Chemistry 2.4 AS 91164

GZ Science Resources

Demonstrate understanding of bonding, structure, properties and energy changes

WORKBOOK

Working to Excellence & NCEA Questions

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CONTENTS

All NCEA answers can be found on C2.4 ppt

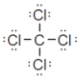
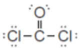
Writing Excellence answers to Molecule shapes and bond angle questions

Molecule shapes and bond angle QUESTION

Question: Carbon atoms can bond with different atoms to form many different compounds. The following table shows the Lewis structure for two molecules containing carbon as the central atom, CCl_4 and $COCl_2$. These molecules have different bond angles and shapes. Evaluate the Lewis structure of each molecule to determine why they have different bond angles and shapes.

In your answer you should include:

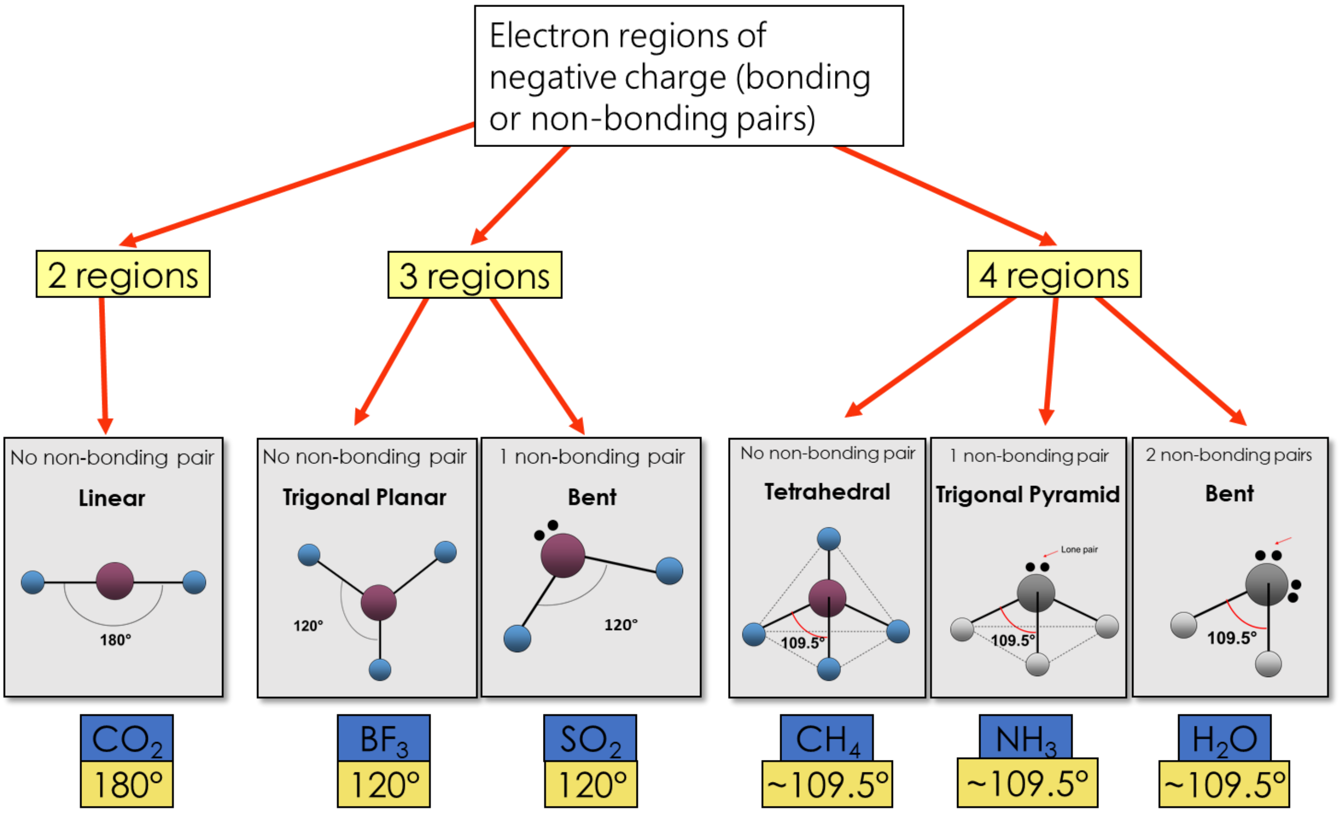
- The approximate bond angle in each molecule
- The shape of each molecule
- Factors that determine the shape and bond angle for each molecule.

Molecule	CCl_4	$COCl_2$
Lewis structure		

ANSWER	
1. for first molecule (name) state number of regions of negative charge around the central atom (name central atom)	
2. state the Valence shell electron pair repulsion (VSEPR) theory	
3. state the base arrangement of negative regions and the bond angle they form	
4. state the number of bonded and non-bonded regions <u>AND</u> the final shape of the first molecule	
5. for second molecule (name) state number of regions of negative charge around the central atom (name central atom)	
6. state the Valence shell electron pair repulsion (VSEPR) theory	
7. state the base arrangement of negative regions and the bond angle they form	
8. state the number of bonded and non-bonded regions <u>AND</u> the final shape of the second molecule	
9. compare differences in bond angle linked to number of regions of negative charge.	

NOTE: The white column is how your answer would appear on your test paper so make sure you write out complete sentences. The grey area is just to help you structure your answer and would not appear in the question.

Determining Molecular Shapes



Electron regions of negative charge (bonding or non-bonding pairs)

2 regions

- No non-bonding pair — **Linear** — 180° — CO_2 180°

3 regions

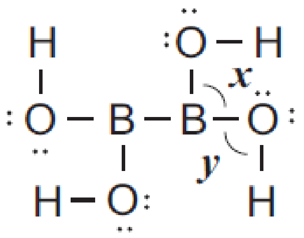
- No non-bonding pair — **Trigonal Planar** — 120° — BF_3 120°
- 1 non-bonding pair — **Bent** — 120° — SO_2 120°

4 regions

- No non-bonding pair — **Tetrahedral** — 109.5° — CH_4 ~109.5°
- 1 non-bonding pair — **Trigonal Pyramid** — Lone pair — 109.5° — NH_3 ~109.5°
- 2 non-bonding pairs — **Bent** — 109.5° — H_2O ~109.5°

Past NCEA questions Molecule Shapes and Bond Angle (ONE)

2014: Question 1b (i): The Lewis structure for a molecule containing atoms of boron, oxygen, and hydrogen, is shown below.



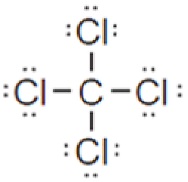
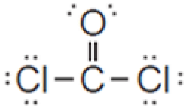
The following table describes the shapes around two of the atoms in the molecule above. Complete the table with the approximate bond angles *x* and *y*.

Central atom	Shape formed by bonds around the central atom	Approximate bond angle
B	trigonal planar	*x* =
O	bent	*y* =

Past NCEA questions Molecule Shapes and Bond Angle (TWO)

2014: Question 1b (ii): The bond angles *x* and *y* in the molecule above are different.
Elaborate on why the bond angles are different.
In your answer you should include:
• factors which determine the shape around the:
- B atom for bond angle *x*
- O atom for bond angle *y*
• reference to the arrangement of electrons around the B and O atoms.

2015: Question 1b: Carbon atoms can bond with different atoms to form many different compounds. The following table shows the Lewis structure for two molecules containing carbon as the central atom, CCl_4 and $COCl_2$. These molecules have different bond angles and shapes.

Molecule	CCl_4	$COCl_2$
Lewis structure		

Evaluate the Lewis structure of each molecule to determine why they have different bond angles and shapes.
In your answer you should include:

- The approximate bond angle in each molecule
- The shape of each molecule
- Factors that determine the shape and bond angle for each molecule.

2016: Question 3a (i): Draw the Lewis structure (electron dot diagram) for each of the following molecules and name their shapes.

Molecule	H_2O	CS_2	PH_3
Lewis structure			
Name of shape			
Approximate bond angle around the central atom	109.5°	180°	109.5°

2016: Question 3a (ii): Compare and contrast the shapes and bond angles of H_2O, CS_2 and PH_3.

Past NCEA questions Molecule Shapes and Bond Angle (TWO)

2017: Question 2a (i): Draw the Lewis structure (electron dot diagram) for each of the following molecules and name their shapes.

Molecule	HOCl	$COCl_2$	NF_3
Lewis structure			
Name of shape			
Approximate bond angle around the central atom	109.5°	120°	109.5°

2017: Question 2a (ii): Justify the shapes and bond angles of HOCl and $COCl_2$

2018: Question 2a. Draw the Lewis structure (electron dot diagram) for each of the following molecules and name their shapes.

Molecule	H_2S	NH_3	BF_3
Lewis Structure			
Name of Shape			
Approximate bond angle around central atom	109.5°	109.5°	120°

Past NCEA questions Molecule Shapes and Bond Angle (THREE)

2018: Question 2b. Compare and contrast the shapes and bond angles of NH_3 and BF_3.

2019: Question 2a. (i) Draw the Lewis structure (electron dot diagram) for the following molecules, and name their shapes.

Molecule	**CH_4**	**NCl_3**	**OF_2**
Lewis structure			
Name of shape			

2019: Question 2a. (ii) The above molecules have different shapes; however, each molecule has an approximate bond angle of 109.5°.

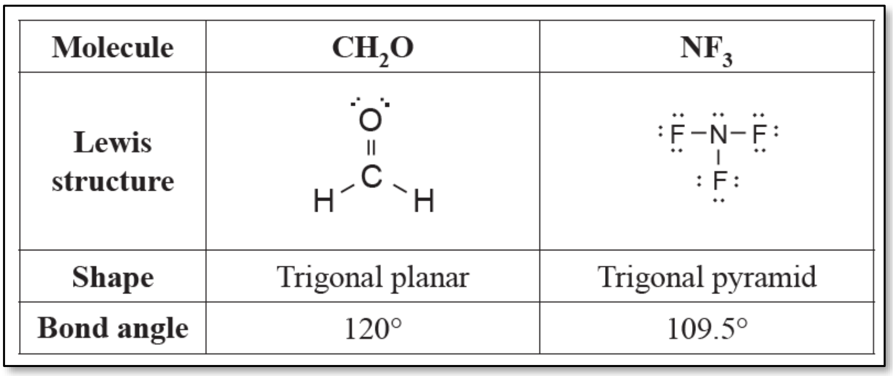
Justify this statement by referring to the factors that determine the shape of each molecule.

2020: Question 2a. Draw the Lewis structure for each of the following molecules and name their shapes.

