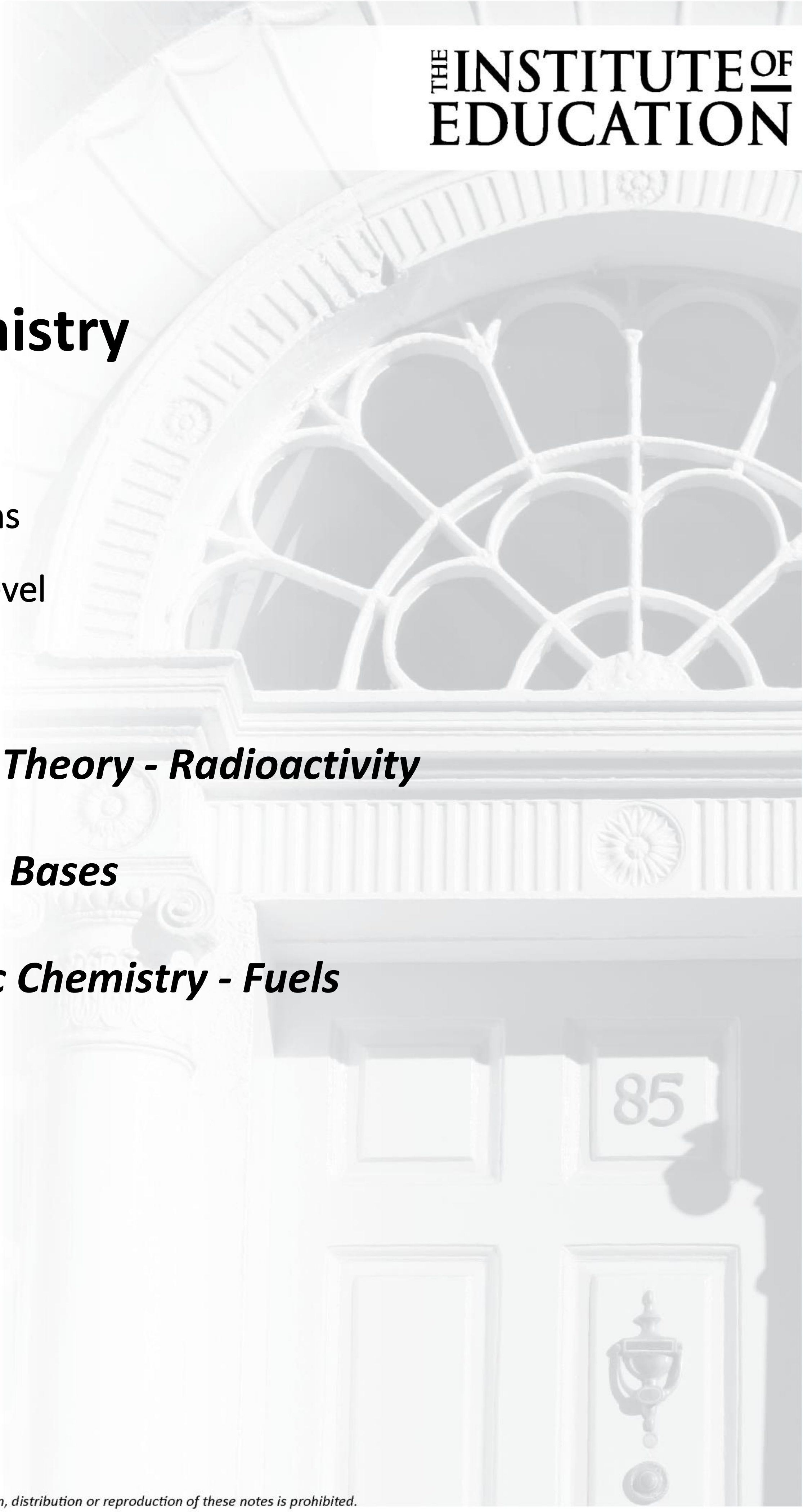


THE INSTITUTE OF EDUCATION

Chemistry

Tara Lyons

Higher Level

2020-21

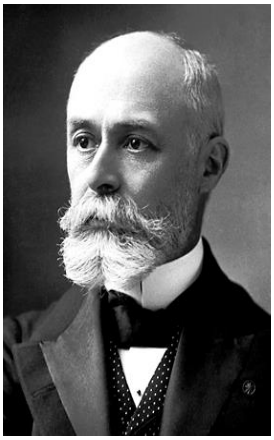
Atomic Theory - Radioactivity

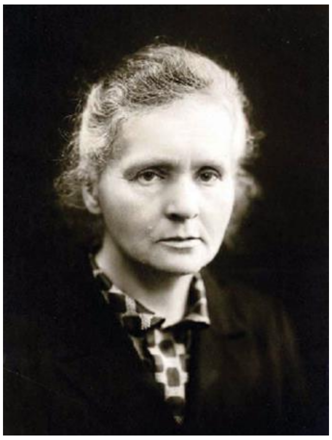
Acids & Bases

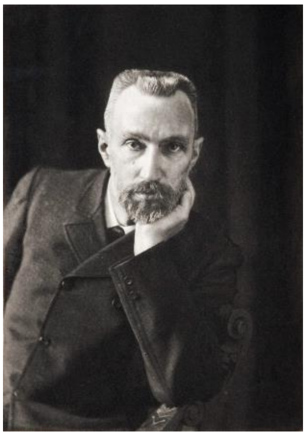
Organic Chemistry - Fuels

RADIOACTIVITY

A French scientist, **Henri** Becquerel **(1852-1908),** noticed while experimenting with uranium that when he left some uranium on a photographic plate covered with black paper, the area of the photographic plate near the uranium became darker despite the fact that it had not been exposed to any sunlight. The uranium was giving off some type of radiation to cause this blackening to happen. Two of his colleagues, Marie and Pierre **Curie,** continued with this idea and discovered two new elements, polonium (Po) and radium (Ra) from impure uranium salt called pitchblende. The radiation was noticed to carry an electrical charge.


