

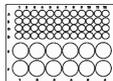
# RATE OF REACTION – FACTORS AFFECTING THE RATE OF A HETEROGENEOUS REACTION

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is required.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.



### 3. Hints

## PART 1: The Effect of State of Division of Reactants

In Part 1, the student will need to rely on personal judgement in deciding what size calcium carbonate lump to use. The lumps are not all uniform in size. If a small lump is used, the quantity of calcium carbonate powder must be reduced. Similarly, more of the powder will be needed for comparison if the lump used is large. Large lumps may also be broken into smaller pieces with a hard object. Do not try and break the lumps in the comboplate® as they are very hard and will crack the comboplate®.

When adding water and hydrochloric acid to the lump, these must not be dropped directly onto the lump as it may begin to break up. The observed rate of reaction will be affected because the surface area of the lump will change.

If the lump of calcium carbonate has not completely reacted after Part 1, it can be removed from the well, rinsed with water and dried in air. The lump can be used again in other experiments.

## PART 2: The Effect of Concentration of Reactants

In Part 2, the calcium carbonate powder must be spread in the large wells to prevent portions of the powder from forming small clumps.

The different concentrations of hydrochloric acid used in Part 2 must be already in the propettes before each is added to the  $\text{CaCO}_3(\text{s})$ . The propettes should be lined up in order of increasing concentration, and then each concentration of acid added quickly so that a good comparison of the rate can be made from one concentration of acid to the next.

## PART 3: The Effect of Temperature

In Part 3, the hot glass rod must be twirled around in the well to ensure uniform heating of the solution.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**11 M hydrochloric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.**

**Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.**

**Calcium carbonate may be harmful if ingested or absorbed by the skin. Wash your hands thoroughly with soap and water after handling this chemical.**

**Methylated spirits is poisonous. Do not inhale the vapour or drink the liquid.**

**Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.**

**Be careful not to burn yourself when working with the microburner and hot rod. Do not allow the hot rod or flame of the burner to touch the comboplate®, as this will melt the plastic. Ensure that all burners are extinguished when not in use.**





## 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

### PART 1: The Effect of State of Division of Reactants

Q1. What can be observed in wells F1 and F2 ?

A1. **Well F1: Small bubbles form around the lump of calcium carbonate. The bubbles rise steadily to the surface of the water for a long period of time.**

**Well F2: A vigorous stream of bubbles occurs in well F2 for a short period of time where the calcium carbonate is in powder form. A fizzing sound is heard.**

Q2. In which well would you say the reaction is going faster ? Give a reason for your answer.

A2. **The reaction is faster in well F2. Bubbles of gaseous carbon dioxide ( $\text{CO}_2(\text{g})$ ) are given off vigorously for a short period of time, whereas the gentle bubbling in well F1 continues steadily. In well F1, the lump of calcium carbonate has a small surface area and thus provides less molecules of calcium carbonate for reaction with molecules of hydrochloric acid. In well F2, the powder form of the calcium carbonate provides a much larger surface area and hence there are more molecules of calcium carbonate able to react with molecules of hydrochloric acid, resulting in the rapid production of gaseous carbon dioxide ( $\text{CO}_2(\text{g})$ ).**

[NB: In this answer we refer to  $\text{CaCO}_3$  molecules. In fact, solid  $\text{CaCO}_3$  is made up of  $\text{Ca}^{2+}$  and  $\text{CO}_3^{2-}$  ions. If your students are familiar with this, then it would be better to refer to the carbonate ions rather than calcium carbonate molecules. Similarly, it is correct to refer to hydrogen ions,  $\text{H}^+(\text{aq})$  or  $\text{H}_3\text{O}^+(\text{aq})$ , instead of molecules of hydrochloric acid.]

Q3. Write a statement describing the effect of the state of division of solid calcium carbonate on the rate of its reaction with hydrochloric acid.

A3. **The state of division of calcium carbonate affects the rate of the heterogeneous chemical reaction between solid calcium carbonate and hydrochloric acid. The more finely divided the calcium carbonate is, the greater is the surface area (exposed reactant molecules) available for reaction with hydrochloric acid and the faster the reaction proceeds.**

### PART 2: The Effect of Concentration of Reactants

Q1. What can be observed in wells F3, F4 and F5 ?

A1. **Well F3: A very slow reaction takes place in well F3 when 0.1 M  $\text{HCl}$  is added.**

**Well F4: Carbon dioxide is given off gently in small quantities in well F4 when 1.0 M  $\text{HCl}$  is added. The bubbles rise to the surface of the water at a steady pace.**

**Well F5: Carbon dioxide is vigorously given off in well F5 when 11 M  $\text{HCl}$  is added. The bubbles rise very quickly to the surface with a fizzing sound.**

Q2. Place the wells in a sequence, from the well in which the reaction is the fastest to the one in which it is the slowest.

A2. **The sequence of wells from the fastest to the slowest reaction is F5, F4, F3.**

Q3. What is the reason for the difference in reaction rates ?

A3. **Wells F3, F4 and F5 have the same amount of calcium carbonate powder, but differing concentrations of hydrochloric acid. The greater the concentration of the acid, the more  $\text{HCl}$  molecules there are available for reaction with the  $\text{CaCO}_3$ . Well F5 contains the highest concentration of hydrochloric acid (i.e. 11 M) and the greatest number of  $\text{HCl}$  molecules per volume. The reaction in well F5 is therefore the fastest and the most rapid evolution of gaseous carbon dioxide is observed. Well F4 contains about one tenth of the previous concentration of hydrochloric acid (i.e. 1,0 M) and less  $\text{HCl}$  molecules per volume are available for reaction with  $\text{CaCO}_3$ . The reaction in well F4 is therefore the next fastest and as a result, gaseous carbon dioxide is formed less rapidly in well F4 than in well F5. Well F3 contains about one tenth of the previous concentration of hydrochloric acid (i.e. 0,1 M) and the least number of  $\text{HCl}$  molecules per volume available for reaction. The reaction in well F3 is therefore the slowest and the least volume of  $\text{CO}_2(\text{g})$  is given off per time. [NB: In this answer we refer to  $\text{HCl}$  molecules. In fact there will be very few of these in aqueous solution because  $\text{HCl}$  is a strong acid. In aqueous solution there would be only hydrogen ions ( $\text{H}^+(\text{aq})$  or  $\text{H}_3\text{O}^+(\text{aq})$ ) and chloride ions. If your students are familiar with this, it would be better to refer to the hydrogen ions rather than  $\text{HCl}$  molecules.]**



- Q4. Write a statement describing the effect of concentration of hydrochloric acid on the rate of its reaction with solid calcium carbonate.
- A4. The greater the concentration of the hydrochloric acid, the faster the reaction with solid calcium carbonate proceeds. We say the reaction rate increases when the concentration of one of the reactants (in this case, hydrochloric acid) increases.**

### **PART 3: The Effect of Temperature**

- Q1. What can be observed in wells E1 and E2 ?
- A1. Well E1: Bubbles of gaseous carbon dioxide rise steadily to the surface in well E1 for some time.  
Well E2: Carbon dioxide bubbles rise quickly and vigorously with fizzing for a short period of time.**
- Q2. In which of these wells would you say the reaction is going faster ? Give a reason for your answer.
- A2. The reaction is proceeding faster in well E2, as shown by the more vigorous and shorter evolution of gaseous carbon dioxide (CO<sub>2</sub>(g)).**
- Q3. What is the reason for your observations in question 1 ?
- A3. The water in well E2 was heated with the glass rod, causing the reaction to proceed faster and thus the formation of carbon dioxide was vigorous and rapid. The water added to well E1 was at room temperature, resulting in a slower reaction with a more gentle stream of carbon dioxide bubbles liberated.**
- Q4. Write a statement describing the effect of temperature on the rate of the reaction.
- A4. The greater the temperature at which the reaction occurs, the faster the reaction proceeds. We say the reaction rate increases when the temperature of a heterogeneous chemical reaction increases.**



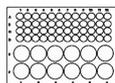
# RATES OF REACTION – THE EFFECT OF CATALYSTS

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. The procedure requires that 10% hydrogen peroxide ( $\text{H}_2\text{O}_2(\text{aq})$ ) be used. This solution should be fresh, since peroxide solutions that are left in storage are susceptible to decomposition. A fresh solution is best prepared from a 30%  $\text{H}_2\text{O}_2(\text{aq})$  solution, and should be kept in dark bottles in a cool, dark place to minimise decomposition.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.



### 3. Hints

As an introduction to the experiment, it may be useful to the students to explain how they can identify the reaction:



i.e oxygen bubbles are given off as the hydrogen peroxide decomposes. The more quickly (or vigorously) the bubbles appear, the faster the hydrogen peroxide is decomposing. Sometimes hydrogen peroxide reacts with other substances and bubbles are also seen. It should then be pointed out to the students that such substances are not catalysts for the decomposition of  $\text{H}_2\text{O}_2$ , because after the reaction new substances have been formed. When  $\text{MnO}_2(\text{s})$  is added to  $\text{H}_2\text{O}_2$ , bubbling occurs and the  $\text{MnO}_2(\text{s})$  does not get used up in the reaction. This is shown by the black mass left in the well after the reaction. If more  $\text{H}_2\text{O}_2$  is added to the  $\text{MnO}_2$  in the well, more bubbles will be seen because the  $\text{MnO}_2$  will catalyse the decomposition of the peroxide just added.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**Hydrogen peroxide is corrosive, and is a bleaching agent. If any solution is spilt on the skin or fabric, the affected area must immediately be rinsed with copious amounts of water.**

**Never point a propette or a syringe containing hydrogen peroxide upwards. A momentary lapse of concentration can result in a nasty accident. If any peroxide is squirted into the eye, immediately rinse the eye under running water.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

## PART 1: Finding a Catalyst for the Decomposition of Hydrogen Peroxide

Q1. What can be observed in wells F1, F2 and F3 ?

