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THINK OF INK GIVES A LINK TO MAKE A MIND PINK AND EYES TO BLINK

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ABSTRACT
Heat, Chemical Reactions and UV light the three musketeers who have capability to make invisible ink write-ups to visible. When you hear the words invisible ink, you probably think of James Bond, magic shows and secretive government operations. While the idea seems complex, reserved for individuals with access to fancy and expensive tools, it is actually quite an old and often simple idea. Writing messages that cannot be seen at first but appear later when the paper is developed (that is, treated in some special way) is a very old idea going back 2,000 years and you can use some pretty mundane techniques to do it. In fact, invisible ink is not so mysterious, once you stop thinking of it as ink. Invisible ink is usually not ink at all. What we think of as ink is a fluid containing a pigment or a dye, which is usually permanent. Invisible ink does not use dye to produce writing or images, but instead uses chemistry. This means you can write a message on paper (or sometimes on other surfaces) and it won't be visible until it is developed, depending on what the invisible ink is that you used. There are basically three types of invisible ink. Each type is defined by how the message can be developed in order to be seen. ***Heat:*** *The fluid used oxidizes when heated (that is, the compounds that make up the liquid lose some electrons therefore changing their chemical makeup) and this oxidation turns the compounds brown. Acids work well for this type of ink, because they not only may oxidize themselves, but they change the chemical makeup of the paper also, causing it to burn and char more easily.* ***Chemical Reactions:*** *The fluid used as ink will be exposed to another chemical, either in liquid or gas form, in order to be developed. This exposure will cause a chemical reaction to occur, which changes the color of the original ink, making it visible. Some of these inks are also acids or bases, but others are metal compounds like iron sulfate (developed using sodium carbonate) and cerium oxalate.* ***UV Light:*** *The fluid does not have any color visible to the naked eye, but will fluoresce (give off light) when put under a UV light. Many organic compounds do this, as do laundry detergents and sunscreens. Of the three types of invisible ink, those developed by heat are the easiest and the safest to use (developing chemicals used for the second type and UV light for the third type can be very dangerous). Let's explore more carefully what these invisible inks are really doing. Paper is made up of a compound called cellulose, which comes from wood and consists of a long chain of linked sugar molecules. The cellulose fibers are pressed together and dried, leaving a thin flexible sheet behind. This flexible sheet is your sheet of paper. One type of invisible ink developed by heat is weak acid, like lemon juice or cola. When these are brushed on the paper they are not visible, but they slowly begin to change the chemical composition of the paper by breaking down the cellulose the paper is made of. The compounds created by this breakdown oxidize more easily than the original cellulose and when they oxidize they turn brown. Heat speeds up chemical reactions, so heating these compounds makes them turn brown faster (give them enough time and they will turn brown without heat...that's why old books sometimes look yellow, they have acid in the paper!). Other types of heat-developed invisible ink contain sugar, which caramelizes when heat is applied.*

KEYWORDS: Heat, Chemicals, UV light, Invisible ink, Disappearing ink, Scantegrity, Fluorescence, SOE.

INTRODUCTION
Invisible ink, also known as **security ink**, is a substance used for writing, which is invisible either on application or soon thereafter and can later be made visible by some means. Invisible ink is one form of steganography. Invisible ink can be applied to a writing surface with a specialty purpose stylus, stamp, fountain pen, toothpick, calligraphy pen, or even a finger dipped in the liquid. Once dry, the written surface looks as if it were blank, with a similar texture and reflectivity as the surrounding surface. The ink can be later made visible by different methods according to the type of invisible ink used. The ink may be revealed by heat or by application of an appropriate chemical, or it may be made visible by

viewing under ultraviolet light. Inks which are developed by a chemical reaction may depend on an acid-base reaction (like litmus paper), reactions similar to the blueprint process, or any of hundreds of others. Developer fluids may be applied using a spray bottle, but some developers are in the form of vaporous, e.g. ammonia fumes used to develop phenolphthalein ink.