Henri Becquerel


Marie Curie


Pierre Curie

A Geiger-Muller tube is an instrument that can detect radioactivity. The SI units of radioactivity is the Becquerel (Bq).

RADIOACTIVITY

Defn – is the spontaneous disintegration of the nucleus with the emission of α,β or γ radiation.

Alpha particles

CHARGE - Positive particles
STRUCTURE - Consist of two protons and two neutrons (hence same as helium nucleus)
PENETRABILITY **- Not very penetrating**, can be stopped by a sheet of paper or 5 cm of air. Strongly ionising and very dangerous if they enter the body through the nose or mouth as can cause mutations in cells.

EXAMPLE OF ALPHA EMMITTER - Americium-241 which is used in smoke detectors. Its half life is over 400 hundred years.

- Mass of 4 a.m.u.
- Symbolised by $_2^4He$

If an alpha particle is lost and you want to find the new element

1. Subtract 2 from the atomic number (bottom number).
2. Look up new atomic number in the periodic table to find symbol for new element.
3. Subtract 4 from mass number (top number).

Example:

$$^{226}_{88}\mathrm{Ra} \longrightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$$

Try the following:

1. Fill in the missing part $^{214}_{84}Po \rightarrow \ldots\ldots\ldots\ldots\ldots + {}^{4}_{2}He$

2. Write a balanced nuclear equation to show that lead – 202 is an alpha emitter.

Beta particles

CHARGE - Negatively charged particles.
STRUCTURE - Are high-speed electrons.
PENETRABILITY - Are more penetrating than alpha particles (**moderately penetrating**!), as they are lighter. They can penetrate up to 5mm of aluminium metal and 500 cm of air.
EXAMPLE OF A BETA EMMITTER - carbon-14, which is used to find the age of objects in 'carbon dating'.

- Mass of 1/1840 a.m.u.
- Formed when there are too many neutrons in the nucleus to be stable.
- A neutron changes into a proton and an electron.
- The electron is ejected from the nucleus, as it would require too much energy to stay in the nucleus. The ejected electron is the beta particle.
- Symbolised by $^{0}_{-1}e$.
- Beta particles are used to kill cancerous skin cells

If a beta particle is lost and you want to find the new element

1. Add 1 to the atomic number (bottom number).
2. Look up periodic table to find the symbol for the new element.
3. Leave the mass number the same (top number).

Example:

$$^{212}_{82}\mathrm{Pb} \longrightarrow {}^{212}_{83}\mathrm{Bi} + {}^{0}_{-1}e$$

Try the following:

$${}^{24}_{11}Na \rightarrow \ldots\ldots\ldots\ldots\ldots\ldots + {}^{0}_{-1}e$$

1. Fill in the missing parts $${}^{214}_{83}Bi \rightarrow \ldots\ldots\ldots\ldots\ldots\ldots + {}^{0}_{-1}e$$

$${}^{198}_{79}Au \rightarrow \ldots\ldots\ldots\ldots\ldots\ldots + {}^{0}_{-1}e$$

2. Write a balanced nuclear equation to show that phosphorus-32 is a beta emitter.

Gamma rays

CHARGE - Neutrally charged.
STRUCTURE - They are high-energy electro-magnetic radiation.
EXAMPLE - An example of a gamma emitter is cobalt-60.
PENETRABILITY - They are **extremely penetrating**, can only be stopped by several cm of lead (very dense metal).

- The loss of gamma radiation does not give rise to a new element, as it is simply the loss of energy from the nucleus.
- Are used to treat cancer as they kill the cancerous cells, but can also cause cancer as they can change the structure of our cells.

	ALPHA	**BETA**	**GAMMA**
Charge	positive	negative	neutral
Structure	2protons +2neutrons	electron	Electromagnetic radiation
Penetrability	Not very penetrating	Moderately penetrating	Extremely penetrating
Example	Am-241	C-14	Co-60

DIFFERENCE BETWEEN NUCLEAR REACTIONS AND CHEMICAL REACTIONS
Defn – a nuclear reaction involves a change in the nucleus of an atom and a new element is usually formed as a result.
Defn – a chemical reaction involves electrons being shared or transferred from one atom to another– the nucleus of the atom remains the same.

HALF-LIFE
Defn – this is the time taken / for half the NUCLEI / in a given sized sample to decay.

NOTE – it is very important that you say 'nuclei' not nucleus….

As we have said the emission of radioactivity by an atom is spontaneous and unpredictable. It also appears to be unaffected by external conditions like chemical reactions, pressure and temperature. However there is one factor that does appear to govern the overall rate of decay – the number of nuclei left undecayed.

