**\*CHEM191: “Cheat sheet” for sequential ordering in explanations – structure and bonding**

The cards of pages 3-14 are colour coded. Print each set **back to back**, cut out the cards and shuffle them. Then try to lay them out in a logical order that you can use in your explanations. The first 2 pages (and first card of each set) gives a recommended layout, is not necessarily the only way. Once you can quickly and easily lay the cards in a logical order, practice answering questions using your layout as a guide so that you include enough detail in your answer. The reverse of each card gives an example answer. Once you know how to write a sequential explanation, you can then practice making your answer less ‘wordy’.

**Lewis structures**

1. Count number of valence electrons (remember that Group 18 elements have 8 valence electrons)
2. Work out the central atom (highest valency / least number of atoms of that element)
3. Arrange the other atoms around the central atom
4. Add single bonds (2 electrons) by drawing a line between each atom and central atom
5. Arrange remaining valence electrons around outer atoms so each atom has an octet (exception = H).
6. If there are electrons left over, then add these around the central atom to give it an octet.
7. If there are not enough electrons to give and octet on the central atom (exception B and Be) make double bonds by moving a non-bonding electron pair from an outer atoms to make a bond until each atom has an octet

e.g. Draw Lewis structures of SOCl2

**Shape and bond angles**

1. What is the central atom?
2. How many regions of negative charge/electron density are around the central atom?
3. What is the electron geometry when these regions of negative charge repel each other?
4. What are the bond angle(s) for this electron geometry?
5. How many bonding electron regions of electrons are around the central atom?
6. What is the shape of these electron regions?
7. What is the shape of the molecule (name and diagram)?

e.g. Explain why SO2 and H2O are both bent but have different bond angles

**Polarity of molecules**

1. Do the bonded atoms have different electronegativities?
2. Are the bonds polar??
3. Do the bonds all have the same polarity?
4. What is the shape of the molecule? (Is this shape symmetrical or asymmetrical?)
5. Do bond dipoles cancel? / Is there an uneven distribution of electron density? / do polar effects cancel out?
6. Is there a molecular dipole?
7. Is the molecule polar or non-polar?

e.g. Explain why CO2 is non-polar yet SO2 is polar

**\* Originally prepared by Delene Holm as a resource for students at Te Kura and adapted for CHEM191 at VUW**

**Properties of solids: melting point and boiling point.**

1. What type of solid is it?
2. What type of particles make up the solid?
3. What type of attractions hold the particles together?
4. Are these attractions strong or weak?
5. What forces are broken when the substance melts/boils?
6. Is a lot of energy needed to break these attractions?
7. Does this result in high or low melting/boiling point?

e.g. Explain why SO2 is a gas while SiO2 is a solid at room temperature

**Properties of solids: malleability / ductility / brittleness.**

1. What type of solid is it?
2. What type of particles make up the solid?
3. Are the types of attractions holding the particles together non-directional or not?
4. Are these attractions strong or weak?
5. Does the solid exist as a 3-D extended lattice?
6. Can layers of atoms slide over each other?
7. Are there any like charges that can repel when the particles move out of position?

e.g. Explain copper can be drawn into wires but rock salt (NaCl) can’t.

**Properties of solids: conduction of electricity**

1. What type of solid is it?
2. What type of particles make up the solid?
3. Does the solid exist in 3-spaced extended lattice?
4. What type of attractions hold the particles together?
5. Are these attractions strong or weak?
6. Are charged particles present in the solid?
7. Under what conditions are these charged particles able to move?

e.g. Explain why copper can conduct electricity as a solid and liquid, but NaCl can only conduct electricity as a liquid