Molecule	**CS_2**	**NOCl**	**CH_2F_2**
Lewis structure			
Name of shape			

2020: Question 2b. CH_2O and NF_3 have the same number of atoms in their formulae, but have different shapes and bond angles.

Justify the shapes and bond angles of CH_2O and NF_3.



Molecule	**CH_2O**	**NF_3**
Lewis structure		
Shape	Trigonal planar	Trigonal pyramid
Bond angle	120°	109.5°

Writing Excellence answers to Molecule Polarity questions

Molecule Polarity QUESTION

Question: The Lewis structures for two molecules are shown below.
Hydrogen cyanide, HCN, is polar, and carbon dioxide, CO_2, is nonpolar.
Both molecules are linear. Explain why the polarities of the molecules are different, even though their shapes are the same.

Molecule	$H-C\equiv N$	$O=C=O$
Polarity of molecule	Polar	Nonpolar

ANSWER

1. For the first molecule (name) state the types of bonds present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	
2. link electronegativity differences to sharing of electrons for your bond	
3. state the shape of your molecule and link to having the same bond dipoles AND being symmetrical or not and result in dipoles cancelling (or not)	
4. link to final polarity of molecule	
5. For the second molecule (name) state the types of bonds present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	
6. link electronegativity differences to sharing of electrons for your bond	
7. state the shape of your molecule and link to having the same bond dipoles AND being symmetrical or not and result in dipoles cancelling (or not)	
8. link to final polarity of molecule	

NOTE: The white column is how your answer would appear on your test paper so make sure you write out complete sentences. The grey area is just to help you structure your answer and would not appear in the question.

Chemistry 2.4 AS 91164 Am I Polar or Non-Polar?

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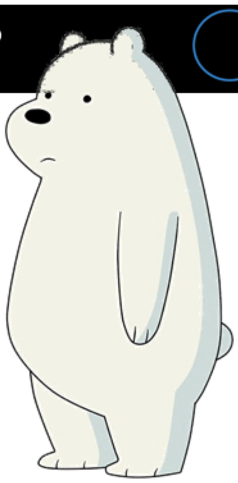
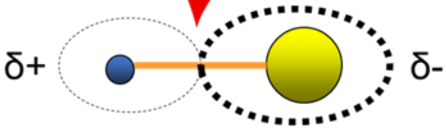


START HERE

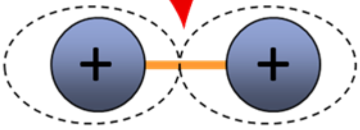
Does my molecule have different atoms in it or the same atoms?

Different

Same



Your molecule has **polar bonds** because the electronegativity is different in both atoms and the electrons are NOT shared evenly. The bond has a **dipole.**

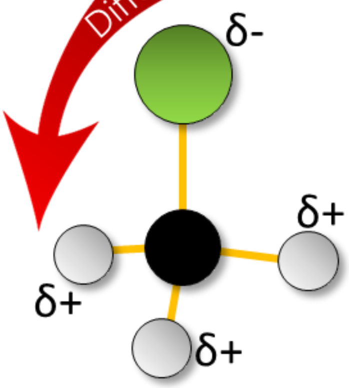


Your molecule has **non-polar bonds** because the electronegativity is the same in both atoms and the electrons are shared (distributed) evenly.

Does your molecule have the same or different atoms around the central atom?

Different

Same



Your whole molecule is **polar** because the dipoles do not cancel out. i.e. CH_3Cl

Polar

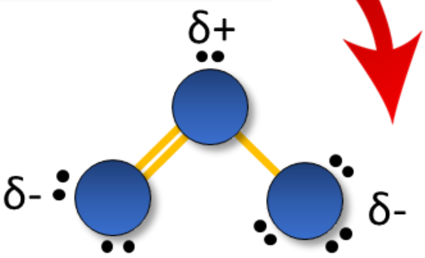
Is my whole molecule symmetrical with no non-bonding pairs?

Yes

No

Your whole molecule is also **non-polar** with no dipoles. i.e. I_2

Non-polar



Your whole molecule is polar. Uneven sharing of electrons across the molecule create dipoles. i.e. O_3

Polar

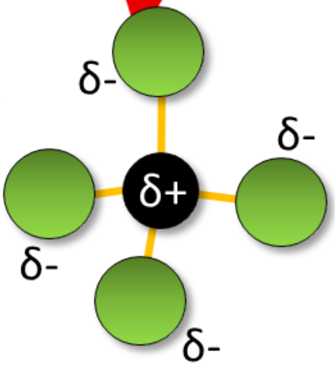
Does your molecule have non-bonding pairs around the central atom?

No

Yes

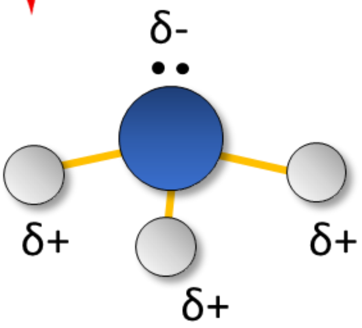
The polar bonds are spread symmetrically around the central atom and therefore the dipoles do cancel out. i.e. CCl_4
Shapes: tetrahedral, trigonal planar and linear

Non-polar



The polar bonds are not spread symmetrically around the central atom and therefore the dipoles do **NOT** cancel out. i.e. NH_3
Shapes:
trigonal pyramid, bent

Polar

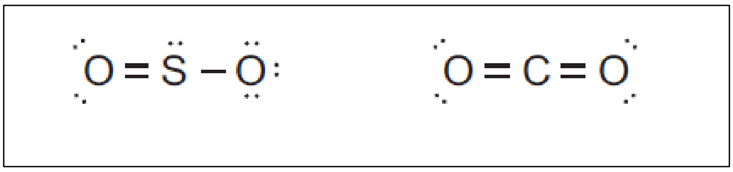


Past NCEA questions Molecule Polarity (ONE)

2013: Question 1c (ii): Elements M and X form a compound MX_2. Atoms of element X have a higher electronegativity value than atoms of element M, therefore the M–X bonds are polar. Depending on what elements M and X are, molecules of the compound formed will be polar or non-polar.
State the most likely shape(s) of the molecule if it is Polar and if it is Non-polar:
Justify your answer and draw diagrams of the possible molecules with dipoles labelled.

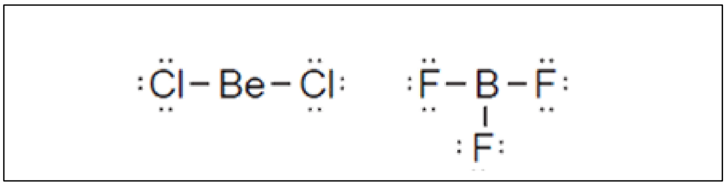
2014: Question 1c: Molecules can be described as being polar or non-polar.
The following diagrams show the Lewis structures for two molecules, SO_2 and CO_2. Identify the polarity

- Justify your choice

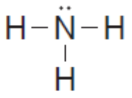
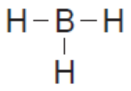


2015: Question 1c: $BeCl_2$ and BF_3 are unusual molecules because there are not enough electrons for the central atoms, Be and N, to have a full valance shell. Their Lewis structures are shown below. Both Molecules have the same polarity.

- Identify the polarity
- Justify your choice



2016: Question 3b: The Lewis structures for two molecules are shown.
Ammonia, NH_3, is polar, and borane, BH_3, is non-polar. Justify this statement.

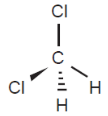
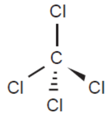
Molecule	 Ammonia	 Borane
Polarity of molecule	polar	non-polar

Past NCEA questions Molecule Polarity (TWO)

2017: Question 2b: Three-dimensional diagrams for two molecules are shown below.

(i) In the boxes above, identify the polarity of each molecule, by writing either polar or non-polar.

(ii) Justify your choices.

Molecule		
Name	Dichloromethane	Tetrachloromethane
Polarity of molecule		

2018: Question 2c. The Lewis structures for two molecules are shown below.

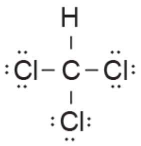
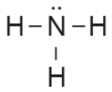
Hydrogen cyanide, HCN, is polar, and carbon dioxide, CO_2, is nonpolar.

Both molecules are linear.

Explain why the polarities of the molecules are different, even though their shapes are the same.

Molecule	H−C≡N	O=C=O
Polarity of molecule	Polar	Nonpolar

2019: Question 2b. The following table shows the Lewis structures (electron dot diagrams) for the molecules, $CHCl_3$ and NH_3.

Molecule	**$CHCl_3$**	**NH_3**
Lewis structure		
Polarity		

(i) In the boxes below, identify the polarity of each molecule by writing either polar or non-polar.

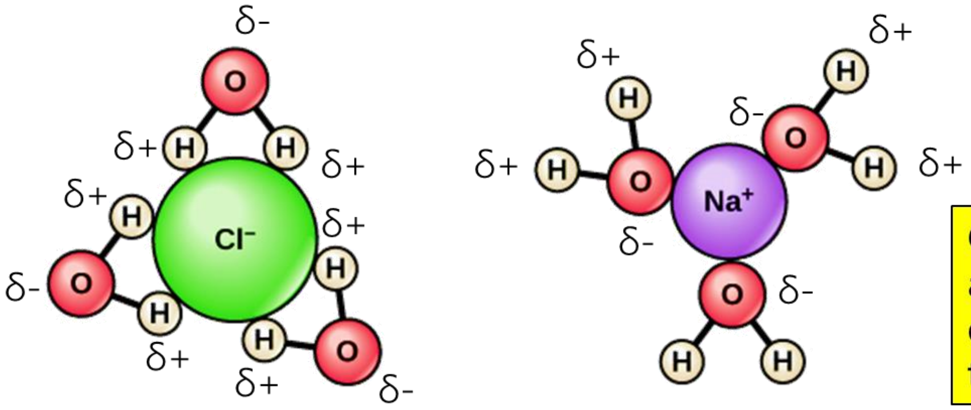
(ii) Justify your choices.

2020: Question 2c. A molecular compound consists of two different elements, X and Z, and contains three atoms. Its formula is ZX_2. The elements have different electronegativities. Depending on the identity of the elements, the molecule could be either polar or non-polar.

(i) State the likely shape if the molecule is: Polar: Non-polar:

(ii). Justify your answer by explaining the factors that affect polarity.

You do not need to identify elements X or Z, or specific molecules.



Only a few ions of each are needed in the diagram. Don't forget to label

Past NCEA questions Solubility and Dissolving

2014: Question 3b: Use your knowledge of structure and bonding to explain the dissolving process of sodium chloride in water. Support your answer with an annotated (labelled) diagram.