Experiments show that the time taken for half of the atoms in a sample of a radioisotope to decay is constant for that particular isotope. For example, the half-life of radon-222 is 3.2 days. If we start with 1 g of radon-222 then after 3.2 days there will be 0.5g left. The rest will have decayed to polonium-218. After another 3.2 days there will be 0.25g left and so on. Can you now identify the type of particle radon-222 has emitted from the information given?

The half-life of elements can vary considerably. Iodine –131 has a half-life of 8 days, whereas uranium-238 has a half-life of 4.5 billion years.

USES OF RADIOISOTOPES – this is an isotope of an element that undergoes radioactive decay.

1. **Nuclear power** – heat generated in nuclear power stations by nuclear reactions is used to produce electricity.
2. **Cancer treatment** – gamma rays of cobalt-60 are used to kill cancerous cells inside the body. Beta rays are used to treat skin cancers, as they are less penetrating.
3. **Sterilisation** – radiation is used to sterilise medical equipment. It is also used to kill bacteria to give food a longer shelf life.
4. **Archaeological uses** – the carbon-14 isotope is radioactive and is present as a very small amount of carbon dioxide in the air that is used by plants in photosynthesis and ends up in animals when they eat plants. The carbon -12 to carbon – 14 ratio remains constant when the organism is alive. When a plant/animal dies the carbon-14 already in the plant/animal starts to decay very slowly and therefore the ratio of carbon-14 to carbon-12 changes in the organism. By **measuring the RATIO of carbon-12 to carbon-14 and knowing the half-life of carbon-14** the time of death of the organism can be calculated.

Nuclear fission – is the splitting of a nucleus into two roughly equal fragments. Uranium splits when bombarded with neutrons. Very large quantities of energy are given out. The fission of uranium produces more neutrons that can cause subsequent fission reactions, leading to a chain reaction.

Nuclear fusion – is the joining of two smaller nuclei to form a larger one. Energy is given out.

In this section of our course we will study both acids and bases. Both of these substances occur around us in our every day lives. For example, indigestion is caused by the over production of acid in our stomachs and to relieve this we take a base i.e. 'Milk of Magnesia'. Bee stings are acidic and can be neutralised by using baking soda paste (sodium hydrogencarbonate). Shampoos are slightly basic and we use conditioner that is slightly acidic to neutralise the effects of the shampoo.
Other examples are limestone can be added to lakes to reduce the effects of acid rain on the flora and fauna. Farmers spread lime on land if the soil is too acidic. Toothpaste is slightly basic to neutralise acidic foods that can cause tooth decay.

ARRHENIUS' THEORY OF ACIDS AND BASES

ACIDS
Defn - An acid produces H^+ ions in water.

For example:

$HCl \to H^+ + Cl^-$

$HNO_3 \to H^+ + NO_3^-$

$H_2SO_4 \to 2H^+ + SO_4^{2-}$

Problems with Arrhenius' theory

- Arrhenius' theory of acids allowed the existence of independent H^+ ions. Now we now that this is not true. The H^+ ion reacts with water to form H_3O^+ (this is known as the hydronium ion or the **oxonium ion**). For simplicity sake we use the term hydrogen ion when discussing acidic solutions, eventhough we know that they do not exist.

- Arrhenius' theory also based his definitions to reactions occurring in polar water, so non-polar organic solvents were excluded.

BASES
Defn - A base produces OH^- ions in water.

For example

$NaOH \to Na^+ + OH^-$

$Mg(OH)_2 \to Mg^{2+} + 2OH^-$

Alkali – an alkali is a base that is soluble in water.
NaOH is an alkali while $Mg(OH)_2$ is not.

Problem with Arhennius' theory

- Arhennius' theory of bases excluded common bases such as NH_3.

From the following equation we can see that NH_3 is a base.

$$NH_3 + H_2O \to NH_4^+ + OH^-$$

Examples-
The Arrhenius definitions of acidity and alkalinity are restricted to aqueous solutions and refer to the concentration of the solvent ions. Under this definition, pure H2SO4 or HCl dissolved in toluene are not acidic, and molten KOH and solutions of sodium amide in liquid ammonia are not alkaline.

General equation for acids dissociating in solution (where HA is an acid):

$$HA + H_2O \rightarrow A^- + H_3O^+$$

Write an equation to show the reaction of nitric acid with water.

Monobasic acids

Defn – A monobasic acid produces one H^+ ion in solution e.g. HCl and $\mathrm{HNO_3}$.

Dibasic acids

Defn – A dibasic acid produces two H^+ ions in solution e.g. H_2SO_4.

Tribasic acids

Defn – A tribasic acid produces three H^+ ions in solution e.g. H_3PO_4.

BRONSTED-LOWRY THEORY OF ACIDS AND BASES.

A newer definition was put forward by two chemists **BRONSTED-LOWRY.**

ACID

Defn - an acid is a proton (H^+) donor.

BASE

Defn - a base is a proton (H^+) acceptor.

For example

$HCl + H_2O \rightarrow Cl^- + H_3O^+$

acid base

$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

base acid

Note - from the two examples we can see that water can act as both an acid and a base, therefore water is said to be amphoteric.

AMPHOTERIC
Defn - a substance that can act as both an acid and a base.

