Coal and Petroleum; Fuel, Fad and Fashion

Coal fields

Coal fields in Canada mark regions where swamps bordered shorelines of ancient seas (similar to modern mangrove swamps). Note that the higher coal grades tends to be found closer to mountains where organic-rich sediment has been pressed and cooked more severely.

Formation of coal

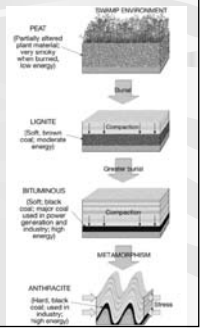
Organic matter derived mostly from land plants accumulates in low-energy environment (like a swamp).

Oxidative decay uses up lots of oxygen, rendering the sediment pore waters devoid of oxygen (anoxic).

Gentle cooking and pressing (lithification) as a result of increasing burial depth remove the pore water and increase carbon content (due to release of volatile components of the organic molecules).

Low grade coal (lignite) cooked very little. High grade coal (anthracite) cooked a lot (close to being a metamorphic rock).

Lower grade coal tends to contain minerals such as pyrite, which formed under the reducing (low-oxygen) conditions.



Uses of Coal

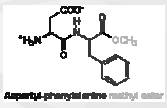
Fuel: Canada does not use as much coal as many other countries do for fuel (due to large hydroelectric and nuclear power developments and small population). However, coal is a very important fuel throughout Asia and remains highly significant in the U.S.A, this country having the largest known coal reserves in the world.

Coke: Bituminous coal that is cooked (charred) to remove nearly all of the remaining volatiles is transformed into a spongy substance called coke (some of the removed gases, e.g. methane, can themselves be used as fuel).

Coke is predominantly burned in blast furnaces to smelt iron from iron ore because it provides the high temperature and gases required for the smelting process (prevents oxidation of the elemental molten iron). It is also used in the production of cement (cooking of limestone and silica).

Byproducts: A number of by-products from processed coal are also useful. These include organic substances used to make some plastics, medicines, and solvents.

Artificial sweeteners such as saccharin and aspartame are also derived from by-products of coal !



Aspartame

Aspartame products

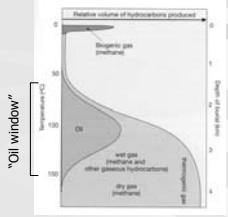
Formation of petroleum (oil and gas)

Oil and gas result from the breakdown of organic molecules (e.g. kerogens) under conditions of increasing temperature, from large complex molecules to smaller, shorter-chain molecules dominated by hydrogen and carbon: a process called "cracking" or "pyrolysis". This occurs largely through the breaking of C-C bonds.

Some gas is produced by decomposition of organic matter by microbes (biogenic gas)

Most oil is produced at temperatures between about 60° and 120° C (the oil window).

Thermogenic gas is produced as oil is broken down to very small molecules (the smallest being methane)



The Oil Window

T below: Organics remain largely unaltered.
T above: Thermal cracking transforms the petoleum into natural gas.

- Oil and natural gas
  - Oil and natural gas, consisting of various hydrocarbon compounds, are produced in a similar manner though are typically derived from different sources of organic remains.
  - Derived from the remains of marine plants and animals (mostly plankton).
  - Oil and natural gas result from the chemical breakdown of these remains in the absence of oxygen, as depth of burial (and therefore temperature) increases.
  - The oxygen and nitrogen in the original organics are driven off, leaving hydrocarbon compounds (compounds of carbon and hydrogen).

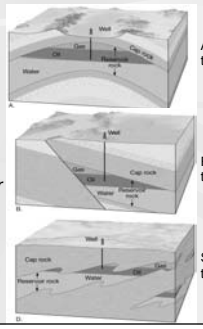
Petroleum Traps

- A geologic environment that allows for economically significant amounts of oil and gas to accumulate underground is termed an oil/petroleum trap
- Oil and gas is contained in a reservoir. A reservoir must be permeable to oil and gas, and contain sufficient interconnected pore space to accommodate the petroleum. Common examples are poorly lithified sandstones, carbonate reefs, diagenetic carbonates.
- The roof of the trap must be made of material that is impermeable to fluids. This is necessary to prevent the upward escape of oil and gas which are much less dense than the surrounding rock.
- Common traps include anticline fold traps, fault-bounded traps (structural traps) as well as various stratigraphic traps.