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| **Lewis structures**   1. Count number of valence electrons (remember that Group 18 elements have 8 valence electrons) 2. Work out the central atom (highest valency / least number of atoms of that element) 3. Arrange the other atoms around the central atom 4. Add single bonds (2 electrons) by drawing a line between each atom and central atom 5. Arrange remaining valence electrons around outer atoms so each atom has an octet (exception = H). 6. If there are electrons left over, then add these around the central atom to give it an octet. 7. If there are not enough electrons to give and octet on the central atom (exception B and Be) make double bonds by moving a non-bonding electron pair from an outer atoms to make a bond until each atom has an octet | **Lewis structures**  Count number of valence electrons (remember that Group 18 elements have 8 valence electrons) | **Lewis structures**  Work out the central atom (highest valency / least number of atoms of that element) |
| **Lewis structures**  Arrange the other atoms around the central atom | **Lewis structures**  Add single bonds (2 electrons) by drawing a line between each atom and central atom | **Lewis structures**  Arrange remaining valence electrons around outer atoms so each atom has an octet  (exception = H). |
| **Lewis structures**  If there are electrons left over, then add these around the central atom to give it an octet. | **Lewis structures**  If there are not enough electrons to give and octet on the central atom (exception B and Be) make double bonds by moving a non-bonding electron pair from an outer atom to make a bond until each atom has an octet |  |

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| **Lewis structures**  C: valency = 4 (as in group 14) so is in the middle.  O has valency = 2 (as in group 16) and  Cl has valency = 1 (as in group 17) | **Lewis structures**  C = 4 valence electrons  O= 6 valence electrons  Cl= 7 valence electrons  Cl= 7 valence electrons  24 valence electrons | **Lewis structures**  Draw a Lewis structure for COCl2 |
| **Lewis structures**  C  O  Cl  Cl  24 valence electrons used  0 valence electrons left | **Lewis structures**  C  O  Cl  Cl  6 valence electrons used  18 valence electrons left | **Lewis structures**  C  O  Cl  Cl |
| **Lewis structures** | **Lewis structures**  C  O  Cl  Cl  A pair of electrons have been moved from O to be between C and O so that each atom has an octet. Cl can only form 1 bond as valency = 1 so cannot share 2 pairs of electrons like O. | **Lewis structures**  C  O  Cl  Cl  0 valence electrons left but C has no octet |

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| **Shapes and bond angles**   1. What is the central atom? 2. How many regions of negative charge/electron density are around the central atom? 3. What is the electron geometry when these regions of negative charge repel each other? 4. What are the bond angle(s) for this electron geometry? 5. How many bonding electron regions of electrons are around the central atom? 6. What is the shape of these electron regions? 7. What is the shape of the molecule? | **Shapes and bond angles**  What is the central atom? | **Shapes and bond angles**  How many regions of negative charge/electron density are around the central atom? |
| **Shapes and bond angles**  What is the electron geometry when these regions of negative charge repel each other? | **Shapes and bond angles**  What is/are the bond angle(s) for this electron geometry? | **Shapes and bond angles**  How many bonding regions of electrons are around the central atom? |
| **Shapes and bond angles**  What is the shape of these electron regions? | **Shapes and bond angles**  What is the molecular shape? | **Shapes and bond angles**  (extra card if needed) |

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| **Shapes and bond angles**  From the Lewis structures:  In SO2 there are 3 regions of electron density on the central atom (S) and in H2O there are 4 regions of electron density on the O atom | **Shapes and bond angles**  The central atom is S in SO2 and is O in H2O | **Shapes and bond angles**  **Explain why SO2 and H2O are both bent but have different bond angles** |
| **Shapes and bond angles**    SO2 has 2 bonding electron regions and while H2O also has and 2 bonding electron regions… | **Shapes and bond angles**  This gives SO2 a bond angle of 120° and H2O a bond angle of 109.5°. | **Shapes and bond angles**  In order to minimise repulsion, the 3 regions of electrons in SO2 take a trigonal planar geometry and in H2O the 4 regions take a tetrahedral geometry. |
| **Shapes and bond angles** | **Shapes and bond angles**  So SO2 and H2O both have a bent shape with different angles | **Shapes and bond angles**  In SO2 the bonding regions take a bent shape with an angle of 120o and in H2O the bonding regions take a bent shape with an angle of about 109o |

