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Crude oil and fractional distillation

Crude oil (petroleum) is composed of mostly hydrocarbons (alkanes and aromatics), and is a tremendous mixture of compounds consisting of between 5 and 40 carbon atoms.\(^{11}\) The components in oil are incredibly useful as fuels and lubricants, but not when they are mixed together. Fractional distillation is used in oil refineries (Figure 5.41) to separate the complex mixture into fractions that contain similar boiling points and therefore similar molecular weights and properties. Gasoline, diesel fuel, kerosene, and jet fuel are some of the different fractions produced by an oil refinery. Figure 5.41: San Francisco Refinery in Rodeo, California. Cyclopentadiene is used in many chemical reactions, including Diels-Alder reactions and polymerizations. The reagent is so reactive, however, that it undergoes a Diels-Alder reaction with itself in the reagent bottle to form dicyclopentadiene (Figure 5.42a). Therefore, chemical companies do not sell cyclopentadiene, and chemists are instead required to distill commercial dicyclopentadiene (Figure 5.42b) to reverse the dimerization reaction and obtain cyclopentadiene (Figure 5.42c). Figure 5.42: a) Dimerization reaction of cyclopentadiene, b) Dicyclopentadiene reagent, c) Retro Diels-Alder reaction. At temperatures above \(150^\text{o} \text{C}\) the dimer reverts to the monomer through a retro Diels-Alder reaction (driven by the favorable change in entropy, Figure 5.42c). Distillation can be used to remove the monomer as it forms. Although the two components (dimer and monomer) have dramatically different boiling points, the temperature required for the reverse reaction is too similar to the boiling point of the dicyclopentadiene that its vapor pressure cannot be ignored. Therefore, a fractional distillation is required for this process. \(^{11}\)About \(6\%\) of crude oil contains hydrocarbons with greater than 40 carbon atoms, a fraction that eventually becomes used for asphalt. Contributor Lisa Nichols (Butte Community College). Organic Chemistry Laboratory Techniques is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. Complete text is available online. A little extra on fractional distillation (for Advanced A Level Students) 1. There is a condenser at the top of the fractionating column that condenses out any remaining molecules with at least 5 carbon atoms. These are most likely to be small amounts of gasoline-petrol sized molecules from the crude oil and are added to the tray outlet pipe for the gasoline-petrol fraction. 2. All the initial fractions listed above are still a mixture of molecules with a range of 3-10 carbon atoms molecules within each fraction e.g. hydrocarbon ranges C5 to C7 or C21 to C30 etc. Therefore in order to separate a narrower range of molecules, perhaps even single molecule fractions, you can fractionally re-distil the initial fractions for further refining the crude oil products. 3. Inside a fractioning column are multiple trays with pipe openings, half of which are covered in bubble caps. The bubble caps increase the surface area and gives a better chance of the fraction condensing out at the right temperature and allowing the lowing boiling fraction vapour to move further up the column. Right up the column, with its negative temperature gradient, the following is happening (follow the blue arrows): The vapour bubbles go up through 'pipe' openings in each tray and into the bubble caps. The highest boiling component condenses out at their condensation temperature - tapped off. The lower boiling liquid vapours then bubble up through the liquid and up to the next tray. This explains why some hydrocarbons are gases and others are liquids at the same point in the column. The lower boiling liquids are passing through as gases upwards and through the descending or condensing higher boiling liquids. More Revision notes on the fractional distillation of crude oil, uses of oil fractions related to size of molecule and intermolecular bonding forces, help when revising for AQA GCSE 9-1 chemistry, Edexcel GCSE 9-1 chemistry, OCR GCSE 9-1 gateway science, OCR GCSE 9-1 21st century science GCSE 9-1 chemistry practice examination questions TOP OF PAGE and sub-index 2d. Relating intermolecular bonding forces in hydrocarbon molecules to their physical properties and uses For section 2b. a mental picture of the increasing length of hydrocarbon molecules will help you understand more about how, and why, the physical properties of hydrocarbon molecules changes with increasing length AND how their physical properties affect how each fraction is used commercially after the fractional distillation of crude oil. Note that the longer the hydrocarbon molecule, the more flexible or wiggly it gets! The important physical properties of hydrocarbons like alkanes all depend on the forces between the molecules - the intermolecular forces (intermolecular bonding). This is NOT covalent bonding, covalent bonds are the much stronger C-C and C-H bonds between the atoms in the molecule itself, these are the weak attractive forces between the individual molecules. Quite simply, with important consequences (e.g. how they are used), the bigger the molecule the bigger these weak electrical attractive forces are, which I've done my best to