C1a 1.1 Limestone
- Limestone consists mainly of calcium carbonate \((\text{CaCO}_3)\).
- Limestone can be used to create glass, cement and concrete.
- When we heat limestone strongly, it breaks down to form quicklime or calcium oxide \((\text{CaO})\). This is called thermal decomposition and it also produces carbon dioxide:
  \[
  \text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2
  \]

C1a 1.2 Quicklime and Slaked Lime
- When we add water to quicklime we get slaked lime or calcium hydroxide, written as \(\text{Ca(OH)}_2\):
  \[
  \text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2
  \]
- The above reaction is **exothermic**, as it gives out heat.
- We can dissolve calcium hydroxide in water in small amounts, and after filtering it, produce lime water. When carbon dioxide is bubbled through clear lime water, it will turn cloudy, because calcium carbonate has formed:
  \[
  \text{Ca(OH)}_2 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O}
  \]

C1a 1.3 Cement, Concrete and Glass
- Heating limestone with clay in a kiln produces cement.
- Limestone which is heated with clay and other minerals produces Portland cement which is ground into a fine powder. This solution is mixed with sand and water so it can be used as a building material which will set when left for a few days.
- Adding crushed rock to the mixture of cement, sand and water makes concrete.
- This stone-like building material can be poured around metal rods or bars, and allowing it to set forms reinforced concrete.
- When powdered limestone is heated with sand and soda (sodium carbonate), it forms glass.
C1a 2.1 Extracting Metals

- Metals are found in the Earth’s crust, and most of them are combined with other elements, usually oxygen, so they must be chemically separated from their compounds.
- A rock containing a reasonable amount of a metal is a metal ore.
- Some metals are so unreactive that they do not combine with other elements (e.g. gold, silver, platinum) and so are found in their native state.
- The way in which we extract metals depends on its place in the reactivity series.
  - A more reactive metal will displace a less reactive metal from its compound in general.
  - Carbon (a non-metal) will also displace a less reactive metal from its oxide.
  - We use carbon to extract metals from their ores commercially.
- Many metals are found in their metal oxide form, like copper, lead and zinc. Because carbon is more reactive than these metals, we can use it to extract them from their ores.
- When you heat the metal oxide with the carbon, the carbon removes the oxygen to form carbon dioxide, leaving the pure element behind:
  
  \[ \text{metal oxide} + \text{carbon} \rightarrow \text{metal} + \text{carbon dioxide} \]
  
  e.g.  lead oxide + carbon  \( \rightarrow \)  lead + carbon dioxide  
  \[ 2\text{PbO} + \text{C} \rightarrow 2\text{Pb} + \text{CO}_2 \]
- We call the removal of oxygen this way a reduction reaction.

C1a 2.2 Extracting Iron – The Blast Furnace

- Iron is the second most common ore in the crust, and iron ore contains oxygen. As iron is less reactive than carbon, we can remove oxygen from the ore using carbon.
- We extract iron using a blast furnace.
- In the blast furnace, we enter three substances:
  - haematite, which is the most common iron ore, containing mostly iron(III) oxide and some sand – written as \( \text{Fe}_2\text{O}_3 \).
  - a substance made from coal which is almost pure carbon called coke.
  - and limestone.
- Hot air is blown into the furnace, making the furnace heat up, forming carbon dioxide as the coke reacts with the oxygen:
  
  \[ \text{C} + \text{O}_2 \rightarrow \text{CO}_2 \]
- The carbon dioxide reacts with the coke a second time, forming carbon monoxide:
  
  \[ \text{CO}_2 + \text{C} \rightarrow 2\text{CO} \]
• The carbon monoxide reacts with the iron oxide, removing its oxygen and reducing it to molten iron, which flows out of the bottom of the furnace

\[
\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2
\]

**C1a 2.3 Iron and Steels**
- The iron produced by the blast furnace is only about 96% iron, and is called *pig iron*
- Pig iron contains carbon, but we can treat it to remove this carbon
- Removing all the carbon and other impurities makes pure iron, which is soft and bendy, and not that useful, so to make sure it is really useful, we ensure it has tiny amounts of other elements in it, including carbon and certain metals
- We call a metal containing other elements an *alloy*
- We call iron which has had other elements alloyed to it a *steel*
- There are many different steels, the most common of which being *carbon steels*, containing from 0.03% to 1.50% carbon. Carbon steels are the cheapest steels to make and can be used for a variety of things, including car bodies and building
- **Low-alloy steels** contain 1% - 5% of many other elements, and are more expensive than carbon steels
- **High-alloy steels** contain between 12% and 15% of other elements, and are even more expensive to make. An example of a high-alloy steel is chromium-nickel steel, more commonly known as *stainless steel*, often used for cooking utensils and cutlery