A1. **Well F1: No reaction occurred in well F1.**

**Well F2: No immediate reaction occurred in well F2. (After a while, some bubbles do form.)**

**Well F3: Bubbles can be observed rising rapidly to the surface of the solution in well F3, and a fizzing sound is heard.**

Q2. Can you still see  $\text{NaCl}(\text{s})$  in well F1 ? Give a reason for your observation.

A2. **No. The  $\text{NaCl}(\text{s})$  has dissolved in the  $\text{H}_2\text{O}_2(\text{aq})$ .**

Q3. Can you still see  $\text{Cu}(\text{s})$  in well F2 ?

A3. **Yes, there is still  $\text{Cu}(\text{s})$  in well F2.**

Q4. What happens when more  $\text{H}_2\text{O}_2(\text{aq})$  is added to F2 ?

A4. **Nothing happens when more  $\text{H}_2\text{O}_2(\text{aq})$  is added to the copper remaining in well F2.**

Q5. Can you still see  $\text{MnO}_2(\text{s})$  in well F3 ?

A5. **Yes, there is a black mass of  $\text{MnO}_2(\text{s})$  at the bottom of well F3.**



- Q6. What happens when more  $\text{H}_2\text{O}_2(\text{aq})$  is added to F3 ?
- A6. As soon as the hydrogen peroxide is added to the manganese dioxide at the bottom of well F3, more bubbling occurs with a fizzing sound.**
- Q7. In which well/s is the decomposition reaction of hydrogen peroxide being catalysed ? Give reasons for your answer.
- A7. Hydrogen peroxide decomposition is being catalysed in well F3 only. This was first shown by the appearance of bubbles, which can be assumed to be gaseous oxygen ( $\text{O}_2(\text{g})$ ) forming as soon as the  $\text{MnO}_2(\text{s})$  was added. (Hint: see the equation). When more hydrogen peroxide was added to the  $\text{MnO}_2(\text{s})$  at the bottom of the well, further decomposition occurred proving that the  $\text{MnO}_2(\text{s})$  was not used up in the first decomposition and was available to decompose more  $\text{H}_2\text{O}_2(\text{aq})$ .  $\text{NaCl}(\text{s})$  slowly dissolved in the aqueous hydrogen peroxide.  $\text{Cu}(\text{s})$  did not actively catalyse the decomposition of  $\text{H}_2\text{O}_2(\text{aq})$ , and when the remaining copper was tested with more hydrogen peroxide, no decomposition was observed.**
- Q8. Write a statement describing which of the substances tested, catalyse the decomposition of hydrogen peroxide.
- A8. Manganese dioxide powder ( $\text{MnO}_2(\text{s})$ ) is a catalyst for the decomposition of hydrogen peroxide ( $\text{H}_2\text{O}_2(\text{aq})$ ),  $\text{NaCl}(\text{s})$  and  $\text{Cu}(\text{s})$  are not.**

## **PART 2: The Effect of Quantity of Catalyst on the Rate of Decomposition of Hydrogen Peroxide**

- Q1. What can be observed in wells F5 and F6 ?
- A1. Well F5: A fizzing is heard and bubbles are rapidly given off from the solution.  
Well F6: A violent fizzing is heard and bubbles are given off more vigorously than in well F6.**
- Q2. In which well does the bubbling stop first ?
- A2. The bubbling ceases first in well F6.**
- Q3. In which well is the decomposition of hydrogen peroxide proceeding faster ? Give reasons for your answer.
- A3. Hydrogen peroxide is decomposing faster in well F6. Gaseous oxygen ( $\text{O}_2(\text{g})$ ) is given off more vigorously here, and the bubbling ceases quickly because the decomposition proceeds more rapidly than in well F5.**
- Q4. Write a statement describing the effect of quantity of catalyst on the rate of decomposition of hydrogen peroxide.
- A4. The greater the quantity of catalyst ( $\text{MnO}_2(\text{s})$ ), the faster the decomposition of hydrogen peroxide.**



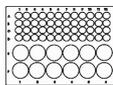
# RATES OF REACTION – THE EFFECT OF CONCENTRATION

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is required.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A stop watch or wrist watch, white paper and graph paper are required.



### 3. Hints

#### PART 1: The Effect of Concentration of Sodium Thiosulphate

As the concentration of sodium thiosulphate decreases so the time taken for the solution to appear milky increases. Hence the last determination (i.e. 1 drop of sodium thiosulphate:7 drops of water, followed by the addition of 5 drops of 11 M  $\text{HCl}(\text{aq})$ ) takes in excess of 4 minutes. It is not essential to obtain this point in order to draw the graph if your class is short of time.

A faint sulphur dioxide ( $\text{SO}_2(\text{g})$ ) smell is produced during the experiment. This originates from the sulphur dioxide generated in the chemical reaction. This could be mentioned to the learners doing the experiment. Alternatively they could be asked to note if they smelt anything during the experiment, and then asked if they could identify what was causing the smell.

#### PART 2: The Effect of Concentration of Hydrochloric Acid

This is investigated in Part 2, where the rates of reaction of 5.5 M hydrochloric acid and 11 M hydrochloric acid with the same concentration of sodium thiosulphate are compared.

The water used in the experiment could be heated beforehand and the experiment repeated, to see how temperature affects the rate of a homogeneous chemical reaction.

The comboplate<sup>®</sup> should be cleaned out as soon as possible after the experiment to prevent the sulphur adhering to the inside of the small wells. If this happens, the comboplate<sup>®</sup> can be flushed out with boiling water. Any stubborn residues can then be removed with a little cotton wool that has been twirled around a toothpick or wooden skewer.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**11 M hydrochloric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.**

**Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

#### Part 1: The Effect of Concentration of Sodium Thiosulphate

Q1. Prepare a table like Table 1 below.

A1. Table 1



| Well | Drops Sodium Thiosulphate Solution | Start time (min:sec) | Finish time (min:sec) | Reaction Time (seconds) | 1/Reaction Time ( $\times 10^{-3} \text{ s}^{-1}$ ) |
|------|------------------------------------|----------------------|-----------------------|-------------------------|---|
| A1   | 1                                  | 0:00                 | > 4:00                | > 240                   |   |
| A2   | 2                                  | 0:00                 | 2:18                  | 138                     | 7.25  |
| A3   | 3                                  | 0:00                 | 1:10                  | 70                      | 14.3  |
| A4   | 4                                  | 0:00                 | 0:59                  | 59                      | 16.9  |
| A5   | 5                                  | 0:00                 | 0:40                  | 40                      | 25.0  |
| A6   | 6                                  | 0:00                 | 0:36                  | 36                      | 27.8  |
| A7   | 7                                  | 0:00                 | 0:28                  | 28                      | 35.7  |
| A8   | 8                                  | 0:00                 | 0:20                  | 20                      | 50.0  |

Q2. Note the starting time and the finishing time (when the "X" is no longer visible) in well A8 and enter your results in the table.

A2. See Table 1.

Q3. Complete your table.

A3. See Table 1.

Q4. What happened when 11 M hydrochloric acid was added to the sodium thiosulphate solution ?

A4. Some time after adding the 11 M hydrochloric acid, the solution went milky.

Q5. Which well has the greatest concentration of sodium thiosulphate solution ?

A5. Well A8 has the greatest concentration of sodium thiosulphate.

Q6. In which well has the reaction taken place in the shortest time ?

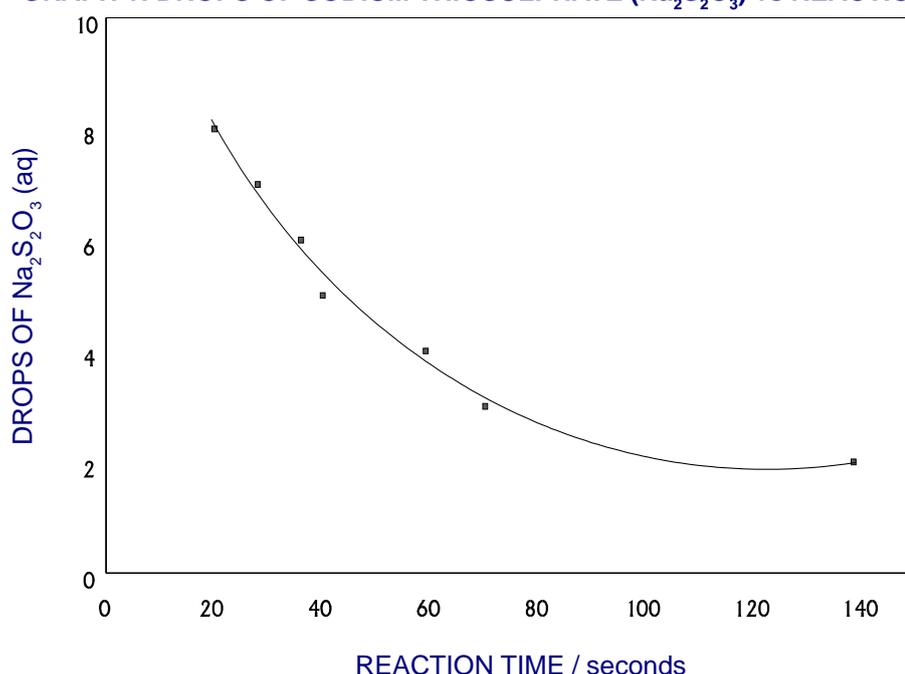
A6. In well A8, the "X" disappeared in the shortest time.

Q7. In which well has the reaction been the fastest ? Explain your answer.

A7. The rate of the reaction has been the fastest in well A8, since that is the well in which the time taken to produce a specific quantity of sulphur is least.

Q8. Draw the graph: Drops sodium thiosulphate solution (y-axis) vs Reaction Time (x-axis).

**GRAPH 1: DROPS OF SODIUM THIOSULPHATE ( $\text{Na}_2\text{S}_2\text{O}_3$ ) vs REACTION TIME**

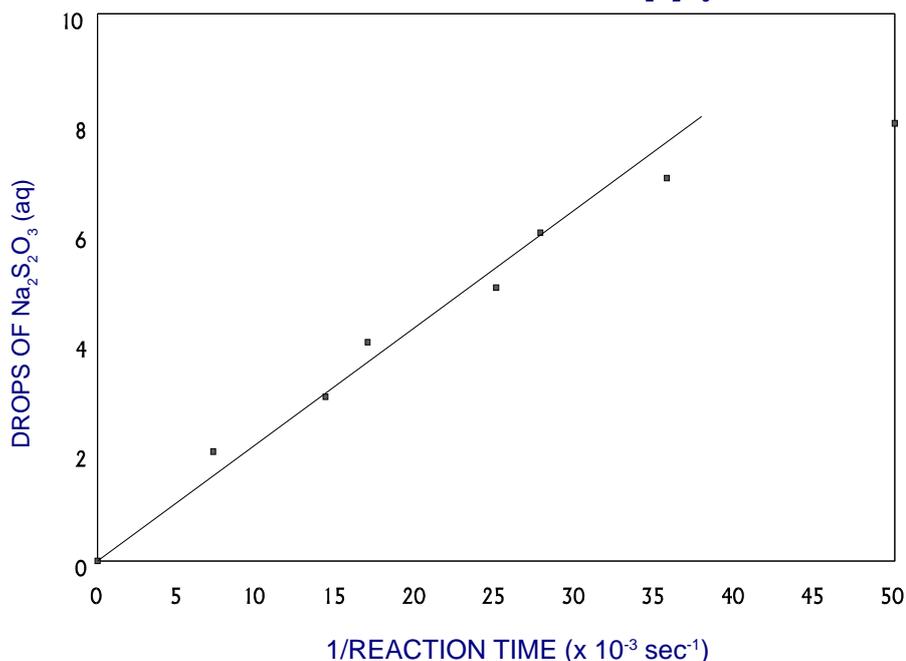


The rate of a chemical reaction is dependent on temperature. These times were determined at 22°C.



Q9. Draw the graph: Drops sodium thiosulphate solution (y-axis) vs 1/Reaction Time (x-axis).

**GRAPH 2: DROPS OF SODIUM THIOSULPHATE ( $\text{Na}_2\text{S}_2\text{O}_3$ ) vs 1/REACTION TIME**



The rate of a chemical reaction is dependent on temperature. These times were determined at 22°C.

Q10. What is the relationship between the number of drops of sodium thiosulphate solution and reaction time ?

**A10. As the number of drops increases the reaction time decreases (see graph 1). In fact, the reaction time is inversely proportional to the number of drops (see graph 2).**

Q11. Write a statement describing the effect of the concentration of sodium thiosulphate on the rate of its reaction with hydrochloric acid.

**A11. The rate of reaction is given by 1/reaction time; the concentration of sodium thiosulphate is proportional to the number of drops used. Therefore, the rate of reaction of sodium thiosulphate with hydrochloric acid is directly proportional to the concentration of sodium thiosulphate in the mixture. As the concentration of sodium thiosulphate increases, the rate of reaction increases and vice versa.**

## **PART 2: The Effect of Concentration of Hydrochloric Acid**

Q1. Note the time when the "X" is no longer visible beneath well A1.

**A1. The "X" is no longer visible at 1 min 15 sec (i.e. 75 seconds).**

Q2. Note the time when the "X" is no longer visible beneath well A2.

**A2. The "X" is no longer visible beneath well A2 at 55 seconds.**

Q3. Write a statement describing the effect of the concentration of hydrochloric acid on the rate of its reaction with sodium thiosulphate.

**A3. When the concentration of hydrochloric acid is increased, the rate of its reaction with sodium thiosulphate increases.**



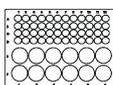
# ENTHALPY CHANGES FOR REACTIONS OF ACIDS WITH A STRONG BASE

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is required for rinsing of the syringe and thermometer.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit. A thermometer is required to measure temperature changes.



### 3. Hints

To make recording of temperature changes easier and more accurate, it is better to supply thermometers that are graduated in 0.1°C intervals. If this is not possible, the learners will have to rely upon personal judgement of the level of mercury in the thermometer.

When measuring temperatures of solutions, wait a few seconds before recording values. Make sure that the bulb of the thermometer is adequately covered with solution. You may need to tilt the comboplate® slightly to achieve this, if the thermometer has a long bulb.

The solutions in the wells of the comboplate® must be stirred thoroughly with the thermometer before the maximum temperature is recorded. Always rinse and dry the thermometer before measuring the temperature of a different solution.

Make sure that the syringe is thoroughly dry inside before it is used to dispense a different solution, otherwise water in the syringe will dilute and/or contaminate the acid/base and introduce errors into the results.

The solutions used to prepare the model answers were standardised prior to the experiment in order to obtain the expected mole ratios of acid:base. This allowed for the most accurate enthalpy changes to be calculated. The acid and base solutions provided by chemical suppliers are often not standardised, and the solutions you have for this experiment may therefore not all be exactly 1.0 M in concentration.

It is not absolutely essential to use standardised solutions for this experiment, but if you wish to obtain results which agree closely you will have to establish the exact concentrations of the acid or base by titration before allowing the learners to perform the experiment. An analyte volume of 10,0 mL sodium hydroxide should be titrated with the acid of choice. The expected volume ratio of acid:base is 1.0 i.e. you should require 10,0 mL of hydrochloric acid to neutralise the sodium hydroxide. If you find that the volume ratio is greater than 1.0 you will have to adjust the concentration of the base by dilution. If the volume ratio is less than 1.0, the acid will need dilution. Another titration should then be carried out to confirm that the acid and base react in a volume ratio of 1:1.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.**

**Acetic acid fumes are irritating to the eyes and mucous membranes of the upper respiratory tract. Keep the bottle closed when not in use.**

**Sodium hydroxide is a corrosive base. If any base is spilt on the skin, treat as for acid burns described above.**

**Never point a propette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. Use a dilute boric acid solution for injuries involving a base. These substances will help neutralise the acid or base in the eye. The patient should be referred to a doctor.**

**Mercury is an expensive, poisonous metal. Be careful not to drop the thermometers!**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.



**PART 1: The enthalpy change ( $\Delta H$ ) for the reaction between hydrochloric acid ( $\text{HCl}(\text{aq})$ ) (a strong acid) and sodium hydroxide ( $\text{NaOH}(\text{aq})$ ) (a strong base)**

Q1. What is the initial temperature of the sodium hydroxide solution ?

**A1. The initial temperature of  $\text{NaOH}(\text{aq})$  is  $22.0\text{ }^\circ\text{C}$ .**

Q2. What is the initial temperature of the hydrochloric acid ?

**A2. The initial temperature of  $\text{HCl}(\text{aq})$  is  $22.7\text{ }^\circ\text{C}$ .**

Q3. Calculate the average of the two initial temperatures. This is the average initial temperature,  $T_i$ .

**A3. The average initial temperature,  $T_i = 22.35\text{ }^\circ\text{C}$ .**

Q4. What is the maximum temperature of the mixture ? This is the final temperature,  $T_f$ .

**A4. The final temperature,  $T_f$ , of the mixture is  $26.7\text{ }^\circ\text{C}$ .**

Q5. Calculate the change in temperature  $\Delta T$ .

**A5.  $\Delta T = T_f - T_i = 26.7\text{ }^\circ\text{C} - 22.35\text{ }^\circ\text{C} = 4.35\text{ }^\circ\text{C}$ .**

Q6. Was the final temperature of the reaction mixture higher or lower than the initial average temperature of the reagents ?

**A6.  $T_f$  was higher than the initial average temperature ( $T_i$ ).**

Q7. Was energy absorbed or released by the surroundings as this reaction took place ?

**A7. Energy was absorbed by the surroundings as the reaction took place.**

Q8. Was energy absorbed or released by the reactants as this reaction took place ?

**A8. Energy was released by the reactants as the reaction took place.**

Q9. Is such a reaction exothermic or endothermic ?

**A9. This is an exothermic reaction.**

Q10. The heat capacity,  $C$ , of the comboplate<sup>®</sup> and contents is approximately  $13.03\text{ J }^\circ\text{C}^{-1}$ . Calculate  $q$ , the energy absorbed or released by the surroundings.