illustrate in the diagrams (above and below). As the hydrocarbon molecule gets bigger, the surface to surface contact area increases allowing more points for the intermolecular bonding attractive forces to happen. Hence the increase in viscosity, melting points and boiling points with increase in molecular mass. The intermolecular bonds are much weaker than the covalent bonds, so when the hydrocarbon molecules have enough kinetic energy, it is the intermolecular forces which are overcome on vaporisation and the molecules stays intact. CONCEPT: The dotted lines represent the weak intermolecular bonding forces of attraction between the molecules. The bigger the molecule, the more dotted line 'connections' there are, the bigger the intermolecular forces! The different fractions are a range of physical properties which vary with molecular size. Remember for points 1. to 5., the longer the carbon chain, the bigger the molecule gets ... ... the more viscous the molecule (stickiness! less runny, more sticky) as the intermolecular attractive forces between molecules increases the bigger the molecule in a series of molecules of similar structure. The more strongly the hydrocarbon molecules are attracted to each other, the less easily they run over each other, so the liquid itself does not flow as easily - not as fluid. Note for advanced level students: Intermolecular forces or intermolecular bonding, are non–polar weak electrical attractive forces, often described as Van der Waals forces, and correctly described as instantaneous dipole – induced dipole forces. You need to distinguish this intermolecular attractive force from the much stronger force of the covalent bonds between the carbon atoms (C-C) of the chain of the hydrocarbon. ... the molecule has a higher melting point as more vibrational kinetic energy is needed to overcome the increasing intermolecular attractive forces holding the molecules together to form the crystals which increases with increase in size of molecule. ... the molecule has a higher boiling point as more particle kinetic energy is needed to overcome the increasing intermolecular forces between the liquid molecules. 3. follows from 2. ie the intermolecular forces increase between the hydrocarbon molecules increases as they get bigger (longer carbon chain). Trends 2. and 3. are readily appreciated e.g. methane gas (CH4), liquid petrol (about C5H12 to C7H16) and solid candle wax (over C21H44). The trend in boiling point is the basis for being able to separate the hydrocarbons into fractions by the use of fractional distillation. The graph shows the boiling point of alkanes from methane CH4 (boiling point -164oC/109 K) to tetradecane C14H30 (boiling point 254oC/527 K). [Remember K = oC + 273] See the ALKANES page for a list of the boiling points of the first 20 linear hydrocarbons found in oil. ... the molecule is less flammable as they become less volatile (less easily vapourised), again due to increasing intermolecular forces with increasing size of molecule so for example, petrol (small molecules) is much more flammable than lubricating oil (much bigger molecules, much longer carbon chain). This raises health and safety issues about handling, distributing and storing flammable hydrocarbons. The smallest molecules (natural gas to petrol) are the most volatile and therefore the most easily ignited. Any naked flame or spark could set off a fire and explosion and even. We can now apply these ideas to explain these hydrocarbons are used, usually as fuels. Further comments on the use of the fractions related to the use of the hydrocarbons from crude oil The examples are discussed in order of increasing molecular size – increase in carbon chain length. Note that all fuels are processed at the oil refinery to reduce the concentration of sulfur/sulphur compounds (desulfurisation) to reduce the air pollution effects on burning. It should be noted that liquid fuels like petrol, diesel, central heating oil etc. are east to store and distribute to wherever they are need in homes or factories and they are so readily available, that change may be necessary, but it will be slow. See notes on pollution, global warming TOP OF PAGE and sub-index 2e. More notes on the USES of these fractions (with reference to 2d. above) CH4 Methane natural gas, either from gas fields (eg under North Sea) or from an oil refinery can be piped to power electricity generation or domestic heating in the home. Ethane C2H6, propane C3H8, butane C4H10The very low boiling refinery gas fractions Propane and butane can be stored under pressure as bottled gas (LPG), and because the gas readily flows under the control of a simple valve, they can be conveniently pumped to burner systems. Being gases, they are easily ignited but explosive ! The intermolecular forces are very weak in a gas, that's why they are gases at room temperature, and they are very fluid just like a liquid, so easily moved through pipes. In the UK butane gas (C4H10) is in blue cylinders and propane (C3H8) in red cylinders. C5H12 to C7H16 The intermolecular forces are now great enough to raise the boiling point of the hydrocarbons to above room temperature and make them liquids at room temperature. Vehicle fuels like petrol must be liquid at room temperature for compact and convenient storage but they must be easily vapourised (low