There are also toy invisible ink pens which have two tips—one tip for invisible ink writing and another tip for developing the ink. Invisible ink is sometimes used to print parts of pictures or text in books for children to play with, always including a decoder pen which is used to show the invisible parts of texts or pictures, thus revealing answers to questions printed in regular ink or completing missing parts of pictures. Security marker pens or UV Markers with fluorescent ink that glows when illuminated with a UV light is often used to invisibly mark valuable household items in case of burglary. There are especially security maker pens formulated for writing on non-porous surfaces such as glass, plastics, metals, etc. The inks that have been applied and can then be identified by using a black light or other UV light source. Security marker pens can be obtained commercially and are widely used as a crime countermeasure. Some commercially available invisible inks glow very brightly, in a variety of colors, under UV light. This makes them suitable for use in readmission such as hand stamping. There some invisible ink types that can only be invisible when applied to certain types of surfaces, but are still visible on others. Some vendors now offer invisible ink for use in computer inkjet printers. Such inks are usually visible under ultraviolet light. Typical uses include printing information on business forms for use by the form processor, without cluttering up the visible contents of the form. For example, some United States Postal Service mail sorting stations use UV-visible ink to print bar codes on mailed envelopes giving routing information for use by mail handling equipment further down the line before delivery. Very rarely, invisible ink has been used in art. It is usually developed, though not always. There are artists who use the effect in conjunction with invisible and other reactive inks and paints to create a variety of effects when used in conjunction with UV lights. An E2E voting system called Scantegrity II uses invisible ink to enable the voter to obtain a confirmation code only for the voted selection.[1]

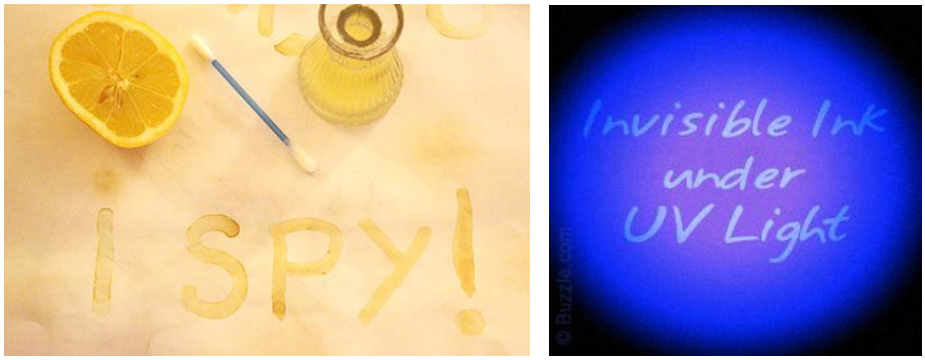


Figure-1: Invisible ink.

Property

Most invisible inks are insecure. World War II SOE (Standard Operating Environment) agents were trained not to risk their lives through reliance on insecure inks, most of which inks were of World War I vintage. The SOE training manual identified the following properties of the ideal invisible ink.

1. Very water soluble, i.e., non-greasy. 2. Non-volatile, i.e., no pronounced smell. 3. Not depositing crystals on paper, i.e., not easily seen in glancing light. 4. Invisible under ultraviolet light. 5. Does not decompose or discolor the paper, e.g., not silver nitrate. 6. Unreactive with iodine, or with any of the other usual developers. 7. Potential developers for the ink should be as few as possible. 8. Should not develop under heat. 9. Easily obtainable and has at least one plausible innocent use by the holder. 10. Not a compound of several chemicals, as this would contradict "7."

In practice, "6" and "9" are usually incompatible. The SOE was known to supply special inks to their field agents, rather than depend on improvisation from obtainable everyday chemicals. Invisible inks are not inherently secure, but this has to be balanced against the fact that it is technically difficult to carry out mass screening of posted letters. It is easier to perform large-scale undetected screening of millions of electronic communications than it is to manually inspect even a small fraction of conventional posted letters. Apart from in dictatorships with large numbers of personnel employed to spy on their fellow nationals, inspection of posted mail can only be used in particular situations, for example focusing on the letters of a particular suspect or the screening of letters entering and leaving a particular facility.

