Teaching Chemistry Through The Jigsaw Strategy

Example 2

Topic
Methanal

Subtopics
1. Production of polymers
2. Methanal in indoor air
3. Methanal in seafood

Level
Secondary 6-7

Curriculum Links
Chemistry of organic compounds
Carbonyl compounds
Uses of aldehydes

Medium of instruction
English

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1. **Production of polymers**

Methanal (H$_2$C=O) is a gas with a pungent smell at room conditions. It is also known as formaldehyde. Methanal is soluble in water and commonly sold as 37% aqueous solution with trade names such as formalin.

More than half of the methanal sold worldwide is used in the production of polymers. For example, urea-methanal is produced by the condensation polymerization of urea and methanal molecules.

\[
\begin{align*}
\text{H}_2\text{N} & \text{C} = \text{O} \quad + \quad \text{H}_2\text{O} \\
\text{N} & \text{C} \text{N} \text{H} \text{C} \text{H}_2 \\
\text{H} & \text{O} \\
\end{align*}
\]

If there are excess methanal molecules, cross-linkages can be formed between polymer chains, resulting in a thermosetting plastic (i.e., it cannot be softened again by heat).
Because urea-methanal is an electrical and heat insulator and is resistant to most chemicals, it can be used to make the following materials:

- Electrical switches
- Lamp fittings
- Handles of kitchenware (e.g., pots and pans)
- Permanent adhesives (e.g., for fibreboard, carpeting)

Chemical suppliers produce about 1 million metric tons of urea-formaldehyde resins annually. Most of these resins are used by the forest products industry to make adhesives for bonding particleboard, medium-density fiberboard, and hardwood plywood.

**Questions**
1. Why is urea-methanal a condensation polymer?
2. What are the properties of urea-methanal?
3. Name some products made of urea-methanal.
2. Methanal in indoor air

When you visit some furniture stores, you can easily detect a special smell. What causes that smell? The answer is methanal (also known as formaldehyde).

Methanal can enter our body by inhalation of fumes, contact with solutions containing methanal or by eating or drinking foods containing methanal. Car exhaust is a major source of methanal. It is important to note that methanal is one of the most common indoor air pollutants. The two main sources of methanal in indoor air are emissions from cigarette smoke and from synthetic materials made of methanal. One common synthetic material is urea-methanal resin produced by the following reaction:

\[
\begin{align*}
    & n \quad \text{H}_2\text{N} \quad \text{O} \quad \text{NH}_2 \\
    + & n \quad \text{H} \quad \text{O} \quad \text{H} \\
    \rightarrow & \quad \left[ \text{N} \quad \text{C} \quad \text{O} \quad \text{NH} \quad \text{CH}_2 \right]_n
\end{align*}
\]

The NH-CH\(_2\) covalent bond is formed by condensation reaction and a H\(_2\)O molecule is eliminated. Urea-methanal resin is widely used as adhesives to make fibreboard, particle board, wallpaper, and carpets. However, one drawback of urea-methanal resin is that the condensation polymerization reaction is reversible. Therefore, methanal is slowly given off over time from materials bonded with urea-methanal adhesives. It may take several months or years to release all the methanal from fibreboard, particle board, wallpaper, or carpets.

Methanal has a pungent smell. At concentrations above 0.1 ppm in air, methanal can irritate the eyes, resulting in watery eyes. If inhaled, methanal at this concentration may cause headaches, a burning sensation in the throat, as well as triggering or aggravating asthma symptoms. It can also cause skin and lung allergies. High levels of exposure of methanal can cause throat spasms and a build-up of fluid in the lungs, leading to death. Methanal has been classified as a probable chemical causing cancer. In the USA, no more than 0.016 ppm of methanal in new buildings is allowed. In Shenzhen, however, 90% of new houses had high levels of methanal in air (Ming Pao, 24 May 2004).

