REVISION: CHEMICAL CHANGE 18 JUNE 2013

Lesson Description

In this lesson, we revise:

- rate of a reaction, the effect various factors have on rate and explain this in terms of collision theory
- chemical equilibrium
- electrochemistry

Key Concepts

Rate of Reaction

A chemical reaction is a process when one or more substances are changed into other substances with new chemical and physical properties

The rate of a chemical reaction is a measure of how quickly or slowly a chemical reaction takes place.

The rate of reaction can be measured in several ways. Namely:

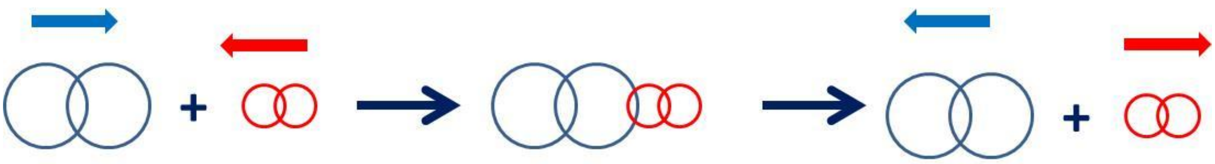
- the rate at which a gas is produced (that is the volume of the gas produced).
- the rate at which mass is lost in an open system.
- the rate at which a colour change is observed.

Collision Theory

In order for a chemical reaction to take place the particles involved need to collide with each other. For these collisions to be effective (i.e. produce the new substance) the following needs to happen:

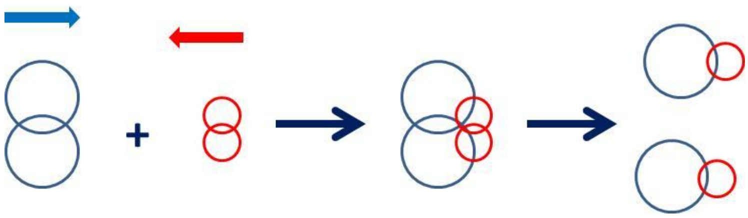
- The particles must collide with the correct orientation

  The diagram below shows two particles colliding with the incorrect orientation



After the collisions the particles will move away as the same reactants

The diagram below shows two particles colliding with the correct orientation



After the collision a new substance has been formed.

- The particles must collide with sufficient energy. The minimum energy required for an effective collision is known as the activation energy. Therefore the particles must collide with energy that is equal to or greater than the activation energy.

Factors that influence the Rate of Reaction

1. Temperature

When the temperature of a reaction is increased the rate of reaction will increase too. With an increase in temperature the particles in the reaction gain more kinetic energy. This means that when the particles collide with each other they are more likely to collide with sufficient energy and thus the collision will be effective. This leads to a greater number of effective collisions and so the reaction rate will increase.

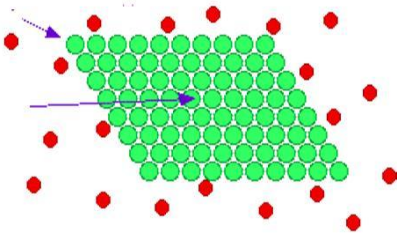
2. Concentration

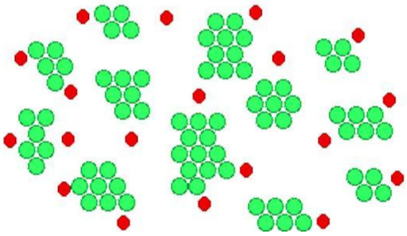
When the concentration of one of the reactants is increased it means that there are a larger number of particles taking part in the reaction. Due to the larger number of particles, there will be more collisions. A larger number of collisions will lead to more collisions having sufficient energy and the correct orientation. Thus a larger number of effective collisions will take place and the rate of reaction will increase.

3. Surface Area

The surface area of a solid is increased with the solid is crushed. This is sometimes referred to as the state of division.

When the solid is a large piece then the particles that are reacting are only the ones on the outer surface of the solid. The inner particles will only start to react once the outer particles have taken part in the reaction. Thus the reaction can be slow, as few collisions are taking place.





When the solid is crushed, more particles become available to take part in the reaction. This leads to more collisions taking place and thus a larger number of effective collisions can take place and the reaction rate increases.

4. Pressure

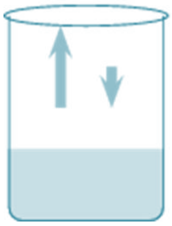
Pressure can only affect a reaction if at least one of the substances involved is a gas. By increasing the pressure on gas when the volume of the container is made smaller, the concentration of the gas increases. An increase in concentration will lead to an increase in the reaction rate. More particles are in smaller space and so will collide more often. This leads to a larger number of effective collisions and so the reaction rate increases.