**A10.  $q = C \times \Delta T$**

$$C = 13.03\text{ J }^\circ\text{C}^{-1}$$

$$\Delta T = +4.35\text{ }^\circ\text{C}$$

$$\text{then, } q = 13.03\text{ J }^\circ\text{C}^{-1} \times 4.35\text{ }^\circ\text{C} \\ = 56.7\text{ J}$$

**As the result is a positive quantity, this energy is absorbed by the surroundings.**

Q11. Write down a balanced chemical equation for the reaction between hydrochloric acid and sodium hydroxide.

**A11.  $\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\ell)$**

Q12. Calculate the enthalpy change of the reaction in J, and the enthalpy change per mole of reaction, in  $\text{kJ mol}^{-1}$ .

**A12.  $q = -\Delta H$  or  $\Delta H = -q$**

**then,  $\Delta H = -56.7\text{ J}$ . This is the enthalpy change for the reaction performed.**

**The balanced chemical equation shows that the mole ratio of  $\text{HCl}:\text{NaOH}$  is 1:1. We used  $1.0\text{ ml}$  each of  $1.0\text{ M HCl}$  and  $1.0\text{ M NaOH}$ .**

**$\therefore$  the no. of moles of each used =  $1.0\text{ mol } \ell^{-1} \times 1.0 \times 10^{-3}\text{ } \ell = 1.0 \times 10^{-3}\text{ mol}$ .**

**$\therefore \Delta H = \frac{-56.7\text{ J}}{1 \times 10^{-3}\text{ mol}} = -56\text{ 700 J mol}^{-1} = -56.7\text{ kJ mol}^{-1}$  (the enthalpy change per mole of reaction)**

**PART 2: The enthalpy change ( $\Delta H$ ) for the reaction between acetic acid ( $\text{CH}_3\text{COOH}(\text{aq})$ ) (a weak acid) and sodium hydroxide ( $\text{NaOH}(\text{aq})$ ) (a strong base)**

Q1. What is the initial temperature of the sodium hydroxide solution ?

**A1. The initial temperature of the sodium hydroxide solution is  $20.0\text{ }^\circ\text{C}$ .**

Q2. What is the initial temperature of the acetic acid ?

**A2. The initial temperature of acetic acid is  $20.1\text{ }^\circ\text{C}$ .**

Q3. Calculate the average of the two initial temperatures. This is the average initial temperature,  $T_i$ .

**A3.  $T_i = 20.05\text{ }^\circ\text{C}$ .**



- Q4. What is the maximum temperature of the mixture ? This is the final temperature,  $T_f$  .  
**A4.  $T_f = 24.0\text{ }^\circ\text{C}$ .**
- Q5. Calculate the change in temperature,  $\Delta T$ .  
**A5.  $\Delta T = + 3.95\text{ }^\circ\text{C}$ .**
- Q6. Was the final temperature of the reaction mixture higher or lower than the initial average temperature of the reagents?  
**A6.  $T_f$  was higher than  $T_i$ .**
- Q7. Was energy absorbed or released by the surroundings as this reaction took place ?  
**A7. Energy was absorbed by the surroundings as the reaction occurred.**
- Q8. Was energy absorbed or released by the reactants as this reaction took place ?  
**A8. Energy was released by the reactants as the reaction occurred.**
- Q9. Is the reaction of acetic acid with sodium hydroxide endothermic or exothermic ?  
**A9. The reaction of acetic acid with sodium hydroxide is exothermic.**
- Q10. Write down a balanced chemical equation for the reaction between acetic acid and sodium hydroxide.  
**A10.  $\text{CH}_3\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{CH}_3\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\ell)$**
- Q11. The heat capacity,  $C$ , of the comboplate<sup>®</sup> and contents is approximately  $13.03\text{ J }^\circ\text{C}^{-1}$ . Calculate the enthalpy change of the reaction in J, and the enthalpy change per mole of reaction in  $\text{kJ mol}^{-1}$ .  
**A11.  $q = -\Delta H = C \times \Delta T$   
 $C = 13.03\text{ J }^\circ\text{C}^{-1}$   
 $\Delta T = +3.95\text{ }^\circ\text{C}$   
then,  $\Delta H = - 13.03\text{ J }^\circ\text{C}^{-1} \times 3.95\text{ }^\circ\text{C}$   
 $= - 51.5\text{ J}$ .**

This is the enthalpy change for the reaction performed.

We used  $1.0\text{ ml}$  each of  $1.0\text{ M CH}_3\text{COOH}$  and  $1.0\text{ M NaOH}$ .

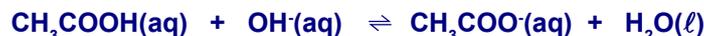
$\therefore$  the no. of moles of each used  $= 1.0\text{ mol } \ell^{-1} \times 1.0 \times 10^{-3}\text{ } \ell = 1.0 \times 10^{-3}\text{ mol}$ .

$\therefore \Delta H = \frac{- 51.5\text{ J}}{1 \times 10^{-3}\text{ mol}} = - 51\ 500\text{ J mol}^{-1} = - 51.5\text{ kJ mol}^{-1}$  (the enthalpy change per mole of reaction)

- Q12. Is the enthalpy change the same as found in Part 1 ?  
**A12. No. The enthalpy change for Part 1 was greater than that for Part 2.**
- Q13. What is the explanation for your finding ?  
**A13. Strong acids and bases are completely dissociated in aqueous solutions. Hence the reaction between solutions of such acids and bases is always essentially,**



However with a solution of a weak acid, there is only partial dissociation. When reaction with a strong base occurs, only part of the reaction is of the above type. The rest involves acid molecules (undissociated) reacting with hydroxide ions, e.g.



This reaction has a different  $\Delta H$ . Therefore the enthalpy change for Part 1 differed from that for Part 2.



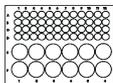
# THE EFFECT OF pH ON THE CHROMATE/DICHROMATE EQUILIBRIUM

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is also required.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.



### 3. Hints

When preparing the potassium dichromate solution in steps 1 and 2 of the procedure, make sure that only a small amount of the solid is added to each well. If too much is added, it will not completely dissolve in the 5 drops of water.

In step 3, the sodium hydroxide solution must be added dropwise and the solution in well A2 must be stirred after each drop is added. Sometimes it may appear that only the surface of the solution has changed colour, but when the solution is stirred and the sodium hydroxide is thoroughly mixed with the potassium dichromate solution, the entire solution will become yellow. This instruction also applies when adding the hydrochloric acid in step 5.

For every drop of sodium hydroxide or hydrochloric acid that is added to well A2, an equal number of drops of water must be added to well A1 (see steps 4 and 6). This is done to prove that the colour change observed is not due to dilution.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**Hydrochloric acid is very corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.**

**Sodium hydroxide solutions are also very corrosive. If any base is spilt on the skin, treat as for acid burns above.**

**Never point a pipette or a syringe containing acid or base upwards. A momentary lapse of concentration can result in a nasty accident. If any acid or base is squirted into the eye, immediately rinse the eye out under running water. In the case of an acid, always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What is the colour of solid potassium dichromate ?

**A1. Solid potassium dichromate is orange in colour.**

Q2. What is the colour of the solutions in wells A1 and A2 ?

**A2. The solutions in wells A1 and A2 are both orange in colour.**

Q3. Which ion in solution is responsible for this colour ?

(Refer to the given equation and your former observation.)

**A3. The dichromate ion ( $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ ) is responsible for the orange colour.**

Q4. What number of drops of sodium hydroxide were required to make the solution change colour ?

**A4. One or two drops of  $\text{NaOH}(\text{aq})$  caused the solution to change colour.**

Q5. Describe the colour change in well A2.

**A5. The colour of the solution in A2 changed from orange to yellow.**

Q6. Which ion in solution is responsible for the new colour ? (Refer to the given equation.)

**A6. The chromate ion ( $\text{CrO}_4^{2-}(\text{aq})$ ) is responsible for the new yellow colour.**

Q7. What number of drops of nitric acid (6 M) were required to make the solution change colour ?

**A7. One drop of  $\text{HNO}_3(\text{aq})$  made the solution change colour again.**



Q8. Describe the colour change in well A2.

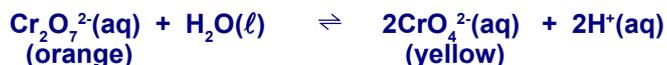
**A8. The colour of the solution in A2 changed from yellow to orange.**

Q9. Which ion in solution is responsible for the new colour ? (Refer to the given equation.)

**A9. The dichromate ion ( $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ ) is responsible for the new colour.**

Q10. Propose a reason why adding sodium hydroxide to the solution of potassium dichromate caused a colour change.

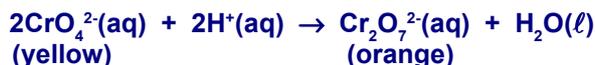
**A10. As a result of the equilibrium that exists when potassium dichromate dissolves in water, there are hydrogen ( $\text{H}^+(\text{aq})$ ) ions in solution. These  $\text{H}^+(\text{aq})$  ions react with the added hydroxide ions ( $\text{OH}^-(\text{aq})$ ) ions to form water. This causes the hydrogen ion concentration in the following equilibrium to decrease:**



**According to Le Chatelier's principle, orange dichromate ions reacted with the water to form yellow chromate ions ( $\text{CrO}_4^{2-}(\text{aq})$ ) and more hydrogen ions.**

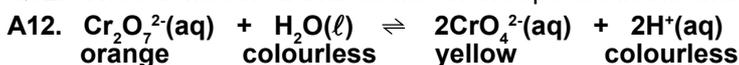
Q11. Propose a reason why adding nitric acid to the solution containing chromate ions caused a colour change.

