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Feature article

DEMONSTRATING CLOSE-PACKING OF ATOMS USING SPHERICAL BUBBLE GUMS

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ABSTRACT: In this paper, the use of spherical bubble gums (Gum Balls) to demonstrate the close-packing of atoms and ions is presented. Spherical bubble gums having distinctive colours were used to illustrate the different layers in variety of crystalline packing and the formation of tetrahedral and octahedral holes. Students with hands-on experience of building the different packing models could better understood the close-packing of atoms.

Key words/phrases: Bubble gums, crystal packing, cubic and hexagonal packing, molecular modelling, octahedral and tetrahedral holes

INTRODUCTION

The concept of close-packing of atoms or ions in crystalline solids is often discussed in general chemistry and junior inorganic chemistry courses. However, the subject of three dimensional close-packing of atoms has always been difficult for students to understand. In particular, students find it difficult to visualize the packing of atoms in different layers. They cannot clearly identify tetrahedral and octahedral holes, and differentiate hexagonal and cubic close-packing.

In order to illustrate close-packing, chemistry instructors have constructed models from tennis balls (Birnbaum, 1972), polystyrene spheres (Lloyd and Silver, 1977), Styrofoam balls (Kenney, 1958; Sime, 1963; Birk and Coffman, 1992) and metal ball bearings (Mellor and Shuk, 1962). However, using these materials has some degree of limitations. For example the Styrofoam balls are unfriendly to the environment. The metal ball bearing and polystyrene spheres are heavy and easily collapse when models are built (Lloyd and Silver, 1977). Most importantly, these materials are relatively expensive and are not readily available.

In this paper, we report the use of spherical bubble gums (gum balls) to demonstrate close-packing of atoms. The advantages of using spherical bubble gums are: 1) very economical, bubble gum packets can be purchased fairly cheap; 2) easily available in grocery stores and shops; 3) available in distinctive vibrant colours making them suitable to clearly show the different layers; 4) easy to build and safe in any environment. Therefore, these advantages make bubble gums simple and effective materials to illustrate close-packing in atoms and ions. The ready availability of bubble gums encourages students to explore the models by themselves at home or school.

MATERIALS

Three bags of bubble gums consisting of different colours, 1.00 mm thick hard plastic sheet (21 x 20 cm), a tape, a ruler and scissors have been used for constructing the models.

The size of the box required to contain the bubble gums depends on their diameters. To make the box four 7.3 cm x 5.0 cm rectangular pieces of plastic were cut from the plastic sheet and all were taped end to end on the long side. The two ends were connected and taped to form a square box. Another 7.3 cm x 7.3 cm plastic piece was cut and used to cover the bottom by attaching with tape. This box is used to build simple and body- centred cubic models. For hexagonal and cubic close-packing, a box with a width of 6.8 cm and length of 5.0 cm was made as described above.

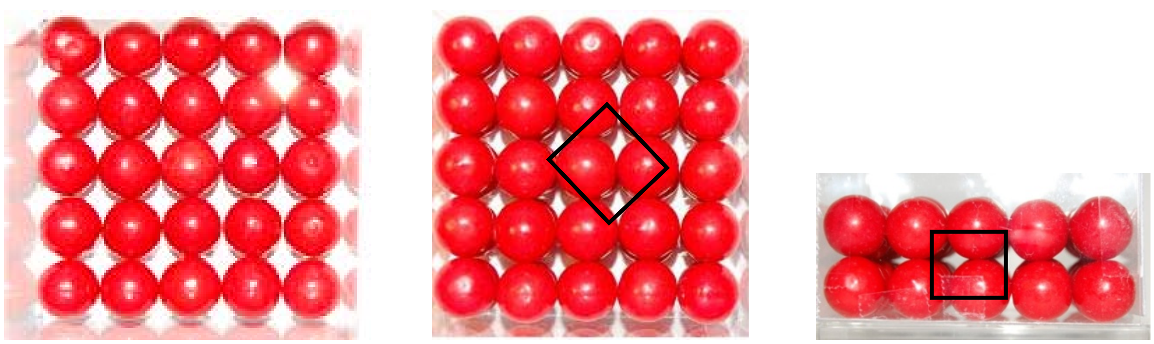
BUILDING THE MODELS

Simple Cube Model

In this illustration, the bubble gums represent atoms or ions of metals. Bubble gums of equal size (1.40 cm in diameter) were placed side by side in the square plastic box to form the first layer as shown on Figure 1a. The successive layers were stacked by placing bubble gums directly above the lower layer. This arrangement resulted in a simple cubic structure. After building the first two or three layers, it is possible to identify a unit cell. Counting the number of gums that are around a given gum will enable to evaluate the coordination number. Figure 1b shows that each gum is touched by four gums on the same plane and one gum below and one above (third layer needed) resulting in a coordination number of six. Figure 1c shows one face of the unit cell. In this packing the gums are in a relatively less compact arrangement due to the large holes between the gums.