Screening

Any invisible ink can be made visible by someone who is sufficiently determined, but the limitation is generally time available and the fact that one cannot apply hours of effort to every single piece of paper. Thus successful use of invisible ink depends on not arousing suspicion that invisible ink may be present. Telltale signs of invisible

ink, such as pen scratches from a sharp pen, roughness, or changed reflective of the paper (either more dull or more shiny, usually from using undiluted ink), can be obvious to a careful observer who simply makes use of strong light, a magnifying glass and his or her nose. Also, key words in the visible letter, such as heat or any other odd code name, in an out of place context may alert a censor to the presence of invisible ink. Invisible ink is not effective with glossy or very smooth paper types, since the sizing of these papers prevents ink from being absorbed deep into the paper and it is easily visible, especially if the paper is examined under glancing light. There are, however, commercially available inks for non-porous surfaces that are only visible under ultraviolet light and are otherwise virtually invisible on such surfaces.

Using ultraviolet light or an iodine fume cupboard, messages can be quickly screened for invisible ink and also read without first permanently developing the invisible ink. Thus, if a censor uses this method to intercept messages, the letter may then be sent to the intended recipient, who will be unaware that the secret message has already been intercepted by a third party. A screening station theoretically could involve visual and olfactory inspection, an examination under ultraviolet light and then the heating of all objects in an oven before finally trying exposure to iodine fumes to produce optimal security in optimal time.

Types

For practical reasons, the inks are listed here according to their method of development. It must be understood however that some inks - particularly those of organic origin or those consisting of a mixture of several chemicals - may be made visible by several methods. For example, invisible writing with soap water may be made visible either by heat, reaction with phenolphthalein and viewing under ultraviolet light, or by placing the page inside an iodine fume cupboard.

Figure-2: Visibility of invisible ink.

Inks developed by heat

Some of these are organic substances that oxidize when heated, which usually turns them brown. For this type of heat fixed ink, any acidic fluid will work. The most secure way to use any of the following substances for invisible ink is by dilution, usually with water, close to the point when they become difficult to develop.

1. Cola drink. 2. Honey solution, sugar solution (sugar turns into caramel by dehydration). 3. Lemon, apple, orange or onion juice (organic acids and the paper forms ester under heat). 4. Milk (lactose dehydrates). 5. Bodily fluids such as blood serum. 6. Soap water (carboxylate partially oxidises). 7. Wine, or vinegar. 8. Cobalt chloride, which turns blue when heated and becomes invisible again after a while (if not overly heated). The writing is rendered visible by heating the paper, either on a radiator, by ironing it, using a hair dryer, or by placing it in an oven. A 100-watt light bulb is less likely to damage the paper.

Inks developed by chemical reaction

In most cases, the substance changes color when mixed with an acid or base. Phenolphthalein, commonly used as a pH indicator, turns pink in the presence of a base such as ammonia fumes or sodium carbonate. Vinegar, is revealed by red cabbage water. Vinegar contains acetic acid that affects the pH indicator in red cabbage water. Vinegar may also be developed by heat, as above. Ammonia, developed by red cabbage water. Red cabbage juice contains anthocyanin and can be used as a pH indicator. It is red, pink, or magenta in acids, (pH < 7), purple in neutral solutions (pH ~ 7) and ranges from blue to green to yellow in alkaline solutions (pH > 7). Copper sulfate, developed by sodium iodide, sodium carbonate, ammonium hydroxide or potassium ferrocyanide.

Reactions:$CuSO_4+2NaI\rightarrow CuI_2+Na_2SO_4$;
$CuSO_4+Na_2CO_3\rightarrow CuCO_3+Na_2SO_4$;
$CuSO_4+2NH_4OH\rightarrow Cu(OH)_2+(NH_4)_2SO_4$
$NH_3+CuSO_4\rightarrow [Cu(NH_3)_4(H_2O)_n]SO_4$;
$2CuSO_4+K_4Fe(CN)_6\rightarrow 2K_2SO_4+Cu_2Fe(CN)_6$)
Lead (II) nitrate, developed by sodium iodide.
Reaction: $Pb(NO_3)_2+2NaI\rightarrow PbI_2+2NaNO_3$
Iron (II) sulfate, developed by sodium carbonate or potassium ferricyanate.
Reactions: $FeSO_4+Na_2CO_3\rightarrow FeCO_3+Na_2SO_4$;
$FeSO_4+ K_3Fe(CN)_6\rightarrow KFe[Fe(CN)_6] + K_2SO_4$

Cobalt (II) chloride, developed by potassium ferricyanide.
Reaction: $CoCl_2$+ $K_3Fe(CN)_6$→2KCl+$KCo[Fe(CN)_6]$
Iron (II) sulfate, developed by sodium sulfide.
Reaction: $FeSO_4$+Na_2S→FeS+Na_2SO_4
Starch, developed by iodine solution which turns starch dark blue and the paper light blue.