**A11. Adding nitric acid caused the  $\text{H}^+(\text{aq})$  ion concentration to increase. The  $\text{CrO}_4^{2-}(\text{aq})$  ions formed in the previous reaction (see answer to question 10) reacted with the  $\text{H}^+(\text{aq})$  ions as follows:**



**The dichromate ions ( $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ ) formed in this reaction are thus responsible for the new colour of the solution.**

Q12. Write down colour indications for the species in the chemical equation:



Q13. You are given the following list of reagents:

Nitric acid ( $\text{HNO}_3(\text{aq})$ ),

sodium chloride ( $\text{NaCl}(\text{s})$ ),

potassium hydroxide ( $\text{KOH}(\text{s})$ ).

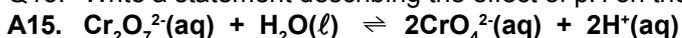
Which would you choose to add to an orange coloured solution of potassium dichromate to cause it to change to a yellow colour ?

**A13. Potassium hydroxide would cause an orange coloured potassium dichromate solution to change to yellow.**

Q14. Give the reason for your answer in question 13.

**A14. From the equation supplied in question 12, it can be seen that adding nitric acid to the dichromate/chromate equilibrium mixture will generate more of the orange dichromate ions. Sodium chloride should have no effect on the equilibrium as neither sodium nor chloride ions are involved in the reaction. However if potassium hydroxide were to be added, the hydroxide ions would combine with the hydrogen ions to form water. The equilibrium would be disturbed by the decrease in the  $\text{H}^+(\text{aq})$  concentration, and dichromate ions would react with the water to form more hydrogen and chromate ions. The solution would then appear yellow.**

Q15. Write a statement describing the effect of pH on the chromate/dichromate equilibrium.



**The presence of hydrogen ions in the equation for the reaction implies that pH will affect the equilibrium. If the pH is increased, e.g by adding a base like  $\text{NaOH}(\text{aq})$ , the  $\text{OH}^-(\text{aq})$  ions react with the  $\text{H}^+(\text{aq})$  ions shown in the above reaction equation. The decreased  $\text{H}^+(\text{aq})$  concentration disturbs the equilibrium and orange dichromate ions react with the water to form more chromate ions and hydrogen ions. The solution becomes yellow. Similarly, if the pH is decreased by the addition of an acid like  $\text{HNO}_3(\text{aq})$ , then the concentration of  $\text{H}^+(\text{aq})$  is high. The equilibrium is disturbed once again, and the chromate ions react with the hydrogen ions to form dichromate ions. The solution becomes orange.**



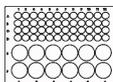
# CHEMICAL EQUILIBRIUM – LE CHATELIER'S PRINCIPLE

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is needed in Part 1. Ice or cold water is required in Part 2.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.



### 3. Hints

#### PART 1: The effect of the concentration of the reactants on the chemical equilibrium:



It may become confusing to learners when they are informed that the blue colour of the copper nitrate solution is due to  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  ions, and the green colour resulting from the addition of  $\text{HCl}$  is due to  $\text{CuCl}_4^{2-}(\text{aq})$  ions. They should be told that when a salt, like copper nitrate, dissolves in water, the ions making up the salt are surrounded by polar water molecules. Thus each  $\text{Cu}^{2+}$  ion in solution becomes bonded to four water molecules and is said to be **hydrated**. When the hydrochloric acid is added to the copper nitrate solution,  $\text{H}^+$  and  $\text{Cl}^-$  ions are introduced. The four water molecules bonded to the  $\text{Cu}^{2+}$  ions can be replaced with four chloride ions to form the green  $\text{CuCl}_4^{2-}$  complex ion.

In Part 1, 8 drops of water must be added to well A2 after the solution has become green upon the addition of 11 M  $\text{HCl}$ . The colour should change back to blue, but sometimes one more drop of water is needed before the colour change is complete.

Remember that well A1 in Part 1 is the standard of comparison for the dilution effect. Whenever a drop of  $\text{HCl}$  is added to well A2, a drop of water must be added to well A1. Similarly, whenever a drop of water is added to well A2, a drop of water must also be added to well A1.

#### PART 2: The effect of temperature on the chemical equilibrium:



In Part 2, the glass rod must not be made too hot, otherwise the solution in well A2 boils. If the colour change is not convincing, the rod can be wiped, passed through the flame again and placed back into well A2. If the rod is twirled in the well, the heat will be distributed more evenly. Similarly, when the cold rod is placed into the well, the colour change may take a long time. The rod should then be cooled again and placed back into the well to make the colour change complete. Note that ice is much better to use than cold water as it makes the rod colder.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**11 M hydrochloric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.**

**Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.**

**Methylated spirits is poisonous. Do not inhale the vapour or drink the liquid.**

**Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.**

**Be careful not to burn yourself when working with the microburner and hot rod. Do not allow the hot rod or flame of the burner to touch the comboplate®, as this will melt the plastic. Ensure that all burners are extinguished when not in use.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.



## PART 1: The effect of the concentration of the reactants on the chemical equilibrium:



Q1. What is the colour of the solution in each well ?

A1. The solution in each well is blue.

Q2. Which ion in solution is responsible for this colour ? (☺ Refer to the given equation.)

A2. The  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  is responsible for the blue colour.

Q3. Describe the colour change.

A3. The colour changes from blue to yellow/pale green when hydrochloric acid is added.

Q4. Which ion in solution is responsible for the new colour ? (☹ Refer to the given equation.)

A4. The  $\text{CuCl}_4^{2-}(\text{aq})$  is responsible for the yellow/pale green colour.

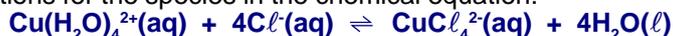
Q5. Note the colour change in well A2.

A5. The colour of the solution changes back from yellow/pale green to blue when water is added to A2.

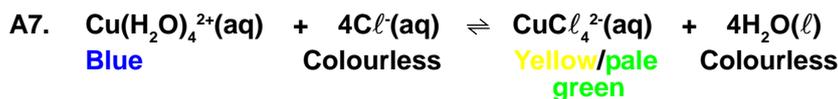
Q6. Propose a reason why adding HCl to the solution containing  $\text{Cu}(\text{NO}_3)_2$  turns it yellow/pale green.

A6. Adding HCl to the solution results in an increase in the concentration of chloride ( $\text{Cl}^-$ ) ions. The concentration of the  $\text{CuCl}_4^{2-}(\text{aq})$  ions then increases, and the concentration of the  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  ions decreases. (The  $\text{CuCl}_4^{2-}(\text{aq})$  ions are responsible for the yellow/pale green colour of the solution. The  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  ions are responsible for the blue colour of the solution.)

Q7. Write down colour indications for the species in the chemical equation:



☺ Water ( $\text{H}_2\text{O}$ ) is colourless.



Q8. You are given the following list of reagents:

nitric acid ( $\text{HNO}_3$ )

sodium chloride ( $\text{NaCl}$ )

sodium hydroxide ( $\text{NaOH}$ )

Which would you choose to add to a blue copper nitrate solution to cause it to turn yellow/pale green ?

A8. Sodium chloride ( $\text{NaCl}$ ) will cause a blue copper nitrate solution to change to yellow/pale green.

Q9. Give the reason for your answer to Question 8.

A9. Adding sodium chloride ( $\text{NaCl}$ ) to the solution results in an increase in the concentration of chloride ( $\text{Cl}^-$ ) ions in solution. Thus, once again the concentration of  $\text{CuCl}_4^{2-}(\text{aq})$  is increased and the solution turns yellow/pale green.

Q10. Write a statement describing the effect of concentration of reactants on the equilibrium you have studied.

A10. By adding chloride ions ( $\text{Cl}^-$ ) or water ( $\text{H}_2\text{O}$ ) to the solution, the concentration of either  $\text{CuCl}_4^{2-}(\text{aq})$  or  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  respectively, is increased. The colour of the solution reflects the colour of the species which are present in the greater concentration. This behaviour is typical of a chemical equilibrium.

## PART 2: The effect of temperature on the chemical equilibrium:



Q1. Describe the colour change in well A2. (If the colour change is not convincing, wipe the rod and repeat step 1.)

A1. The colour in well A2 changes from blue to pale green.

Q2. Which ion in solution is responsible for the new colour ? (☹ Refer to the chemical equation.)

A2.  $\text{CuCl}_4^{2-}(\text{aq})$  is responsible for the pale green colour.

Q3. Describe the colour change in well A2. (If the colour change is not convincing, repeat step 2.)

A3. The colour changed from pale green to blue.

Q4. Which ion in solution is responsible for the new colour ? (☺ Refer to the chemical equation.)

A4.  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  is responsible for the blue colour.

Q5. Do you observe the same colour changes as for well A2 ?

A5. No colour changes are seen in well A1.



