Kiss notes : production of materials essay

HSC Chemistry Topic 1 PRODUCT ON of MATERIALS What is this topic about? To keep it as simple as possible, (K. I. S. S.) this topic involves the study of: 1. POLYMERS FROM PETROCHEMICALS & BIOMASS 2. ALTERNATIVE FUELS – ETHANOL & THE ALKANOLS 3. REDOX CHEMISTRY & BATTERIES 4. RADIOACTIVITY & ITS USES … all in the context of society's use of energy and materials but first) an introduction … In the previous topic in the Preliminary Course, you learnt about carbon chemistry of petroleum Then you will learn more carbon chemistry when you study the alcohols and the importance s a fuel source. and the most important of this group member TIlls topic begins by taking this idea further. Petroleum not only provides fuels, but is a source of chemicals for making plastics. ETHANOL a possible candidate for replacing petrol as a fuel. Then onto REDOX Chemistry, and its involvement in electric Cells & Batteries Finally, we go into phenomenon of the atomic nucleus to study the Radioactivity To understand this, you need to learn about a vital chemical Ethylene, and the important industrial process of Polymerization. You will learn about natural polymers, too.

All living things are built from polymers, and as the Petrochemicals run out, we need to look to living things to provide our raw materials in the future. CONCEPT DIAGRAM (" Mind Map") OF TOPIC Some students find that memorizing the OUTLINE of a topic helps them learn and remember the concepts and important facts. As you proceed through the topic, come back to this page regularly to see how each bit fits the whole. At the end of the notes you will find a blank version of this " Mind Map" to practise on. Polyethylene PVC Condensation Polymers Polystyrene The Alkanols. Structure & Properties

Conversion of Ethylene to/from Ethanol Ethylene; Chemistry & The Potential of Cellulose ! J thanol from Fermentation Combustion of Alkanols Sources Polymers from Petrochemicals & Biomass Heat of Combustion Alternative Fuels. Ethanol & the Alcohols Assessment of Ethanol as an Alternative Fuel PRODUCTION Displacement Reactions & of MATERIALS REDOX Chemistry & Batteries Activity Series of the Metals Oxidation & Radioactivity & its Uses Reduction Galvanic Cells. Structure & Chemistry Production & Uses of Commercial Radioisotopes Radioactivity Alpha Beta Gamma Standard Electrode Potentials & Cell EMF

Oxidation States Oxidation Number Transuranic Elements Commercial Cells & Batteries Petrochemicals When petroleum is refined, the major products are the fuels such as petrol and diesel. However, its not all about fuels. Our chemical industry depends on a whole range of other compounds extracted from petroleum, which are collectively called " Petrochemicals". Petrochemicals are vital raw materials for the manufacture of • plastics and synthetic fibres • pigments for inks, dyes and paints • detergents & adhesives • cosmetics & pharmaceuticals • explosives … and much more. Addition Reactions of Ethylene

These are not required learning, but study each diagram to make sure you understand the concept of an " Addition Reaction" across the double bond , H C= C, H H H / / H I H I H-C -C-H I I H H Ethene (Ethylene) CZH4 ~ Ethene is also known by its C = C common name, " Ethvlene". I I This is the name favoured in H H the syllabus, so it will be used from here on. 7 , H C= C, H H H / / Br Br I I H-C -C-H I I H H Reaction with HCl Ethylene is the simplest of the Alkene homologous series. You previously learnt about the Phvsical

Properties of the alkenes: • low m. p. & b. p. ‘ s. • insoluble in water. • non-conductors of electricity.

Due to non-polar bonding within, there are only weak “ Dispersion Forces” between the molecules H ‘ C= C/ / H H Cl I H , H + HCl I H-C -C-H I I H H The only Chemical Property you know about so far is that alkanes and alkenes will undergo combustion … they burn. Now you’ll find out more … , H C= C, H H H / / H I OH I H-C -C-H I I H H Chemistry of Ethylene The reason that ethylene is one of the most useful chemicals on the planet is all about that double C= C bond. ~ “ c ‘ ,/’/ ‘ Ifi——- —–, THIS IS CALLED AN “ ADDITION REACTION” These are just a few of the possible Addition that can occur across the double bond

Reactions C Ethylene CzH4 ~ ~ is the simplest, and most important of the Alkenes. It is one of the most important Petrochemicals ~ /The double ” bond is highly reactive ~ It readily “ splits open” leaving a single C-C bond, and creating 2 new bond positions for other atoms/groups to attach to the molecule ~ ~ ~ – ‘ lR I ~ because of the variety of products that can be made from it. Its chemical versatility is due to the double C= C bond which is highly reactive and allows many “ Addition Reactions” to occur. ,~ ‘: ,. , C:. :. :. :. :. : C – ~ I ~ Practical Work Identifying Alkenes with Bromine

You may have done siinple experiments alkene can be quickly and easily differentiated from an alkane. to learn how an identified, and If it is in contact with a liquid hydrocarbon, the water and the hydrocarbon form separate layers … they are immiscible liquids. Water, being denser, will always be at the bottom. Bromine is actually more soluble in a hydrocarbon, so when shaken, it will switch to the top hydrocarbon layer, and changes colour from brown to purple. In an alkane (hexane is often used) the colour will change and switch layers, but it will remain co loured because no reaction occurs.

