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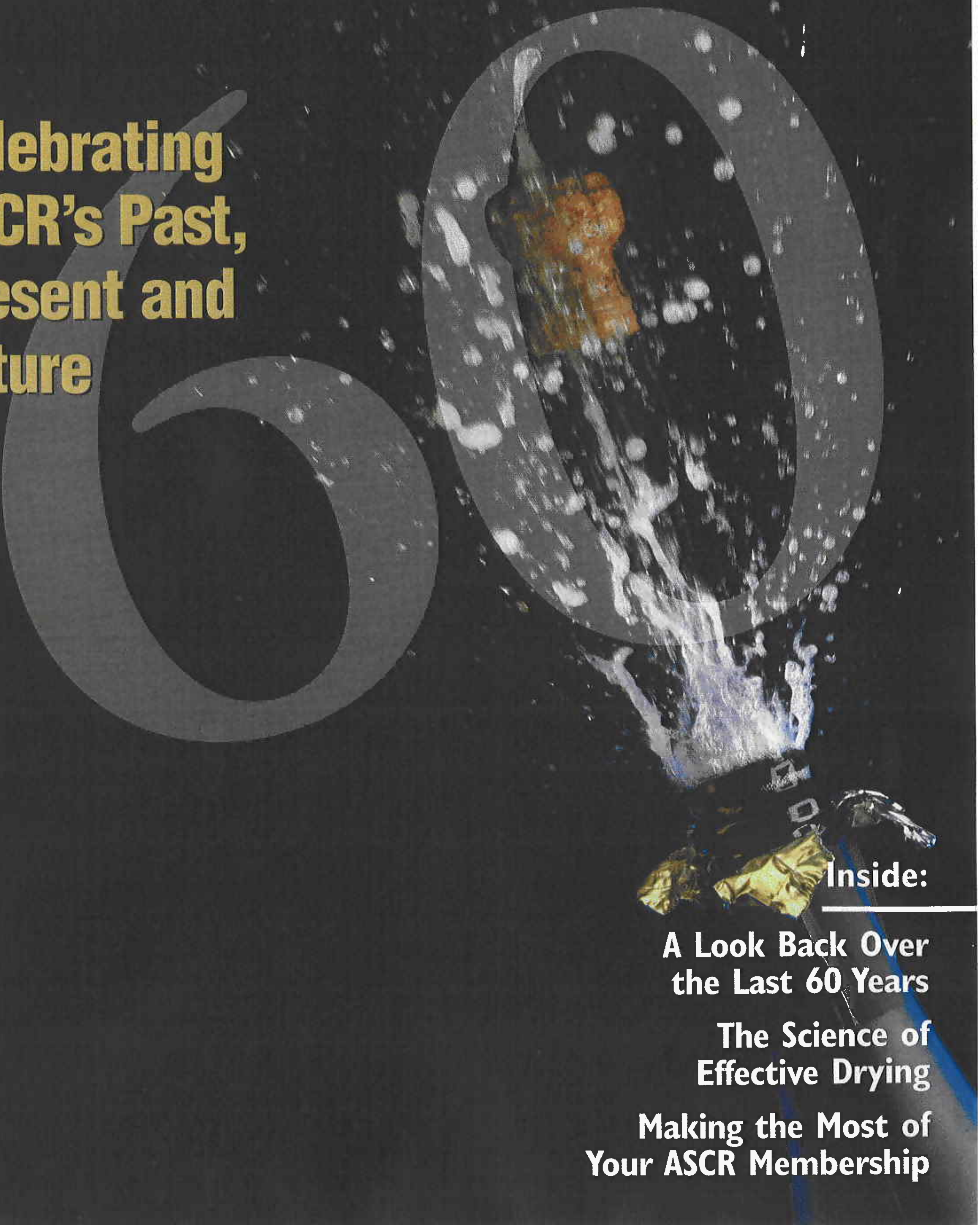