boiling point) to mix with air in the engine prior to ignition. However, the ease of vaporisation due to weak intermolecular forces, does however make them highly flammable ! C10H22 to C16H34 Paraffin and kerosene are bigger molecules, bigger intermolecular forces, so less volatile and flammable. This makes safer to use in domestic heating and jet aircraft fuel, but not as easily ignited. C14H30 to C20H42 Diesel oil is not as volatile, flammable or as easily ignited as petrol due to the higher boiling point and intermolecular forces. However as a vehicle fuel it doesn't have to be vapourised first, the diesel fuel is sprayed into the engine cylinder and mixed with air and ignites under compression from the piston action. C14H30 to C20H42 Fuel oil molecules are getting quite big, higher boiling points, higher intermolecular forces and more viscous, but not too viscous to pump to a ships boiler or locomotive diesel engine. Fuel oil is not very volatile and so not as flammable and dangerous to use as petrol or diesel etc. > C21H44 (typically 36 C atoms, C36H74) Lubricating oil must be quite viscous to stick onto surfaces and are virtually non-volatile due to the even higher intermolecular forces. Smaller molecules might be more runny but they would evaporate away! It is also water repellent and helps reduce corrosion on moving metal parts from factory machines to cars and bicycles. > C21H44 (typically 31 C atoms, C31H64) Candle wax is very convenient as a solid for a humble lamp (especially in power cuts!), but via a wick, the heat from the flame is sufficient to vaporise the hydrocarbons to burn them and give a big enough luminous yellow flame to act as a source of light. At this point in the fractions the intermolecular forces are now sufficient to create solids at room temperature, albeit low melting like candle wax. > C60H122 (many much bigger) Bitumen is a water repellent solid at room temperature but is readily melted (sometimes too easily in hot weather!). Used as base for a road chipping top surface or sometimes directly as the top layer in roads. Bitumen is also used to make waterproof roofing felt. Bitumen consists of the largest molecules in crude oil with the greatest intermolecular forces between them, so they are solid at room temperature and very high boiling up to 700oC. For more products derived from crude oil other than fuels see ... TOP OF PAGE and sub-index 2f. Energy resource evaluation - What makes a good fossil fuel? (some are not quite as bad as others!) It may seem a curious question these days, but its only fair to consider what is the best fossil fuel? but some fossil fuels pollute more than others, and some leave a bigger 'carbon footprint'! Factors that should be taken into consideration - often factors overlap Combustion - burning characteristics (see also toxicity, pollution and climate change): Ease of ignition - how easily does it burn, gas most easy to ignite and control, less so for petrol/diesel and coal the most difficult to ignite and control. Examples described on previous section 2b. on uses. Energy value: e.g. kJ of heat energy released per kg, sometimes referred to as the 'energy density', the bigger the better. See Calorimeter methods of determining energy changes - burning fuels Waste material: Burning hydrocarbons doesn't produce must waste other than the gaseous products, but burning coal produce smoke and large quantities of ash. Availability: Geographical convenience - is it imported?, fluctuations in oil production levels and the market price. The price of oil can vary with market forces determined by the World's economy AND political instability and wars, particularly in the major oil producing Middle-East Arab Gulf states affect the price too. Therefore, without alternative energy resources, we are at the mercy of forces beyond our control. If stocks or production rates fall, the price of crude oil rises and richer countries can afford more costly oil and can stockpile it, developing countries will struggle to compete. In order to preserve our crude oil and gas supplies we sometimes compromise our ideals when dealing with the politics of countries we may think unsuitable. Storage and distribution: Important health and safety issues to consider here e.g. Coal is very dirty but safe to store, difficult to ignite, Natural gas (explosive flammable gas) much more dangerous to store in large tanks under pressure, but the gas is easy and more convenient to distribute via pipes, but gas leaks are potentially VERY dangerous, as you see sometimes on the news! Petrol is quite volatile and the flammable vapour easily ignited. Diesel is not as volatile and central heating oil even less so, but spills of any of these fuels is potentially harmful to the environment or a fire hazard. Again, some specific examples were described in the previous section 2b. Production Costs: Costs of exploration and extraction can be high for oil Coal mines are dangerous to operate, good health and safety policies don't come cheaply, and its the same for operating oilfields and petrochemical complexes - oil refineries. Costs of transporting the fuel. AND even after considering all of these factors, as already mentioned ... ... the market price can fluctuate with market forces and may also depend on political situations too! eg the politics of the Middle East