In an alkene (e. g. hexene) the bromine tot; Il)1 loses aU colour because an addition reaction occurs. Brown “ Bromine ‘ 1ater” layer The bromine is discoloured by any alkene. H” H H H H I I I I C= C -C-C -C -C-H H/ I I I I I H H H H H Br Br H H H H I I I I I I H-C-C-C-C-C-C-H H H H H H H I I I I I I The Industrial Source of Ethylene Crude petroleum contains very little ethylene. When the “ fractions” are separated by Fractional Distillation, there is a large fraction of low-value alkanes with 15 or more carbon atoms. If you add up all the atoms in these 3 product molecules, you’ll see that the total is the same

H “ C= C H / H/ “ H H H H H H H H H H H H H H H H I I I I I I I I I I I I I I I H-C-C-C-C-C-C-C-C-C-C-C-C-C-C-C-H I I I I I I I I I I I I I I I H H H H H H H H H H H H H H H These large molecules are broken into smaller molecules by a process called “ Cracking”, which can be done by simply heating (“ Thermal Cracking”) or by the use of a Zeolite catalyst … “ Cat Cracking”. X! hen the molecule is broken into fragments, some pieces form as alkanes, but others must form as alkenes, because tllere are no extra atoms to occupy the bond positions that are created.

Once “ cracked”, the mixture is fed back into the Fractional Distillation process. Many of the smaller molecules end up in the valuable petrol or diesel fractions. H ‘ H H H C= C-C-C-C-H H H I I I I I H/ H I H I H H H H H H H H I I I I I I I I H-C-C-C-C-C-C-C-C-H HHHHHHHH I I I I I I I I Ethylene is obtained from the “ Cracking” of long-chain petroleum fractions keep it simple science Northmead High School SL#603217 Polymers One general category of chemicals are known as “ Polymers”. All polymers are large molecules made by joining together many small molecules, called monomers. “ poly” = many, “ mono” = one, “ mer” = unit) Many of the important molecules in living cells are Industrial Production of Polyethylene More Polyethylene is manufactured than all other plastics put together … it is one of the most used materials in our world. There are basically 2 different production methods, which produce 2 different forms of polyethylene. Low Density Polyethylene If the monomer ethylene is treated with • high pressure (over 1, 000 atmospheres) • high temperature (300°C) • an “ initiator” chemical addition polymerization occurs, with about 2, 000 monomers joining to form each “ super-molecule” of polymer.

In this case, the initiator chemical also causes the polymer molecules to have side-branches. These molecules cannot pack together closely, so the plastic is low-density, high Iv flexible, soft and clear … polymers, for example: • starch is a polymer of many glucose molecules. • proteins are polymers of amino acids. • DNA is a polymer of nucleotides, sugar and phosphate. Many common, widely used substances are manufactured polymers, including all the different plastics and synthetic fibres such as nylon. Ethylene is the starting chemical (“ feedstock”) in the manufacture of many polymers.

Addition Polymerization of Ethylene Not only can ethylene carry out addition reactions with bromine, water, etc. , but many ethylene molecules can react with each other. You may have used molecular models to help visualize the process. High Density Polyethylene is manufactured • at lower pressure (2-3 atmospheres) • at lower temperature (about 60°C) • with a complex catalyst This time there are no side-branches. The long polymer molecules can pack together forming a higher-density, harder plastic used for toys, plastic utensils, and the tough, “ crinkly” carry bags from shops.

The result is that the ethylene monomers join together by addition reactions across the double bond. This is an “ Addition Polymerization” process and results In a polymer called “ Polyethylene”, also known by the trade name “ Polythene” Addition Polymerization is an Addition Reaction across a double C= C bond which joins monomers to make a polymer. Polymers can be named by adding “ poly-” as a prefix to the monomer name. As with all materials, the uses of these plastics is closely linked to the properties they have, and their properties are controlled by their chemical and molecular structure and bonding. eep it simple science Systematic Name of Monomer Common Name of Monomer Polymer Name(s) Other Important Addition Polymers The compound chloroethene is an ethylene molecule with one hydrogen atom replaced by a chlorine. H “ C= C / H / H “ CI Chloroethene is also known by its common name “ vinyl chloride” Polyethylene Polycthene Polythene P. Ve. polyvinylchloride polychloroethene polystyrene polyethenylbenzene Since this molecule contains a double bond, it can undergo addition polymerization to form “ Poly Vin” l Chloride” or P. V. c. H H H H H H H I I I I I I I ~C-C-C -C -C-C-C-C I I I I H CI H CI H CI H

H I Uses, Properties & Structure ... •. The molecular structure and bonding of each plastic determines its properties, and the properties determine what uses the material is best suited for. To keep it simple (K. I. S. S. Principle) consider just the 3 plastics above, and consider just their hardness and rigidity. In low-density polyethylene, the molecules are long, nonpolar, branched chains (diagram previous page). Being nonpolar (so only weak dispersion forces operate) and unable to get close together, each molecule can bend and twist easily. So, the plastic is soft and very flexible.

It is perfect for clingwrap fIlm, sandwich bags and as the plastic lining in milk or juice cartons. I I I CI I If one of the hydrogen atoms of an ethylene molecule is replaced by the ring-shaped " benzene" group, the compound has the technical name " ethenylbenzene", but is :~monl,/~ww/n" """'ffi"'. " H/C= C, Thisis commonly abbreviated H as H / " C= C H ~C" /H H/ H /c -...... : H :-..... C/C,~ I H ' f ~ Benzene ring /0 1 Bonding & Structure If this undergoes addition polymerization, the polymer is " polystyrene", so familiar in insulation, hot-drink cups, bean-bag fIlling, etc.