- Q6. Having noted the colour changes in well A2 which species,  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  or  $\text{CuCl}_4^{2-}(\text{aq})$ , would you say is preferred under the following conditions:
- 6.1. Hot solution ?
  - 6.2. Cold solution ?
- A6. 6.1.  **$\text{CuCl}_4^{2-}(\text{aq})$  is preferred in hot solution.**  
 6.2.  **$\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  is preferred in cold solution.**
- Q7. Using the given chemical equation, explain why the colour changes when the temperature of the solution in well A2 is:
- 7.1. increased
  - 7.2. decreased
- A7. 7.1. **The concentration of the yellow/pale green  $\text{CuCl}_4^{2-}(\text{aq})$  increases and the concentration of the blue  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  decreases, when the temperature of the solution is increased.**  
 7.2. **When the solution temperature is decreased, the concentration of the blue  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  increases and the concentration of the yellow/pale green  $\text{CuCl}_4^{2-}(\text{aq})$  decreases.**
- Q8. Write a statement describing the effect of temperature on the chemical equilibrium you have studied.
- A8. **Higher temperatures give a greater concentration of  $\text{CuCl}_4^{2-}(\text{aq})$  at equilibrium. Lower temperatures give greater concentrations of  $\text{Cu}(\text{H}_2\text{O})_4^{2+}(\text{aq})$  and chloride ( $\text{Cl}^-$ ) ions at equilibrium.**
- Q9. A student says that the temperature affects the colour of all coloured solutions.
- 9.1. Do you think the student is correct in his view ?
  - 9.2. If not, how could you prove that the temperature only changes the colour of a solution when it changes the concentration of one or more of the coloured species in the solution ? Suggest an experimental set-up.
- A9. 9.1. **No! The student is incorrect.**  
 9.2. **An experimental set-up could involve a solution of  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$  in water to test the student's hypothesis. The solution in well A1, for example, was treated with both the hot rod and the cold rod. It should be noted that in neither case did the colour change.**



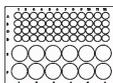
# CHEMICAL EQUILIBRIUM – THE COMMON ION EFFECT

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is also required.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.



### 3. Hints

The solution of saturated sodium chloride should be tested beforehand with 11 M hydrochloric acid. If it was prepared at a different temperature from your classroom, it may not be saturated. It may therefore not produce a precipitate when 11 M hydrochloric acid is added. If this happens, add more solid sodium chloride to the solution and stir. Each student can also prepare their own saturated sodium chloride solution as follows:

Fill about one third of one of the large wells in the comboplate® with solid sodium chloride ( $\text{NaCl}(s)$ ). Fill the well with water. Use a plastic microspatula or glass rod to stir the solution thoroughly. Allow any undissolved  $\text{NaCl}(s)$  to settle at the bottom of the well. Use a clean propette to suck up the solution above the undissolved salt, being careful not to disturb the solid. The volume of saturated sodium chloride solution in the propette should be sufficient to complete the experiment.

If the solution appears cloudy, it will need filtering. Remove the plunger of a syringe and push a small piece of cotton wool into the nozzle of the syringe. Dispense all of the solution from the propette into the syringe. Replace the plunger and position the syringe over an empty, large well. Gently push in the plunger to force the solution through the cotton wool filter and into the large well. Use a clean propette to remove the filtered solution from the well and continue with the experiment.

Remember that a precipitate will form only if the **concentration** of the common ion is **increased**. If the substance added to the saturated solution is a solid, then the amount of common ion increases but the volume of the solution remains the same. The concentration of the common ion will therefore increase and a precipitate will be observed.

However, if the substance added is a solution (eg.  $\text{HCl}(aq)$ ), a precipitate will only be observed if this solution is concentrated. This is because a dilute solution contains a smaller amount of ions per volume than a concentrated solution. When a dilute solution of the common ion is added to a saturated solution, the total volume of the resultant solution increases much more than the total amount of common ion in the solution. The concentration of the common ion decreases and a precipitate is not observed. This can be shown by allowing learners to repeat the experiment with 1 M hydrochloric acid. A precipitate will not form.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**Nitric acid and hydrochloric acid are very corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.**

**Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. What happens when you add the nitric acid to the saturated sodium chloride solution ?

A1. **The solution appears unchanged when nitric acid is added to the saturated sodium chloride solution.**

Q2. What happens when you add hydrochloric acid to the saturated sodium chloride solution ?

A2. **When hydrochloric acid is added to the saturated sodium chloride solution, the solution turns milky at first then a white precipitate forms.**



Q3. Do the solutions added in well A1 have ions in common with one another ? If so, state which they are.

A3. **No, the nitric acid and sodium chloride solutions do not have ions in common.**

Q4. Do the solutions added in well A2 have ions in common with one another ? If so, state which they are.

A4. **Yes, the chloride ion ( $\text{Cl}^-(\text{aq})$ ) is common to the hydrochloric acid and sodium chloride solutions.**

Q5. What is the name and chemical formula of the solid formed in well A2 ?

A5. **The solid formed in A2 is sodium chloride ( $\text{NaCl}(\text{s})$ ).**

Q6. In a saturated sodium chloride solution, solid sodium chloride is in equilibrium with the aqueous solution of sodium chloride, as represented in the balanced reaction equation,



Use this information to explain what happened in well A2.

A6. **When hydrochloric acid was added to the saturated sodium chloride solution, the concentration of chloride ions was increased. The extra chloride ions reacted with sodium ions to form solid sodium chloride, which precipitated. A new equilibrium was established.**

Q7. What happened to the contents of well A2 on adding water ?

A7. **When water was added to A2, the precipitate dissolved and a colourless solution formed again.**

Q8. Explain what happened in well A2.

A8. **The sodium chloride precipitate dissolved because the ion concentrations were decreased by adding the water. The equilibrium:**



**was disturbed, and  $\text{NaCl}(\text{s})$  dissolved to form  $\text{Na}^+(\text{aq})$  and  $\text{Cl}^-(\text{aq})$  ions. It dissolves completely if sufficient water is added.**

Q9. Explain what is meant by the "common ion effect".

A9. **When two or more different kinds of ions in solution are in equilibrium with a solid, the equilibrium can be disturbed by several factors in accordance with Le Chatelier's Principle. One of these factors involves the concentrations of the ions in solution. If another substance is added to the solution, it may also form ions. One of these ions may be the same as that already present in the solution. This ion is common to the two substances. The equilibrium reaction is disturbed by the change in concentration of the common ion. If the concentration of the common ion increases, then solid will precipitate. This outcome is described as the "common ion effect".**

Q10. A student makes a mistake when doing the above experiment and uses 1 M hydrochloric acid instead of 11 M hydrochloric acid in step 3.

Predict what the student will observe.

A10. **There will be no precipitate formed if the student adds 1 M hydrochloric acid to the saturated sodium chloride solution.**



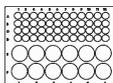
# CONCENTRATION AND AMOUNT OF SUBSTANCE IN SOLUTION

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is needed.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.



### 3. Hints

Solid copper nitrate absorbs water from the atmosphere. As a result, it can become a hard solid mass inside the bottle or container in which it is stored. The learners will be unable to use it in this form. It is therefore recommended that you break up the solid in the bottle with a sharp object before the experiment is attempted. A pointed, wooden skewer works well to crush the solid copper nitrate into small, even-sized grains.

When using the spooned end of the plastic microspatula to measure out the copper nitrate, make sure that level spatulas of solid are placed in the required wells. This will ensure that proper colour comparisons are made, and that the colour of the blue solution is equally intense in the wells which contain the same concentration of copper nitrate solution.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**Never point a propette or a syringe upwards. A momentary lapse of concentration can result in a nasty accident.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Which well, comparing wells F1 and F2, has the greater concentration of  $\text{Cu}^{2+}(\text{aq})$  ions ?



**What is the definition of concentration ?**

Give the reason for your answer.

**A1. Well F2 has the greater concentration of  $\text{Cu}^{2+}(\text{aq})$  ions. The blue colour is more intense in well F2. This is because well F2 has twice as much solid  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$  per volume of water, as well F1.**

Q2. Which well, comparing wells F1 and F3, has the greater concentration of  $\text{Cu}^{2+}(\text{aq})$  ions ?

Give a reason for your answer.

**A2. Both wells F1 and F3 have the same concentration of  $\text{Cu}^{2+}(\text{aq})$  ions. The blue colour is equally intense in the two wells. This is because the ratio of the quantity of  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$  added, to the volume of water added, is the same in both cases.**

Q3. Which well, comparing wells F1 and F2, has the greater amount of  $\text{Cu}^{2+}(\text{aq})$  ions ?



**What is the definition of amount ?**

Give the reason for your answer.

**A3. Well F2 contains the greater amount of  $\text{Cu}^{2+}(\text{aq})$  ions. Twice the quantity of solid  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$  has been placed in well F2, as in well F1. Twice the number of  $\text{Cu}^{2+}(\text{aq})$  ions are thus present in solution in well F2 than in well F1.**

Q4. Write a statement describing what is meant by the concentration and the amount of a substance in solution.

**A4. Concentration of a substance in solution refers to the amount of substance per volume of water. In this case, concentration is the ratio of the quantity (number of spatulas) of  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$  added, to the volume (millilitres) of water added. Amount refers to the quantity of a substance in solution. This quantity is not affected by the volume of water. In this experiment, the amount of copper nitrate solid refers to the number of spatulas of  $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$  in the solution.**



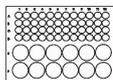
# ACID/BASE TITRATION – DETERMINING THE CONCENTRATION OF AN ACID

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet. Tap water is not required, but the syringe must be rinsed with tap water during the calibration procedure.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.