2017: Question 1b: (iii) Sodium chloride, NaCl, is another compound that is excreted from the body in sweat. Use your knowledge of structure and bonding to explain the dissolving process of sodium chloride, NaCl, in water.
Support your answer with a labelled diagram.

2018: Question 3d (i). Use an annotated diagram to show how solid A (ionic solid) is able to dissolve in water.
Show the solid before dissolving, and the dissolving process of the solid.
(ii) Explain the attractions that allow solid A to be soluble in water.

2019: Question 1c Compare the solubilities of iodine, $I_{2(s)}$, in water, $H_2O_{(l)}$ – a polar solvent, and in cyclohexane, $C_6H_{12(l)}$ – a non-polar solvent.

Use your knowledge of structure and bonding to explain the solubility of iodine in these two solvents.

2020: Question 1c. Solid potassium chloride, $KCl_{(s)}$, is soluble in water. Chlorine gas, $Cl_{2(g)}$, is not readily soluble in water.

Use your knowledge of structure and bonding to explain the difference in solubility of these two substances in water. You should include a diagram in your answer to illustrate the dissolving of $KCl_{(s)}$ in water.

Molecular solids

Non-metals forming molecules

I_2 iodine

S_2 sulfur

HCl Hydrogen chloride

Particles: Molecules
Bonding (attractive force): weak intermolecular

Ionic solids

Non-metals and metals together forming a ionic compound

NaCl Sodium chloride

KI Potassium iodide

$CuSO_4$ Copper sulfate

Particles: ions
Bonding (attractive force): ionic (or electrostatic)

Metallic solids

Elements that are metals

Cu copper

Al aluminium

Fe iron

Particles: atoms
Bonding (attractive force): metallic

Covalent network solids

Carbon and silicon dioxide

SiO_2 Silicon dioxide

C diamond

C graphite

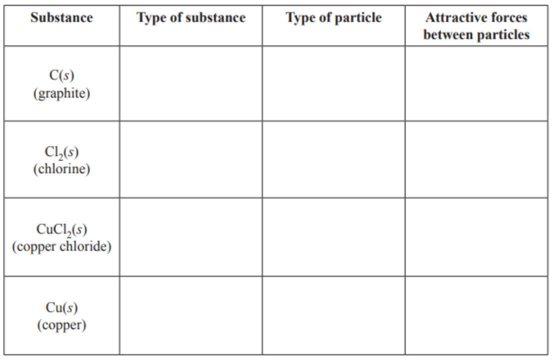
Particles: atoms
Bonding (attractive force): covalent

Substance (for example)	Type of substance	Type of particle	Attractive forces between particles
$C_{(s)}$ Graphite	Covalent (extended) network (2-D)	Atom	Strong Covalent
$Cl_{2\ (s)}$ chlorine	Molecular	Molecules	Weak intermolecular forces
$CuCl_{2(s)}$ copper chloride	Ionic	Ion	Ionic bonds / electrostatic attraction
$Cu_{(s)}$ copper	Metal	Atom / cations and electrons	Metallic bonds / electrostatic attraction

Substances KEY words for structure			
Molecular	Ionic	Metallic	Covalent Network
X is a molecular substance composed of X molecules together by weak intermolecular forces.	X is an ionic substance. It is composed of a lattice of positive X ions and X chloride ions held together by strong electrostatic attraction between these positive and negative ions. This bonding is directional.	X is a metallic substance composed of X atoms packed together. Valence electrons are loosely held and are attracted to the nuclei of the neighbouring X atoms, which results in metallic bonding, that is non-directional.	Graphite is a covalent network solid composed of 2-D layers of C atoms covalently bonded to three other C atoms. The remaining valence electrons are delocalised (ie free to move) between layers
			Diamond / SiO_2 is a covalent network made up of atoms covalently bonded together in a 3D lattice structure.

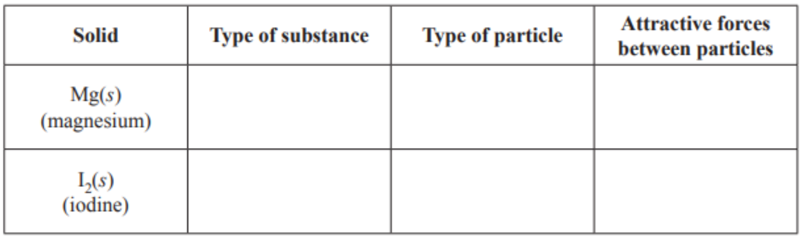
Past NCEA questions Structure and Bonding – Summary Charts

2013: Question 2a: Complete the table below by stating the type of substance, the type of particle, and the bonding (attractive forces) between the particles for each of the substances.



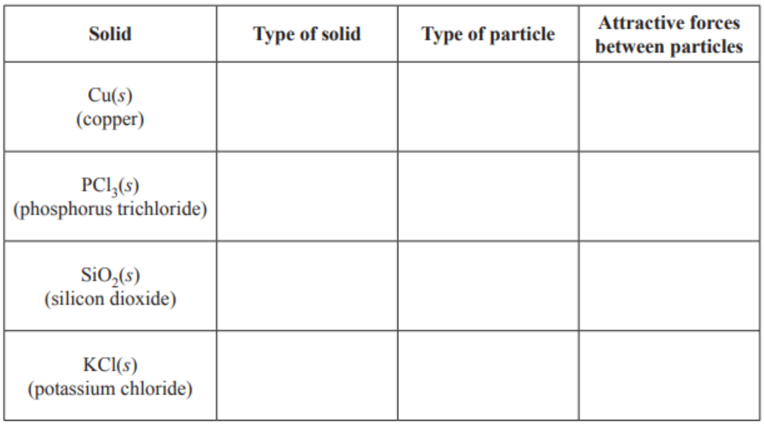
Substance	Type of substance	Type of particle	Attractive forces between particles
C(*s*) (graphite)			
$Cl_2(s)$ (chlorine)			
$CuCl_2(s)$ (copper chloride)			
Cu(*s*) (copper)			

2014: Question 2a: Complete the table below by stating the type of substance, the type of particle, and the type of bonding (attractive forces) between the particles for each of the two substances. Mg (magnesium) and I_2 (iodine)



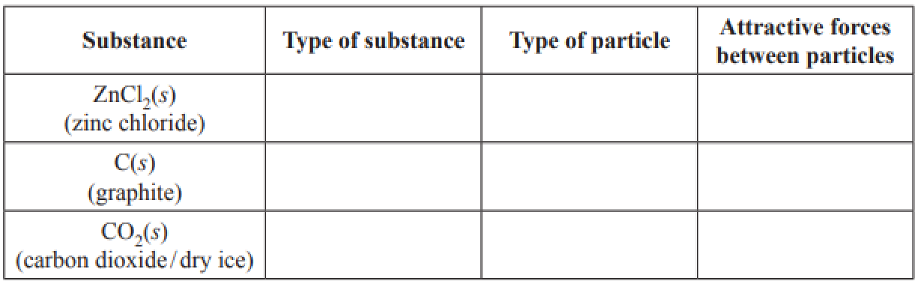
Solid	Type of substance	Type of particle	Attractive forces between particles
Mg(*s*) (magnesium)			
$I_2(s)$ (iodine)			

2015: Question 3a: Complete the table below by stating the type of solid, the type of particle, and the attractive forces between the particles in each solid.



Solid	Type of solid	Type of particle	Attractive forces between particles
Cu(*s*) (copper)			
$PCl_3(s)$ (phosphorus trichloride)			
$SiO_2(s)$ (silicon dioxide)			
KCl(*s*) (potassium chloride)			

2016: Question 2a: Complete the table below by stating the type of substance, the type of particle, and the attractive forces between the particles in the solid for each substance.



Substance	Type of substance	Type of particle	Attractive forces between particles
$ZnCl_2(s)$ (zinc chloride)			
C(*s*) (graphite)			
$CO_2(s)$ (carbon dioxide / dry ice)			

Past NCEA questions Structure and Bonding – Summary Charts

2017: Question 3a: Complete the table below by stating the type of solid, the type of particle, and the type of bonding (attractive forces) between the particles in each solid.

Solid	Type of solid	Type of particle	Attractive forces between particles
Al(*s*) (aluminium)			
$MgCl_2$(*s*) (magnesium chloride)			
S_8(*s*) (sulfur)			

2018: Question 3a. Complete the table below by choosing the appropriate type of solid that matches the properties shown in the table. Types of solid: Ionic, Metallic, Covalent Network, Molecular.

Solid	Melting point (°C)	Boiling point (°C)	Conducts electricity?	Soluble in water?	Type of solid
A	290	732	solid – no molten – yes	Yes, solution conducts electricity	
B	44	280	No	No	
C	1710	2230	No	No	
D	660	2470	Solid and molten – yes	No	

2019: Question 1a. Complete the table below by stating the type of solid, the type of particle, and the type of bonding (attractive forces) between the particles in each solid.

Solid	Type of solid	Type of particle	Attractive forces between particles
Na(*s*) (sodium)			
NaI(*s*) (sodium iodide)			
I_2(*s*) (iodine)			

2020: Question 1a. Complete the following table for the given substances in their solid state.

Solid	Type of solid	Type of particle	Attractive forces between the particles
Silicon dioxide $SiO_2(s)$			
Chlorine $Cl_2(s)$			
Potassium chloride KCl(*s*)			

Writing Excellence answers to Structure and Bonding – Solubility questions

Structure and Bonding – Solubility QUESTION

Question: Justify this statement in terms of the particles, structure, and bonding of these solids. You may use diagrams in your justification. Potassium chloride is soluble in water while Silicon dioxide and copper are insoluble in water (you will need to fill in the chart below correctly as part of the question and use the terms in your answer)

Substance	Type of substance	Type of particle	Attractive forces between particles
$KCl_{(s)}$ potassium chloride	ionic	ion	Ionic bonds / electrostatic attraction
$SiO_{2(s)}$ silicon dioxide	Covalent network	atoms	covalent
Cu(s) copper	metal	atom	Metallic bonds / electrostatic attraction

ANSWER

1. For the first substance (name) state the type of solid that it is	
2. describe the structure of this type of substance using the *terms* above in the table	
3. explain how the bonding relates to the attraction between particles in your substance and water particles	
4. link to the observation (solubility) in your question for the first substance	
5. For the second substance (name) state the type of solid that it is	
6. describe the structure of this type of substance using the *terms* above in the table	
7. explain how the bonding relates to the attraction between particles in your substance and water particles	
8. link to the observation (solubility) in your question for the second substance	
9. For the third substance (name) state the type of solid that it is	
10. describe the structure of this type of substance using the *terms* above in the table	
11. explain how the bonding relates to the attraction between particles in your substance and water particles	
12. link to the observation (solubility) in your question for the third substance	

NOTE: The white column is how your answer would appear on your test paper so make sure you write out complete sentences. The grey area is just to help you structure your answer and would not appear in the question.