Celebrating ASCR's Past, Present and Future

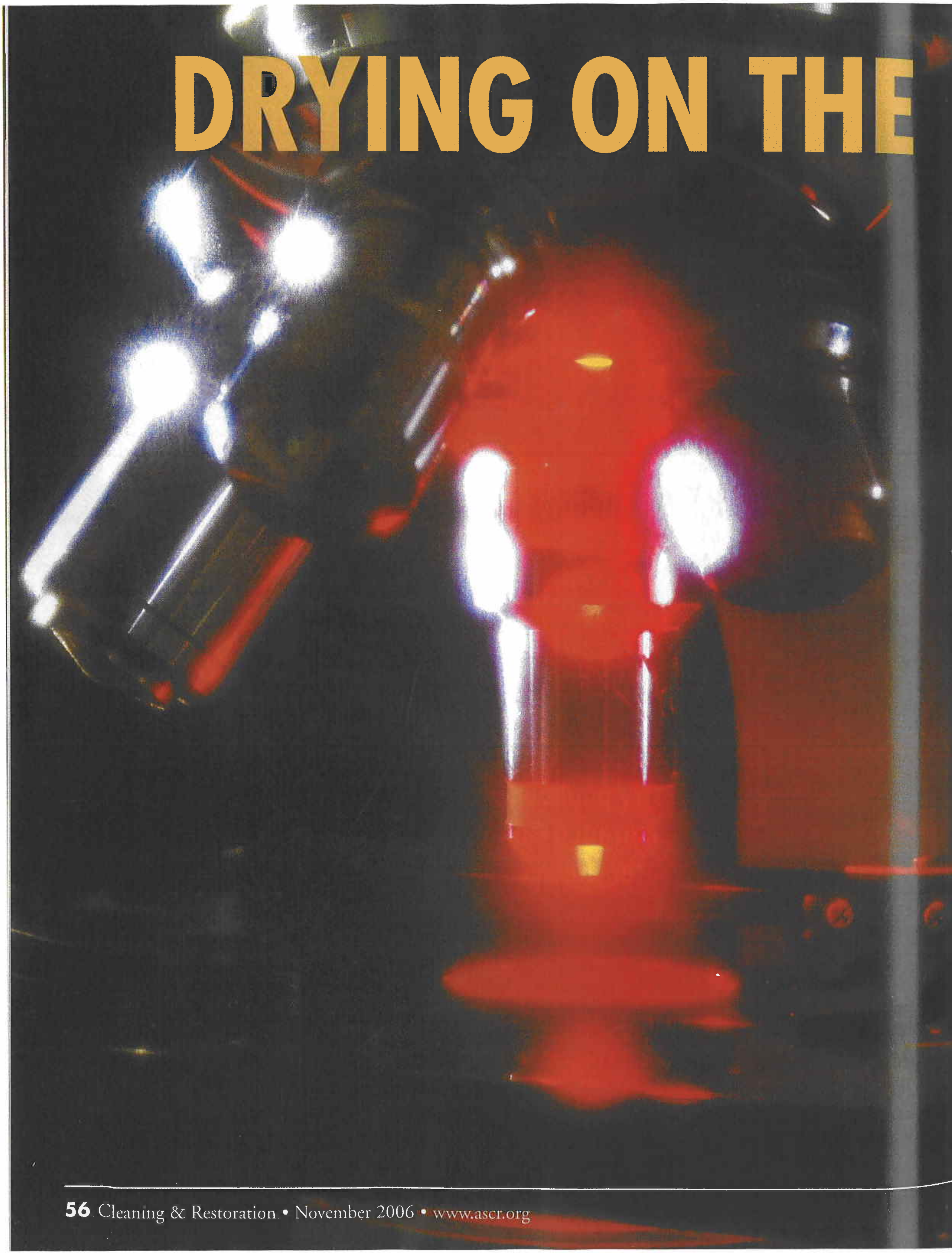
Inside:

A Look Back Over the Last 60 Years

The Science of Effective Drying

Making the Most of Your ASCR Membership

DRYING ON THE



MOLECULAR LEVEL

By Ralph E. Moon, Ph.D., CHMM, CIAQP

On the molecular level, all methods of drying (i.e., solar, mechanical fans, refrigerant, desiccant, convection and microwave) accomplish precisely the same task: convert free or absorbed water to the vapor phase. If you are in the drying business, your understanding of water on the molecular level will help you understand the effectiveness and speed of your drying effort.