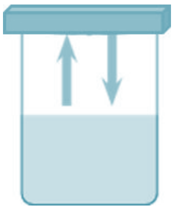
5. Catalyst

When catalyst is introduced into a system it will lower the activation energy of the reaction. This means that less energy is required for the reaction to take place. Thus when the particles collide the amount of energy needed for an effective collision to take place is less and so a larger number of effective collisions will take place. In turn, this means that the rate of reaction will increase.

Phase Equilibrium

When water is in an open system, such as an open beaker, water particles are able to escape. Eventually all the water will evaporate. The water particles will not condense as the system is open so no equilibrium can be established.





However if the beaker is sealed off, the water will eventually get to a place when a phase equilibrium will be formed. This means that as quickly as the water evaporates some of the water will condense.

So if a person was watching the beaker, they would see the water level drop for a period of time and then it would appear as if the water has stopped evaporating as the water level will remain constant.

A dynamic phase equilibrium has been reached with the water. This means that the rate of evaporation is equal to the rate of condensation and both processes are happening continuously.

Phase equilibrium can be represented as follows: $Liquid \rightleftharpoons vapour$

Phase equilibrium is an equilibrium that is established with a physical process as phase change is a physical change.

It is possible to establish a chemical equilibrium as well.

Chemical Equilibrium

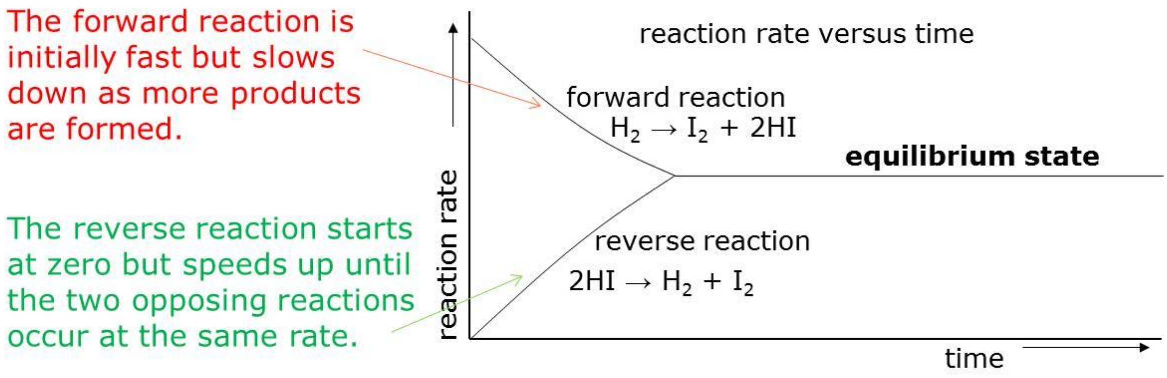
Many chemical reactions are spontaneously reversible if they are in a closed system.

For example: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

When the hydrogen and Iodine are first placed into the reaction container, they will quickly form hydrogen iodide. This means that the forward reaction will be fast at the beginning. However, as the hydrogen iodide is formed, so hydrogen iodide molecules will collide and react to form hydrogen and iodine, thus the reverse reaction starts to take place.

Eventually the rate at which hydrogen iodide is being formed will be equal to the rate at which hydrogen and iodine is formed. So the forward rate is equal to the reverse rate.

This can be represented on a rate graph, as shown below.



For chemical equilibrium to be established the following needs to be present:

1. there must be a closed system
2. the concentrations of the reactants and products must remain constant
3. the rate of the forward reaction must be equal to the rate of the reverse reaction

Le Chatelier's Principle

When the equilibrium of a system is disturbed, the system tries to restore equilibrium by counteracting the factors causing the disturbance

There are three factors which can have an influence on equilibrium:

- Concentration
- Temperature
- Pressure

Effect of Concentration

Consider the reaction: $CoC\ell_4^{2-} + 6H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4C\ell^-$ $\quad \Delta H < 0$

- Adding water:

  When more water is added to the solution, it makes more H_2O molecules available in the reaction. The equilibrium will shift to use up the extra H_2O, and we say that the forward reaction is favoured. This means the products concentration will increase and the solution will turn pink

- Adding hydrogen chloride ($HC\ell$)

  When hydrogen chloride is added, the $C\ell^-$ ion concentration will increase. This is also known as the **common ion effect**. The equilibrium will shift to use up the extra chloride ions. Thus the reverse reaction is favoured and the solution will turn blue

Effect of Temperature

Consider the reaction: $CoC\ell_4^{2-} + 6H_2O \rightleftharpoons Co(H_2O)_6^{2+} + 4C\ell^-$ $\quad \Delta H < 0$

- Increase temperature:

  When the temperature of the system is increased, the system must try to decrease the temperature. Due to the reverse reaction being endothermic, the reverse reaction will be favoured and the reaction will turn blue.