Past NCEA questions Structure and Bonding – Solubility

2014: Question 2c: Solid Mg and I_2 were tested for three physical properties. The table below shows the results of the tests. Use your knowledge of structure and bonding to explain the results of the tests.

	Physical property		
Substance tested	Ductile	Soluble in cyclohexane (non-polar solvent)	Conducts electricity
Mg	yes	no	yes
I_2	no	yes	no

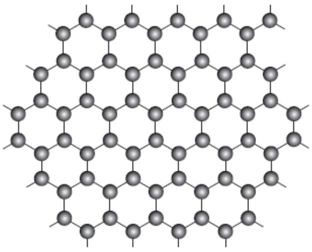
2015: Question 3c: Consider each of the solids copper, Cu, silicon dioxide, SiO_2, and potassium chloride, KCl. Complete the table below by identifying which of these solids have the listed physical properties:
Justify TWO of your choices in terms of the particles, structure, and bonding of these solids. You may use diagrams in your justification.

Physical properties	**Solid**
The solid is insoluble in water and is malleable.	
The solid is soluble in water and is not malleable.	
The solid is insoluble in water and is not malleable.	

2016: Question 2c : Solid zinc chloride, $ZnCl_{2(s)}$, is soluble in water. Dry ice, $CO_{2(s)}$, is not readily soluble in water. Justify these statements in terms of the particles, structure, and bonding of these substances

Past NCEA questions Structure and Bonding – Covalent Network Structure

2014: Question 2b: Graphene is a new 2-dimensional material made of carbon atoms. Graphene can be described as a 'one-atom-thick' layer of graphite. A diagram of graphene and two of its properties is shown below. Use your knowledge of structure and bonding to explain the two properties of graphene given above



Properties of graphene:
Melting point: very high
Electrical conductivity: excellent

2016: Question 2b: Carbon (graphite) conducts electricity when it is solid, whereas zinc chloride, $ZnCl_2$, will not conduct electricity when solid, but will conduct when molten.
Justify this statement in terms of the particles, structure, and bonding for both substances.

Writing Excellence answers to Structure and Bonding –State questions

Structure and Bonding – State QUESTION

Question: Explain why chlorine is a gas at room temperature, but copper chloride is a solid at room temperature. In your answer, you should refer to the particles and the forces between the particles in both substances. (you will need to fill in the chart below correctly as part of the question and use the terms in your answer)

Substance	Type of substance	Type of particle	Attractive forces between particles
$Cl_{2\ (s)}$ chlorine	Molecular	Molecules	Weak intermolecular forces
$CuCl_{2(s)}$ copper chloride	Ionic	Ion	Ionic bonds / electrostatic attraction

ANSWER

1. For the first substance (name) state the type of solid that it is	
2. describe the structure of this type of substance using the *terms* above in the table	
3. explain how the bonding relates to the energy required to break bonds of your substance	
4. link to the observation (state at room temperature) in your question for the first substance	
5. For the second substance (name) state the type of solid that it is	
6. describe the structure of this type of substance using the *terms* above in the table	
7. explain how the bonding relates to the energy required to break bonds of your substance	
8. link to the observation (state at room temperature) in your question for the first substance	

Past NCEA questions Structure and Bonding – State

2013: Question 2b: Explain why chlorine is a gas at room temperature, but copper chloride is a solid at room temperature.
In your answer, you should refer to the particles and the forces between the particles in both substances.

2015: Question 3b: Phosphorus trichloride, PCl_3, is a liquid at room temperature, and does not conduct electricity. Explain these two observations in terms of the particles, structure, and bonding of PCl_3.

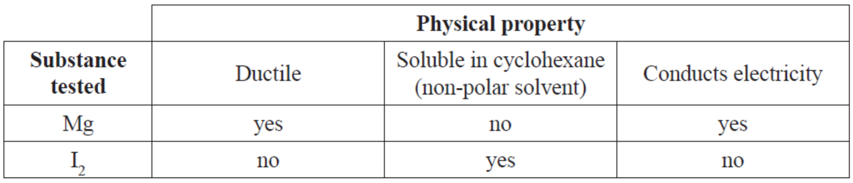
2017: Question 3b: Circle the substance which has the lowest melting point.
$Al_{(s)}$ $MgCl_{2(s)}$ $S_{8(s)}$
Justify your choice, referring to the attractive forces between the particles of ALL three substances.

2018: Question 3c. Elaborate on the differences in the melting points of solids B (Molecular) and D (Metallic) with reference to their particles, structure, and bonding.

Past NCEA questions Structure and Bonding – Conductivity

2013: Question 2b (ii): Using your knowledge of structure and bonding, explain why, although both graphite and copper are good conductors of electricity, copper is suitable for electrical wires, but graphite is not.

2014: Question 2c: Solid Mg and I_2 were tested for three physical properties. The table below shows the results of the tests. Use your knowledge of structure and bonding to explain the results of the tests.



Substance tested	**Physical property**		
	Ductile	Soluble in cyclohexane (non-polar solvent)	Conducts electricity
Mg	yes	no	yes
I_2	no	yes	no

2015: Question 3b: Phosphorus trichloride, PCl_3, is a liquid at room temperature, and does not conduct electricity. Explain these two observations in terms of the particles, structure, and bonding of PCl_3.

2016: Question 2b: Carbon (graphite) conducts electricity when it is solid, whereas zinc chloride, $ZnCl_2$, will not conduct electricity when solid, but will conduct when molten. Justify this statement in terms of the particles, structure, and bonding for both substances.

2018: Question 3b. Explain why Solid A (ionic) does not conduct electricity in the solid state but will conduct when molten or when dissolved in water. Refer to the particles, structure, and bonding of this substance.

2019: Question 3a. (ii) In the reaction below, $C_{(s)}$ in the form of graphite can conduct electricity. The product, carbon dioxide, $CO_{2(g)}$, does not conduct electricity. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

2020: Question 1b. The electrical conductivity of silicon dioxide and potassium chloride in different states is given below. Use your knowledge of structure and bonding to explain these observations
of structure and bonding to explain this observation

Writing Excellence answers to Structure and Bonding – Conductivity questions

Structure and Bonding – Conductivity (Ductility) QUESTION

Question: Using your knowledge of structure and bonding, explain why, although both graphite and copper are good conductors of electricity, copper is suitable for electrical wires, but graphite is not. (note two properties to discuss)
(you will need to fill in the chart below correctly as part of the question and use the terms in your answer)

Substance	Type of substance	Type of particle	Attractive forces between particles
$C_{(s)}$ Graphite	Covalent network	Atom	Covalent (and weak intermolecular forces)
$Cu_{(s)}$ copper	metal	Atom / cations and electrons	Metallic bonds / electrostatic attraction

ANSWER

1. For the first substance (name) state the type of solid that it is	
2. describe the structure of this type of substance using the *terms* above in the table	
3. explain how the bonding relates to the present of free moving charged particles to conduct electricity in your substance (property 1)	
4. link to the observation (conductivity) in your question for the first substance	
5. explain how the bonding relates to ductility in your substance (property 2)	
6. link to the observation (forming wires) in your question for the first substance	
7. For the second substance (name) state the type of solid that it is	
8. describe the structure of this type of substance using the *terms* above in the table	
9. explain how the bonding relates to the present of free moving charged particles to conduct electricity in your substance (property 1)	
10. link to the observation (conductivity) in your question for the second substance	
11. explain how the bonding relates to ductility in your substance (property 2)	
12. link to the observation (forming wires) in your question for the second substance	

NOTE: The white column is how your answer would appear on your test paper so make sure you write out complete sentences. The grey area is just to help you structure your answer and would not appear in the question.

Past NCEA questions Structure and Bonding – Malleability / Ductility

2013: Question 2b (ii): Using your knowledge of structure and bonding, explain why, although both graphite and copper are good conductors of electricity, copper is suitable for electrical wires, but graphite is not.

2014: Question 2c: Solid Mg and I_2 were tested for three physical properties. The table below shows the results of the tests. Use your knowledge of structure and bonding to explain the results of the tests.

	Physical property		
Substance tested	Ductile	Soluble in cyclohexane (non-polar solvent)	Conducts electricity
Mg	yes	no	yes
I_2	no	yes	no

2015: Question 3c: Consider each of the solids copper, Cu, silicon dioxide, SiO_2, and potassium chloride, KCl. Complete the table below by identifying which of these solids have the listed physical properties:
Justify TWO of your choices in terms of the particles, structure, and bonding of these solids. You may use diagrams in your justification.

Physical properties	**Solid**
The solid is insoluble in water and is malleable.	
The solid is soluble in water and is not malleable.	
The solid is insoluble in water and is not malleable.	

2017: Question 3c: Circle the substance which is malleable.
$Al_{(s)}$ $MgCl_{2(s)}$ $S_{8(s)}$
Justify your choice by referring to the structure and bonding of your chosen substance.
You may include a diagram or diagrams in your answer.

2019: Question 1b. Sodium, Na(*s*), is malleable, whereas sodium iodide, NaI(*s*), is brittle.

Explain these observations by referring to the structure and bonding of each substance.

Writing Excellence answers to Enthalpy questions

Enthalpy QUESTION

Question: Pentane, C_5H_{12}, is a liquid at room temperature. It evaporates at 36.1°C in an endothermic process.

(i) Explain why the evaporation of pentane is an endothermic process.

(ii) Draw, including labels, the energy diagram for the combustion of pentane, $C_5H_{12(l)}$.