In P. V. C. , the chlorine atoms more than double the mass of each molecule. Since dispersion forces increase with molecular weight, it means that the polymer molecules attract each other more strongly. Each molecule is held in place more, so the entire substance is harder and less flexible. P. Ve. is a tougher, more rigid plastic. This makes it ideal for drainage pipes, guttering and electrical conduit pipes. H H H H H H H H H H ~C-C-C-C-C-C-C-C-C-C~ ~6~6~6~6~6 The Syllabus Requires that you know both the Systematic and Common Names for these important monomers I I I I I I I I

I I In polyswrene, the compact benzene side group is almost twice the mass of a chlorine atom, so the molecules are even heavier and dispersion forces stronger. Polystyrene is a hard, tough, rigid plastic, often used for making handles for cookware and hand-tools such as hammers or chisels. Note that the more familiar use of polystyrene is in lightweight “ foam-plastic” for insulation, hot-cups and packaging. In this form it has been injected with gas to make very light, fluffy granules. The plastic itself is hard and rigid. keep it simple science Northmead High School SL#603217

Condensation Polymers When the Petrochemicals Run Out There is another way that polymers can form. For example; the monomer “ 6-aminohexanoic acid” has the structure NH2 .. mino”………… H H H H H O-H a group ~ I I I I I I H-N-C -C -C-C-C-C ~ I I I I I I ~ H H H H H HOg Petroleum is a non-renewable, fossil fuel. The estimates are that it will last only about 30 years at current usage rates. When supplies begin to run short, (this may already be happening) we will not only face a shortage of fuel, but of vital chemicals for our manufacturing industries .

Ethylene is an example of a critical petrochemical. It is one of the raw “ feedstock” chemicals for making plastics, fibres and fabrics, medicines, dyes and pigments for ink and paint, cosmetics, detergents, and much more. Eventually, and maybe sooner than we realize, we will need to find new raw material resources to replace the dwindling oil supplies. It makes sense that the new sources are renewable and sustainable, so that we can manufacture the things we need far into the future. COOH acid roup Two of these molecules can join together as follows These atoms form water, H20 O-H I

For renewable and sustainable, we must use living things and their products … ~ ” “‘-I- – – Ij~~:~CH2)S-~ O-H — —‘ H ~ 0 Cellulose You may be aware that all plant cells are surrounded by a rigid cell wall which supports, protects and strengthens plant tissue. The plant cell wall is made of cellulose. H-N-(CH2)s-C ~ ~ and the moleculesjoin together at the vacant bond positions H O-H I Since a molecule of water is formed each time 2 monomers combine, this reaction is called “ Condensation”. Each molecule can join to another at each end, so many monomers can join in long chains … polymer is formed. The example above results in the polymer we call “ Nylon”, widely used in fabrics and clothing. Cellulose is a condensation polvmer. The monomer glucose, the sugar made by plants during photosynthesis. IS Condensation Polymers are formed when monomer molecules join together by eliminating a molecule of WATER As well as nylon, other common condensatIOn polymers are polyester (fabrics) and PET. (drink bottles) . • ALL BIOLOGICAL POLYMERS, and starch, ARE CONDENSATION such as proteins POLYMERS. .~~. •. •… …. —-. ,,… …. / ellulose, thousands of glucose Interlocking chams. •• •• When glucose molecules join together, each pair eliminates a water molecule … a condensation reaction. To make molecules join into ~ ~ ~~ . J • ~ •••••• ~ • You are familiar with cellulose … it is the fibrous stuff of cotton and linen. We make enormous use of it as ~. We also waste a lot of it in the plant husks, leaves, stalks and stubble left over from our crop growing and timber industries. Could it be better used? keep it simple science Cellulose as a Future Raw Material The glucose molecule petrochemicals.

CAN be used to replace many Biopolymers The word “ Biopolymer” refers to those naturally occurring polymers made by living things, such as starch and cellulose. Humans have always used these polymers (e. g. using cotton for clothing) and for nearly 100 years have been using chemically modified versions of them. For example, “ rayon” is a synthetic fibre made from modified cellulose. Research has been going on for many years on ways to get living things to make polymers with properties more like Fermentation will be studied in the next section those of the useful petrochemical-based lastics. tpcocess; ng I Chemical A lot of the research has centred around the polymer " polyhydroxvbutyrate" (PHB) which has properties not too different from polyethylene. It was discovered 80 years ago that PHB can be made by bacteria, such as the species Bacillus magaterium. In recent years, the Monsanto company has used Genetic Engineering (G. E.) to transfer the genes for PI IE production into corn plants. The crop is grown, harvested and eaten as usual, but then the stalks and leaves are harvested for their PHB content, which is as high as 20% of the dry weight. Ethylene I —….. Feedstock for Plastics & other manufacturing Unfortunately, we have not yet developed a simple, efficient and economical way to break the cellulose polymer down into molecules of glucose. We can make ethanol and ethylene on a large scale from starch or sugar, but real sustainability will come by being able to use the cellulose in all the " waste" plant matter. Anal)Isis • PEB has properties which make it suitable to replace some plastics for packaging, but it tends to be brittle, and extra breakages must be accepted. PEB has the major advantage of being biodegradable, but this also limits its range of uses, since it can rot and disintegrate during use. • There is resistance from farmers and consumers regarding the use of G. E. plants. • The production of PI-ill is not yet as cheap as using petrochemical plastics. Conclusion: PEB grown in corn has potential, wllikely to become widely used yet. but 1S When petroleum is refined the main products are a) , but there are also other chemicals extracted for use in manufacturing. These chemicals are collectively called " b) " and the most important is c) .

The reason for ethylene's great usefulness is the d) carbon-carbon bond. This bond is highly e) and readily " splits open" allowing other atoms/groups join onto the molecule. This is called an f) Reaction. . . to . Other important polymers are: • p. v: c. which stands for y) . The monomer is commonly called z) , but its correct chemical name is aa) . The added chlorine atom makes the molecular mass much higher, so that the ab) forces between molecules are stronger. The plastic 1S ac) and more ad) so it is used for ae) . • Polystyrene is made from the monomer af) . for which the correct systematic name is ag) . . The " side group" on this molecule is the ring-shaped ah)……………………………. group. This increases the molecular mass so that the ai) . forces hold the polymer molecules even more strongly so the plastic is aj) and . Polymers can also form by a ak) reaction. This occurs when 2 monomer together by elimination of a al) Examples of condensation polymers am) and biological polymers, such as an) ……………………………………. are condensation . join . In the laboratory, compounds containing a double bond can be identified using a solution of g) .

