Chapter 24
Animal, Vegetable, Mineral: It’s All Chemistry!

Have you read chapter 24?

a) Yes
b) No, I’m going to smuggle dice into the testing center.

What is the point?

• Atoms can join together.
• Little pieces (atoms and molecules) can make bigger pieces.
• The properties of the bigger pieces depend on the same ideas as the properties of the little pieces.

What we’ve talked about so far

• Some properties depend on forces within each unit. (intramolecular forces)
  – Conductivity, color both depend on electron orbital configurations
• Some properties depend on forces between units. (intermolecular forces)
  – Melting points, malleability

Atomic-Level Structure of Complex Materials Determines Properties

Animals & Vegetables
Fats (obtained from animals) & Oils (obtained from vegetables)
  Covalent Molecules Whose Melting Points Are Related To Behavior in Our Bodies

Minerals
Silicate Mineral Family Primarily Ionic Material
  Different Arrangements of SiO$_4^{4-}$ units leads to stringy, sheet-like and chunky minerals

Fats and Oils differ in Their Physical State at Room Temperature

<table>
<thead>
<tr>
<th></th>
<th>Solid</th>
<th>Fat</th>
<th>Liquid-Solid mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicken Fat &amp;</td>
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<tr>
<td>Marbling in Meat</td>
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<td>Shortening (Crisco)</td>
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<tr>
<td>Butter</td>
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<td>Margarine</td>
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<tr>
<td>“Promise” or “Benacol”</td>
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<tr>
<td>Olive Oil</td>
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<td>Canola Oil</td>
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<tr>
<td>Fish Oil</td>
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Fish Oil Liquid Oil
**Sequence of Melting Temperatures**

<table>
<thead>
<tr>
<th>canola oil</th>
<th>olive oil</th>
<th>butter spread</th>
<th>stick margarine</th>
<th>butter</th>
<th>shortening</th>
</tr>
</thead>
</table>

**WHY THIS SEQUENCE? UNDERLYING MOLECULAR STRUCTURES**

**Heart Healthy Sequence (approximately)**

- maybe the best for you

**Which is Worse, and Why?**

- Margarine
- Olive oil

**Fatty Acids – major component of fats and oils**

Describe the structures: What molecular groupings do they have in common?

- Hydrocarbon tail
- CO₂H

**Fatty Acids – major component of fats and oils**

Describe the structures: How does one differ from another?

- Length of the tail
  - \((\text{CH}_2)_n\text{CH}_3\)
  - \(n=10\)
  - \(n=14\)
  - \(n=16\)
  - \(n=18\)

**What difference does a tail make?**

<table>
<thead>
<tr>
<th>Melting Temperature (°C)</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>20</td>
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<td>40</td>
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<tr>
<td>60</td>
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<tr>
<td>80</td>
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</table>

<table>
<thead>
<tr>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
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<tbody>
<tr>
<td>0</td>
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Fats containing these fatty acids are solids at room temperature

Room temperature

**Why does making the tail longer increase the melting temperature?**

1. As the tail lengthens, the molecule gets heavier so it does not move as fast
2. As the tail lengthens, the opportunity for dispersion interactions increases (there are more points of contact)
3. As the tail lengthens, it becomes more likely to tangle with tails on neighboring molecules
4. All of the above
How do we get oils? (lower melting temperatures) A new family of fatty acids

Its members have the CO2H — group

How do we get oils? (lower melting temperatures) A new family of fatty acids

They have the hydrocarbon tail.

So What’s Different?

THE TAILS HAVE KINKS!

Straight chain vs Kinky chain

Room temperature

Fats containing these fatty acids are solids at room temperature

Oils containing these fatty acids are liquid at room temperature

What difference does a kink make?

If you were a fish, swimming in the cold North Atlantic, what would you want flowing through your veins?

What causes the kinks? Differences in the Tails

- **Saturated** fatty acids
  - No kinks
  - each C has 2 H atoms
  - (carbon-carbon single bonds)

- **Unsaturated** fatty acids
  - One kink (mono)
  - More than 1 kink (poly)
  - Some C have only 1 H atom
  - (carbon-carbon double bonds)

Kinks occur at double bonds. (True of Unsaturated Fatty Acids that are found in Nature.)

Why do kinks make a difference?

Molecules without kinks can snuggle closer together.

