Using resources

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 Waste water from homes in Manchester flows through sewers to a treatment works. It contains organic matter, harmful microbes and some solid rubbish. After treatment the water is released into a river.

Describe the stages used to treat sewage so that it is safe to release into the environment. (6 marks)

Model answer

When the sewage arrives at the works it is first screened. Large objects such as rags, wet wipes and plastic are caught by screens, and grit is also removed.

The water then goes into large settlement tanks. Heavier solids sink to the bottom and form sewage sludge. The lighter liquid on top is called effluent, and the two are separated.

The effluent still contains dissolved organic matter and harmful microbes. It is treated aerobically, which means air is bubbled through it. This lets aerobic bacteria break down the organic matter and kill off many harmful microbes.

The sewage sludge is treated separately by anaerobic digestion. Bacteria break it down without oxygen. This produces methane gas, which can be burned as a fuel to generate electricity for the works. The digested sludge that is left can be spread on farmland as a fertiliser.

After these stages the treated water is clean enough to be released into rivers or the sea without harming the environment.

Marking points (credit any 6 relevant points, linked in a sensible order)

- screening removes large solid objects such as rags and plastic, and grit is removed
- the water goes into settlement (sedimentation) tanks
- heavier solids sink to form sewage sludge at the bottom
- the lighter liquid on top is called effluent
- the effluent is treated by aerobic biological treatment
- air is bubbled through so that bacteria can break down the organic matter and harmful microbes
- the sewage sludge is digested anaerobically by bacteria
- anaerobic digestion produces methane, which can be burned as a fuel to generate electricity
- the digested sludge can be used as a fertiliser on farmland
- the treated water is then safe to release into rivers or the sea

How it is marked

- 5-6 marks: describes screening, sedimentation, aerobic treatment of the effluent and anaerobic digestion of the sludge in order, with what happens to the products.
- 3-4 marks: describes screening and sedimentation and one of the biological treatments, with some gaps or errors in the sequence.
- 1-2 marks: makes one or two correct statements, such as solids are removed or bacteria break down the sewage.

What loses marks

- adding chlorine and calling it sewage treatment (that is for making potable water)
- swapping aerobic and anaerobic stages
- leaving out what happens to the sludge
- confusing sewage treatment with desalination

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2 A sports club in Glasgow is deciding whether to give members a reusable stainless steel water bottle or to keep selling single-use plastic (PET) bottles. The table shows estimates for one steel bottle used 500 times and for 500 plastic bottles.

Stage	One steel bottle	500 plastic bottles
raw materials	iron ore, chromium and nickel mined	made from crude oil
energy to make, in MJ	85	500
energy to wash or transport during use, in MJ	60	90
carbon dioxide over life, in kg	9	40
end of life	steel easily recycled	some recycled, many go to landfill or litter

Evaluate the two choices using a life cycle assessment approach. (6 marks)

Model answer

A life cycle assessment looks at the environmental impact of a product at every stage: getting the raw materials, making it, using it and disposing of it.

For raw materials, the steel bottle needs iron ore, chromium and nickel to be mined, which damages the landscape. The plastic bottles are made from crude oil, which is a finite resource.

Making 500 plastic bottles needs 500 MJ of energy, compared with only 85 MJ for one steel bottle. Adding the energy used during use, the steel bottle needs 145 MJ in total and the plastic bottles need 590 MJ, about four times as much. The plastic bottles also release 40 kg of carbon dioxide compared with 9 kg for steel.

At the end of life, steel can easily be recycled. Many plastic bottles go to landfill or become litter, which lasts for a very long time and can harm wildlife.

However, the figures assume the steel bottle is used 500 times. If members lose it after a few uses, the benefit is much smaller. Some values, such as the washing energy, are estimates, so they may not be exact.

Overall the steel bottle is the better choice, because it uses less energy, releases less carbon dioxide and is recycled more easily.

