STABLE MATES

Materials: Collection of “magic” marbles.

COMMENTARY

We might ask why Nature chooses to arrange things according to certain patterns. Why do you suppose snowflakes have six sides and not five or seven? Why do bees make honeycombs with cells in the shape of hexagons? Why is DNA a double helix? Why are crystals of rock salt always cubes? Why do atoms mate, or arrange themselves in molecules only in certain ways?

Perhaps we might look for an answer that takes into account the binding forces between objects, like atoms, and the relative stability of the assembled structure.

In this exercise, you will be messing about with some special marbles. Let’s call them “concentrically constructed dipolar spheroids” for now. Your task is to determine how they “work”, how to test for stability of assembled structures, and to determine which structures are the most stable. You will also take a look at the forces between the marbles and groups of marbles when they interact.

INQUIRY

Firstly, let’s try and figure out just how these spheroids, or magic marbles work by making some indirect observations. Take three of the marbles and devise a means of testing which will allow you to determine how they are constructed. In your portfolio, write what your experimental was and, if you later modified it, what changes you made. Next, write your conclusion. What do you think is inside the marbles that makes them behave as they do?

Now we will be assembling the marbles to produce structures. Let’s start with two very simple ones. We will also confine ourselves to two dimensions (a flat surface) unless otherwise stated.

- Start with only three marbles (again). You can produce two possible structures, or stable arrangements. One is a straight line and the other is an equilateral triangle. Experiment a bit and find a means of determining which arrangement is more stable and describe it in your portfolio. Rank the two arrangements using one of the three following descriptors: **very stable**, **somewhat stable**, or **unstable**.

- Repeat the ranking exercise with four marbles. Draw a diagram of the arrangements you produce and describe each as very, somewhat, or not stable.

- Repeat the above for five marbles. Include diagrams and ranking.

- Repeat the above again for six marbles.

- Arrange six marbles so they form a hexagonal ring. This is an important structure in biology and organic chemistry known as a Benzene ring. Is it very stable? Now try and insert extra marbles inside the ring. Does adding one reduce the stability of the ring structure? Two? What happens when you squeeze in three? Is there a preferred arrangement (meaning it is more stable)?

- Produce as many structures as you can which are very or somewhat stable and rank them as one or the other, along with a diagram. Some of these structures can be quite complicated, perhaps symmetrical shapes with other arrangements inside. You can feel free to work in three dimensions as well as two.

I think you've determined that there are permanent magnets inside the marbles. A magnet is a good example of something called a ***dipole***. There is a North pole on one end and a South pole at the other. Dipoles can also be electrical in nature, opposite charges separated by some, usually small, distance. A water molecule, the most important solvent from the standpoint of living things, is also highly dipolar, with a positive end and a negative one. We have been observing stable arrangements for dipolar objects. Now let's look at how dipoles interact, or how the forces between them behave as a function of distance, or separation.

- Start with a line of three marbles. Bring a fourth one near the ends and near the center. Where is the interaction the strongest?

- Repeat this with lines of four, five, and six marbles.

- Now make a long line, perhaps ten or fifteen marbles long. Bring another one close to the end. It moves like a snake, doesn't it? Would you classify the interaction with the end marble as a strong one? What happens when you bring the marble near the center?

- Do the forces (attractive or repulsive) between marbles drop off, or decrease, when the distance between them is increased more rapidly near the end of the chain or the center?

- Now, compare forces between one marble and the end of the chain to that between two marbles and the end. Repeat for three and four. Which results in the strongest interaction?

- Finally, draw a conclusion about how magnetic marbles interact. Can the fields reinforce or detract from one another depending on how they are arranged? Support your answer with a diagram or two: