STUDY NOTES

A1 Tuition
PROGRESSIVE EDUCATION

2nd edition

CHEMISTRY
UNIT 4

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CHEMISTRY
UNIT 4 STUDY NOTES
"CHEMISTRY AT WORK"

$24.95

CONTENTS

INTRODUCTION

Hi and welcome to Year 12 chemistry. I hope that you found last years and the first half of this years work helpful and it is still somewhere in your minds cause guess what its back. Over the rest of the year we will be exploring concepts that you learned in Units 1, 2& 3 and continue to build upon them. Now I know there are a few of you thinking 'help! I did not do Units 1 & 2' or 'help! I am still having trouble with the old concepts'. Do not worry, if you have not yet check them out there are study guides available fro Units 1, 2 and 3 in this series. I suggest you have a look at them. If you still are having trouble I suggest you enlist the help of a tutor. This agency have really good highly qualified tutors that are more than happy to help you throughout the year so not hesitate to ask for help.

Towards the end of this guide is a set of 8 appendices which are designed for a reference point for different topics. I have placed in these appendices a lot of tables, formula you have already learnt and conversion factors. This should help you throughout the year. If you have previous guides for chemistry from us you will notice these appendices are standard every guide and increase each unit.

Now to introduce you to what you will be learning this year. I must admit that a lot of these topics will be unfamiliar, which is unusual as normally there is some link amongst the topics. Topic 1 is devoted to equilibrium. In unit 2 we hinted that reactions did not go to completion, this topic is learning how to deal with these reactions and how to do calculations. Please try not to get disorientated with this topic, it is not that bad, just try to remember the calculations you have already learnt and the new stuff will be easy.

Topic 2 is also a new concept, only there are some aspects of this topic you have already seen before. For example we have already done a lot of work into redox reactions for two units now. In unit 2 we will also be revising the definitions of a galvanic cell and also taking it further into fuel cells and electrolytic cells. We also briefly in unit 2 played around with the specific heat capacity of water. This idea we shall also expand.

I wish you the best of luck with this half of the year and hope you find this guide handy. Good luck with the VCE and I hope you get the results you are striving for!

Amy Paul

INDUSTRIAL CHEMISTRY

INDUSTRIAL CHEMISTRY

COLLISION THEORY

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EQUILIBRIUM

EQUILIBRIUM & pH

MANAGEMENT & DISPOSAL OF CHEMICALS

DISPOSAL OF WASTE

INDUSTRIAL PRODUCTION OF CERTAIN CHEMICALS

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COLLISION THEORY

Collision theory must be considered to see why the different factors change the speed of a reaction. There are four main ways the reaction rates can be increased;

- Increasing the surface area.
    - By crushing up a solid before adding it to a reaction, you increase the surface area of the solid making more of a target for the other reactant to collide into the solid and therefore the rate at which the reaction increases.

- Increasing the concentration of reactants (or pressure of gaseous reactants).
    - With more molecules or ions moving around in solution the frequency of collisions is increased and therefore speeds up the reaction rate.
    - Increasing the pressure on a gas, raises the concentration, and therefore causes more collisions.

- Increasing the temperature.
    - As temperature is increased the average speed of the particle is also increases, causing faster moving particles to collide more often.
    - A small increase in temperature gives a large increase in the reaction rate.

- Adding a catalyst.
    - A catalyst is an element or compound that helps to speed up a reaction, but doesn't change itself, hence not being part of the reactants or the products.
    - There are two types of catalysts:
        - Homogenous catalysts are in the same state to the reactants and the products.
        - Heterogenous catalysts are in different states to the reactants.
            - Chemists prefer to use heterogenous catalysts for industrial processes as they are more easily separated from the products of the reaction.
    - A catalyst works through a lock and key analogy. The catalyst particle latches onto one of the reactants and then helps to bind it to the other reactant.

- The minimal amount energy required to break bonds of the reaction and therefore allow the reaction to occur is known as the activation energy of the reaction.

ENERGY PROFILE DIAGRAMS

- All substances have chemical energy.
- The chemical energy of a substance is the sum of its potential energy (stored energy) and kinetic energy (energy of movement).
- Chemical energy is a result of
    - Attractions between electrons and protons in atoms;
    - Repulsions between nuclei;
    - Repulsions between electrons;
    - Movement of electrons;
    - Vibrations and rotations of nuclei.
- The chemical energy of a substance is sometimes known as the heat content or enthalpy, and is given by the symbol H.
- The energy released or absorbed in a chemical reaction is called the heat of reaction, ΔH. The heat of reaction is the difference in enthalpy in the reaction between the products and the reactants.

$$\Delta H = H\text{(products)} - H\text{(reactants)}$$

- A reaction that releases energy is known as an exothermic reaction, $\Delta H < 0$.
- A reaction that absorbs energy is known as an endothermic reaction, $\Delta H > 0$.
- Thermochemical equations show the energy released or absorbed during a chemical reaction.
- An energy profile diagram of an endothermic and exothermic reaction is shown on the following page.