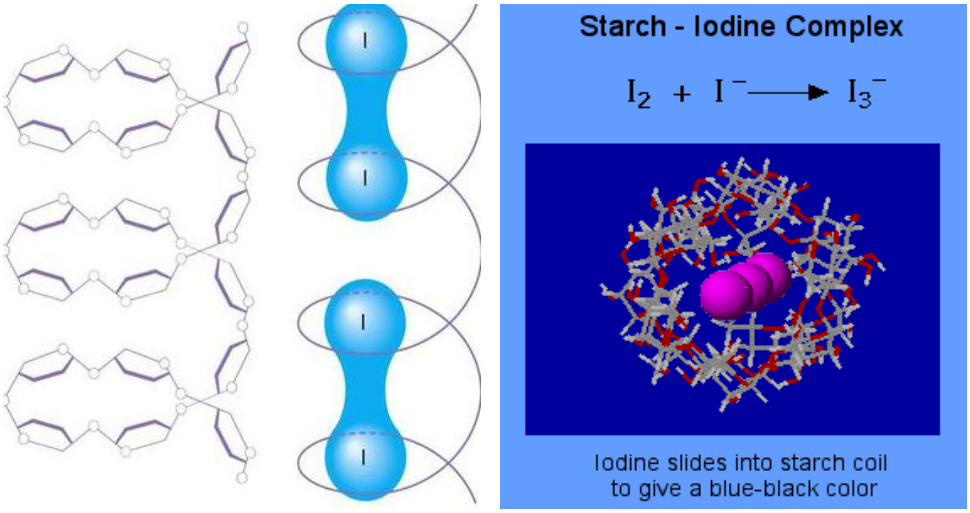


Figure-3: Iodine complex with starch.

Reaction
Lemon juice, developed by iodine solution (ink turns white, paper turns light blue).

Reaction: In this experiment lemon juice developed by iodine solution is used to prepare invisible inks. When paper with written message is treated with iodine solution the starch contained in paper reacts with iodine to form a colored complex.
$(C_6H_{10}O_5)_n$+I_2→I_2*$(C_6H_{10}O_5)_n$

The paper turns blue but the message still stays white. Lemon juice contains vitamin C which prevents the reaction between starch and iodine: $I_2 + I^- \rightarrow I_3^-$; $C_6H_8O_6+I_3^-+H_2O \rightarrow C_6H_6O_6+3I^-+2H^+$

Sodium chloride (common table salt), developed by silver nitrate.
Reaction: NaCl+$AgNO_3$→$NaNO_3$+AgI

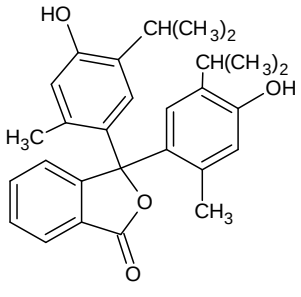
Cerium oxalate developed by manganese sulfate and hydrogen peroxide
Reaction: Ce (III)+$MnSO_4$+H_2O_2→2Ce (IV)+$MnSO_4$

Inks visible under ultraviolet light
Some inks glow faintly (fluoresce) when under an ultraviolet lamp. This is a property of many substances, particularly organic substances and body fluids. Other inks work in a near opposite way by absorbing ultraviolet light but without fluorescing. When these are used on fluorescent paper, the inked areas fluoresce less than the surrounding paper area when under an ultraviolet lamp. This is especially a property of inks with a yellow tint.

Some UV-visible inks may be detected on a photocopy, due to the relatively strong ultraviolet component in light from the photocopier scanning head. Examples of inks revealed by ultraviolet light are: Laundry detergents containing optical brighteners, Soap, Body fluids, tonic water, serum, saliva, Sunscreen, Lemon juice, Vitamin B_{12}.