$H_2O + H_2O \rightarrow H_3O^+ + OH^-$
acid   base

Note - An acid only acts as an acid in the presence of a base.

CONJUGATE PAIRS
Defn - Two substances that differ by one proton.

CONJUGATE ACID
Defn – a base plus a H^+ ion.

CONJUGATE BASE
Defn – an acid minus a H^+ ion.

For example each of these pairs are a conjugate pair as they differ by only one proton.

$$HCl / Cl^- \qquad HNO_3 / NO_3^- \qquad NH_3 / NH_4^+$$

Sample question
Pick out the acid, base and conjugate acid, conjugate base from the following equation.

$$H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$$

acid   base   c.a   c.b

H_2SO_4 is the acid as it donates a H^+ to become HSO_4^-.
HSO_4^- is the conjugate base.

H_2O is the base as it accepts a proton to become H_3O^+.
H_3O^+ is the conjugate acid.

QUESTIONS

1. Which of the following acid/base pairs is not a conjugate pair? (LCH 1991)

$$H_3O^+ / H_2O \qquad HSO_4^- / H_2SO_4 \qquad H_3PO_4 / HPO_4^{2-}$$

2. Identify the two species acting as acids in the following system: (LCH 1992)

$$H_2SO_4 + H_2F_2 \rightleftharpoons H_3SO_4^+ + HF_2^-$$

3. Write down the conjugate acid of the following:

(a) NH_3 __________
(b) SO_4^{2-} __________
(c) HS^- _________

Note – if the question is looking for the conjugate acid then the substances in the question must be bases so accept a proton onto each to get the answer.

4. Write down the conjugate base of the following:

(a) H_2O _________

(b) HS^- _________

(c) NH_4^+ _________

Note – if the question is looking for the conjugate base then the substances in the question must be acids so donate a proton from each to get the answer.

5. Indicate in each of the following equations the acids, bases and conjugate acids and conjugate bases.

(a) $HNO_3 + OH^- \rightarrow NO_3^- + H_2O$

(b) $NH_4^+ + CO_3^{2-} \rightarrow HCO_3^- + NH_3$

DISSOCIATION

When acids are placed in solutions they **split up** into their ions, hydrogen ions and anions. (The anion produced depends on the acid involved.) This is known as **dissociation**. The number of dissociations depends on whether the acids are monobasic, dibasic or tribasic.

DISSOCIATION EQUATIONS

Monobasic acids have <u>one equation</u> for their dissociation.

Example 1-

$HCl + H_2O \rightarrow Cl^- + H_3O^+$

Example 2 –

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

Ethanoate ion

Dibasic acids have <u>two equations</u> to show their dissociations:

1st dissociation of H_2SO_4

$H_2SO_4 + H_2O \rightarrow HSO_4^- + H_3O^+$

2nd dissociation of H_2SO_4

$HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$

Tribasic acids have <u>three equations</u> to show their dissociations:

1st dissociation of H_3PO_4

2nd dissociation of H_3PO_4

3rd dissociation of H_3PO_4

Fill in the appropriate equations!!!

REACTIONS OF ACIDS WITH METALS AND BASES

1. $\text{Acid} + \text{Metal} \rightarrow \text{Salt} + H_2$
2. $\text{Acid} + \text{metal oxide/ hydroxide} \rightarrow \text{Salt} + H_2O$
3. $\text{Acid} + \text{Metal carbonate / hydrogencarbonate} \rightarrow \text{Salt} + H_2O + CO_2$

Note – these must be learned off by heart!

WRITE AND BALANCE THE FOLLOWING EQUATIONS

(a) Sulphuric acid + calcium
(b) Nitric acid + potassium hydroxide
(c) Hydrochloric acid + magnesium hydrogen carbonate
(d) Nitric acid + aluminium oxide
(e) Sulphuric acid + sodium carbonate

NEUTRALISATION REACTION

Alkalis react with acids to produce a salt and water; this is called a neutralisation reaction. The H^+ from the acid reacts with the OH^- from the alkali to form H_2O which is neutral.

SALTS

Defn - A salt is formed when the H^+ of the acid is replaced by a metal ion or NH_4^+ (ammonium ion).

The non-metal part of a salt is called a radical or complex ion.

‘STRONG’ AND’ WEAK’

We have already learned that when acids are placed in solution they dissociate into their ions. When some acids are placed in solution **ALL of the molecules will dissociate**. However when other acids are placed in solution only **SOME of the molecules will dissociate**, the remaining molecules will remain undissociated. **The degree to which acids dissociate is referred to as the ‘strength’ of the acid.**

You will not be able to identify the strength of an acid or base by looking at it, you must familiarise yourself with the ones on your course as you meet them.

STRONG ACID

Defn –a strong acid is an acid that fully dissociates in solution and is a good proton donor.

i.e. all the acid molecules split up into hydrogen ions and anions.

Strong acids are good proton donors.

Examples: HCl, $\mathrm{HNO_3}$, $\mathrm{H_2}SO_4$. These acids fully ionise in solution. This is not evident from the equation and must be memorised.

A strong acid has a weak conjugate base.

WEAK ACID

Defn - is an acid is a poor proton donor and only slightly dissociated in solution.

i.e. only some of the molecules split up into hydrogen ions and anions.

Weak acids are poor proton donors.