Marking points (credit any 6 relevant points, linked in a sensible order)

- a life cycle assessment looks at the environmental impact at each stage: raw materials, manufacture, use and disposal
- steel bottle raw materials need mining, which damages landscapes and uses energy
- plastic bottles use crude oil, a finite resource
- making 500 plastic bottles uses 500 MJ compared with 85 MJ for one steel bottle
- total energy: steel 145 MJ, plastic 590 MJ, so plastic uses about four times as much
- plastic bottles release 40 kg of carbon dioxide compared with 9 kg for steel
- steel is easily recycled at the end of its life; many plastic bottles end up in landfill or as litter, which lasts a long time and harms wildlife
- the steel bottle only wins if it really is used many times; if lost early the benefit is smaller
- some values, such as washing energy and number of uses, are estimates and can be biased or hard to measure
- conclusion: the steel bottle is the better choice for the environment

How it is marked

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- 5-6 marks: uses data from several stages of the life cycle, including totals or comparisons, considers a limitation of the data and reaches a justified conclusion.
- 3-4 marks: compares the two choices using some of the data and gives a conclusion with a reason.
- 1-2 marks: states one advantage of one bottle or gives a conclusion without using the data.

What loses marks

- only looking at one stage of the life cycle
- not adding up the energy figures to compare totals
- ignoring that the steel bottle must be reused many times
- saying plastic is better because it is lighter without using the data

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3 **Higher tier**

The supply of high-grade copper ore is running out. An old mine site in Cornwall has spoil heaps containing only low-grade copper ore.

Compare phytomining and bioleaching as ways of getting copper from this low-grade ore. (6 marks)

Model answer

Both phytomining and bioleaching are used to get copper from low-grade ores, which contain too little copper to be worth extracting in the traditional way. Both avoid having to dig up, move and dump huge amounts of rock, so they do less damage to the environment than normal mining.

They use different living things. Phytomining uses plants. The plants are grown on the spoil heaps and absorb copper compounds from the soil through their roots. Bioleaching uses bacteria, which break down the ore and release the copper compounds.

The products are different. In phytomining the plants are harvested and burned, and the ash contains copper compounds. In bioleaching the bacteria produce a leachate, which is a solution containing copper compounds.

Both methods are slow. Phytomining is limited by how quickly the plants grow, often taking years. A drawback of bioleaching is that the leachate can be toxic, so it must not leak into rivers or soil.

In both cases the copper is not yet a metal. It is extracted from the compounds either by displacement, for example adding scrap iron to a solution of a copper compound, or by electrolysis of the solution.

Marking points (credit any 6 relevant points, linked in a sensible order)

- both are used to extract metals such as copper from low-grade ores
- both avoid the large scale digging, moving and disposal of rock that traditional mining needs
- phytomining uses plants that absorb copper compounds from the soil through their roots
- the plants are harvested and burned, and the ash contains copper compounds
- bioleaching uses bacteria that break down the ore
- bioleaching produces a leachate, a solution containing copper compounds
- phytomining is slow because plants take time to grow; bioleaching is also slow but gives a solution directly
- bioleaching solutions can be toxic and must be prevented from leaking into the environment
- in both methods copper is then obtained from the compounds by displacement with scrap iron or by electrolysis
- both have lower environmental impact than traditional mining and smelting

How it is marked

- 5-6 marks: compares how each method works, what it produces and its drawbacks point by point, and explains how copper is finally obtained from the compounds.
- 3-4 marks: describes both methods correctly with some comparison, or describes both but misses how the copper is finally obtained.
- 1-2 marks: gives one or two correct facts about one method, such as plants are used in phytomining.

What loses marks

- saying the plants or bacteria produce pure copper metal
- missing the final step of displacement or electrolysis
- describing each method separately with no comparison
- mixing up which method uses plants and which uses bacteria

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4 **Higher tier | Separate science only**

Ammonia is made by the Haber process for use in fertilisers.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The forward reaction is exothermic. A typical plant uses a temperature of 450 °C, a pressure of 200 atmospheres and an iron catalyst.

Explain why these conditions are chosen. (6 marks)

Model answer

The forward reaction is exothermic. If the temperature is lowered, the position of equilibrium shifts to the right to release energy, so the yield of ammonia increases. However, at a low temperature the particles move more slowly and collide less often with enough energy, so the rate is too slow. 450 °C is a compromise: the yield is lower than at a cool temperature, but ammonia is made quickly enough to be economic.

On the left of the equation there are 4 moles of gas and on the right there are 2 moles. Increasing the pressure shifts the equilibrium towards the side with fewer gas molecules, so the yield of ammonia goes up. Higher pressure also increases the rate because the particles are closer together. But very high pressures need expensive, thick-walled equipment and a lot of energy for the pumps, and they are more dangerous. 200 atmospheres is a compromise between yield, rate, cost and safety.

