Name: ……………………………………… (   )   Class: …………….
Date: …………….

Raffles Institution
Year 5 H2 Chemistry 2024

ChemFocus T3W5 – Chemical Bonding 1

Pre-ChemFocus Activity

- Rewatch lecture video on how to draw dot-and-cross for molecules
  IVY > C2025 – H2 CHEMISTRY (FOR LECTURES) > 4.3 (Dot-&-cross Diagrams of Simple Covalent Molecules)
- Watch the online Info-pack video
  IVY > C2025 – H2 CHEMISTRY > Pages > [ChemFocus] T3W5 Chemical Bonding > First video **ONLY**

Notes:

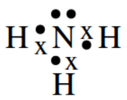
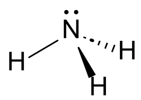
Self-Check Questions

Check your answers at IVY > C2025 – H2 CHEMISTRY > Pages > [ChemFocus] T3WX Chemical Bonding > Remaining videos

1. Complete the following table.

Substances	Structure	Bonding affecting melting/boiling point
ICl		
$MnSO_4$		
BH_3		
$NaBrO_3$		
CH_3OH		

2. Complete the following table.

molecule	dot-and-cross diagram	shape of molecule	structure (include lone pair of e⁻ on central atom)	Check the boxes with (✓/✗) to check for polarity	Predominant intermolecular interactions
NH_3		trigonal pyramidal		☑ polar bond present ☑ net dipole moment polar / non-polar	☑ polar molecule ☑ H bonded to FON ☑ lp of e⁻ on FON id-id / pd-pd / H-bond
CO_2				☐ polar bond present ☐ net dipole moment polar / non-polar	☐ polar molecule ☐ H bonded to FON ☐ lp of e⁻ on FON id-id / pd-pd / H-bond
H_2O				☐ polar bond present ☐ net dipole moment polar / non-polar	☐ polar molecule ☐ H bonded to FON ☐ lp of e⁻ on FON id-id / pd-pd / H-bond
SO_2				☐ polar bond present ☐ net dipole moment polar / non-polar	☐ polar molecule ☐ H bonded to FON ☐ lp of e⁻ on FON id-id / pd-pd / H-bond

Learning point(s):

3. Draw a dot-and-cross diagram to illustrate the electron arrangement in the following substances.

1. CO_3^{2-} *2.* ICl_2^+

Learning point(s): *Learning point(s):*

4. In terms of structure and bonding, explain why the melting point of MgO is higher than that of SO_2.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

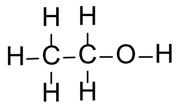
……………………………………………………………………………………………………..

Learning point(s):

5. In terms of structure and bonding, explain why the boiling point of carbon dioxide is lower than that of ethanol.

O=C=O

carbon dioxide



ethanol

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

Learning point(s):

<u>Tutorial Discussion Questions</u> (to complete before Chemfocus session)

1a Draw a dot-and-cross diagram to illustrate the electron arrangement in the following substances. [3]

(1) O_3

(2) ClO_2^+

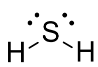
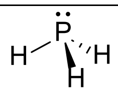
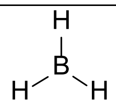
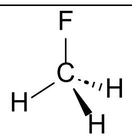
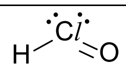
Learning point(s):

Learning point(s):

(3) NO_3^-

Learning point(s):

2a The structures of the molecules, including the lone pair of electrons on the central atoms, are provided in the table below. Complete the table by indicating the shape, polarity and interactions between the molecules.

Structure of molecule	shape and bond angle	Is it polar? (✓/ ✗)	Predominant IMFOA (id-id/pd-pd/H-bond)
e.g. 	bent, 105 °	✓	Permanent dipole-permanent dipole
			
			
			
			

3a (i) The melting point of NaC*l* was found to be 801 °C. Suggest, with reasons, whether the melting point of MgO will be higher or lower than that of NaC*l*.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………[2]

Learning point(s):

(ii) In terms of structure and bonding, explain why $SiCl_4$ has a lower boiling point than H_2O.

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………[2]

Learning point(s):

(iii) Draw a labelled diagram to show the significant force of attraction between **two** water molecules. Include the name of the attraction in your diagram.