The Water Molecule

If it were possible to see water molecules at room temperature and observe their behavior, you would immediately notice their mutual attraction or innate "stickiness." These forces of attraction originate from the unique spatial arrangement between the hydrogen and oxygen atoms in the water molecule (Figure 1).

Water molecules (H_2O) are composed of one oxygen and two hydrogen atoms. This arrangement is asymmetrical and means that the molecule cannot be simply divided to create two equal parts (Figure 2). The asymmetrical arrangement creates areas with non-uniform electrical charge and is the result of the uneven sharing of electrons in the bond between oxygen and hydrogen. This concept can also be understood by observing that the water molecule is not balanced.

The uneven sharing of electrons creates a "polar molecule" with distinct areas that are weakly negative (oxygen) and weakly positive (hydrogen) (Figure 3). The polarity of water results in many remarkable properties including its solvent properties (water is a universal solvent) and the ability of water to "wick" and move vertically by capillary action. Polar molecules can also orient themselves in specific directions.

The polar nature of water naturally orients the molecule with the oxygen atom (negative) attracted to a hydrogen atom (positive). Opposite charges attract, so the electrostatic attraction occurs between the negatively charged hydrogen atom and the positively charged oxygen atom. This molecular orientation creates a weak chemical bond.

The Hydrogen Bond

The weak attraction (oxygen to hydrogen) between water molecules is called a "hydrogen bond." At room temperature, water molecules are in constant motion and hydrogen bonds between water molecules are constantly broken and renewed. This explains water's apparent "stickiness," fluidity and strength.

Though an individual hydrogen bond is weak, the collective influence of many hydrogen bonds is very strong. For example, we have all experienced the strength of hydrogen bonding when we've tried to separate two pieces of wet glass. You can easily slide them apart, but pulling them apart is nearly impossible.

The cumulative strength of hydrogen bonds also explains why water remains a liquid over a wide temperature range [0°C (32°F) to 100 C (212°F)]. At room temperature, a small percentage of water molecules may have sufficient motion (kinetic energy) to escape from the liquid phase to the vapor phase. When water molecules gain sufficient energy to over-