**C1a 2.4 Alloys**
- Copper is a useful metal which we have used for thousands of years
- *Bronze*, probably the first alloy made, is formed by alloying copper with tin – but we can also add a range of other elements to give the bronze different properties
- More workable than bronze is *brass*, made by alloying copper with zinc
- Aluminium is a metal with over 300 alloys, as it can be alloyed with many elements
- If we bend (or *deform*) alloys and heat them, some will return to their original shape. These *shape memory alloys* (or SMAs) are examples of *smart alloys*

**C1a 2.5 Aluminium and Titanium**
- Aluminium is a metal with many uses. Some of its most useful properties are that it is a reactive metal, but it does not corrode easily
- The most common aluminium ore is named *bauxite*, and it is mined using *open-cast mining*
- Because carbon is less reactive than aluminium, carbon will not reduce aluminium oxide to aluminium, but instead we need to use *electrolysis*
- Electrolysis requires a lot of electricity. The aluminium oxide must be in *liquid form*, so high temperatures are needed. During the process, aluminium forms at the *negative electrode* and the oxygen forms at the *positive electrode*. The oxygen reacts with the carbon electrode and lots of carbon dioxide (and some carbon monoxide) are formed. The aluminium is released from the electrolysis cell as a liquid
C1a 3.1 Crude Oil
- Crude oil is made of many different chemical compounds
- Crude oil contains hydrocarbons, which are compounds of carbon and hydrogen atoms only
- Hydrocarbons which are saturated are called alkanes. Being saturated means they have as much hydrogen in their molecules as possible
- The main alkanes are:

\[
C_nH_{2n+2}
\]
- This means that for every carbon atom there is \( n \) – there are twice as many hydrogen atoms plus two more – \( 2n + 2 \)

C1a 3.2 Fractional Distillation
- We can separate crude oil using fractional distillation
- The chains of hydrocarbons vary in size, and differently-sized hydrocarbon chains have different properties, as shown in the table on the following page
- We separate crude oil into fractions, which are groups of hydrocarbons with similar properties
- Each fraction of hydrocarbon molecules contains hydrocarbons with similar amounts of carbon atoms, each of these fractions boil at different temperatures because of the number of carbon atoms per molecule
- Crude oil is fed into the bottom of the fractioning column as hot vapour. The tower is kept at high temperatures at the bottom and is cooler at the top, so the column decreases in temperature as you go up the column
- These different gases condense when they reach their boiling points, and the different fractions are collected at different levels
- Hydrocarbons with the smallest molecules have the lowest boiling points, and are collected at the top of the tower. At the bottom, fractions have high boiling points, they cool to form thick liquids or solids at room temperature
C1a 3.3 Cleaner Fuels
- Burning hydrocarbons releases substances such as carbon dioxide into the atmosphere.
- Some substances dissolve in droplets of water and fall as acid rain.
- Carbon dioxide released by burning fuels is a greenhouse gas which reduces the rate at which energy is lost from the surface of the Earth by radiation.
- We can use cleaner fuels which don’t release any or as many greenhouse gases, e.g. gasohol.

C1b Cracking Hydrocarbons
- We can break down hydrocarbons in a process called cracking.
- Cracking is normally carried out at high temperatures using a catalyst. This is known as catalytic cracking.
- Catalytic cracking takes place in a cat cracker:
  - The fraction produced from crude oil is heated to form a gas.
  - The hydrocarbon gas is passed over a hot catalyst where thermal decomposition takes place.
  - The larger molecules split apart to form smaller molecules, which are more useful.
• Here is an example of cracking:

\[
\text{C}_{10}\text{H}_{22} \xrightarrow{800^\circ\text{C} + \text{catalyst}} \text{C}_{2}\text{H}_{12} + \text{C}_{3}\text{H}_{6} + \text{C}_{2}\text{H}_{4}
\]

(decane) (pentane) (propene) (ethene)

- Some hydrocarbons are **unsaturated** because they have carbon=carbon **double bonds**. These are called **alkenes**.
- The main alkenes are shown in the diagram to the left.