If this is added to an alkene, the g) will be h)……………………………………. because of an addition reaction. With an alkane, the colour may change and shift from one solvent to the other, but will not be h) : . The yield of Ethylene from petroleum is greatly increased by the process of " i) " in which long-chain alkanes are broken into smaller fragments by either j) or This increases the yield of valuable fuel fractions such as k) and increases the yield of ethylene which is extracted from the 1) fraction.

The major use of ethylene is the manufacture of m) Thousands of ethylene monomers join together by n) reactions to form 0) If the reaction is carried out at high p) and . with an “ initiator” chemical, the result is g) density polyethylene. The long chain molecules have many r) and cannot pack close together, so the plastic is soft and s) , ideal for soft plastic bags and t) flim. If the reaction is carried out at lower pressure and temperature with a u) , the polymer molecules lack branches and can v) . ……………………………. to form w) -density polyethylene, used (for example) in “ crinckly” x) . …………………………… from shops. molecules are nylon, All and polymers. One important biological polymer is ao) . which is a polymer of ap) and is found in large amounts in all plants, where it forms tlle cell aq) which strengthens and protects all plant tissues. We already use cellulose for fabrics such as ar) and and process it to make as) When the petroleum supplies run out, cellulose has great potential to supply our needs. Its monomer at) can easily be turned into the alcohol au) which can be used as a fuel, or chemically converted to av) . o feed the plastics industry. Unfortunately, we have not yet developed a simple, efficient and economical way to convert cellulose to aw) to begin the process. Research is also progressing in the use of engineered “ Biopolymers” such as ax) (abbreviation). This polymer has properties sinlllar to some petrochemical plastics, but is made naturally by microbes such as the bacterium ay) …………………. (scientific name). The Monsanto company has used az) . ………………………… techniques to transfer the genes for PHB into ba) plants.

After normal growth and harvesting, PHB can be extracted “ waste” leaves and stems of the crop. from the WHEN COMPLETED, WORKSHEETS BECOME SECTION SUMMARIES Although this is very promising, it is unlikely to be used on a large scale while cheaper petrochemicals are still available. The Alkanols (Alcohols) You should recall that the Alkanes and Alkenes are 2 “ Homologous Series” of compounds. In each series, the compounds follow a pattern of having the same basic structure, and are able to be described by a general molecular formula.

Properties of the Alkanols What a difference that oxygen atom makes! Non-Polar Covalent Bonds creates electric charge dipole Now you Homologous “ Alcohols” . to another are introduced also Series… the Alkanols, important known as The polar covalent bond in the -OH group creates a charge dipole, and strong hydrogen bonding exists between the molecules. This results in: • mp’s and b. p’s being much higher than the corresponding alkanes. The first 8 alkanols are all liquids at room temperature. smaller alkanols are soluble and fully miscible in water, because they can form hydrogen bonds with water molecules. The larger ones become less soluble as the nonpolar hydrocarbon chain grows longer. • the alkanols (especially ethanol) are excellent solvents, able to dissolve many water-soluble (polar) solutes, but also able to dissolve many non-polar substances which do not dissolve well in water. This is why ethanol is widely used in industry to dissolve reagents, pharmaceuticals and food chemicals. Around the home “ methylated spirit” is used as a cleaning agent… t dissolves things well. (Methylated Spirit, or “ metho” is about 95% ethanol with water and small amounts of additives to make it distasteful to discourage anyone from drinking it) • alkanols are inflammable, and can be used as fuels, although their energy content is not as high as the corresponding alkanes. Ethanol is, of course, the alcohol in beer, wine and spirits. The alkanols contain all C-C single bonds, but on one of the carbon atoms there is an -OH group … an oxygen atom and hydrogen atom. To name any ALKANOL add "-ANOL" to the appropriate General Formula refix. CnHZn+10H Methanol CH30H (Formula could be written CH40, but it is usual to emphasize the -OH group) O-H H-C-H I H I H O-H H-C-C-H This is by far, the most important member of the series. I I I I H Condensed Formula H Structural H H O-H C3H70H CH3CHzCHzOH and then … Butanol Penta no I Hexanol Heptanol Octanol H-C-C-C-H I I I I I I H H H CH3(CHz)zCHzOH CH3(CHz)3CHPH CH3(CHz)4CHzOH CH3 (CHz) sCHzOH CH3(CHz)6CHzOH These are made by the process of fermentation carried out by living microbes, especially yeast, which is a singlecelled fungus organism.

You should be aware that, despite our society's acceptance of the consumption of alcohol as a social drug, all the alcohols are toxic. Our bodies can tolerate ethanol in small doses, but others such as methanol or propanol, are quite deadly. C4H90H CSHllOH C6H130H C7H1SOH CgH170H keep it simple science Northmead High School SL#603217 Ethylene to Ethanol Ethylene can readily be converted to ethanol by an Addition Reaction across the double bond. You may have used molecular model kits to help visualize this reaction.