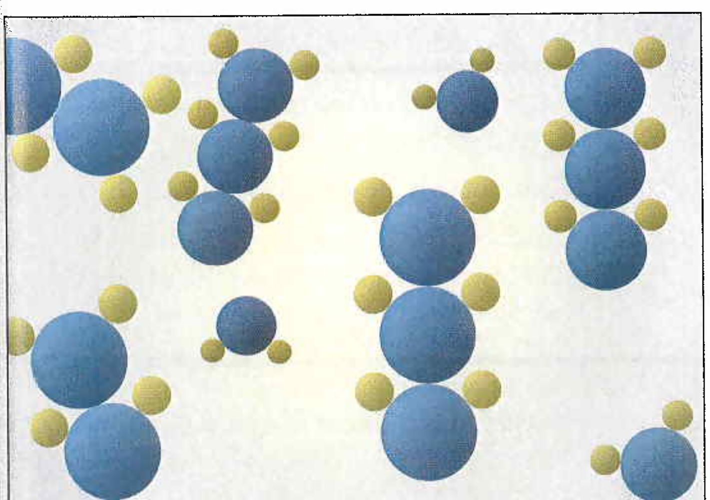


Figure 1

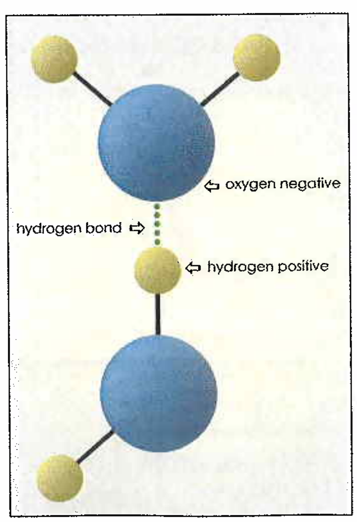


Figure 2

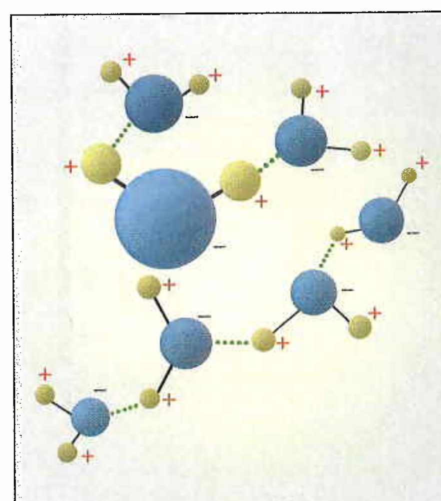


Figure 3

come the mutual attractive forces (in liquid water) and become a vapor, we call this process evaporation.

Definition: *All forms of energy are divided up between two main kinds of energy: kinetic energy and potential energy (Lenntech, 2006). The first main kind of energy is kinetic energy, the energy of motion and action. Heat is a total of kinetic energy of atoms, ions or molecules. When these chemical compounds are in motion due to kinetic energy, they will warm up. The second main kind of energy is potential energy, energy that is stored and potentially available for use. Before potential energy can be used, it is transferred into kinetic energy. An example of an object containing merely potential energy is a dice that you hold in your hand. When you throw the dice, the potential energy is transferred into kinetic energy and this will cause the movement.*