Exothermic Reaction   Endothermic Reaction
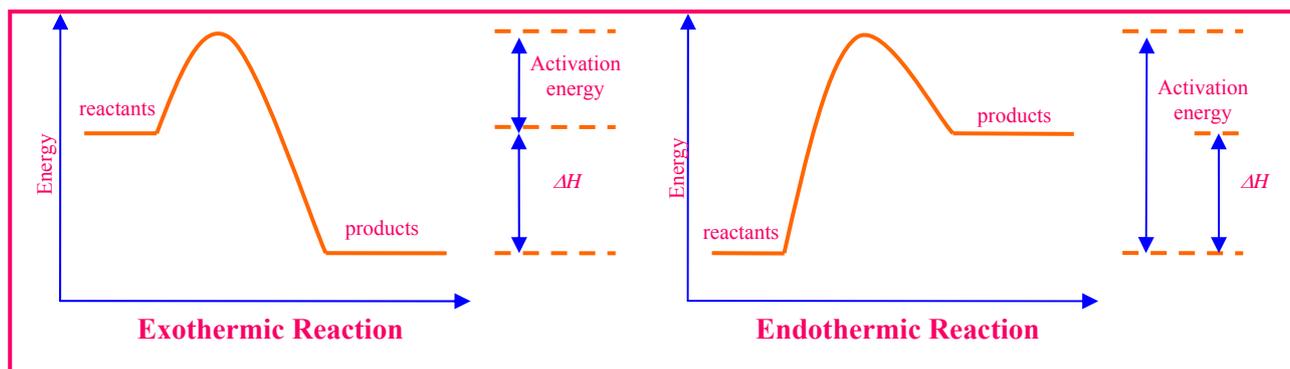
EQUILIBRIUM

- Not all chemical reactions turn all their reactants to products.
- Some reactions can be reversed.
- In some cases the forward and reverse reaction occurs simultaneously.
- The percentage yield allows a chemist to know how much of a substance was created. It is given by this formula:

$$\% \text{ yield} = \frac{\text{amount of substance obtained}}{\text{theoretical amount that should have been obtained}} \times \frac{100}{1}$$

EQUILIBRIUM

- Equilibrium is the dynamic state since the forward and back reactions have not ceased, but occur simultaneously at the same rate. During dynamic equilibrium:
    - The amounts and concentrations of chemical substances remain constant.
    - The total gas pressure is constant (if gases are involved);
    - The temperature is constant;
    - The reaction is 'incomplete' (all of the substances involved in the reactions are present in the equilibrium mixture.
- Not all reactions reach equilibrium.

THE EQUILIBRIUM LAW

The concentration constant K_c for any reaction at equilibrium,

$$aW + bX \rightleftharpoons cY + dZ$$

$$K_c = \frac{[Y]^c [Z]^d}{[W]^a [X]^b}$$

The fraction $\dfrac{[Y]^c [Z]^d}{[W]^a [X]^b}$ is known as the concentration fraction. This is known as the equilibrium law.

From studies of equilibria, chemists have concluded that:
- Different chemical reactions have a different value for K_c;
- For a particular reaction, K_c is a constant fro all equilibrium mixtures at a fixed temperature.

NOTE: It is very important to specify the equation and the temperature when the equilibrium constant is quoted as this constant varies depending on the reaction and the temperature.

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WHAT DOES THE EQUILIBRIUM CONSTANT TELL US?

K_c gives the indication of the extent of a reaction. For values of K_c that are:

- $10^{-4} \le K_c \le 10^4$ – there will be a significant amount of products and reactants in the reaction.
- $K_c < 10^{-4}$ – The reaction contains mainly concentrations of the reactants with relatively small concentrations of the products.
- $K_c > 10^4$ – The reaction contains mainly concentrations of the product with relatively small concentrations of the reactants.

EFFECT OF TEMPERATURE ON EQUILIBRIA

As mentioned already, the equilibrium constant is only a constant for constant temperature. The effect that temperature has on the equilibrium constant is dependent on the reaction being an exothermic or endothermic reaction. In general:

- For exothermic reactions, the value of K_c decreases (so the amounts of products decrease);
- For endothermic reactions, the value of K_c increases (so the amounts of product increase).

If the temperature of the equilibrium mixture is to decrease, the opposite effect will happen.

NOTE: Since values of K_c depend on temperature, it is important to specify the temperature at which the equilibrium constant has been measured.

CALCULATIONS INVOLVING THE EQUILIBRIUM CONSTANT

There are many different calculations that can occur when doing calculations with the equilibrium constant. Because of this it is hard to list all information on how to solve problems. These view hints however, will help you through the questions.

- The volume for all products and reactants is the same throughout the experiment.
- [ ] notation means molar concentration.
- It is often handy to put your information in table form, stating the initial conditions, change in equilibrium and the end point. From this you can calculate exact concentrations without worry about making mistakes. An example of this table has been placed below:

|	**W**	**X**	**Y**	**Z**
Initial	$[W]_0$	$[X]_0$	$[Y]_0$	$[Z]_0$
Change in equilibrium	$\Delta[W]$	$\Delta[X]$	$\Delta[Y]$	$\Delta[Z]$
Final values at equilibrium	$[W]_0 + \Delta[W]$	$[X]_0 + \Delta[X]$	$[Y]_0 + \Delta[Y]$	$[Z]_0 + \Delta[Z]$

NOTE: Denote direction of change in equilibrium – for a decrease and + for increase. The final values (third row) are what you use for the constant. Sometimes your table will house unknown values, which will be what you are solving in the end.

Example 1: In a gas-phase equilibrium mixture of H_2, I_2, and HI at 500K, $[HI] = 3.41 \times 10^{-3}$ M and $[I_2] = 2.64 \times 10^{-3}$ M. Given the value of $K_C = 160$, calculate the concentration of H_2.

This type of question is very straight forward as we are given all the values to start off with, so we do not need to worry about setting the information in table format.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$
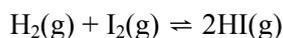
$$K_C = \frac{[HI]^2}{[H_2][I_2]}$$

$$[H_2] = \frac{[HI]^2}{K_C[I_2]} = \frac{(3.41 \times 10^{-3})^2}{160 \times 2.64 \times 10^{-3}} = 2.75 \times 10^{-5} \, M$$

Example 2: A 50.0g sample of ammonium carbamate, $NH_4(NH_2CO_2)$, was placed in an evacuated 500mL flask and kept at 25°C. At equilibrium, 34.8mg of CO_2 was present. What is the value of K_C for the decomposition of ammonium carbamate into ammonia and carbon dioxide?

$$NH_4(NH_2CO_2)(s) \rightleftharpoons 2NH_3(g) + CO_2(g).$$
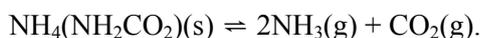
Okay this question we need to use a table to formulate our results, however before we mess around with tables we need to convert our data into concentrations.