### 3. Hints

The hydrochloric acid ( $\text{HCl}(\text{aq})$ ) chosen for the purpose of providing model answers is approximately 0.1 M, but any concentration of this acid may be used. Bear in mind, however, that the best results will be obtained if the concentration of  $\text{HCl}(\text{aq})$  does not exceed 0.1 M. If larger concentrations are used, the number of drops of 0.1 M sodium hydroxide ( $\text{NaOH}(\text{aq})$ ) required to neutralise the acid will be too many to fit in the small wells of the comboplate®.

The graduation markings printed on the side of the syringe are not standard. This means that learners may get different numbers of drops per unit volume with different syringes, even when the same acid or base is used for calibration. As a result the precision and accuracy of the results obtained may be less than desired. However, learners must be encouraged to complete the experiment because the final calculations will yield suitable answers.

Step 4 in the calibration procedure suggests that the number of drops of  $\text{HCl}(\text{aq})$  be counted from the zero mark, until the volume of acid reaches another measuring mark a few units above the zero mark. You will notice that the model answers show the number of drops obtained for 0.5 ml of  $\text{HCl}(\text{aq})$  and  $\text{NaOH}(\text{aq})$ . You may use 0.2 or 0.3 ml, especially if you want to save chemicals.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**Hydrochloric acid is corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water.**

**Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.**

**Sodium hydroxide is a corrosive base. If any base is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. As with acids, propettes containing a base should never be pointed upwards.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Prepare a table like Table 1 below.

**TABLE 1**

| Solution Used | Volume of syringe from "zero mark" /ml | No. of drops of solution needed for set volume | Average No. of drops of solution needed for set volume |
|---------------|--|--|--|
| HCl           | 0.5                                    | 32   | 33 drops   |
|               | 0.5                                    | 33   |  |
|               | 0.5                                    | 35   |  |
| NaOH          | 0.5                                    | 30   | 29 drops   |
|               | 0.5                                    | 30   |  |
|               | 0.5                                    | 28   |  |



Q2. Enter your results into your table.

A2. See Table 1.

Q3. Enter your results into your table.

A3. See Table 1.

Q4. Enter your results into Table 1.

A4. See Table 1.

Complete the procedure for the conversion, that follows.

**CONVERSION:**

I) Hydrochloric acid:

**33** (average) drops of HCl occupy **0.5 ml**.

Therefore 1 drop of HCl occupies **0.015 ml**.

II) Sodium hydroxide:

**29** (average) drops of NaOH occupy **0.5 ml**.

Therefore 1 drop of NaOH occupies **0.017 ml**.

Q5. What is the colour of the solution ?

A5. The colour of the solution in well A1 is orange.

Q6. What is the colour of the solution ?

A6. The colour of the solution in well A2 is red.

Q7. Prepare a table like Table 2 below.

**TABLE 2**

| Acid used | No. of drops of HCl | No. of drops of NaOH | Average No. of drops of NaOH |
|-----------|---------------------|----------------------|------------------------------|
| HCl       | 5                   | 5                    | 5                            |
|           | 5                   | 5                    |                              |
|           | 5                   | 5                    |                              |

Q8. What number of drops of NaOH was required ? Enter the result in your table.

A8. See Table 2.

Q9. Enter your result in your table.

A9. See Table 2.

Q10. What average volume of the 0.10 M sodium hydroxide solution was required to titrate the hydrochloric acid ?

A10. We calculated that 1 drop (average) of sodium hydroxide solution occupies 0.017 ml (see calibration). But we used an average number of 5 drops in the titration.

$$\therefore \text{Average Volume NaOH} = \frac{0.017 \text{ ml}}{1 \text{ drop}} \times 5 \text{ drops NaOH}$$

$$= 0.085 \text{ ml} = 0.085 \times 10^{-3} \ell$$

$$= 8.5 \times 10^{-5} \ell$$

Q11. What amount of sodium hydroxide was this ?

A11. We know that the concentration of sodium hydroxide is 0.10 M or 0.10 moles of NaOH per 1 litre of solution. Since there are only  $8.5 \times 10^{-5} \ell$  of sodium hydroxide used then:

$$\text{Conc. of NaOH} = \frac{\text{amount of NaOH}}{\text{volume of solution}}$$

or in other words:

$$\text{Amount of NaOH} = \text{conc. of NaOH} \times \text{volume of solution}$$

$$= 0.10 \text{ moles } \ell^{-1} \times 8.5 \times 10^{-5} \ell$$

$$= 8.5 \times 10^{-6} \text{ moles}$$



Q12. What amount of  $\text{HCl}$  reacted with this sodium hydroxide ?

A12. The chemical equation which represents this reaction is:



We can see that the stoichiometric ratio is 1  $\text{HCl}$  : 1  $\text{NaOH}$  in this case. Thus at the end point of this titration (when the colour of the solutions in wells A2, A3 and A4 had just changed from red to orange) then for every mole of sodium hydroxide that reacted, one mole of hydrochloric acid reacted with it.

For this reason  $8.5 \times 10^{-6}$  moles of  $\text{HCl}$  reacted with  $8.5 \times 10^{-6}$  moles of sodium hydroxide.

Q13. What *volume* of  $\text{HCl}$  solution contained this amount of  $\text{HCl}$  ?

A13. We calculated that 1 drop (average) of hydrochloric acid occupies  $0.015 \text{ ml}$  (see calibration). But we used an average number of 5 drops in the titration.

$$\therefore \text{Average Volume HCl} = \frac{0.015 \text{ ml}}{1 \text{ drop}} \times 5 \text{ drops HCl}$$

$$= 0.075 \text{ ml} = 0.075 \times 10^{-3} \text{ l}$$

Q14. What is the concentration of the hydrochloric acid ?

A14. We know that  $8.5 \times 10^{-6}$  moles of  $\text{HCl}$  are contained in a volume of  $7.5 \times 10^{-5} \text{ l}$ . Thus the unknown concentration of the hydrochloric acid is:

$$\text{Conc. of HCl} = \frac{8.5 \times 10^{-6} \text{ moles of HCl}}{7.5 \times 10^{-5} \text{ litres of solution}}$$

$$= 0.11 \text{ moles l}^{-1}$$

Q15. If the 5 drops of hydrochloric acid ( $\text{HCl(aq)}$ ) supplied were replaced with 5 drops of sulphuric acid ( $\text{H}_2\text{SO}_4(\text{aq})$ ) of the same concentration, how many drops of  $0.10 \text{ M}$  sodium hydroxide ( $\text{NaOH(aq)}$ ) solution would be required to reach the end point in this titration ? Explain your answer.

A15. 10 drops of  $0.10 \text{ M NaOH(aq)}$  will be required. This is because sulphuric acid ( $\text{H}_2\text{SO}_4(\text{aq})$ ) is a diprotic acid whereas hydrochloric acid ( $\text{HCl(aq)}$ ) is a monoprotic acid. Thus for every molecule of sulphuric acid two hydrogen ions will be generated, while for every molecule of hydrochloric acid one hydrogen ion will be generated. Even though the concentration of the two acids is the same, twice as much sodium hydroxide solution will be needed to reach the end point. The equation which represents this reaction is:



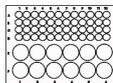
# THE ZINC/ COPPER CELL

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit. A 9V battery, a voltmeter and connecting wires for the voltmeter are required.



### 3. Hints

The syringe must be thoroughly rinsed before a new solution is dispensed, otherwise the copper nitrate and zinc nitrate solutions will be contaminated.

The 9V battery is a source of potential difference in the electrical circuit. It must be explained to the learner that the battery does not make the LED glow on its own. If the conducting wires are not placed in some electrolyte solution, the LED will not glow. It may be important to state this so as to avoid the misconception that the battery makes the LED glow, whether a conducting solution is present or not.

It is a good idea to try and attach the red and black wires from the current indicator to the terminals of the battery, for example by using crocodile clips or prestik. If the LED does not glow at first, check that the connections to the battery and electrodes are secure.

If the zinc electrode used in well F2 is a galvanised iron coil, it will have to be discarded after the experiment as the zinc is oxidised to  $Zn^{2+}(aq)$  ions. The galvanised iron coil normally turns black after the zinc layer has been oxidised. This is because the now-exposed iron is oxidised to black iron oxide. If the zinc electrode is a pure zinc coil, it may be reused.

The copper electrode will appear dull after the cell has been connected for approximately 10 minutes, as a result of copper depositing at the surface of the electrode. The coil can be rubbed clean with sandpaper and used again.

The copper and zinc coils must be removed from the comboplate<sup>®</sup> as soon as possible after the experiment to prevent the wells staining.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**Make sure that all learners wash their hands thoroughly after the experiment, as copper nitrate, zinc nitrate and potassium nitrate solutions can be irritating to the skin.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Does the current indicator glow ?

**A1. No, the current indicator does not glow.**

Q2. Is there a current flowing ?

**A2. No, there is no current flowing.**

Q3. Does the current indicator glow now ?

**A3. Yes, the current indicator glows when F1 and F2 are connected via the cotton wool strip.**

Q4. Is there a current flowing ?

**A4. Yes, current is flowing.**

Q5. What is the function of the salt bridge ?

**A5. The salt bridge provides electrical connection between the two solutions i.e  $Cu(NO_3)_2(aq)$  and  $Zn(NO_3)_2(aq)$ .**

Q6. Is there a potential difference ?