[2]

Learning point(s):

<u>Tutorial In-Class Practice Questions</u> (to be attempted **<u>IN CLASS</u>**)

1b Draw a dot-and-cross diagram to illustrate the electron arrangement in the following substances. [2]

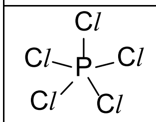
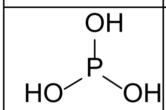
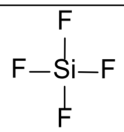
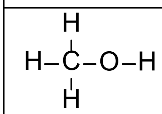
(1) NO_2

(2) ICl_4^-

Learning point(s):

Learning point(s):

2b The structures of the molecules are provided in the table below. Complete the table by indicating the shape, polarity and interactions between the molecules.
(Hint: you should first determine the number of electron density regions and number of lone pair of electrons on the central atom)

molecule	shape and bond angle	Is it polar? (✓/ ✕)	Predominant IMFOA (id-id/pd-pd/H-bond)
			
S=C=O			
	(about P)		
			
	(about C)		

3b (i) *Use of the Data Booklet is relevant to this question.*

The following table shows the theoretical and experimental lattice energies of $CaSO_4$ and $MnSO_4$.

compound	theoretical lattice energy / kJ mol^{-1}	experimental lattice energy / kJ mol^{-1}
$CaSO_4$	–2480	–2489
$MnSO_4$	–2825	–2920

Explain why the theoretical and experimental values of lattice energy differ more for $MnSO_4$ as compared to $CaSO_4$.

....

....

....

....[2]

Learning point(s):

(ii) Explain why the melting point of H_2O (0 °C) is lower than that of I_2 (387 °C).

....

....

....

....[2]

Learning point(s):

(iii) Iron(II) chloride is an ionic compound that dissolves readily in water. With the aid of a suitable diagram, explain why.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………[3]

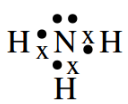
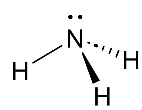
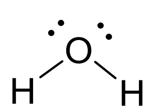
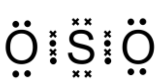
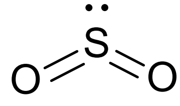
Learning point(s):

Self-Check Questions

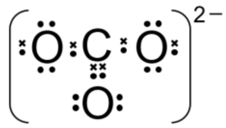
1. Complete the following table.

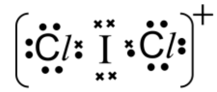
Substances	Structure	Bonding affecting melting/boiling point
ICl	simple molecular structure	intermolecular forces of attraction
$MnSO_4$	giant ionic lattice structure	ionic bonds
BH_3	simple molecular structure	intermolecular forces of attraction
$NaBrO_3$	giant ionic lattice structure	ionic bonds
CH_3OH	simple molecular structure	intermolecular forces of attraction

2. Complete the following table.

molecule	dot-and-cross diagram	shape of molecule	structure (include lone pair of e⁻ on central atom)	Check the boxes with (✓/✗) to check for polarity	Predominant intermolecular interactions
NH_3		trigonal pyramidal		☑ polar bond present ☑ net dipole moment polar / non-polar	☑ polar molecule ☑ H bonded to FON ☑ lp of e⁻ on FON id-id / pd-pd / H-bond
CO_2		linear	O=C=O	☑ polar bond present ☒ net dipole moment polar / non-polar	☒ polar molecule ☒ H bonded to FON ☒ lp of e⁻ on FON id-id / pd-pd / H-bond
H_2O		bent		☑ polar bond present ☑ net dipole moment polar / non-polar	☑ polar molecule ☑ H bonded to FON ☑ lp of e⁻ on FON id-id / pd-pd / H-bond
SO_2		bent		☑ polar bond present ☑ net dipole moment polar / non-polar	☑ polar molecule ☒ H bonded to FON ☑ lp of e⁻ on FON id-id / pd-pd / H-bond

3. (1) CO_3^{2-} (2) ICl_2^+





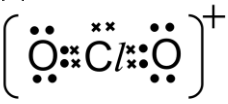
4. MgO has a giant ionic lattice structure, while SO_2 has a simple molecular structure. More energy is needed to overcome stronger electrostatic forces of attraction between oppositely charged ions in MgO than the weaker intermolecular forces of attraction in SO_2.

5. Both CO_2 and C_2H_5OH have simple molecular structure. CO_2 is non-polar while C_2H_5OH is polar. More energy is required to overcome stronger intermolecular hydrogen bond in ethanol than the weaker instantaneous dipole-induced dipole interactions between CO_2 molecules.