Inks which alter the surface of paper: This includes virtually all invisible inks, but pure distilled water can also be used in this way. Application of any fluid will alter the paper surface fibers or sizing. Fumes created from heating iodine crystals will develop the writing, which will appear brown because the iodine sticks preferentially to the altered areas of the paper. Exposing the paper to strong sunlight will return the writing to its invisible state, as will using a bleach solution. Slightly dampening paper with a sponge or by steam and then drying it before writing a message will prevent writing from being developed by this method, but overdoing dampening will result in telltale paper cockling.

Disappearing inks
Inks that are visible for a period of time without the intention of being made visible again are called disappearing inks. Disappearing inks typically rely on the chemical reaction between thymolphthalein and a basic substance such as sodium hydroxide.



Figure–4: Thymolphthalein.

Thymolphthalein, which is normally colorless, turns blue in solution with the base. As the base reacts with carbon dioxide (always present in the air), the pH drops below 10.5 and the color disappears. Pens are now also available that can be erased simply by swiping a special pen over the original text. Disappearing inks have been used in gag squirtguns, for limited-time secret messages, for security reasons on non-reusable passes and for fraudulent purposes. Invisible ink is fun and exciting to use. You can send secret messages to your friends and family using ingredients that can be found lying around the house. There are many different solutions that you can use as ink and even more options for how to reveal the message. Any liquid that is slightly acidic can be used as invisible ink. With a little bit of heat, you can reveal all of the secrets![2]

Figure–5: Visibility in UV light.

Making of invisible inks

Using an Acidic Solution

1: Gather the necessary materials. To make an invisible ink pen, you will need Q-tips or a paintbrush, an acidic solution, a shallow dish or bowl, white paper and a source of heat. The Q-tips or paintbrush will be used to do the actual writing. Choose the item that works the best for you. Any of the following can serve as the acidic solution for the invisible ink: milk, vinegar, or lemon juice. The heat source can be a candle, a hair dryer, an iron, or even a lamp. All of these items should easily be found around the home or purchased at the grocery store.

2: Pour the acidic solution into a bowl. If you are using a lemon, squeeze the lemon until the juice comes out into the bowl. If you are using milk or vinegar, pour about half of a cup into the bowl. The exact amount isn't important. You will only need enough to write your message. Dispose of the liquid down the drain when you are finished. Do not use the liquid for anything else once you have used it for invisible ink.

3: Write on the paper. A Q-tip is a very easy device to use as a pen. Dip it in the solution until it is damp. Write your secret message, dipping the Q-tip into the ink every few letters. This ensures that you have used enough ink for the message to show up later. It may be difficult to keep track of what you are writing because the writing will be invisible as well. If you write at a well-lit table you will be better able to see what you are writing while the ink is still wet.

4: Let the ink dry fully. Before revealing your hidden message, you need to let the ink dry completely. It shouldn't take more than 30 minutes for the ink to finish drying. Set the first paper aside and write more messages while you wait for the first one to dry.

5: Apply heat to the paper. Once you have obtained a heating device, apply it to the paper where something has been written with the invisible ink. As the paper heats up, the areas that have invisible ink on them will begin to turn brown. When the message starts to appear, remove the heat source from the paper. If the message is unclear, keep the heat on for a few more seconds until it comes clear. Be extremely cautious not to light the paper on fire if you are using a candle. Adult supervision is recommended for this to avoid burns or other injury. If you are using a hair dryer, use the low heat seating and wave it across the paper until the words appear. If you are using an iron, use it on a low setting. To avoid burning the paper away, place a piece of parchment paper between the iron and the paper before rubbing the iron on top.

6: Reveal the writing with salt. You can tweak this method a little bit by using salt instead of heat to reveal the message. When the ink is still wet, cover it in salt. Let the salt sit for at least two minutes and then brush it away from the ink. Let the ink fully dry and then color over the message with a wax crayon. The wax will not stick to the salt in the ink and you will be able to read what is written! There is no exact amount of salt to use, just make sure the message is covered completely while the ink is still wet.

Using Petroleum Jelly as Invisible Ink

1: Gather the necessary materials. Petroleum jelly is a fun ink to use because it will glow in the dark under a black light (UV light). To use this type of invisible ink, you will need petroleum jelly, Q-tip cotton swabs, white

computer paper and a black light. Most of these materials should be easily found around the house. You can purchase a black light at a local superstore or online.

2: Write on the paper with the jelly. Dip the cotton swab into the petroleum jelly until you have a small amount on the end. You don't want a big glob of it because that will be difficult to write with. Write your message with the tip of the cotton swab. For best results, try to make the writing smooth, avoiding bumps from the jelly.

