SUGGESTED ANSWERS

Level 2 Chemistry

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.

You should attempt ALL the questions in this booklet.

A periodic table is provided in the Resource Sheet.

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

Check that this booklet has pages 2 – 9 in the correct order and that none of these pages is blank.

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

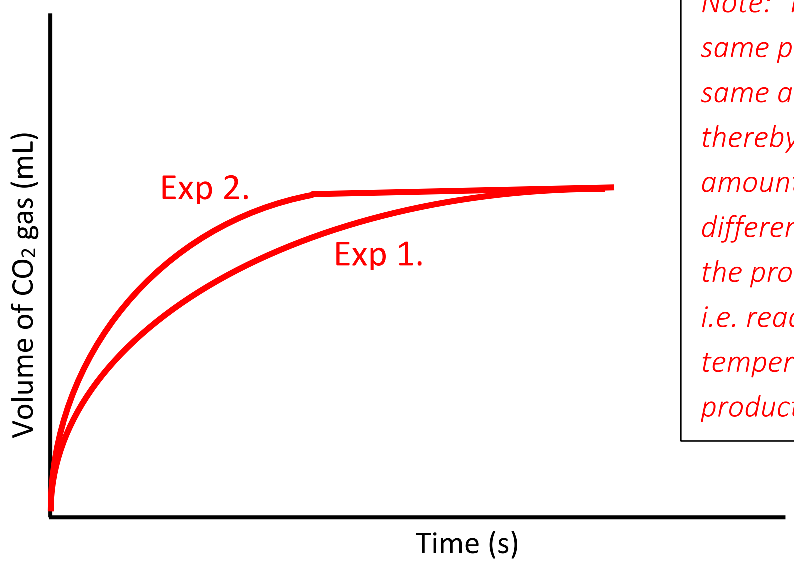
QUESTION ONE

Marble is mostly made of the chemical calcium carbonate ($CaCO_3$). It reacts with dilute hydrochloric acid (HCl) as shown in the equation below:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

(a) (i) Sketch a labelled diagram for the rate of reaction curves for the following two experiments, on the axes below. The temperature is held constant at 25°C in both experiments.

- Experiment 1: 1.00 g of marble chips is added to 200 mL of 1.00 mol L^{-1} HCl.
- Experiment 2: 1.00 g of crushed (powdered) marble is added to 200 mL of 1.00 mol L^{-1} HCl.



Note: The lines finish in the same position as there are the same amounts of reactants, thereby producing the same amount of products. The only difference is the rate at which the products are produced, i.e. reaction at higher temperature produces products at a faster rate.

(ii) Experiment 1 was repeated at 35°C. Explain how the increase in the temperature of the system would affect the rate of reaction.

You should refer to collision theory and activation energy in your answer.

An increased temperature means an increase in the rate of the reaction because the kinetic energy (E_K) of the particles has increased. This means the particles move faster, increasing the frequency of (successful / effective) collisions / more collisions per second. In addition, a greater percentage / proportion of collisions are likely to be successful because more particles have enough kinetic energy to overcome the activation energy. This causes the rate of reaction to increase / more gas to be produced.

Sulfuric acid is manufactured by the Contact process. One stage in this process is the conversion of sulfur dioxide into sulfur trioxide in the presence of vanadium(V) oxide, V_2O_5.

The addition of vanadium(V) oxide to a mixture of sulfur dioxide and oxygen gases helps to speed up the production of sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

(b) Identify and explain the role of vanadium(V) oxide in this reaction. In your answer, you should refer to activation energy and collision theory.
You may include a diagram or diagrams in your answer.

Identifies V_2O_5 as a catalyst.

V_2O_5 provides an alternative pathway with lower activation energy for the reaction. Therefore, more reacting particles will collide with sufficient (kinetic) energy equal to or above activation energy, (resulting in a higher frequency of successful collisions) resulting in an increase in the rate of reaction.