$V = 500mL = 0.5L$

$m(NH_4(NH_2CO_2)) = 50.0$ g
$M(NH_4(NH_2CO_2)) = 14.01 \times 2 + 1.008 \times 6 + 12.01 + 16.00 \times 2 = 78.078$ g·mol^{-1}
$n(NH_4(NH_2CO_2)) = \dfrac{m(NH_4(NH_2CO_2))}{M(NH_4(NH_2CO_2))} = \dfrac{50.00}{78.078} = 0.640$ mol
$[NH_4(NH_2CO_2)]_I = \dfrac{n(NH_4(NH_2CO_2))}{V} = \dfrac{0.640}{0.500} = 1.28$ M

$m(CO_2) = 34.8mg = 3.48 \times 10^{-2}$ g
$M(CO_2) = 12.01 + 16.00 \times 2 = 44.01$ g·mol^{-1}
$n(CO_2) = \dfrac{m(CO_2)}{M(CO_2)} = \dfrac{3.48 \times 10^{-2}}{44.01} = 7.91 \times 10^{-4}$ mol
$[CO_2]_E = \dfrac{n(CO_2)}{V} = \dfrac{7.91 \times 10^{-4}}{0.500} = 1.58 \times 10^{-3}$ M

Putting this information into the table (**pink** values) we get:

	$[NH_4(NH_2CO_2)]$ M	$[NH_3]$ M	$[CO_2]$ M
Initial	1.28	0	0
Change in equilibrium	- 1.58 × 10⁻³	+ 3.16 × 10⁻³	+ 1.58 × 10⁻³
Equilibrium	1.28	3.16 × 10⁻³	1.58 × 10⁻³

✍ If you look at $[CO_2]$ column we can easily work out the change in equilibrium by subtracting the equilibrium concentration via the initial to give us what we have in **blue**

✍ Comparing moles ratios we have:

$[NH_4(NH_2CO_2)] : [NH_3] : [CO_2] = 1 : 2 : 1 =$ **1.58 × 10⁻³ : 3.16 × 10⁻³ : 1.58 × 10⁻³**

We can compare this with the change in equilibrium to give the answers in orange. Remember that the ammonium carbamate will be losing concentration.

✏ Now we can finish the table by adding the rest of our values. I have placed this in green. If you are wondering why the ammonium carbonate indicates no change in value, it is because of the number of significant figures. If we used more we would see a slight change.

Now we can calculate the equilibrium constant:

$$K_C = \frac{[NH_3]^2[CO_3]}{[NH_4(NH_2CO_2)]} = \frac{(3.16\times10^{-3})^2 \times 1.58\times10^{-3}}{1.28} = 1.23\times10^{-8}$$

Example 3:
a) A sample of 10.0mmol Cl_2 was sealed into a 2.0L reaction vessel and heated to 1200K to study its dissociation into Cl atoms. Given that the equilibrium constant is 1.70×10^{-5} calculate the equilibrium composition of the mixture. What is the percentage decomposition of the Cl_2?
b) If 10.0 mmol I_2 were placed into the reaction vessel instead of chlorine, given that the equilibrium constant is 6.80×10^{-2} what would the equilibrium composition of the mixture? What is the percentage composition of I_2.
c) Use your results from (a) and (b) to determine which is more stable at 1200K; I_2 or Cl_2?

This question is a little more interesting as we are starting with initial factors. When dealing with equilibrium we need to assign a variable for the change and solve. If you are not doing Mathematical Methods in conjunction to this course you may run into trouble to solve these questions. In general to solve quadratic equations use the quadratics formula

$$\text{If } ax^2 + bx + c = 0$$
$$\text{Then:}$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

This equation will give you two answers; remember that you cannot have a negative answer for a concentration!

a)

$$n(Cl_2) = 10.0 \times 10^{-3} \text{ mol} \qquad (\text{mmol} = 10^{-3} \text{ mol})$$
$$V = 2.0 \text{ L}$$
$$[Cl_2]_I = \frac{n(Cl_2)}{V} = \frac{10.0\times10^{-3}}{2.0} = 5.00\times10^{-3} \text{ M}$$

$$Cl_2(g) \rightleftharpoons 2Cl(g)$$
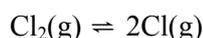
	[Cl$_2$] M	[Cl] M
Initial	5.00×10^{-3}	0
Change with equilibrium	$-x$	$+2x$
Equilibrium	$5.00 \times 10^{-3} - x$	$2x$

$$K_C = \frac{[Cl]^2}{[Cl_2]}$$

$$1.7\times10^{-5} = \frac{4x^2}{5.00\times10^{-3} - x}$$

$$4x^2 + (1.7 \times 10^{-5})x - 8.5 \times 10^{-8} = 0$$

$$x = \frac{-1.7 \times 10^{-5} \pm \sqrt{\left(1.7 \times 10^{-5}\right)^2 - 4 \times 4 \times \left(-8.5 \times 10^{-8}\right)}}{2 \times 4} = -1.48 \times 10^{-4}, 1.44 \times 10^{-4} \, M$$

Now we cannot have the first value as it is negative so $x = 1.44 \times 10^{-4} M$