Examples: CH_3COOH (ethanoic acid). In a dilute solution only about one molecule of ethanoic acid in a hundred splits into ions. This is not evident from the equation.

A weak acid has a strong conjugate base

A ***STRONG BASE*** is a good ***acceptor*** of protons and a ***WEAK BASE*** is a poor ***acceptor*** of protons.

Household examples of acids and bases.

1. Ethanoic acid in vinegar
2. Citric acid in citrus fruits such as oranges and lemons.
3. Carbonic acid in fizzy drinks.
4. Ammonia solution in cleaning agents. Ammonia is very caustic and will burn through the dirt.
5. Magnesium hydroxide in indigestion remedies i.e. Milk of Magnesia
6. Zinc oxide in skin creams.

OIL REFINING AND ITS PRODUCTS

CRUDE OIL (PETROLEUM)

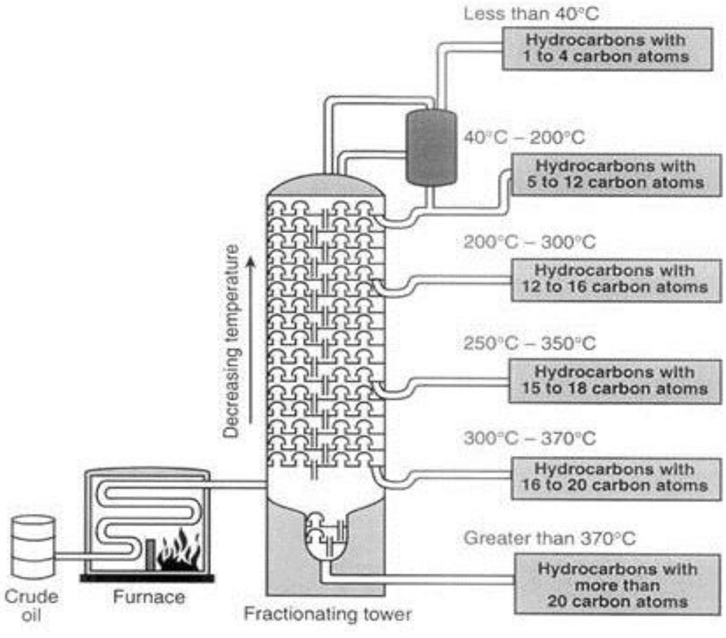
1. Crude oil is a fossil fuel. It is formed by the decomposition of dead bodies of creatures that died millions of years ago.
2. It is pumped from under the ground or sea
3. It is a thick, black, viscous, pungent liquid and is of little or no use in this form.
4. It is found in large quantities in countries like Iran, the North Sea, the USA, Russia etc.

COMPOSITION OF CRUDE OIL

It consists of a **mixture of hydrocarbons**. Mixture means not chemically combined.
The types of hydrocarbons present in oil depends on where it is found in the world. The hydrocarbons may be small chained molecules e.g. ethane, or may consist of many carbon atoms. The smaller hydrocarbons are volatile (low b.p.) and are used as fuels or chemical feedstocks while the larger ones are heavy and may be used in heavy industry or may be broken down into smaller molecules we will see later (thermal or catalytic cracking).

FRACTIONATION OF CRUDE OIL

Fractional distillation is a process that is used to separate the crude oil into its components. This method can be used as the oil is a mixture of molecules. The principle involved is that the oil is **separated into 'fractions' on the basis of the different boiling points** of the compounds. These 'fractions' are now more useful and can be used for various purposes.



STAGES

1. The crude oil is heated to high temperatures and is fed into large fractionating towers. These towers may be 80 m high.
2. The tower is kept at a high temperature at the bottom.
3. As you go up the tower there are trays present to collect the 'fractions'.
4. The temperature **decreases** as you ascend the tower.
5. As the crude oil rises up the tower the fractions will reach a temperature that is **just below their boiling point** and turn into liquids which collect on the tray.
6. The heavier hydrocarbons will condense first, while the lighter hydrocarbons will rise higher and condense higher up the tower.

THE FRACTIONS AND THEIR USES

NAME OF FRACTION	**CARBONS**	**USES**
Gas B.P – 25 °C to 40 °C	$C_1 - C_4$	Refinery fuel Liquefied to form propane or butane gas (LPG).
Light gasoline B.P. – 40 °C to 75 °C	$C_5 - C_{10}$	Motor fuel
Naptha (v. important) B.P. – 75 °C to 150 °C	$C_7 - C_{10}$	**Petrol** Feedstock for petrochemical industry
Kerosene B.P. – 150 °C to 240 °C	$C_{10} - C_{14}$	Fuel for planes Paraffin lamps/stoves
Gas oil and heavy gas oil B.P. – 240 °C to 500 °C	$C_{14} - C_{40}$	Diesel oil Lubricating oil for engines
Residue B.P. - > 500 °C	C_{35} and upwards	Heavy industrial fuel Used in catalytic cracking Bitumen for road surfaces

NATURAL GAS

1. Natural gas is a mixture of hydrocarbons.
2. Usually made up of methane, ethane, propane and butane.
3. The North Sea and Kinsale gas fields are made mainly of methane (95%).
4. In the USA natural gas mainly consists of propane and butane.
5. Propane and butane are sold as **liquefied petroleum gas (LPG**) in Europe.
6. As natural gas is odourless for safety reasons compounds called **MERCAPTANS** (usually sulfur containing compounds) are added to the natural gas before distribution. Mercaptans have a strong smell so this alerts to a leakage.

