Extracting oil and gas

This volume's 'Focus on industry' columns will explore crude oil and natural gas as raw materials for the chemical industry. We will look at their formation and methods of extraction, and how important hydrocarbons are separated and then processed to produce gaseous and liquid fuels and compounds needed to make a vast number of products, from plastics to medicines. Here, we look at how petroleum is formed and the drilling techniques that are used to extract it

Exam links

This 'Focus on industry' links to the following A-level topics:

- hydrocarbons (alkanes)
- oil and gas extraction
- industrial processes

When we refer to oil as a raw material for the chemical industry, we are usually referring to crude oil, which is a mixture of hydrocarbons. Strictly speaking, we should be using the term 'petroleum', derived from Latin *petra* (meaning rocks) and *oleum* (oil). Petroleum describes not only the mixture of hydrocarbons in crude oil, including the gases and solids that are dissolved in the liquid, but also any free gas, known as natural gas, associated with it.

Petroleum that is worth extracting is usually found trapped in layers of permeable rocks by other layers of impermeable rock, but more recently reserves of gas and oil are being extracted from shale, which is an impermeable rock but is porous in the sense that there are spaces (pores) within its structure in which liquids and gases can be trapped. Extracting gas and oil from shale requires different techniques to those used in extraction from layers of permeable rock.

Formation of gas and oil

Well over 200 different hydrocarbons can be identified in a sample of crude oil. They were formed in remote periods of geological time, anything from 50 to 500 million years ago, from the remains of living organisms. It is, therefore, a *fossil fuel*.

Weathered rock material, eroded from land masses and carried to the sea, accumulated in layers over millions of years in subsiding basins, and the remains of large quantities of marine plant and animal organisms became incorporated in the sediment.

Glossary

Anaerobic A reaction that occurs in the absence of oxygen. Anaerobic organisms live without the need for free oxygen.

Owing to the thickness of the sediments, high pressures built up that, probably in conjunction with biochemical activity, led to the formation of petroleum. The detailed mechanism is obscure, but it is probable that **anaerobic** microbes lowered the oxygen and nitrogen content of what had been living matter.

Subsequent earth movements, which caused uplift of the sedimentary basins, also caused migration of the petroleum through pores in the rocks, sometimes to areas far from where it was formed. In the course of migration, some of the petroleum accumulated in traps where the permeable rock was bounded by impermeable rock. The principal types of trap in oil fields found around the world are the *anticline* (an upfold in the strata) as shown in Figure 1, the *fault trap* (Figure 2) and the *salt dome* (Figure 3).

Drilling and separating

Because the liquid oil and associated gas are trapped, in large amounts, into one area of permeable rock, it is possible to drill vertically into this rock and the oil and gas, under pressure, rises up a pipe to the surface. The gas is separated from the oil and the crude oil is then said to be *stabilised*.

The gas and oil are transported by pipes, either by land to a refinery, or to a ship (tanker). If they are being transported by

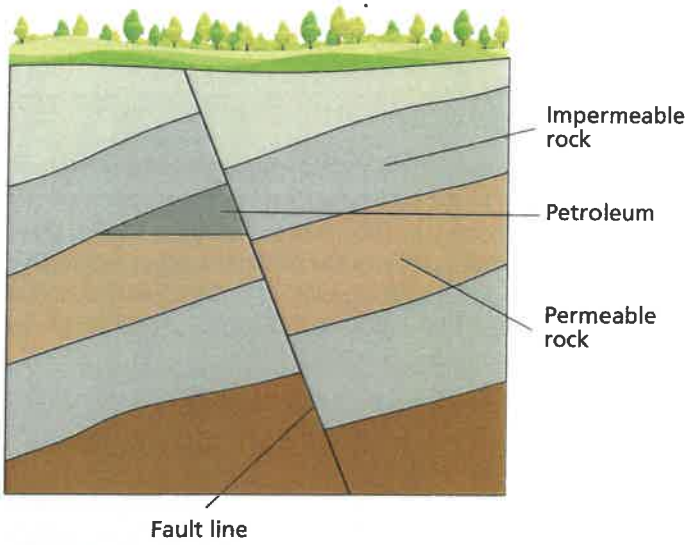


Figure 2 A fault line is the line along which the strata on one side have been displaced and are no longer aligned with the strata on the other side. In the example depicted here a layer of impermeable rock has trapped the petroleum by preventing it migrating further through the layer of permeable rock. This is a fault trap

