociation of each of these compounds in water.

Calcium hydroxide: $Ca(OH)_{2(aq)} + H_2O_{(l)} \rightarrow CaO_{(aq)} + H_3O_{(aq)}$ ~~$CaOH + H_2O$~~

Calcium chloride: $CaCl_{2(aq)} + H_2O_{(l)} \rightarrow CaO_{(aq)} + H_2Cl_{2(aq)}$

Calcium ethanoate: $Ca(CH_3COO)_{2(aq)} + H_2O_{(l)} \rightarrow CaO_{(aq)} + $ ~~$(CH_3COOH)_2$~~ $2CH_3COOH_{(aq)}$

(ii) Calcium ethanoate will react further once dissolved.

Write an equation for the reaction of ethanoate, CH_3COO^-.

(iii) The pH of 0.10 mol L^{-1} solutions of these three compounds are below.

Solution	**$Ca(OH)_2$**	**$CaCl_2$**	**$Ca(CH_3COO)_2$**
pH	13.2	7	8

Discuss the differences in their pH.

In your answer:

- give a definition for acids and bases
- explain how proton transfer is linked to pH
- discuss any ability for these compounds to transfer protons.

There is more space for your answer on the next page.

QUESTION THREE

Phosphorus pentachloride, PCl_5, is a common chlorinating agent in organic chemistry. It is produced as a gas using phosphorus trichloride, PCl_3, and chlorine gas, Cl_2:

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$$

(a) (i) During the manufacturing process, some of the PCl_5 is removed from the reaction vessel.

Explain, using equilibrium principles, how the system responds to restore equilibrium.

In your answer, refer to each of the species present.

the system will respond to counteract the change, as ~~once~~ the ~~PCl5~~ PCl_5 is removed, the reactants PCl_3 and Cl_2 will be creating more of the products (PCl_5) than PCl_5 is reactants (PCl_3 + Cl_2), but as the reaction continues, the system will reach a new equilibrium with less PCl_5/products than reactants/PCl_3 + Cl_2

(ii) Explain why producing PCl_5 is favoured when the reaction is transferred to a vessel with a much smaller volume.

In your answer, include:

- a description of the changes occurring
- an explanation of equilibrium principles
- what happens to the position of equilibrium when the pressure is increased.

(b) (i) The equilibrium expression for the reaction is shown below.

products ~~high~~

$$K_c = \frac{[PCl_5]}{[PCl_3][Cl_2]}$$

Calculate the equilibrium constant at 300 °C if the concentrations are as follows:

$[PCl_3] = 0.016$ mol L^{-1}

$[Cl_2] = 0.021$ mol L^{-1}

$[PCl_5] = 0.00013$ mol L^{-1}

$K_c = \frac{0.00013}{0.016 \times 0.021} = 0.388$ at 300° C

(ii) Explain the effect of increasing the concentration of Cl_2 on the equilibrium system AND K_c value.

$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$

The system would respond to counteract the change, more PCl_5 will be created from the increased rate of forward reaction from the Cl_2 added, and a higher K_c value means the concentration of PCl (the products) would be higher/increased.

(iii) The reaction is set up under new conditions, with different temperatures to favour the production of phosphorus pentachloride, PCl_5.

	Condition 1	Condition 2
Temperature	200 °C	700 °C
K_c	49	0.023
$[PCl_3]$	0.12 mol L^{-1}	0.15 mol L^{-1}
$[Cl_2]$	0.09 mol L^{-1}	0.12 mol L^{-1}

Use the K_c values to explain which set of conditions (1 or 2) would increase production of PCl_5.

the conditions on condition 2 includes a higher temprature, which would increase how fast the particles are moving around ~~aswell~~ increasing rate of reaction, aswell as an increased coacentration on reactants, which means the product PCl_5 will be produced more often. Therefore, condition 2 would increase production of PCl_5

(iv) Calculate the concentration of PCl_5 under each of the new conditions listed in (iii).

at 700°C
$0.023 = \frac{[PCl_5]}{0.018}$

$[PCl_5] = 4.14 \times 10^{-4}$ mol L^{-1}

Question Three continues on the next page.

(c) Chlorine gas, $Cl_2(g)$, can also be used to produce nitrosyl chloride, NOCl(g), a catalyst and industrial bleaching agent.

$$Cl_2(g) + 2NO(g) \rightleftharpoons 2NOCl(g)$$

The formation of NOCl(g) is favoured when the temperature is decreased.

Explain why this reaction is performed at 95 °C instead of a lower temperature (for example, 25 °C).

In your answer:

- identify whether the forward reaction is exothermic or endothermic
- explain any disadvantages of a higher temperature using equilibrium concepts
- explain any advantages of using a higher temperature for a reaction using collision theory and rate of reaction principles.

Achievement

Subject: L2 Chemistry

Standard: 91166

Total score: 12

Q	Grade score	Marker commentary
One	A4	The candidate was awarded an A4 for the following reasons: In part (a)(iii) they identified that the reverse reaction is endothermic and the forward is exothermic. In part (b), the candidate identified the correct value pH of 0.25 mol L^{-1} solution of HCl and, in (iii) the candidate has not linked the $[H_3O^+]$ to pH, nor linked dissociation to [ions] for both merit points.
Two	A4	The candidate was awarded an A4 and demonstrated sufficient knowledge across part (a) and part (b). In part (a), the candidate identified the "pitted shell degrades" and that the rate of reaction increases with the larger surface area. In part (b), a second line is drawn to show a faster rate on the graph, and they provided basic discussion that a catalyst increases rate of reaction. Part (c) was partially attempted. To achieve at a higher level, the candidate would need provide more detailed and thorough responses, including reference to the frequency of successful collisions (in part (a)) and no alternative pathway or link to frequency of successful collisions (in part (b)).
Three	A4	The candidate was awarded an A4 for the following reasons: In part (a) the candidate provided a correct explanation in (i). In part (b), the correct K_c value is shown, though the K_c statement is incorrect, the candidate recognised that forward is favoured. One condition was correctly calculated. Part (c) was not attempted.