The iron catalyst increases the rate so equilibrium is reached faster. It does not change the yield.

The ammonia is removed by cooling so it liquefies, and unreacted nitrogen and hydrogen are recycled, so little is wasted.

Marking points (credit any 6 relevant points, linked in a sensible order)

- the forward reaction is exothermic, so a lower temperature shifts the equilibrium to the right and gives a higher yield of ammonia
- but at a low temperature the rate of reaction is too slow
- 450 °C is a compromise between a reasonable yield and a fast enough rate
- there are 4 moles of gas on the left and 2 moles on the right
- a higher pressure shifts the equilibrium towards the side with fewer gas molecules, increasing the yield of ammonia
- higher pressure also increases the rate because the gas particles are closer together
- very high pressures are expensive to produce and need strong, costly equipment, and are more dangerous
- 200 atmospheres is a compromise between yield, rate, cost and safety
- the iron catalyst speeds up the reaction so equilibrium is reached faster, but does not change the yield
- unreacted nitrogen and hydrogen are recycled, and ammonia is removed by cooling so it liquefies

How it is marked

- 5-6 marks: explains the effect of temperature and pressure on both yield and rate using the equation and the energy change, explains why each condition is a compromise and states the role of the catalyst.
- 3-4 marks: explains the effect of temperature or pressure on yield correctly, with some reference to rate or cost, and mentions the catalyst.
- 1-2 marks: states the conditions are a compromise or that the catalyst speeds up the reaction, with no explanation.

What loses marks

- saying a high temperature increases the yield
- saying the catalyst increases the yield
- not using the number of moles of gas to explain the effect of pressure
- saying 'compromise' without explaining what is being balanced

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5 Siobhan runs a boatyard on the coast near Swansea. The steel hulls of her boats sit in sea water, and the steel railings around the yard are exposed to wet, salty air. Both are rusting.

Suggest and explain ways Siobhan could reduce rusting of the steel hulls and the railings.

Separate science only

(6 marks)

Model answer

Steel rusts when the iron in it reacts with both oxygen and water, and salt water makes rusting happen faster, so the boatyard is a very bad place for steel.

For the railings, Siobhan could use a barrier method. Painting them, or coating them in plastic, stops air and water from reaching the steel. This is cheap and easy to do on long railings. The problem is that if the paint is scratched or chipped, rusting will start at that point, so the paint must be checked and touched up.

A better option for new railings would be to buy galvanised steel. This has a coating of zinc. The zinc acts as a barrier, but even if it is scratched it still protects the steel, because zinc is more reactive than iron and corrodes first.

For the hulls, she should use sacrificial protection. Blocks of a more reactive metal, such as zinc or magnesium, are fixed to the hull. In the sea water the more reactive metal corrodes instead of the iron, so the hull is protected. This suits the hulls because they are always wet and paint below the waterline is easily damaged. The blocks get used up, so they must be replaced regularly.

Marking points (credit any 6 relevant points, linked in a sensible order)

- rusting of iron and steel needs both oxygen (air) and water
- salty water speeds up rusting
- barrier methods stop air and water reaching the metal: paint, grease, oil or a plastic coating
- painting or coating the railings is cheap and works on large structures
- if a barrier is scratched, rusting starts again at that point
- sacrificial protection: blocks of a more reactive metal such as zinc or magnesium are attached to the hull
- the more reactive metal corrodes instead of the iron, so the hull is protected
- sacrificial blocks must be replaced from time to time as they are used up
- galvanising coats steel with zinc, which acts as a barrier and still protects the steel if scratched
- sacrificial protection suits the hulls because paint below the waterline is easily damaged and the hull is always wet

How it is marked

- 5-6 marks: suggests suitable barrier and sacrificial methods, explains how each works, and matches the methods sensibly to the hulls and the railings.
- 3-4 marks: suggests at least two methods with some explanation of how they work.
- 1-2 marks: suggests a method such as painting with little or no explanation.

What loses marks

- saying rusting only needs water or only needs air
- choosing a less reactive metal such as copper for sacrificial protection
- naming methods without explaining how they work
- forgetting that scratched paint lets rusting start again

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