Equilibrium composition:

$$[Cl_2]_E = [Cl_2]_I - x = 5.00 \times 10^{-3} - 1.44 \times 10^{-4} = 4.86 \times 10^{-3} \, M$$

$$[Cl] = 2x = 2.88 \times 10^{-3} \, M$$

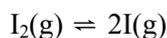% decomposition $= \dfrac{x}{[Cl_2]_I} \times 100 = \dfrac{1.44 \times 10^{-4}}{5.00 \times 10^{-3}} \times 100 = 2.88\%$

b)

$$n(I_2) = 10.0 \times 10^{-3} \, mol$$
$$V = 2.0 \, L$$

$$[I_2]_I = \frac{n(I_2)}{V} = \frac{10.0 \times 10^{-3}}{2.0} = 5.00 \times 10^{-3} \, M$$

$$I_2(g) \rightleftharpoons 2I(g)$$

	$[I_2]$ M	$[I]$ M
Initial	5.00×10^{-3}	0
Change with equilibrium	$-x$	$+2x$
Equilibrium	$5.00 \times 10^{-3} - x$	$2x$

$$K_C = \frac{[I]^2}{[I_2]}$$

$$6.8 \times 10^{-2} = \frac{4x^2}{5.00 \times 10^{-3} - x}$$

$$4x^2 + (6.8 \times 10^{-2})x - 3.4 \times 10^{-4} = 0$$

$$x = \frac{-6.8 \times 10^{-2} \pm \sqrt{\left(6.8 \times 10^{-2}\right)^2 - 4 \times 4 \times \left(-3.4 \times 10^{-4}\right)}}{2 \times 4} = -2.10 \times 10^{-2}, 4.04 \times 10^{-3} \, M$$

Now we cannot have the first value as it is negative so $x = 4.04 \times 10^{-3} M$

Equilibrium composition:

$$[I_2]_E = [I_2]_I - x = 5.00 \times 10^{-3} - 4.04 \times 10^{-3} = 9.60 \times 10^{-4} \, M$$

$$[I] = 2x = 8.08 \times 10^{-3} \, M$$

% decomposition $= \dfrac{x}{[I_2]_I} \times 100 = \dfrac{4.04 \times 10^{-3}}{5.00 \times 10^{-3}} \times 100 = 80.8\%$

c) From the % decompositions in parts a) and b), I_2 decomposes a lot more than Cl_2. Hence Cl_2 is a lot more stable than I_2.

COMBINATIONS OF EQUILIBRIA

If you know the equilibrium constant of a certain reaction, you can find the equilibrium constant of other reactions relating to it by these simple rules:

- Add equilibria, multiply their equilibrium constants
- Subtract equilibria, divide their constants
- Halve an equilibrium, take square root of constant
- Reverse an equilibrium reaction, invert the constant.

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CHANGING THE POSITION OF EQUILIBRIUM OF A REACTION

LE CHATELIER'S PRINCIPLE

If an equilibrium system is subjected to change, the system will adjust itself to partially oppose the effect of the change.

METHODS OF CHANGING THE POSITION OF EQUILIBRIUM.

In industrial chemistry, controlling the yield of a reaction is important. The position of the equilibrium in a reaction can be changed by:

- Adding or removing a reactant or product;
  - Add reactant →
  - Add product ←

- Changing the pressure by changing the volume (for equilibria involving gases);
  - Eg: 2 reactant particles ⇌ 1 product particle →
  - Eg: 1 reactant particle ⇌ 2 product particles ←

- Dilution (for equilibria in solution);
  - Eg: 2 reactant particles ⇌ 1 product particle →
  - Eg: 1 reactant particle ⇌ 2 product particles ←

- Changing the temperature.
  - Increase temperature
    - Endothermic reaction →
    - Exothermic reaction ←
  - Decrease temperature
    - Endothermic reaction ←
    - Exothermic reaction →

- A catalyst does not alter the extent of a reaction.

NOTE: forward reaction is denoted by →, backwards reaction is denoted by ←.

EQUILIBRIUM AND PH

THE IONISATION CONSTANT OF WATER

The ionisation constant of water, K_w, is defined as:

$$K_w = [H_3O^+][OH^-]$$

THE PH SCALE

- The pH of a solution measures the acidity of a solution.
- In solution:
  - An acidic solution has:
    - more H_3O^+ ions than OH^- ions;
    - $[H_3O^+] > 10^{-7}$ M and $[OH^-] < 10^{-7}$ M;

- Have a pH < 7;
- Have a pOH > 7;

- A neutral solution has:
  - equal number of H_3O^+ and OH^- ions;
  - $[H_3O^+] = [OH^-] = 10^{-7}$ M;
  - pH = pOH = 7;

- A basic solution has:
  - less H_3O^+ ions than OH^- ions
  - $[H_3O^+] < 10^{-7}$ M and $[OH^-] > 10^{-7}$ M
  - Have a pH > 7;
  - Have a pOH < 7;

- At 25^oC, $[H_3O^+] \times [OH^-] = 10^{-14}$ M^2

- pH = $-\log_{10}[H_3O^+]$

- $[H_3O^+] = 10^{-pH}$

Example 1: 100 mL of 0.20 M of HNO_3 is diluted to 200 mL. Find concentrations of H_3O^+ and OH^- ions in an acid and hence find pH of an acid.

$$C_1 = 0.20M$$
$$V_1 = 100 \text{ mL}$$
$$V_2 = 200 \text{ mL}$$
$$C_1V_1 = C_2V_2$$

$$[HNO_3] = \frac{0.20 \times 100}{200} = 0.100 \text{ M}$$

HNO_3 (aq)	+	H_2O(l)	$\rightarrow$	H_3O^+(aq)	+	NO_3^-(aq)
1	:	1	:	1	:	1
0.100M	:	0.100M	:	0.100M	:	0.100M

$$[H_3O^+] = 0.100 \text{ M} = 10^{-1} \text{ M}$$
$$\text{Now } [H_3O^+] \times [OH^-] = 10^{-14}$$
$$10^{-1} \times [OH^-] = 10^{-14}$$
$$[OH^-] = 10^{-13} \text{ M} = 1.0 \times 10^{-13} \text{ M}$$
$$pH = -\log_{10}[H_3O^+] = -\log_{10}10^{-1} = 1.0$$

