# Five-Layer Density Column

A density column consists of layers of liquids of different densities which do not mix with each other, and which are clearly distinguishable from each other. The highest density material is at the bottom of the column, and as you proceed up the column, the density of each successive layer decreases, with the lowest density layer on top.

Three methods for construction of a five-layer density column are discussed in this write-up. All methods use the same five liquids.
• **Method 1** gives the names of the liquids and the order for adding them, and its goal is to directly construct the density column without any experimentation.
• **Method 2** assumes names and densities of the five materials to be unknown, and involves open-ended experimenting, with few instructions, to construct the column.
• **Method 3** also assumes names and densities of the materials to be unknown, and outlines a systematic way to approach the experimentation involved in constructing the column.

## METHOD 1

Obtain a clear plastic container whose size meets your needs, and **carefully** add appropriate amounts of the following materials in the order specified (the first material listed is the most dense, and should be added first:

**water** -- color with an appropriate amount of food color before pouring

**canola oil** -- don't add food color (it won't dissolve in oil)

**60% isopropyl alcohol** -- you can buy 70% isopropyl at drug stores and grocery stores -- it's used as rubbing alcohol and disinfectant -- you then have to dilute it to make it 60% -- add 2 ml of water to every 10 ml of alcohol, or 20 ml of water to every 100 ml of alcohol -- before pouring, color with an appropriate amount of food color different from the first one

**mineral oil** -- baby oil is mineral oil, and can be used here, but ordinary mineral oil is easily obtained at pharmacies and is cheaper -- don't add food color (it won't dissolve in oil)

**91% isopropyl alcohol** -- you can buy 91% isopropyl at most drug stores, and sometimes at grocery stores -- it's used as a disinfectant, particularly for pierced ears -- before pouring, color with an appropriate amount of food color different from the previous two

**Helpful Hints:**
• Layers should probably be a minimum of about 1/2 inch thick, and pouring should be gentle, to avoid a layer falling through the layer it is being poured on and interacting with the layer below that one. If the container is small, consider using a pipette or eyedropper. This is easier than pouring, and allows you to add the liquids very slowly and gently to prevent unwanted mixing.
• Sometimes the material the container is made of plays a role in how well the layers form, possibly due to surface tension effects.
• Try tilting the container a little so that the liquid you are adding runs down the side more slowly. Or try laying the new liquid very gently on the previous layer by having the dropper tip just barely above the liquid surface, so that the new liquid doesn't fall and hit the surface hard.
• Don't use too much food coloring – depending on the amount of liquid you are using, even one drop of food color may be enough. If the color is too dark, you can't see through it, and it's not as effective.

## METHOD 2

Treat the five materials as unknowns. Play around with them (i.e., experiment!) to determine which ones will allow food color dissolve in them, and the relative order of their densities. Use your results to construct the density column.


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## METHOD 3

Students receive liquids in containers labeled A, B, C, D and E. Neither the identity or density of any of the materials is given. Students also receive a copy of the Data Table below (or have them draw their own if desired). This is what students will fill in as they experiment. (NOTE FOR TEACHERS: In addition to the blank Data Table below, you will also find later in this handout a Sample Completed Data Table showing expected results, and a Teacher Reference Data Table showing actual substance names).

## Procedure

• use small test containers to find whether or not food coloring will mix with each of the five substances, and record in the data table

• for the liquids in which food color will dissolve, add food color to the supply BEFORE experimenting further with pairs of liquids -- also see **Helpful Hints** for Method 1 above

• use small test containers to carefully mix each of the required combinations to complete the table (e.g., A with B, A with C, etc.) -- note whether they mix or whether they form two layers -- if they mix, indicate MIX on the table -- if layers are formed, record the letter of the substance which is on top in the upper part of the data box, and the letter of the layer which is on the bottom in the lower part of the data box

## Data Table

| SUBSTANCE | A | B | C | D | E |
|---|---|---|---|---|---|
| FOOD COLOR DISSOLVES | | | | | |

| X | A | B | C | D | E |
|---|---|---|---|---|---|
| A | X | | | | - |
| B | X | X | | | |
| C | X | X | X | | |
| D | X | X | X | X | |
| E | X | X | X | X | X |


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## Analysis

Each time a substance is on the BOTTOM of a two-substance combination, give it a score of -1.
Each time a substance is on the TOP of a two-substance combination, give it a score of +1.
Each time two substances MIX, give each a score of 0.
When all combinations have been scored, add up the total score for each substance. The one with the LOWEST score is the MOST DENSE, and should be added first to the density column. The substance with the next lowest score should be added next, etc. (TEACHER NOTE: For more on this, see the Teacher Reference Data Table, and the detailed analysis following it.)