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| **Polarity of molecules**   1. Do the bonded atoms have different electronegativities? 2. Are the bonds polar?? 3. Do the bonds all have the same polarity? 4. What is the shape of the molecule? (Is this shape symmetrical or asymmetrical?) 5. Do bond dipoles cancel? / Is there an uneven distribution of electron density? / do polar effects cancel out? 6. Is there a molecular dipole? 7. Is the molecule polar or non-polar? | **Polarity of molecules**  Do the bonded atoms have a different electronegativity? | **Polarity of molecules**  Are the bonds polar? |
| **Polarity of molecules**  Do the bonds all have the same polarity? | **Polarity of molecules**  What is the shape of the molecule? (Is the shape symmetrical or asymmetrical?) | **Polarity of molecules**  Do bond dipoles cancel? / Is there an uneven distribution of electron density? / do polar effects cancel out? |
| **Polarity of molecules**  Is there a molecular dipole? | **Polarity of molecules**  Is the molecule polar or non-polar? | **Polarity of molecules**  (extra card if needed) |

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| **Polarity of molecules**  So both  CO2 and SO2 have polar bonds and therefore  all the bonds are polar. | **Polarity of molecules**  Both molecules of CO2 and SO2 are made up of **two different** elements which have **different** electronegativities | **Polarity of molecules**  **Explain why CO2  is non-polar  yet SO2 is polar** |
| **Polarity of molecules**  In CO2 the linear shape means that the bond dipoles cancel but in SO2 the bent shape means that they do not cancel. | **Polarity of molecules**  CO2 is a linear molecule (symmetrical) and SO2 is bent / V-shape (asymmetrical). | **Polarity of molecules**  In both  CO2 and SO2 are all the bonds have the same polarity. |
| **Polarity of molecules** | **Polarity of molecules**  So SO2 is polar  and CO2 is non-polar | **Polarity of molecules**  This results in SO2 having a molecular dipole and CO2 having no molecular dipole. |

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| **Properties: melting point and boiling point**   1. What type of solid is it? 2. What type of particles make up the solid? 3. What type of attractions hold the particles together? 4. Are these attractions strong or weak? 5. What forces are broken when the substance melts/boils? 6. Is a lot of energy needed to break these attraction when the substance melts/boils? 7. Does this result in high or low melting/boiling point? | **Properties: melting point and boiling point**  What type of solid is it? | **Properties: melting point and boiling point**  What type of particles make up the solid? |
| **Properties: melting point and boiling point**  What type of attraction holds the particles together? | **Properties: melting point and boiling point**  Are these attractions strong or weak? | **Properties: melting point and boiling point**  What forces of attraction are broken when the substance melts/boils? |
| **Properties: melting point and boiling point**  Is a lot of energy needed to break these attractions when the substance melts/boils? | **Properties: melting point and boiling point**  Does this result in high or low boiling point? | **Properties: melting point and boiling point** |

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| **Properties: melting point and boiling point**  The particles in SO2 are molecules  while the particles in SiO2 are individual Si and O atoms | **Properties: melting point and boiling point**  SO2 is a molecular solid while SiO2 is a network solid | **Properties: melting point and boiling point**  **Explain why SO2  is a gas while  SiO2 is a solid at room  temperature** |
| **Properties: melting point and boiling point**  When SO2 melts the intermolecular forces need to be broken. When SiO2 melts the covalent bonds need to be broken | **Properties: melting point and boiling point**  The intermolecular forces between the SO2 molecules are much weaker than the covalent bonds between the Si and O atoms | **Properties: melting point and boiling point**  In SO2 there are weak intermolecular forces (IMF) between the particles (SO2  molecules) while in SiO2 there are only strong covalent bonds between the particles (Si and O atoms) |
| **Properties: melting point and boiling point**  It takes much less energy to break the intermolecular forces in SO2 than to break the covalent bonds in SiO2 | **Properties: melting point and boiling point**  This results in SiO2 having a much higher melting point than SO2. | **Properties: melting point and boiling point** |