PETROL

In order for the engines in cars to run smoothly petrol and oxygen react and this produces the power to turn the wheels of the car.
The petrol and oxygen must ignite and explode evenly at the correct time to ensure the engine runs smoothly.

- **Auto – ignition (‘knocking’)** - Sometimes this reaction between the petrol and air can happen too soon due to increased pressure in the engine and auto-ignition occurs – this is also called ‘knocking’. ‘Knocking’ happens if the petrol and oxygen explode due to an increase in pressure in the engine instead of the explosion being caused by a spark (from the spark plugs!). This can damage the engine and lead to loss of power.
- If the petrol is rich in straight chained hydrocarbons i.e. hexane or octane, auto-ignition occurs. So straight chained hydrocarbons are the problem.
- **Petrol rich in branched chained hydrocarbons burns more smoothly and efficiently. An example of a branched-chained hydrocarbon is 2,2,4-trimethylpentane (iso-octane). Draw the structural formula of this compound.**

OCTANE NUMBER

Defn- the measure of the tendency of a fuel to resist auto-ignition

- **2,2,4-trimethylpentane (iso-octane)** is one of the most efficient so it is given an octane number of 100. This type of petrol does not auto-ignite or 'knock'. (Note - Heptane is given an octane value of 0!)
- In straight chained hydrocarbons, the **shorter the alkane** the higher the octane number.
- In branched-chained hydrocarbons, the **greater the number of branches** the higher the octane number.
- **Cyclic and aromatic hydrocarbons** also have a high octane number.
- A 'good' quality petrol can have an octane number of 97.

Structural features of alkanes that prevent autoignition -

1. Short chained
2. Highly branched
3. Cyclic.

SOLUTIONS TO AUTO-IGNITION (KNOCKING)

1. **Add lead to the petrol (additive)**. Lead was added in the form of **tetraethyl lead**. This allowed the petrol to burn smoothly. However, leaded petrol is toxic, therefore harmful to the environment and people's health. Leaded petrol is being phased out due to these reasons.
2. **Isomerisation (reforming)** – this involves changing straight-chained hydrocarbons into branched-chained isomers. The branched-chained isomers burn more smoothly and therefore have a higher octane number.
3. **Dehydrocyclisation (reforming)** – this process involves the conversion of straight-chained hydrocarbons to form ring compounds. The ring compounds are then converted into aromatic compounds. This is done in the presence of a catalyst. As hydrogen is a by-product of this reaction it is called 'dehydro'. Aromatic compounds have a high octane number but are also carcinogenic.
4. **Catalytic cracking (reforming)** – this process involves breaking down long chained hydrocarbons for which there is low demand into short chained molecules for which there is high demand. These short-chained hydrocarbons have a higher octane number and also tend to be highly branched.
5. **Addition of oxygenates (additive)** - this is the addition of oxygen compounds to the petrol. These tend to be of two types (a) **addition of alcohols** i.e. methanol (octane no. of 114) and (b) **addition of ethers** i.e. methyl tert-butyl ether (MTBE) (octane no. of 118). These compounds (a) increase the octane number of the petrol and (b) **they also cause less pollution as they reduce the level of carbon monoxide in the exhaust fumes.**

Whichever process or combination of processes are used to improve the octane number is dependant on the cost!! Unleaded petrol is more expensive to produce than leaded petrol but the latter is being phased out due to public pressure.

REFORMING
Defn – reforming involves changing straight chained hydrocarbons into branched chained hydrocarbons or cyclic hydrocarbons.

CRACKING
Defn – cracking involves changing long chained hydrocarbons for which there is low demand, into short chained hydrocarbons for which there is high demand.

<u>AUTO-IGNITION</u>
Defn – the <u>early explosion</u> of a petrol-air mixture caused by <u>increasing pressure</u> in the engine.

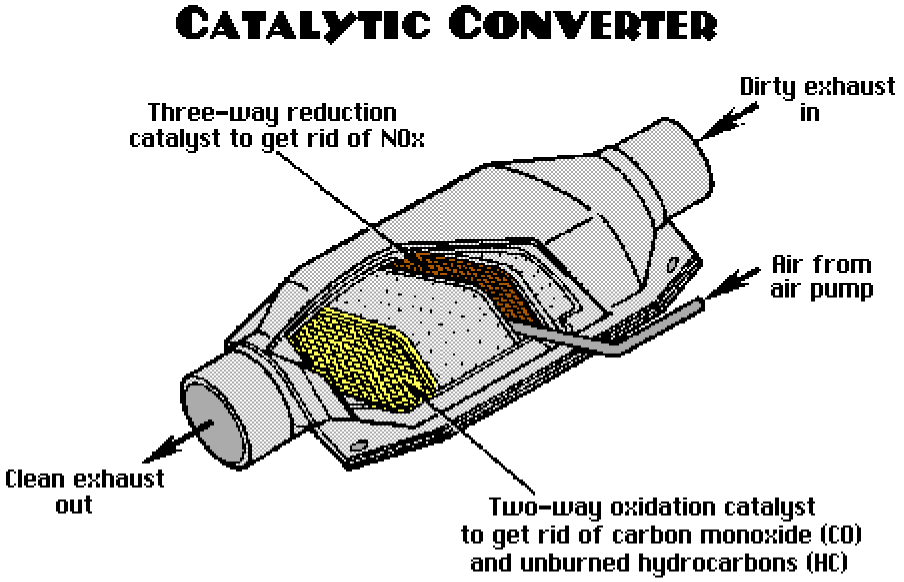
<u>OCTANE NUMBER</u>
Defn – the octane number of a fuel is the measure of its tendency to resist 'knocking'.

