The Second Law of — What?

Contents: Reading and questions explaining very simply the ideas behind the Second Law of Thermodynamics and relating them to everyday problems such as pollution and the provision of energy.

Time: 2 periods. Could be used for homework.

Intended use: GCSE Chemistry, Physics, Biology and Integrated Science. Links with work on diffusion, fuels, energy sources, electricity generation and photosynthesis.

Aims:

- To complement work on energy supply
- To develop a simple understanding of the idea of the inevitable spreading out of matter and energy as the origin of all change
- To develop awareness of some of the fundamental problems involved in pollution control
- To develop awareness of the fundamental limiting problems of energy supply, the need for conservation of fossil fuels and the potential and limitations of alternative energy sources
- To provide opportunities to practise skills in reading and comprehension.

Requirements: Students' worksheets No. 308

The Second Law of Thermodynamics is not (yet) part of any GCSE science syllabus, but the principles it embodies are so relevant to the world and its problems that every citizen can benefit from an awareness of them. There is of course no intention here of formalizing the law, which is simply stated in terms of 'spreading out' of matter and energy.

The term 'entropy' is not used anywhere in the unit, though the teacher might want to introduce it, simply as a measure of how spread out energy is. Able students might be interested in exploring the idea of the 'energy crisis' further. How can there be an energy crisis, when the Law of Conservation of Energy says we can never use it up? Perhaps 'entropy crisis' might be a more appropriate term.

Further resources

The following SATIS units are relevant to this topic:

107 *Ashton Island — a problem in renewable energy*
201 *Energy from Biomass*
301 *Air Pollution — where does it come from?*
403 *Britain's Energy Sources.*

A range of resource materials and information relating to alternative energy sources is obtainable from Earthscan. Catalogue from: Earthscan, 3 Endsleigh Street, London WC1H ODD.

The major oil companies produce a wide range of resource materials relating to energy supply. A particularly useful film is 'Time for Energy' from Shell, which looks at the problem of future energy supply, conservation and alternative sources. Available as film or video, on free loan from: Shell Film Library, 25 The Burroughs, Hendon, London NW4 4AT.

Acknowledgement Figure 4 supplied by the Intermediate Technology Development Group.

THE SECOND LAW OF — WHAT?

Everything spreads out

Why does sugar dissolve in water? Why does a cup of tea cool — but never freeze? Why is pollution such a problem? Why do we have an energy problem? In this unit we will be looking for an answer to all these questions.

The answers can be traced to a simple rule:

Everything in nature tends to spread out

You are probably familiar with the idea of 'spreading out', or *diffusion*, as it is also called. Answer questions 1 and 2.

Questions

1 *What are the three states of matter?*

2 *Which state spreads out most easily? Which spreads out least easily?*

Gases spread out easily because their molecules move freely. Molecules do not care where they go. Moving around at random, they spread out to fill whatever space is available.

In a solid, on the other hand, the molecules cannot spread out. They are held back by bonds. But solids can spread out if they are turned to liquid or gas by heating. Solids also spread out when they dissolve in liquids. Drying washing is another example of spreading out (Figure 1).

Answer question 3.

Question

3 *Suppose you have a bottle of perfume. What would you do to allow the perfume to spread out through the air?*

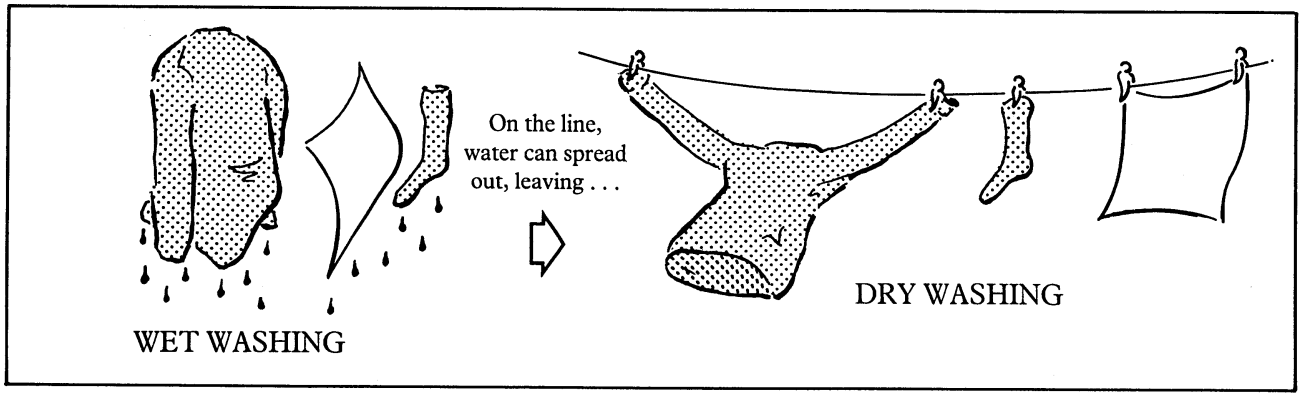

Figure 1 Drying washing depends on letting the water spread out into the air

Spreading out can be a nuisance

The tendency of things to spread out can cause a lot of problems. One of these problems is pollution.