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| **Properties: malleability / ductility / brittleness**   1. What type of solid is it? 2. What type of particles make up the solid? 3. What are the attractive forces between the particles? 4. Are these attractions strong or weak? 5. Does the solid exist as an extended 3-D lattice? 6. Is the bonding disrupted if layers of atoms slide over each other? 7. Is the solid malleable or brittle when hammered? | **malleability / ductility / brittleness**  What type of solid is it? | **malleability / ductility / brittleness**  What type of particles make up the solid? |
| **malleability / ductility / brittleness**  What are the attractive forces between the particles? | **malleability / ductility / brittleness**  Are these attractions strong or weak? | **malleability / ductility / brittleness**  Does the solid exist as an extended 3-D lattice? |
| **malleability / ductility / brittleness**  Is the bonding disrupted if layers of atoms slide over each other? | **malleability / ductility / brittleness**  Is the solid malleable or brittle when hammered? | **malleability / ductility / brittleness**  (extra card if needed) |

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| **malleability / ductility / brittleness**  Cu is made up of delocalised valence electrons and Cu2+ ions (formed when the valence e-s are delocalised).  NaCl consists of Na+ cations and Cl– anions. | **malleability / ductility / brittleness**  Copper is a metallic solid and NaCl is an ionic solid… | **malleability / ductility / brittleness**  **Explain why copper  can be drawn  into wires but rock salt (NaCl) can’t.** |
| **malleability / ductility / brittleness**  In both ionic and metallic solids the particles are arranged in an extended 3-D lattice. | **malleability / ductility / brittleness**  Both metallic bonds and ionic bonds are strong. | **malleability / ductility / brittleness**  The bonding in Cu is metallic with the delocalised valence electrons attracted to all the metal cations.  The bonding in NaCl is ionic and an in NaCl with the Na+ ions being attracted to the Cl- ions. |
| **malleability / ductility / brittleness** | **malleability / ductility / brittleness**  The Cu metal can be flattened without breaking (malleable) but the salt will break when it is hammered (is brittle) | **malleability / ductility / brittleness**  When Cu metal is hammered, the layers slide over each other without disrupting the bonding.  When NaCl is hammered the ions are displaced such that like ions will move next to each other and repel. |

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| **Properties: Conduction of electricity**   1. What type of solid is it? 2. What type of particles make up the solid? 3. What are the attractive forces between the particles? 4. Are these attractions strong or weak? 5. Does the solid exist as an extended 3-D lattice?   6. Are there charged particles in the solid that are free to move?  7. Does the solid conduct? | **Properties: Conduction of electricity**  What type of solid is it? | **Properties: Conduction of electricity**  What type of particles make up the solid? |
| **Properties: Conduction of electricity**  What are the attractive forces between the particles? | **Properties: Conduction of electricity**  Are these attractions strong or weak? | **Properties: Conduction of electricity**  Does the solid exist as an extended 3-D lattice? |
| **Properties: Conduction of electricity**  Are there charged particles in the solid (and/or liquid) that are free to move? | **Properties: Conduction of electricity**  Does the solid (and/or liquid) conduct? | **Properties: Conduction of electricity**  (extra card if needed) |

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| **Properties: Conduction of electricity**  Cu is made up of delocalised valence electrons and Cu2+ ions (formed when the valence e-s are delocalised).  NaCl consists of Na+ cations and Cl– anions. | **Properties: Conduction of electricity**  Cu is a metallic solid and NaCl is an ionic solid… | **Properties: Conduction of electricity**  **Explain why copper can conduct electricity as a solid, but NaCl can conduct in the liquid state but not when it is solid.** |
| **Properties: Conduction of electricity**  In both ionic and metallic solids the particles are arranged in an extended 3-D lattice. | **Properties: Conduction of electricity**  Both metallic bonds and ionic bonds are strong. | **Properties: Conduction of electricity**  The bonding in Cu is metallic with the delocalised valence electrons attracted to all the metal cations.  The bonding in NaCl is ionic and an in NaCl with the Na+ ions being attracted to the Cl- ions. |
| **Properties: Conduction of electricity** | **Properties: Conduction of electricity**  This means that Cu can conduct in the solid state but NaCl can conduct in the liquid state but not when it is a solid. | **Properties: Conduction of electricity**  In Cu metal the delocalised electrons are charged and free to move.  In NaCl the ions are charged but they are in fixed positions so cannot move around. However, in solution the ions are separated and move freely. |