- Decrease temperature

  When the temperature of the system is decreased, the system must try to increase the temperature. Due to the forward reaction being exothermic, the forward reaction will be favoured and the reaction will turn pink.

Effect of Pressure

Consider the reaction: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

- Increase pressure:

  When the pressure of the system is increased, the equilibrium will shift in order to decrease the pressure. The pressure will be decreased by favouring the reverse reaction due to there being less gas molecules.

- Decrease pressure:

  When the pressure of the system is decreased, the equilibrium will shift in order to increase the pressure. The pressure will be increased by favouring the forward reaction due to there being more gas molecules.

Effect of a Catalyst

A catalyst does not affect the equilibrium, but it will increase the rate at which equilibrium is reached.

Electrochemical Cells

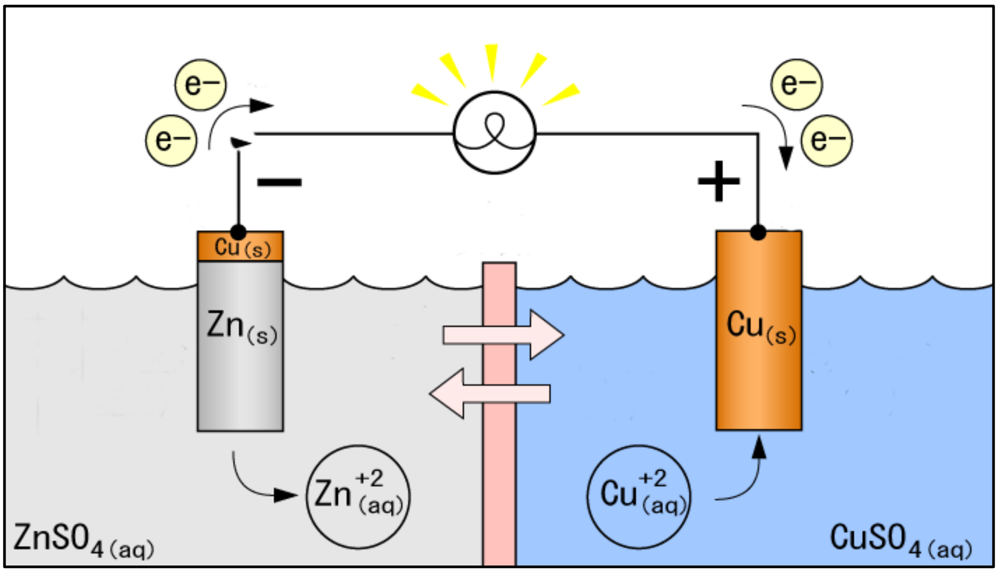
- Electrochemical cells fall into two categories:
- **Galvanic cells** turn **chemical potential energy** into **electrical energy**. They are spontaneous and give off energy.
- **Electrolytic cells** turn electrical energy into chemical potential energy. They are non-spontaneous and take in energy.

Terminology

Electrode	A conductive rod that moves electricity in and out of cells.
Cathode	The electrode where reduction takes place.
Anode	The electrode where oxidation takes place.
Oxidation	Loss of electrons.
Reduction	Gain of Electrons
Cell	A combination of reduction and oxidation half-reactions with an attached circuit.

Galvanic Cells

- These change **Chemical Potential Energy** into **Electrical Energy.**
- What do we need?
  1. Two metals with different oxidising reducing ability.
  2. Electrolyte
- The Zinc-Copper cell is an excellent example of a galvanic cell



- Zinc electrode: Zn → Zn^{2+} + 2 e^-
- Copper electrode: Cu^{2+} + 2 e^- → Cu
- Zinc is where oxidation takes place, we call this the "anode".
- Copper is where reduction takes place, this we call the "cathode".

Electrolytic Cells

- These change **Electrical Energy** into **Chemical Potential Energy.**
- What do we need?
  1. Two electrodes with a voltage across them.
  2. Electrolyte.
- Negative electrode: $2H^+$ + 2 e^- → H_2
- Positive electrode: $2H_2O$ → O_2 + 4 e^- + $4H^+$

Standard Electrode Potential

- The Standard Electrode Potential table ranks the half reactions from lowest to highest.