Take a power station, for example. The fuels burned in power stations often contain sulphur. When sulphur burns, it forms sulphur dioxide, an acid gas.

Like all gases, sulphur dioxide spreads out, unless something is done to stop it (Figure 2 on the next page). It spreads out of the chimney and into the atmosphere, where it can cause acid rain. Removing the sulphur dioxide is possible, but can be expensive. Answer questions 4 and 5.

Questions

4 *Modern farmers use a lot of fertilizers. These can spread out away from the fields, and cause pollution problems. Where do they spread to, and what problems do they cause?*

5 *Give one more example of a pollutant that causes a nuisance by spreading out.*

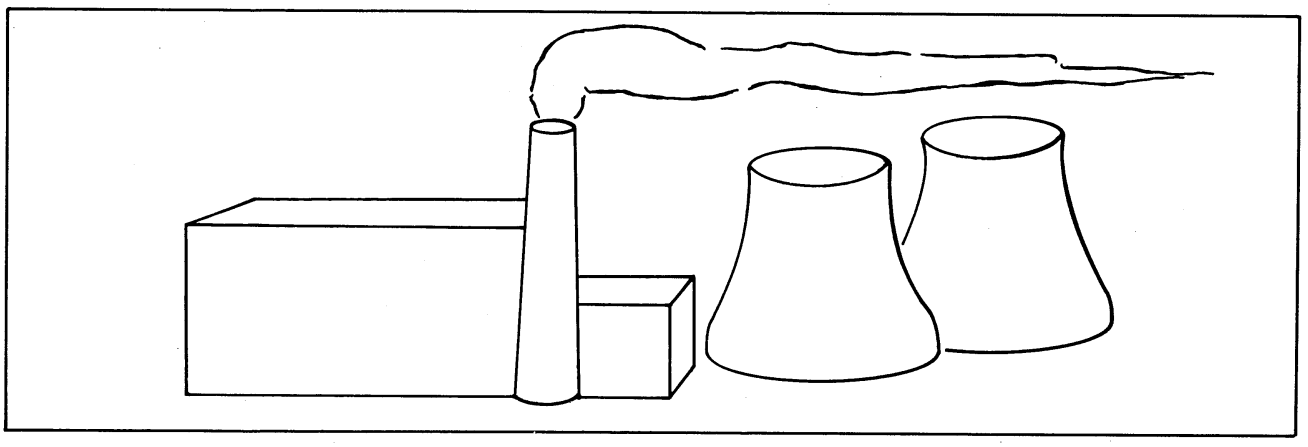

Figure 2 Pollution spreads out . . .

Spreading out can be useful

Spreading out is not always a nuisance. In fact, we depend on it. Imagine what life would be like if nasty smells did not spread out and disappear! And washing would never dry without the tendency of water to spread out into the air as water vapour. Answer question 6.

Question

6 *Why is it important to living things that gases like oxygen and carbon dioxide spread out?*

Energy spreads out too

A hot cup of tea always cools. When it is hot, the tea has more energy than when it is cool. But energy does not care where it is, and there are more ways it can be spread out through the air than locked up in the tea. So the energy spreads out, away from the tea, and the tea cools.

But the tea does not freeze. The energy spreads out as much as possible, but this leaves some energy in the tea. The tea cools until it is at the same temperature as the air around.

So, we can say:

Energy tends to spread out

Answer questions 7 and 8.

Questions

7 *In what ways is the spreading out of energy a nuisance to householders?*

8 *In what ways is the spreading out of energy useful to householders?*

To keep our houses warm we burn fuels and we use electricity to produce heat. Unfortunately, the heat always tends to spread out — out of the house through the roof, windows and walls. That is why people insulate their lofts, double-glaze their windows and put in cavity-wall insulation. Insulation helps lock up the energy inside the house. Eventually it will escape though — it always does.

The energy that leaks out of roofs and windows is not much use to anyone. It is too spread out to be useful. *Energy is at its most useful when it is concentrated.* Unfortunately, energy always tends to get *less* concentrated, by spreading out.

Answer question 9.

Question

9 *What sources of concentrated, locked-up energy do we use most commonly?*

Why are fuels so useful?

Fuels are energy stores. When the fuel burns in air, it combines with oxygen and the stored energy is released.

Fuels are useful because they are a way of locking up energy in a concentrated form until it is needed. Once the fuel is burnt, though, energy is released and tries to spread out. Some of this energy is bound to be wasted.