QUESTION TWO

(a) (i) Identify two species that represent a conjugate acid–base pair in the equation below.

$$HSO_4^-(aq) + H_2O(l) \rightleftharpoons OH^-(aq) + H_2SO_4$$

Either H_2SO_4 / HSO_4^- OR H_2O / OH^-
Note: must list acid before base

(ii) Explain by means of equations how the hydrogen carbonate ion (HCO_3^-) can act both as an acid and as a base.

HCO_3^- can act as an acid (proton donor) by donating a proton to water:

$HCO_3^- + H_2O \rightleftharpoons CO_3^{2-} + H_3O^+$

Alternatively, HCO_3^- can act as an base (proton acceptor) by accepting a proton from water:

$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$

(b) (i) Describe the meaning of the term 'weak acid' using ethanoic acid, CH_3COOH to illustrate your answer. In your answer you should include an appropriate chemical equation.

A weak acid has an incomplete reaction with water / partially dissociates/ionises in water, producing fewer H_3O^+ ions, so is a weak acid

$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

(ii) Compare and contrast solutions of 0.500 mol L^{-1} hydrochloric acid (pH 0.30) and 0.500 mol L^{-1} ethanoic acid (pH 2.5). In your answer you should elaborate on

- their relative pH values
- the electrical conductivity of the two acids
- the rate of their reaction with magnesium ribbon

When these substances dissociate / ionise in water, they both produce hydronium ions / donate protons. However HCl is a strong acid and dissociates completely, and the higher $[H_3O^+]$ concentration means the solution has a lower pH, than CH_3COOH, a weak acid, that only partially dissociates. However the hydronium ions are in greater concentration than hydroxide ions (OH^-), so the pH will be below 7 and therefore both are acidic.

Charged particles that are free to move are needed to conduct electricity. HCl is a good conductor of electricity because it completely dissociates in water, releasing ions into solution giving a high concentration of ions to carry charge. The CH_3COOH partially dissociates/ionises in water, producing fewer ions, so is a poor conductor of electricity.

Both acids will react with the Mg ribbon, but since HCl completely dissociates, it has a higher concentration of H_3O^+, so HCl will have a faster rate of reaction with Mg than CH_3COOH. There are more H_3O^+ ions available to react in a given volume so there will be more effective collisions per second.

(c) (i) A solution of hydrochloric acid, HCl(aq), has a hydronium ion concentration, [H_3O^+], of 0.0524 mol L^{-1}. Calculate the pH and hydroxide ion concentration, [OH^-], of the solution.

pH: 1.28

[OH^-]: 1.91×10^{-13} mol L^{-1}

(ii) Calculate the H_3O^+ and OH^- concentration of a sodium hydroxide solution, NaOH, with a pH of 11.2

$H_3O^+ = 6.31 \times 10^{-12}$ mol L^{-1}

$OH^- = 1.58 \times 10^{-3}$ mol L^{-1}

(Apologies – was error in original version of this question)

QUESTION THREE

Consider the following reaction: $A_2(g) + 3B(g) \rightleftharpoons A_2B_3(g)$

Quantities of all three chemicals are placed into a 1.0 L sealed container, the temperature was raised to 200°C and the system was allowed time to come to equilibrium.

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

$$K_c = \frac{[A_2B_3]}{[A_2][B]^3}$$

(ii) The K_c for the reaction at 200°C is 83.
Calculate the concentration of A_2, if the concentration of B is 0.100 mol L^{-1} and the concentration of A_2B_3 is 0.520 mol L^{-1}. Give your answer to appropriate significant figures.