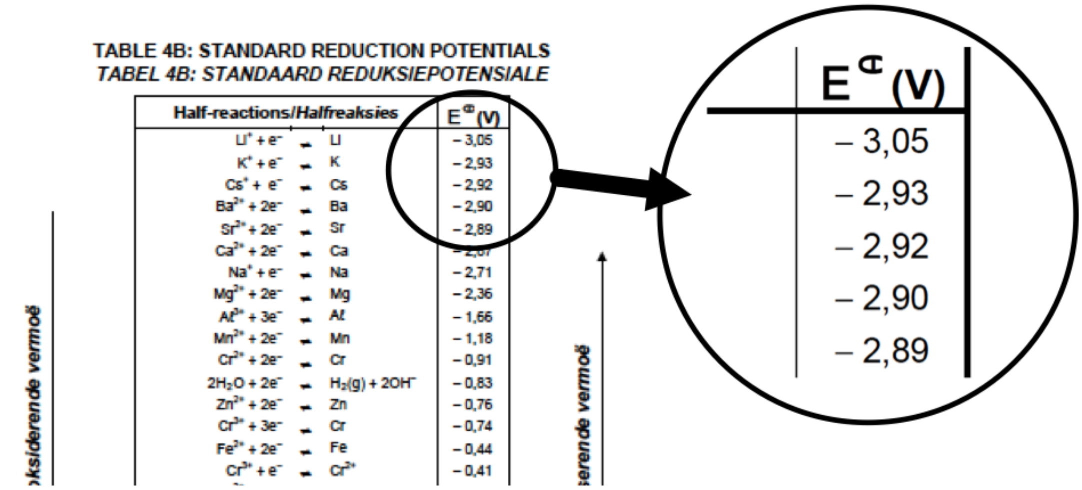


TABLE 4B: STANDARD REDUCTION POTENTIALS
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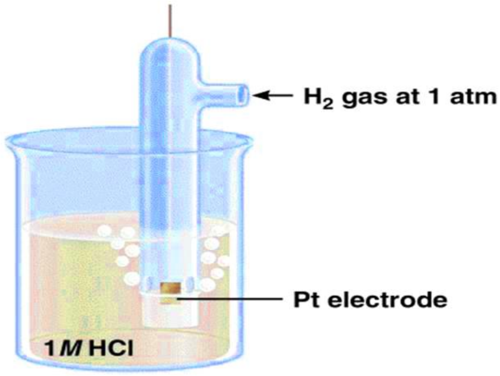
Half-reactions/*Halfreaksies*	E^θ (V)
$Li^+ + e^- \rightleftharpoons Li$	−3,05
$K^+ + e^- \rightleftharpoons K$	−2,93
$Cs^+ + e^- \rightleftharpoons Cs$	−2,92
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	−2,90
$Sr^{2+} + 2e^- \rightleftharpoons Sr$	−2,89
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	[illegible]
$Na^+ + e^- \rightleftharpoons Na$	−2,71
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	−2,36
$Al^{3+} + 3e^- \rightleftharpoons Al$	−1,66
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	−1,18
$Cr^{2+} + 2e^- \rightleftharpoons Cr$	−0,91
$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$	−0,83
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	−0,76
$Cr^{3+} + 3e^- \rightleftharpoons Cr$	−0,74
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	−0,44
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	−0,41

- These are reduction potentials - the likelihood that the reaction would undergo reduction.

- Notice how the reactions are ranked from left to right.

Standard Hydrogen Electrode

- These voltages are found by comparing the unknown electrode to the Standard Hydrogen Electrode
- $2H^+ + 2e^- \rightarrow H_2$
- The standard conditions are: 1mol·dm^{-3} concentration of H^+, 1atm. pressure of H_2 and 25 °C.



- Because hydrogen is a non-conductive gas, platinum is used to capture and react the hydrogen gas.

Cell Potential

By using the numbers on the table, we can calculate the voltage, or emf, that we can expect from a combination of two electrodes.

$E_{cell} = E_{cathode} - E_{anode}$

So, first you need to find out where oxidation is taking place (anode) and then reduction (cathode).

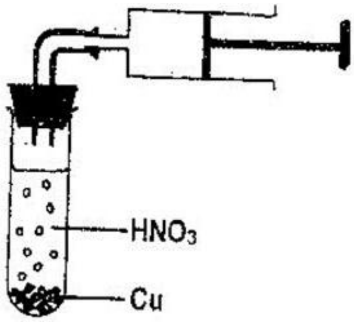
<u>Hint:</u> Always substitute using brackets as the signs may need to change.