We can never turn all the energy stored in the fuel into useful work. Some is always lost. Power stations are a good example (Figure 3).

Answer question 10.

Question

10 In a car engine, fuel is burned to give useful energy but some energy is wasted.

(a) What form does the useful energy take?
(b) What form does the wasted energy take?

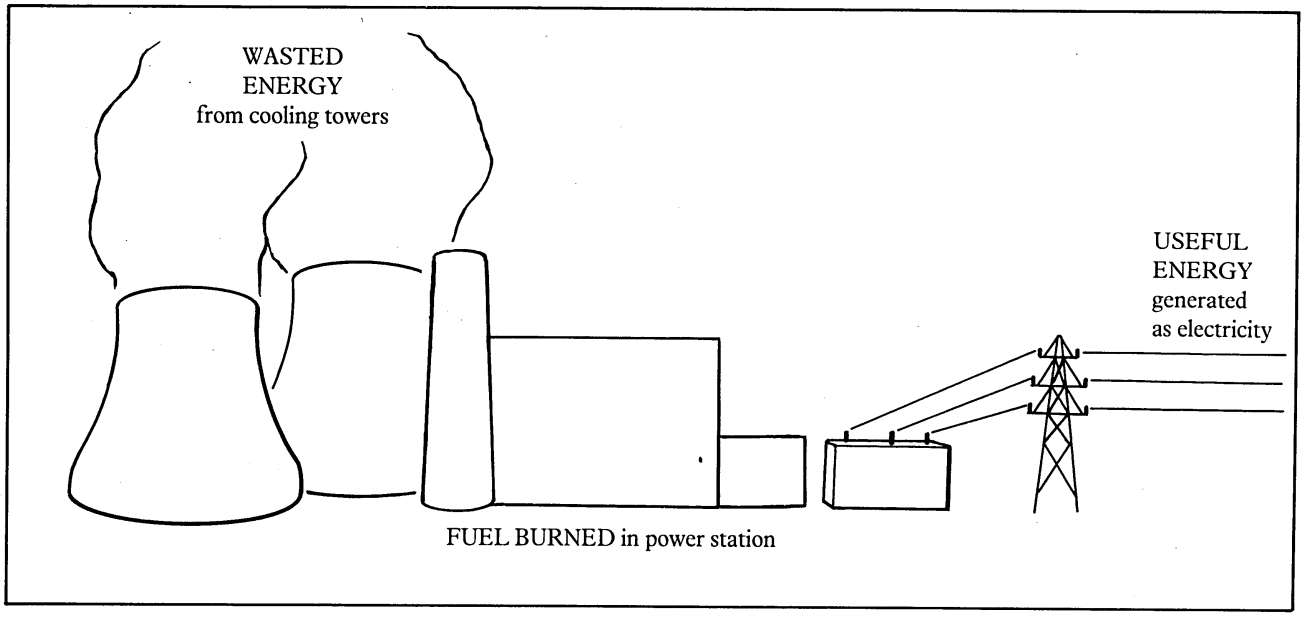

Figure 3 Using fuel to generate electricity in a power station

The energy problem

Fossil fuels such as coal and oil are in limited supply and cannot last forever. Once they are burned, their concentrated, locked-up energy gets spread out and becomes much less useful. This is why it is so important to save fuels whenever possible, and to look for alternative sources.

Alternative energy sources

Here are some of the alternative energy sources which might be used instead of fossil fuels:

Solar energy from the Sun
Hydroelectric energy from falling water
Wind energy
Wave energy from waves on the sea
Tidal energy from the rising and falling tides
Biomass — energy from plants
Geothermal energy from inside the Earth

Some of these alternative sources are quite concentrated. For example, water falling from a great height has concentrated energy that can easily be converted to electricity in a hydroelectric power station.

Unfortunately, some of the most attractive energy sources are not very concentrated. Solar energy is useful for warming houses, and scientists are finding ways to convert it to electricity. But solar power stations present more problems than ordinary oil- or coal-fired power stations, because they depend on a less concentrated energy source.

