Early use of gas
From the early 1800s coal gas was used for street lighting in cities such as London, Paris, Dublin and Cork. Later gas was piped to individual consumers, mainly for lighting. Some large houses had their own gas production facilities. New gas-powered devices were developed: heaters, cookers, refrigerators etc. The gas consisted mainly of hydrogen (H2, 50%), methane (CH4, 35%), carbon monoxide (CO, 10%), with small amounts of other gases. It was generally produced by heating coal in the absence of air; the resultant gas was stored in ‘gasometers’. During the mid 1800s other processes were developed to produce combustible gases.

Natural gas
When large deposits of natural gas (up to 99% methane) were found it was considered feasible to pipe it from gas fields (generally off-shore) to major cities. This happened in Britain in the 1960s following the discovery of North Sea gas, and in Ireland in the 1980s following the development of the Kinsale gas field.

The changeover entailed:
- laying high-pressure pipelines over long distances (this was new)
- replacing nozzles in gas cookers and other equipment with ones of larger diameter; natural gas is mostly methane and is denser than coal gas
- conversion of furnaces in power stations, in industry and in private houses
- replacement of older cast iron gas pipes with newer ones made of polyethylene
- the construction of interconnectors to link different gas supplies.

Because of its carbon monoxide content coal gas was poisonous but natural gas is not inherently poisonous. However large gas leaks in an enclosed space could dilute the oxygen in the air to an unsafe level (from 21% to below 18%).

A more serious concern is carbon monoxide poisoning. Appliances burning oil or natural gas need enough air to burn safely. If the oxygen level falls below about 18%, carbon monoxide can be produced along with carbon dioxide (See Safety Rules panel).

Interconnectors and energy security
Energy security is becoming increasingly important throughout the world. The EU is not self-sufficient and in Ireland indigenous gas production currently meets only about 9% of present demand; the remainder is sourced from the North Sea and transported through the UK to Ireland by three subsea interconnectors that link Moffat (Scotland) with Belfast, Gormanston, Co. Meath, and Loughshinny, Co. Dublin. Ireland’s security of supply was enhanced following the completion of the South-North Pipeline from Dublin to Belfast in 2006. This connected the gas networks in Ireland and Northern Ireland for the first time.

Moving gas
Gas can be pumped through pipes or transported by tanker in liquefied form. **Liquefaction** is expensive because of the low temperature involved (-164 °C) and also because trace impurities (such as helium and water vapour) must first be removed to avoid later complications. Transporters must also be equipped with cooling systems. ('Bottled gas' is generally a mixture of propane and butane; it is much denser than methane and so can be more easily liquefied. It can be transported as a liquid at a relatively low pressure – about twice atmospheric pressure – but at normal temperatures.)

Pumping gas at high pressure to centres of population is more economical than transporting by tanker. High-pressure pipelines (6000 kPa or 60 bar) are used for the longer distances and low pressure (400 kPa or 4 bar) for local networks. The inlet pressure to gas-powered consumer equipment is about 3.5 kPa (0.5 psi).

Measuring the rate of flow
The volume of a gas is inversely proportional to the pressure; the greater the pressure the smaller the volume, all else being equal. The volume also varies with the absolute temperature. How then can we express the flow rate of gas? A flow rate of 20 L/s at ten times atmospheric pressure
would be equivalent to 200 L/s at atmospheric pressure. Traditional gas meters, such as those formerly used for town gas, measured the volume of gas passing through them regardless of the pressure or the temperature.

Gas flow can be expressed as energy per unit time ($J/s$) if the energy of combustion is known. For example, 20 L/s of methane at 10 atmospheres is equivalent to 7.86 MJ/s

**Energy value**

The energy derived from the combustion of a pure substance is called its *heat of combustion* or enthalpy of combustion and is expressed in joules per mole (J/mol). For mixtures of substances it is more appropriate to express the energy of combustion in joules per kilogram (J/kg); this quantity is sometimes referred to as its *energy density*. The table shows the energy of combustion (in megajoules per kilogram, MJ/kg) of a number of substances; some foods are included for comparison.