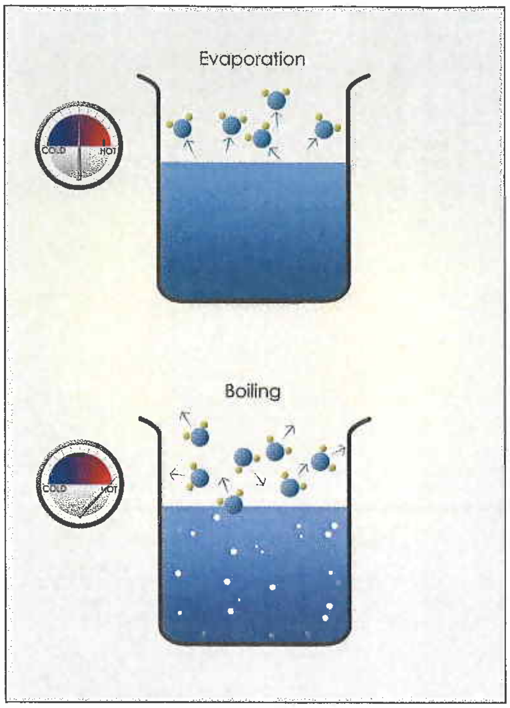


Figure 4

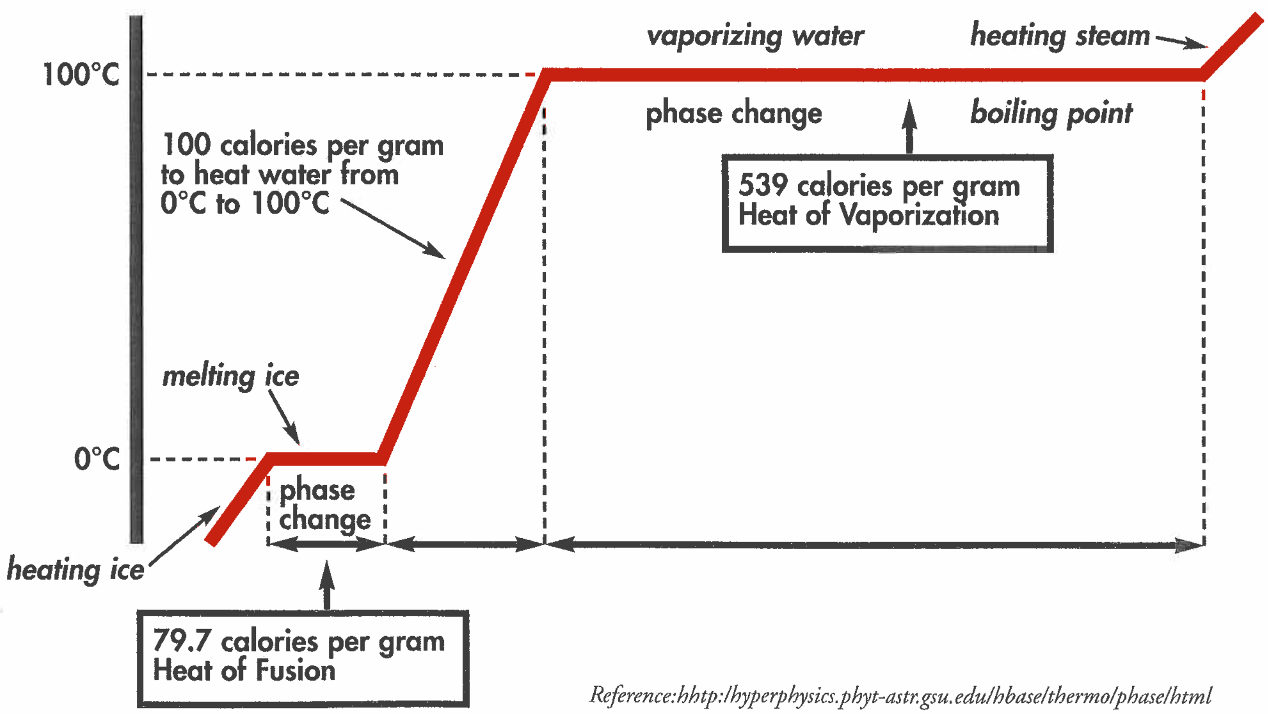
Evaporation removes heat (or kinetic energy) from the system (see definition). When water molecules (vapor) containing the high kinetic energy are released into the atmosphere, there is a loss of energy. So, when evaporation lowers the amount of kinetic energy, you must continue to add energy to maintain high rates of molecular motion and evaporation. "Heat" in this context could be represented by several forms of "kinetic energy"...any process that increases the kinetic motion of the water molecules represents the addition of energy.

In the context of drying, raising the temperature near the drying surface would qualify as adding heat (or kinetic energy). You could also add energy by decreasing the vapor pressure by condensing water vapor from the air (desiccant or refrigerant drying) or by placing the wet materials under a vacuum (vacuum drying). All techniques will improve drying by adding "kinetic energy" to the system.

When water changes from solid (ice) to a liquid (water) and to a gas (water vapor), we refer to these molecular transitions as "phase changes." Evaporation represents a phase change from a liquid to a vapor; the change from a vapor to a liquid is condensation. Both phenomena can occur across a range of temperatures.

The amount of heat required for the transition from ice to water is 79.7 calories per gram (cal/gm) (Table 1). Raising the temperature of water to the boiling point requires 100 cal/gm. Relative to the professional drying business, the transition from water to water vapor, however, requires 539 cal/gm. This explains why it takes so much energy to remove moisture from water damaged homes. The transition from water to water vapor represents the energy required to break hydrogen bonds.

Table 1



Reference:hhtp://hyperphysics.phyt-astr.gsu.edu/hbase/thermo/phase/html

Evaporation at room temperature is slow because the cumulative attraction between water molecules distributes the (kinetic) energy evenly and prevents the majority of water molecules from escaping into the vapor phase (Figure 4). As the temperature reaches the boiling point, the water does not "flash off" because hydrogen bonds hold the fluid together with the exception of those molecules nearest the surface.