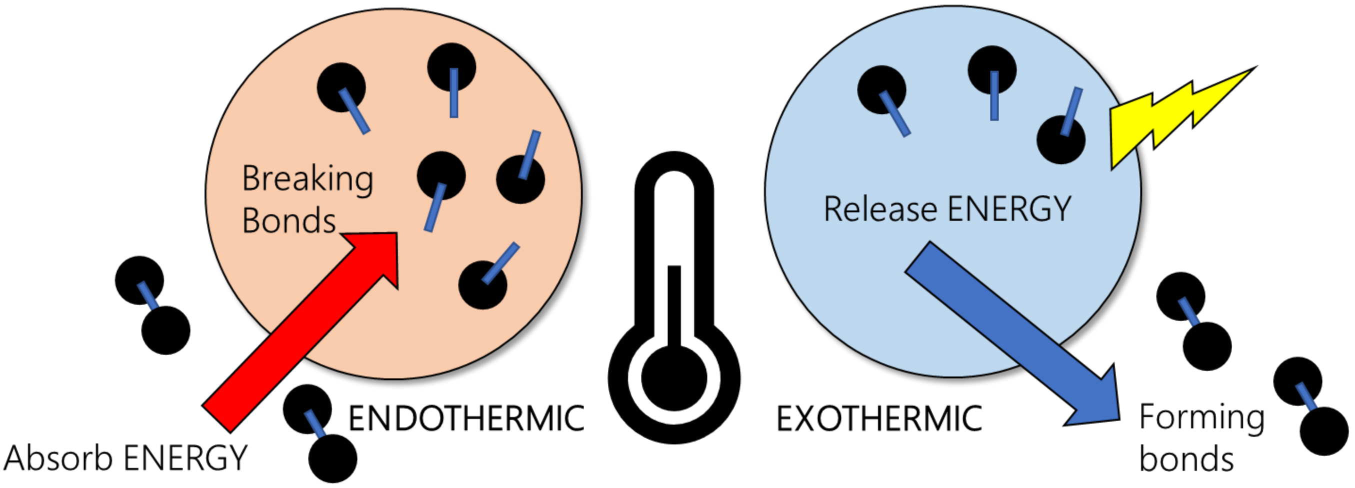
Pentane combustion: $C_5H_{12(l)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(l)}$ $\Delta_rH^\circ = -3509$ kJ mol^{-1}

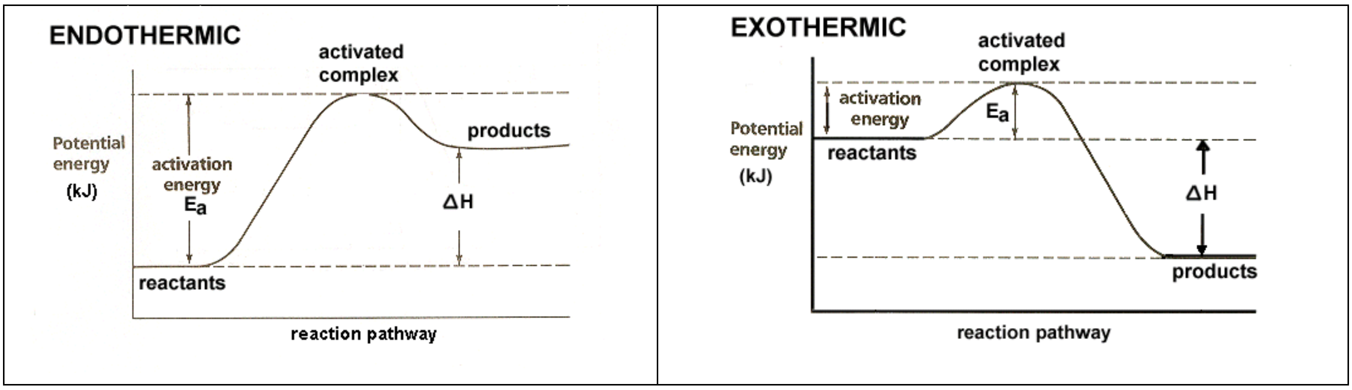
Include in your diagram the reactants, products, and change in enthalpy.

ANSWER

1. define an endothermic process	
2. For the substance (name) state the type of "solid" that it is	
3. link state change (liquid to gas) to breaking bonds requiring energy	
3. link state change to endothermic process	
4. draw labelled diagram including labelled axis's, reactants H_R, products H_P and change in enthalpy ΔH	

NOTE: The white column is how your answer would appear on your test paper so make sure you write out complete sentences. The grey area is just to help you structure your answer and would not appear in the question.





Past NCEA questions – Enthalpy (ONE)

2013: Question 3a: Dissolving ammonium nitrate in a beaker containing water can be represented by the following equation: $NH_4NO_{3(s)} \rightarrow NH_4{}^+{}_{(aq)} + NO_3{}^-{}_{(aq)}$ $\Delta_rH° = 25.1$ kJ mol^{-1}
Give the term below that best describes this process and give the description that best describes what you would observe happening to the beaker during this process.

2013: Question 3b: Glucose is an important source of energy in our diet. The equation below shows the combustion of glucose to form carbon dioxide and water.
$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(\ell)}$ $\Delta_rH° = -2\,820$ kJ mol^{-1}
Give the term below that best describes this process and give a reason

2014: Question 3a (i): When solid sodium hydroxide is added to water, the temperature increases.
- Identify the term that best describes this reaction
- Give a reason for your choice

2014: Question 3a(ii): The freezing of water to form ice can be represented by the following equation.
$H_2O_{(l)} \rightarrow H_2O_{(s)}$
- Identify the term that best describes this reaction
- Give a reason for your choice

Past NCEA questions – Enthalpy (TWO)

2015: Question 2a: Hand warmers contain a supersaturated solution of sodium ethanoate which, when activated, crystallises and releases heat.

- Identify the term that best describes this reaction
- Give a reason for your choice

2015: Question 2b(i): Glucose is made in plants during photosynthesis when carbon dioxide gas, $CO_{2(g)}$, and water, $H_2O_{(l)}$, react to produce glucose, $C_6H_{12}O_{6(aq)}$, and oxygen gas, $O_{2(g)}$. The photosynthesis reaction can be represented by the following equation: $6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)}$ $\Delta_rH° = +2803$ kJ mol^{-1}

2015: Question 2c (iii): Complete, including labels, the energy diagram for the combustion of butane gas showing reactants, products, and the change in enthalpy.

2015: Question 2c (iv): Butane gas is a useful fuel because when it undergoes combustion, energy is released. Explain why energy is released in this reaction, in terms of making and breaking bonds.

2016: Question 1a. Instant cold packs are useful for treating sports injuries on the field. They contain salts such as ammonium nitrate, NH_4NO_3. When the packs are activated, the salt dissolves in water, causing the temperature to decrease.

- Identify the term that best describes this reaction
- Give a reason for your choice

2016: Question 1b: The equation for hydrating anhydrous copper sulfate is as follows:
$CuSO_{4(s)} + 5H_2O_{(l)} \rightarrow CuSO_4.5H_2O_{(s)}$ $\Delta_rH° = -78.2$ kJ mol^{-1}

- Identify the term that best describes this reaction
- Give a reason for your choice

2016: Question 1c (i): Pentane, C_5H_{12}, is a liquid at room temperature. It evaporates at 36.1°C in an endothermic process.
(i) Explain why the evaporation of pentane is an endothermic process.

2016: Question 1c(ii): Draw, including labels, the energy diagram for the combustion of pentane, $C_5H_{12(l)}$.
Pentane combustion: $C_5H_{12(l)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(l)}$ $\Delta_rH° = -3509$ kJ mol^{-1}
Include in your diagram the reactants, products, and change in enthalpy.

Past NCEA questions – Enthalpy (THREE)

2017: Question 1a: When solid calcium chloride, $CaCl_{2(s)}$, reacts with water, the temperature increases. Which term that best describes this reaction.

2017: Question 1b (i): When a person sweats, water is lost from the body by evaporation. This is an endothermic process. This evaporation speeds up when a person exercises.
(i) Explain why the evaporation of water in sweat from the body is endothermic, and why exercise increases this evaporation.

2017: Question 1b (ii): Draw a labelled enthalpy diagram for the evaporation of water, $H_2O_{(\ell)}$.
$H_2O_{(\ell)} \rightarrow H_2O_{(g)}$ $\Delta_rH° = 40.7$ kJ mol^{-1}

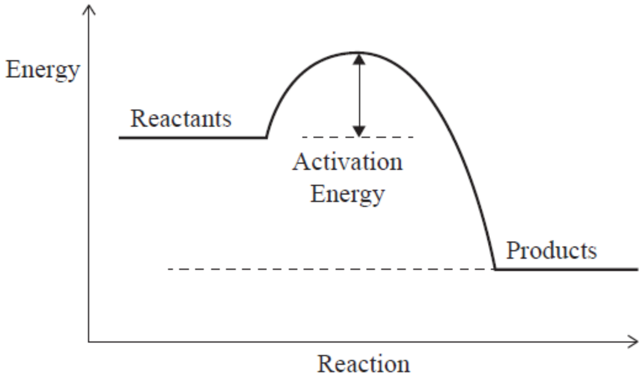
2018: Question 1a. The equation for the dissolving of ammonium chloride, NH_4Cl, in water is shown below.
$NH_4Cl_{(s)} \rightarrow NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$ $\Delta_rH° = +17.8$ kJ mol^{-1}
Circle the term that best describes this reaction: Endothermic exothermic
Give a reason for your choice.

2018: Question 1b (i) Respiration is the process by which energy is released from glucose.
$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(\ell)}$
Circle the term that best describes this reaction: endothermic exothermic
Give a reason for your choice.

2018: Question 1b (ii) . Water formed in the respiration reaction evaporates.
$H_2O_{(\ell)} \rightarrow H_2O_{(g)}$ Explain whether this process is endothermic or exothermic

2018: Question 1c. (i) Butane is used to fuel a camping stove. Butane burns readily in oxygen.
The following is an energy profile diagram for the combustion of butane.

Explain how the diagram shows that the enthalpy change for this reaction is negative.



Past NCEA questions – Enthalpy (FOUR)

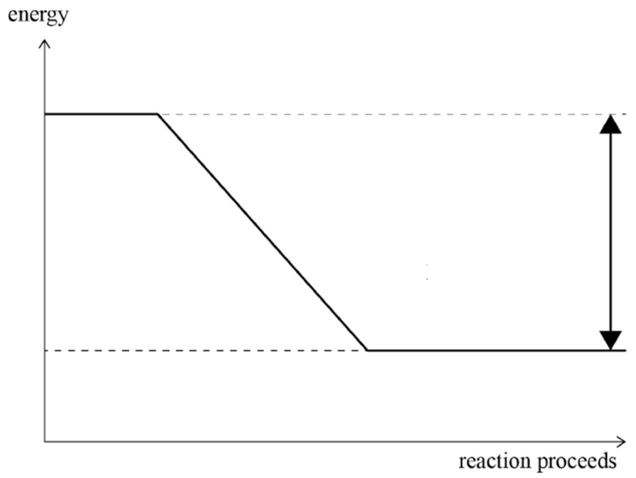
2019: Question 1d. Ice, $H_2O_{(s)}$, is often placed into drinks. As the ice melts, the drink cools.

$H_2O_{(s)} \rightarrow H_2O_{(l)}$ Δ_rH = + 6.01 kJ mol^{-1}
Use your knowledge of enthalpy changes associated with changes of state to elaborate on the reason why the drink cools.

2020: Question 3a. Octane, $C_8H_{18(l)}$, is used as a fuel.

