REVIEW and INTRODUCTION:

A. Problem Analysis:

1. Review of errors associated with indirect restorations:
   a. Impressions = 0
   b. Casts and Dies = 0
   c. Wax-up = 0
   d. Investing = +
   e. Casting = −
   f. Finishing, Polishing = 0
   g. (Porcelain Application) = ?
   h. Cementation = 0

B. Requirements for Casting Investments:

1. Expansion: 1.2-2.2% compensation for alloy shrinkage
   a. Gold alloy contraction: 1.4-1.7%
   b. Base metal alloy contraction: 2.0-2.3%
2. Accuracy: Resistance to distortion during setting
3. Strength: Resistance to casting forces and high temperatures
   a. Refractory: Material with high mp that resistant to high temperature

C. General Formulation for Investment Materials:

1. Refractory FILLER: [66%] = Quartz, Cristobalite
2. BINDER (Matrix): [33%] = Gypsum, Phosphate, Silicate
3. ADDITIVES (Modifiers): [1%]

D. Dimensional Changes in Investment and Casting:

1. Setting Reaction: Chemical Reaction (Formation) = [-]
   Physical Reaction (Xl Growth) = [+]
2. Hygrosopic Reaction: Physical Reaction (Xl Growth) = [+]
3. Thermal Reaction: Chemical Reaction (Decomposition) = [-]
   Physical Reaction (Thermal Expansion) = [+]
4. Casting Shrinkage: Physical Reaction (Thermal Contraction) = [-]

TOTAL: = [0]
ANALYSIS OF INVESTMENT REACTIONS:

A. Setting Reaction:
   1. Chemical reaction involves minor contraction
   2. Crystallization involves crystal impingement and expansion

B. Hygroscopic Reaction:

![Graph showing expansion over time for normal setting investment and hygroscopic setting investment.]

![Diagram illustrating various temperature changes and volume changes during setting and investment processes.]

\[ +\Delta V \text{ from LCTE and inversion of the fillers} \]
\[ +\Delta V \text{ from hygroscopic expansion} \]
\[ -\Delta V \text{ from cooling of alloy} \]
C. **Thermal Reactions:**

1. Review of Phase Changes for Solid Phases:
   a. *Reconstructive Phase Transformation:*  
      (Equilibrium transformation)  
      (New crystal structure; Long range diffusion required; Very SLOW)
   b. *Displacive Phase Transformation:*  
      (Non-equilibrium transformation= INVERSIONS)  
      (Distorted crystal structure; No diffusion required; Very FAST)

2. Review of Equilibrium and TTT Diagrams for SiO₂:

   ![TTT Diagram](image)

3. Silica Filler:
   a. Exists as 4 forms (3 undergo displacive transformations and inversions)
   b. Unique thermal expansion coefficients for each form

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
<th>Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fused Silica</td>
<td>(Non-Crystalline, Glass)</td>
<td>1.7% from RT to 600 °C</td>
</tr>
<tr>
<td>Cristobalite</td>
<td>(Crystalline)</td>
<td>0.9% from RT to 600 °C</td>
</tr>
<tr>
<td>Tridymite</td>
<td>(Crystalline)</td>
<td>1.5% from RT to 600 °C</td>
</tr>
<tr>
<td>Quartz</td>
<td>(Crystalline)</td>
<td></td>
</tr>
</tbody>
</table>

![Thermal Expansion Curves](image)
A.D.A. SPECIFICATIONS FOR INVESTMENTS:

A. Specification #2:

1. Type I: Inlays, Crowns: Thermal Expansion Types (0.0-0.6%)
2. Type II: Inlays, Crowns: Hygroscopic Types (1.0-2.0%)
3. Type III: Partial Dentures: Thermal Expansion Types

ANALYSIS OF INVESTMENT MATERIALS:

A. Gypsum Bonded Investment, GBI: (Low Temperature Investment)

1. Chemical Composition:
   a. Binder: 25-45% alpha calcium sulfate hemihydrate
   b. Filler:
      (1) Quartz, or
      (2) Cristobalite
   c. Modifiers
      (1) Colorants:
      (2) Reducing Agents:
      (3) Shrinkage Controllers: Boric Acid, NaCl

2. Setting Reaction:

\[
CaSO_4 \cdot (1/2)H_2O + (3/2)H_2O \rightarrow CaSO_4 \cdot (2)H_2O
\]

3. Dimensional Changes:
   a. Contraction due to the chemical reaction
   b. Expansion due to impinging crystal growth
   c. Expansion facilitated by hygroscopic technique
   d. Contraction due to calcium sulfate dehydration (~200 °C)
   e. Contraction due to calcium sulfate de-sulfonation (~700 °C)
   f. Expansion due to thermal inversions of cristobalite (and quartz)
   g. Contraction due to cooling of casting alloy

4. Applications: Gold casting alloys
B. **Phosphate Bonded Investment:**

1. Chemical Composition:
   a. Binder:
      (1) MgO + Acidic Phosphate (Mono-ammonium phosphate) as powder
      (2) Aqueous colloidal silica suspension generally as liquid
   b. Filler:
      (1) Quartz, and/or
      (2) Cristobalite
   c. Modifiers:

2. Setting Reaction:

   \[
   \text{NH}_4\text{H}_2\text{PO}_4 + \text{MgO} + 5\text{H}_2\text{O} \rightarrow \text{NH}_4\text{MgPO}_4 \cdot 6\text{H}_2\text{O}
   \]
   (Many more complex reactions take place during heating)

3. Dimensional Changes:

   (Parallels GBI investment in all ways except that there is much less chance for alloy contamination by investment decomposition reactions.)

4. Applications:
   a. Generally used for P/M restorations
   b. Much more popular use for all restorations

5. Commercial Examples (Ceramigold, Fast-Fire, Powercast)

C. **Silicate Bonded Investment:**

1. Chemical Composition:
   a. Binder:
      Sodium Silicate + Acid
   b. Filler:
      (1) Quartz, or
      (2) Cristobalite
   c. Modifiers:

2. Setting Reaction:

   Sodium Silicate + Acid \(\rightarrow\) Silicic Acid Gel
   (Silicic acid gel reverts to silica during burnout)

3. Dimensional Changes:

   (Same as for GBI case)
   (Better expansion because matrix and filler both silica for inversion)

4. Applications: High temperature casting alloys

5. Commercial Examples: (Hi-Temp)
MULTIPLE CHOICE STUDY QUESTIONS:

1. What are the error limits overall for indirect dental procedures?
   a. 0.2 %
   b. 0.5 %
   c. 1.0 %
   d. 1.5 %
   e. 2.0 %

2. What are the typical ranges of casting shrinkage that must be compensated for by the investment?
   a. 0.2 -0.5 %
   b. 0.5 -1.0 %
   c. 1.0 -1.2 %
   d. 1.2 -2.2 %
   e. 2.2 -3.0 %

3. How much filler is there in a typical investment composition?
   a. 20%
   b. 45%
   c. 66%
   d. 75%
   e. 94%

4. During the setting reaction of investment materials, the formation of the reaction product generate which one of the following dimensional changes?
   a. No change
   b. Contraction
   c. Slight expansion
   d. Large expansion
   e. Expansion and then contraction

5. How does hygroscopic expansion of investment materials occur?
   a. Crystal impingement producing expansive forces
   b. Production of more reaction products
   c. Production of a secondary reaction product
   d. Absorption of water by the filler phase
   e. Imbibition of water into the spaces between the phases

6. Thermal expansion of investment materials occurs by:
   a. Chemical reaction in the filler phases
   b. Chemical reaction in the binder phase
   c. Inversion of the filler
   d. Allotropic phase transformation
   e. Dehydration of the binder

7. Which one of the following filler phases undergoes the most expansion per unit of temperature?
   a. Fused Quartz
   b. Quartz
   c. Tridymite
   d. Cristobalite
8. What is the difference between quartz and cristobalite?
   a. The water content of the phases
   b. They are different inversions of the same phase
   c. They are different allotropic phases
   d. They are different chemical compositions
   e. They represent different amounts of crystallinity

9. Inversion of cristobalite occurs:
   a. Slowly over a range of temperature
   b. Slowly over a narrow range of temperature
   c. Rapidly over a narrow range of temperature
   d. In direct proportion to the temperature change

10. ADA specifications for Type II investment refer to materials that involve:
    a. Only hygroscopic expansion
    b. Only thermal expansion
    c. Both hygroscopic and thermal expansion
    d. No expansion

11. Gypsum bonded investments are generally used for:
    a. Gold casting alloys
    b. Ni-Cr casting alloys
    c. Titanium casting alloys
    d. Co-Cr casting alloys
    e. Ag-Pd casting alloys

12. The maximum usable temperature for gypsum bonded investment is:
    a. 650 °C
    b. 800 °C
    c. 1000 °C
    d. 1100 °C
    e. 1400 °C

13. Gypsum bonded investment materials do NOT contain which one of the following?
    a. Calcium sulfate hemihydrate
    b. Quartz
    c. Tridymite
    d. Cristobalite
    e. Boric Acid

NEW QUESTIONS (on PBI and SBI) from this point forward

14. Phosphate bonded investment materials do NOT contain which one of the following?
    a. Mono-ammonium phosphate
    b. Cristobalite
    c. Quartz
    d. Aqueous colloidal silica
    e. Silicic acid gel

15. What is the major application for phosphate bonded investments?
    a. Gold casting alloys for full crowns
    b. Partial denture frameworks
    c. Titanium casting alloys
    d. Casting alloys for P/M applications
    e. Low gold casting alloys
16. What is the advantage of phosphate-bonded-investment over gypsum-bonded-investment?
   a. Less alloy contamination during decomposition
   b. Much more expansion than the other two investment types
   c. Much more hygroscopic expansion is possible
   d. There is no shrinkage during the initial setting reaction
   e. They produce the smoothest surface castings of all types

17. Why does silicate-bonded-investment materials generally produce more expansion than the other two types of investment?
   a. Additions of tridymite filler
   b. Formation of silica binder as well during burnout
   c. Use of special modifiers
   d. Use of large particle sized quartz particles
   e. Use of less liquid during the setting reaction

18. What types of alloys generally require the use of silicate-bonded-investment?
   a. Gold based alloys
   b. Ag-Pd alloys
   c. Low gold alloys
   d. Co-Cr alloys
   e. Titanium alloys

DISCUSSION STUDY QUESTIONS:

- Why are phosphate bonded investment or silicate bonded investment NOT used for casting gold based alloys?
- Which one of the three types of investment materials is more prone to decomposition and subsequent alloy surface contamination?
- During expansion there is mold space distortion due to the asymmetry of the space involved?
- Does distortion occur more during hygroscopic expansion or during thermal expansion?
- What type of investment material should be used for casting titanium? Be careful in your answer.