The reaction is facilitated by dilute sulfuric acid, which acts as a catalyst. Fermentation of Sugar to Ethanol The fermentation process is the oldest known chemical process used by humans. We don't really know when it was discovered by ancient peoples, but the brewing of beer and wine was practiced by all the early civilizations of the Middle East, Europe and Asia. It looks simple enough, but the actual chemistry is very complicated, involving many separate steps, each catalysed by a different ~ produced by the living yeast cells. Ethanol to Ethylene

The reverse reaction is also possible: However, you don't need to know all those details, and just like any maker of home-brew beer soon finds out, it really is simple as long as you provide certain conditions. For fermentation to work there must be: • a suitable carbohydrate source. This can be sugar from fruit, starch from wheat, corn, potatoes, etc. (Note that the yeast is able to digest starch and other carbohydrates to glucose, so it is not necessary to actually start with glucose.) • live yeast. • a temperature kept fairly constant around 22-25°C. • anaerobic conditions (i. . no oxygen available). If oxygen is available, the yeast will produce only CO2 and H20, but no alcohol. Practical Work Fermentation You may have carried out an experiment with fermentation which is essentially a little " home-brew" exercise. The photo shows a typical laboratory Sealed flask contains sugar & yeast. Temp. kept at about set-up. Any gas produced bubbles through a beaker of limewater Once again a catalyst is need to make the reaction run at a practical rate for an industrial process. The same catalyst, sulfuric acid, is used but in concentrated (not dilute) form.

Since water is produced as a product, it is reasonable to describe the reaction as a " Condensation", but it is also known as a " Dehydration", meaning to " take water from". The significance of this reaction is that ethanol can be made from plant materials, by processes that are renewable and sustainable. Making ethylene from ethanol would result in a major chemical resource being available without the use of petrochemicals. Fractional Distillation of Your “ Home-Brew” 2SoC You may have weighed the flask before, and after, several days of fermentation. It will have lost mass due to the loss of gas.

Heat gently and monitor the vapour temp. Collect the fraction produced at about 80°C. To test vour distillate: pour into a watch glass and ignite carefully in a darkened room or fume-cupboard. If it burns with a blue flame, your distillate is 80-90% ethanol. You would also observe bubbling in the flask over several days, and the limewater would rapidly go “ milky” proving that the gas produced is CO2, When the bubbling subsides, the contents of the flask may have the yeasty, alcohol smell of beer. You may have even distilled your brew to collect ethanol, as described at left. eep it simple science Northmead High School SL#603217 Getting Pure Ethanol Even under ideal conditions the fermentation of sugar to ethanol by yeast can only produce a “ brew” with about 15% ethanol. At about this level, the yeast is killed by the alcohol, and no further fermentation takes place. To get close to pure ethanol, the fermented liquor must be distilled. In the making of brandy, whiskey, rum, etc, the “ spirit” is usually around 40% ethanol. Fractional distillation will yield a distillate which is about 95% ethanol, which is quite suitable as a fuel.

Combustion of the Alkanols Ethanol has been mentioned as a possible fuel, so what is the chemistry of the combustion? The Industrial Process Today . • Due to the cheap availability of petrochemicals, most of the ethanol used as an industrial solvent or for cleaning (i. e. non-drinking purposes) is made from ethene by the addition reaction with water, and NOT from the fermentation of sugar. The only industrial-scale use of fermentation to make high-purity ethanol is in the sugar industry. A major waste product from sugar refining is “ molasses” which contains a large amount of sugar.

Rather than waste it, molasses is used as the sugar source for yeast fermentation, and the fermented liquor is distilled for the ethanol. In Australia, the sugar industry is based in Queensland, and this is where the sugar-to-ethanol production takes place. Apart from producing the famous “ Bundy” rum, the ethanol produced is used for: • • • • manufacture of vinegar. “ extending” petrol by adding 10% ethanol. (more later) industrial and pharmaceutical solvent. domestic cleaner, in the form of “ metho”. The only tricky part is balancing … e careful balancing the oxygen atoms, noting that there is already 1 oxygen atom on the left side in the alkanol molecule. Heat of Combustion of a Fuel How much energy is actually released when a fuel burns? All combustion profile is reactions are exothermic, so the energy Ea = Activation Energy Although technically the value for fJ. H is a negative quantity, for “ Heat of Combustion” the value is usually written ~ positive quant. ity because the formal definition is: The Molar Heat of Combustion is the heat given out when 1 mole of a fuel is burned completely, with all reactants and products in their “ standard states” at SLC.

Notes: 1. Since the definition is the “ heat given out”, it follows that the value is expressed as a positive quantity. You must remember that combustion is exothermic, and technicaJlyit has a negative value, for example when using an equation such as ~II = -mCSr 2. You learned previously that fuels generallyburn only after being vapmized, and that the water forms in the gas state, as shown in the equation above. r r owever, the definition demands that all substances are in their “ standard states” at SLC, so both ethanol and water must be in the liquid state.

So, the Molar IIeat of Combustion (~HJ of ethanol would be the (positive) quantity of heat released when 1 mole of ethanol (= 46. 1g) burns as follows: . (note the states) keep it simple science Northmead High School SL#603217 Prac Work Measuring . 0. Hc of Alkanols You may have carried out experiments to measure and calculate values for the Heat of Combustion of several alkanol fuels. A typical school experimental set-up is shown: Comparing . 0. Hc of Fuels The syllabus requires that you measure and compare the Heat of Combustion for at least 3 different alkanols, on a per gram, and per mole basis.

Hopefully you’ve done exactly that. To help you understand the figures, here is a summary of typical results. For comparison purposes, values for an alkane fuel (octane is a typical component of petrol) are included. Heat of Combustion School Experiment kJ/gram 10 11 12 14 kJmorl 350 630 720 1040 Values “ Text” kJ/gram kJmorl 22. 7 726 29. 7 33. 6 36. 1 47. 9 1367 2021 2676 5470 Thermometer measures temp. change in water. Metal can holds a measured quantity of water. It acts as a calorimeter, absorbing heat released by the fuel. “ Spirit burner” burns an alkanol fuel using a wick.