NOTE: in Mathematical Methods this year you should at some point learn all about logs and indices. If you do not understand the manual calculations, because you are not doing this course just plug it into your calculator.
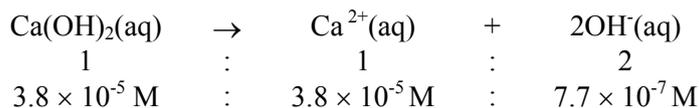
Example 2: A solution of Calcium hydroxide is discovered to have a pH of 7.9. Find concentrations of H_3O^+ and OH^- ions and hence find the concentration of the base.

$$Ca(OH)_2(aq) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$$
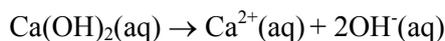
$$[H_3O^+] = 10^{-pH} = 10^{-7.9} = 1.3 \times 10^{-8} \text{ M}$$

$$[H_3O^+] \times [OH^-] = 10^{-14}$$

$$[OH^-] = \frac{10^{-14}}{1.3 \times 10^{-8}} = 7.7 \times 10^{-7} \text{ M}$$

$$
\begin{array}{ccccc}
Ca(OH)_2(aq) & \rightarrow & Ca^{2+}(aq) & + & 2OH^-(aq) \\
1 & : & 1 & : & 2 \\
3.8 \times 10^{-5} \text{ M} & : & 3.8 \times 10^{-5} \text{ M} & : & 7.7 \times 10^{-7} \text{ M}
\end{array}
$$

$$[Ca(OH)_2] : [OH^-] = 1 : 2$$

$$[Ca(OH)_2] = \frac{1}{2}[OH^-] = 3.2 \times 10^{-5} \text{ M}$$

THE ACIDITY EQUILIBRIUM CONSTANT

We have so far looked at the calculations for strong acids. So how can we deal with weak acids? Back in unit 2 we learnt that weak acids to not completely ionise. So therefore we can use the equilibrium law to calculate different values with week acids.

Consider the equation:

Acid(aq) + water(l) $\rightleftharpoons$ H_3O^+(aq) + conjugate base(aq)

The acidity constant, K_a, is defined as:

$$K_a = K_c[H_2O] = \frac{[H_3O^+][\text{conjugate base}]}{[\text{acid}]}$$

Percentage hydrolysis measures how much the acid ionises.
Percentage of hydrolysis (or percentage ionisation) is defined by:

$$\% \text{ hydrolysis} = \frac{[\text{conjugate base}]}{[\text{acid}]} \times \frac{100}{1}$$

Example 3: 50.0 g of acetic acid is mixed with 1.00 L of water, after the reaction is left to settle it is discovered that there is 3.80×10^{-3} M of $[H_3O^+]$ ions at equilibrium. Calculate the K_a of acetic acid.

$$V = 1.00 \text{ L}$$

$$m(CH_3COOH) = 50.0\text{g}$$

$$M(CH_3COOH) = 12.01 \times 2 + 1.008 \times 4 + 16 \times 2 = 60.052 \text{ g·mol}^{-1}$$

$$n(CH_3COOH) = \frac{m(CH_3COOH)}{M(CH_3COOH)} = \frac{50.0}{60.052} = 0.833 \text{ mol}$$

$$[CH_3COOH] = \frac{n(CH_3COOH)}{V} = \frac{0.833}{1} = 0.833$$

	[CH₃COOH] M	[CH₃COO⁻]	[H₃O⁺]
Initial	0.833	0	0
Change in equilibrium	-3.80×10^{-3}	$+3.80 \times 10^{-3}$	$+3.80 \times 10^{-3}$
Equilibrium	0.829	3.80×10^{-3}	3.80×10^{-3}

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]} = \frac{(3.80 \times 10^{-3})^2}{0.829} = 1.74 \times 10^{-5}$$

Example 4: Boric acid (HBO_3) has a K_a value of 1.51×10^{-5}. If 115 g of boric acid is mixed with 500mL of water, and left to come to equilibrium, calculate the equilibrium chemical composition and the % hydrolysis.

$$V = 500 \text{ mL} = 0.5 \text{ L}$$

$$m(HBO_3) = 115g$$

$$M(HBO_3) = 1.008 + 10.81 + 16.00 \times 3 = 59.818 \text{ g·mol}^{-1}$$

$$n(HBO_3) = \frac{m(HBO_3)}{M(HBO_3)} = \frac{115}{59.818} = 1.92 \text{ mol}$$

$$[HBO_3] = \frac{n(HBO_3)}{V} = \frac{1.92}{0.5} = 3.84 \text{ M}$$

	[HBO₃] M	[BO₃⁻]	[H₃O⁺]
Initial	1.92	0	0
Change in equilibrium	$-x$	$+x$	$+x$
Equilibrium	$1.92 - x$	x	x

$$K_a = \frac{[H_3O^+][BO_3^-]}{[HBO_3]}$$

$$1.51 \times 10^{-5} = \frac{x^2}{1.92 - x}$$

$$x^2 + (1.51 \times 10^{-5})x - 2.90 \times 10^{-5} = 0$$

$$x = \frac{-1.51 \times 10^{-5} \pm \sqrt{(1.51 \times 10^{-5}) - 4 \times 1 \times (-2.90 \times 10^{-5})}}{2 \times 1} = -5.39 \times 10^{-3}, 5.38 \times 10^{-3}$$