In Ireland most of the natural gas is used for electricity production (69% in 2007); of the rest 17% went to industrial or commercial enterprises and 14% to homes. Although average industrial and domestic consumption fell in 2007 due to milder weather and improved energy efficiency the total amount of gas transported increased by 8% due to the expansion of the gas network and increased use in power generation.

**Environmental sensitivity**

In planning new pipelines Bord Gáis welcomes input from environmental and heritage groups in order to minimise the impact on the environment. An environmental assessment is conducted before the route of the pipeline is finalised; it assesses the potential positive and negative effects of the work on the environment.

**AGI (Above Ground Installation)**

Bord Gáis Networks manages low pressure networks within towns and cities. Before gas is delivered to end users, the pressure is reduced at above ground installation stations (AGIs). Gas is distributed to towns and cities in yellow polyethylene pipes; these are replacing the older cast iron pipes.

**Archaeological**

In 2002 Bord Gáis, in consultation with the Department of Arts, Heritage, Gaeltacht and the Islands, developed an environmental code of practice to safeguard archaeological heritage whilst facilitating Bord Gáis providing new gas supplies. The code of practice sets guidelines for dealing with environmental and archaeological issues that arise during pipeline construction.

**Land reinstatement**

Bord Gáis has an agricultural liaison team to deal with landowners and land reinstatement. All land traversed by pipelines is returned to its original state following installation. This involves levelling subsoil, spreading topsoil, tilling topsoil, re-sowing grass, reinstating fences, hedges and stone walls. The agriculture liaison team monitor the quality of land reinstatement throughout the project.

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Energy Value (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>143</td>
</tr>
<tr>
<td>Natural gas</td>
<td>55</td>
</tr>
<tr>
<td>LPG (propane / butane)</td>
<td>34</td>
</tr>
<tr>
<td>Coal (good quality)</td>
<td>33</td>
</tr>
<tr>
<td>Fat</td>
<td>38</td>
</tr>
<tr>
<td>Sugar or dry carbohydrate</td>
<td>16</td>
</tr>
</tbody>
</table>

Fig. 5 Energy values of fuels and foods (MJ/kg)

**Safety rules**

Using a gas appliance in an enclosed space decreases the oxygen concentration and increases the carbon dioxide concentration. Combustion may then be incomplete and carbon monoxide (CO) may be produced. CO poisoning is dangerous and can be fatal. Ensure adequate ventilation where gas appliances are used.

If you smell gas at home:
- Ensure gas appliances haven’t been left on and unlit.
- Do not smoke or use a naked flame.
- Do not unplug or switch anything electrical on or off.
- Open windows and doors to let the gas disperse.
- Call the 24-hour Emergency Service 1850 20 50 50 or dial 999.

If you smell gas on the street:
- Call the 24-hour emergency service 1850 20 50 50 or dial 999.
- Don’t assume someone else has reported the smell.

Bord Gáis is a leading energy supplier of gas and electricity to over 600,000 industrial, commercial and residential customers on the island of Ireland. Bord Gáis currently employs over 900 people, 38% of whom work in engineering and technical roles.

The company has developed one of Europe’s most modern energy networks and is expanding beyond its core gas business into other areas such as electricity and renewable energy. Bord Gáis was established in 1976 following the discovery of natural gas off the south coast of Ireland. It is owned by the Government of Ireland.

The company has two main businesses: Bord Gáis Networks which constructs and extends the natural gas network and connects all customers to the network and Bord Gáis Energy Supply which sells gas and electricity to customers.

For further information visit [www.bordgais.ie](http://www.bordgais.ie)
Hydrogen.

The changeover entailed:

A more serious concern is carbon monoxide poisoning. Appliances piped to individual consumers, mainly for lighting. Some large refrigerators etc. The gas consisted mainly of methane, although quite high concentrations of carbon dioxide were present. This was because of the natural gas, and other equipment with ones connected at the gas station. The gas was further cleaned of contaminants and impurities before reaching consumers.

Students should study:

3.2 Gas Laws

Boyle’s law

PV = constant (p. 52)

Leaving Certificate Chemistry

3.1 States of Matter

Motion of particles in solids, liquids and gases.