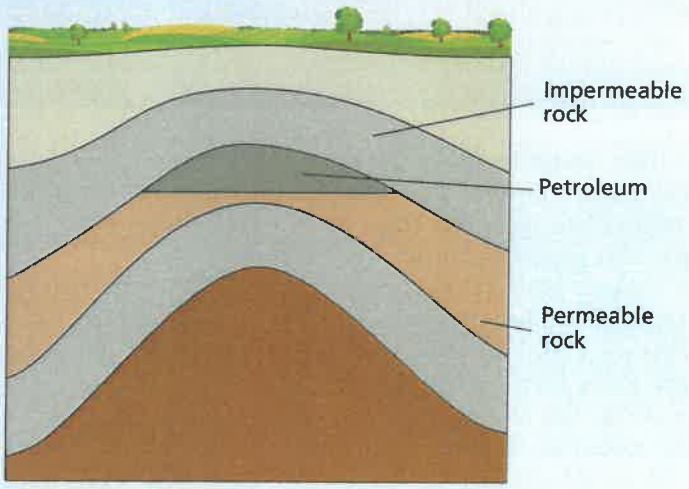


Figure 1 An anticline is where previously flat strata have been bent upwards by earth movements to form an arch. In this case the petroleum has migrated upwards in the permeable rock and become trapped by the overlying impermeable rock

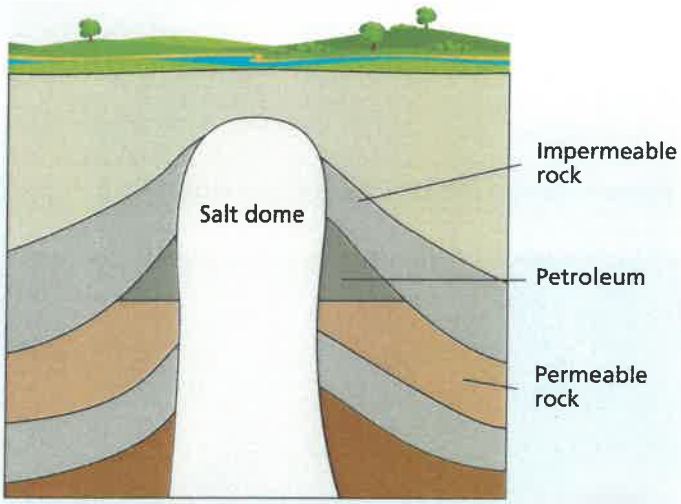


Figure 3 Rock salt, when subjected to heat and pressure, can move slowly upwards over millions of years, forcing its way through the overlying rock strata and so forming a salt dome. In the case shown, petroleum in the layer of permeable rock has become trapped by the overlying impermeable rock and the salt dome

ship, the gas is liquefied before being pumped into the tanker. So that the tankers can readily offload the gas and oil, refineries are built near the coastline.

Composition

The liquid oil contains mainly alkanes (with between five and 125 carbon atoms in the molecules), cycloalkanes and aromatic hydrocarbons (Figure 4). The relative amounts of the three classes of compound vary with the oilfield: alkanes (15–60%), cycloalkanes (30–60%) and aromatics (3–30%), with a residue of very high molecular mass hydrocarbons (e.g. bitumen) making up the remainder.