CATALYTIC CONVERTERS IN CARS

- A catalytic converter is fitted to car exhausts to reduce pollution from the exhaust fumes.
- Exhaust fumes contain **carbon monoxide, nitrogen monoxide, nitrogen dioxide** and **lead compounds** if leaded petrol is used. It also contains **unburned hydrocarbons.**
- The catalytic converter changes these harmful gases into harmless gases.

$$CO + NO \rightarrow CO_2 + \frac{1}{2}N_2$$

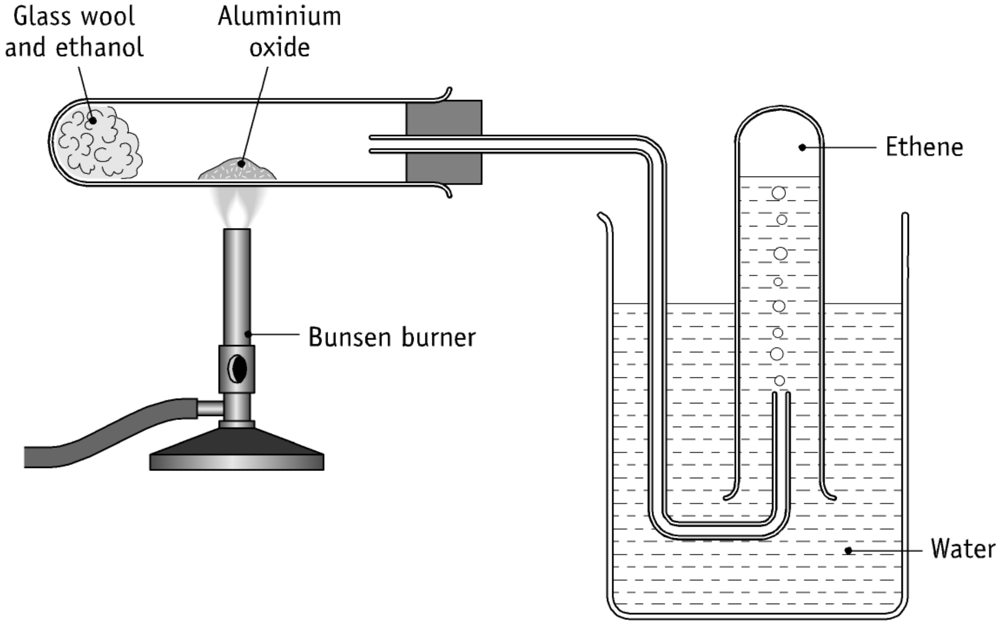
- The catalytic converter contains catalysts such as **platinum, palladium and rhodium** inside a stainless steel case. The inside of the converter looks like a <u>honeycomb.</u> This honeycomb arrangement allows for a **large surface area** so increased removal of harmful gases into harmless gases such as carbon dioxide and nitrogen..
- The lifetime of a converter is dependent on the type of petrol used. If leaded petrol is used then the lifetime of the converter is shorter than if unleaded petrol is used. The lead poisons the catalysts.
- It is policy in the EU since 1993 that all new cars are fitted with catalytic converters.



ETHENE

Ethene is a very important organic compound as it is the 'building block' from which many plastics are made.
In the laboratory, ethene is prepared by a **dehydration reaction** of **ethanol.** Dehydration means removing water.
This is an example of an **elimination reaction**.

EXPERIMENT – THE PREPARATION OF ETHENE



Equation - $C_2H_5OH \xrightarrow[-H_2O]{Al_2O_3} C_2H_4 + H_2O$

Apparatus – boiling tube, retort stand, glass tubing, water bath, test tubes, Bunsen burner, rubber bung.

Materials – ethanol, aluminium oxide, water.

Method –

1. Some ethanol is poured into a boiling tube.
2. **Glass wool** is pushed down into the tube to (a) **soak up the ethanol** and (b) to **hold the ethanol in place** at the end of the tube during the experiment as it is a liquid.
3. The boiling tube was clamped in a horizontal position using the retort stand.
4. Some **aluminium oxide** (white powder) is placed half way along the tube. Aluminium oxide is the <u>dehydrating agent/catalyst</u> for the reaction.
5. The tube is stoppered with a rubber bung and glass tubing is attached through the rubber bung into the water bath.

6. A test tube is filled with water and placed in the water bath as shown in the diagram.
7. A Bunsen burner is placed under the aluminium oxide and is lit to give a blue flame.
8. The heat from the Bunsen burner vaporises the ethanol and as it passes over the aluminium oxide the ethanol is dehydrated to produce ethene.
9. The first test tube collected will have a low yield of ethene, as it will mainly consist of displaced air from the boiling tube.
10. Collect 5 more test tubes of ethene and stopper them.
11. **N.B. - Before turning off the Bunsen burner it is very important to remove the glass tubing from the water bath to prevent 'suck back'**. If the tubing was left in the water bath, once the heat is removed the gases in the boiling tube would contract and this would cause water to be drawn back into the boiling tube to balance the drop in pressure which would cause the boiling tube to shatter.
12. **Other precautions include** – keep gas away from flames as gas is flammable and there is a risk of explosion, wear safety glasses, use of tongs when handling glass wool.

