Technical Report - 36

Models and Activities for Interactive Chemistry

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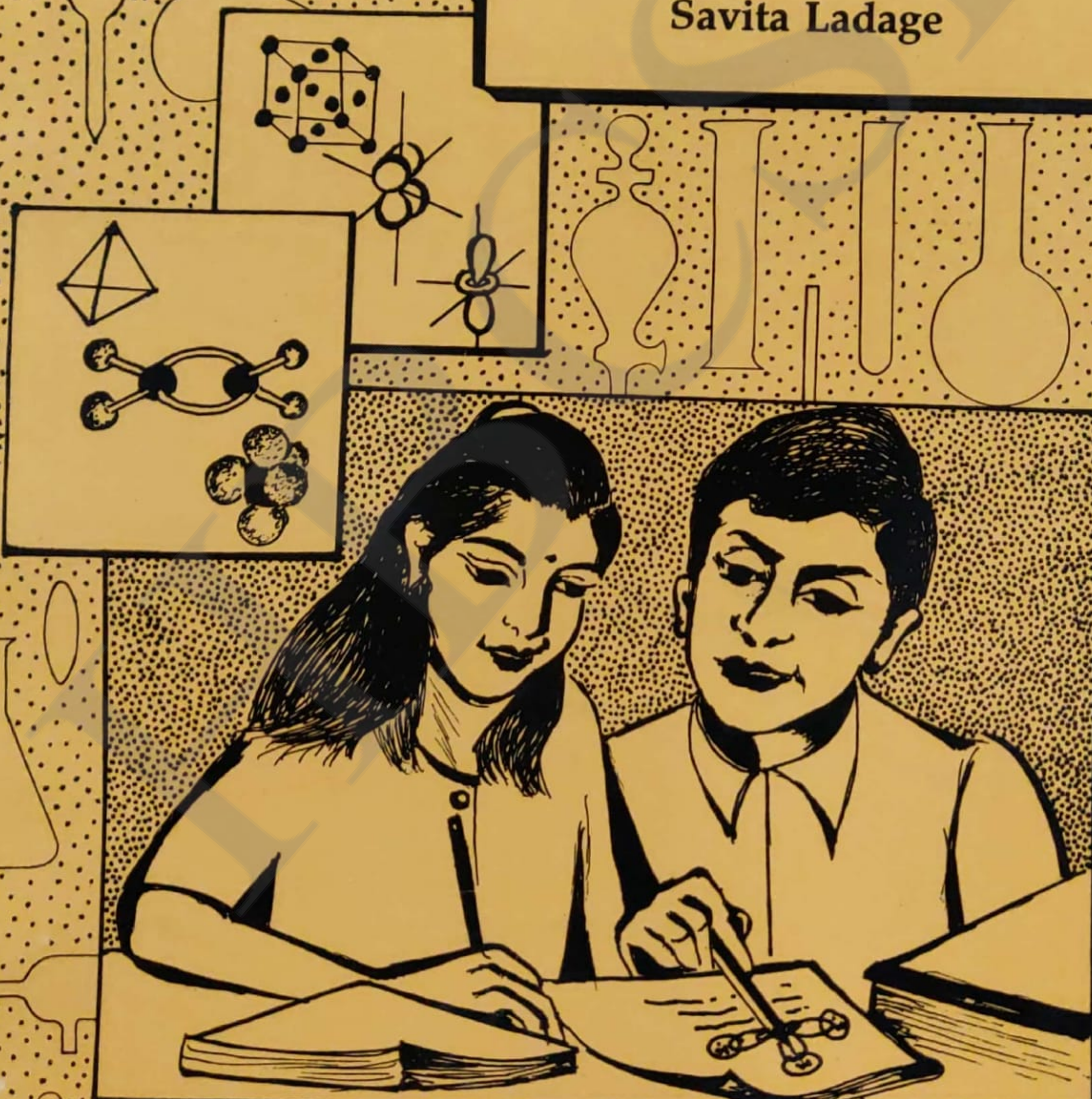

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Nilima Srivastava

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UNIT 1

INTRODUCTION

1.1 Background

The chemistry syllabus which is taught in the schools today, has three major components (Johnstone, 1993) - i) macro (visible and tangible descriptive chemistry), ii) micro or sub-micro (atomic and molecular) and iii) representational (symbols,formulae and equations). To learn concepts in chemistry, students have to deal with all these aspects simultaneously. Further, understanding of macro and representational aspects in terms of the sub-micro aspect is crucial in chemistry. This makes most of the fundamental concepts in chemistry abstract in nature and hence chemistry is perceived as a difficult subject (Ben-Zvi, 1988; Nakhleh, 1992). Because of the abstractness of many concepts, models, analogies, experiments are considered to play a crucial role in chemistry. The current monograph, describes attempts made at developing of activities and models for understanding of Lewis structures, shapes of molecules, periodic table and crystal structure. Many models for the stated topics are available in the market. However, the focus in the case of developed models and activities is on cheap and easily available material. Most of the activities and models can be done or assembled by the individual student, group of students or can be used for classroom demonstrations. The act of constructing and making of the models is important as it forces oneself to think analogically.

While using models (specially about abstract concepts such as atoms and molecules), it is important to note certain aspects. All these concepts which are presented through models have no perceptible instances or imperceptible attributes. So often there is a tendency to confuse a representation (that is, a model) with the represented concept itself. It is important to keep this fact in mind while using models and attempts should be made to sensitize students regarding such things.

The introductory chapter of the monograph initially discusses the chemistry syllabus from class IX to XII which gives an idea about the level at which the topics mentioned above are introduced to students. Subsequently, the chapter presents the analysis of a questionnaire which was administered to students of class X to seek their opinions about chemistry syllabus taught at class IX level. At the end of the unit, outline of the further units is presented.

1.2 Chemistry Syllabus from class IX to XII

This section discusses the various chemistry topics that students study from class IX to XII (please note that the syllabus stated for class IX and X is that of NCERT whereas for class XI and XII is that of Maharashtra state board). As the current monograph discusses the activities and models about covalent bonding and shapes of molecules; the periodic table and crystal structures, more emphasis is given to these topics as compared to other topics of the syllabus.

At class IX, students study the nature of matter which discusses Dalton's atomic theory, the structure of atom and radioactivity. The chapter on 'how elements are classified' deals with Mendeleef's periodic table and law, modern periodic table and some details about electronic configuration of elements. Since this is an introductory chapter, it concentrates more on structural aspects of the periodic table rather than the studying periodic trends of various properties.

The chapter on 'chemical bonding' deals with inert gas configuration, ions, atoms and valency, lattice structure of NaCl, bonding in ionic and covalent compounds and molecular shapes. This chapter introduces various diagrams for NaCl lattice structure, Lewis dot structures, projection diagrams for methane, ammonia and water, ball & stick diagram of ethylene, space filling model diagrams for sulphur hexafluoride & phosphorus pentachloride and ball and stick diagrams presenting the entire framework showing various planes of a molecule. No introduction regarding understanding of these structural representations is presented in the chapter.

The topic of chemical reactions deals with different types of chemical reactions, chemical formulae and equations, introduction to mole and balancing equations. The remaining part of the chapter pertains to energy changes in chemical reaction and some discussions related to photochemistry, electrochemistry and metallic corrosion.

Thus, at class IX, the main focus of syllabus is on conceptual chemistry rather than descriptive and applied chemistry. However, at class X, the focus of the syllabus shifts entirely to descriptive chemistry and applied fields of chemistry. During this stage, students study metal and metallurgy; hydrocarbons and also get acquainted with synthetic fibres, plastic, rubber, soaps and detergents. The latter topics present diagrams presenting covalent network of bonding of carbon atoms, in diamond and graphite. The hydrocarbon section deals with ball and stick model for methane and Lewis structures for ethane, ethene and ethylene.

At class XI, topics covering conceptual and descriptive chemistry are presented in the syllabus. The topics such as laws of chemical combinations, gas laws, mole concept, chemical equilibrium, redox reactions and atomic structure deal with conceptual chemistry. The chapter on the periodic table concentrates on periodic trends of various properties rather than structural aspects of the table. The other topics focus on metallurgy and study of aliphatic and aromatic hydrocarbons. The topic related to principles and methods of purification presents pictorial representations of four different shapes of crystals.

At class XII, more complex concepts related to chemical energetics, ionic equilibria, electrochemistry, nuclear chemistry, adsorption & colloids are introduced to the students. The topic dealing with 'nature of chemical bond' discusses covalent bonding in terms of atomic orbitals and geometry of various molecules in an elaborate manner. The topic uses pictorial diagrams presenting overlap of atomic orbitals for discussion. The topic 'chemistry of third row elements' deals the periodic variations of different properties in third row, chemistry of these elements and crystal structure of sodium, magnesium and aluminium in considerable detail. The chapter provides pictorial diagrams using solid spheres to illustrate the crystal structures. Other chapters concentrate on detail study of halogen derivatives of alkanes, hydroxy organic compounds aldehydes and ketones; acids, esters and ethers; amines and proteins; fats, oils and carbohydrates.

Thus, in conclusion, at class IX students are introduced to covalent bonding and various pictorial diagrams presenting shapes of molecules (average age of representative student is 14 years). However, detail study of chemical bonding is done at class XII (average age of students 17 years).

Regarding periodic table, structural aspects of modern periodic table along with Mendeleef's periodic table are studied at class IX whereas periodic variations of different properties within groups and periods are discussed at class XI. The chemistry of third row elements is done at class XII.

Brief introduction of crystal structure is presented at class IX whereas the crystal structures of three metals are studied at class XII. Pictorial representations of four shapes of crystals are presented at class XI.

1.3 Analysis of the questionnaire

In order to have some feel about students' views regarding different topics taught in chemistry, a questionnaire based on chemistry syllabus of class IX was administered to students of class X (class IX students had not completed the syllabus). It was not possible to administer similar questionnaire at class XI and XII for two reasons -
i) The study was conducted towards the end of second term and so to obtain a suitable sample was difficult and ii) The time period available to the researchers was rather short.
The sample of class X is also limited due to the same reasons.

1.3.1 <u>Data Collection</u>

a) *The questionnaire*

The questionnaire consisted of four different types of questions. The aim of the first question was to enable students to rate various chemistry topics from class IX syllabus according to the difficulty level on a three point scale. In the second question, similar rating for liking of the topics using a three point scale was done. The next question dealt with students' opinion about various strategies which will be useful for better understanding of the topics. The opinions regarding how interesting all these methods could be was asked in the last question. The time required for completing the answering of the questionnaire was 20 to 30 minutes. The questionnaire is presented in appendix 1A.

b) *Sample*

The questionnaire was given to the students of class X during the first week of February. The questionnaire was not administered to one particular class but to students belonging to different classes. These students belonged to Atomic Energy Central School No.4 (Bombay) and have all the facilities like well equipped laboratory, library etc. and favourable environment of teaching and learning. The group of children under study consisted of above average, average and below average students (no data in terms of marks was collected). However, one of the researcher is familiar with these students (as she teaches in the same school). The total sample of the students was 50. The age of students varied between 14 to 16 years. There were 27 girls and 23 boys in the sample.

Table A : Details of the Sample (N = 50)

Class	Age (years)	No. of girls and boys	Time taken	Period of administration
X	14 -16	G = 27;B = 23	20-25 mins	1st week of Feb.

1.3.2 Analysis of the data

As stated before, students were asked to rate the topics on a three point scale, that is, difficult, average and easy. Table 1.1 presents the responses of students to this question. The ranking of chapters was done by calculating the mean rating for each chapter in the following manner. The sum of the weighed ratings given by all students for that chapter was divided by total number of students. The chapter receiving lowest rating was ranked 1, the chapter with next lowest rating was ranked 2 and so on, till all the chapters were ranked.

Table 1.1 : Mean rating and ranking of various chapters at class IX

No.	Topic	Mean rating	Ranking
1	Atomic structure	2.54	8
2	Radioactivity	2.20	4
3	Periodic table	2.36	7
4	Chemical bonding	2.26	5
5	Mole Concept	1.70	1
6	Chemical reactions	2.00	3
7	Balancing equation	2.28	6
8	Energy changes in chemical reaction	1.76	2

The above table indicates that the topic of mole concept was perceived as the most difficult topic by the students. The next difficult topic was energy changes in chemical reactions. The topic of chemical bonding was perceived as average whereas the periodic table and atomic structure were perceived as easy to understand.

In the second question, students were asked to rate the topics according to their liking. The mean ratings and rankings of students is presented in table 1.2. The topic which is ranked the lowest, that is, 1 is the most liked topic whereas the topic which ranked 8 is the least liked by the students.

Table 1.2 : Mean ratings and ranking for liking of the topics

No.	Topic	Mean rating	Ranking
1	Atomic Structure	1.48	1
2	Radioactivity	1.56	2
3	Periodic Table	1.78	5
4	Chemical Bonding	1.76	4
5	Mole Concept	2.06	8
6	Chemical Reactions	1.96	6
7	Balancing Equation	1.68	3
8	Energy Changes in Chemical Reaction	1.98	7

The topic of atomic structure which was ranked as the most easy topic was perceived to be most interesting one and the most difficult topic, that is, mole concept was considered to be the most boring topic. The topics which were ranked average from difficultly point of view, viz. Chemical bonding and the periodic table were ranked moderately interesting (that is, OK). So in general, the easy topics were ranked as most interesting ones and vice-versa.

In the third question, students' opinions about various strategies that may be useful for better understanding of the topics were asked. The options provided were 'more interactive discussions', 'more of laboratory experiments', 'demonstrations', 'construction of various models' and 'drawings for illustration of concepts'. Table 1.3 displays the responses of students to the various options.

In case of chemical bonding, students prefer constructions of models and drawings for illustration (34% and 30% of total number of students, respectively). Interactive discussions (52%) and drawings for illustrations of concepts (30%) were preferred options for the periodic table. Regarding mole concept and balancing equations, 48% and 57% of students wanted more interactive discussions. Laboratory experiments including demonstration type were preferred for understanding of chemical reactions and energy changes involved.

Table 1.3: Students' responses to useful methods for understanding of topics

Sr	Topic	Inter-active discussion	More lab. expts.	Demons-tration expts.	Constru-ction of various models	Drawing for illustr-ation of concepts
1	Atomic Structure	14(28%)	4(8%)	5(10%)	30(60%)	8(16%)
2	Radioactivity	18(36%)	6(12%)	12(24%)	6(12%)	8(16%)
3	Periodic table	26(52%)	1(2%)	2(4%)	9(18%)	15(30%)
4	Chemical Bonding	9(18%)	8(16%)	6(12%)	17(34%)	15(30%)
5	Mole Concept	24(48%)	5(10%)	7(14%)	5(10%)	7(14%)
6	Chemical Reaction	7(14%)	30(60%)	9(18%)	3(6%)	7(14%)
7	Balancing Equation	27(54%)	8(16%)	3(6%)	7(14%)	6(12%)
8	Energy Changes in Chemical Reaction	15(30%)	13(26%)	14(28%)	8(16%)	6(12%)

In the last question, students were asked to rate the above options along with few other options on a three point scale, that is, like very much, ok and not at all. The following table 1.4 displays mean ratings and rankings for various options.

Table 1.4: Students' mean rating and ranking to various methods

NO	Methods	Mean rating	Raking
1	Lecture	2.26	9
2	Problem solving	1.52	6
3	Discussions	1.58	8
4	Demonstrations	1.44	5
5	Experiments	1.10	1
6	Building models	1.54	7
7	Quizzes on topics	1.34	3
8	Trips to ...	1.30	2
9	Class activities	1.38	4

The above table indicates that the methods in which the students can participate actively were preferred by students as compared to lectures where they were just passive listeners. The options that are liked most by students are experiments, trips to various places and quizzes on topics. Class activities, demonstrations and problem solving are moderately liked by students. However, building models is ranked as not so much liked option by students. One probable reason for this ranking could be lack of such experiences in regular school hours (as compared to other options). Rarely, sessions devoted to constructions of models in order to understand the scientific concepts are conducted in the classroom situations. Sometimes, models are built as a part of an activity during the science exhibitions or projects during school vacations.

1.3.3 Conclusion

The topics like periodic table and chemical bonding are perceived as average from difficulty point of view and these topics are moderately liked by students. Participatory methods such as doing experiments, solving quizzes are liked more as compared to the methods where students are passive listeners or observers. For better understanding of topics, students, once again prefer participatory methods such as performing experiments, interactive discussions and constructing models.

1.3.4 Outline of subsequent units

As stated before, the monograph covers activities and models regarding chemical bonding, periodic table and crystal structure. For the unit of chemical bonding, details regarding various models and activities are presented along with worksheets which concentrate on sequencing of various concepts required to understand the topic. This also illustrates as to how to use the prepared models and activities while teaching. However, it should be noted here that the actual testing of these developed worksheets is not carried out due to constraint of time. All the diagrams and material used for preparation of models are stated in the unit along with some options.

Regarding periodic table, the focus is on how to prepare cards of different elements for construction of periodic table with some suggestions pertaining to use of these cards. No separate worksheets like the previous chapter are given in the unit of periodic table. For crystal structure, once again the emphasis is laid on preparations of models for learning the packing arrangement of atoms in different metals.

UNIT II

ACTIVITIES AND MODELS FOR CHEMICAL BONDING

2.1 Introduction

This chapter presents activities and models regarding chemical bonding. The topic begins with discussion on Lewis structures followed by VSEPR approach for prediction of geometry of molecules. The orbital approach for molecular shapes is discussed after the VSEPR approach. In all these sections, the developed activities and/or models are discussed first followed by worksheets which can be used while teaching these concepts. Before going to these sections, a brief summary of research regarding students' difficulties about covalent bonding and molecular shapes is presented in the next section.

2.2 Difficulties regarding covalent bonding and molecular shapes

Research regarding students' difficulties with various chemical concepts started somewhere in 1980s'. Nakhleh (1992) has presented excellent review of various studies conducted. Peterson and Treagust (1989) by using paper and pencil test have studied grade 12 students' difficulties (N = 243) about covalent bonding and structures. They came across eight misconceptions dealing with bond polarity, molecular shape, the octet rule and intermolecular forces. It was observed by them that 74% of the students could not apply valence shell electron repulsion theory (VSEPR theory) to the resultant geometry and structure of molecules. Furio and Calatayud (1996) summarise the knowledge, skills and main difficulties of students in predicting geometry of molecules. They state that students have difficulties in visualising three-dimensional structures. Students confuse between arrangement of electron pairs and shape of molecules. Another observed difficulty was that Lewis structure representations were frequently mistaken as the shapes of molecule. Turkey, Selvaratnam and Bradley (1991) have mentioned about difficulties of university level students with three-dimensional thinking. In their research, they have suggested methods to improve such thinking with proper remedial programmes. Barke (1993) states that spatial ability with respect to structural chemistry is not developed sufficiently till eighth grade (age 14 years). He further states that using structural models and illustrations, it is possible to improve the spatial abilities of students.

As all these studies indicate, that the students do have genuine problems in understanding molecular shapes. It is difficult to imagine three dimensional shapes of molecules from the two dimensional diagrams or representations which are presented in the textbooks. Three dimensional models are therefore more useful for understanding of molecular shapes and should be preferably used while teaching molecular shapes. Many models such as ball & stick models, space filling models, framework models are available in the market but remain inaccessible to students. The space filling models in general focus more on precise size of atoms whereas in case of the framework models, greater attention is paid to bond lengths and bond angles. The role played by the ball and stick models is somewhere between the two approaches as they try to represent both the features, that is, atomic size and bond lengths. All of these molecular models are analogical models and use of such models help students to think analogically. Hardwicke (1995) has presented a good review about various available models.

2.3 Lewis Structures

A Lewis structure is a representation of covalent bonding using Lewis dot symbols in which the shared electron pairs are shown as lines or as pair of dots between two atoms. Lone pairs of electrons or non-bonding electrons, that is , the electrons which have not participated in bonding are shown as pair of dots along the side of individual atoms. The Lewis structure shows electrons present in the valence shell of an atom.

Although Lewis structures do not give a complete picture of covalent bonding, they are an essential prerequisite which should be understood by students before going into further details of covalent bonding. Students should be able to write the Lewis structures of many compounds. As discussed in the introductory chapter, students are introduced to Lewis structures at class IX (NCERT books). They further study these structures at class XII (Maharashtra state board) in the chapter related to chemical bonding.

Even though students can write the correct number of valence electrons around the atoms forming a compound, they make mistakes in recognising the central atom and bonding atoms and in representing sharing of electrons between these atoms. Often, students are asked to draw circles in order to show that the 'octet' has been achieved by each atom by bonding and the overlapping region of circles, to show the shared pair/s of electrons (most of the examples in the textbook follow the octet rule). Errors are made while drawing circles and students show the octet completed for one of the atoms and neglect the others. The circles make the drawings complicated but they are necessary, specially for beginners, to trace whether each atom has attained 'octet'.

2.3.1 Activity for learning Lewis structures

a) *Material*

Transparency sheets - 3 to 4 (if possible, coloured), scissors, marker pens, a circular disc (diameter - 3 to 4 cm).

b) *Procedure*

With the help of a circular disc draw circles on transparencies using marker pens. These circles are cut out using a pair of scissors (in case of colourless transparencies, the coloured outlines should be retained). Circles of coloured transparencies can be used to represent atoms of different elements. The symbol of element is written at the centre of the circle and the dots representing valence electrons are placed near the circumference of the circle. While placing dots care should be taken to see that during sharing, required number of dots are accommodated in the overlapping region. For molecules having three or more atoms, the circle for central atom is prepared first. The circles for other bonding atoms are arranged around the circle of central atom in the required manner in order to make dots on these circles. For each element, at least 8 to 10 circles are prepared.

For using this activity a list of diatomic, triatomic and tetratomic molecules that are formed by covalent bonding is prepared and these examples are arranged in order of their difficulty. Students should be given a sheet of plain white paper to place the circles and look out for the correct arrangements. Once students complete the correct arrangement for given molecule, they can draw the pictorial representations of completed structure.

c) *Advantages and disadvantages*

The advantages are as follows:

i) These circles can be kept on overhead projector and possible arrangements for different molecules can be demonstrated to the whole class at a time. This would save the time which is usually required to draw the figures on the blackboard.

ii) Students can be asked to prepare the circles. They can be asked to represent valence shell electrons on the circles (preparation of circles for particular element can be assigned to individual student or group of students). Errors while preparing these circles should be used for discussions.

iii) These circles help students to recognise and distinguish the bonding atoms and central atom and in learning the correct formulae of compounds.

iv) The circles offer opportunities for students to try out sharing of electrons in different type of molecules and the task is less tedious.

v) When made of coloured transparencies, these circles are quite attractive and trigger students' interest.

vi) The cost for making these circles is very low (about Rs 20/- for colourless transparencies and Rs.30 to 35/- for coloured transparencies and most of the students can possess and use them (if made out of tracing paper the production cost can be reduced further). The circles can be easily transported when required.

vii) These circles can also be used to study co-ordinate bond (a special case of covalent bond) with slight modification. In case of co-ordinate bond, the electrons are represented as dots for the donor atom. It can be shown by placing the circles in such a way that the region of one circle having dots (which represents the atom donating electron) is overlapped with a region of the other circle which is having no dots (which represents the atom accepting electron). Thus, students can form the structure of molecules like SO_2, H_2SO_4, O_3 etc.

The disadvantages are -

i) Since the circles are made out of transparencies, an overhead projector is required when this activity is demonstrated to the whole class.

ii) These circles can become dull and wear out with constant use. Thin acrylic sheets can be a better substitute.

iii) The prepared circles are suited only for those molecules which follow the octet rule.

iv) The arrangement of the circles to show the sharing of electrons to complete the octet may be confused for direction of the bonds in the molecules.

2.3.2 Worksheets for using the activity on Lewis structure

Worksheets are developed in order to have some feel about how to use developed activities in the classroom situation. The worksheets provide minimum information and ask students to do many small exercises in order to draw further conclusions. Summary points are presented on worksheet (wherever required) in order to gather the facts for which a particular worksheet is prepared. These worksheets have not been tested in the classroom settings and therefore, it is not possible to state the required time period to use them.

Worksheet no.1

In this worksheet students are asked to write atomic numbers, electronic configuration, electrons in the outermost orbit as electron dot structures for first twenty elements. Students should also be able to identify the nearest inert gas along with its electronic configuration. In the last column, they are asked to state the ways in which the outer octet (or duplet) configuration of nearest inert gas can be achieved by other elements. Try to fill the above mentioned information in the provided table.

Table 2.1

At.No	Symbol	Electronic Configuration	Nearest inert gas with electronic configuration	Ways to achieve the nearest inert gas confg.
1	H			
2	He			
3	Li			
4	Be			
5	B			
6	C			
7	N			
8	O			
9	F			
10	Ne			
11	Na			
12	Mg			
13	Al			
14	Si			
15	P			
16	S			
17	Cl			
18	Ar			
19	K			
20	Ca			

Conclusion : Elements try to achieve the outermost stable electronic configuration, that is, octet or duplet configuration of nearest inert gas by giving, accepting or sharing electrons.

After completing the worksheet, students are provided with circles made out of transparencies and can be asked to draw dots in order to represent electrons in the outermost shell of the atom. In this manner, circles can be prepared for all the elements mentioned in the table 2.1.

In the next worksheet, students can be asked to work out the structure of simple diatomic molecules of a particular element by choosing appropriate circles and overlapping them. Please note, that students should always make more than one molecule of the given compound (It is advisable to do so, as chemical reaction is not a single particle reaction).

Worksheet No 2

With the help of worksheet No. 1, prepare the circles (for different elements) with the symbol of the element and coloured dots showing the electrons in the outermost orbit of the element. Choose the appropriate circles and arrange them in a suitable manner to represent molecules stated in table 2.2.

Table 2.2

Diatomic molecule of some elements	**Electronic dot structure of individual atoms used (from the circles used)**	**Pictorial representation of the molecule (from the prepared structure)**
H_2 (Hydrogen)		
Cl_2 (Chlorine)		
O_2 (Oxygen)		
N_2 (Nitrogen)		

You have to overlap the circles and share the dots (that is, electrons) to form the above molecules. The bond formed through sharing of electrons is known as *covalent bond.* This is different as compared to the bond formed by accepting or donating electron,that is, ionic bond (like in NaCl).

In the above examples atoms have shared one, two or three electron pairs. Yet another notation, that is, small horizontal line is used to show the number of shared electron pairs. If one electron pair (consisting of one electron each from the individual atom) is shared as in case of hydrogen molecule, a single horizontal line is used as follows :

H : H / will be represented as H-H

This means that in case of hydrogen molecule, a single bond exists between the two hydrogen atoms. Now, represent the bonds using lines for all other examples in the table.

Worksheet No 3

You have already learnt about the covalent bond formation between the atoms of same element by sharing of the electrons. In this worksheet, let us try to study examples of molecules formed by atoms of different elements. Choose the circles and start making structures for the following molecules. Please remember that after you finish the structure, the stable octet (or duplet in case of hydrogen) should be achieved for all the atoms present in the molecule (it should be noted here that some circles have to prepared again for proper overlap). Complete table 2.3 as you finish the structures.

Table 2.3

Molecule	Electronic dot structure of individual atoms	Pictorial representations of molecule	Representation of bonds using lines
HF			
HCl			
H_2O			
H_2S			
CH_4			
$BeCl_2$			
NF_3			
CS_2			
NH_3			
$AlCl_3$			

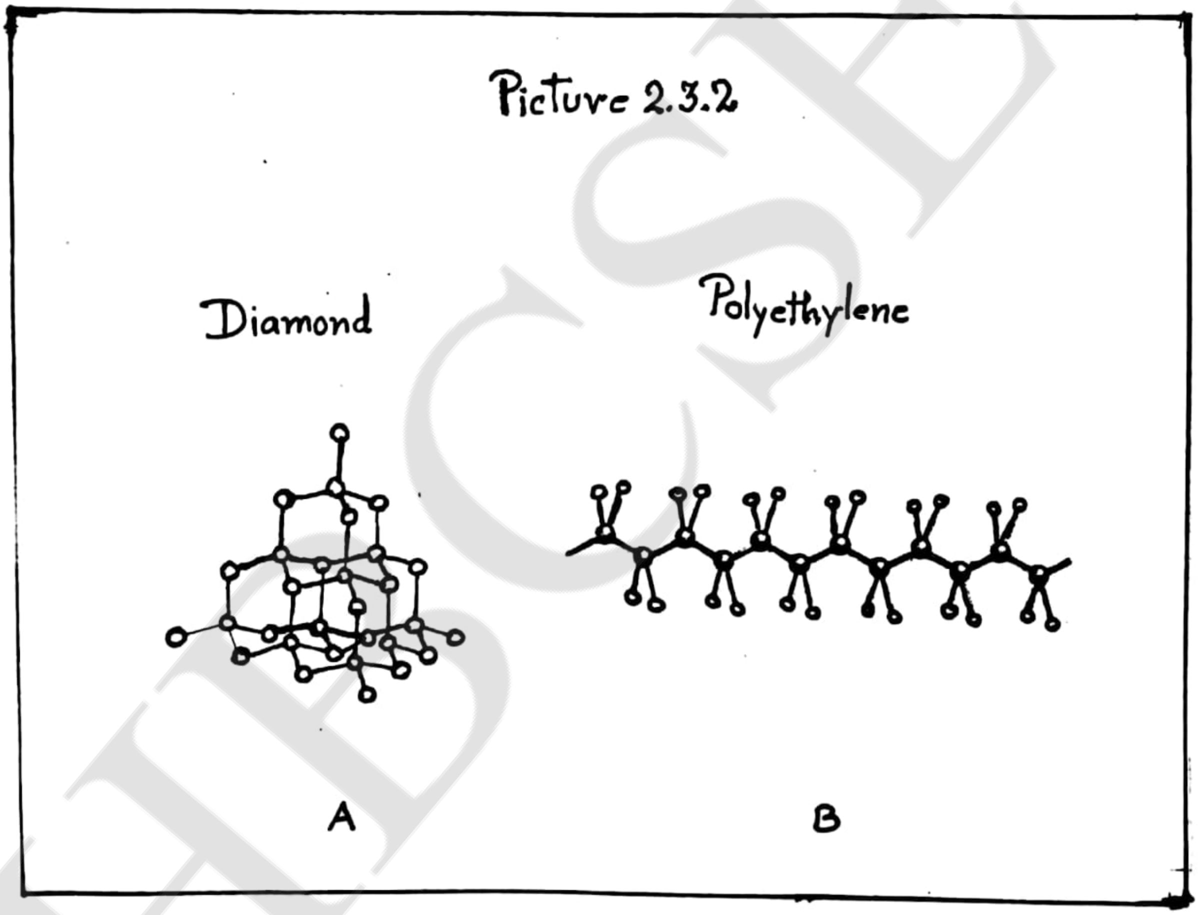
In all the above examples, bonds are formed by sharing of electrons. Therefore, all these bonds are covalent bonds. Each atom has a full octet (or duplet) like the inert gases.

In any chemical reaction, there are always many atoms or molecules of an element which can react with one another. If there is an excess of atoms of one element, they remain without reacting. During chemical reactions we encounter precipitates, colour changes or deposits which show that a new substance or compound is formed. After finishing the above table try forming the structure of following molecules:

C_2H_4 (ethylene), C_2H_2 (acetylene), HNO_3 (nitric acid), HCN (hydrogen cyanide), CH_2O (formaldehyde), HCOOH (formic acid).

Worksheet No 4

Let us try to understand covalent bonding in case of carbon. You can use the circles given to work out an arrangement by which each carbon atom is able to, attain the stable octet electronic configuration. You will find out that the central carbon achieves the octet configuration, but the other four carbon atoms are not able to do so unless each one of them combines with three more carbon atoms. This way of combining leads to a giant networking of carbon atoms through covalent bonding. The kind of bonding described here exists in diamond, an allotrope of carbon. See the picture 2.3.2A. In fact, the strong covalent bonds formed in the three dimensional structure contribute to the unusual hardness of diamond (in case of graphite, each carbon is connected to three other carbon atoms. So the octet is not completed). The ability of carbon to get covalently bonded with other carbon atoms is also used in preparing polymers. See the picture 2.3.2B.



Picture 2.3.2

2.4 Predicting geometry of molecules

The Lewis structures are inadequate to explain the geometry of atoms in a molecules. Molecular geometry refers to three dimensional arrangement of atoms in a molecule. But the geometry of molecule can be predicted with the help of number of electrons surrounding the central atom obtained from Lewis structures.

In a covalent bond, a pair of electrons is responsible for holding the atoms together. When there are two or more bonds between the central atom and the surrounding atoms as in the case of polyatomic molecules, the repulsions between the electrons in different bonding pairs causes these pairs to remain as far as possible. The geometry that the molecule ultimately obtains minimizes the repulsion (thus, maximum stability). The valence shell electron pair repulsion model accounts for the geometric arrangement of electron pairs around a central atom in terms of the repulsion between electron pairs. In other words, this is known as VSEPR approach.

2.4.1 Activity for understanding VSEPR approach

The activity mentioned here is to give some feel about how the geometry of the molecule can be predicted on the basis of number of electron pairs involved in bonding. The examples of molecules were taken of such type, in which the central atom has lone paris, like $BeCl_2$, BCl_3, CH_4, NH_4^+, PCl_5, SF_6 etc.

a) *Materials*

Thermocole balls, toothpicks or pins with heads, a hollow/solid transparent plastic ball (if not available,regular rubber ball will solve the purpose).

b) *Procedure*

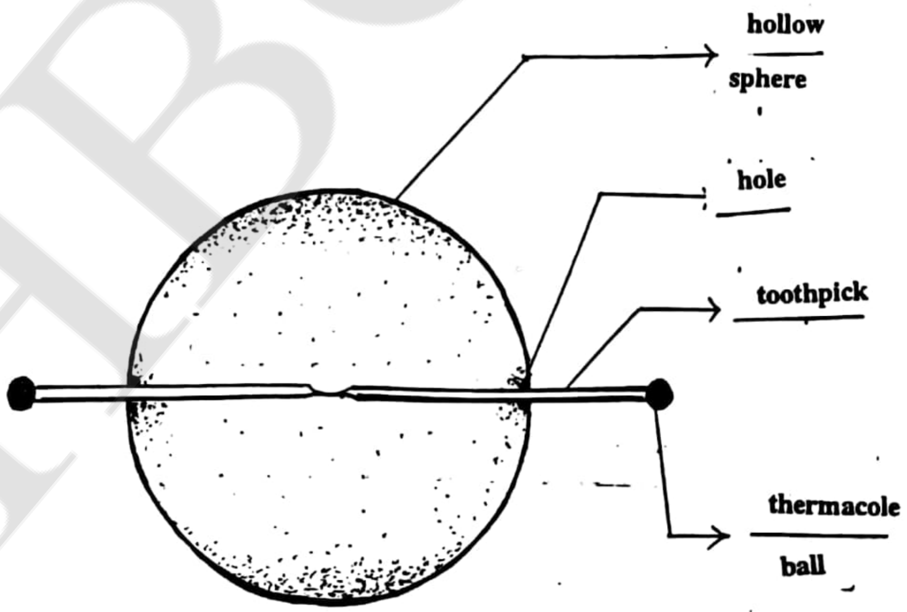
A hollow (or solid) transparent sphere of 4 to 6 cm diameter is taken for the study purpose. One thermocole ball is taken to represent an electron pair and the thermocole ball is fixed and glued to the end of a toothpick. Students are given two toothpicks (each having one ball) and asked to place them on top of the sphere in such a way that they are at maximum distance (which represent minimum repulsion between electron pairs). If pins with roundheads are selected then the head represents one electron pair and such pins can be used effectively to perform the activity with a ball of smaller size. When students are satisfied with their results, they are asked to mark the two points on the sphere and then the toothpicks(or pins) are pierced into the ball so that they almost touch each other (see figure 2.4.1A. The resultant shape made by the two toothpicks (or pins) will be linear and the angle between the two pairs will be 180^0 . In fact, students should be asked to guess the shape and angle and also represent the same by drawings done on paper. Similarly, students can try with three toothpicks or pins and can be asked to guess the resultant shape which will be trigonal linear. They can thus, go on experimenting with four, five and six toothpick or pins and predict the geometry of molecules having four, five and six electron pairs (see figure 2.4.1B and 2.4.1C).

c) *Disadvantages*

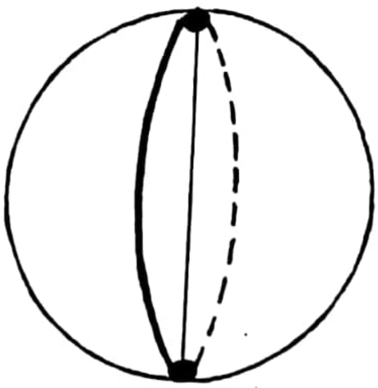
i) This activity is restricted only to molecules having no lone pair of electrons.

ii) It is rather a difficult activity for the students to perform individually. So the activity should be conducted under teacher's guidance.

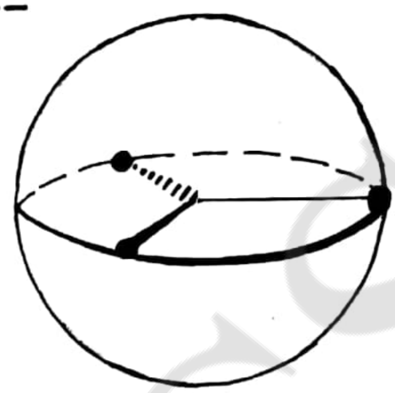
Predicting the shape of the molecules



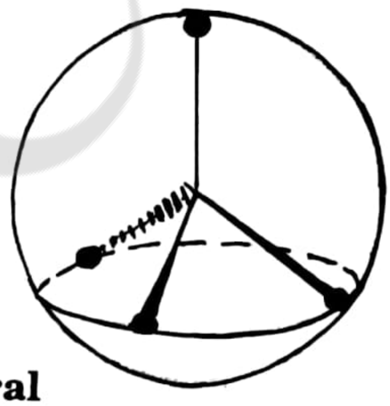
2.4.1 A Activity for understanding VSEPR approach with the help of a hollow sphere



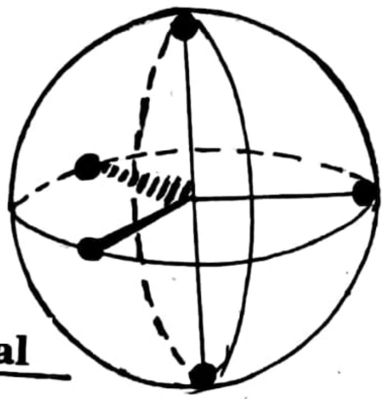
Linear



Trigonal

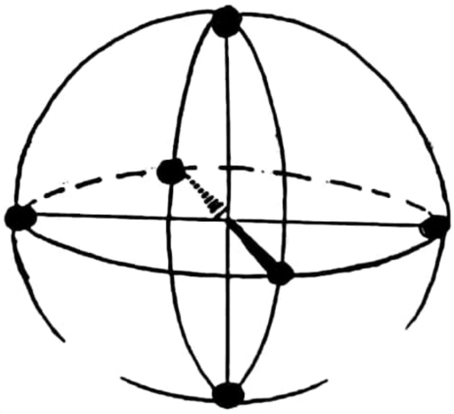


Tetrahedral

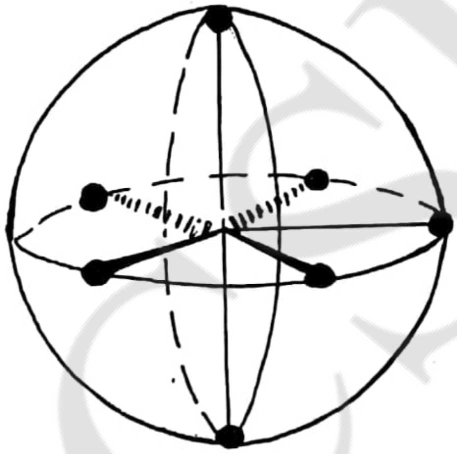


Trigonal Bypyramidal

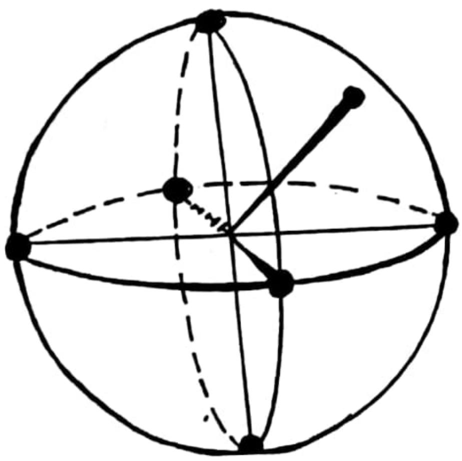
2.4.1 B Geometries of molecules predicted by VSEPR approach for 2, 3, 4, 5 electron pairs on the central atom



Octahedral



Pentagonal Bipyramidal



Monocapped Octahedron

2.4.1 C **Geometries as predicted by VSEPR approach for 6, 7 electrons pairs**

2.4.2 Activity for making molecular models

In this activity attempts are made to develop molecular models (similar to ball and stick models) in order to foster the understanding regarding three dimensional molecular geometry. The emphasis is once again on the idea that students themselves should prepare these models in order to have a better understanding about number of bonds, angles between the bonds and bond lengths. Attempts are also made to show various planes or faces of a molecule. As stated before, it is difficult for students to understand molecular shapes from the two dimensional figures drawn in the textbooks and the concepts may become clearer if three dimensional views of molecules are provided with the help of models. In fact, the prepared models can be projected on an overhead projector and compared with the figures drawn in the book in order to understand the correspondence between the two. The activity concentrates on preparing models for tetrahedral,trigonal bipyramidal and octahedral shapes of molecules.

a) *Materials*

Thermocole balls, toothpicks, transparencies, scissor, glue (fevicol), sharpener, cello-tape, empty refills, candle, copper wire (gauge 1mm), soldering rod and soldering material.

b) *Procedure*

Take toothpicks of equal lengths (approximately 5 cm) and sharpen them at both ends. Select a thermocole ball of particular colour which represent the central atom of the molecule. The thermocole balls of other colours can be used for showing other atoms present in the molecule. To begin with, appropriate number of toothpicks have to glued to the thermocole ball representing central atom with the help of fevicol. Attention should be paid to angles between the glued toothpicks. For example, in case of octahedral, six toothpicks should be attached to the central thermocole ball. The angle between any two toothpicks should be 90^0 (see figure 2.4.2A-3). For tetrahedral and trigonal pyramidal, use the diagrams from figure 2.4.2A-2 and 2.4.2A-1 respectively. Once all the toothpicks are glued to the central thermocole ball, then start placing the thermocole ball at the remaining end of the toothpicks representing the other atoms in the molecule. There is yet another way of making these structures. Copper wires can be used instead of toothpicks. If you find that central thermocole ball is unable to accommodate the copper wires due to the small size, then the wires can be soldered to one another to make the framework. Care must be taken not to deviate from the actual bond angles.

Now we will prepare the cases to enclose the above prepared models from the transparencies. For this purpose, take three colourless transparency sheets. Draw different figures required to prepare tetrahedral, octahedral and trigonal bipyramidal cases (see figure 2.4.2B) with the help of a marker pen and then cut out the figures with the help of a pair of scissors. The next step is to make folds along the dotted lines and press firmly as shown in the drawn figures. The thin folded parts that you observe will be glued together when the structure is completed. Now we have to use these cut outs to make the actual structures. The cut out having six equilateral triangles is used to prepare trigonal bipyramidal structure. The required folds for the structure are shown in figure 2.4.2B-1. The cut out having eight equilateral triangles is used to make octahedral structure. For the folds, refer to figure 2.4.2B-2. Similarly, prepare the remaining tetrahedral shape (figure 2.4.2B-3). The prepared bond assembly from toothpick (or copper wire) and thermocole ball is then slipped carefully inside the three dimensional shapes made out of transparency sheets. All the sides can be secured together with the help of cello-tape.

There can be another way of preparing the bond assembly. Empty ballpen refills can be cut into small pieces of 1 cm length and can be used to make frameworks. These small pieces can be heated at one end with candle flame and then joined together at different angles to make small 'connectors' (refer to figure 2.4.2C) The toothpicks can be pushed inside these small connectors to form different type of bond assemblies. The central atom is assumed to be at the junction of the connector and the bonded atoms are shown by the thermocole balls fixed at the end of the toothpicks (figure 2.4.2D and 2.4.2E).

c) *Advantages and Disadvantages*

The advantages are as follows -

i) These models can be prepared by students (the soldering and case making will require teacher's guidance).

ii) The models can be used for classroom teaching with the help of an overhead projector. These projections and the two dimensional representations in the textbooks can be compared easily.

iii) Students can be asked to draw the projections which will give them practice regarding drawing the two dimensional representations.

iv) All the prepared models can be rotated on the overhead projector to have a view of the molecules at different angles.

v) The copper wires and the toothpicks can be cut of required lengths corresponding to different bond lengths.

vi) The production cost is low (maximum Rs 40/-) and the used material is available with ease.

vii) The copper wire method and the connector method give sturdy structures and the bond angles can be shown with more precision.

The disadvantages are as follows-

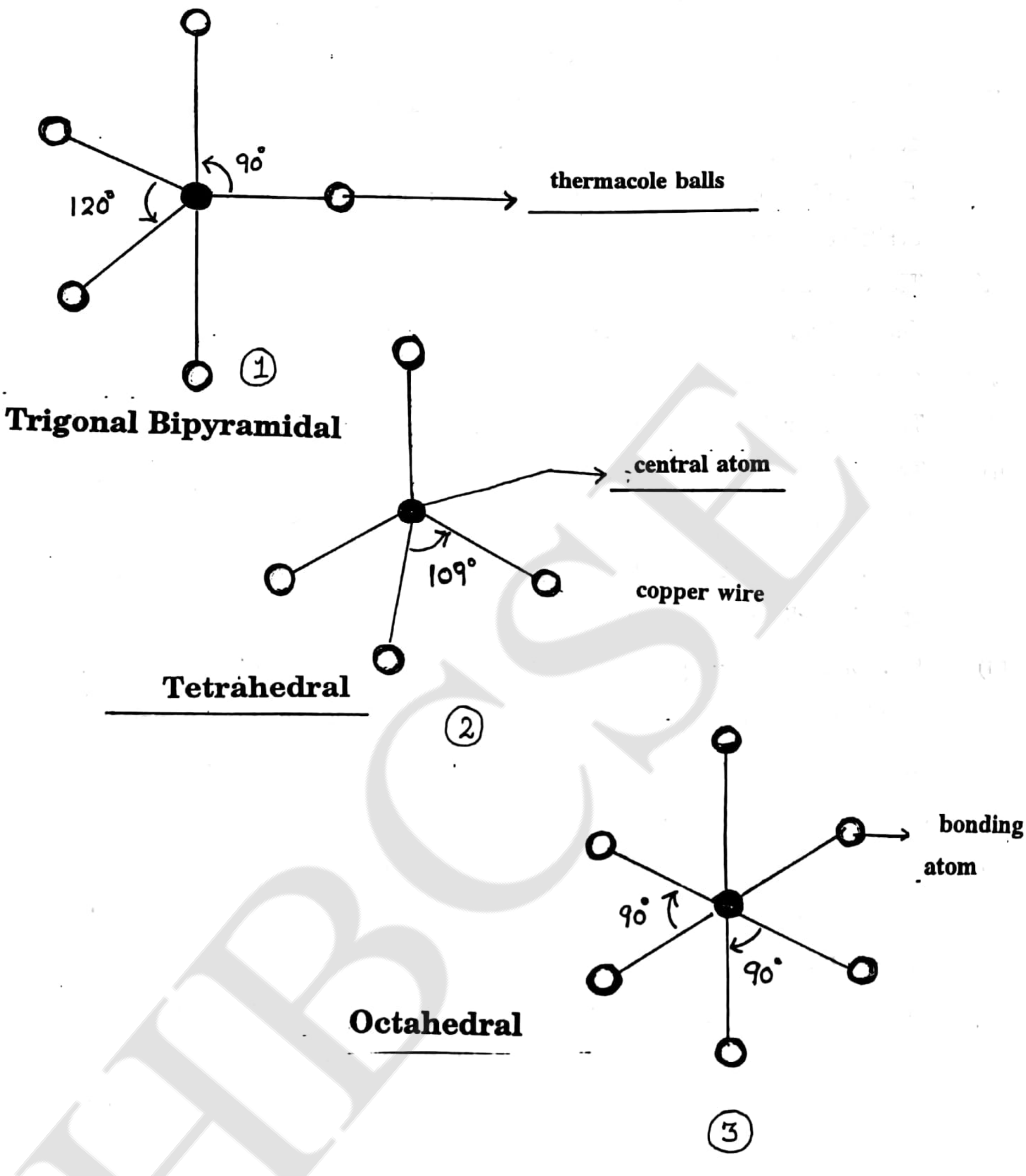
i) The thermocole models are fragile and will not last long.

ii) The sizes of available thermocole balls are rather limited which give less choice for selecting balls representing different atoms. So the sizes used are not in correspondence to the actual sizes of atoms (if available, plastic beads of various diameters may be a better choice).

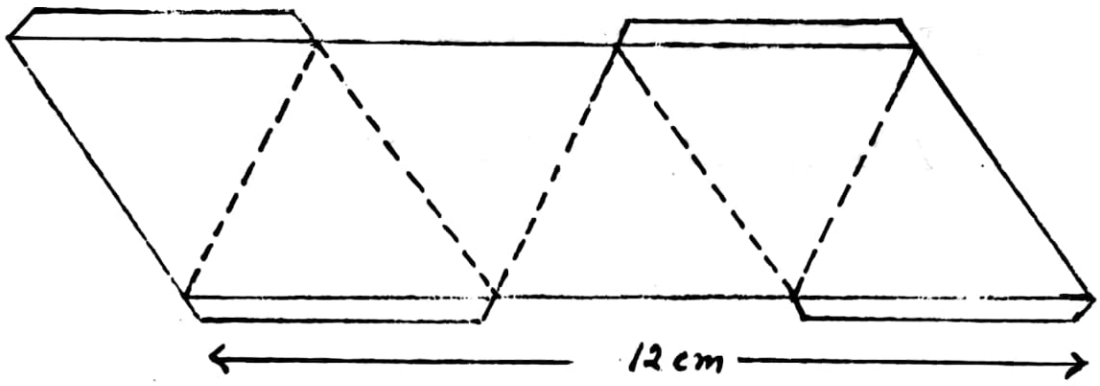
iii) Transparencies also get spoiled after frequent handling. Thin transparent acrylic sheets (thickness of 1mm.) can be used for the three dimensional structures. The glue used (that is, feviquik) gives some amount of opacity and so care must be taken while using the glue.

iv) Preparing connectors takes time and skill and thus, can not be easily done by students. If possible, the plastic connectors can be fabricated in a large amount for use.

v) The prepared models are restricted to central atoms having no lone pair of electrons. With slight modifications, the models prepared through copper wires can be used to discuss the effect of lone pairs present on the central atom.

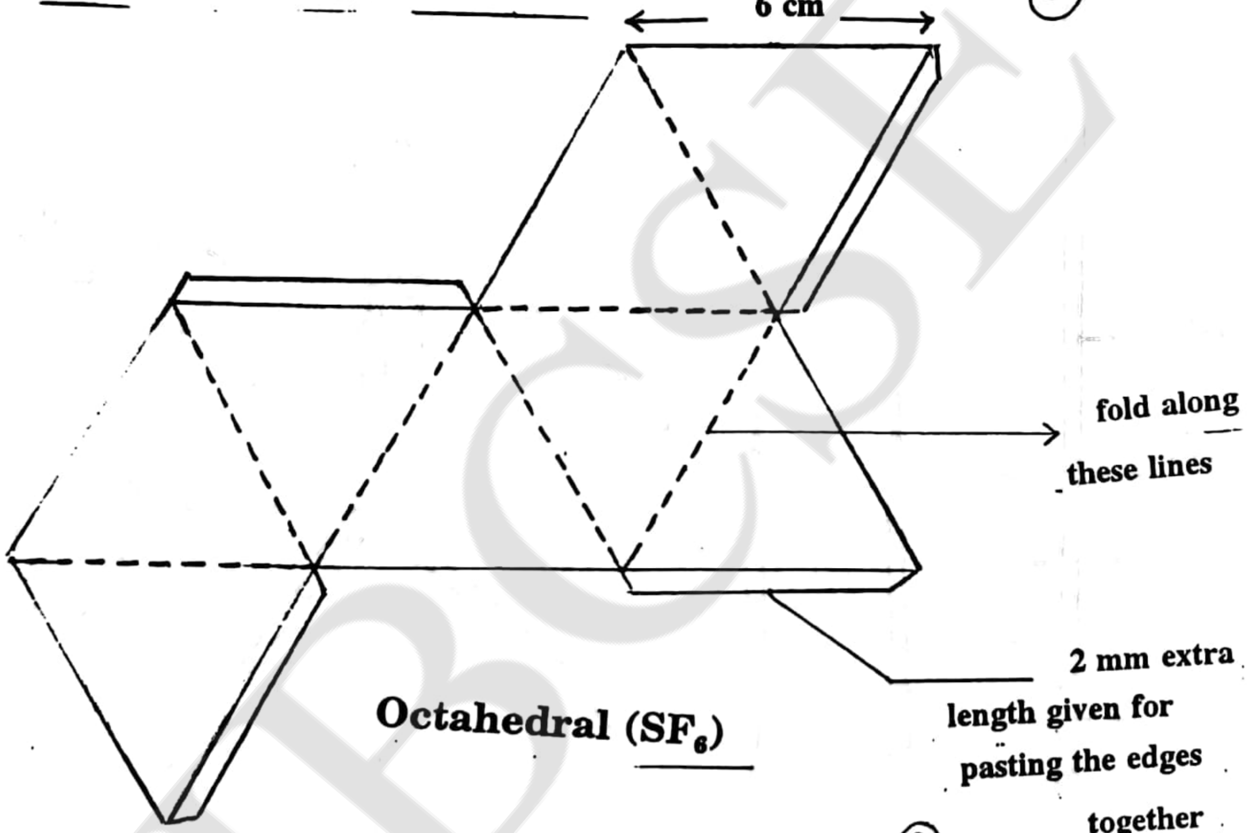


2.4.2 A Activity used for making molecular models for understanding geometries of molecules



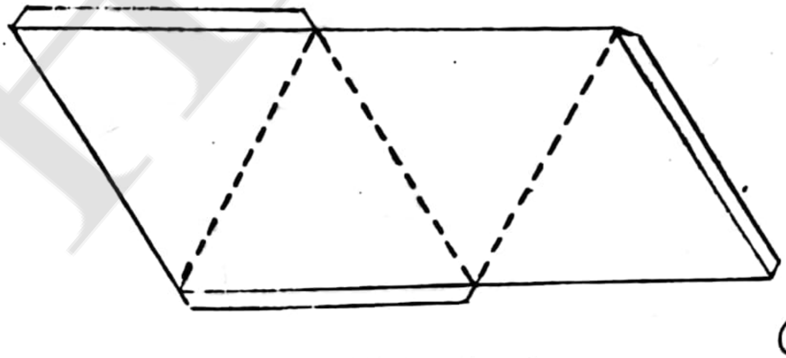
Trigonal Bipyramidal

①



Octahedral (SF_6)

②



③

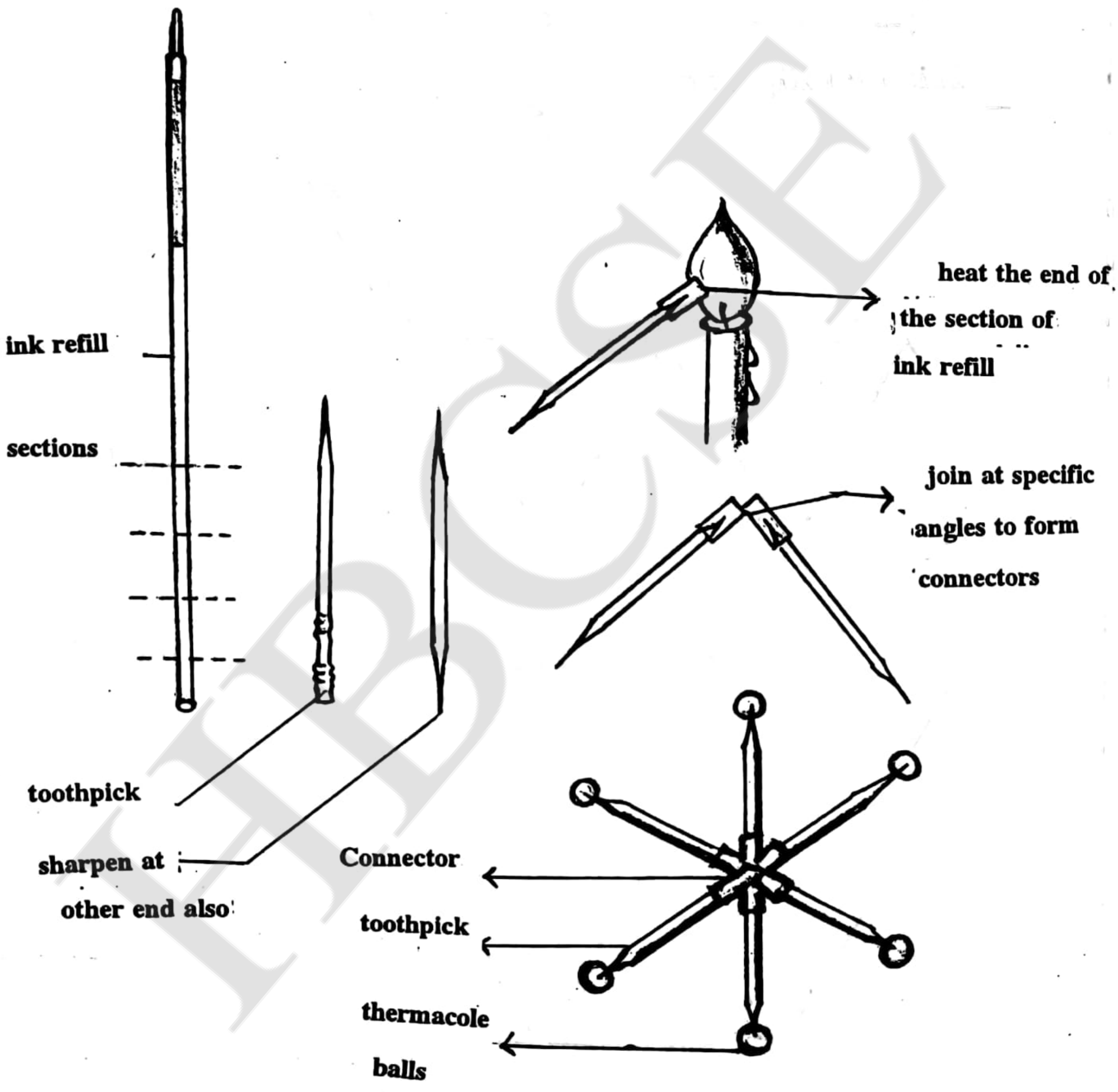
Tetrahedral

2.4.2 B The design on transparency sheet fro preparing envelopes of molecular models

BOND ASSEMBLY MADE OUT OF

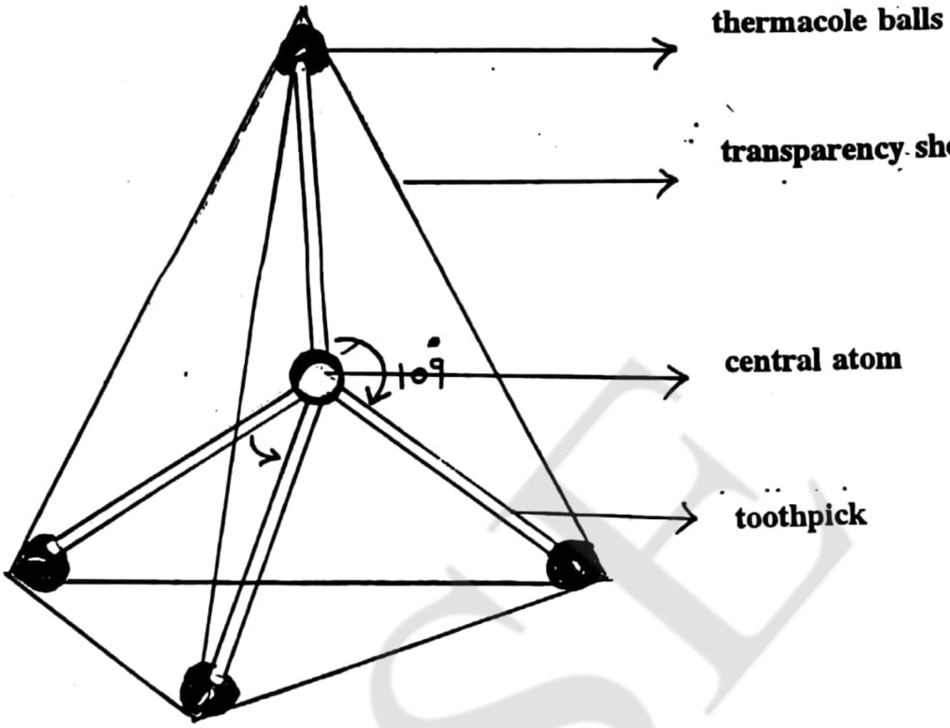
INK-REFILL, TOOTHPICK

AND THERMACOLE BALLS

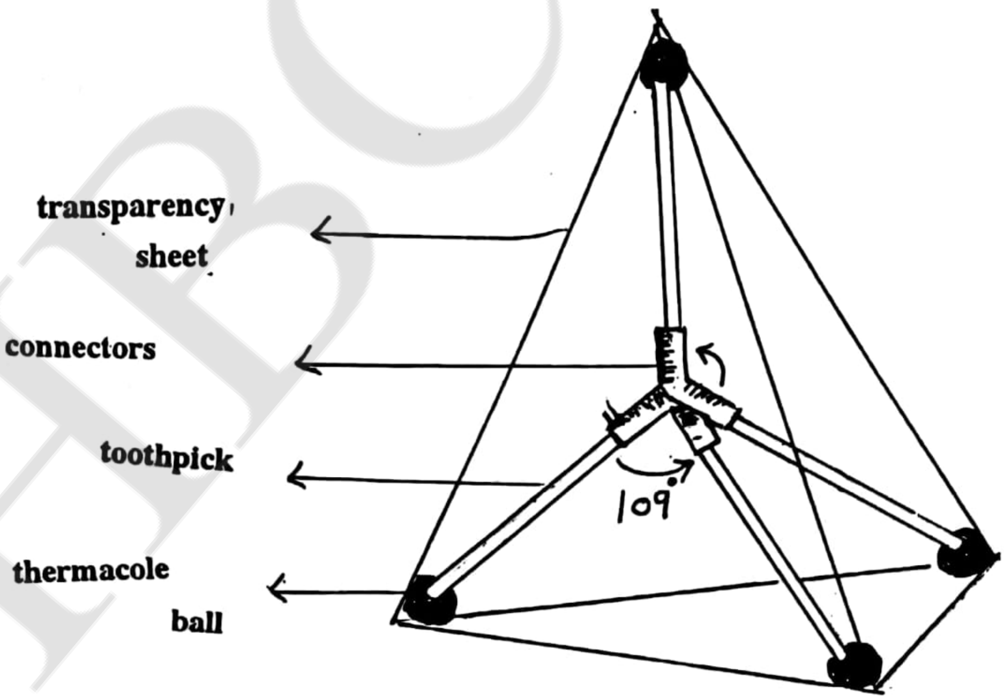


2.4.2 C Procedure for making connectors out of ink refills

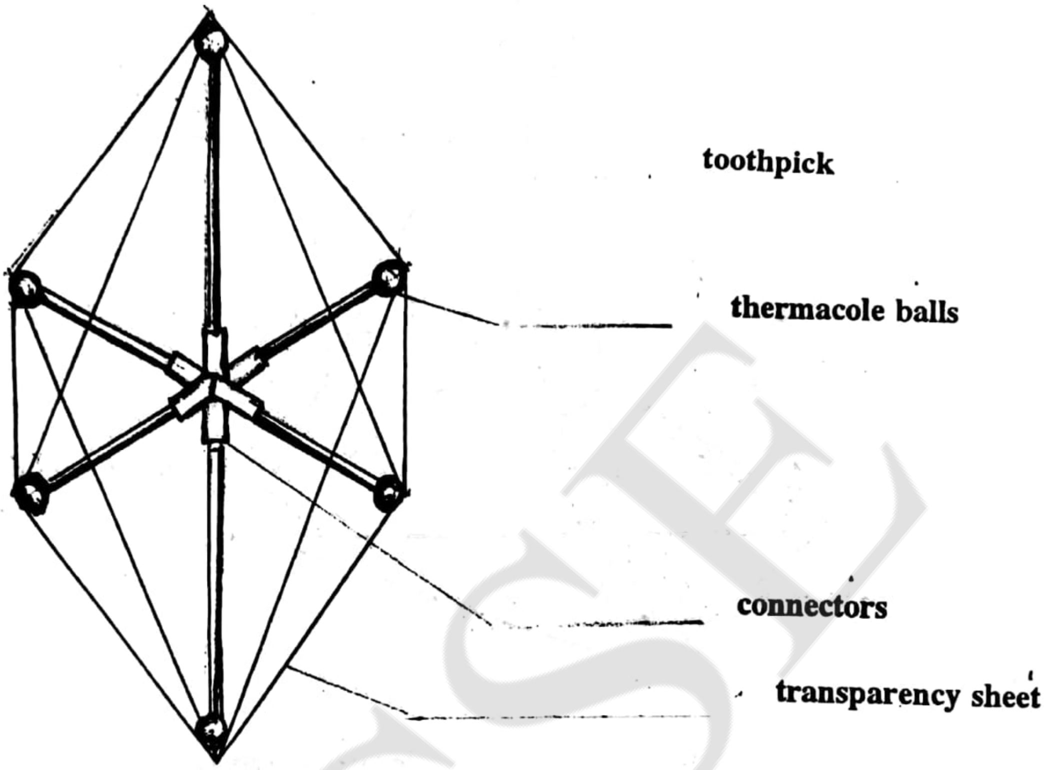
Structure of Methane



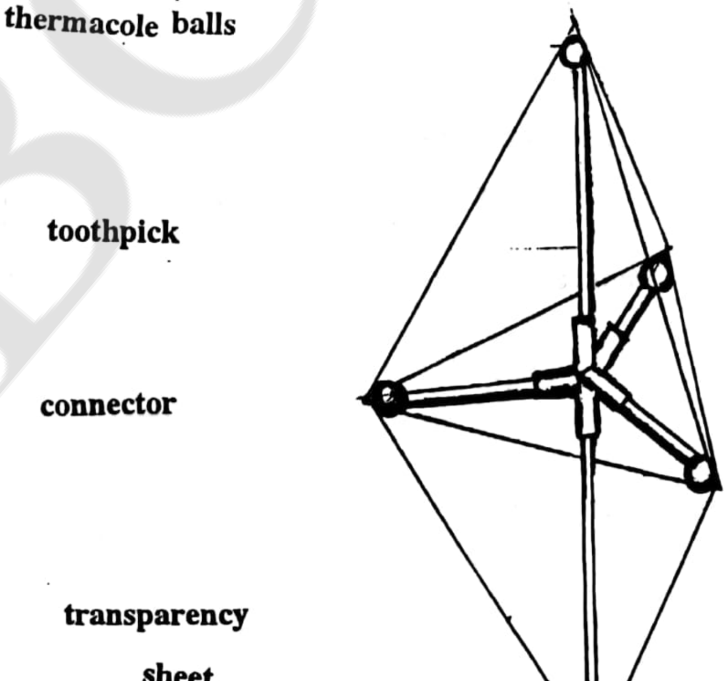
Tetrahedral



2.4.2 D **Molecular models of Methane constructed from transparency sheet, thermocole ball, toothpicks and connectors**



Octrahedral



Trigonal Bipyramidal PCL_5

2.4.2 E Molecular models for SF_6 and PCl_5

2.4.3 Activity for making molecular models by orbital approach

The VSEPR theory provides a simple and straightforward method for predicting the geometry of molecules using repulsion between electron pairs. It is based on Lewis dot structure and does not say as to why a chemical bond exists. To understand chemical bonding and electronic structure, two theories, namely, valance bond theory and molecular orbital theory, based on quantum mechanics are studied. Both these theories talk about chemical bonding in terms of orbitals (orbital represents the region in space where the probability of finding the electron is maximum). Both these theories, do not explain all aspects of bonding. The basic assumptions of valance bond theory are :

i) Electrons in a molecule occupy atomic orbitals of individual atoms.

ii) Two orbitals involved in bonding share a common region in space. In other words, the orbitals overlap with each other.

iii) The total number of electrons in the two orbitals can not be more than two.

The chapter on chemical bonding at class XII discusses valency bond approach for various molecules with some discussion about molecular orbital theory. The models described in this section are prepared in order to get some feel about the valency bond theory.

a) *Materials*

Plastic inkfiller droppers, copper wire (gauge 1mm), acrylic sheets, red, blue and yellow plastic coatings of old wires (any other three colours will also be applicable), coloured transparency sheets (any three colours blue, yellow and red are used by us), glue (feviquik) and small plastic coloured beads (approximately, 1cm in diameter).

b) *Procedure*

Before preparing the orbital models for molecules, the models for various atomic orbitals are prepared. To begin with, a skeleton or grid representing 'x', 'y' and 'z' axes is prepared by soldering three pieces of copper wire together (length of each wire 8 to 10 cm). The angle between the axes is 90^0 (figure 2.4.3A-1). The top sections of ink fillers (length 3.5 cm) are cut out as shown in the figure 2.4.3B-1). One hole at the tip of the elongated region is done so as to insert it through the copper wire. Students should insert six inkfiller top sections (representing six lobes of p orbitals) along the three axes provided to them by the copper wire grid in order to prepare p orbital (figure 2.4.3B-2 & figure 2.4.3E-2). The small red, blue and yellow coloured plastic coating pieces are used to indicate x, y and z axis. For, d_{x2-y2} , insert two inkfiller sections on x axis and other two sections on y axis respectively. For, d_{z2} orbital, insert two pieces on z axis and stick two semitransparent washers in the xy plain as shown (see figure 2.4.3C). Please note that the same grid used for p-orbital is used for these two d-orbitals.

The grids for d_{xy} , d_{yz} and d_{xz} are slightly modified. These grids are prepared by soldering two more wires (length 4cms) in between the corresponding axes. For d_{xy}, solder two copper wires in between xy plane. Similarly, d_{yz}, solder two wires between the y and z axes and for d_{xz} , solder two wires between x and z axes respectively (refer to figure 2.4.3D). Students are asked to insert the inkfiller sections through the wires soldered in between the axes to complete the models (figure 2.4.3D). Appropriate grid should be selected for preparing d_{xy} ,d_{yz} and d_{xz} . In order to show the different axis, they can slip tiny coloured pieces of plastic covering of wires.

In order to show the shape of 's' orbital, a tiny plastic ball (diameter 2 to 3cms) is taken and six holes are drilled through the ball (hot copper wire can also be used to make holes). The copper wires are pushed through the holes made at right angles to show the x, y and z axis (figure 2.4.3E-1). All these prepared models can be used on overhead projector to discuss the orientations of different orbitals.

The inkfiller tops can also be used to prepare VSEPR molecular models described in the previous section. The copper grids have to prepared by soldering copper wires (length 5 cms) at proper angles as described in the previous activity (figure 2.4.3A-2 to 5). The inkfiller tops are introduced in the grid to show the hybrid orbitals (hybrid orbitals refer to equivalent orbitals obtained through combination of atomic orbitals of the isolated atom). These models give better feel about molecular geometry. For showing non-bonding electrons, big rubber dropper top is used (length 6 cms) which occupies more space (figure 2.4.3F). So the effect of presence of non-bonding electron can also be discussed.

The models for C_2H_4, and C_2H_2 can also be prepared by using the copper grid and inkfiller dropper tops. In order to show the overlapping region between the two carbon atoms of the molecules stated, the following method can be used. Two top sections of inkfiller are taken and the front tips of these sections are cut out as shown in the figure 2.4.2G. The hemispheres, thus, obtained are inverted and glued with the help of glue to the remaining section as shown in the figure.

For preparation of molecule of ethylene, you will require two copper grids prepared for trigonal bipyramidal structures. Insert the modified inkfiller tops as shown and then glue both these sections to represent the carbon-carbon bond (refer to figure 2.4.3H). Now insert the normal inkfiller sections in the copper wire which is coming out of the plane. This will leave two copper wires empty for each grid. Before inserting the inkfiller tops in these remaining wires, cut the tips of the inkfiller tops as shown. These will be used to show overlapping of s orbitals of two hydrogen atoms. Small beads (diameter 1 cm) are used for this purpose. The completed model is presented in figure 2.4.3H . In order to represent the bonding between the p orbitals of carbon atoms, a copper wire is joined as shown in the figure. See the construction of acetylene in figure 2.4.3I and plate number 6 (page xii). The grid used is the one that is prepared for showing p-orbitals (that is, three axes at 90^0) .

Overlapping of orbitals in different molecules can be also shown by another method, that is, by using cut outs from colour transparencies. The cutouts are done for regular s and p orbitals. The cutouts from transparencies for a hybrid orbitals is made with a large lobe at one end and a very small lobe at the other end. In case of a lone pair, the size of the larger lobe is still bigger as compared to the large lobe of hybrid orbital representing the bonding electrons. This is done to show that the non bonding electron cloud occupies more space (refer to figure 2.4.3J).

These transparencies cutouts are then placed inside a box. These cut outs are used to represent the structure of various molecules shown in the textbook like $BeCl_2$, BCl_3, CH_4, NH_3, H_2O, C_2H_4, C_2H_2. In order to learn the structure of these molecules, the students can be asked to choose the correct cut-outs and arrange them on a sheet of plain white paper. The hybridised orbitals are made of yellow colour whereas blue and red colour are used for unhybridised p-orbitals and s orbitals.

c) *Advantages and Disadvantages*

The advantages are as follows -

i) All the prepared models can be used on overhead projector.

ii) The prepared models made out of inkfiller top sections and copper wires can be used to understand the molecular geometry in better way. The projections of the models can be compared with the textbook diagrams that is generally referred to for the student's study. This will help in understanding the correspondence between the two dimensional and three dimensional representation of molecule.

iii) The models will be helpful in understanding concept of orbitals, different shapes of orbitals, overlapping of orbitals and bond angles of molecules.

iv) The production cost is very low (Rs 30 to 40/-).

The disadvantages are as follows -

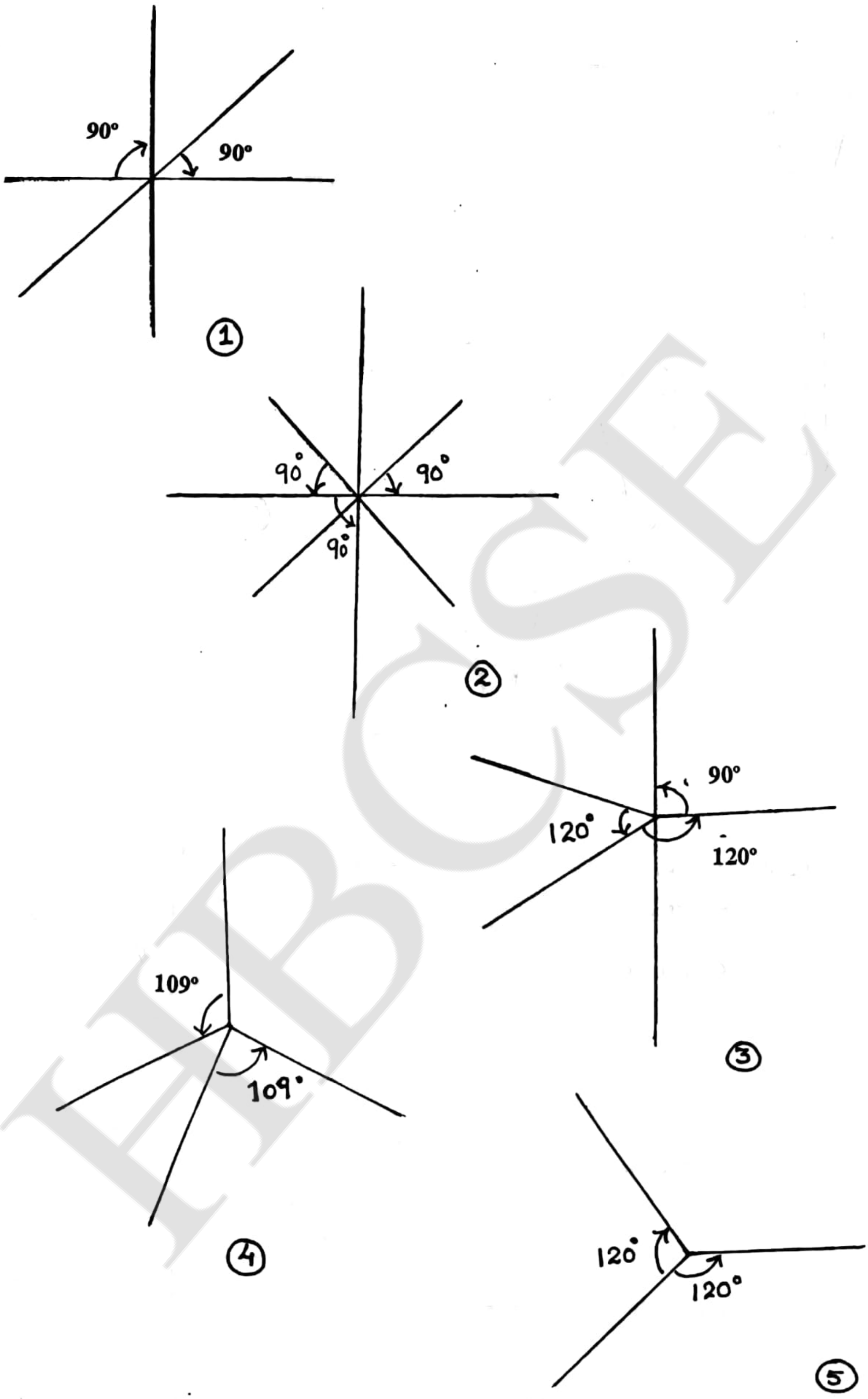
i) Even though the cutouts made from transparency sheet help students to construct the diagrams for various molecules, it does not give the three dimensional feel about the molecular shapes.

ii) The models of copper grid and inkfiller droppers for molecular shapes do not represent the central atom and other bonding atoms. In other words, these models are sort of framework models which show the orientations of orbitals (hybridised or unhybridised) in space along with the bond angles.

iii) In the prepared models, same top sections are used for hybridised and unhybridised orbital. This can confuse students. If possible, dropper tops of different sizes can be used. If such dropper tops are not available, then transparent colours can be used to colour the white inkfiller tops used in the models.

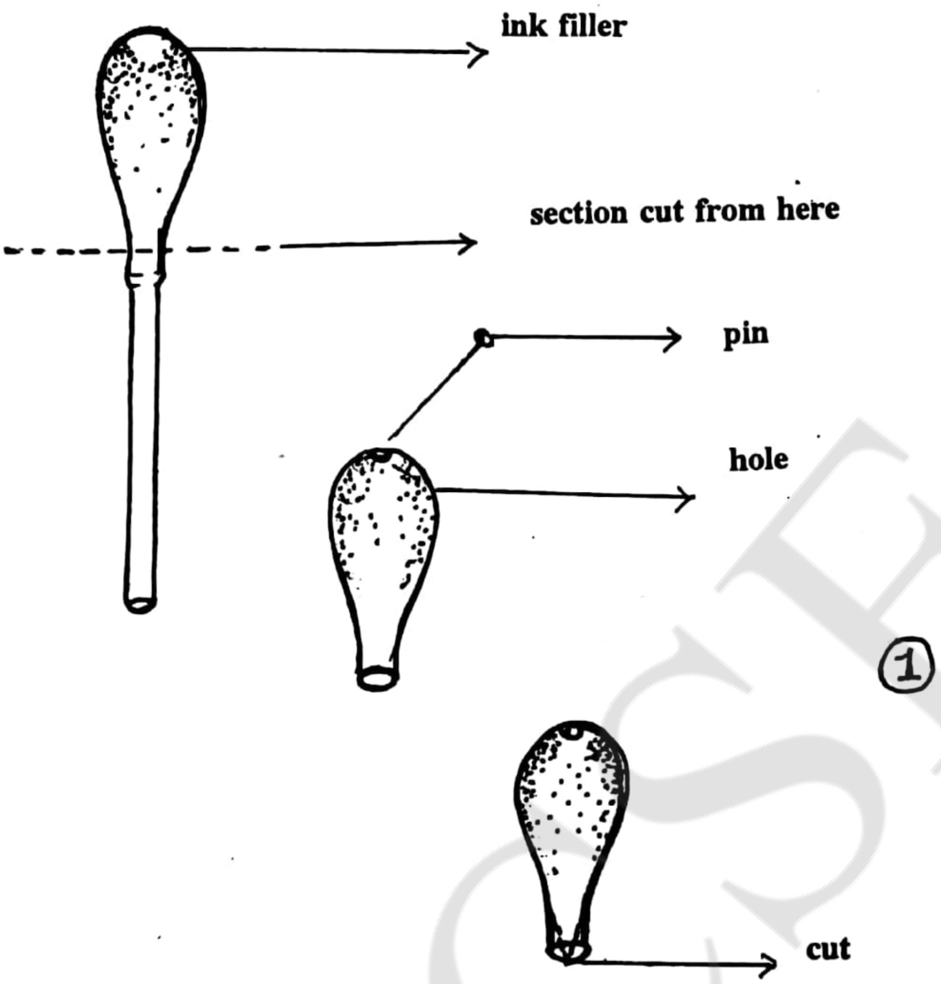
iv) The time required for preparing grid models is more. So the entire construction (from grid to final model) is not feasible in the class room situation.

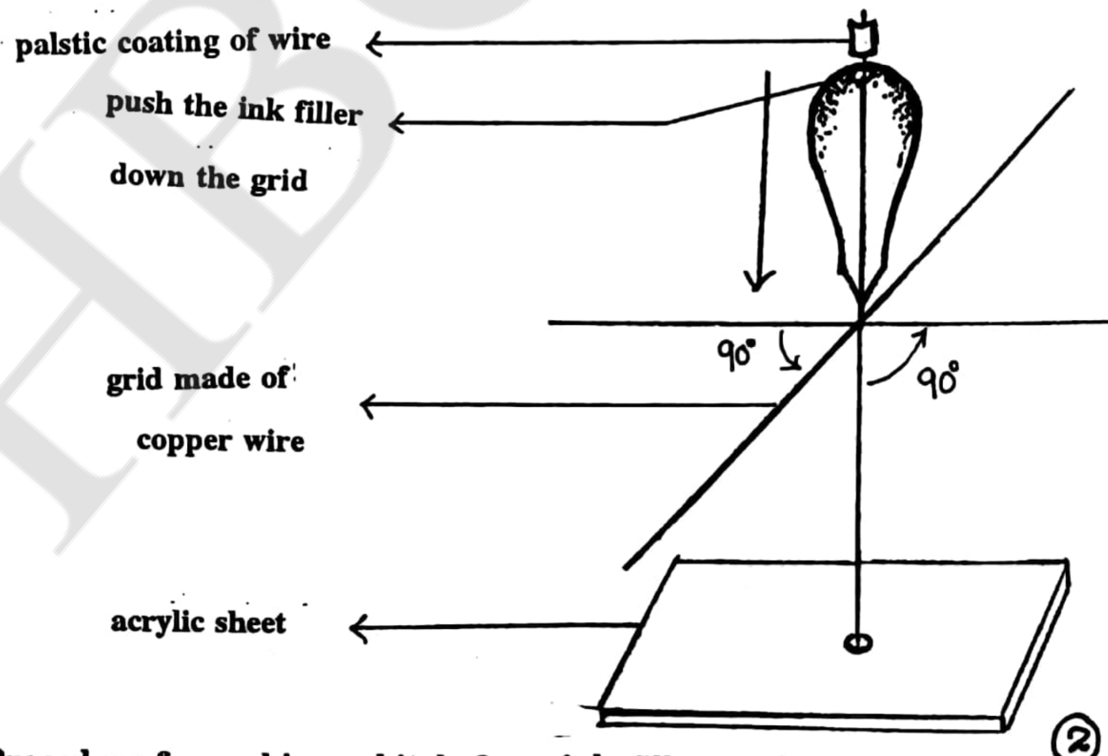
iv) The models are a bit fragile due to the thin copper wires. The grid can be made up of thicker copper wires or steel can be used for preparation of models suitable for classroom demonstrations. If the sections cut from inkfillers are fabricated out of plastic, they will be more suitable and durable.



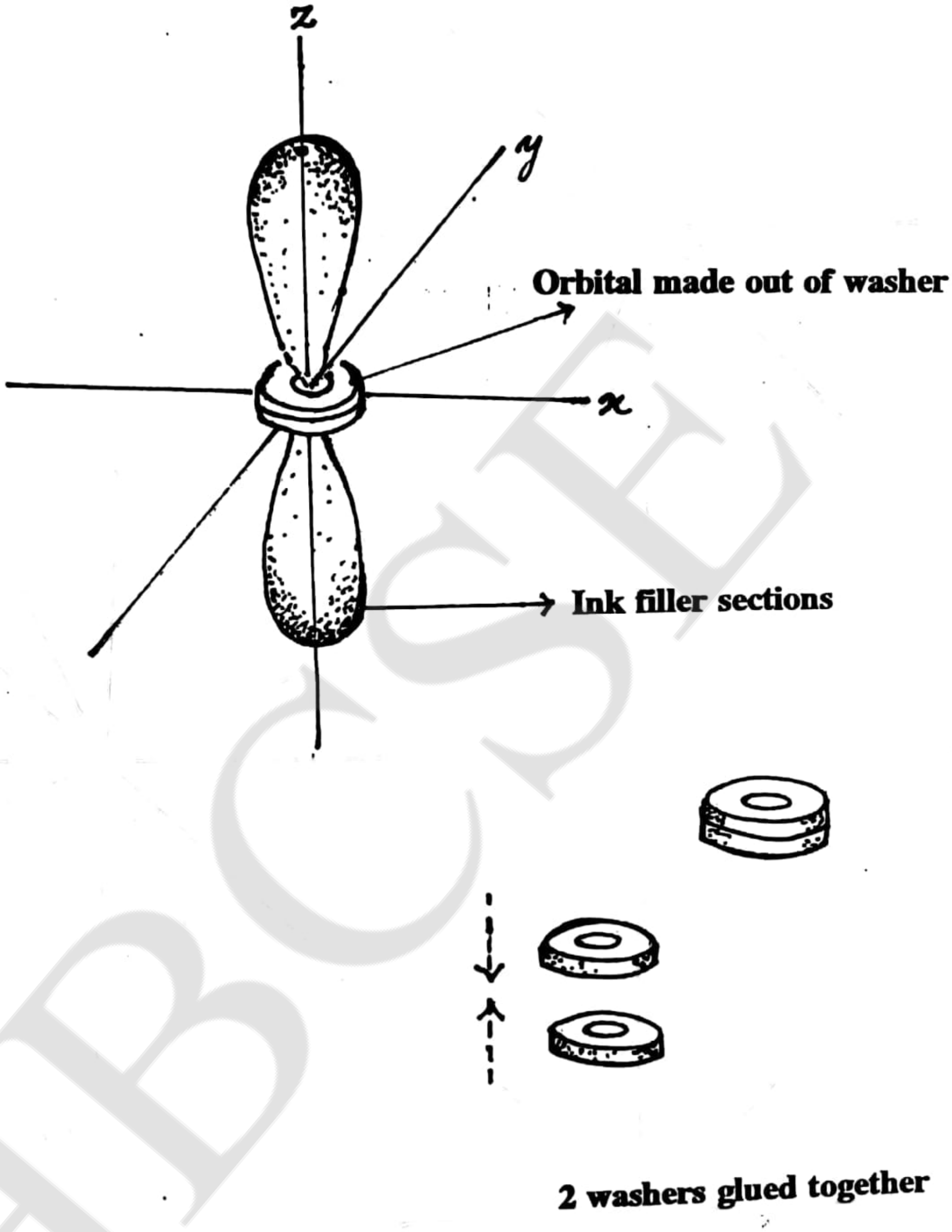
2.4.3 A **Grid structure made out of copper wires**

MODEL MADE OUT OF INK FILLERS

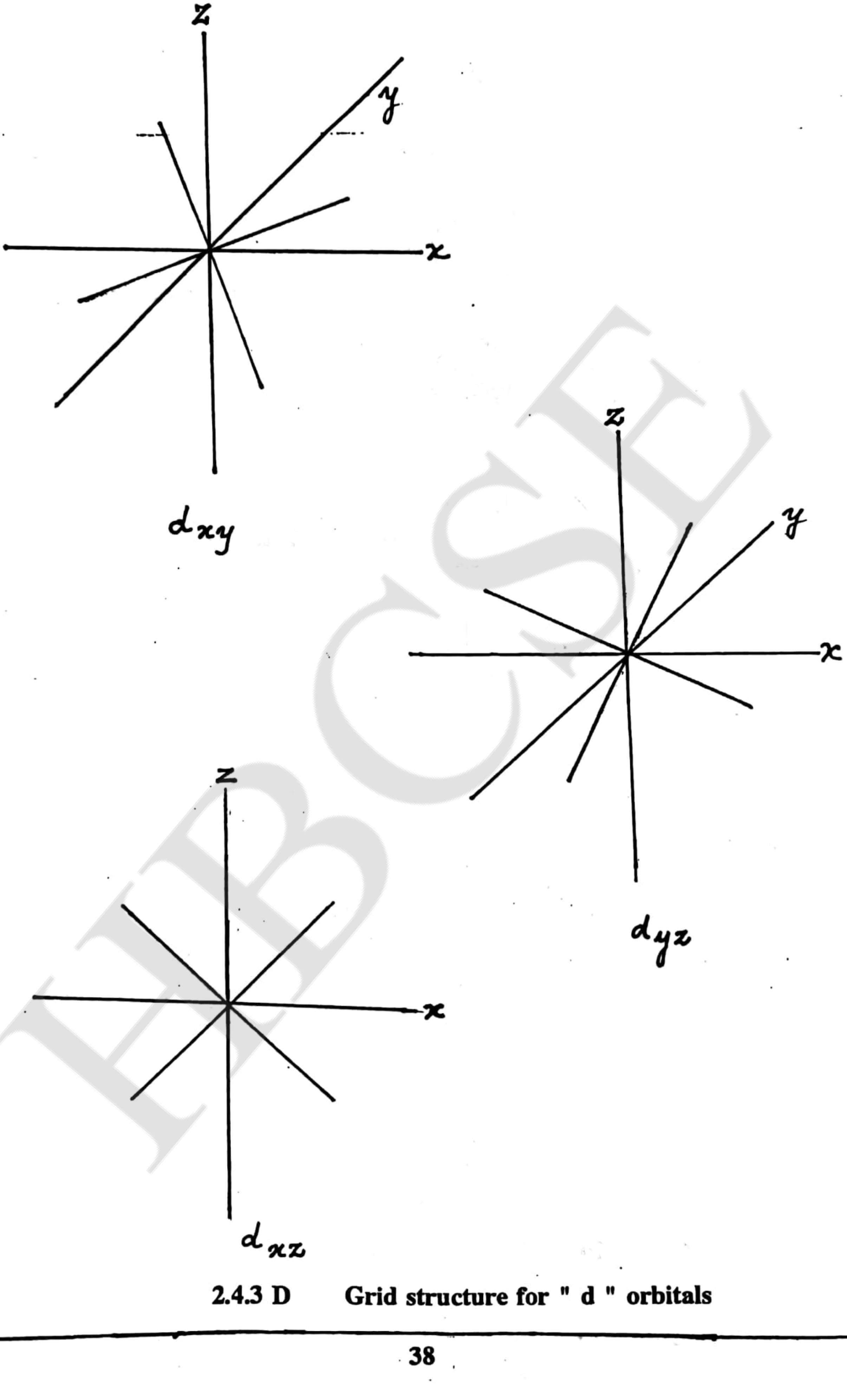




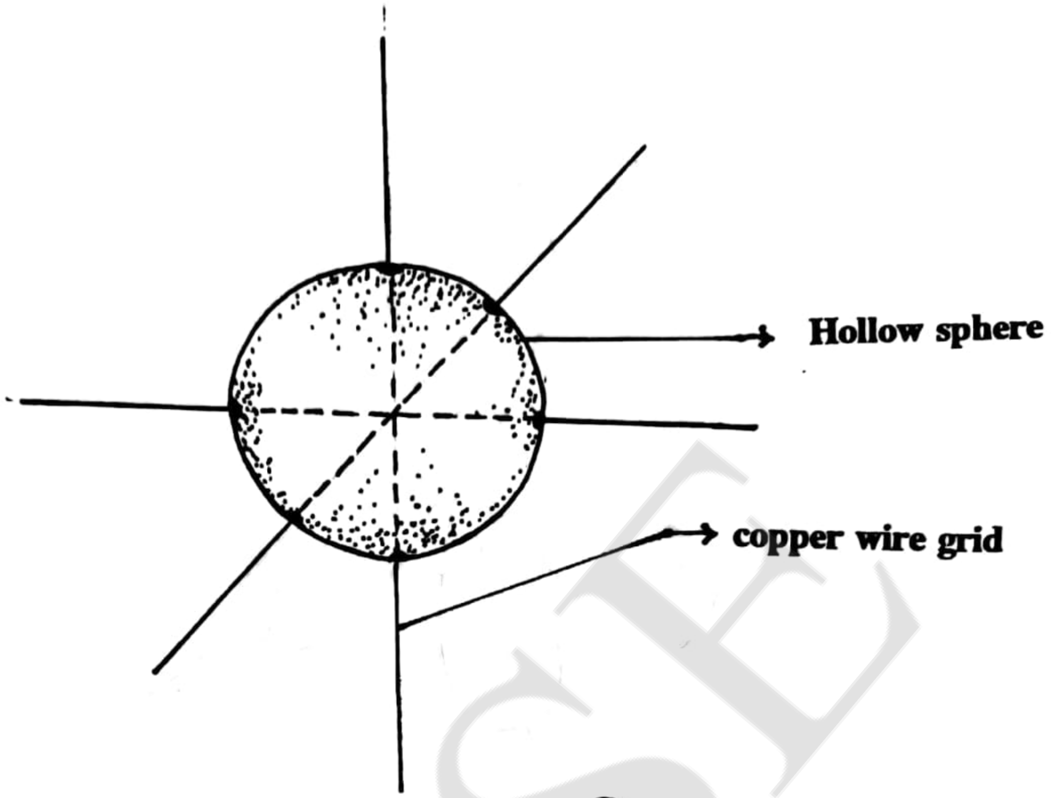
2.4.3 B Procedure for making orbitals from ink filler sections



2.4.3 C Model of " dz_2 " orbital



2.4.3 D Grid structure for " d " orbitals



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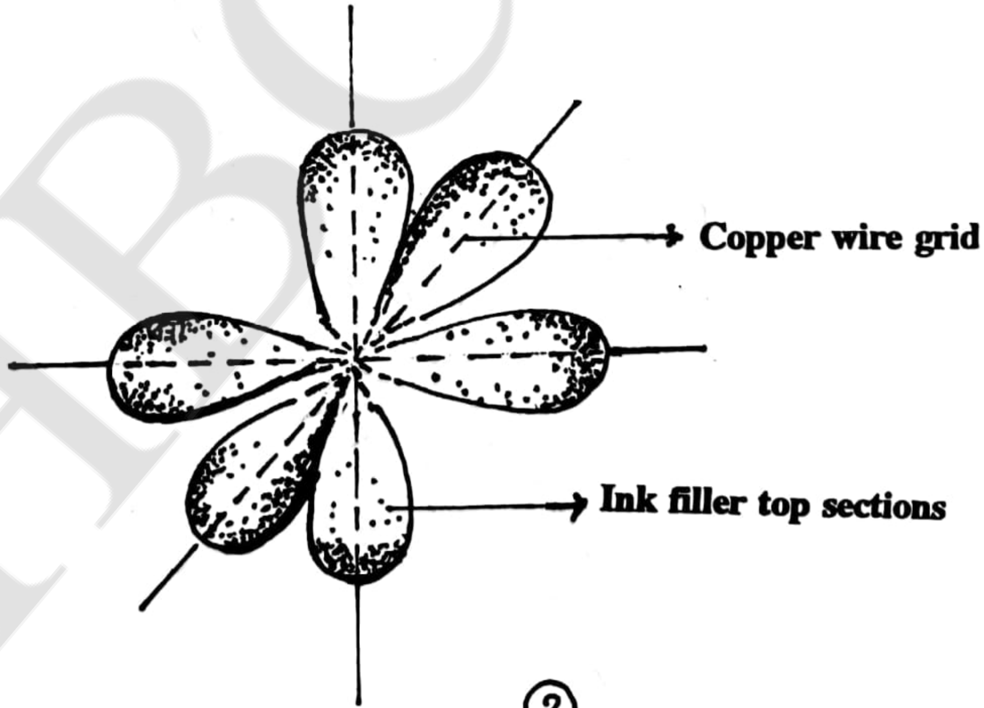

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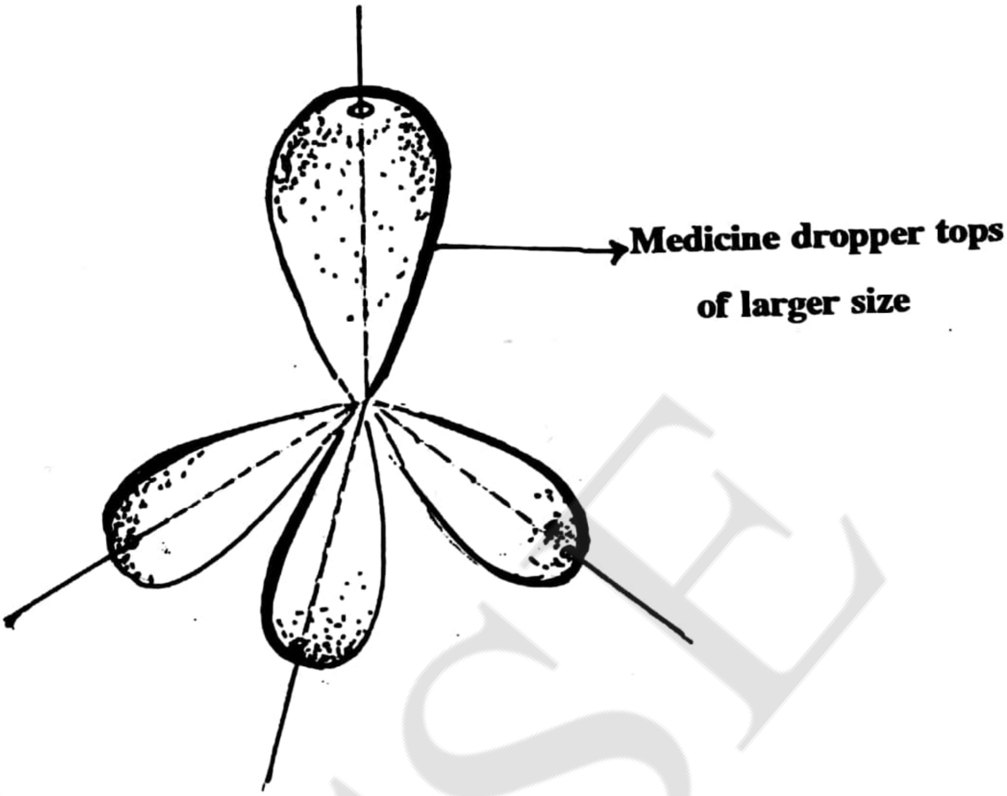
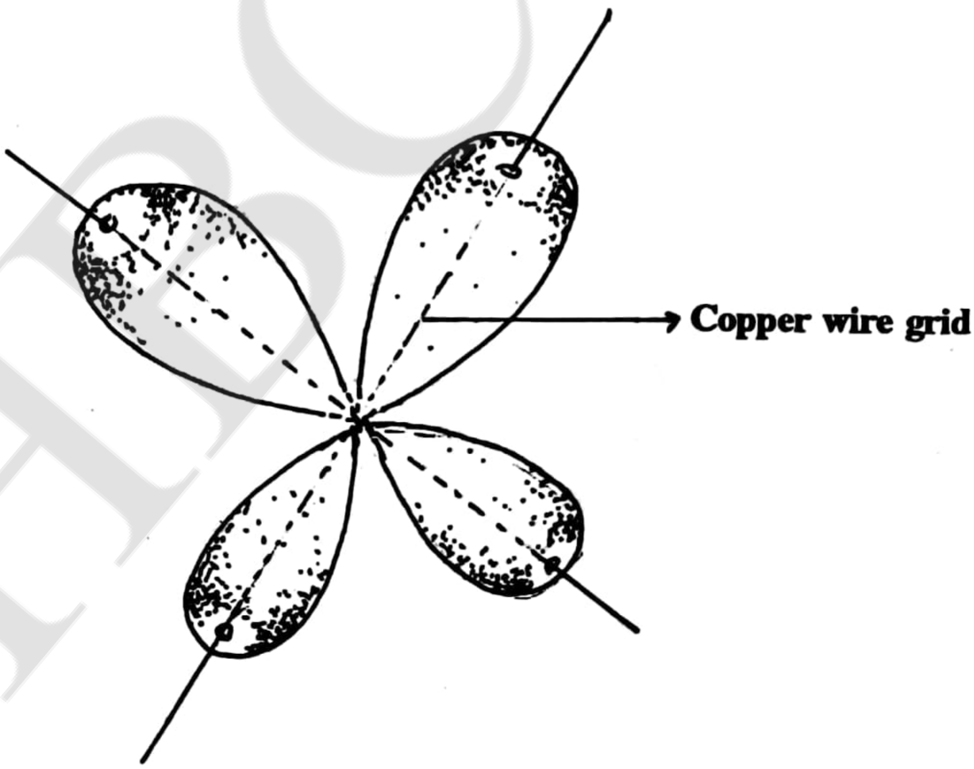
2.4.3 E Models of " S " and " P " orbitals

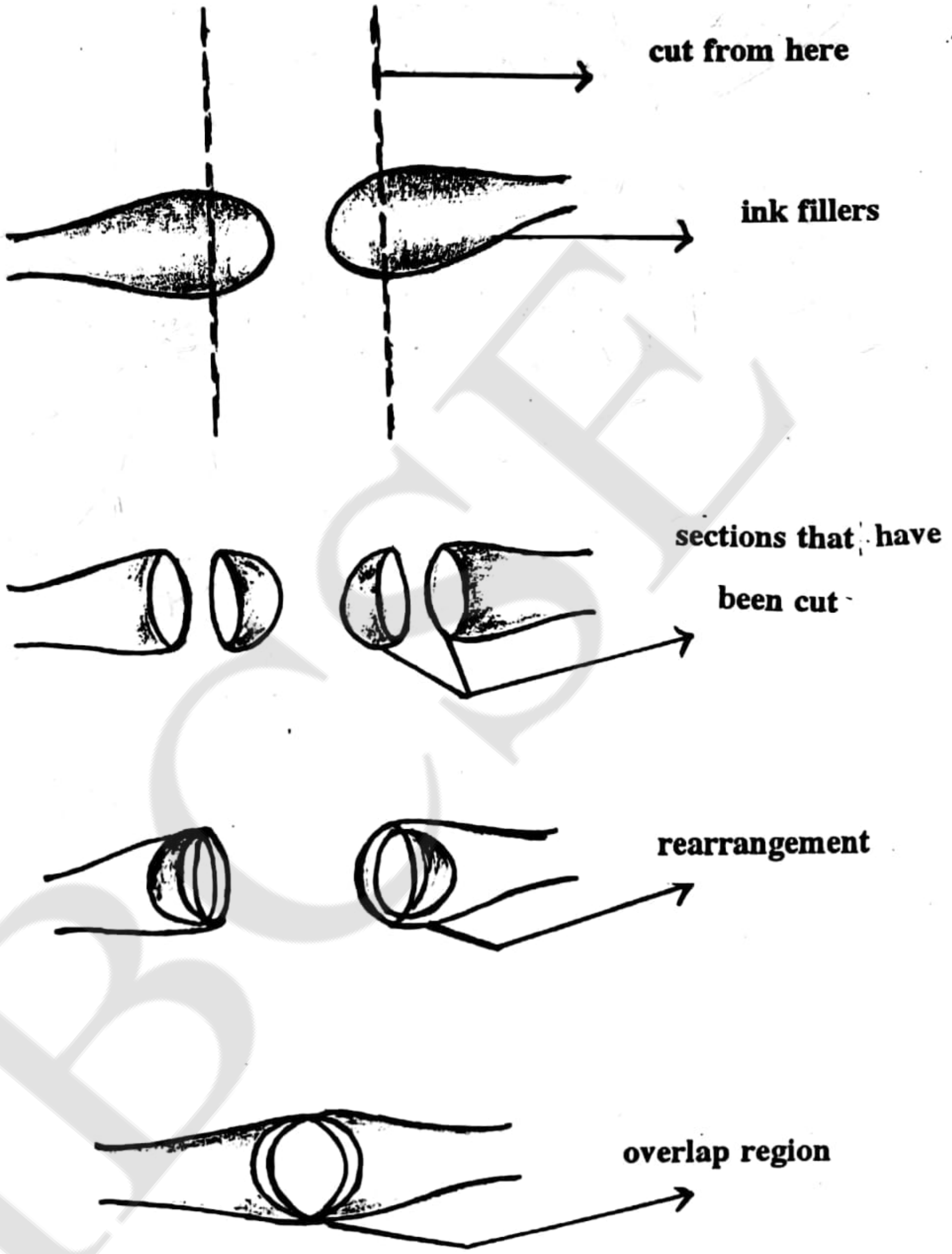




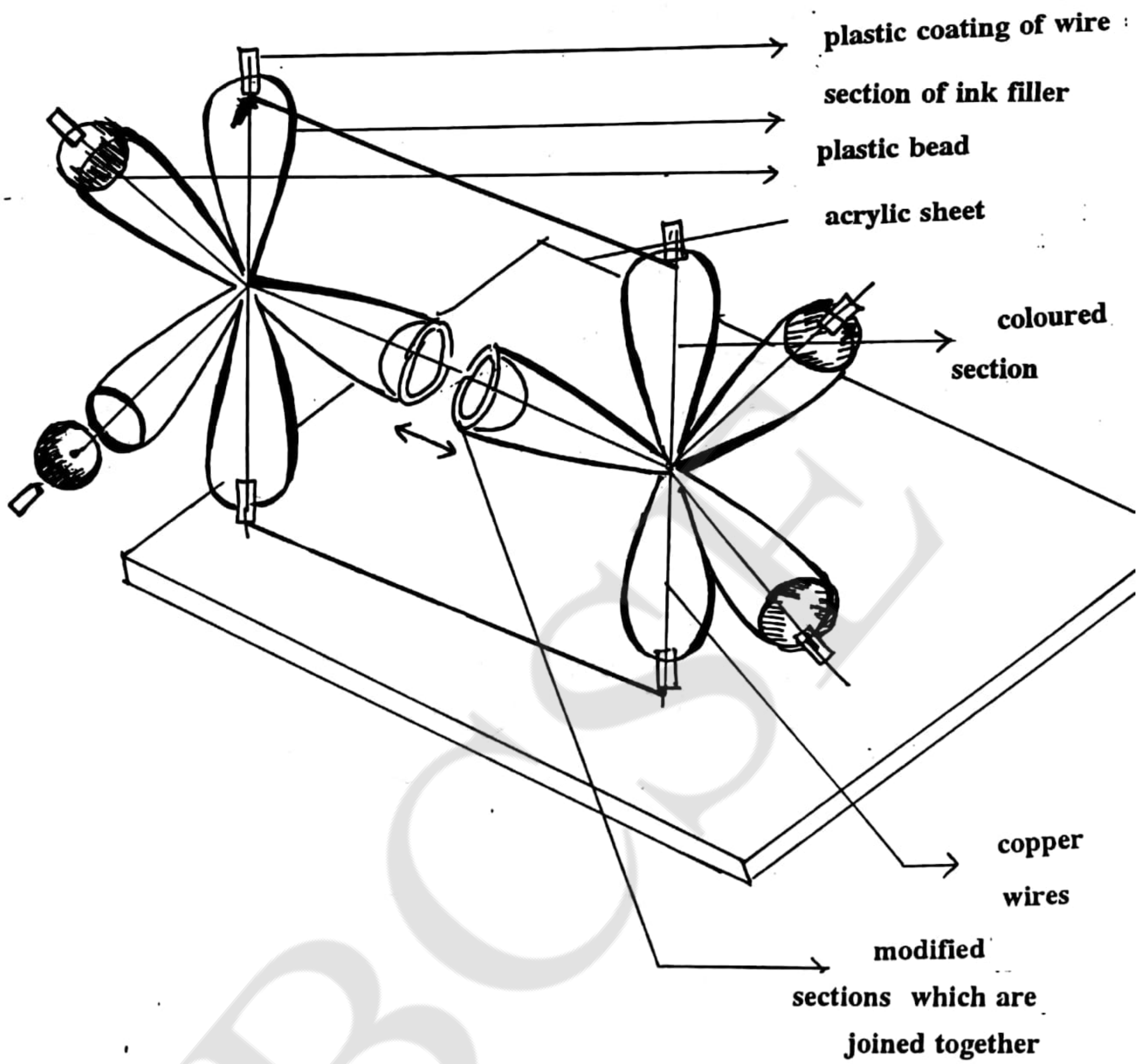
2.4.3 F Models of NH_3 and H_2O

METHOD FOR MAKING

OVERLAPPING REGION

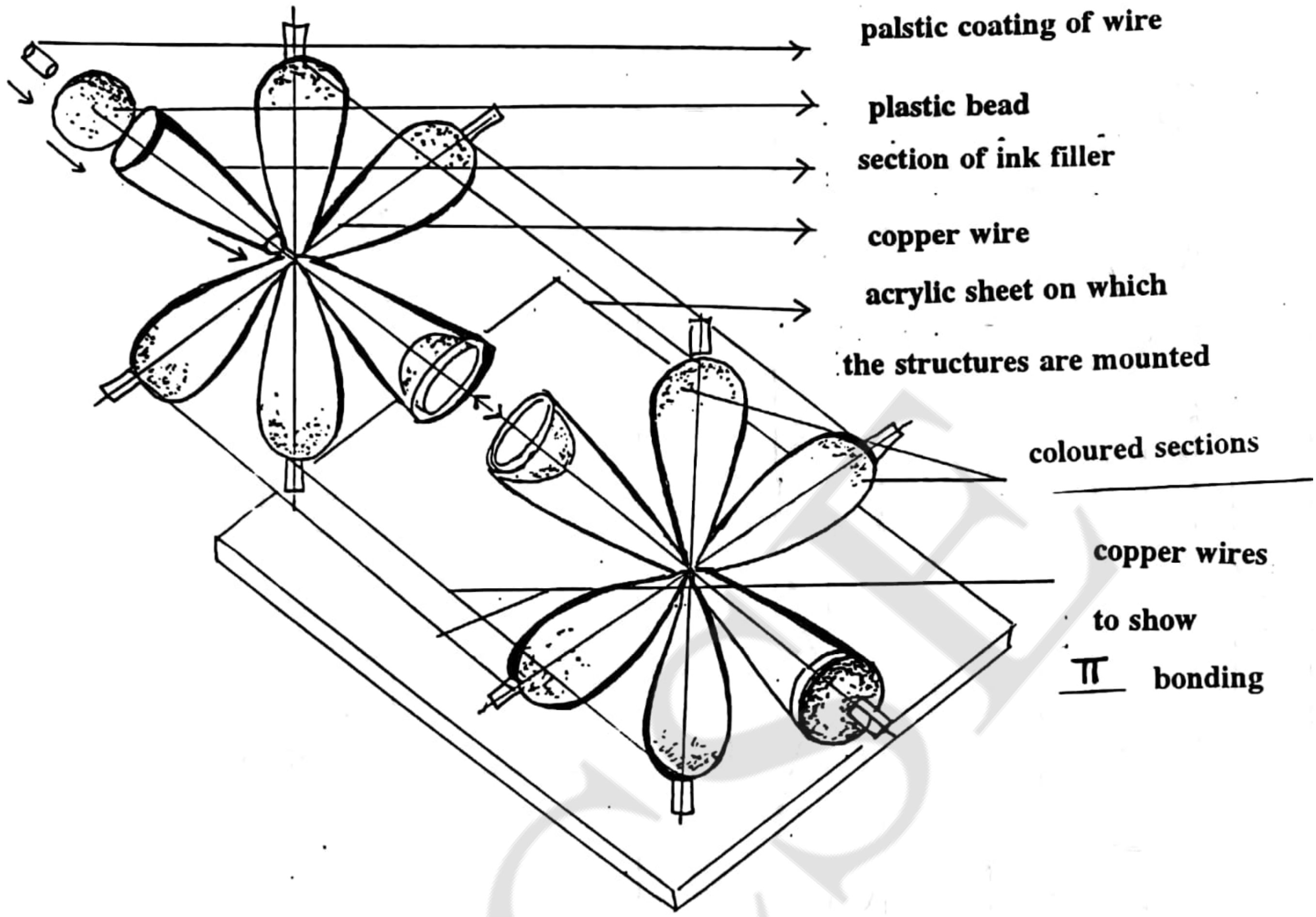


2.4.3 G Procedure for making overlapping region from ink filler sections



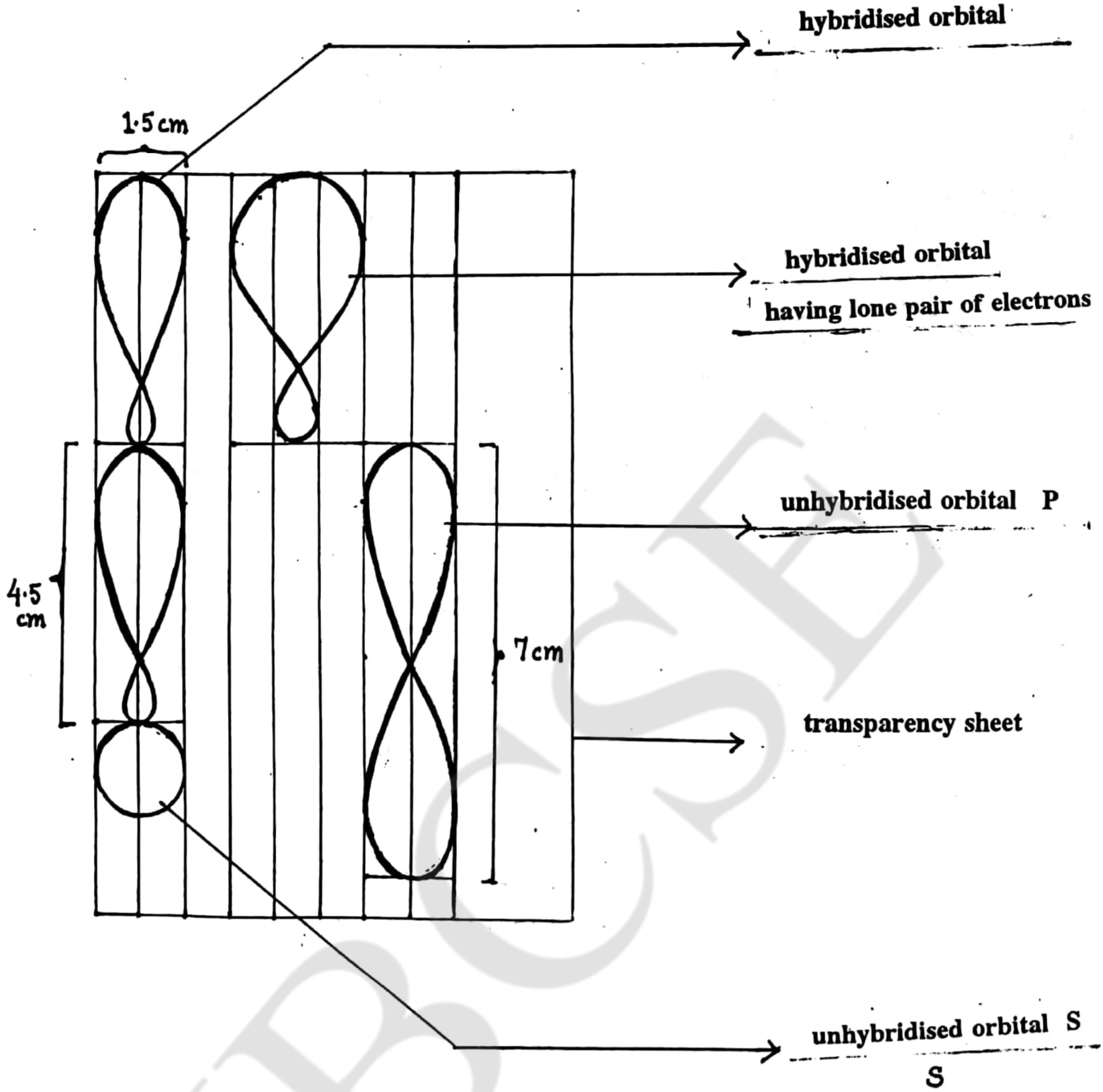
Ethylene (C_2H_4)

2.4.3 H Model of Ethylene



Acetylene (C_2H_2)

2.4.3 I Model of Acetylene



2.4.3 J **Different Shapes of Orbitals Made from Transparency Sheet**

2.4.4 Worksheets for molecular shapes

Worksheet 1

This worksheet can be completed after students perform the activity of placing thermocole balls on the sphere. Here students are provided with molecular formulae of some compounds. Students are asked to write the Lewis dot structure (as they are familiar with Lewis dot structure). Then, they are asked to identify the central atom and number of electron pairs involved in bonding and thereby to predict the geometry of the molecule. See table 2.4.41.

Table 2.4.41 : Predicting shapes of molecules

Molecule	Lewis dot formula	Central Atom	No. of Bonding Electron Pairs	Predicted Molecular Geometry with bond angles
BeF_2				
CO_2				
BF_3				
PCl_5				
CH_4				
SF_6				

(Students should be asked to draw the diagrams of molecular shapes).

Worksheet No. 2

This worksheet should help students to understand the role of non-bonding electron pair/s present on the central atom which affects the predicted geometry of molecule. Students are given three examples of molecules of compounds methane, ammonia and water. Methane does not have any lone pair, but it is given in the worksheet as it helps to understand the shapes of other two molecules. This worksheet should be attempted after the previous worksheet. The models that have been prepared by using inkfiller sections and copper grid can be used to discuss the molecular geometry of following molecules. As stated before, top sections of big droppers should be used to show the non-bonding or lone pair of electron pairs. To begin with, students are asked to predict the geometry with the help of bonding pairs. The models showing the observed geometries of molecules are given to students and the difference between the predicted shape and observed one are discussed.

Students are also asked to draw the shapes of the observed geometries of molecules.

Table 2.4.42 : Effect of lone pairs on molecular geometry

Molecule	No.of bonding Electron pairs	Predicted shape	Observed shape with bond angle	Pictorial representation of the observed shape
CH_4			tetrahedral (angle = 109.5^0)	
NH_3			pyramidal (angle = 107^0)	
H_2O			bent (angle = 104.5^0)	

Students should be asked to measure all the bond angles of a particular molecule. More examples of such types like SF_4 , SO_2 , ClF_3 can be discussed. In the above table the total number of electron pairs around the central atom are same (that is, 4), however, the shapes differ as a result of the number of lone pairs of electrons present on the central atom.

Worksheet 3

In this worksheet, some examples of molecules are given whose bonding can be studied by using the orbital models prepared by inkfiller tops and copper grids. Students are given the molecular formulae. They should use the orbital models to understand the overlap and draw the corresponding figures. As a first step, students can be asked to observe the shape of s and p orbitals and draw their shapes.

Table 2.4.43 : Overlapping of atomic orbitals in different molecules

Molecules	Electronic Configuration	Type of Overlap	Pictorial Representation of Orbitals taking Part in Overlap
H_2			
Cl_2			
HCl			

Worksheet 4

The concept of hybrid orbitals is essential to explain the shapes of various molecules for example, methane. VSEPR predicts the shape of methane molecule to be tetrahedral. However, the bond angle of 109^0 can not be explained with the help of normal atomic orbitals as no atomic orbitals are oriented at this angle with respect to each other. Hybrid atomic orbitals are formed by mixing of simple s,p and d orbitals. The number of hybrid orbitals produced are same as the number of atomic orbitals combined. The new hybrid orbitals formed have new shapes and new directional properties. Transparency cutouts can be used to show the shapes, orientations and overlapping of various hybrid orbitals. The following table can be completed through discussion. The models made out of copper grid and inkfiller tops can be used to show orientations of different hybrid orbitals. To differentiate the hybrid orbitals from the original atomic orbitals colour the used inkfiller tops. However, in this case the size of unhybridised and hybridised orbitals is same which will confuse students. The better alternative is to use dropper head of slightly bigger sizes for hybridised orbitals.

Table 2.4.44 : Hybrid orbitals from the atomic orbitals

Type of Hybridization	Combining atomic orbitals	Orientation in space	Bond Angle	Pictorial representation	Examples
sp	s+p				Be in BeH_2
sp^2	s+p+p				B in BCl_3
sp^3	s+p+p+p				C in CH_4
sp^3d	s+p+p+p+d				PCl_5
sp^3d^2	s+p+p+p+d+d				SF_6

The shapes obtained from spatial orientations of hybrid orbitals are similar to those obtained by VSEPR theory. Students can be taught to represent the hybridisations by using the diagrams which use small circles to represent the valance shell along with the electrons present in it. Such representations are used in the textbooks and solving the worksheet will help students to understand these representations. Similar discussion can be done for examples in which central atom has lone pairs of electrons.

Worksheet 5

This worksheet deals with hybridisation in case of molecules having double and triple bond. The examples of ethylene and acetylene are discussed. The models prepared for these two molecules and the transparency cut outs should be used for this worksheet.

Table 2.4.45 : Hybridisation in molecules containing double & triple Bonds

Molecule	Lewis Structure	No.of Electron Pairs for each C	No.of C-C Bonds	Type of Hybridisation for carbon
C_2H_4				
C_2H_2				

After students understand the type of hybridisation for the central atom, discussion can be done for carbon-hydrogen overlapping. After understanding the chemical bonding for the entire molecule, students should be asked to draw the diagrams of stated molecules. The discussion should be then extended to other molecules such as benzene, nitrogen and formaldehyde. Bonding should also be represented by the diagrams which use small circles to represent the valance shell along with the electrons present in it.

UNIT III

ACTIVITY FOR LEARNING PERIODIC TABLE

3.1 Introduction

This unit discusses the activity prepared for teaching and learning of the periodic table. Section 3.2 gives some background regarding the activity. The next section is devoted to preparation of activity followed by some discussion about how to use the developed activity.

3.2 Background

It is important that students of chemistry should be exposed to the relation between chemical properties of elements and the atomic/ molecular structure of materials, that is, understanding of macro aspect of chemistry in terms of the micro aspect. Such an exposure helps students to understand as to, why a particular element or a compound have certain characteristic properties. The concept that forms the very basis for such an understanding, is the Periodic Table of Elements. The periodic table not only displays the interconnections of properties and the atomic structure, but also reveals how the periodicity in the electronic shell structure leads to the periodicity of properties of elements. It would be natural, therefore, to expect that attempts at instruction in chemistry at the secondary school level (that is, an understanding of properties, chemical formulae and equations etc) would be built around the periodic table. However, this is not the practice.

The periodic table of elements, that is, the long form of the periodic table which is introduced in standard IX (NCERT textbooks), as a two dimensional array of elements displays symbols, atomic weights and atomic numbers of elements. The chapter 'how elements are classified' mainly deals with the Mendeleef's Periodic Table, it merits and demerits, modern periodic law, characteristics of groups and periods. Some discussion regarding predicting properties of an element is also done in the chapter. Thus, at class IX more emphasis is on understanding the construction of periodic table as compared to understanding the periodic trends in properties. The chapter 'periodicity of elements' for class XI in Maharashtra state board text- book deals mainly with the periodicity of the properties of the elements. As periodic trends of properties are not discussed significantly, when the chapter on periodic table is introduced, it is difficult for students to understand the importance of this most important classification in chemistry.

If the relevance of the periodic table is to be brought out, its information content must be chosen properly and exhibited in a manner suitable for highlighting the periodic nature of properties and their relation to atomic structure (Campbell, 1989). Apart from this difficulty, the periodic table is generally taught using charts, which are hung high on walls making it difficult for students to read the information being displayed (Campbell, 1989). These charts do not provide any opportunity for students to play with the given information, or to seek more relevant information. In other words, wall charts of the periodic table do not provide an opportunity for students to construct their own periodic table, filling the required information. Therefore charts, are not necessarily the best teaching-learning aid, with reference to the periodic table.

To present information in an interactive mode and to overcome the shortcomings of the conventional periodic table, an attempt has been made to develop an activity to learn the periodic table in an interactive manner. The description of the activity is presented in the following section.

3.3 Activity for learning the periodic table

One of the first formal arrangement of elements in a tabular format was completed by Mendeleef in 1869. Apparently, he made a card for each of the 63 then known elements and recorded the properties of each element on the same card. Placing together the cards of the elements having similar properties, Mendeleef constructed the periodic table.

The same idea is used in order to create an element of joy, in learning the topic of periodic table. The main emphasis in preparing the activity is to involve students in construction of the periodic table rather than presenting the table directly to them (in fact, NS, the teacher fellow, has given this activity as a project to students which could be done during the winter vacation. During the vacation, each child was asked to design six cards and submit after the vacation in the school laboratory. The activity was very well received by students).

3.3.1 Preparation of the cards for elements

The cards can be cut from ordinary chart paper or cardboard from old notebooks. Students can also use card-paper which can be obtained from old greeting cards. The length and breadth of the cards is kept same as that of the playing cards so that it is easy to pack and sort them out. If blank playing cards or plastic coated cards used for preparing visiting cards are available, then such cards can also be used. In case of cards prepared from ordinary chart paper or card paper, a similar size of white paper can be glued on both the sides.

The card is divided in two regions. The top region roughly occupies two-third part of the card. The atomic number of the element is stated at the extreme left hand side corner on the top. The top right hand side displays the electronic configuration of the element. The symbol of the element is written in the centre of the card (see the figure given below). Different colours, are used to indicate metal(orange), non-metals (green) and metalloid (yellow). To represent, transition and inner transition elements blue and purple colours are used (it is possible to show the normal states of elements using different colours). Just below the electronic configuration, the oxidation states of the element is represented.

The bottom one third part of the card has more details than the top part. The extreme bottom right hand side shows the relative atomic mass whereas the left hand side gives the name of the element in the same colour as that of the symbol. The ionisation potential (KJ/MOL) and electronegativity (KJ/MOL) are shown just above the relative atomic mass. The centre of the bottom part of the card is used for pictorial representation of atomic size. It also states the atomic radii in picometers (see plate 1). The melting point and boiling points of element are stated towards the bottom left hand side portion of the card. Different colours can be used to write the figures in order to make them clearly visible. The back view of the card can be designed to trigger the interest of students. Some interesting information that can be furnished is distribution of the elements in the earth's crust and the living system, the main type of ore along with the photographs of elements in pure state. For representing distribution of elements, four colour codes were chosen and can be used on the other side of the card.

green	-	0.1%	pink	-	0.001% - 0.1%
blue	-	$1x10^{-6}$%	yellow	-	$1x10^{-6}$% - $1x10^{-3}$

the element (students can be asked to refer to the textbooks, data books or encyclopedias for required information). Discussions regarding representing this information should be conducted with students. Clues regarding certain properties, observed during the lab sessions can also be presented on the card. In this process, students are exposed to a wide range of information regarding elements.

A sample clue card may contain clues regarding properties as follows -

i) Latin name means 'sons of the earth', ii) hard, silvery lustrous metal with low density, iii) liberates hydrogen with steam at high temperature, iv) not readily attacked by acids, although dissolves in concentrated HCl and H_2SO_4 .

The other side of the card, (that is, the back side) of the card includes uses of elements related to chemistry and applied fields of chemistry. As before, the number of clues that can be put on the card is four to five. The most popular uses of the elements should be picked and placed first along with one or two unfamiliar ones.

A sample clue card may contain clues regarding properties as follows -

i) essential constituent of body fluids, cells, bones and teeth, ii) needed for correct functioning of nervous system, muscular contraction and blood clotting, iii) compounds used in building industry, agriculture, paper and glass manufacture etc.

Students may be familiar with the chemical uses of the elements, however, uses in other areas are not known to them. This activity when performed by students help them to understand the uses of elements in various areas. Experience with students tells that they enjoy doing this activity. The activity forces them to read information regarding elements and students put in a lot of efforts to go through the available information and choose the suitable ones. Solutions to the clue card should be prepared separately. The elements are arranged alphabetically and then the numbers are given in serial order. Appropriate serial numbers are used to mark the clue cards. All the cards once marked with serial numbers are collected and kept together.

3.3.3 Activities using the clue cards

Many activities are possible with the prepared set of cards. This section discusses some of them. The activities are divided into several steps called *attempts*. The whole class (consisting of 40 to 45 students) can be divided into group consisting 3 to 5 students. The groups are decided by the teacher in such a manner that each group consists of some above average, average and below average students. Students should do all the attempts sequentially. They should be asked to write down the observations which can be used for discussion. Students should be allowed to discuss their errors as it helps in understanding of the topic. Some scores are assigned to each attempt.

First attempt

To begin with, simple exercises are given to students. At first, set of cards are distributed to students in such a manner that all groups get equal number of cards. A lay out of periodic table showing the atomic numbers of different elements is given to students (or placed on blackboard). Students are asked to study the layout first. Then, they are asked to search for proper places of the elements for which they are having cards. The analogy given for the periodic table can be that of a building. In this building, students are looking for various floors, blocks and block numbers of the elements (20 to 25 minutes are devoted to this attempt).

Difficulties faced while placing the cards should be discussed. In general, students have problems placing transition and inner transition elements. The labels, that is, representative elements transitional metals and lanthanides and actinides can be introduced to students.

Students are asked to see the placements of metals, metalloid and non-metals in the periodic table classification. They can be asked to make observations regarding the number of metals, non-metals and metalloid. Observations regarding atomic number and atomic weight sequence should also be made.

Second attempt

During this attempt, students can do observations regarding number of elements in each group and each row of the periodic table. It will help students to observe number of groups and periods in the table and placement of lanthanides and actinides. Students can be asked to state the smallest, largest and incomplete period.

Third attempt

Observations regarding electronic configuration of the elements are done in this attempt. Variations in the electronic configuration in periods and groups (first study the main groups and then the transition elements). Discussion regarding valency/oxidation states can be conducted at this stage. Since the chemical properties of an element depend upon the valence electrons, students should be able to state that chemical properties of elements in a group are same. Some chemical properties of a particular element can be given to students and they can be asked to guess the properties of other element from the same group.

Fourth attempt

This attempt concentrates on studying the variations of other properties stated on the cards. First, the atomic sizes can be studied as it is represented pictorially. Students should be asked to note the general trend of the property under study. Subsequently, ionisation potential and electro-negativity, melting points and boiling points can be studied. Interconnections between atomic sizes, ionization potentials and electronegativities should be discussed. Observations of these properties in context of metals and non-metals should be done. This activity at the end should help students to guess the properties of element depending on its placement in the periodic table.

Fifth attempt

The prepared clue cards are used in this attempt. The game can be played between groups of students. Each group can be allotted cards for 20 elements. The clue cards for these elements should be given to other opposite team. The team speak out the clues of an element and if the opposite team guesses the element, then they win the corresponding clue card and a pair is formed of the card of an element and its clue card having properties and uses (Note : The code numbers given on clue cards do not show any relation to the atomic number of the elements).

This game enabled the children to learn the properties and uses of the elements and children worked hard to learn the properties and uses of all elements in order to win the game.

UNIT IV

MODELS FOR STUDYING CRYSTAL STRUCTURE

4.1 Introduction

This unit discusses the models prepared to understand crystal structure of metals, specially those discussed at class XII chemistry syllabus. It includes simple cubic, body centred and face centred and close packed hexagonal structure.

4.2 Background

Crystal structure is one of the fascinating areas in chemistry. In a crystal the atoms, molecules or ions are arranged in regular repeating pattern. To describe the structure of crystal lattice, concept of unit cell, the simple basic unit is useful. By repeating this simple structural unit up and down, back and forth, in all directions entire crystal lattice can be built. For diagrammatic representation, these particles are treated as sphere and are represented as small circles. Most often the models in schools are used for demonstration purpose and rarely students get an opportunity to build such models to arrive at appropriate conclusions. The activity and models discussed below can be done and assembled by students.

4.3 Activity for crystal structure

a) *Material*

Tiny circles (diameter - 2 to 3 cm) cut from colour transparencies

b) *Procedure*

This activity concentrates on arrangement of various layers to obtain the required crystal structure by using prepared circles. In each case, students start with the first layer of unit cell. The second layer can be built up by using circles of different colours, for example, in case of body centred cubic structure (for example, sodium) if the first layer is made using green circles, the red circles can be used for the next layer. For body centred crystal structure, the circles of second layer are placed between the void of any four green circles of first layer. The third layer of yellow circles is placed directly above the green circles of first layer.

In case of face centred cubic structure (for example, aluminium), one red coloured circle is placed between the four green circles in the first layer itself. Thus, the four green circles do not touch each other. While working out the second layer, students place one red circle between any two green circles, present in horizontal and vertical direction. The third layer can be done again with green and red circles as in the case of first layer. The difference in shades of the final structure can help students to distinguish between the different layers. They can also observe that there is no room for a circle at the centre of face centred cubic structure.

The study of hexagonal close packing structure and cubic close packing structure can be studied by drawing about sixteen circles on a plain transparency sheet. The voids in between the circles are marked as 'A' & 'B' as shown in the figure 4.3A. The second layer of yellow circles (that is, layer B) is placed covering the voids marked A. A third layer consisting of green circles, is placed directly above the first layer. This arrangement is called as AB-AB arrangement. Students can observe, that in case of AB-AB type of arrangement, the voids marked B are never covered. Thus, the AB-AB pattern of packing in case of hexagonal close packed structure (for example, magnesium) should become clear with this activity. They can observe that the third layer is directly above the first and the fourth layer is directly above the second by choosing different colour circles for different layers.

The other alternative structure formed from the circles drawn on the transparency sheets is called as ABC-ABC type. After placing the circles of second layer as in the previous case, the circles of third layer are placed in such a way that they cover the voids represented by b in the first layer. So ultimately, all voids are covered up. Here the pattern repeats after every third layer, that is, the fourth layer is above the first; the fifth is above the second and the sixth is above the third and so on. This type of lattice structure is known as cubic close packing structure which is actually face centred cubic structure (plate 7).

c) *Advantages and disadvantages*

The advantages are as follows -

i) Students can prepare this structure on their own.

ii) The prepared structures can be used on overhead projector for classroom demonstrations.

iii) The material is available with ease and the production cost is low (Rs 20 to 30/-).

The disadvantages are as follows -

i) The prepared circles do get faded after some use.

ii) The activity does not give the three dimensional view of crystal.

iii) The overhead projector is required if the activity has to be used for classroom demonstration.

4.4 Three dimensional Models for studying lattice structure

a) *Materials*

acrylic sheet, cycle spokes along with nuts and bolts, plastic balls of two different colours or preferably three colour (diameter about 3.7cm), glue(Feviquik) and acrylic sheet cutter.

b) *Procedure*

The diameter of the plastic balls is noted with the help of vernier calliper. The balls used in the stated models have diameter of 3.7cm. Two different types of grids were prepared for constructions of models.

Type A grid - This grid is prepared for FCC structure only. For drilling holes acrylic sheet, refer to Fig.4.4A. The nuts are placed in the acrylic sheets with the help of bolts and secured by the glue (feviquik). The cycle spokes are cut of equal lengths & fitted into the holes. The holes of 2mm diameter are made into the plastic balls with the help of drill so that they can easily slide down the spokes (plate 10 -b). Students can be provided with the acrylic sheet with holes, cycle spokes and plastic balls with holes and are asked to build the F.C.C. structure. Use different coloured balls for the spheres which will be placed in the centre. The voids present in the structure can be noted by looking from top and sides of the prepared structure. The co-ordination numbers can be also observed while building up the structure.

Type B Grid - This grid is prepared so that students can build b.c.c., s.c.c. (simple cubic structure) and h.c.p. structures. So this grid is more complex as compared to the first one. Students should arrange the cycle spokes in different patterns needed for the various structures mentioned above. The design for this acrylic sheet is given in Figure 4.4B. Students can compare the voids present in all the prepared structures and can get a feel about the closest packed structure (plate 10 - a).

c) *Advantages and disadvantages*

The advantages are as follows -

i) The activity offers some concrete experiences regarding arrangement of atoms in various types of crystals.

ii) Since the prepared activity and models give opportunity to students to participate in construction of models, the structures can be understood in better way. It provides scope for more interactions among teachers and students.

iii) The prepared models can be dismantled easily.

iv) The materials used are easily available in local markets and production cost is low (around Rs 100/-).

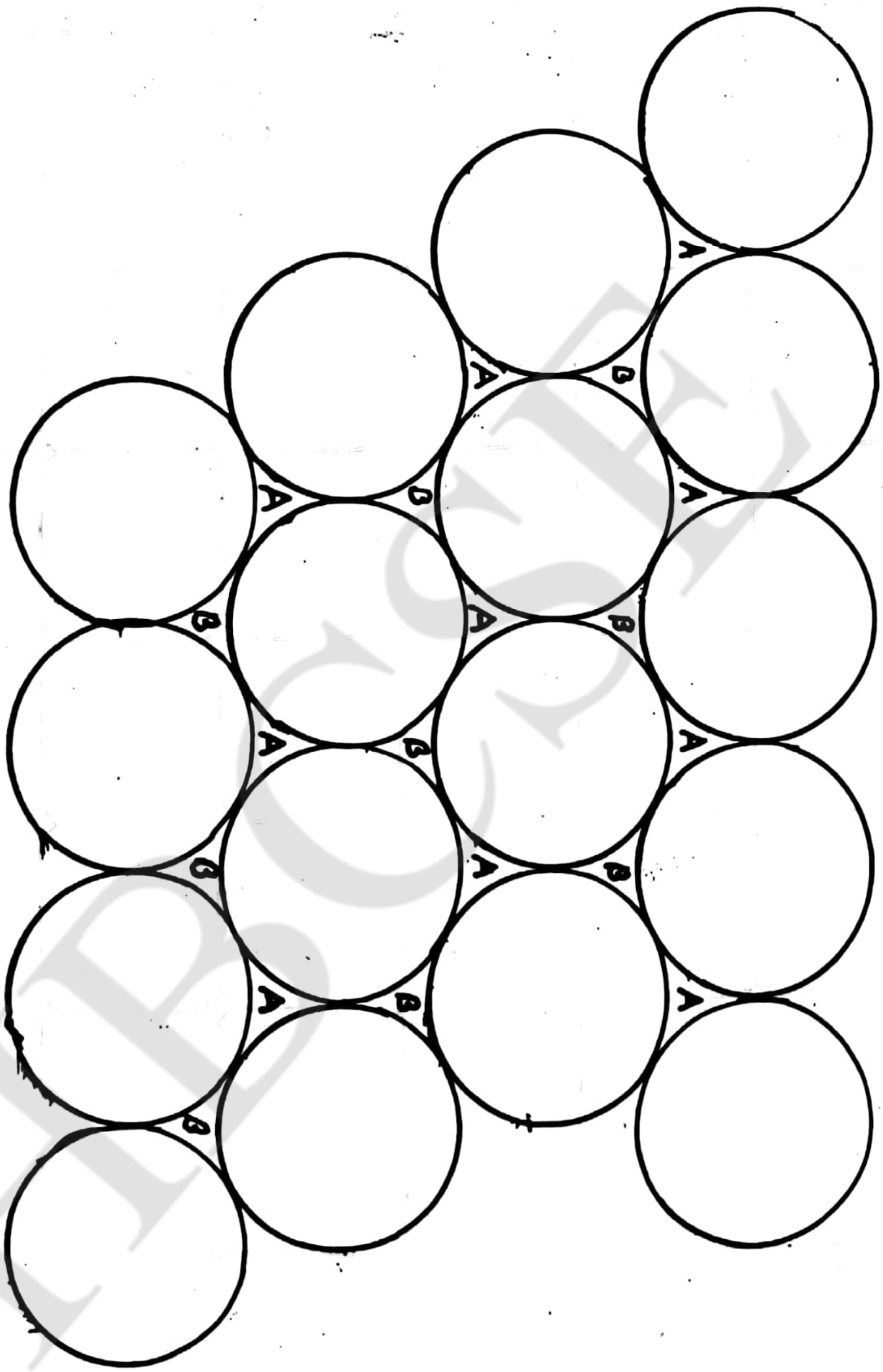
The disadvantages are as follows -

i) The prepared activity and models are restricted to crystal lattice structure of metals.

ii) The drilling of acrylic sheet requires technical help.

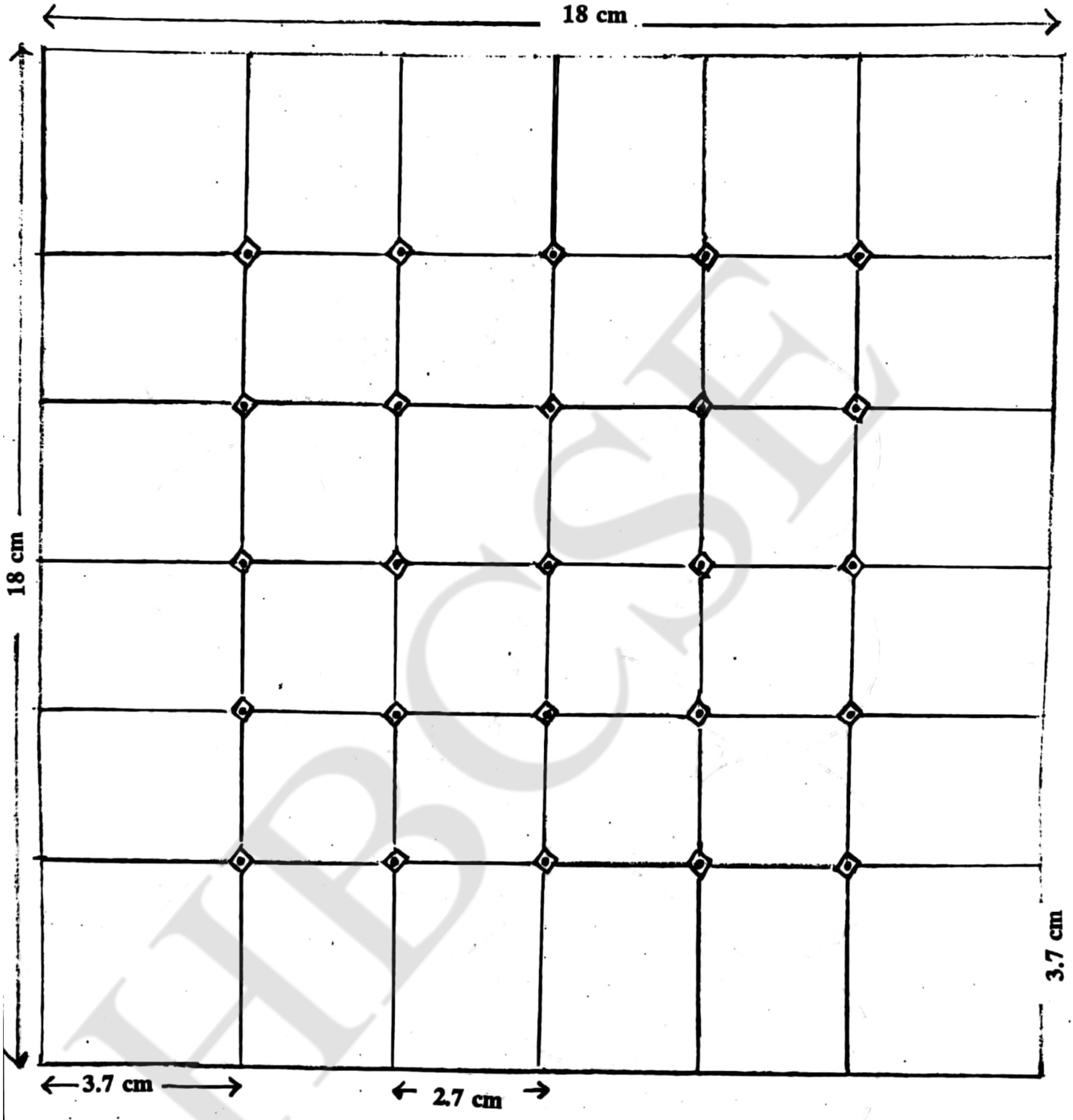
iii) The diameter of locally available balls is not uniform which creates problems for preparation of grids. Wooden beads which are used abacus may be a better choice.

iv) The transparency cut outs wear out after being used for certain period of time.

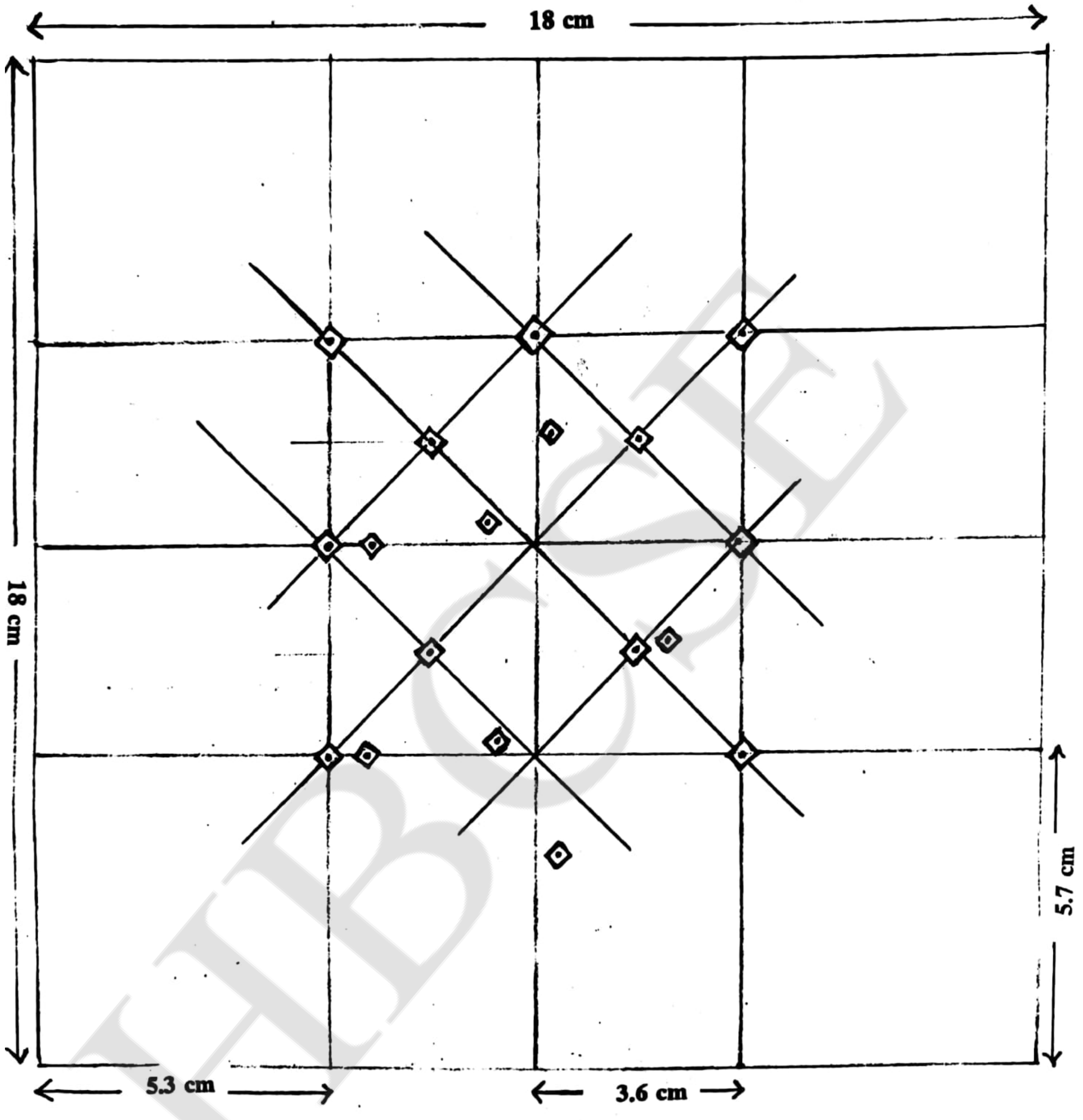


First layer for AB - AB type structure

4.4 A DESIGN OF GRID STRUCTURE FOR FCC LATTICE



4.4 B DESIGN OF GRID STRUCTURE FOR SCC, BCC AND HCP LATTICE



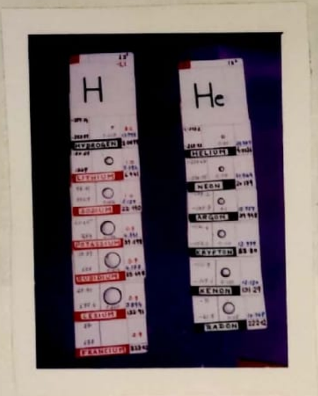


Plate 1 : Prepared periodic table cards - arrangement showing gradation in atomic radii down a group.

Plate 2 : Molecular structure of MX_6 type eg. SF_6 - 6 electron pairs involved in bonding with no lone pair, all bond angles can be visible due to transparent central atom

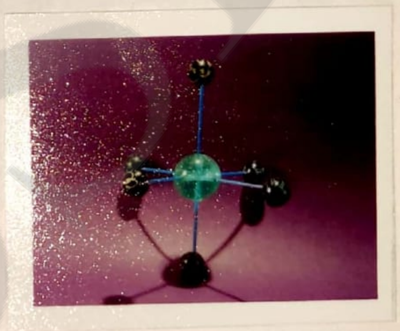


Plate 3 : Tetrahedral structure of Methane (CH_4) - made out of transparency sheet, thermocole balls and toothpicks. Suitable for projections on overhead projector.

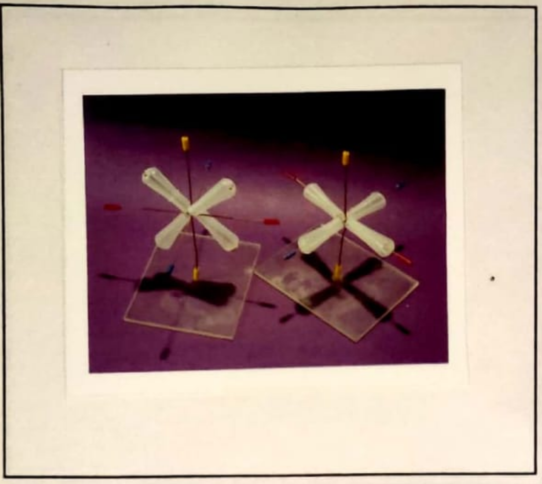


Plate 4 : Representations of d orbitals - dxz, dx^2y^2 -- made out of copper wires, ink filler tops and acrylic sheet.

Plate 5 : Shapes of molecules in the case of orbitals having 3, 4, 5 and 6 electron pairs -- eg. BCl_3, CH_4, PCl_5 and SF_6.

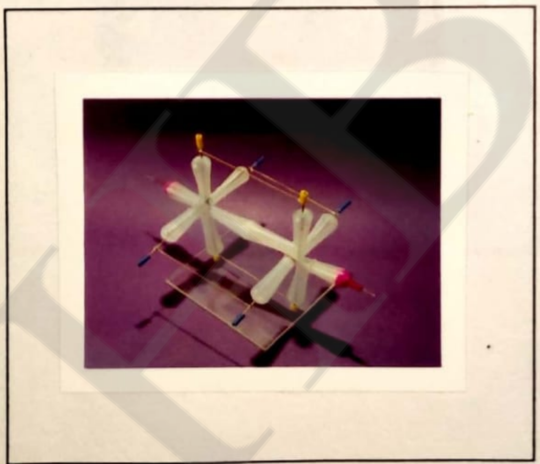


Plate 6 : Molecular structure of Acetylene(C_2H_2) -- made from copper wires, ink filler tops and acrylic sheet (sp hybridisation)

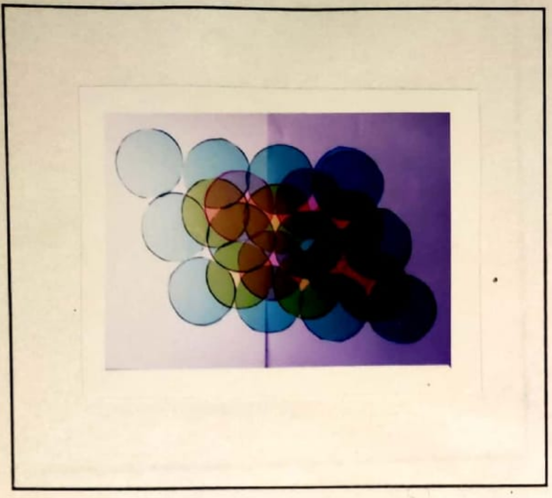


Plate 7 : Arrangement of circles made out of coloured transparency sheets -- to explain the lattice structure of cubic close packing (ABC - ABC type)

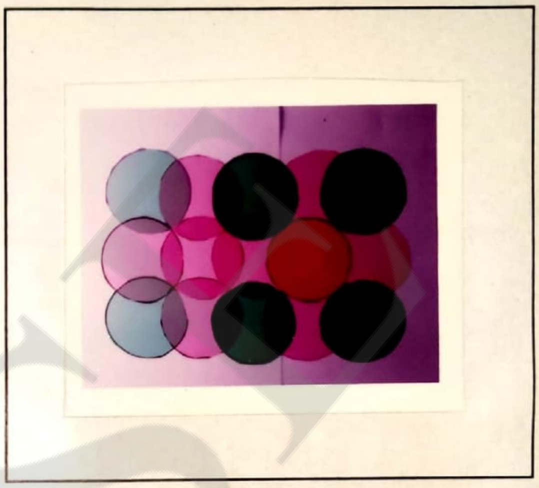


Plate 8 : Arrangement of circles - made out of coloured transparency sheets to show the lattice structure of F.C.C type.

Plate 9 : Crystal lattice structure - made from plastic balls and acrylic sheet to show B.C.C, C.C.P and F.C.C lattice structure.

Plate 10 : Grid structure a) S.C.C, B.C.C, H.C.P b) F.C.C structures.

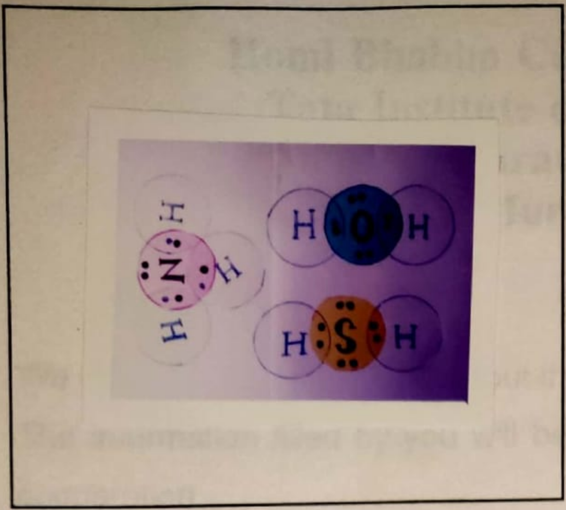


Plate 11 : Lewis structures for H_2O, NH_3, H_2S - made out of circles from transparency sheets.

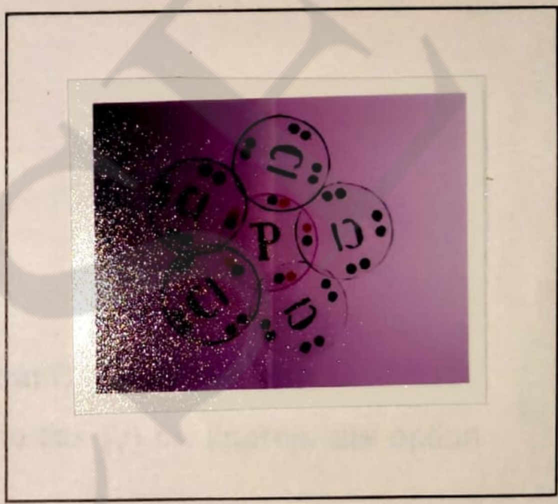


Plate 12 : Lewis structure for PCl_5 - made out of circles from transparency sheet(example of molecules that do not obey octet rule)

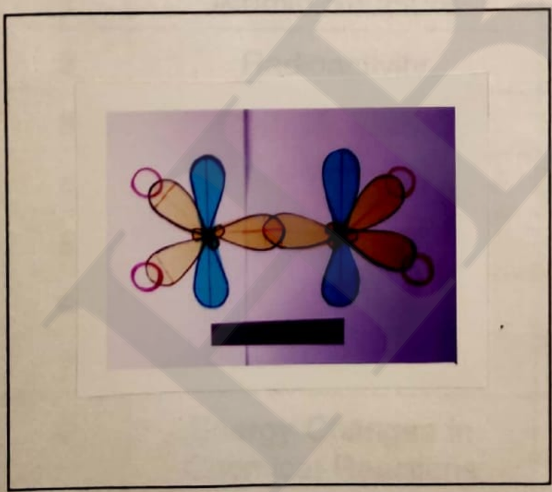


Plate 13 : sp^3 hybridised Ethylene molecule (C_2H_4) - Structures made from cut-outs of transparency sheets (blue colour shows unhybridised orbital and yellow colour shows hybridised orbitals).

Appendix A

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We want to know your views about the chemistry topics which you studied at Class-IX. The information filled by you will be helpful to us in our study. Thank you for your cooperation.

Name:-

Age:-

Class:-

I. The following topics were taught to you at Class-IX. Three opinions are given to you for each topic. You have to tick (✓) on appropriate option for each topic.

[illegible]	Topic	Difficult	Average	Easy
1	Atomic Structure			
2	Radioactivity			
3	Periodic Table			
4	Chemical Bonding			
5	Mole Concept			
6	Chemical Reaction			
7	Balancing Equation			
8	Energy Changes in Chemical Reactions			

II. Now you have to tick whether the stated topic was interesting, OK or boring while you were learning the topics. Please tick (✓).

S.N.	Topic	Interesting	Okay (so-so)	Boring
1	Atomic Structure			
2	Radioactivity			
3	Periodic Table			
4	Chemical Bonding			
5	Mole Concept			
6	Chemical Reaction			
7	Balancing Equation			
8	Energy Changes in Chemical Reactions			

III. For better understanding of the topics given below, which of the following things will be useful from your point of view. Tick all the relevant options. (✓)

	Topic	More interactive discussion	More of lab. Expts	Demonstration on Expts.	Construction of various models	Drawing for illustration of concepts
1	Atomic Structure					
2	Radio-activity					
3	Periodic Table					
4	Chemical Bonding					
5	Mole Concept					
6	Chemical Reaction					
7	Balancing Equation					
8	Energy Changes in Chemical Reactions					

IV. Of the list given below, tick in the appropriate column, on the basis of your liking.

	Methods	Like very much	Okay	Not at all
1	Lecture			
2	Problem Solving			
3	Discussion			
4	Demonstration			
5	Experiments			
6	Building Models			
7	Quizzes on Topics			
8	Trips to....			
9	Class Activities			

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