## Making the Density Column

Add the liquids to the density column in the order determined above.
**Helpful Hints:** For the liquids in which food color will dissolve, add food color to the liquid BEFORE adding the liquid to the density column. Also see **Helpful Hints** noted for Method 1 above.

# TEACHER INFORMATION FOR DENSITY COLUMNS

**Sample Completed Student Data Table** (having students include numbers is optional)

| SUBSTANCE | A | B | C | D | E |
|---|---|---|---|---|---|
| FOOD COLOR DISSOLVES | *NO* | *YES* | *NO* | *YES* | *YES* |

| X | A | B | C | D | E |
|---|---|---|---|---|---|
| **A** | X | *A (+1)*<br>*B (-1)* | *MIX* | *D (+1)*<br>*A (-1)* | *E (+1)*<br>*A (-1)* |
| **B** | X | X | *C (+1)*<br>*B (-1)* | *MIX* | *MIX* |
| **C** | X | X | X | *D (+1)*<br>*C (-1)* | *C (+1)*<br>*E (-1)* |
| **D** | X | X | X | X | *MIX* |
| **E** | X | X | X | X | X |


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## Teacher Reference Completed Data Table

| **SUBSTANCE** | **A** *CANOLA OIL* | **B** *WATER* | **C** *MINERAL OIL* | **D** *91%ALCOHOL* | **E** *60%ALCOHOL* |
|---|---|---|---|---|---|
| **FOOD COLOR DISSOLVES** | *NO* | *YES* | *NO* | *YES* | *YES* |

| X | **A** *CANOLA OIL* | **B** *WATER* | **C** *MINERAL OIL* | **D** *91%ALCOHOL* | **E** *60%ALCOHOL* |
|---|---|---|---|---|---|
| **A** *CANOLA OIL* | X | *canola* ---------- *water* | MIX | *91% alcohol* ---------- *canola* | *60% alcohol* ---------- *canola* |
| **B** *WATER* | X | X | *mineral oil* ---------- *water* | MIX | MIX |
| **C** *MINERAL OIL* | X | X | X | *91% alcohol* ---------- *mineral oil* | *mineral oil* ---------- *60% alcohol* |
| **D** *91%ALCOHOL* | X | X | X | X | MIX |
| **E** *60%ALCOHOL* | X | X | X | X | X |

Analysis of results shows the following:
Substance A (canola oli) was on top once, and on the bottom twice; we will call this a net score of **–1**
Substance B (water) was on the bottom twice, for a net score of **–2**
Substance C (mineral oil) was on the top twice and the bottom once, for a net score of **+1**
Substance D (91% alcohol) was on top twice for a net score of **+2**
Substance E (60% alcohol) was on top once and on the bottom once, for a net score of **0**

Arranging the substances in order, from most dense to least dense (i.e., starting with –2, and proceeding to +2, we find the order of density to be: **WATER, CANOLA OIL, 60% ALCOHOL, MINERAL OIL, 91% ALCOHOL**.

When placed into a container in this order, with food colors added to the water and the two alcohols, a 5-layer density column will be formed.


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## Other Miscellaneous Items

Post-Lab Question: For each of the statements below, circle T if true, or F if false

a. T F water mixes with alcohol
b. T F water mixes with oil
c. T F oil mixes with alcohol
c. T F oils mix with each other
d. T F alcohols mix with each other

A NOTE ON HELPFUL HINTS: READING THE HELPFUL HINTS BEFORE MIXING LIQUIDS AND MAKING THE COLUMN MAKES FOR A MORE EFFICIENT PROCESS WITH BETTER CHANCE FOR INITIAL SUCCESS. BUT IF TRYING THINGS FIRST IS INTRIGUING, IT IS HIGHLY ENCOURAGED. THE HINTS CAME FROM ACTUAL TRIAL AND ERROR EXPERIENCES, AND IN FACT WERE GENERATED AS MUCH BY FAILURE, AND THE NEED TO FIND A BETTER TECHNIQUE, THAN BY INITIAL SUCCESS. YOU CAN OFTEN LEARN A LOT FROM "FAILURE," AND IN BYPASSING IT YOU SOMETIMES LOSE SOME OF THE RICHNESS OF THE EXPERIENCE. ONE GOOD THING ABOUT MAKING A SMALL COLUMN IS THAT YOU DON'T WASTE MUCH MATERIAL IF YOU BLOW IT AND HAVE TO START OVER!

## References

Sarquis, Jerry L.. Mickey Sarquis, John P. Williams, *Teaching Chemistry with Toys*, TAB Books, 1995. See Frustration Bottles, pp. 239-243.
Borgford, Christie L., Lee SR. Summerlin, *Chemical Activities; Teacher Edition*, American Chemical Society, 1998. See Layers of Liquids, pp. 27-28.


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