Burner is weighed before and after to measure the mass of fuel used. Fuel Methanol Ethanol Propanol Butanol Octane Starting temperature of water Final temperature of water = 16°C = 42°C = 26°C Although the values that are typically obtained in a simple school experiment are well below the accepted “ text” values, the trends are the same: the Heat of combustion of the alkanols increases steadily (on both per gram and per mole basis) with increasing molecule size. It is notable also, that ethanol’s LiHe is much lower than the typical value for the compounds found in petrol.

This means that ethanol, a candidate to replace petroleum fuels, is a much lower-energy fuel. liT Analvsis of Results: Heat absorbed by water in the calorimeter: . 6H = -mC~T (C = Specific Heat Capacity of =-100×4. 18×26 water= 4. 18j/oC/g) = – 10, 868 j ~ 11 kJ of heat released. This is the heat released for 0. 80g of ethanol burnt. Ethanol as a Renewable Fuel The use of ethanol as a fuel to eventually replace petrol, as the petroleum supplies run out, has been proposed because: • the technology to make ethanol from the fermentation of sugar (followed by distillation) is a well known and proven process … e know it can be done. • sugar for ethanol production can be harvested from plants, so it is a renewable and sustainable energy source. Di~cussion: -1 The “ text book value” of ld-Ie (ethanol) = 1367 kJmol . Typically, in a ~chool experiment, values of only about half, or less, arc obtained. Why? The analysis of results assumes that all the heat released by the burning fuel is absorbed by the water in the “ calorimeter” can. However, this calorimeter is very primitive and inefficient. A lot of (most of?) the heat of the fuel can escape into the surroundings, and therefore docs not get measured.

The set-up can be improved by using a larger can, wind baffles, insulation, ete. , but will always give results well below “ text” values. • when ethanol from plants is burnt, the carbon dioxide released is exactly the same amount that was absorbed by tIle plants during photosynthesis to make the sugar.

Therefore, the use of plant-derived ethanol does not contribute to the " Greenhouse Effect". There is no doubt renewable fuel. that ethanol can be considered as a keep it simple science Northmead High School SL#603217 U sing Ethanol as an Alternative to Petrol Advantages & Disadvantages of Ethanol Fuel have already been discussed:

Ethanol can be added to petrol in mixtures up to about 1020% and burnt in car engines without any modifications needed, and with only a slight loss of engine performance. This use of ethanol as an " extender", to conserve petrol and help reduce Greenhouse emissions has been around for years on a small scale. Following the fuel price crisis of 2005, the fustralian Government has proposed making it happen on a very large scale. As long as the ethanol is being made from the wastes of the sugar industry, and used only at about the 10-20% level with petrol, this strategy seems both economical and scientifically sound.

To run vehicles on pure total new engine design tends to be corrosive, ignition temperature and ethanol fuel however, requires a to allow for the fact that ethanol has a different energy content, burn characteristics. Some of the Advantages • It can be mixed with petrol up to about 20% and used without any modifications to existing engines. Disadvantages and Difficulties • To totally replace petrol with ethanol, the use of sugar industry wastes would be nowhere near enough. Huge tracts of land would have to be dedicated to growing sugar cane (or other crops) to supply the ethanol industry.

The attempt by Brazil to do exactly this in the 1980's was an economic failure, and disrupted a lot of their food production farming to make way for " ethanol farming". • The current technology for ethanol production requires massive amounts of energy for the distillation process. Currently, fossil fuels are used for tlle heating, and so tlle process is not as renewable nor " Greenhouse-friendly" as first thought. • As mentioned at left, entirely new engines are needed to run on pure ethanol. The cost of tlle change-over, to both manufacturers and car-owners is too high to be feasible.

Assessment Weighing up advantages and disadvantages, the following conclusions seem realistic: • The use of about 10-20% ethanol (derived from sugar industry wastes) to extend petrol seems likely to continue and even become more widespread. • The use of pure plant-derived etllanol fuel seems very unlikely until one or both of these technologies develops; – efficient production of glucose from cellulose, derived from crop wastes, so that no crops have to be grown just for ethanol production. – renewable energy sources (e. g. solar power) to operate tlle distillation process for ethanol.

The cost of setting up factories to make a totally new engine design is such that it is very unlikely that ethanol will be used as any more than a 20% fuel-extender anytime soon. Although the reaction should have a al) stated as a am) definition. The Alkanols are an a) series of carbon compounds with general formula b) . They are also known as the " c) " Each alkanol has an d) group attached to one of the carbon atoms. This group contains a e) . covalent bond which creates an electric f) . on the molecule. This causes quite strong g) . bonds between the molecules, which result in the following properties: • m. p. s & b. p. ' s are much h) corresponding alkanes. • alkanols are generally i) • they are excellent j) dissolve both k) (opposites) solutes. • they are inflammable, although their m) the alkanes. Ethylene can be converted to ethanol by an n) . reaction, adding 0) across the double bond. Dilute p) acts as a catalyst for this reaction. The reverse reaction, converting q)………………. to is also possible if r) H2S04 is the catalyst. This reaction could be considered as a " condensation", but is usually referred to as " s) . " Biologically, ethanol can be made from t) by the process of u) are the v) in living w) .

