

Microwave

Microwave ovens seem to work like magic: food gets hot but the oven stays cool. It is not surprising that there are many popular myths and misconceptions about microwave cooking. One advice sheet says food should stand for a few minutes after being microwaved so the waves in the food can finish the job of heating. True or false? False! Switching off a microwave oven is like turning off a light switch—the microwaves stop instantly.

But what about the following statements:

True or false?

1. Food tastes different when cooked in a microwave oven.
2. Microwaved milk is bad for babies.
3. Microwaves can turn low-grade oil into high-grade fuel.
4. Microwaves cause cancer.
5. Some people can hear microwaves.

Are they myths as well?

You will find the answers on pages 8 and 9.

Nearly every American home has a microwave oven. They are ideal for warming drinks, heating snacks, roasting popcorn, defrosting food, and cooking dinners. They are quick, easy to use, clean, and safe. Microwave ovens are also found in some chemistry labs, but here we need to be more careful about safety. Some simple chemicals will rocket to 1000 °C within a minute in a microwave oven. Some compounds may even explode.

What are microwaves and how do they work?

Microwaves are a type of electromagnetic radiation. Their wavelength is longer than

visible light or infrared waves, and shorter than radio or television waves. They have frequencies of between 300 million and 300 billion cycles per second. (A billion cycles per second is more properly called a gigahertz, or GHz.) The frequency of all domestic microwave ovens is 2.45 GHz, chosen so the waves heat water efficiently (see box "Making Waves" p. 8). The power of domestic ovens is usually 700 watts.

But cooking is by no means the only practical use of microwaves! Microwaves

are also used for radar control of air and sea traffic, for sending signals to satellites, and for some industrial processes. The Cha Corporation of Laramie, Wyoming, has discovered that the polluting gases from power plants can be destroyed by microwaves. Sulfur dioxide is converted to sulfur, which can be recovered for sale, and nitrogen oxides are turned into harmless nitrogen gas.

Ultraviolet light has enough energy to break molecules apart, visible light can excite their electrons, infrared waves make molecules vibrate, but microwaves can only make them spin. Even so, chemists can measure the speed at which they revolve and calculate the distances between the atoms in the molecule. Such chemists, called

microwave spectroscopists, work with microwaves of higher frequencies, up to 18 GHz, than those used for domestic ovens.

Microwaves can be turned to heat if they interact with a *polar* material and cause it to rotate. To be polar a molecule must have a positive and negative end. Water is strongly polar with the oxygen at the negative end and the two hydrogens at the positive end. For this reason water is excellent at absorbing and converting microwaves to heat, which is what happens in foods, especially vegetables, meat, and fruit that contain a lot of water.

Not all water molecules can absorb microwaves. If they are held rigid, as in a block of ice, they cannot rotate and thus stay cool. You can demonstrate this by putting a cup of water and a cup of ice cubes in the microwave together for 90 seconds. The water will be almost boiling but the ice will not have melted. (If you want to try this experiment, then take the ice cubes straight from the deep freeze so they do not have a film of liquid water on the surface.)

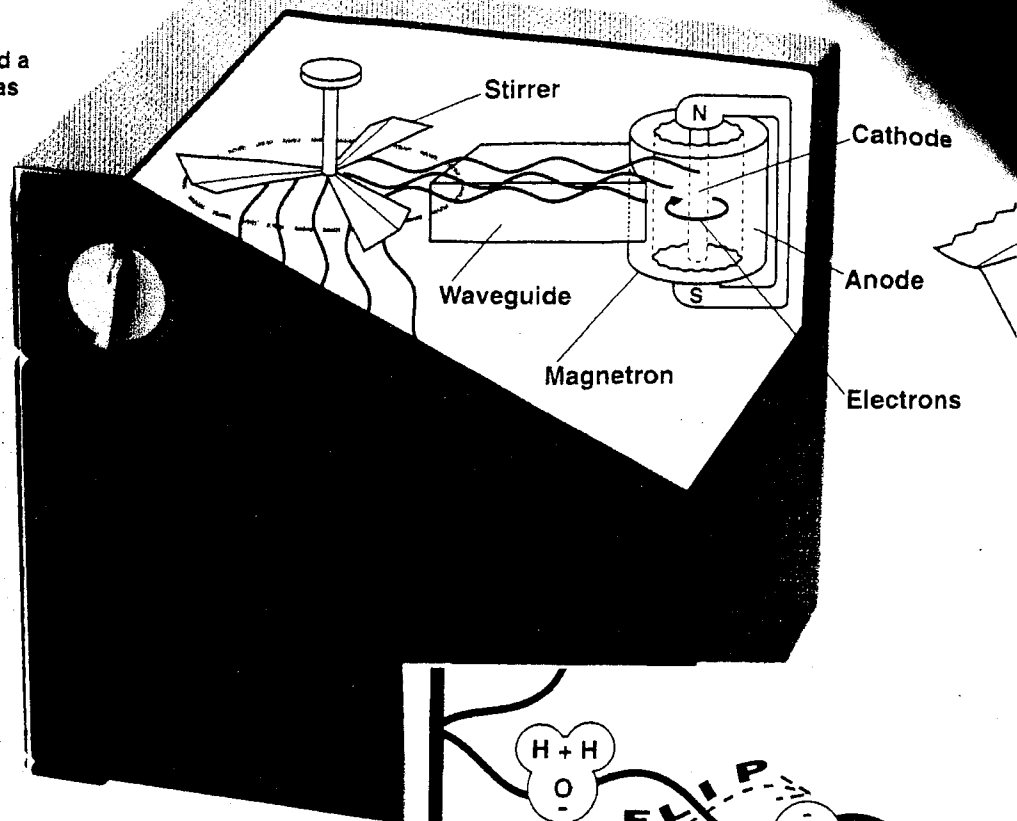
Microwave ovens at home and in the lab

Power for microwave ovens is supplied by a magnetron, a device that generates microwaves at 2.45 GHz. These have a wavelength of 12.24 cm (4.82 inches), which means that within the cavity of the oven the waves will have regions of high energy and low energy (nodes). If we put our food at a low-energy node some of it will be poorly heated. For this reason some microwave ovens have a turntable so that all the food will pass through regions of maximum wave intensity.