$$83 = \frac{[0.520]}{[A_2][0.1]^3}$$

$[A_2]$ = 6.26 mol L^{-1}

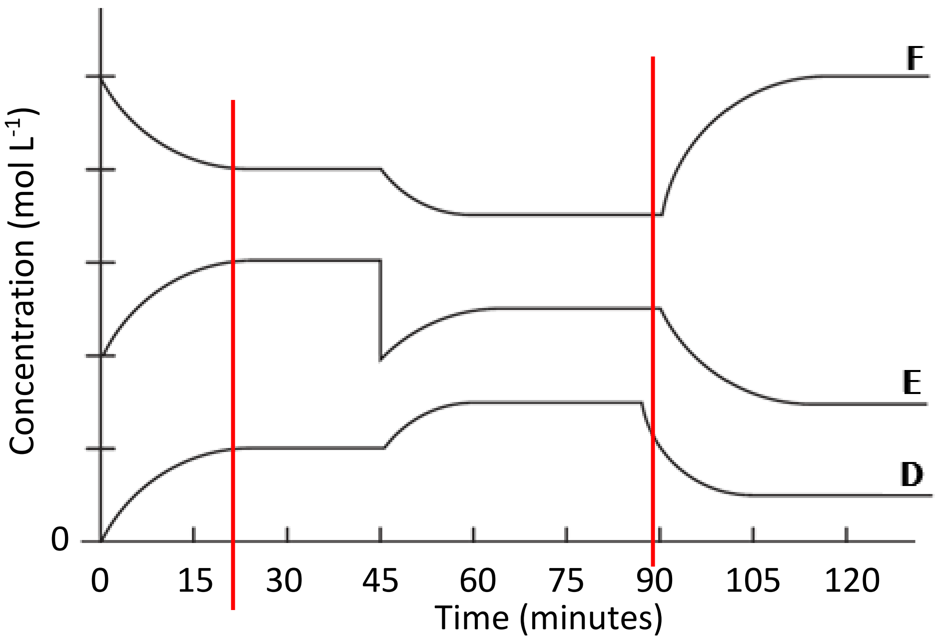
(iii) Explain the effect on K_c if the concentration of B, is increased to 0.200 mol L^{-1} at 200°C (no calculations are necessary).

No effect at all on the value of K_c as it is a constant – and is only altered if the temperature is changed, not concentration as here.

(b) In another reaction D(g) can react with E(g) to make F(g)

$$D(g) + E(g) \rightleftharpoons F(g)$$

A chemist studied this reaction at 300°C. He measured the concentration of each of these gases in a sealed container over two hours (120 minutes). During this time the chemist imposed **two** changes on the system, at around 45 and 90 minutes.



(i) What gas or gases were present in the sealed container at the start of the experiment?

E and F

(ii) The graph above shows that the reaction came to equilibrium three times:

- Estimate the time when the reaction *first* reached equilibrium
- Explain how you know the reaction had reached equilibrium

Around 20-22 minutes

This is because this is the first time that the concentrations of D, E and F became constant (the lines are horizontal), which would only occur when the rate of the forward and back reactions were equal because the reaction was at equilibrium.

(iii) The first change was imposed on the system at 45 minutes. In your answer you should

- identify what the change was
- refer to equilibrium principles to explain the observed data

E was removed / the concentration of E was reduced; the concentration of E dropped suddenly.

$$D(g) + E(g) \rightleftharpoons F(g)$$

To reverse reaction was favoured, to counteract the imposed change which meant that the concentration of F decreased and the concentration of D increased, as seen in the graph.

(iv) At around 90 minutes the temperature of the sealed container was changed to 100°C.
With reference to the graph, explain how the data provides evidence to determine if the forward reaction is exothermic or endothermic.

$$D(g) + E(g) \rightleftharpoons F(g)$$

At this time the concentration of D and E both decreased and the concentration of F increased, which clearly shows that the decrease in temperature from 300°C to 100°C favoured the forward reaction which makes F.

A decrease in temperature favours the exothermic reaction as it releases heat energy, counteracting the imposed change.
Therefore the forward reaction must be exothermic in this case.

Extra paper if required.

Write the question number(s) if applicable

This is Draft 1 of the answers – please let us know if you spot any errors, or answers need more clarification.