But we cannot have a negative solution so $x = 5.38 \times 10^{-3}$

Final composition:

$$[HBO_3] = 1.92 - 5.38 \times 10^{-3} = 1.92M$$

$$[BO_3^-] = 5.38 \times 10^{-3} \text{ M}$$

$$[H_3O^+] = 5.38 \times 10^{-3} \text{ M}$$

$$\% \text{ hydrolysis} = \frac{[BO_3^-]}{[HBO_3]} \times 100 = \frac{5.38 \times 10^{-3}}{1.92} \times 100 = 0.280\%$$

MANAGEMENT & DISPOSAL OF CHEMICALS

MANAGEMENT OF CHEMICALS

In any workplace the management and storage of chemicals is paramount to a safe working environment. For example, if you think of the chemicals you use everyday in the science labs at school; behind the scenes there are strict guidelines on how every chemical can be stored and also how they are disposed of.

When looking at how the chemical industry deals with the management of chemicals the first thing we need to consider is their classifications. In 1990, a new regulation; 'The Dangerous Goods (Storage & Handling) Handling Regulations', came into effect. This law takes into account how different chemicals are classified in Australia and internationally and, hence, comes up with safe guidelines for the storage and handling of different chemicals.

So the first step is to classify chemicals into nine different categories. These categories depend on different characteristics and properties. Within each major category there could be more sub categories. Below I have provided a table with these groups, their definitions, HAZCHEM signs and storage guidelines:

Class	Definition	Examples	HAZCHEM
1	**Explosive**	dynamite	
2	**Gases: Compressed, liquefied or dissolved Under Pressure**		
2.1	Flammable Gases	LPG (Liquid Petroleum Gas)	
2.2 / 2.2	Non-Flammable Non-Toxic Gases / Oxidizing Gases	Nitrogen / Oxygen	
2.3	Poisonous Gases	Chlorine Carbon Monoxide	
3	**Flammable Liquids**	Petrol	
4	**Flammable solids. Substances Liable to Spontaneous Combustion and Substance which in Contact with Water Emit Flammable Gases**		
4.1	Flammable Solids	Phosphorus matches	
4.2	Spontaneously Flammable Substance	White phosphorus	
4.3	Flammable Substance if Wetted	Calcium Carbide	

INDUSTRIAL CHEMISTRY

STUDY NOTES

Class	Definition	Examples	HAZCHEM
5	**Oxidising Agents & Organic Substances**		
5.1	Oxidizing Substances	Nitrates, Hydrogen peroxide	
5.2	Organic Peroxide	Methyl ethyl ketone peroxide	
6	**Poisonous (toxic) and infections Substances**		
6.1(a)	Poisonous Substances	Cyanides, Arsenic compounds	
6.1(b)	Harmful Substances	Cadmium Compounds	
6.2	Infectious Substances	Vaccines	n/a
7	**Radioactive Substances**	Uranium, radioisotopes	
8	**Corrosive Substances**	Sulphuric Acid, Sodium Hydroxide	
9	**Miscellaneous Dangerous Goods**	Dry Ice, Aerosols	

(2008, http://www.minerals .csiro.au/safety/hazchem.htm)

Under the regulations small minute quantities of chemicals may go without some idea of its classification. Larger quantities by law must have an appropriate label so everyone knows the risks associated with handling these chemicals.

Using these classifications, we can figure out the logistics of how to store and handle chemicals. This is important especially with waste chemicals because some chemicals should not be stored together. How we tell this is by the segregation rules. What happens is an industrial plant or lab will have a table that tells you the rules for two classes. To use it all you need to do is to find the classifications of the two chemicals and compare one with the row and the second with the columns to find a single piece of information for both. I have included a table on the following page.

INDUSTRIAL CHEMISTRY

STUDY NOTES

Class	2.1	2.2	3.1	3.2 3.3 3.4	4.1	4.2	4.3	5.1	5.2	6.1	8	9
2.1	N/A	N/A	FS	FS	FS	PR	FS	PR	PR	FS	FS	SG
2.2	N/A	N/A	SG	SG	SG	FS	SG	SG	FS	SG	SG	SG
3.1	FS	SG	N/A	N/A	FS	FS	FS	PR	PR	FS	SG	SG
3.2 3.3 3.4	FS	SG	N/A	N/A	SG	FS	FS	PR	PR	FS	SG	SG
4.1	FS	SG	FS	SG	N/A	FS	FS	PR	PR	FS	SG	SG
4.2	PR	FS	FS	FS	FS	N/A	FS	PR	PR	FS	SG	SG
4.3	FS	SG	FS	FS	FS	FS	N/A	PR	PR	FS	FS	SG
5.1	PR	SG	PR	PR	PR	PR	PR	N/A	FS	FS	FS	FS
5.2	PR	FS	PR	PR	PR	PR	PR	FS	N/A	PR	FS	FS
6.1	FS	SG	FS	FS	FS	FS	FS	FS	PR	N/A	SG	SG
8	FS	SG	SG	SG	SG	SG	FS	FS	FS	SG	N/A	SG
9	SG	SG	SG	SG	SG	SG	SG	FS	FS	SG	SG	N/A

(2008, http://www.minerals .csiro.au/safety/hazchem.htm)

Key:

N/A – separation is not needed, they may be stored in the same area

SG – The two classes must be at least 3 meters away from each other

FS – The two classes must be fire separate.

PR – These classes must not be stored in the same or adjoining areas. That is they must be at least 10m apart.