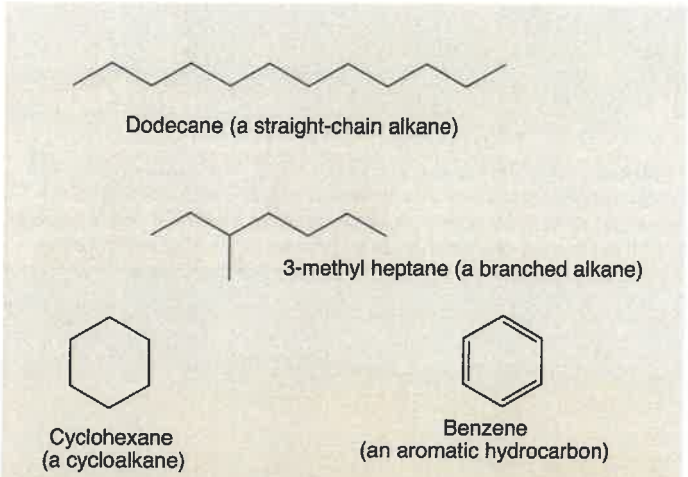
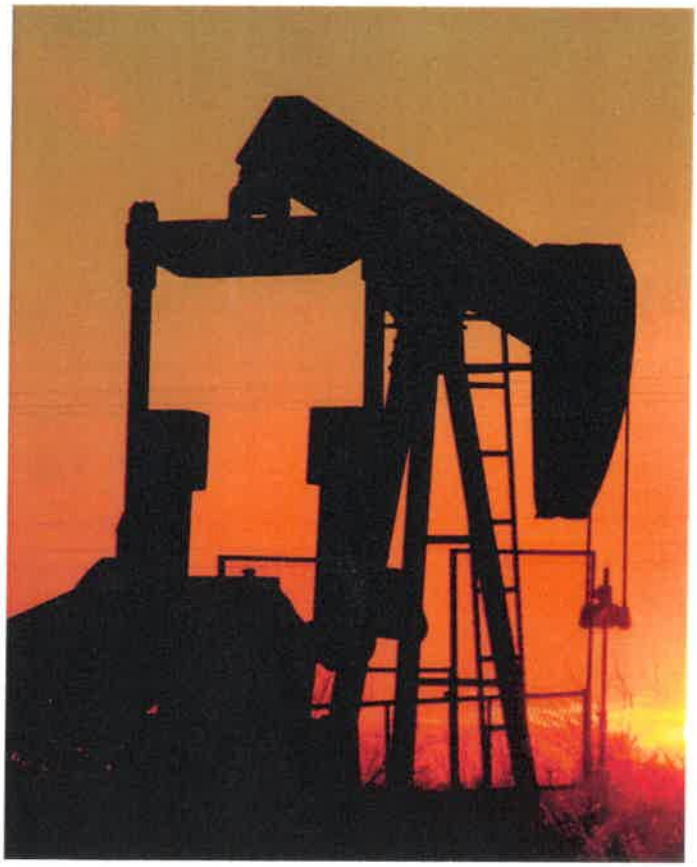
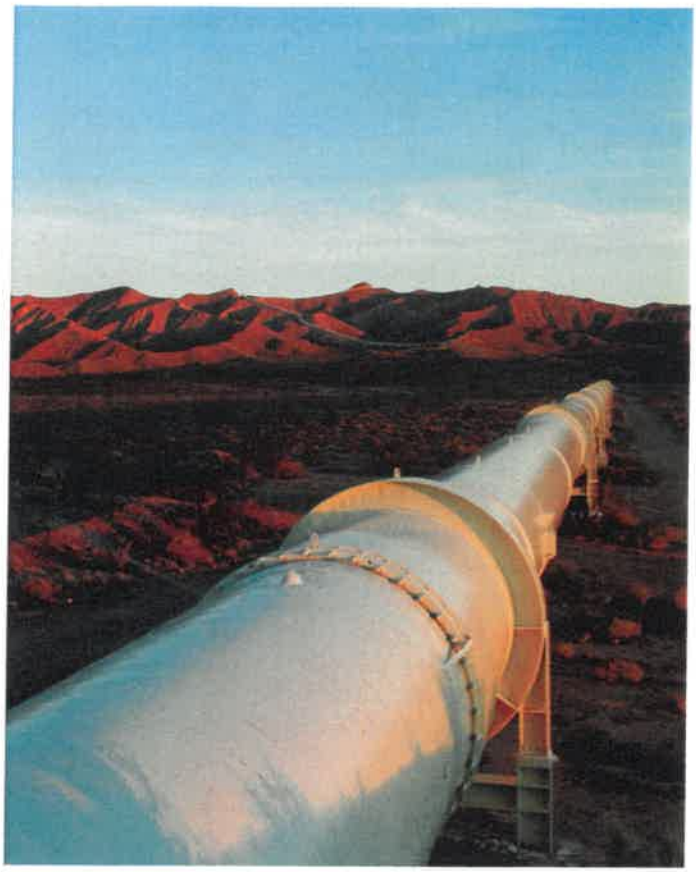


Figure 4 Examples of hydrocarbons found in crude oil





The average length of the carbon chains also varies from field to field. In some areas, there is a preponderance of smaller hydrocarbon molecules (light crude oil). In heavy crude oil, there is a greater proportion of larger molecules.

Natural gas is principally methane (CH_4), with smaller amounts of other alkanes, ethane (C_2H_6), propane (C_3H_8) and butanes (C_4H_{10}). As with liquid oil, the composition of natural gas varies from field to field. In some fields, methane may make up 98% of the gas, and this is known as *dry natural gas*. In *wet natural gas*, as much as 20% of the gas is made up of other alkanes, ethane, propane and butanes. Some natural gas fields, such as in southern France, contain large amounts of hydrogen sulfide (up to 16%), and others, such as in the USA, contain considerable amounts of helium. In some fields, the natural gas contains up to 7% of helium by volume.

Many oilfields are located offshore, which presents additional challenges. Once extracted, the crude oil and gas are delivered to refineries to be separated by distillation into fractions with different boiling points. These fractions undergo further processes (cracking, isomerisation, reforming and alkylation) to form the useful products required by the chemical industry.

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