3.2 Gas Laws

Boyle’s law

PV = constant (p. 52)

Leaving Certificate Technology

Resource Management

• the economic use of resources
• recognise the need for economic and sustainable use of energy and materials (including recycling), and take account of time and other factors

Leaving Certificate Geography

4.5 Environmental impact

Statement: Economic activities have an environmental impact.

Students should study:

• the use of renewable and non-renewable resources in the economy
• the impact of the burning of fossil fuels and the use of alternative energy sources
• environmental pollution at a local, national and global scale
• sustainable economic development so as to control its environmental impact. Students should examine past experiences, future prospects and the necessity for environmental impact studies
• conflicts that may develop between local and global economic interests and environmental interests. Students should be familiar with the issues relating to at least two examples.

General Learning Points

• Gas was originally produced by heating coal in the absence of air and it was stored in ‘gasometers’.
• Once large quantities of natural gas were found it was then pumped to major cities. Pipes were changed from cast iron to polyethylene. Interconnectors were constructed to connect different gas supplies.
• Coal gas was poisonous due to its large carbon monoxide content whereas natural gas is not inherently poisonous.
• Gas can be liquefied but it is an expensive process; because low temperatures are involved impurities must be removed.
• ‘Bottled gas’ is a mixture of propane and butane; it is denser than air and is much more easily liquefied than methane.
• High pressure gas pipelines are used for longer distances whereas low pressure is used for local networks.
• The volume of gas is inversely proportional to the pressure – the greater the pressure the smaller the volume. The volume also varies in proportion to the absolute temperature.
• Ultrasonic gas flow meters measure the flow rate as mass per unit time (kg/s). If the energy of combustion is known this can be expressed as energy per unit time in joules per second (J/s).
• The energy derived from the combustion of a pure substance is called its heat of combustion and is expressed in joules per mole (J/mol).

Student Activities

1. When carbon compounds are burned the carbon content is generally oxidised to carbon dioxide. What circumstances would favour the formation of carbon monoxide as well as carbon dioxide?

2. Draw up a safety awareness campaign for the general public outlining the risks of carbon monoxide poisoning.

3. What precautions should be taken when using gas-fired equipment?

True/False Questions

a) Polyethylene is a polymer of methane. T F

b) All land traversed by pipelines is returned to its original state following installation. T F

c) Liquefaction of gases is used to remove impurities. T F

d) The volume of a gas is inversely proportional to its pressure. T F

e) Heat of combustion is expressed in moles per joule (mol·J). T F

f) Mercaptans are added to natural gas so that it remains in a gaseous form. T F

g) Natural gas, which is mostly methane, is denser than coal gas. T F

h) ‘Bottled gas’ is a mixture of propane and butane. T F

Check your answers to these questions on www.sta.ie
Learning Outcomes

Students should study:

- Environmental Impact Statement: Economic activities have an impact on the environment.
- Resource Management: The economic use of resources.
- Hydrocarbons: The economic use of energy sources.

The appropriate syllabus references are:

- understanding why the volume of gas per second does not fully describe how natural gas was piped from gas fields to major cities.
- the economic use of resources.
- conflicts that may develop between local and global economic activities.
- environmental pollution at a local/national and global scale.
- energy sources.

True/False Questions

- Natural gas is the most environmentally friendly fossil fuel; burning gas produces less sulphur, carbon and nitrogen compounds than burning any other fossil fuel.
- The largest natural gas field is South Pars which is shared between Iran and Qatar.
- Scientists are investigating new ways to obtain natural gas from biomass – a fuel source derived from plant and animal waste rather than from food crops. Shallow wells have been drilled into landfills to recover methane gas.
- Aquatic animals can also convert biomass into methane gas; in the future huge kelp farms could produce renewable gas supplies.
- Algal fuels are being investigated at present and appear to have greater potential than first generation biofuels.
- The natural gas pipeline network in Ireland currently measures 12,375km and includes Transmission (high-pressure) and Distribution (low-pressure) pipelines with 3 sub-sea interconnectors linking the island of Ireland with Scotland. The Bord Gáis network serves over 140 population centres in 19 counties in Ireland. The Bord Gáis pipeline network is monitored 24 hours a day, 365 days a year and involves constant monitoring of gas flows and system pressures.