Oil traps occur in many forms

In all of these cases:

- *oil and gas accumulates in a restricted area and the top of the permeable reservoir rock unit is sealed by an impermeable caprock*



Anticline fold trap

Fault-bounded trap

Stratigraphic trap

Recovery of Oil and Gas

When the cap rock is penetrated by drilling, the oil and natural gas, under pressure, migrate from the pore spaces of the reservoir rock to the drill hole.

Note: world's first commercial oil well was drilled in 1858 at Oil Springs, Ontario (near Sarnia).

Before methods were developed to control the upward flow of oil in wells (e.g. blowout preventers), dangerous gushers took place when pressure was suddenly released from oil traps.

Geographic distribution of oil and gas

Major occurrences of oil and gas on continents mark formerly low-lying regions (basins) that were covered by seas (remember that oil and gas is derived from remains of marine organisms).

Organic matter in these regions were buried under thick deposits of sediments and gently cooked (e.g. Michigan and Appalachian basins in Ontario).

Distillation of crude oil

Oil is extracted from the ground as crude oil.

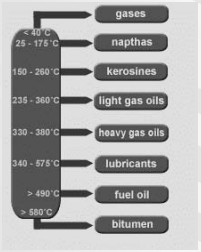
It is then refined in a distillation tower that is divided into a series of collecting trays at different temperature conditions.

The crude oil is boiled to produce vapour.

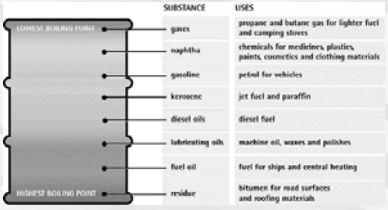
The vapour is allowed to diffuse up the tower to cool and condense at different temperatures (lightest compounds will have lowest boiling temps).

The different components of crude oil can therefore be separated.

Note: the "naptha" fraction is basically gasoline.



Fractions obtained from crude oil



Fractions that condense in each tray are extracted and used for different purposes.

The smallest (lightest; at top) hydrocarbon molecules are used as gases.
Intermediate hydrocarbon molecules are used in liquid form.
Largest (heaviest; at bottom) hydrocarbon molecules as used as solids (e.g. tar).

The Versatility of Petroleum

…But petroleum-derived organic molecules are also used in an incredible number of other products that include:

Solvents, used in paints, lacquers, and printing inks, and cleaners

Lubricating oils and greases for machinery

Petroleum (or paraffin) wax used in candy making, candles, packaging, matches, and polishes

The Versatility of Petroleum

The most obvious use for petroleum is as fuel. In Canada, lots of petroleum is used as fuel for heating, transportation, cooking, and electricity generation.

Petroleum jelly (Vaseline), used in medical products and toiletries

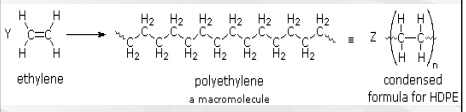
Asphalt, used to pave roads and airfields and to make roofing materials and floor coverings

Plastics and synthetic rubber, used in packaging, casings, fabrics, bubble gum, etc.

…and many more !

Plastics

Plastics are organic polymers (long chains of smaller carbon-based chains that have been linked together).



ethylene — polyethylene, a macromolecule — condensed formula for HDPE

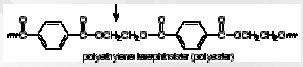
Recycling symbol for High Density Polyethylene (HDPE) commonly used in household plastic items such as milk cartons and liquid laundry detergent bottles.

Linkages of more complex units, cont'd

The plastics that we use are more complex than simple carbon-hydrogen units, but are linked together in the same way.

No, you don't have to remember the chemistry of these molecules – just appreciate the fact that plastic molecules are made of smaller, repeating (structural) units.

Single "ester" unit (monomer)



Linked "ester" units (polymer)

Some desirable qualities of plastics:

- Can be made lightweight or heavy
- Can be very weak or very strong
- Can be moulded into solid pieces or extruded as fibres
- Are excellent insulators
- Various forms range from strong and brittle to weak and elastic
- Waterproof
- Relatively cheap to manufacture

Perhaps most significantly, plastic products can be manufactured to meet very specific "needs" of consumers.

This is because the properties of plastics can be readily modified through the manipulation of chemical components (hence varieties such as nylon, polyester, polyethylene, vinyl, etc....and can be moulded or extruded into a wide variety of forms.

Shatter-proof polyester bottle

Polyester fibre leisure suit

Even at the most trival level, plastics have remained front-and-centre in culture

Major Fads (and year invented):

Silly Putty (1949)

Frisbee (1957)

Hula Hoop (1958)

Super Ball (1965)

Rubik's Cube (1980)

Wacky Wallwalker(1982)

END OF LECTURE