or European countries importing Russian natural gas etc.! Toxicity, Pollution and climate change: Greenhouse effect - which fuel produces the least or most carbon dioxide for the energy released?, methane is one of the best fossil fuels in this respect. The sulphur content of fuel (most removed before fuel used to minimise sulphur dioxide and acid rain formation), some coals are very high in sulfur, but can't be removed from it, though you can clean the smoke by removing the sulfur dioxide using an alkali like calcium hydroxide (limewater). The efficiency of combustion e.g. minimum carbon monoxide and soot levels, again methane is one of the most clean burning fuels. Coal produces a lot of smoke and larger hydrocarbon fuels like oil, tend to burn with a sooty flame. Ease of use: Transferred easily e.g. oil and gas readily piped around and readily ignited for a quick start in power station. Coal is more trouble to transport and does not ignite as easily. Each fossil fuel has a different cost, efficiency and cleanliness on burning. Generally speaking in 'cleanliness' the order is ... methane (natural gas) > alkanes in petrol > heavy oil ... and from left to right there is also an increase in C/H atom ratio in the molecule so more CO2 is produced too. TOP OF PAGE and sub-index 2g. Alternative fuels to fossil fuels - more on other energy resources OIL IS A VALUABLE CHEMICAL RESOURCE but non-renewable Apart from the obvious value of crude oil as an non-renewable energy source, should we using this very valuable source of organic chemicals by merely burning most of it? AND how long will oil reserves last? AND what happens if the oil runs out? Therefore isn't it in our own interest to manage the finite oil reserves remaining and conserve them? AND seek other sources of energy to power our lives? AND perhaps influence the course of global warming? BUT the trouble is, oil is very convenient, readily available, and new reserves are still being found and the oil and gas trapped in deep layers of shale are being exploited, AND it will take time to develop new technologies. The world's population is steadily increasing and countries like China and India have huge energy demands for home and industry, and are pressured into building many fossil fuel power stations, though China is a leading player in large scale wind power projects. It should be noted that liquid fuels like petrol, diesel, central heating oil etc. are east to store and distribute to wherever they are need in homes or factories and they are so readily available, that change may be necessary, but progress will be slow. HYDROGEN - FUEL of the FUTURE?: Hydrogen gas can be used as fuel and a long-term possible alternative to fossil fuels. It burns with a pale blue flame in air reacting with oxygen to be oxidised to form water. hydrogen + oxygen ==> water 2H2(g) + O2(g) ==> 2H2O(l) It is a non-polluting clean fuel since the only combustion product is water and so its use would not lead to all environmental problems associated with burning fossil fuels. It is easily distributed in pipes like natural gas, but there are health and safety issues to do with storage and distribution since it is, like natural gas, highly flammable and explosive. It would be ideal if it could be manufactured by electrolysis of water e.g. using solar voltaic-cells or some kind of but the technology is in its infancy. Hydrogen can be used to power fuel cells see the "Extra Electrochemistry" page Other alternative renewable fuels are discussed on other pages ... whatever, be aware at least that nuclear power, wind turbine power, solar energy, biofuels are all under consideration and being developed and you have a few things to say about each of them. See also Energy resources: general survey & trends, comparing renewables, non-renewables, generating electricity Renewable energy (1) Wind power and solar power, advantages and disadvantages gcse physics notes Renewable energy (2) Hydroelectric power and geothermal power, advantages and disadvantages Renewable energy (3) Wave power and tidal barrage power, advantages and disadvantages gcse physics notes Doc Brown's School Science Website TOP OF PAGE and sub-index GCSE/IGCSE/O Level Oil Products & Organic Chemistry INDEX PAGE ALL my Advanced A Level Organic Chemistry revision notes Multiple Choice Quizzes and Worksheets KS4 Science GCSE/IGCSE m/c QUIZ Oil Products (easier–foundation–level) KS4 Science GCSE/IGCSE m/c QUIZ on Oil Products (harder–higher–level) KS4 Science GCSE/IGCSE m/c QUIZ on other aspects of Organic Chemistry and 3 linked easy Oil Products gap–fill quiz worksheets ALSO gap–fill ('word–fill') exercises originally written for ... ... AQA GCSE Science Useful products from crude oil AND Oil, Hydrocarbons & Cracking etc. ... OCR 21st C GCSE Science Worksheet gap–fill C1.1c Air pollutants etc ... ... Edexcel GCSE Science Crude Oil and its Fractional distillation etc ... ... each set are interlinked, so clicking on one of the above leads to a sequence of several quizzes TOP OF PAGE and sub-index Keywords and phrases: This page describes the separation of useful products from crude oil by the process of fractional distillation, part of the oil refining process in the petrochemical industry. Crude oil provides the starting raw material for making lots of different chemicals for a variety of