3: Shine the black light on the paper. To reveal the written message, shine a black light on the paper. You can even turn the normal lights out or look at it in a dark closet. The words you wrote will glow in the dark under the black light. You don't have to wait for the jelly to dry completely before revealing the message.

Writing with Baking Soda

1: Gather the necessary materials. For this type of ink, you will use baking soda for writing and grape juice to reveal the hidden message. To do this, you will need ¼ cup of water, ¼ of baking soda, Q-tips, grape juice concentrate and a paintbrush/sponge brush. All of these items should be found around the house or purchased at the grocery store.

2: Dissolve the baking soda in the water. Pour the baking soda into the water and stir until it is fully dissolved. The baking soda will dissolve faster if you use warm water. This solution will serve as the invisible ink for your secret messages. The exact amounts of baking soda aren't important as long as you have equal amounts of baking soda and water.

3: Write your secret message. Dip the Q-tip into the baking soda solution until the tip is damp. As you write, you will need to dip the Q-tip into the solution again to make sure you have enough ink. It can be hard to see what you're writing because the ink is invisible. While the ink is still wet you can see it if you are working in a well-lit room.

4: Set it aside to dry completely. The ink must dry completely before you try to reveal it or the reaction will not work. Put your papers off to the side and write more messages while the first ones dry. The ink shouldn't take more than 30 minutes to dry. When the ink is fully dry, you won't be able to see anything on the paper. It will look like a normal blank sheet of paper.

Figure-6: Heat produces visibility of invisible ink.

5: Brush the message with grape juice. Once the writing has dried completely, you can reveal your message. To do this, dip a paintbrush in grape juice and brush it across the message. When the message is covered in grape juice, the writing will change color and you will be able to read what is written. This works because grape juice is acidic and reacts with the baking soda in the invisible ink to change color. Avoid getting the grape juice on your clothes because it can stain.

CONCLUSION

Any invisible ink can be made visible by someone who is sufficiently determined, but the limitation is generally time available and the fact that one cannot apply hours of effort to every single piece of paper. Successful use of invisible ink depends on not arousing suspicion. Telltale signs of invisible ink, such as pen scratches from a sharp pen, roughness or changed reflectivity of the paper (either duller or shinier, usually from using undiluted ink) can be obvious to a careful observer who simply makes use of strong light, a magnifying glass and their nose. Also, key words in the visible letter, such as red cabbage or heat, in an odd context may alert a censor to the use of invisible ink. Invisible ink should not be used with glossy or very smooth paper types, since the sizing of these papers prevents ink from being absorbed deep into the paper and it is easily visible, especially when the paper is examined under glancing light. There are, however, commercially available inks for non-porous surfaces that are only visible under ultraviolet light and are otherwise virtually invisible on these kinds of surfaces.

Using ultraviolet light or an iodine fume cupboard, messages can be quickly screened for invisible ink and also read without first permanently developing the invisible ink. Thus, if a censor uses this method to intercept messages, he may then let the letter be sent to the intended recipient who will be unaware that the secret message has already been intercepted by a third party.

A screening station could theoretically involve visual and olfactory inspection, an examination under ultraviolet light and then the heating of all objects in an oven before finally trying exposure to iodine fumes. In theory, some invisible inks may even show up using a camera sensitive to infrared light. Other invisible inks can be made visible by heating or spraying something on the piece of paper in question. These inks are most commonly used in mystery novels. They involve chemical reactions. For example phenolphthalein is a colorless liquid if you have a water-based solution. If you write something and then expose the paper to e.g. ammonia, the writing becomes visible (pink). This is an example in which the neutral molecule and it's anionic form have different colors. Exposing the paper to ammonia, deprotonates the phenolphthalein in the invisible ink, the hydrogens are removed from the hydroxyl groups and a ring opening reaction takes place, this changes which part of the visible light is absorbed by the molecule and it looks pink. An example of an invisible ink that can be made visible by heating is lemon juice. Lemon juice contains an organic acid and if you heat the writing the acid decomposes and you are left with carbon on the paper, this is what you see. You basically destroy the acid by burning it. This is of course an irreversible process. Once the message is visible it stays visible.

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