**A6. Yes, the needle of the voltmeter deflects showing that there is a potential difference across the cell.**

Q7. Does it look as shiny as when you put it in the copper nitrate solution ?

**A7. No, the copper wire coil is dull in appearance where it has been immersed in the solution.**



- Q8. From your observations of the copper electrode, what would you say is happening ?  
Suggest a chemical equation for this process.  
Is this a reduction or oxidation process ? Give a reason for your answer.
- A8. Copper ions ( $\text{Cu}^{2+}(\text{aq})$ ) from the solution are being reduced to copper atoms ( $\text{Cu}(\text{s})$ ) at the surface of the copper electrode, causing the copper electrode to be dull in appearance.**

The chemical equation for this process is  $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$ .

This is a reduction process because copper ions ( $\text{Cu}^{2+}(\text{aq})$ ) receive electrons at the copper electrode surface.

- Q9. What is taking place at the zinc electrode ?  
Write down an equation to illustrate this.  
Is this a reduction or oxidation process ? Give a reason for your answer.
- A9. The zinc electrode is oxidised. (A galvanised iron electrode gradually becomes black as the zinc metal coating is oxidised and the iron is exposed.)**

An equation to illustrate this is  $\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{e}^-$

This is an oxidation process because zinc atoms ( $\text{Zn}(\text{s})$ ) at the zinc electrode surface release electrons to the connecting wire.

- Q10. What is the direction of the electron flow through the connecting wire ?
- A10. The electron flow through the connecting wire is from the zinc electrode (anode) to the copper electrode (cathode).**

- Q11. Write down the chemical equation for the overall reaction.

**A11.  $\text{Cu}^{2+}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{Zn}^{2+}(\text{aq})$**

or  $\text{Cu}(\text{NO}_3)_2(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{Zn}(\text{NO}_3)_2(\text{aq})$



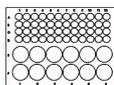
# ORGANIC CHEMISTRY – ESTERS

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Advanced Microchemistry Kit. Older versions of the kit will contain a glass sample vial suitable for esterification, while the newer editions of the kit possess a special sample vial made of a plastic that is resistant to organic solvents. **Do not use the vial of the microburner or any other plastic vial, as these will be destroyed by the organic liquids!**



### 3. Hints

When heating the glass rod, wave one end of the glass rod through the flame of a microburner a few times. Dip the hot end of the rod into the sample vial. If the fruity ester smell is weak or not evident, you may need to repeat the heating procedure.

Make sure that the sample vial is cleaned thoroughly before commencing step 6 of the experiment.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**18 M sulphuric acid is extremely corrosive. If any acid is spilt on the skin, the affected area must immediately be rinsed with copious amounts of water. Severe burns must receive medical attention.**

**Ethanoic acid has a strong vinegary odour that is harmful if inhaled. The acid also causes skin and eye irritation. It is flammable and must be kept sealed away from all flames.**

**Never point a propette or a syringe containing acid upwards. A momentary lapse of concentration can result in a nasty accident. If any acid is squirted into the eye, immediately rinse the eye out under running water. Always have a dilute solution of sodium hydrogencarbonate (household baking soda), or milk close by to apply to the injury. These substances will help neutralise the acid in the eye. The patient should be referred to a doctor.**

**Ethanol is very flammable. It must be kept separate from sulphuric acid and must never be brought near a flame, heat or sparks. The bottle containing ethanol must be kept closed, as inhalation of high concentrations of this chemical causes headaches and dizziness. Store in a cool place away from sources of ignition.**

**Never allow the learners to play with matches. Treat any burn with cold running water or ice, and seek medical assistance where necessary.**

**The methylated spirits used in the microburner is poisonous. Do not inhale the vapour or drink the liquid.**



### 5. Model Answers to Questions in the Worksheet

It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

Q1. Describe the smell of the contents in the sample vial.

**A1. The contents have a pleasant, fruity smell.**

Q2. Describe the smell of the contents in the sample vial.

**A2. The contents have a sour, acidic odour (like vinegar).**

Q3. What is the name of the ester that can be formed when ethanoic acid reacts with ethanol ?

**A3. Ethyl ethanoate (or ethyl acetate) forms when ethanoic acid reacts with ethanol.**

Q4. What is the name given to the type of reaction by which esters form from a carboxylic acid and an alcohol ?

**A4. Esters form in an esterification reaction.**

Q5. Was there such a reaction in the sample vial each time ?

**A5. A carboxylic acid and an alcohol were both added to the sample vial each time. However, an ester was only formed in the sample vial where the sulphuric acid had been added.**

Q6. What can you conclude about the role of concentrated sulphuric acid in the esterification reaction ?

**A6. Concentrated sulphuric acid catalysed the reaction.**



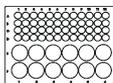
# ORGANIC CHEMISTRY – SATURATED AND UNSATURATED HYDROCARBONS

## TEACHER GUIDE



### 1. Chemicals

All of the required chemicals are listed in the worksheet.



### 2. Equipment

Most of the apparatus required can be found in a RADMASTE Basic or Advanced Microchemistry Kit.



### 3. Hints

The decolourisation of the bromine solution ( $\text{Br}_2(\text{aq})$ ) with hex-1-ene occurs as soon as the bromine/hex-1-ene mixture is stirred. You may also notice that if the bromine/cyclohexane mixture is left to stand in well A1, the brown colour of the bromine layer begins to disappear. This reaction is very slow and fumes of hydrogen bromide ( $\text{HBr}(\text{g})$ ) begin to appear. eg:



This is not the reaction for unsaturated hydrocarbons and must not be confused with the rapid decolourisation of the bromine when mixed with an unsaturated hydrocarbon.



### 4. Cautions

Please remember the following cautions and inform your students of all safety hazards:

**Bromine has a high vapour pressure i.e. the vapour above the solution will expand with an increase in temperature. It must therefore be kept in a cool, dark place in a well stoppered bottle.**

**The halogens are corrosive. Avoid dropping the bromine solution onto fabrics and skin. Wash hands thoroughly if any bromine solution makes contact with the skin.**

**The organic reagents, cyclohexane and hex-1-ene, as well as the bromine solution form toxic fumes. Avoid inhaling these fumes and make sure the experiment is performed in a well ventilated room.**



### 5. Model Answers to Questions in the Worksheet

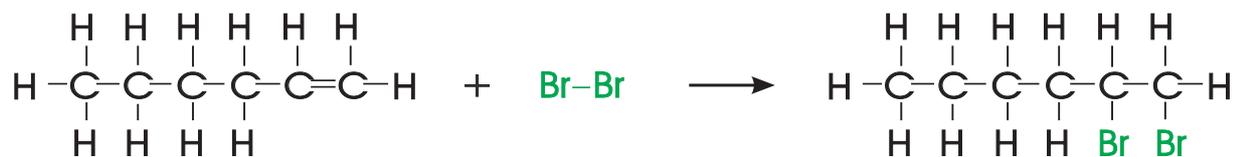
It is recommended that learners write down all of the questions and answers in their workbooks. If this is done, then the answers to questions do not have to be in full sentences. If the learners do not copy the questions into their workbooks, then answers should be written in full sentences. Note that some of the questions can only be answered by learners in higher grades. Word equations can be written instead of chemical equations where required.

- Q1. What happens in each well immediately after adding the bromine ?  
A1. **Well A1: Cyclohexane/bromine: The brown colour remains in the aqueous layer.**  
**Well A3: Hex-1-ene/bromine: The brown colour remains in the aqueous layer.**
- Q2. What happens in each well after stirring the contents ?  
A2. **Well A1: Cyclohexane/bromine: The brown colour remains in the aqueous layer.**  
**Well A3: Hex-1-ene/bromine: The aqueous layer becomes colourless.**
- Q3. Explain what happened when cyclohexane was in contact with aqueous bromine.  
A3. **Cyclohexane does not react with aqueous bromine and therefore the brown, bromine colour of the aqueous layer did not change.**
- Q4. Is cyclohexane a saturated or unsaturated hydrocarbon ? Justify your answer.  
A4. **Cyclohexane is a saturated hydrocarbon. Cyclohexane molecules have no multiple bonds.**
- Q5. Why was it necessary to stir the contents of each well ?  
A5. **The bromine remained in the aqueous layer. When the contents of the wells were stirred, the bromine molecules were able to make contact with the organic molecules in order for a reaction to take place.**
- Q6. Explain what happened when hex-1-ene was in contact with aqueous bromine.  
A6. **Hex-1-ene reacts with aqueous bromine. As the bromine is consumed in the reaction the brown colour of the aqueous layer disappears.**
- Q7. Is hex-1-ene a saturated or unsaturated hydrocarbon ? Justify your answer.  
A7. **Hex-1-ene is an unsaturated hydrocarbon. Hex-1-ene molecules have double bonds.**



Q8. What type of reaction occurs between hex-1-ene and aqueous bromine ? Write an equation to represent it.

A8. An addition reaction occurs between hex-1-ene and bromine i.e:



Q9. How can you test whether a hydrocarbon is saturated or unsaturated ?

A9. It is possible to test if a hydrocarbon is saturated or not with aqueous bromine. If the aqueous bromine is decolourised then the hydrocarbon is unsaturated. If, however, the aqueous bromine is not decolourised then the hydrocarbon is saturated.