Questions

Question 1

(Adapted from 2001 National Higher Grade Paper 2)

Pieces of copper are covered by an excess of concentrated nitric acid (HNO_3) in a test tube. A reddish brown gas forms in the reaction and it is noted that the contents of the test tube become hot. The test tube is connected via a tube to a syringe and the gas is collected in the syringe.



How will each of the following changes in the conditions affect the rate at which the gas develops? (Write only INCREASES, DECREASES or STAYS THE SAME)

a.) More copper is used
b.) The temperature of the acid is increased
c.) More concentrated HNO_3 is used.

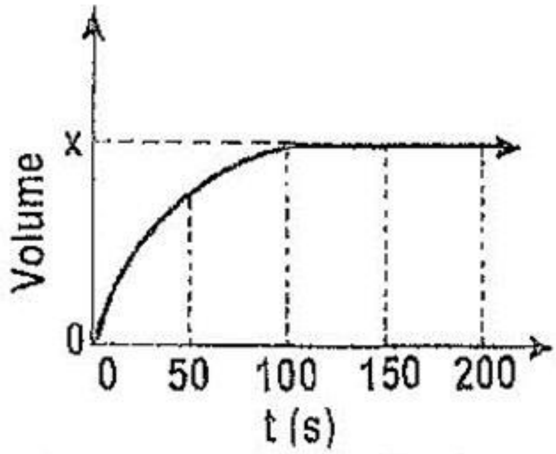
Question 2

(Adapted from 1999 Higher Grade OFS Paper 2)

A beaker contains a dilute solution of H_2SO_4 with a volume of 140 cm^3. The concentration of the acid is 0,1 $mol.dm^{-3}$ and the temperature is kept at 25^oC all the time.

Na_2CO_3 powder is added to the H_2SO_4 solution and exactly neutralises the acid. The balanced equation of the reaction which takes place is:

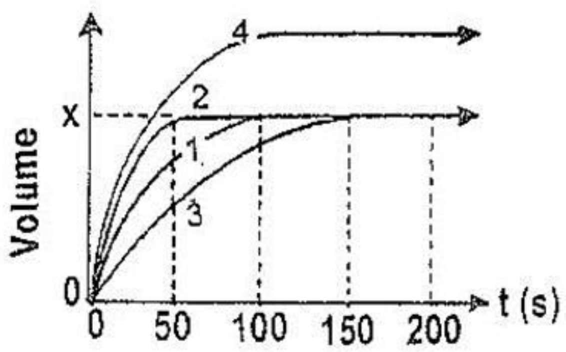
$Na_2CO_3(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$



The reaction rate of the above reaction is investigated and the following graph shows the volume of $CO_2(g)$ formed against time. The temperature is kept constant at 25^oC.

a.) How long did the reaction between the two solutions take to reach completion?
b.) According the graph, the reaction rate is a maximum directly after the two reactants have been added together. Given an explanation for this.

An identical sample of Na_2CO_3 powder is added to a H_2SO_4 solution, again with a concentration of 0,1mol.dm^{-3}, in a further investigation. A catalyst is also added to the reaction mixture while the temperature is kept at 25^{o}C. Consider the following graphs for this:



c.) If graph 1 represents the conditions of the original investigation, which one of 2, 3 or 4 represents this investigation?

Question 3

(Adapted from Mar 2012, NSC, Paper 2, Question 2.8)

Which ONE of the following statements regarding a copper-silver galvanic cell is TRUE?

A Silver is formed at the anode.

B Copper is formed at the anode.

C Silver is formed at the cathode

D Copper is formed at the cathode.

Question 4

(Adapted from Mar 2010, DoE, Paper 2, Question 10)

Batteries consist of one or more galvanic cells. A galvanic cell is a combination of two half-cells.

John wants to determine which one of Options A or B, shown below, can be used to assemble a galvanic cell with the highest potential difference.

Option	Combination of half-cells
A	Ag(s) in $AgNO_3$(aq) & Ni(s) in $Ni(NO_3)_2$(aq)
B	Mg(s) in $Mg(NO_3)_2$(aq) & Ag(s) in $AgNO_3$(aq)

a.) Draw a fully labelled diagram of the galvanic cell that John can use to measure the potential difference for the cell in Option B. Use a positive (+) and negative (-) sign to indicate the positive and negative electrodes respectively. (5)

b.) Write a balanced chemical equation, excluding spectator ions, for the net (overall) cell reaction for the galvanic cell in Option B. (3)

c.) Calculate the initial potential difference that can be obtained under standard conditions for the galvanic cell in Option B. (4)