uses. The uses of the fractions from fractional distillation fuel gas, LPG, refinery gas, gasoline, petrol, naphtha, paraffin, kerosene, diesel oil, gas oil, fuel oil, lubricating oils, wax and bitumen fractions are tabulated and many are non–renewable fuels. The uses of a fraction is related to its physical properties e.g. ease of vaporisation & boiling point or its viscosity ('stickiness') and the dangers of flammability are pointed out too. There is also a discussion on what makes a good fuel and reference to alternative fuels. These notes on fractional distillation of oil and the uses of oil fractions are designed to meet the highest standards of knowledge and understanding required for students/pupils doing GCSE chemistry, IGCSE chemistry, O Level chemistry and KS4 science courses. These revision notes should prove useful for the AQA GCSE chemistry, Edexcel GCSE chemistry & OCR GCSE chemistry (Gateway & 21st Century) GCSE (9–1), (9-5) & (5-1) science courses. Revision notes on fractional distillation of crude oil uses of fractions KS4 Science GCSE/IGCSE/O level Chemistry Information on fractional distillation of crude oil uses of fractions for revising fractional distillation of crude oil uses of fractions for AQA GCSE Science, Edexcel Science chemistry IGCSE Chemistry notes on fractional distillation of crude oil uses of fractions OCR 21st Century Science, OCR Gateway Science notes on fractional distillation of crude oil uses of fractions WJEC gcse science chemistry notes on fractional distillation of crude oil uses of fractions CIE O Level chemistry CIE IGCSE chemistry notes on fractional distillation of crude oil uses of fractions CCEA/CEA gcse science chemistry (help for courses equal to US grade 8, grade 9 grade 10) science chemistry courses revision guides explanation chemical equations for fractional distillation of crude oil uses of fractions educational videos on fractional distillation of crude oil uses of fractions guidebooks for revising fractional distillation of crude oil uses of fractions textbooks on fractional distillation of crude oil uses of fractions explanations of fractional distillation of crude oil uses of fractions what molecules are in crude oil? how do we separate the hydrocarbon molecules in crude oil? how is fractional distillation used to separate the alkanes in crude oil? describe the types of hydrocarbons in crude oil, what do we mean by refining oil? why is the petrochemical industry so important? describe the process of fractional distillation of crude oil, why is a fractionating column used in the distillation of crude oil? describe the properties and uses of the oil fractions refinery gas, LPG, gasoline, petrol, naphtha, paraffin, kerosene, diesel oil, gas oil, fuel oil, lubricating oil, waxes and bitumen, diagrams of the fractional distillation of crude oil, diagrams of oil fraction hydrocarbon molecules, how does viscosity affect the use of an oil fraction? how does intermolecular bond strength affect the properties of hydrocarbon molecules from oil? how do intermolecular forces affect the use of oil fractions? how does the flammability of an oil fraction vary with intermolecular bonding? why do oil fraction molecules vary in boiling point? diagrams of intermolecular forces in oil molecules, diagrams of intermolecular bonding between oil molecules, what makes a good fossil fuel from oil? hw clean do fuels from oil burn? how readily available is a fuel? which fuels from oil are safest to use and distribute? gcse chemistry revision free detailed notes on properties & uses of oil fractions to help revise igcse chemistry igcse chemistry revision notes on properties & uses of oil fractions O level chemistry revision free detailed notes on properties & uses of oil fractions to help revise gcse chemistry free detailed notes on properties & uses of oil fractions to help revise O level chemistry free online website to help revise properties & uses of oil fractions for gcse chemistry free online website to help revise properties & uses of oil fractions for igcse chemistry free online website to help revise O level properties & uses of oil fractions chemistry how to succeed in questions on properties & uses of oil fractions for gcse chemistry how to succeed at igcse chemistry how to succeed at O level chemistry a good website for free questions on properties & uses of oil fractions to help to pass gcse chemistry questions on properties & uses of oil fractions a good website for free help to pass igcse chemistry with revision notes on properties & uses of oil fractions a good website for free help to pass O level chemistry why are smaller hydrocarbon molecules more volatile? why do bigger hydrocarbons have higher boiling points? how the uses of oil fractions related to their physical properties like viscosity and boiling point? TOP OF PAGE and sub-index crude oil and fractional distillation bbc bitesize. crude oil and fractional distillation worksheet answers. crude oil and fractional distillation worksheet. gcse chemistry - crude oil and fractional distillation #45. products of fractional distillation of crude oil and their uses. fractional distillation and cracking of crude oil. fractional distillation of crude oil products and uses. draw and label fractional distillation of crude oil

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