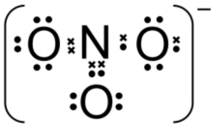
Tutorial Discussion Questions

1a (1) O_3

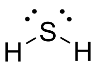
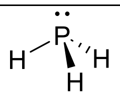
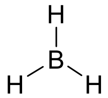
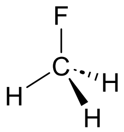
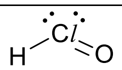
(2) ClO_2^+



(3) NO_3^-



2a

Structure of molecule	shape and bond angle	Is it polar? (✓/ ×)	Predominant IMFOA (id-id/pd-pd/H-bond)
e.g. 	bent, 105 °	✓	Permanent dipole-permanent dipole
	trigonal pyramidal, 107°	✓	Permanent dipole-permanent dipole
	trigonal planar, 120°	×	Instantaneous dipole-induced dipole
	tetrahedral, 109°	✓	Permanent dipole-permanent dipole
	bent, 105°	✓	Permanent dipole-permanent dipole

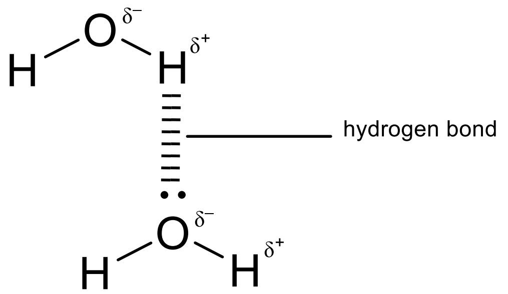
3a **(i)**

$$|\text{lattice energy}| \propto \left|\frac{q^+q^-}{r^+ + r^-}\right|$$

Both Na*Cl* and MgO have giant ionic lattice structures. Mg^{2+} and O^{2-} are both doubly-charged whereas Na^+ and Cl^- are both singly charged, and the *ionic radii* of Mg^{2+} and O^{2-} are smaller than that of Na^+ and Cl^- respectively. Hence, the lattice energy of MgO is more exothermic than that of Na*Cl* / the ionic bond in MgO is stronger than that in NaCl. Thus, MgO has a higher melting point.

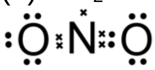
(ii) Both $SiCl_4$ and H_2O have simple molecular structures, but H_2O is polar while $SiCl_4$ is non-polar. More energy is required to overcome stronger hydrogen bonds between H_2O molecules than the weaker instantaneous dipole-induced dipole interactions between $SiCl_4$ molecules.

(iii)

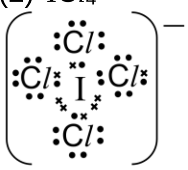


<u>Tutorial Practice Questions</u>

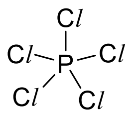
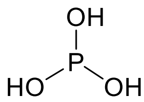
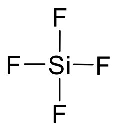
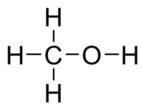
1b (1) NO_2



(2) ICl_4^-



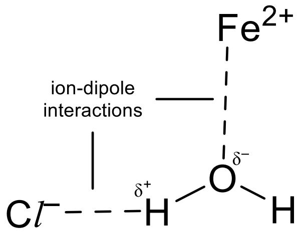
2b

molecule	shape and bond angle	Is it polar? (✓/ ✕)	Predominant IMFOA (id-id/pd-pd/H-bond)
	trigonal bipyramidal, 120°, 90°	✕	instantaneous dipole-induced dipole
S=C=O	linear, 180°	✓	permanent dipole-permanent dipole
	trigonal pyramidal, 107°	✓	hydrogen bond
	tetrahedral, 109°	✕	instantaneous dipole-induced dipole
	tetrahedral, 109°	✓	hydrogen bond

3b **(i)** Since Ca^{2+} and Mn^{2+} have the <u>same charge</u> but Mn^{2+} has a <u>smaller ionic radius</u>, Mn^{2+} has a <u>higher charge density</u> and <u>polarising power</u> than Ca^{2+}, leading to <u>greater covalent character</u> in the ionic bond for $MnSO_4$. Hence the theoretical and experimental values of lattice energy differ more for $MnSO_4$ as compared to $CaSO_4$.

(ii) Both H_2O and I_2 have <u>simple molecular structures</u>, but <u>H_2O is polar while I_2 is non-polar</u>. However, I_2 has a <u>larger electron cloud</u> that is <u>easily polarised</u>, hence, I_2 has <u>stronger instantaneous dipole-induced dipole (id-id) interactions</u> between them, as compared to the <u>weaker hydrogen bonds and id-id interactions between H_2O molecules</u>. Hence, <u>more energy</u> required to overcome stronger id-id between I_2 than the intermolecular forces of attraction between H_2O molecules.

(iii)



Iron(II) ions and chloride ions form <u>strong ion-dipole interactions with water</u> molecules, <u>releasing sufficient energy to compensate</u> for the breaking of <u>hydrogen bonds between water molecules</u> and <u>ionic bonds between Fe^{2+} and Cl^{-}</u>.