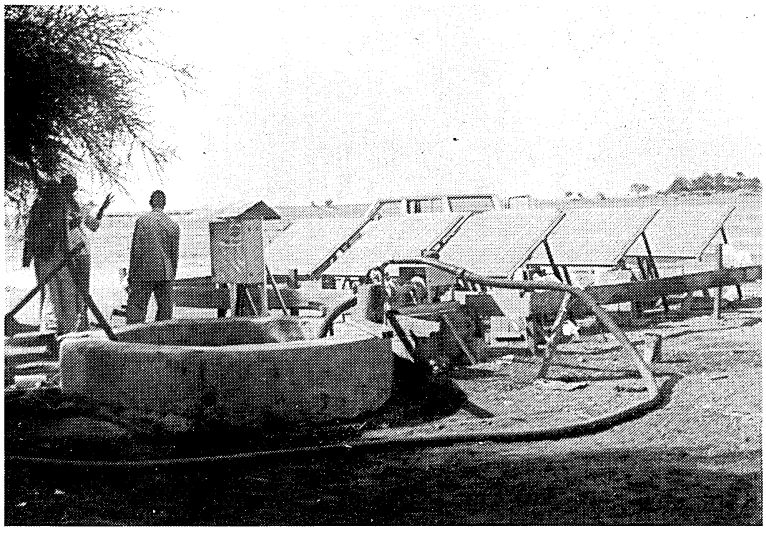

Figure 4 A solar powered pump in Mali, Africa

There are similar problems with wave energy and wind energy. Neither of them are very concentrated energy sources. Waves are normally quite small, so to get a lot of energy you need a lot of waves. The wind normally blows quite gently, so to get a lot of energy you need a big windmill, or lots of small ones.

However, these problems are not impossible to overcome. Alternative energy sources have many attractions. For one thing, they are *renewable* — they do not get used up. What is more, they cause far less environmental damage (pollution, etc.) than fossil fuels.

Answer questions 11 and 12.

Questions

11 Which alternative energy sources do you think have the greatest chance of success in Britain?

12 Alternative energy sources tend to be used more in tropical countries like India than in Britain. Why do you think this is?

Plants have the knack

Plants are an excellent energy source. Wood is a good fuel. Fossil fuels such as coal, oil and gas store the energy of plants that grew millions of years ago. We rely on plants for our own energy source — food.

Plants have a very clever knack. They can take energy from the Sun and lock it up. This is photosynthesis. The plants lock up energy in sugars, starch and cellulose, which they make during photosynthesis.

The word *biomass* is used for all the living things on Earth which depend on photosynthesis. This includes animals as well as plants, because animals depend on plants for their food.

Scientists are looking at ways of using the clever knack of photosynthesis to solve our energy problems. For example, in Brazil a lot of sugar cane is grown. This sugar can be fermented to give alcohol. Alcohol is an excellent liquid fuel which can be used in cars (Figure 5).

Answer question 13.

Question

13 Another important fuel made from plants is biogas. *Try to find out what biogas is.*

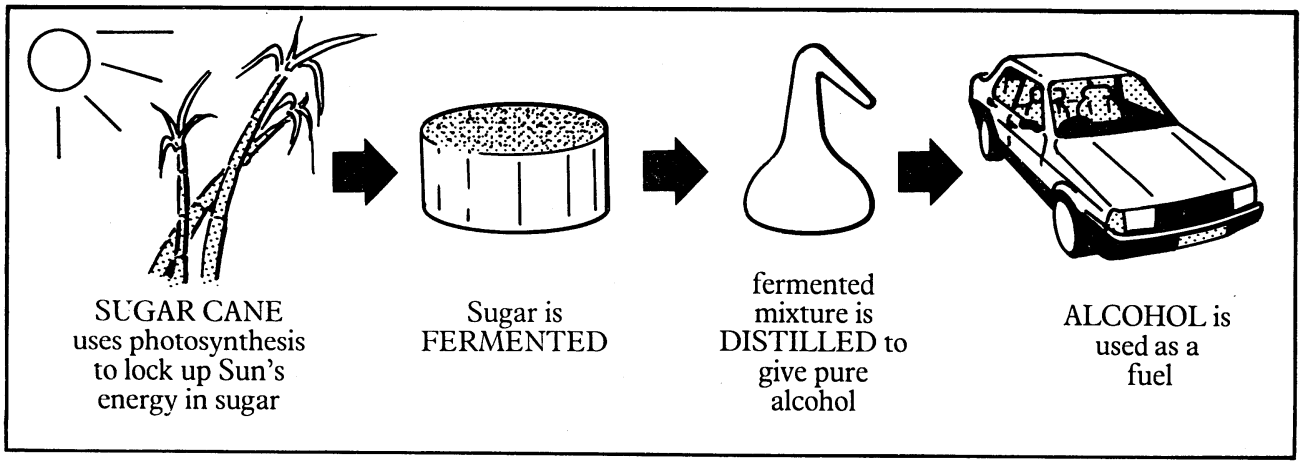

Figure 5 Using photosynthesis to make fuel for cars

Biomass fuels such as gasohol and biogas may be very important in the future. But even photosynthesis only locks up energy temporarily. Eventually all plants die and decay, or get eaten. Eventually all fuels get burned. When this happens, the locked-up energy is released and gets spread out again. In the end, we cannot stop it spreading out.

You might be interested to know that the rule 'Energy tends to spread out' is a simplified version of a scientific law called the Second Law of Thermodynamics. It is perhaps the most important of all the laws of science, because it applies to everything in the universe.