Microwave cooking does not brown food, but a browning and frying effect can be achieved by cooking food inside packaging with "heat susceptors," which are metallized films laminated onto paper. In this way popcorn, pizzas, and meat can be made crispy

Making waves

Microwaves are generated in a device called a magnetron, a World War II invention that was the heart of anti-aircraft radar. The magnetron is a hollow cylinder with irregular walls, a rod-like cathode in the center, and a strong magnet positioned with N and S poles at opposite ends of the cylinder. An electric current flows from the cathode (which is electrically heated to help free electrons), across the air space, to the cylinder wall that serves as the anode. As electrons begin this passage, the magnetic field forces them to move in circles around the cathode. The circular acceleration of the charged electrons creates electromagnetic waves. The magnetron in ovens is designed to produce waves that vibrate 2.45 billion times a second, that is, at a frequency of 2.45 gigahertz (GHz). Called *microwaves* because of their relatively short length (12 cm), the waves flow through a pipe-like guide to the stirrer, which looks like a fan but acts to reflect the microwaves in many directions.



they contain. Chemists in these labs have commercial microwave ovens that are programmable, have built-in safety features, and cost about \$10,000. These were developed by Howard Kingston of the National Institute of Standards and Technology, Washington, DC.

Metals should never be put into microwave ovens because they will generate an electric current and cause sparks. Graphite, which also conducts electricity, will glow white hot in a microwave oven. Methane gas will spin off its hydrogen atoms, leaving bare carbons, and these can be condensed onto surfaces to form diamond films.

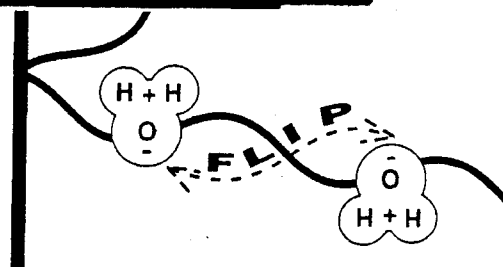
Perhaps the most unexpected effect of microwaves is seen when heating simple metal oxides such as those of copper and zinc. The temperature of a five-gram sample can jump ten degrees a second so that within a minute these oxides have melted. Superconducting mixed metal oxides, such as yttrium barium copper oxide, can be made within minutes in a microwave instead of the usual method of heating for more than 24 hours. (See "Superconductivity," *Chem Matters*, October 1987.)

Microwave myths—true or false

From its earliest days microwave cooking has spawned popular myths. How did you answer the questions on page 6?

The microwaves bounce off the metal walls of the oven and strike the food dish from many angles. The waves pass

through dishes made of glass or plastic with no effect, but strongly affect mobile, charged particles (such as dissolved ions or polar molecules). As each wave crest passes a polar molecule, the molecule is forced to turn and align with the wave. A moment later, as the trough of the wave passes, the molecule is turned in the opposite direction. Water is the most common polar molecule in food and the microwaves vibrate at 2.45 GHz because this is close to the optimum rate for making H_2O oscillate. The friction of the back-and-forth oscillation heats the water and the surrounding food.



Food tastes different when cooked in a microwave oven: true

Takayuki Shibamoto and Helen Yeo of the University of California, Davis, researched the volatile molecules that cooking produces, which give cooked food its attractive flavor. They found that conventional cooking produces more of the desirable flavors such as thiazole, furan, and pyrazine whereas microwave cooking produced less desirable flavors such as oxazole, thiophene, and pyrrole. They blame shorter cooking times and lower temperatures for these chemical differences, but say that adding salt before microwaving food can enhance the production of the more desirable flavors. However, salted food may not cook as well because

hydrated salt ions act as polar molecules and absorb the microwaves at the surface of the food. The result is that the interior of the food remains cool. Varoujan Yaylayan of McGill University in Montreal has developed a solution of amino acids and sugar with which foods such as chicken can be coated before being microwaved, to produce a freshly roasted flavor.

Microwaved milk is bad for babies: false

It is true that microwaving milk converts some amino acids such as L-proline into D-proline, which babies cannot digest. However, research by Leonard Petrucelli and George H. Fisher of the Department of Chemistry at Barry University, Miami,

Microwave article questions: Please answer in full well thought out sentences on a separate page.

1. The article lists six true or false myths about microwave ovens. List four of them and briefly explain why they are either true or false.
2. Are microwaves longer or shorter than visible light waves? Than radio and television waves? Is the energy of microwaves higher or lower than that of visible light? Than that of radio and television?
3. Why was a frequency of 2.45 GHz chosen as the standard for domestic microwave ovens?
4. What feature of water molecules makes them very susceptible to interaction with microwaves?
5. Most modern microwave ovens have either a turntable to slowly rotate the cooking food, or a rotating metal deflector that moves the microwave beam around in the oven cavity. Why are these devices needed?
6. What is a "heat susceptor" used in microwave popcorn bags, and microwave pizzas? Why are heat susceptors needed?
7. For further investigation, place a cup of water and a cup of ice cubes (taken directly from the freezer) in a microwave oven for about ninety seconds. The water will be very hot, but the ice will still be frozen. Explain this observation in terms of the structure of solid ice compared with the structure of liquid water.