STRUCTURE, BONDING, SOLUBILITY, PROPERTIES

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**CHEMISTRY DEPARTMENT**

STRUCTURE, BONDING, SOLUBILITY, PROPERTIES

NAME\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ CLASS \_\_\_\_\_\_\_\_\_

We are going to compare the behavior of water, ethanol and hexane as solvents.

**PRACTICAL WORK**

SAFETY: WEAR LAB COAT and SAFETY GLASSES. If in doubt, ask the lecturer!

**Stations are already set up containing:**  burette, deionized water, ethanol, hexane, polythene rod + wool for rubbing (electrostatic charges), corks for hexane tubes.

Other materials: test tubes, powdered graphite, iodine, calcium chloride. *Make appropriate tables for the results.*

PROCEDURES

**Stations 1-3.** Charge a polythene rod by rubbing it on a piece of wool; hold the rod about 1cm from a jet of fluid issuing from a burette and note what happens:

(1) water (2) ethanol (3) hexane

Q1 What sort of particles does each contain?

Water is composed of hydrogen and oxygen particles. Ethanol consists of particles of hydroxyl and ethyl. Both of these molecules have a dipolar effect. Hexane, on the other hand, is an alkane containing 6 carbon atoms.

Q2 Are these particles polar?

Water is a polar molecule, containing partial negative charge near oxygen atoms and positive one near hydrogen atoms due to an uneven distribution of electron density. Ethanol, on the other hand, is a very polar molecule due to the presence of hydroxyl group. Hexane has even distribution of positive and negative charges and is thus non-polar.

Q3 Explain the effect of a charged rod on each jet?

The charge in the rod only affects the polar liquid because the polar liquid contains molecules with an unequal charge distribution (a dipole moment). For example, a water molecule has a significant negative charge concentration on its oxygen because a majority of the molecule's electrons are around the oxygen molecule.

The charge in the rod attracts either a positive or negative charge and repels the other. In nonpolar liquids, the positive and negative charges are spread evenly throughout the individual molecules, and the resulting attractive and repulsive forces balance each other out. In polar liquids, however, the uneven charge distribution in the liquid's molecules means that the attractive and repulsive forces will not balance each other out, and the liquid will deflect upon encountering an electric field (such as the charged rod).

Q4 What might happen with a rod of opposite charge? (Ask for a glass rod + cloth)

It is dependent upon the texture of cloth used. Glass rod rubbed with silk creates a positive charge and with fur will give a negative charge. These variant charges are created due to the presence of electric force.

Q5 Explain the behaviour of liquids with the charged rod to the nature of particles?

The behaviour of liquids depending on the polarity of liquids. If they are polar like water or ethanol, they will align with the electric field created by the charged rod. If the liquid is non-polar like hexane, it will not be attracted to the electric field of the charged rod.

Q6 Look up the boiling points and relative molecular masses of water, ethanol and hexane; compare their values in terms of polarity?

Generally, it is believed that higher the molecular mass, greater the boiling point is. But sometimes, this does not happen. For instance, take the case of water, it has a low molecular mass of 18.0 g.mol−1 but has a high boiling point. In such cases, another aspect of intermolecular forces existence is taken into consideration. In the case of water, the intermolecular force of hydrogen bonding operates which keep the molecules strongly intact that it requires high temperature to change the state of matter. Ethanol has relatively high molecular mass as compared to water which is 46.0 g/mol and a boiling point of 78 degree C due to the presence of strong hydrogen bonding. Hexane has high molecular mass of 86.176 g/mol and boils at 154 degree C. This is also due to strong intermolecular interactions. Though water and ethanol are polar molecules and hexane a non-polar one, yet their boiling patterns are different which means polarity is not directly related to their boiling points and masses. Inter-molecular forces and their masses are their contributing factors.

**Test tubes 4-6.** Observe and note the solubility, colour etc. of one crystal of

* calcium chloride (b) powdered graphite (c) iodine in test tubes (9 tubes) containing 4cm depth each of:

**(4a, b, c)** water **(5a, b, c)** ethanol **(6a, b, c)** hexane

Q7 What sort of particles do calcium chloride, powdered graphite and iodine contain?

Calcium chloride is an ionic molecule of calcium and chloride ions. Powdered graphite is a crystalline form of carbon element arranged hexagonally. It is considered to be highly stable form containing carbon. Iodine is a chemical element containing iodine and is known to be heaviest of stable halogens.

Q8 What forces hold these particles together in the solid?

Calcium chloride has ionic forces created due to the presence of chloride and calcium ions which keep them intact. Powdered graphite has strong covalent bonding between carbon atoms and an additional van der Waals dispersion forces due to the presence of delocalized electrons. Two atoms of iodine are covalently attached to each other, overall iodine molecule is held intact due to the existence of weak van der Waal interactions also known as London dispersion forces, which are strong enough to keep the molecule together as solid.

Q9 Explain the relative solubility of each solid in each of the three liquids?

Calcium chloride being an ionic compound has the ability to get dissolved in water which is a polar compound. Powdered graphite is insoluble in water, ethanol as well as hexane for the reason that graphite is intact due to such strong covalent linkages that attractions between solvent molecules and carbon atoms are weaker than it to help them in dissolution. A very little amount of iodine gets dissolved in water, like just one gram of it dissolves in 3500 ml of water. Water molecules have strong hydrogen bonding which does not allow iodine molecule to interrupt the normal bonding pattern. Therefore, relatively calcium chloride readily dissolves in water due to ionic properties and polar nature of water. 'Like dissolves like', so the solubility of iodine in ethanol is also less, but it is readily dissolved in non-polar solvent which is hexane. Ethanol is less polar than water and is therefore unable to break the ionic lattice of calcium chloride completely so dissolution is less. While hexane being non-polar cannot dissolve calcium chloride at all.

Q10 Try to explain the colour of iodine in different solvents. Make a brief plan of another experiment you could do to test your idea.

In polar solvents like water and ethanol, iodine gives a brown colour to a solution. In non-polar solvents like hexane, iodine is readily dissolved and forms a violet colour solution.

Take three conical flasks and name them A, B, C. Put water, ethanol and hexane respectively in three of the flasks. Add iodine in A, B and C and observe the colour change.

**Test tube 7.** Miscibility of water and hexane: **Dispense into one test tube in order:**

(7) 2 cubic cm water then 2 cubic cm hexane, then one crystal of iodine; replace cork and gently mix. Note your observations, *replace in the rack.*

Q11 Which solvent do you think forms the upper layer. *Explain!*

Hexane is a non-polar and water is a polar compound. They are immiscible in each other. Hexane is less dense than water, therefore, hexane forms the upper layer and water the lower one.

**3 (.a)** Use your periodic table to complete the table below

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Name | Atomic number | Number of protons | Number of electrons | Electronic configuration (s, p, d, f notation) |
| C Carbon | 6 | 6 | 6 | 1s2,2s2,2p2 |
| Ca Calcium | 20 | 20 | 20 | 1s2, 2s2,2p6,3s2,3p6,4s2 |
| Ca2+ Calcium ion | 20 | 20 | 18 | 1s2, 2s2,2p6,3s2,3p6 |
| Br Bromine | 35 | 35 | 35 | 1s2,2s2,2p6,3s2,3p6,3d10,4s2,4p5 |
| S2- Sulfide | 16 | 16 | 18 | 1s2,2s2,2p6,3s2,3p6 |
| Mn Manganese | 25 | 25 | 25 | 1s2,2s2,2p6,3s2,3p6,3d5,4s2 |
| Cu Copper | 29 | 29 | 29 | 1s2,2s2,2p6,3s2,3p6,3d10,4s1 |

(Periodic Table of the Elements, 1998)

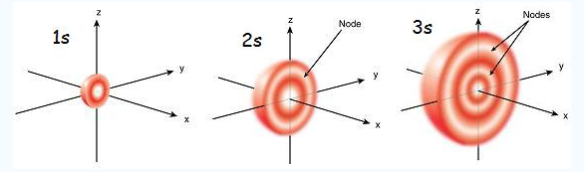
**b)** What is the meaning of ''atomic number'' and how was it obtained?

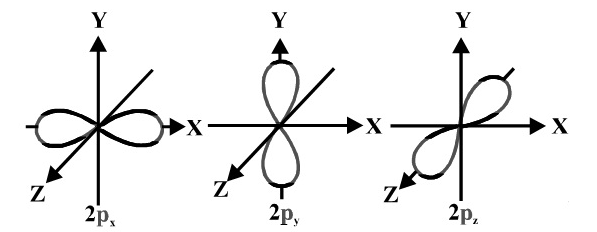
A number of protons in the nucleus of an atom is defined as its atomic number. The atomic number identifies how many protons an atom possesses. It never changes.