In April 2002, the Consumer Council checked 20 wooden bookcases sold in Hong Kong and found that the amounts of methanal released from four of those bookcases were above the acceptable level.

A serious case was reported in Ming Pao (18 July 2004). A man brought a wooden wardrobe
in Guang Zhou, China. His wife suffered from abortion due to inhalation of excessive amount of methanal emitted from the wardrobe. The furniture supplier paid him $13,000 as a compensation.

In 2006, a survey conducted in Guang Zhou, China indicated that 60% of children’s rooms had levels of methanal above the standard. Furthermore, in Beijing and Shenzhen, 90% of children who suffered from blood cancer had new furniture or building materials in their homes.

In April 2007, a school in China renovated its classrooms but 398 students were poisoned after breathing in methanal emitted from the new construction materials. They were sent to hospital for treatment.

In air, methanal decomposes within 24 hours to produce methanoic acid (HCOOH) and poisonous carbon monoxide (CO). Opening windows and using fans are the easiest ways to lower the methanal level in a home. The Indoor Air Quality Information Centre in Hong Kong has also recommended the following tips to reduce methanal in your home:

- Avoid using pressed-wood building materials or furniture made with urea-methanal resins.
- Ask the suppliers to have your new furniture aired for at least several days or weeks before delivery.
- Try to keep your old furniture and furnishings, particularly those made of solid wood.
- Reduce the humidity and temperature of your room to lower the emission of methanal from materials

**Questions**
1. Why is methanal often released from some construction materials in a house?
2. What are the harmful effects of methanal on the humans?
3. What precautions can we take to reduce the concentration of methanal in indoor air?
3. Methanal in seafood

If the fresh meat of sea animals such as fish, crab, and shrimp is not properly handled and stored, it will go bad and produce “fishy” odour. Scientists have found that trimethylamine oxide (TMAO) is naturally present in the living tissues of many marine animals. The concentration of TMAO in tissues varies with species, types of tissues, habitats, and season. The mass of TMAO in muscle tissues usually ranges from 1 to 7%. TMAO is very important to the osmoregulatory system in these marine animals because it provides the following advantages:

- Prevent the animal from becoming dehydrated in seawater
- Lower the freezing temperature of the body fluid
- Counteract the toxic effects of urea on proteins and enzymatic activities
- Counteract the effects of hydrostatic pressure on enzyme function in deep-sea animals

An enzyme called trimethylamine oxide demethylase (TMAOase) catalyzes the conversion of TMAO into dimethylamine and methanal (also known as formaldehyde).

\[ \text{H}_3\text{C} \text{N} \text{O}^- \xrightarrow{\text{TMAOase}} \text{H}_3\text{C} \text{NH} \text{CH}_3 + \text{H}_2\text{C} \text{O} \]

Much of the methanal is bound to the tissues. The water holding capacity of meat will lose. As a result, the texture of meat will change and the meat will lose its fresh flavour. The conversion of TMAO into dimethylamine and methanal also takes place during frozen storage of fishy products such as fish fingers and cakes. Therefore, the concentration of methanal in frozen fishy products will increase with time.

Although methanal can serve as a preservative, fishermen should never use it to preserve seafood. However, shrimp will produce black spots during storage. To inhibit the formation of black spots, fishermen often immerse fresh shrimp in a solution of sodium bisulphite (NaHSO\(_3\)) or sodium metabisulphite (Na\(_2\)S\(_2\)O\(_5\)·H\(_2\)O). Unfortunately, scientists found that the use of these sulphite compounds can speed up the formation of methanal from TMAO.

In addition, sea animals will produce “fishy” smell when stored for some time. The smell is particularly strong in spoiling fish. Actually, the fishy smell is due to trimethylamine formed by bacterial decomposition of TMAO.
Questions
1. Why is methanal present in some seafood?
2. What are the effects of methanal on the quality of seafood?
3. What causes the characteristic “fishy” smell of spoiling sea animals?