The equation for the complete combustion of octane is shown below.
$2C_8H_{18(l)} + 25\ O_{2(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(g)}$ Δ_rH = –11 018 kJ mol^{-1}
(i) Classify this reaction as endothermic or exothermic, with a reason.

(ii) Complete, including labels, the energy diagram for the combustion of octane showing reactants, products, and the change in enthalpy.



2020: Question 3b. Ethanol, $CH_3CH_2OH_{(l)}$, is a liquid at room temperature with a boiling point of 78.4 °C.

Explain whether the change of ethanol from liquid to gas is an endothermic or exothermic process by referring to the attractive forces between particles.

Writing Excellence answers to Thermochemical Calculations questions

Thermochemical Calculations QUESTION

Question: Hexane, C_6H_{14}, like pentane, will combust (burn) in sufficient oxygen to produce carbon dioxide gas and water.

Pentane combustion: $C_5H_{12(l)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(l)}$ $\Delta_rH^\circ = -3509$ kJ mol^{-1}

Hexane combustion: $2C_6H_{14(l)} + 19O_{2(g)} \rightarrow 12CO_{2(g)} + 14H_2O_{(l)}$ $\Delta_rH^\circ = -8316$ kJ mol^{-1}

Justify which alkane – pentane or hexane – will produce more heat energy when 125 g of each fuel is combusted in sufficient oxygen.

$M(C_5H_{12}) = 72.0$ g mol^{-1} $M(C_6H_{14}) = 86.0$ g mol^{-1}

(An equation and n=m/M are required for this type of thermochemical calculation)

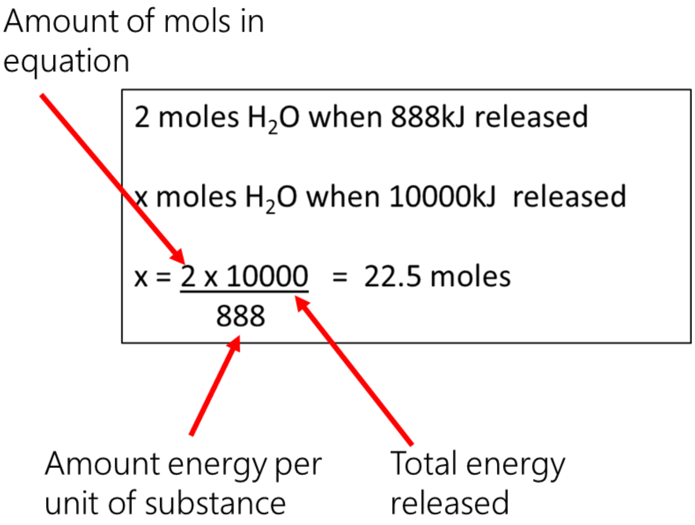
ANSWER

1. Calculate the amount of energy per mol from the equation (divide Δ_rH° by number mol of substance in equation) – substance ONE	
2. calculate the number of mols of the known (K) n = m/M	
3. multiply amount of energy per mol (step 1) by number of mols calculated (step 2) to get energy per mass *Answer with units plus 3sgf*	
4. Calculate the amount of energy per mol from the equation (divide Δ_rH° by number mol of substance in equation) – substance TWO	
5. calculate the number of mols of the known (K) n = m/M	
6. multiply amount of energy per mol (step 4) by number of mols calculated (step 5) to get energy per mass *Answer with units plus 3sgf*	
7. compare both substances with summary statement	

NOTE: The white column is how your answer would appear on your test paper so make sure you write out complete sentences. The grey area is just to help you structure your answer and would not appear in the question.

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$ $\Delta_r H = -888 kJmol^{-1}$

Calculate the **amount** (in moles) of **H_2O** produced when the reaction above releases **10,000kJ**.



Amount of mols in equation

2 moles H_2O when 888kJ released

x moles H_2O when 10000kJ released

$x = \frac{2 \times 10000}{888} = 22.5$ moles

Amount energy per unit of substance

Total energy released

An **alternative method** is to find out how much energy is released per mole first

2 moles H_2O = 888kJ

Therefore 1 mole H_2O = 444kJ

10,000kJ/444kJ = 22.5

So 22.5 moles of water are produced at 444kJ to reach 10,000kJ

(22.5 x 444 = 10,000)

Past

NCEA questions – Thermochemical Calculations (ONE)

2013: Question 3b(ii): Females who are moderately active need 9 800 kJ of energy per day. Calculate the number of moles of glucose that would provide this daily energy requirement.

$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(\ell)}$ $\Delta_r H° = –2\ 820$ kJ mol$^{–1}$

2013: Question 3c(ii) : The equation below shows the combustion of butane.

$C_4H_{10(g)} + 13/2\ O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(g)}$ $M(C_4H_{10}) = 58.1$ g mol$^{–1}$.

When 100 g of butane undergoes combustion, 4 960 kJ of energy is released.

Calculate the enthalpy change when 1 mole of butane undergoes combustion.

2013: Question 3d: The iron oxides Fe_3O_4 and Fe_2O_3 react with aluminium as shown below.

$3Fe_3O_{4(s)} + 8Al_{(s)} \rightarrow 4Al_2O_{3(s)} + 9Fe_{(s)}$ $\Delta_r H° = –3\ 348$ kJ mol$^{–1}$

$Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(s)}$ $\Delta_r H° = –851$ kJ mol$^{–1}$

Justify which iron oxide, Fe_3O_4 or Fe_2O_3, will produce more heat energy when 2.00 kg of iron is formed during the reaction with aluminium.

Your answer should include calculations of the heat energy produced for the given mass of iron formed.

$M(Fe) = 55.9$ g mol$^{–1}$.

Past NCEA questions – Thermochemical Calculations (TWO)

2014: Question 3c: Methanol and ethanol can both be used as fuels. Their combustion reactions can be represented by the following equations:
Methanol combustion: $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$ $\Delta_r H^o = –1450$ kJ mol^{-1}
Ethanol combustion: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ $\Delta_r H^o = –1370$ kJ mol^{-1}
Justify which fuel, methanol or ethanol, will produce more heat energy when 345 g of each fuel is combusted in excess oxygen.
$M(CH_3OH) = 32.0$ g mol^{-1}
$M(C_2H_5OH) = 46.0$ g mol^{-1}

2015: Question 2b(ii) : Calculate how much energy is absorbed or released in the photosynthesis reaction if 19.8 g of carbon dioxide gas, $CO_{2(g)}$, reacts completely with excess water, $H_2O_{(l)}$, to form glucose, $C_6H_{12}O_{6(aq)}$, and oxygen gas, $O_{2(g)}$.
Show your working and include appropriate units in your answer. $M(CO_2) = 44.0$ g mol^{-1}
$6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(aq)} + 6O_{2(g)}$ $\Delta_r H° = +2803$ kJ mol^{-1}

2015: Question 2c: A small camp stove containing butane gas, $C_4H_{10(g)}$, is used to heat some water, as shown in the diagram below. A student measures the temperature change in the water and calculates that when 3.65 g of butane is combusted, 106 kJ of heat is released.
The reaction for the combustion of butane is shown in the equation below.
$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(l)}$
(i) Calculate the enthalpy change ($\Delta r\ H$) for this reaction, based on the above measurements. $M(C_4H_{10}) = 58.0$ g mol^{-1}

2015: Question 2c: (ii) The accepted enthalpy change for the combustion reaction of butane gas, $C_4H_{10(g)}$, is $\Delta r\ H = –5754$ kJ mol^{-1}. Explain why the result you calculated in part (c)(i) is different to the accepted value.
In your answer, you should include at least TWO reasons.

2016: Question 1c(iii): Hexane, C_6H_{14}, like pentane, will combust (burn) in sufficient oxygen to produce carbon dioxide gas and water. Pentane combustion: $\Delta_r H^\circ = -3509$ kJ mol^{-1}
Hexane combustion: $2C_6H_{14(l)} + 19O_{2(g)} \rightarrow 12CO_{2(g)} + 14H_2O_{(l)}$ $\Delta_r H^\circ = -8316$ kJ mol^{-1}
Justify which alkane – pentane or hexane – will produce more heat energy when 125 g of each fuel is combusted in sufficient oxygen.
$M(C_5H_{12}) = 72.0$ g mol^{-1} $M(C_6H_{14}) = 86.0$ g mol^{-1}

2017: Question 1c: Thermite reactions occur when a metal oxide reacts with a metal powder.
The equations for two thermite reactions are given below:
Reaction 1: $Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow 2Fe_{(s)} + Al_2O_{3(s)}$ $\Delta_r H° = –852$ kJ mol^{-1}
Reaction 2: $3CuO_{(s)} + 2Al_{(s)} \rightarrow 3Cu_{(s)} + Al_2O_{3(s)}$ $\Delta_r H° = –1520$ kJ mol^{-1}
Use calculations to determine which metal oxide, iron(III) oxide, $Fe_2O_{3(s)}$, or copper(II) oxide, $CuO_{(s)}$, will produce more heat energy when 50.0 g of each metal oxide is reacted with aluminium powder, $Al_{(s)}$.
$M(Fe_2O_3) = 160$ g mol^{-1} $M(CuO) = 79.6$ g mol^{-1}

Past NCEA questions – Thermochemical Calculations (THREE)

2018: Question 1c. (ii) The following is the equation for the combustion of butane gas in oxygen.
$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(g)}$ $\Delta_rH^o = –5760 \text{ kJ mol}^{-1}$
The fuel cylinder for the stove contains 450 g of butane gas.
Calculate the energy released when this mass of butane gas is burned completely in oxygen.
Show your working and include appropriate units in your answer.
$M(C_4H_{10}) = 58.0 \text{ g mol}^{-1}$

2018: Question 2d. Methanol, $CH_3OH_{(\ell)}$, is made industrially by reacting carbon monoxide, $CO_{(g)}$, and hydrogen, $H_{2(g)}$.
$CO_{(g)} + 2H_{2(g)} \rightarrow CH_3OH_{(\ell)}$ $\Delta_rH^o = –91.0 \text{ kJ mol}^{-1}$
Calculate the volume of methanol made when 4428 kJ of energy is released.
The mass of 1.00 L of methanol is 0.790 kg.
$M(CH_3OH) = 32.0 \text{ g mol}^{-1}$

2019: Question 3b. When magnesium, $Mg_{(s)}$, is burned, it produces a white powder according to the equation below.
$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$ $\Delta_rH = –1203 \text{ kJ mol}^{-1}$
(i) Calculate the mass of oxygen required to produce 1804.5 kJ of energy. $M(O) = 16.0 \text{ g mol}^{-1}$
(ii) Calculate the energy change when 100 g of $MgO_{(s)}$ is produced. $M(MgO) = 40.3 \text{ g mol}^{-1}$

2019: Question 3c. A common industrial process is the extraction of metals from their ores. Aluminium is found naturally in aluminium oxide, and the oxygen is removed to produce the metal. Information is given below of the enthalpy change when aluminium, $Al_{(s)}$, is extracted.
$2Al_2O_{3(s)} \rightarrow 4Al_{(s)} + 3O_{2(g)}$ $\Delta_rH = 3350 \text{ kJ mol}^{-1}$
A production plant produces 65.0 kg (65 000 g) of aluminium per minute.
Calculate how much energy is required per hour of production of aluminium.
Round your answer to 3 significant figures. $M(Al) = 27.0 \text{ g mol}^{-1}$

2020: Question 2d. Sulfur dioxide, $SO_{2(g)}$, can be made by burning sulfur, $S_{(s)}$, in an excess of oxygen, $O_{2(g)}$.