RESULT:
- more & stronger dispersion forces between tails
- stronger hydrogen bonding between CO2H groups on different molecules
- Strong forces mean high melting temperatures
Vegetable oils have double bonds, so they tend to
1. Melt at lower temperatures than animal fats
2. Melt at higher temperatures than animal fats
3. Fight cavities

Cis vs Trans Double Bonds – Where are the H atoms?
- Cis Double Bond Gives Kink
- Trans Double Bond Has No Kink

When you compare which has the highest melting point?
What forces are important? How big are they in each case?
- Unsaturated Fatty Acid Kink at Double Bond
- Unsaturated Fatty Acid But no Kink at Double Bond

Good Fats vs Bad Fats
- Good Fats: kinky unsaturated fats
  - low melting points
  - don’t clog your arteries
  - good for your brain
  - olive oil
  - cold water fish
- Bad Fats: un kinky fats
  - saturated & trans-fats
  - high melting points
  - solidify and block blood flow
  - lard
  - shortening
  - prime rib

What are rocks made of?
- MINERALS!
  - MOST rock forming mineral belong to a family of minerals called “SILICATES”
  - They all utilize the SiO₄⁻ covalently bonded molecular ion (What is its shape?)
  - This molecular ion may be put together in many different ways (just like the C and H molecules of organic matter)
    - Chains
    - Rings
    - Sheets
    - Isolated SiO₄ groups

Which structures do these minerals have? How can you tell?
The basis of Silicate Minerals:
The Silicate ion, $\text{SiO}_4^{4-}$

![Tetrahedral arrangement of oxygen atoms around a central silicon atom](image)

What else do we need to make silicate minerals?

- The $\text{SiO}_4^{4-}$ group is negatively charged, so...
  - We need some positive charge to make the mineral electrically neutral
    - K$^+$ and Na$^+$
    - Fe$^{2+}$, Ca$^{2+}$, and Mg$^{2+}$
    - Al$^{3+}$
    - Ti$^{4+}$
  - Or we need to arrange the $\text{SiO}_4^{4-}$ groups so that the mineral is neutral

Some silicate minerals are colored, and others are not. What is a reasonable hypothesis to explain this?

1. Colored silicates contain transition metal ions, which have electronic transitions in the visible
2. Colored silicates contain alkali metal ions, with electronic transitions in the UV
3. Colored silicates contain noble gas atoms, making them very stable

Minerals with Isolated Silica Tetrahedra

- Olivine – $(\text{Mg,Fe})_2\text{SiO}_4$
  - This is the main mineral component in the Earth’s mantle
  - How does this mineral achieve neutral charge?
  - How are the $\text{SiO}_4^{4-}$ groups arranged in the mineral?
  - Why do most olivine crystals contain both Mg and Fe?

SiO$_4^{4-}$ - a versatile connector

- It is found in minerals
  - as isolated units
  - as chains or double chains
  - or as flat sheets of connected chains
  - Two tetrahedra share an oxygen atom at the connection

Wait, there’s still more….

- or as networks connected equally in all directions
Formation of Fibers

Positively Charged Ions (Ca²⁺, Mg²⁺) → Double Chain → Strongly-bound unit: “Submarine sandwich” → You can pull apart fibers with your fingers

Formation of Sheets

silicate sheets with negative charges → Positively Charged Ions, K⁺ and/or Na⁺ → Small Al³⁺ Ions → You can pull apart sheets with your fingers

Which of these minerals do you think contains a transition metal?

- Muscovite mica
- Biotite mica

Formation of Irregular Chunks

Tetrahedron-tetrahedron connections extend in 3 directions. Interactions are equally strong in all directions. → You need a hammer to break crystal into smaller chunks

Minerals with Connected Silica Tetrahedra

- If the silica tetrahedra share some or all of their oxygen atoms, how does that affect the total negative charge?
  - Where does the negative charge come from?
    - Each O atom has a -2 charge, Si a +4 charge

Remember: The corners of the tetrahedra are the O atoms
### Silicate Structures

<table>
<thead>
<tr>
<th>Type of Structure</th>
<th>Ratio of Si/O atoms</th>
<th># O’s shared</th>
<th>+ charge needed</th>
<th>Examples of Minerals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated Tetrahedra</td>
<td>SiO$_4$ 1:4</td>
<td>0</td>
<td>+4</td>
<td>Olivine</td>
</tr>
<tr>
<td>Double Tetrahedra</td>
<td>Si$_2$O$_7$ 1:3½</td>
<td>1</td>
<td>+3</td>
<td>Epidote</td>
</tr>
<tr>
<td>Single Chains</td>
<td>SiO$_2$ 1:3</td>
<td>2</td>
<td>+2</td>
<td>Pyroxene</td>
</tr>
<tr>
<td>Double Chains</td>
<td>Si$_2$O$_7$ 1:2½</td>
<td>2.5</td>
<td>+1.5</td>
<td>Asbestos</td>
</tr>
<tr>
<td>Sheets</td>
<td>Si$_2$O$_7$ 1:2½</td>
<td>3</td>
<td>+1</td>
<td>Mica</td>
</tr>
<tr>
<td>Framework</td>
<td>SiO$_2$ 1:2</td>
<td>4</td>
<td>0</td>
<td>Quartz</td>
</tr>
</tbody>
</table>