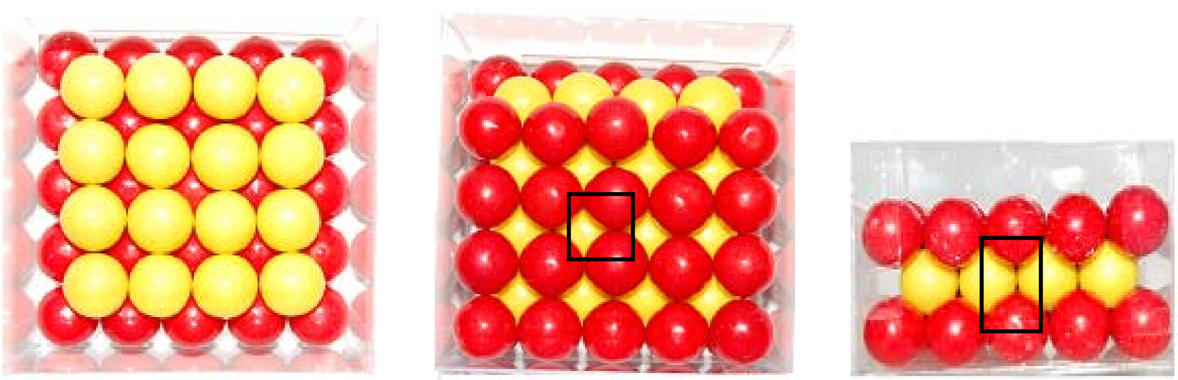
Body-Centred Cube Model

A better close-packing model with more compact arrangement than simple cube is obtained by placing the second layer of bubble gums over the holes of the first layer (Fig. 2a). The third layer was placed on the holes of the second layer (Fig. 2b). This stacked the third layer exactly over the gums of the first layer and provided a body-centred cubic (*bcc*) structure. From the packing structure, it is possible to identify a unit cell and note the coordination number. Each bubble gum (yellow) is surrounded by four other gums above and four below its plane resulting in a coordination number of eight (Fig. 2b-c).



a b c

Figure 1. Simple cube model. a) top view of the first layer, b) top view of the first two layers, c) side view of the two layers.

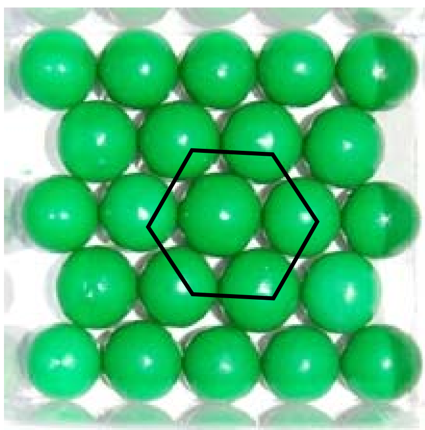


a b c

Figure 2. Body centred cube model. a) top view of the two layers, b) top view of three layers, c) side view of three layers.

Hexagonal and Cubic Close-Packing Models

The gums were placed in the plastic box in hexagonal arrangement as shown in Figure 3a to make the first layer. In this arrangement, the voids between gums are smaller than the one shown on Figure 1a. The second layer was made by placing different colour bubble gums on the voids of the first layer (Fig. 3b). Looking down the top of the second layer, one can clearly see the tetrahedral (Td) hole (green) and the octahedral (Oh) hole, the hole that is visible through both layers. To obtain the hexagonal close-packing (*hcp*), the third layer was placed on the voids directly over the bubble gums on the first layer (tetrahedral holes). This gave an ABAB… structure (Figs 3c-d). Placing the third layer above the octahedral holes, gave ABCABC… structure, called cubic close-packing (*ccp*) (Figs 4a-b). Both *hcp* and *ccp* have a coordination number of 12, six gums around the central gum and three above and three below. The numbers of tetrahedral and octahedral holes in Figure 3b were counted. There are two tetrahedral holes for each gum and these are located under each gum of the second layer and above each gum of the underneath layer. The number of octahedral holes for each gum is one. Octahedral holes are visible through both the first and the second layers surrounded by three gums on each layer.



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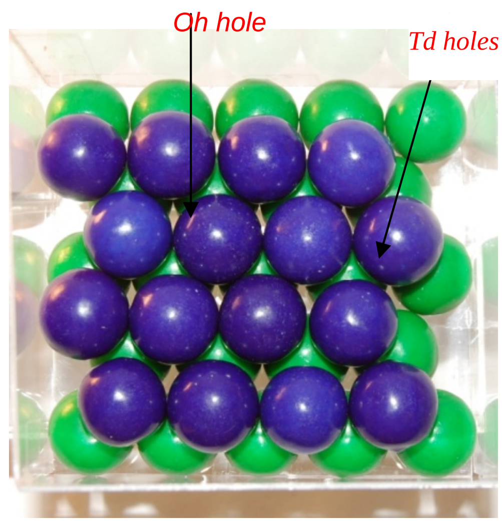

b

c

d

Figure 3. Hexagonal close-packing model. a) top view of the first layer of hexagonal packing, b) top view of the first two layers, c) top view of three ABAB… layers, d) side view of ABAB… layer.

a

b

Figure 4. Cubic close-packing model. a) top view of ABCABC.. layer, b) side view of ABCABC.. layer

Some students in our general chemistry courses have used bubble gums to build the close-packing models shown above. These students with hands-on experience were able to better understand the different types of packing and visualize the tetrahedral and octahedral holes. Other spherical materials of about the same size can also be used to build these packing structures.

CONCLUSIONS

Constructing close-packing models using bubble gums is a wonderful learning experience for college chemistry students. Students can build the models as hands-on activity in the class-room or at home. These activities enable students to clearly see the different patterns of packing in atoms as well as identify the octahedral and tetrahedral holes. Bubble gums are readily available, inexpensive and easy to build and visualize the models. These features make them attractive learning tools and will encourage students to use them as aids to understand close-packed structures.

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