Henry Moseley worked in Rutherford's team. He was investigating X-rays given off by metals. He fired an electronic beam at various elements and examined the spectrum of X-rays which followed a simple rule. X-ray spectrum's frequency depends upon the position an element possess in the list of elements which is now termed as the periodic table. He called this place of an element its atomic number which is always a number of positive charges on the nucleus.

**c)** Define the term 'atomic orbital' and draw and describe the shapes of the s and p orbitals.

An atomic orbital is a mathematical equation that explains the discrete, quantized energy levels of atoms. It represents the most likely location of an electron around an atom. These atomic orbitals are 1s, 2s, 2p and so on. Each atomic orbital has a maximum of 2 electrons with opposite spins. S orbital is a sphere, in 2-D, we can draw it as a circle. p orbital is drawn as figure 8.





**d)** List the orbitals in the first four shells in order of increasing energy. (If you prefer, you can show it in the diagram)

As per empirical theory, orbitals and shells exist around an atom. Within each shell, a certain combination of orbitals exist. Following is the pattern followed:

n=1 shell has s orbital

n=2 shell has s and p orbitals

n=3 shell has s, p and d orbitals

n=4 shell has all four types of orbitals (s, p, d and f) (Magnasco, 2013).

Access to Science

Chemical Bonding

Task 1

1.1 Explain the factors which influence ionization energy

1.2 Interpret ionization energy data to predict electronic structures

1.3 Explain s, p and d electronic configurations for given atoms and ions.

**1.** The values of the first ionization energies of neon, sodium and magnesium are 2080, 494 and 736 kJ/mol-1, respectively.

(a) Explain the meaning of the term *first ionization* of an atom.

First ionization is the energy required to remove valence electron/most loosely held electron from 1 mole of an atom or molecule.

(b) Write an equation to illustrate the process occurring when the second ionization energy of magnesium is measured.

Mg+ (g) -> Mg2+ + 2e-

(c) Explain why the value of the first ionization energy of magnesium is higher than that of sodium.

Magnesium has a high nuclear charge, it has one extra proton than sodium that is 12. It creates more force of attraction for the valence electron. With this increased attraction, it becomes difficult to remove electrons from the outermost shell in case of magnesium than in sodium. That is why it is said that the first ionization energy of magnesium is higher than that of sodium.

(d) Explain why the value of the first ionization energy of neon is higher than that of sodium.

Neon has 7 more protons than sodium, which means that former one has higher nuclear charge. This is the reason for higher first ionization energy of neon than that of sodium.

**1.1, 1.2**

**2 (a)** The table below shows the first successive ionization energy values for an element.

|  |  |
| --- | --- |
| Ionization energy | Value/KJ/mol |
| 1st | 577 |
| 2nd | 1820 |
| 3rd | 2740 |
| 4th | 11600 |
| 5th | 14800 |

Use this data and the periodic table to suggest an element which could have produced these results. Explain your answer.

The table shows the first successive ionization energy values for 'Aluminium'. Referring to the periodic table for the value of Z (atomic number) and a number of electrons (which are same until and unless any loss or gain of electrons has occurred), the ionization energy is determined by squaring Z and multiplying it with 13.6.

(b) Explain the factors which influence ionization energy.

The ionization energy of an atom depends on the following important factors:

a. Size of an atom

Size of an atom is basically the distance of outermost electronic shell from the nucleus. More is this distance means the size of an atom is large and ultimately electrons are lesser influenced by the force nucleus exerts on the electrons to remain intact. This indicates that it will be easier to remove an outermost electron when the size of an atom increases. Thus, it can be said that ionization energy and size of an atom are inversely proportional to each other.

b. Charge on nucleus

Charge on nucleus means that an attractive force exists between nucleus and electrons. More is the attractive force, more is the ionization energy required.

c. Half-filled & completely filled sub-levels

Such atoms which have half and completely filled sub-levels are more stable and it becomes difficult to remove electrons due to these stable configurations. Therefore, more ionization energy is required (BrainKart, 2019).

**References**

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