PROPERTIES OF ETHENE GAS

1. **Physical appearance** – colourless gas with a sweetish smell.
2. **Solubility in water** – the gas is insoluble in water as water is a polar solvent and ethene is non-polar therefore ethene does not form hydrogen bonds with water. This is why ethene can be collected by the displacement of water.
3. **Combustion** – when a lighted taper is placed in a test tube of ethene, **a luminous flame** is observed. A small amount of smoke may also be produced. If limewater is added after burning, the limewater goes 'milky'. What does this prove? Write a balanced equation for the combustion of ethene gas -

   ____

4. Tests for unsaturation:

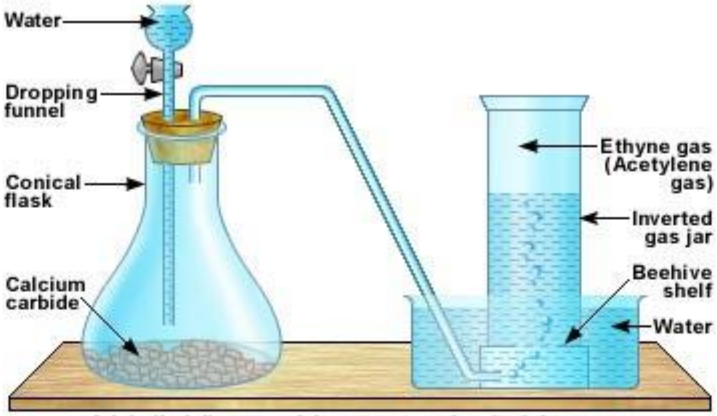
(a) **Addition of bromine water** – bromine water is a red/brown colour. When bromine water is added to ethene an *addition reaction* occurs. The bromine adds across the double bond to form 1,2-dibromo ethane. This colour change from **red-brown to colourless** proves that ethene is unsaturated.
Equation - $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

(b) **Addition of dilute potassium manganate (VII)** – a dilute solution of potassium manganate (VII) is **light purple** in colour. When this solution is added to ethene gas and shaken the purple colour of the solution goes **colourless**. This test also proves the presence of the carbon – carbon double bond, thus proving that ethene is unsaturated.

ETHYNE

Ethyne is used for cutting and welding metals as when burned in oxygen it can reach temperatures over 3000 ° C.

EXPERIMENT – PREPARATION OF ETHYNE



A labelled diagram of the apparatus for the laboratory preparation of ethyne or acetylene.

Equation - $CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$

Calcium dicarbide reacts with water to produce ethyne and calcium hydroxide.

Apparatus – dropping funnel, Buchner flask, glass tubing, conical flask, two holed rubber bung, test tubes, water bath.

Materials – calcium dicarbide, water, [acidified copper (II) sulfate solution.]

Method –

1. Set up the apparatus as shown in the diagram.
2. Do not touch the calcium dicarbide as sweat from hands may start the reaction.
3. Note that the **calcium dicarbide** is a **greyish solid.**
4. Slowly add the water from the dropping funnel.
5. Note **effervescence** (fizzing) as the water reacts with the calcium dicarbide.
6. Also note the production of calcium hydroxide in the Buchner flask. This appears as a white suspension (foamy).
7. The first gas jar collected will have a low yield of ethyne, as it will contain mainly displaced air from the Buchner flask. Discard this carefully.
8. Collect 4 test tubes of ethyne gas.

Important notes –

(a) Impurities are present in the calcium dicarbide. These solid impurities are calcium phosphide, Ca_3P_2 and calcium sulfide, CaS .

(b) These solid impurities give rise to gaseous impurities in the ethyne gas collected. The gaseous impurities are phosphine, PH_3 and hydrogen sulfide, H_2S .

(c) The gaseous impurities are removed by bubbling the impure ethyne gas through acidified copper (II) sulfate solution.

PROPERTIES OF ETHYNE GAS

1. **Physical properties** – ethyne is a colourless gas with a sweetish smell if pure.
2. **Solubility in water** – ethyne is insoluble in water, as water is a polar solvent and ethyne being non-polar does not form hydrogen bonds with water. This is why ethyne can be collected by the displacement of water.
3. **Combustion** – N.B. very dangerous and must be done in a fume cupboard!! Ethyne burns with a **smoky luminous flame**. The smoke is due to unburned carbon (very sooty). To ensure no soot use an excess of oxygen when burning. Write a balanced equation for the combustion of ethyne:____
4. **Tests for unsaturation** –

(a) **Addition of bromine water** – when bromine is added across the carbon-carbon triple bond the red-brown colour of the bromine goes colourless thus proving that the ethyne is unsaturated. An equation showing this reaction was asked in 2003.

(b) **Addition of dilute potassium manganate (VII)** – the purple colour of the manganate (VII) solution goes colourless also proving the presence of a multiple bond (carbon-carbon triple bond) hence ethyne is unsaturated.