The catalysts . than the in water. is always ak) -thermic and value for t:. H, the value is quantity because of the Generally, the values for t:. Hc for the an) with increasing molecular are much lower than the values for an ao) alkanols size, but . The advantages of using ethanol as a fuel are • it is a ap) resource • the aq) is known & proven • it is " ar) -friendly" • it can be mixed with petrol to about as) % without any modifications to existing car engines. Disadvantages include: , because they can and . • to totally replace petrol, vast areas of land would have to be at) . nd can be used as 1) is lower than , • large amounts of energy are needed for the au) . ……………………………….. process, and we cannot yet do this in' a renewable and eco-friendly way. would have to be totally re• vehicle av) designed and replaced to run on pure ethanol. 1. Combustion Equations for Alkanols Write a balance equation for the complete combustion a) methanol c) hexanol 2. Heat of Combustion b) propanol d) octanol Problems of a) In an experiment, lAg of butanol was burnt and the heat collected by a metal can containing 200g of water. The water temperature rose by 23°C.) Write a balanced equation for the combustion, showing all chemicals in their standard states. ii) Calculate the value of t:. Hc per gram & per mole. b) In a similar experiment using pentanol, 0. 50g of fuel was burnt, which raised the temperature of lS0g of water from 18 to 30°C. i) Write a balanced equation for the combustion showing all chemicals in their standard states. ii) Calculate the value of t:. Hc per gram & per mole c) The accepted value for t:. Hc(ethanol) = 1367 k]mor1. If 2. 80g of edlanol was burnt in a " perfect" calorimeter containing SOOg of water, by how temperature of the water rise? much would the ells. The requirements for the reaction are: • a suitable source of x) from fruits or grams. • live y) • at temperature • aa) Fermentation maximum ab) . maintained around z) conditions can oC (no oxygen). produce a mixture containing a % ethanol. This can be purified by ac)……….. to obtain about ad) % purity. Industrial scale fermentation (apart from beer & wine production) uses wastes from the ae) industry, and then fractional af) to obtain near-pure ethanol for manufacturing ag) (food use) or for solvent and cleaning purposes. ' Vhen alkanols burn, the products of complete combustion ~~ ~ is defmed as ai) The " Molar Heat of Combustion" . d) The accepted value for t:. Hc(Pentanol) = 3330 k]mor If O. SOgof pentanol was burnt in a " perfect" calorimeter containing lS0g of water, by how much would dle temperature of the water rise? Compare your answer to the data in Q(b) and comment. 1 Displacement of Metals From Solution And now for something completely different, we go back to some Chemistry you learned in Preliminary topic 2 " Metals". Remember the Activity Series of the Metals? copper(II) sulfate + zinc zinc sulfate Most Active React readily with I I I I I I oxygen water acid This is a " Metal Displacement".

It will occur whenever a metal is placed into a solution containing ions of a lessactive metal. The reverse will not react. Transfer of Electrons The equation above can be re-w11tten in ionic form: C u 2+ (aq) + SO 4 2- (aq) + Z n(s) —.. Zn 2+ (aq) + SO 4 2- (aq) +Cu(s) Mg AI Look carefully and you will see that the sulfate ions (SO /-) have not changed at all... they are " spectators" can be left out, to form the " net ionic equation": 2+ 2+ (aq) and Cu + Zn(s) Zn (aq) + CU(s) Now you can see what really happened; copper ions turned into copper atoms, and zinc atoms turned into zinc ions. This can only happen if:

Cu 2+ (aq) + 2e- Ag Least Active No reaction, or very slow ~—• CU(s) ... •. •••• ~ Electrons ~ transferred Au Zn 2+ (aq) + 2e . , One of the best " hands-on" ways to see the Activity Series in action is to place a piece of metal into a solution containing the ions of a less-active metal. This experiment is not actually specified by the syllabus, but hopefully you have seen what happens. Example: Drop a piece of zinc into copper(II) sulfate solution. A reaction occurs which slowly " eats away" the zinc, and a solid deposit forms at the bottom. Later, the deposit is seen to be orangecoloured ... it is copper metal.

The zinc has dissolved, and displaced solution. the copper ions from This is one of the most common and important general types of chemical reaction; when electrons are transferred from one chemical species to another. Reactions where this occurs are called " OXIDATION-REDUCTION" or simply Note that neither part can occur alone. To lose electrons, there must be another species to accept them, and to gain electrons, there must be another species to give them. keep it simple science Northmead High School

SL#603217 REDOX and the Activity Series Now the Activity Series of the metals can be seen in a new way. Metals higher up the tendency to be oxidized atoms readily form ions water, or the ions of less .. Activity Series have a greater (= lose electrons) and so their by reacting with acids, oxygen, active metals. Galvanic Cells Just because Oxidation & Reduction must always occur together doesn't mean that they must occur in the same container. It was discovered about 200 years ago that the 2 processes can be separated to 2 different locations, so long as there is a conducting wire to allow the flow of electrons from the site of oxidation to the site of reduction .

This forms a " Galvanic Cell" which is the basis of all our electric cells and batteries. " Galvanic" is named for one of the pioneering scientists, the Italian Luigi Galvani who lived 200 years ago. At that time, electron transfer and REDOX • Metals lower down the Activity Series have a greater tendency to be reduced (= gain electrons). Their atoms are less likely to react with acids or oxygen, and their ions are more likely to be displaced from solution by more active metals.

You should recall also, that less active metals are easier to extract from their ores, (or may even be found uncombined in nature) while more active metals require more and more energy to extract from their ores. Extracting any metal from its ore involves reducing the metal's ions, so this idea links to that above. Prac Work: Galvanic Cells You may have done several experiments to investigate the construction of simple Galvanic Cells, and to measure the voltage (" potential difference") produced by different combinations of metals. chemistry was NOT understood.

Connecting wires allow electrons to flow from one halfcell to the other Conditions under which a Galvanic Cell works • Half-cells must be connected by a wire to allow electron flow from one to the other. • Half-cells must be connected by a " salt-bridge" (explanation next page) • Electrodes must be 2 different metals . • Electrodes must dip into an " electrolyte" solution containing ions. Which Electrode is Which? You will quickly fmd that if you connect the voltmeter the wrong way around, that the needle deflects backwards. To make it read correctly, the more active metal is always connected to the negative connection.