Examination Questions

Leaving Certificate Chemistry 2003 Higher Level

- Define heat of combustion.
- Propane may be used in gas cylinders for cooking appliances.
- Propane burns according to the equation

\[ \text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O} \]

(i) The heats of formation of propane, carbon dioxide and water are -104, -394 and -286 kJ mol\(^{-1}\) respectively.
- Calculate the heat of combustion of propane.
(ii) If 500 kJ of energy are needed to boil a kettle of water what mass of propane gas must be burned to generate this amount of heat?
- Express your answer to the nearest gram.

Leaving Certificate Chemistry 2003 Higher Level

- The following hydrocarbons can all be used as fuels.
- Methane (\(\text{CH}_4\)), butane (\(\text{C}_4\text{H}_{10}\)), 2, 2, 4-trimethylpentane (\(\text{C}_{10}\text{H}_{22}\))

(a) Butane is a major component of LPG. What do the letters LPG stand for?
- Draw two structural isomers of butane.
(b) Methane is a major component of natural gas.
- Why are mercaptans often added to natural gas?
- What environmental change or effect is associated with the release of methane to the atmosphere?
- Apart from leaking gas pipes, name a major source from which methane is released to the atmosphere.
(c) What structural feature of 2, 2, 4-trimethylpentane results in it having a high octane rating?
- Give one other structural feature which increases the octane number of a hydrocarbon.
(d) Define heat of combustion of a compound.
(e) The combustion of butane is described by the following balanced equation.

\[ 2\text{C}_4\text{H}_{10(g)} + 13\text{O}_2(g) \rightarrow 8\text{CO}_2(g) + 10\text{H}_2\text{O(l)} \]

- Calculate the heat of combustion of butane given that the heats of formation of butane, carbon dioxide and water are -125, -394 and -286 kJ mol\(^{-1}\), respectively.

For further examples of past questions check www.sta.ie

Did You Know?

- As early as 200 BC people in China piped natural gas from shallow wells and burned it under large pans to evaporate seawater from salt.
- Religious temples in early Russia were built around sites where burning natural gas seepages formed ‘eternal flames’.
- The development of the Bunsen burner by Robert Bunsen in 1885 led to the use of natural gas as a source for heating and cooking.

Biographical Notes

Robert Wilhelm Eberhard Bunsen (1811 – 1899)

Robert Bunsen was a German chemist who worked on emission spectra of heated elements. Along with Gustav Kirchoff he discovered rubidium and caesium. When he was hired by the University of Heidelberg in 1852 he was promised a new laboratory building. The new lab. was to be supplied with illuminating gas. Bunsen had been unhappy with the previous laboratory lamps due to the quality of the flame so he decided to design his own burner that would maximize the temperature and minimize the luminosity. While the lab was under construction Bunsen suggested certain design principles to the university’s mechanic Peter Desaga, and asked him to construct a prototype. The Bunsen/Desaga prototype succeeded in generating a hot, non-luminous, sootless flame by mixing the gas with air in a controlled fashion before combustion. Slits for air, were created at the bottom of the cylindrical burner, which could be opened or closed depending on what type of flame was required. By the time the new laboratory was finished Desaga had made fifty of the burners for Bunsen’s students. The burner was called the ‘Bunsen Burner’. Bunsen published a description of it two years later and many of his colleagues adopted the design.

Revise the Terms

Can you recall the meaning of the following words?

- absolute temperature
- atmospheric pressure
- bar
- butane
- carbon monoxide
- coal gas
- combustion
- energy density
- energy security
- heat of combustion
- hydrogen
- inversely proportional
- joule
- kPa
- liquefaction
- helium
- methane
- mole
- nozzle
- polyethylene
- pressure
- propane
- psi
- ultrasonic
- volume

Check the Glossary of Terms for this lesson at www.sta.ie