When thinking about managing chemicals in the chemical industry, there are several points to consider. Over the page I have draw these points in a pyramid. When it comes to waste disposal we need to think of the environment, and therefore, these points:

- ✎ Prevention: if we prevent the waste from occurring in the first place is what we really need, though this is not always easy in the chemical industry, nor cost effective.
- ✎ Minimisation: keeping waste to a minimum is also a good alternative.
- ✎ Reuse: is the next step down and a good way to cut costs.
- ✎ Recycling: similar to reuse, but instead the substance is turned into another useful product.
- ✎ Energy recovery: energy use is one of the worse sources of pollution in chemical industry. It is important to try and conserve or recover energy instead of letting it escape out into the environment.
- ✎ Disposal: the bottom level of the pyramid is when all other alternatives are not viable. Of course sending waste to a garbage dump is the last thing we want to do, because there are a lot of consequences for the environment.
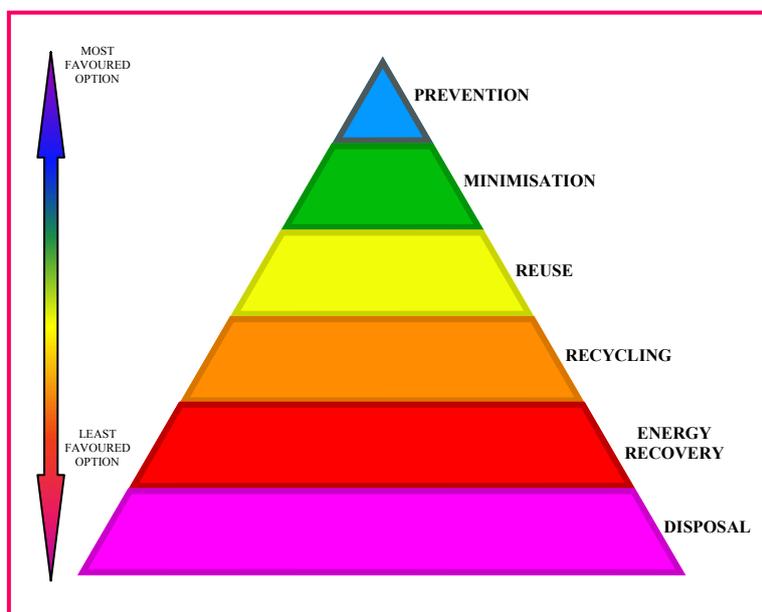
DISPOSAL OF WASTE

DISPOSAL

There are two main ways the chemical industry can dispose of waste. They are:

- Dumping the waste in a **landfill**
  - A landfill is a pit that sometimes comes from already dug pits that we dump waste into.
  - A lot of factors need to be taken into effect when managing a landfill
    - Heavy clay base or a plastic lining of the pit to contain the liquid produce by the decomposition of waste. This liquid is known as leachate.
    - Having the waste compacted to both increase the amount of waste that can be stored but also increases the stability of rubbish and eliminates the threat to rubbish blowing around and further littering the environment.
    - The waste is also buried to prevent the attraction of vermin such as rats from foraging the dump.
    - As the waste decomposes a lot of gases are released in the process. Some of these gases such as carbon dioxide and methane are greenhouse gases and need to be monitored closely. Some plants combat this problem by siphoning of the methane gas and burning it to produce electricity for the power grid.
    - Older landfills did not think of these issues and even today are slowly polluting the environment around us.
  - In some areas, especially rural areas it is difficult to create more landfills because of increasing opposition from the local communities. This causes fewer places where rubbish can be dumped and often the rubbish needs to be shipped far away to other landfills.
  - Dumping waste in a landfill maybe a cheap option but the impact that it has on the environment means that we need to reduce, reuse and recycle more.

- Incineration:
  - Incineration is where we burn the waste to convert it into ash, gas, steam and heat.
  - Incineration is widely used in the chemical industry as it is a safe way to dispose of hazardous materials.
  - This method is very controversial though as the gas emitted is not good for the greenhouse and adds to the already polluted atmosphere. Gases need to be carefully monitored to strict guidelines by the EPA (Environmental Protection Authority).
  - If you think about though the heat and steam produced can be used to create the electricity.
  - The ash is great as compost and clean of anything that could endanger us.

RECYCLING

Recycling is one of the best ways to reduce waste. There is a lot of waste out there that can be recycled, and the chemical industry needs to make sure that they recycle everything in the plants. Here are some examples of recycling in the chemical industry:

- Energy produced in reactions is reused in plants to run other equipment, or converted to electricity.
- Water is constantly recycled throughout plants in the process of chemicals. Used water from chemical production can usually be cleaned through the same processes as cleaning our sewage this is outlined later on in this section.
- Harmful greenhouse gases such as methane can be burnt to create more electricity and heat energy. Other gases such as sulfur dioxide and nitric oxide can be recycled to other plants to create other chemicals.
- Plant and food matter can be stored in huge compost piles and resold as mulch.
- Paper that has not had food or other materials stuck to it can be recycled into new paper and cardboard products.
- Most metals can be cleaned up and recycled in some manner.
- Some plastics can be recycled. To know whether a plastic can be recycled or not you need to check the codes on the object. In the table below is a summary of what can be recycled and what can not.

| Product Identification Code (PIC)	Polymer Type	What abbreviations stand for:	Description	Products	Recyclable
1	PET	Poly ethylene terephthalate	Clear tough plastic	Soft drink, water and fruit juice bottles	Yes
2	HDPE	High density poly ethylene	Most common type of plastics, comes in a variety of colours	Milk, cream and juice containers	Yes
3	PPVC	Plasticised poly vinyl chloride	Flexible clear plastic	Garden hoses, soles of shoes	Yes
4	LDPE	Low density poly ethylene	Soft flexible plastic	Ice-cream containers, garbage bags	No
5	PP	Poly propene	Hard but flexible plastic	Ice-cream containers, drinking straws, hinged lunchboxes	No
6	PS	Poly styrene	Rigid, brittle plastic which may be clear or glassy	Yogurt containers, plastic cutlery	No

✍ Even old electrical equipment such as computers and mobile phones can be recycled, though this is a lot more costly due to the disassembly and sorting of parts.