This is because the more active metal always oxidizes (loses electrons). Therefore, electrons flow from the more active metal. Zinc electrode in solution of zinc ions They must be connected Copper electrode in solution of copper ions by a " salt bridge" The Size of the Potential Difference If you test various combinations of metals (but always use the same concentration of solutions) you will fmd that… for ion transfer Each beaker is a " half-cell", containing a metal electrode dipping into a solution of ions of the same metal. … he further apart the metals are in the Activity Series, the higher the cell voltage (potential difference). -"~ Electrons always flow from ANODE to CATHODEin the external circuit J Metal ~ atoms Metal + electrons ions ; + ; I CIJ CIJ Metal + electrons .. •. Metal ions atoms ZnCs)—-. – Zn 2+ Caq) + 2e- The zinc electrode would dissolve, as zinc ions go into solution Electrolyte solution C U 2+ Caq) + 2e – –.. C uCs) e. g. ZnCI2 solution e. g. CUS04 Solid copper deposits onto the electrode solution Half-cell where OXIDATION occurs If both electrodes are metals, this will be the more active metal

Half-cell where REDUCTION occurs If both electrodes are metals, this will be the less active metal Definitions & Things To Know… An “ Electrolyte” is a substance which will conduct electricity when molten, or in solution. Generally, it refers to ionic solutions An “ Electrode” is a conductor placed in each half-cell to pick up or release electrons. Sometimes the electrode is involved in the reaction; in other cases it can be “ inert”. The Salt Bridge can be just a filter paper soaked in electrolyte, or a tube of electrolyte jelly, or even just the electrolyte solution itself.

It must allow diffusion of ions from one half-cell to the other Ions migrate through the Salt Bridge to keep the total charge in each half-cell neutral Each cell can be described by a “ short-hand”, The cell above would be described by Zn1Zn2+ II Cu2+ICu I t salt bridge cathode species anode species Spectator Ions Be aware that there must be other ions in the solutions as well. For example, the solutions shown contain eland S042- ions as well as the metal ions. They take no part, except to migrate through the Salt Bridge. keep it simple science Northmead High School SL#603217 Standard Electrode Potentials

The actual voltage reading you get when you set up an electrochemical cell depends on many factors: • the metals used at the electrodes (in particular, how far apart the 2 metals are in the Activity Series) • the concentration of electrolyte solutions • the temperature • the gas pressure, if any gases are involved Therefore, to make comparisons and predictions, it is necessary to specify a set of standard conditions for measuring the voltage of any cell. The standard conditions are (predictably) • all solutions are 1. 0 molL-1 •

temperature o and gas pressure at SLC (2S C & 1 atmos) Using Electrochemical Data

Consider the cell described previously, which contained zinc and copper electrodes in solutions of matching ions. Short-Hand ZnIZn2+" Cu2+ICu Under these conditions, each half-cell has a " Standard Electrode Potential" when measured against a " Reference Half-Cell". The reference used is the reaction Cu 2H+ (aq) + 2e ~ H2(g) 2+ (aq) EO Zn(s) ~ Zn 2+ (aq) + 2e- +0. 76 V + 2e- -... CU(s) This half-cell has been assigned a Standard Electrode Potential (Eo) of zero volts, and all other half-cells are measured from this. You may have been given a " Chemistrv Data Sheet" containing a list of standard electrode potentials.

Here is a shorter version for quick reference, which will be used throughout these notes and exercises. Some Standard Ca2+ Mg2+ Zn2+ Fe2+ 2H+ Cu2+ + + + + + + + + + 4H + 2e 2e2e 2e2e2e 2e e + (aq) + 2e Potentials EO (V) Cats) Mg(s) Zn(s) Fe(s) H2(g) CU(s) 2r(aq) Fe 4e -. :::.. 2+ This means that, under standard conditions, this cell will produce a voltage (technically, an " Electromotive Force" (EMF), or " Potential Difference") of 1. 10 volts. Notes: 1. The zinc reaction was written as an oxidation, the reverse of the half-cell equation given in the table at left. Since the equation was reversed, the sign of the EO value was reversed also. . The total cell voltage is simply the sum of the half-cell EO values. 3. The overall equation for the reaction can be found by simply adding together the 2 half-equations, being sure that the same number of electrons are on each side and therefore, " cancel-out" as follows: Zn(s) + Cu2+(aq/~ ~ CU(s) + Zn2aq)+~- ~ ~ ~ -. :::.. -2. 87 -2. 36 -0. 76 -0. 44 0. 00 +0. 34 +0. 62 +0. 77 +1. 23 +1. 36 -. :::.. -. :::.. -. :::..

~ -. :::.. ~ ~ -. :::.. Any 2 half-equations can be combined this way, but sometimes it may be necessary to multiply one or both by a factor so that the electrons will cancel.

Example: Clz(aq) + 2e)00 2Cr(aq) combined with 2+ 3+ Fe Fe (s) + e You need to multiply everything in the 2nd equation before combining them)00 -. :::.. I2(aq) Fe3+ ~ -. :::.. ~ (s) 2H2O(1) 02(g) ~ x2 Cl2(aq) ~ 2Cr(aq) CI2(aq)+ ~ 2 + 2Fe + ~ 3 2Fe +(s)+; z{ + 2Cr(aq) Notice that each half-equation is written as a reduction. If you need to write it backwards as an oxidation, then simply reverse the sign of the EO value. HSC Chemistry Topic 1 However, when you do this, the EO values DO NOT CHANGE