

1.3.1 Particle models, polarity and periodic properties

Name: _____ Class: _____ Date: _____

Total: 25 marks

KEY WORDS polarising power • polarisability • delocalised electrons

Objective

Use particle models to explain ionic, covalent and metallic properties and to predict an unfamiliar molecular shape. Do not infer every property from one observation.

1 Key knowledge and worked examples

■ Separate particle formation from bonding

Electron transfer forms cations and anions. The ionic bond is the net electrostatic attraction throughout their lattice. In the isoelectronic series N^{3-} , O^{2-} , F^- , Na^+ , Mg^{2+} , Al^{3+} , all ions have ten electrons; increasing nuclear charge pulls them closer and decreases radius.

A small highly charged cation has strong polarising power. A large anion has a readily distorted cloud, so more covalent character can occur. Metallic bonding attracts positive metal ions to delocalised electrons. The electrons conduct in solid metal; ionic solids lack mobile ions.

■ Shape depends on regions around the central atom

Four regions with three bonds and one lone pair give a pyramidal molecule, with a bond angle smaller than the tetrahedral value. A double bond counts as one region. Bond polarity and molecular polarity differ because the bond dipoles may cancel.

2 Practice

2.1 Rank N^{3-} , F^- and Al^{3+} from largest to smallest. Explain using both electron number and nuclear charge. [3]

2.2 Al^{3+} polarises I^- more strongly than Na^+ polarises F^- . Explain the cation and anion contributions to this comparison. [3]

2.3 Explain why solid copper conducts but solid sodium chloride does not, and why molten sodium chloride conducts. [3]

3 Exam-style questions

3.1 PH_3 has three P–H bonds and one lone pair around phosphorus. Use electron-pair repulsion to predict its shape. Explain why a rule subtracting exactly 2.5° for each lone pair cannot reliably predict its angle. [3]

3.2 Compare diamond, graphite and graphene in terms of carbon bonding and electrical conductivity. Give one property-based use of each, with a reason. [6]

3.3 Across Period 3, silicon has a much higher melting temperature than phosphorus, sulfur and argon. Explain the structural change, and why sulfur can melt at a higher temperature than phosphorus despite both being molecular. [4]

3.4 Compare the electrostatic lattice attraction in MgO and NaCl, assuming similar ion separations. Explain why comparing charges is useful but does not alone predict every measured melting temperature. [3]

Solutions

Original guidance; do not award a conductivity explanation based on moving protons.

2.1 $\text{N}^{3-} > \text{F}^- > \text{Al}^{3+}$. Each has ten electrons, but proton number increases $7 \rightarrow 9 \rightarrow 13$, increasing nuclear attraction and drawing the electron cloud closer.

2.2 Al^{3+} is smaller and more highly charged than Na^+ , giving greater polarising power. I^- is larger than F^- and its cloud is more readily distorted, giving greater polarisability. This increases covalent character; it does not mean all bonding becomes purely covalent.

2.3 Copper has mobile delocalised electrons. In solid NaCl the ions are fixed in the lattice. On melting, ions can move and carry charge; electrons are not released as the charge carriers.

3.1 Four electron regions arrange approximately tetrahedrally, with a lone pair occupying one region; molecular shape is pyramidal. Lone-pair/bond-pair repulsion affects angles, but actual values also depend on atom, orbital and bonding details, so no fixed subtraction applies to every molecule. An exact angle is not requested.

3.2 Diamond: each carbon bonds to four others in a rigid giant covalent network; no freely mobile electrons, so insulating; cutting tools use its hardness. Graphite: each carbon bonds to three others in layers, with delocalised electrons that conduct along layers; lubricant uses layers sliding over one another. Graphene: one covalently bonded carbon layer with delocalised electrons; conducting, strong films can use its conductivity and strength. Accept other scientifically justified uses.

3.3 Silicon has a giant covalent structure requiring many strong bonds to be broken on melting. P_4 and S_8 are molecules and argon is monatomic; melting overcomes much weaker attractions between their particles. S_8 has more electrons than P_4 , so stronger London attractions require more energy to overcome. Melting does not break every P–P or S–S bond in these molecules.

3.4 Mg^{2+} and O^{2-} have higher charge magnitudes than Na^+ and Cl^- , giving stronger attraction at similar separation. Actual ion sizes and lattice structure also affect the energy and melting behaviour, so the charge comparison is a model-based trend rather than a universal numerical prediction.