MAINTAINING WATER QUALITY

In Unit 2 we discovered how great water is when it comes to dissolving substances. This, however, is not good for us, as sometimes all the products dissolved in the water can make it toxic for us to use period.

So we need to now look at how water is treated for our own usage. How we get rid of a majority of the impurities so we can actually drink the water. If you went out to any water supply there is a number of nasties that should be in the water; bacteria, solids, colour, and odour all hint at what we could be consuming if we did not clean the water before hand.

How we clean the water so it is fit for human consumption is through four steps. These steps are outlined below. I have also below drawn a diagram of a basic water treatment system.
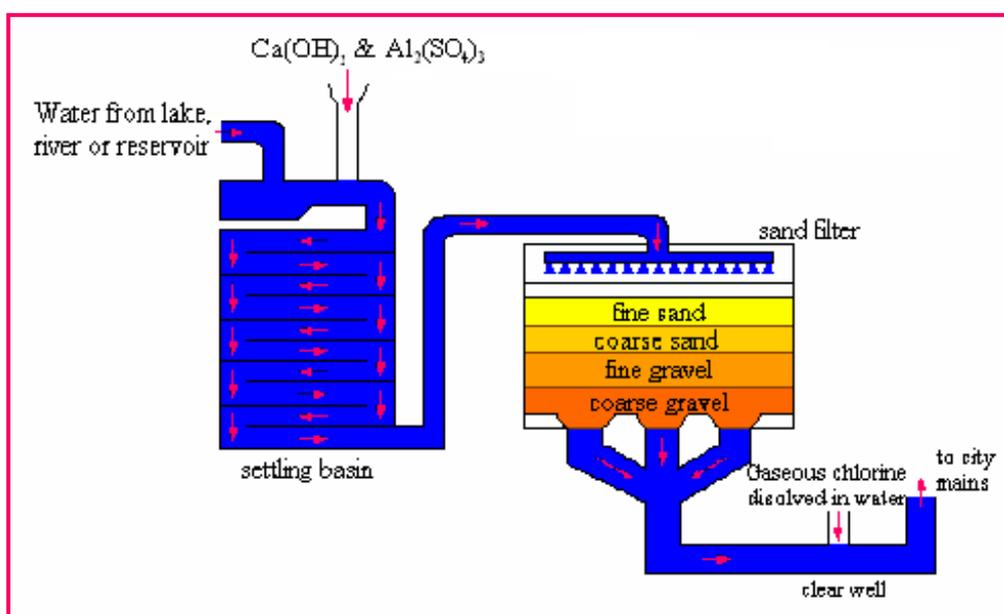
- Flocculation is the process where small suspended particles in the water join together to form larger particles. These larger particles grow heavy and fall out of the water, sinking to the bottom of the basin.
  - Alum, (aluminum sulfate) is added to the water.
  - Lime (calcium hydroxide) is added to neutralise acids in the water and to add more hydroxide ions.
  - $Al_2(SO_4)_3 (aq) + 3Ca(OH)_2 (aq) \rightarrow 2Al(OH)_3 (s) + 3CaSO_4 (aq)$

$$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$$
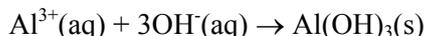
  - Aluminum hydroxide is a jelly like substance known as 'floc'. 'Floc' helps to trap microorganisms, colour and small particles.
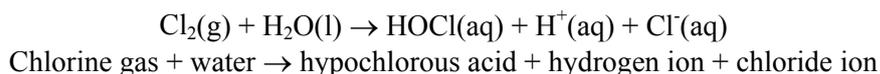
- Settling the 'floc'
  - Water is left to stand for a long period of time. The 'floc' settles to the bottom of the settling basin as sludge and the 'floc' cleaned water is moved onto the filtering tank.

- Filtering:
  - The water moves through a sand filter that has four layers of sand, each getting a little bigger the further the water flows through.
  - This process removes any suspended matter the 'floc' did not take care of.

- Chlorination:
  - Gaseous chlorine is added to the clean water after filtering.
  - The chlorine react with the water to form the following:

$$Cl_2(g) + H_2O(l) \rightarrow HOCl(aq) + H^+(aq) + Cl^-(aq)$$
Chlorine gas + water $\rightarrow$ hypochlorous acid + hydrogen ion + chloride ion

  - Hypochlorous acid (HOCl) kills any remaining animal and plant life in the water. The acid does this by travelling through the walls of the microrganisms and destroying their ability to function.

AVOIDANCE AND REDUCTION

As stated before this method of waste management is the best method in waste productions. By thinking wisely about the way each process in a chemical plant works a lot of the time waste can be avoided, and therefore produce a more cost effective plant.

STUDY NOTES

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Amy has been current with the VCE system throughout its changes since 2000. She is experienced, up to date with the current curriculum and this experience has enabled her to identify key problem areas that students face when dealing with the subject at the VCE level.

Amy attained her first paid tutoring job in 2000. In 2003 Amy also gained a position as an author for Heinemann Education, writing 4 mathematics CD-ROMs, to help students and teachers with their schoolwork. In 2005 Amy began her formal training as a teacher.

One of Amy's ethos is not only to help the students with the subject she is paid to teach, but also to help them to formulate good study routines, for every subject they study. She also has a strong ethos about having up to date information and strives to find more resources to help her students in their studies.

Amy offers <u>full service</u> private and group tuition with comprehensive study notes in the following VCE subjects:

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