Water vapor (steam) contains the most kinetic energy and will remain a vapor until the molecule contacts cooler surfaces and returns to a liquid state (Figure 5). This is the process of condensation. *In summary, drying is accomplished by increasing the kinetic energy of water molecules, breaking the hydrogen bonds between water molecules and moving the water vapor away from the wet surface.*

The Drying Rules

There are three basic rules that apply no matter what material you are attempting to dry (USDA, 2000):

Rule 1: Raise the (kinetic) energy input (raise the temperature),

Rule 2: Improve the surrounding environment so that it is capable of receiving the moisture (i.e., less than 100 percent relative humidity), and

Rule 3: Increase air movement to force water vapor away from the drying site.

These three drying rules are fundamental components of every drying technique. Solar and radiant heat drying increase the kinetic energy of water molecules near the surface and encourage them to separate from lower energy molecules (Rule 1). Refrigerant, desiccant and vacuum drying remove water molecules (latent heat) from the air by creating a vapor pressure gradient that encourages evaporation by reducing the kinetic energy required for water molecules to escape (Rule 2). As a consequence of mechanical operation, refrigerant drying methods also increase the ambient temperature and indirectly enhance drying (Rule 1). Floor fans accelerate the movement of water molecules across an evaporative surface and replace them with air containing less water molecules (Rule 3). Floor fans are also used in conjunction with refrigerant and desiccant drying to increase drying efficiency. Convectant drying uses all three drying rules.

Can construction materials dry too quickly?

Yes! Damage can result from an accelerated rate of drying. Wood kilns dry wood slowly for a reason. Kilns want to avoid the damaging effects of steam inside the wood cells. When moisture inside building materials (most often wood) gets too hot, the capillary moisture can be converted to steam. Steam is high in kinetic energy and will permanently damage (split) wood cells.

From a molecular perspective, drying slowly allows the water molecules to migrate in an orderly fashion from the interior spaces by allowing hydrogen bonds to pull adjacent molecules toward the surface to be released as a vapor. If the exterior surface is too hot and the outer shell of the wood dries, then water molecules can remain trapped inside to absorb kinetic energy and be converted to a vapor (steam). This must be avoided and requires monitoring of the ambient relative humidity and temperature. There is no available literature on the optimum temperatures to dry water-damaged contents and homes; however, there are many benefits of maintaining operating temperatures below 120°F (Moon, 2006).

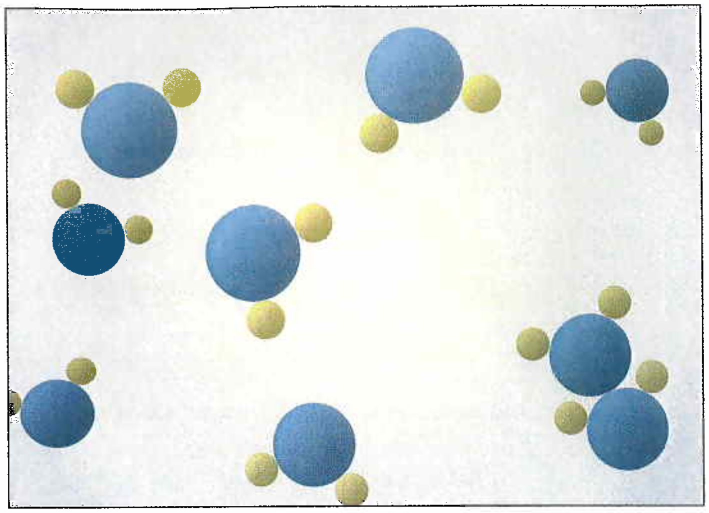


Figure 5

All forms of drying share one important similarity: they convert water to a vapor. This requires energy to break the hydrogen bonds between water molecules. On a molecular level, drying is. . .breaking hydrogen bonds and then moving the water vapor out of the way. ■

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