$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$ $\Delta_rH = –296 \text{ kJ mol}^{-1}$
Calculate the mass of sulfur burned when 740 kJ of energy is released.
$M(S) = 32.1 \text{ g mol}^{-1}$

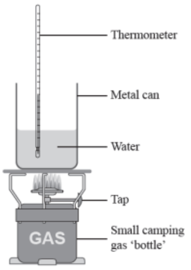
2020: Question 3d. Ethanol can be burned as a fuel. The equation for its complete combustion is shown below.

$CH_3CH_2OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(g)}$
When 1.50 kg of ethanol is burned completely, it releases 40 600 kJ of energy.
Use this information to determine the enthalpy, Δ_rH, in kJ mol^{-1} for this reaction.
$M(CH_3CH_2OH) = 46.0 \text{ g mol}^{-1}$

Writing Excellence answers to Specific Heat Capacity questions

Specific Heat Capacity QUESTION

Question: The accepted enthalpy change for the combustion reaction of butane gas, $C_4H_{10(g)}$, is $\Delta r\ H = -5754$ kJ mol^{-1}.
Explain why calculated enthalpy is different to the accepted value.
In your answer, you should include at least TWO reasons.



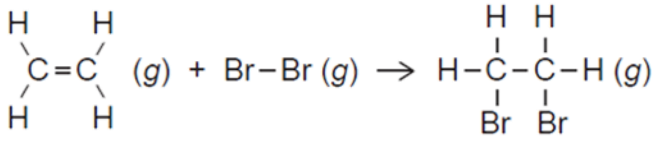
ANSWER	
1. state values for both calculated data (worked out from a previous question on experimental data) and accepted data *Units, sign and 3sgf*	
2. link results from experimental data to errors in experimental design	
3. explain error number 1.	
4. explain error number 2.	
5. explain error number 3.	
6. explain error number 4. (may need only 2 or 3 in answer)	
7. make summary statement linking that not energy released is transferred to heating the water	

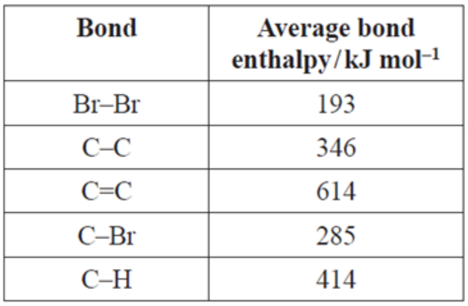
NOTE: The white column is how your answer would appear on your test paper so make sure you write out complete sentences. The grey area is just to help you structure your answer and would not appear in the question.

Writing Excellence answers to Bond Enthalpy questions

Bond enthalpy QUESTION

Question: Ethene gas, $C_2H_{4\,(g)}$, reacts with bromine gas, $Br_{2(g)}$, as shown in the equation below. Calculate the enthalpy change, $\Delta_r H°$, for the reaction between ethane and bromine gases, given the average bond enthalpies in the table below. Show your working and include appropriate units in your answers.

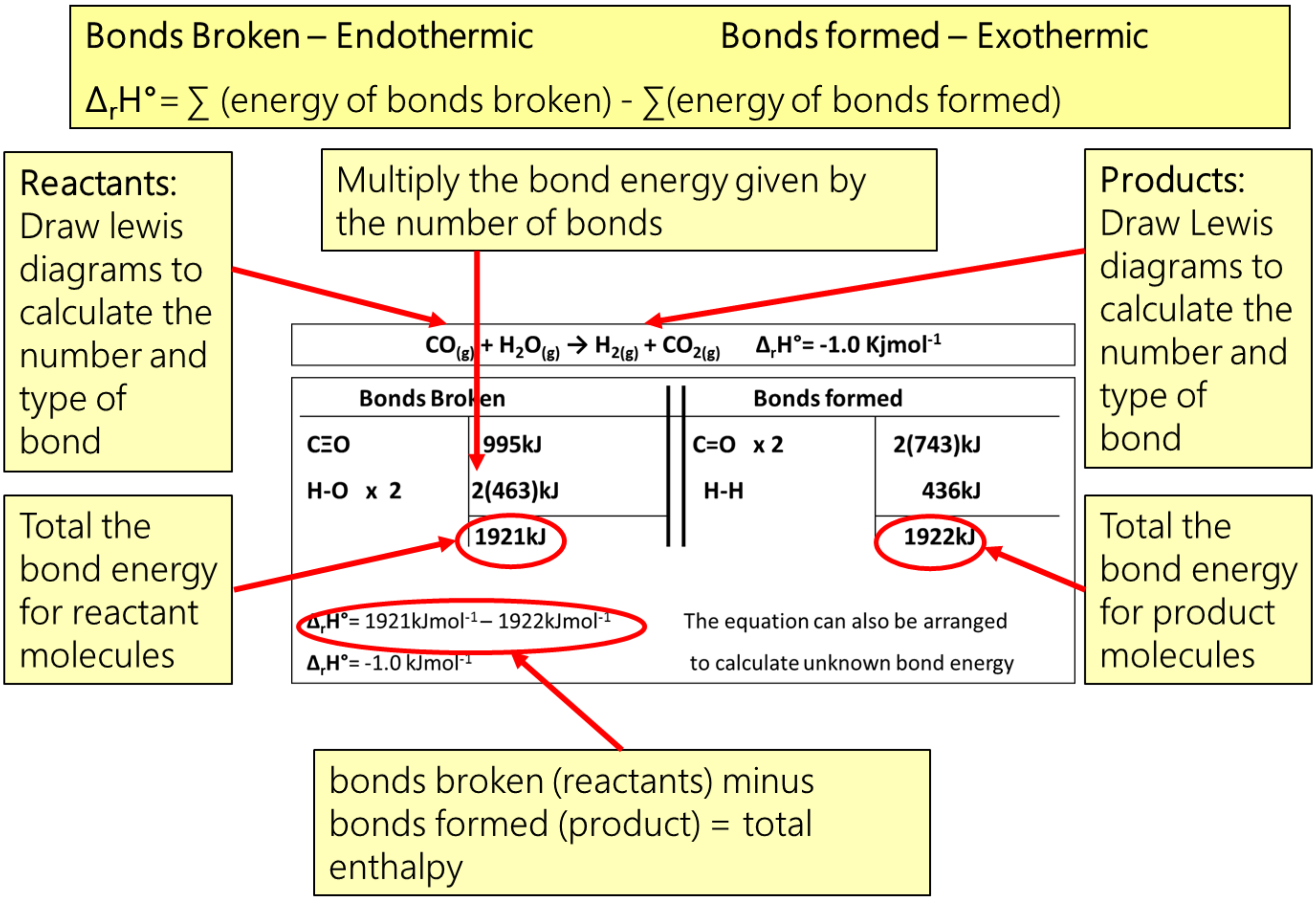




Bond	Average bond enthalpy/kJ mol^{-1}
Br–Br	193
C–C	346
C=C	614
C–Br	285
C–H	414

ANSWER

1. list types of bonds for reactants (bonds broken) and products (bonds formed) AND number of each, in a table. Watch for double or triple bonds as these are separate (Draw Lewis structures if not given)	Bonds broken (reactants)				Bonds formed (products)			
2. write bond type for each reactant (bonds broken) and product (bonds formed). Watch for double and triple bonds as they are different. Cross off on lewis diagram as you go	Bond type	number	enthalpy	Total enthalpy	Bond type	number	enthalpy	Total enthalpy
3. write the number of each bond type beside 4. multiply bond enthalpy by number of each bond								
5. total reactant bond enthalpy and total product enthalpy	Total Enthalpy (bonds broken)				Total enthalpy (bonds broken)			
6. calculate enthalpy change *(sign, units and 3sgf)* $\Delta_r H^o$ = ΣBond energies (bonds broken) – ΣBond energies(bonds formed)	Total enthalpy =							
7. you may have to rearrange equation if enthalpy for a bond is required $\Delta_r H^o$ = ΣBond enthalpy (bonds broken) – ΣBond enthalpy (bonds formed)								



Bonds Broken – Endothermic **Bonds formed – Exothermic**

$\Delta_r H° = \sum$ (energy of bonds broken) - $\sum$(energy of bonds formed)

Reactants: Draw lewis diagrams to calculate the number and type of bond

Multiply the bond energy given by the number of bonds

Products: Draw Lewis diagrams to calculate the number and type of bond

$CO_{(g)} + H_2O_{(g)} \rightarrow H_{2(g)} + CO_{2(g)}$ $\Delta_r H° = -1.0\ Kjmol^{-1}$

Bonds Broken		Bonds formed	
C≡O	995kJ	C=O x 2	2(743)kJ
H-O x 2	2(463)kJ	H-H	436kJ
	1921kJ		1922kJ

$\Delta_r H° = 1921kJmol^{-1} – 1922kJmol^{-1}$

$\Delta_r H° = -1.0\ kJmol^{-1}$

The equation can also be arranged to calculate unknown bond energy

Total the bond energy for reactant molecules

Total the bond energy for product molecules

bonds broken (reactants) minus bonds formed (product) = total enthalpy

Past NCEA questions Solids – Bond Enthalpy (ONE)

2013: Question 2c: Chlorine reacts with methane to form chloromethane and hydrogen chloride, as shown in the equation below.

$CH_{4(g)} + Cl_{2(g)} \rightarrow CH_3Cl_{(g)} + HCl_{(g)}$

Use the following bond enthalpies to calculate Δr *H*° for this reaction.

Bond	Bond enthalpy /kJ mol^{-1}
H – Cl	431
C – H	414
C – Cl	324
Cl – Cl	242

2014: Question 1d: Hydrogen gas, $H_{2(g)}$, reacts with oxygen gas, $O_{2(g)}$, as shown by the following equation

$H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(g)}\ \Delta_r H^o = –242\ kJ\ mol^{–1}$

Given the average bond enthalpies in the table below, calculate the average bond enthalpy of the O – H bond in H_2O.