C1b 4.2 Polymers

- We can make chemicals from crude oil which we use to make **plastics**.
- Plastics are made from huge molecules, which consist of many smaller molecules joined together. The small molecules are **monomers**, and the larger molecules are called **polymers**.
- We are able to make many different plastics which all have different properties.
- Ethene (\(\text{C}_2\text{H}_4\)) is the smallest unsaturated hydrocarbon molecule, which we can turn into a polymer known as poly(ethene) or polythene.
- Propene (\(\text{C}_3\text{H}_6\)), another alkene can be used to form the polymer poly(propene) or polypropylene.
- Monomers join together when the double bonds in the alkenes ‘open up’ and are replaced by single bonds of thousands of other molecules joining together.
- This reaction is an **addition reaction**, and since a polymer is made, we call it **addition polymerisation**.
C1b 4.3  Plastics

- The atoms in polymer chains are very strong, but the size of the forces between the molecules differs for different plastics. We call these forces between molecules intermolecular forces, and the size of them depends on:
  - the monomer used
  - the conditions we choose to carry out polymerisation
- In some plastics, the intermolecular forces waken when heated, and the bonds become strong again when cooled. Plastics which behave in this way are thermosoftening plastics
- Poly(ethene), poly(propene) and poly(chloroethene) [or polyvinylchloride / PVC for short] are all thermosoftening plastics
- Some bonds are made to be so strong when formed that they cannot be softened. Plastics like this are useful for things such as kettles, and are called thermosetting plastics

C1b 5  Vegetable Oils

5.1  EXTRACTION OF PLANT OILS
5.2  COOKING WITH VEGETABLE OILS
5.3  EVERYDAY EMULSIONS
5.4  WHAT SUBSTANCES ARE ADDED TO OUR FOOD?

C1b 5.1  Extraction of Plant Oils

- We can use distillation or pressing to extract vegetable oils
- Distillation involves boiling the plant and condensing the evaporated oils released and removing water and other impurities
- All vegetable oils have chains of carbon atoms with hydrogen atoms attached
- Some vegetable oils have carbon=carbon double bonds. These are unsaturated oils
- We can test for unsaturated oils using either bromine water or iodine solution:
  - Originally, bromine water is orange/yellow, but will turn colourless if it meets an unsaturated vegetable oil
  - Originally, iodine solution is red/violet, but will turn colourless also
  - unsaturated oils + bromine water → colourless solution
  - unsaturated oils + iodine solution → colourless solution

C1b 5.2  Cooking with Vegetable Oils

- Vegetable oils are useful in cooking because:
  - they have a high boiling point, and so foods can be cooked in them at very high temperatures
  - they allow food to absorb the oils, increasing their energy content
- Vegetable oils can be hardened where they are reacted with hydrogen to increase their melting and boiling points
- To make oils harden, you must use a nickel catalyst and carry it out at around 60°C
- Oils that have been treated this way are called hydrogenated oils. Because they are solids at room temperature, it means they can be made into spreads (e.g. butter and margarine for bread, etc)
**C1b 5.3 Everyday Emulsions**

- Oils do not naturally dissolve or mix with water
- Oils can be used to produce **emulsions** which have special properties
- **Emulsifiers** do not dissolve oils in water, they simply mix smaller droplets of oil in the water
- Emulsions made from vegetable oils can be used in foods such as salad dressings and ice creams

**C1b 5.4 What Substances are Added to our Foods?**

- We use **food additives** to improve the features of our foods
- Approved European food additives are allocated **E-numbers**
- The different E-numbers are:

<table>
<thead>
<tr>
<th>Additive</th>
<th>Purpose</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1… Colours</td>
<td>Improves the appearance of foods</td>
<td>E150 – caramel</td>
</tr>
<tr>
<td>E2… Preserves</td>
<td>Helps to keep the foods’ lives last longer</td>
<td>E211 – sodium benzoate</td>
</tr>
<tr>
<td>E3… Antioxidants</td>
<td>Stops foods from reacting with oxygen</td>
<td>E300 – vitamin C</td>
</tr>
<tr>
<td>E4… Emulsifiers, Stabilisers and Thickeners</td>
<td>Helps to improve the texture of the food</td>
<td>E440 – pectin</td>
</tr>
<tr>
<td>E5… Acidity Regulators</td>
<td>Helps to control the food’s pH</td>
<td>E501 – potassium carbonate</td>
</tr>
<tr>
<td>E6… Flavourings</td>
<td>Helps to improve the taste of the food</td>
<td>E621 – sodium glutamene</td>
</tr>
</tbody>
</table>

- We can detect unknown food additives using **chromatography**, by comparing their **chromatograms** against those of substances we already know
- We can also use a **mass spectrometer**

**C1b 6 Planet Earth**

6.1 THE STRUCTURE OF THE EARTH
6.2 THE CHANGING WORLD
6.3 THE EARTH’S ATMOSPHERE IN THE PAST
6.4 THE EARTH’S ATMOSPHERE TODAY
6.5 THE CARBON CYCLE

**C1b 6.1 The Structure of the Earth**

- The Earth is made up of layers that formed millions of years ago, when heavy material sank to the centre of our planet, and lighter material floated up to the top
- The crust and the uppermost part of the mantle make up the Earth’s **lithosphere**
- The **crust** is the outermost layer, ranging from about 6km under oceans to 35km under continents.
- The **mantle**, found under the crust behaves like a solid but is able to flow very slowly.
- The **core** is made up of two parts: the outer core and the inner core. They are both made of nickel and iron and the outer core is a liquid whilst the inner core is a solid.

**C1b 6.2 The Changing World**
- The supercontinent **Pangaea** is believed to have existed until 250 million years ago.
- Around 100 million years ago, Pangaea split into two vast continents: **Laurasia** and **Gondwanaland** were formed.
- 50 million years ago, and the continents as we know them today had formed, and carried on drifting apart.
- These land masses move because the lithosphere is cracked into a number of large pieces called **tectonic plates**.
- It is due to **convection currents** which push these plates over the Earth’s surface that the plates move a few centimetres each year.
- Convection currents are there because radioactive decay causes vast amounts of energy to be produced. This heats up molten minerals in the mantle which expand. They become less dense and rise towards the surface and are replaced by cooler material.
- When tectonic plates meet, **earthquakes** and **volcanoes** can happen.

**C1b 6.3 The Earth’s Atmosphere in the Past**
- The early atmosphere was compressed into large amounts of carbon dioxide, water vapour, methane and ammonia (NH₃).
- When the Earth’s surface cooled below 100°C, the steam condensed to form oceans.
- As the oceans absorbed the carbon dioxide, the carbon dioxide concentration in the atmosphere fell dramatically.
- 3000 million years ago, simple plant life developed and by photosynthesis happening, the carbon dioxide concentration further dropped and oxygen produced.
- In the absence of air, temperatures that were about combined with the pressure formed fossil fuels, further reducing the carbon dioxide concentration.
- Shell formations in the oceans reduced carbon dioxide levels even more.
- Ammonia was removed via nitrification of bacteria (as they evolved), turning ammonia into nitrates.
- Denitrifying of bacteria turned the nitrates into nitrogen.
- Oxygen and ammonia also reacted to form water vapour and nitrogen:
  \[
  \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \\
  4\text{NH}_3 + 3\text{O}_2 \rightarrow 2\text{N}_2 + 6\text{H}_2\text{O} 
  \]

**C1b 6.4 The Earth’s Atmosphere Today**
- The atmosphere on our planet is roughly the same as it was 200 million years ago:
  - 78% nitrogen
  - 21% oxygen
  - 0.9% argon
  - 0.04% carbon dioxide
  - trace amounts of other gases
C1b 6.5 The Carbon Cycle

- The carbon cycle shows how carbon rotates between the rocks, the oceans, and the atmosphere.
- The oceans absorb excess carbon dioxide and produce it when it is needed – making them useful carbon dioxide ‘reservoirs’.
- Plants also take in carbon dioxide during the process of photosynthesis.
- Therefore, plants and the oceans play good carbon dioxide sinks.
- Carbon dioxide is released back into the atmosphere when animals and plants respire, as well as when dead animal bodies decompose.