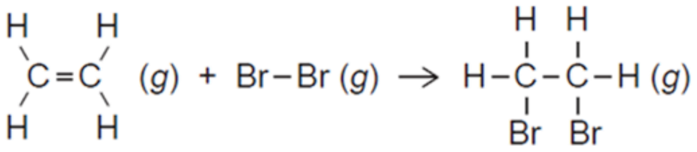
Bond	Average bond enthalpy / kJ mol^{-1}
H – H	436
O = O	498

Past NCEA questions Solids – Bond Enthalpy (TWO)

2015: Question 1d: Ethene gas, $C_2H_{4\ (g)}$, reacts with bromine gas, $Br_{2(g)}$, as shown in the equation below.

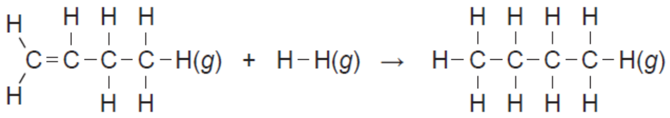
Calculate the enthalpy change, $\Delta_rH°$, for the reaction between ethane and bromine gases, given the average bond enthalpies in the table below. Show your working and include appropriate units in your answers.

Bond	Average bond enthalpy/kJ mol^{-1}
Br–Br	193
C–C	346
C=C	614
C–Br	285
C–H	414



2016: Question 3c: Calculate the enthalpy change, $\Delta_rH°$, for the reaction of but-1-ene gas, $C_4H_{8(g)}$, with hydrogen gas, $H_{2(g)}$, to form butane gas, $C_4H_{10(g)}$.

Use the average bond enthalpies given in the table below.



Bond	Average bond enthalpy / kJ mol^{-1}
C=C	614
C–C	346
C–H	414
H–H	436

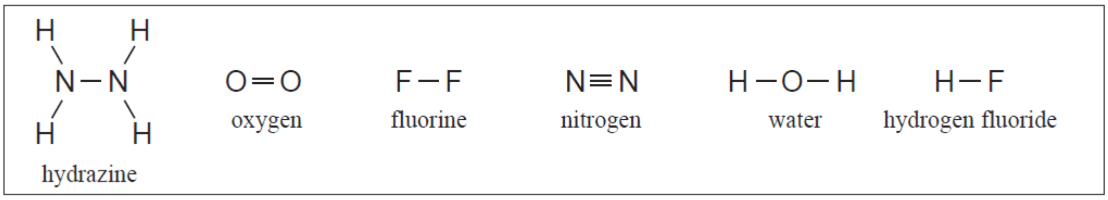
2017: Question 2c: Hydrazine, N_2H_4, is used as rocket fuel.

Use calculations to determine which of Reaction 1 or Reaction 2 releases more energy.

Reaction 1: $N_2H_{4(g)} + O_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$

Reaction 2: $N_2H_{4(g)} + 2F_{2(g)} \rightarrow N_{2(g)} + 4HF_{(g)}$

The structure of each chemical species is shown in the box below. Show your working and include appropriate units in your answer.



Bond	Average Bond enthalpy /kJ mol^{-1}	Bond	Average Bond enthalpy /kJ mol^{-1}
H–H	436	N–N	158
H–F	567	F–F	159
N–H	391	O=O	498
O–H	463	N≡N	945

Past NCEA questions Solids – Bond Enthalpy (THREE)

2018: Question 1d. Nitrogen gas, $N_{2(g)}$, reacts with hydrogen gas, $H_{2(g)}$, to produce ammonia gas, $NH_{3(g)}$, as shown by the following equation:

$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)} \quad \Delta_rH^o = -92.0 \text{ kJ mol}^{-1}$

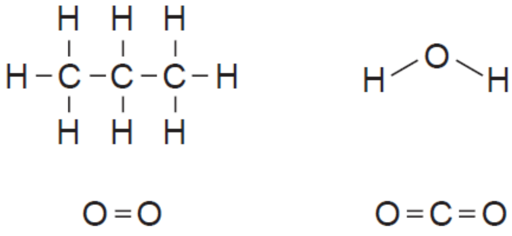
Calculate the average bond enthalpy of the N–H bond in 3, using the average bond enthalpies in the table below.

Bond	Average bond enthalpy kJ mol^{-1}
N≡N	945
H–H	436

2019: Question 2c. When propane, $C_3H_{8(g)}$, is burned, it reacts with oxygen, $O_{2(g)}$, in the air to form water, $H_2O_{(g)}$, and carbon dioxide, $CO_{2(g)}$.

$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 4H_2O_{(g)} + 3CO_{2(g)} \quad \Delta_rH = -2056 \text{ kJ mol}^{-1}$

Calculate the average bond enthalpy of the C = O bond using the data below.

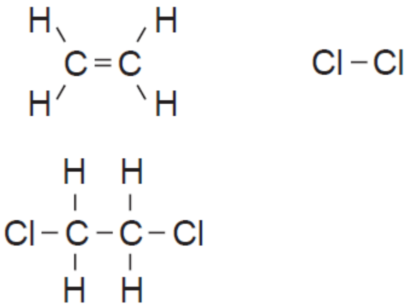


Bond	Average bond enthalpy/kJ mol^{-1}
C – C	348
C – H	413
O = O	495
O – H	463

2020: Question 3c. The chlorination of ethene can be shown by the following equation.

$C_2H_{4(g)} + Cl_{2(g)} \rightarrow C_2H_4Cl_{2(g)} \qquad \Delta rH = -148 \text{ kJ mol}^{-1}$

Calculate the bond enthalpy of the C – Cl bond using the data below.



Bond	Average bond enthalpy/kJ mol^{-1}
C – C	346
C – H	414
C = C	614
Cl – Cl	242

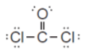
Writing Excellence answers to Molecule shapes and bond angle questions

Molecule shapes and bond angle QUESTION

Question: Carbon atoms can bond with different atoms to form many different compounds. The following table shows the Lewis structure for two molecules containing carbon as the central atom, CCl_4 and $COCl_2$. These molecules have different bond angles and shapes. Evaluate the Lewis structure of each molecule to determine why they have different bond angles and shapes.

In your answer you should include:

- The approximate bond angle in each molecule
- The shape of each molecule
- Factors that determine the shape and bond angle for each molecule.

Molecule	CCl_4	$COCl_2$
Lewis structure		

ANSWER

1. for first molecule (name) state number of regions of negative charge around the central atom (name central atom)	In each CCl_4 molecule, there are four negative electron clouds / regions around the central C atom.
2. state the Valence shell electron pair repulsion (VSEPR) theory	These regions of negative charge repel each other as far away from each other as possible around the central C atom
3. state the base arrangement of negative regions and the bond angle they form	in a tetrahedral (base) arrangement, resulting in a 109.5° bond angle
4. state the number of bonded and non-bonded regions AND the final shape of the first molecule	All of these regions of electrons are bonding, without any non-bonding regions, so the final shape of the molecule is tetrahedral.
5. for second molecule (name) state number of regions of negative charge around the central atom (name central atom)	In each $COCl_2$ molecule, there are three negative electron clouds / regions around the central C atom.
6. state the Valence shell electron pair repulsion (VSEPR) theory	These regions of negative charge repel each other as far away from each other as possible around the central C atom
7. state the base arrangement of negative regions and the bond angle they form	in a triangular / trigonal planar (base) shape, resulting in a 120° bond angle.
8. state the number of bonded and non-bonded regions AND the final shape of the second molecule	All of these regions of electrons are bonding, without any non-bonding regions, so the final shape of the molecule is trigonal planar.
9. compare differences in bond angle linked to number of regions of negative charge.	Both molecules have no non-bonding pairs but because CCl_4 has 4 regions of negative charge around the central atom compared to the 3 regions that $COCl_2$ has, then CCl_4 has a smaller bond angle of 109.5° compared to the 120° bond angle of $COCl_2$

Writing Excellence answers to Molecule Polarity questions

Molecule Polarity QUESTION

Question: The Lewis structures for two molecules are shown below.
Hydrogen cyanide, HCN, is polar, and carbon dioxide, CO_2, is nonpolar.
Both molecules are linear. Explain why the polarities of the molecules are different, even though their shapes are the same.

Molecule	H−C≡N	O=C=O
Polarity of molecule	Polar	Nonpolar

ANSWER

1. For the first molecule (name) state the types of bonds present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	In HCN, the two bonds are polar due the difference in electronegativity between H and C, and C and N.
2. link electronegativity differences to sharing of electrons for your bond	The resulting bond dipoles are differing in size as H and N have different electronegativities,
3. state the shape of your molecule and link to having the same bond dipoles AND being symmetrical or not and result in dipoles cancelling (or not)	So, despite the symmetric linear arrangement the bond dipoles do not cancel
4. link to final polarity of molecule	and HCN is overall polar.
5. For the second molecule (name) state the types of bonds present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	The C=O bond is also polar due to O being more electronegative than C giving these bonds dipoles.
6. link electronegativity differences to sharing of electrons for your bond	The resulting bond dipoles are the same on either side, as both are O=C
7. state the shape of your molecule and link to having the same bond dipoles AND being symmetrical or not and result in dipoles cancelling (or not)	But because both bonds are identical and are arranged symmetrically in a linear shape, the bond dipoles cancel
8. link to final polarity of molecule	and the molecule is non-polar overall.

NOTE: The white column is how your answer would appear on your test paper so make sure you **write out complete sentences**. The grey area is just to help you structure your answer and would not appear in the question.

Writing Excellence answers to Structure and Bonding – State questions

Structure and Bonding – State QUESTION

Question: Explain why chlorine is a gas at room temperature, but copper chloride is a solid at room temperature.

In your answer, you should refer to the particles and the forces between the particles in both substances.

(you will need to fill in the chart below correctly as part of the question and use the terms in your answer)

Substance	Type of substance	Type of particle	Attractive forces between particles
$Cl_{2\ (s)}$ chlorine	Molecular	Molecules	Weak intermolecular forces
$CuCl_{2(s)}$ copper chloride	Ionic	Ion	Ionic bonds / electrostatic attraction

ANSWER

1. For the first substance (name) state the type of solid that it is	Chlorine is a molecular substance
2. describe the structure of this type of substance using the *terms* above in the table	composed of chlorine molecules held together by weak intermolecular forces
3. explain how the bonding relates to the energy required to break bonds of your substance	The weak intermolecular forces do not require much heat energy to break, so the boiling point is low (lower than room temperature);
4. link to the observation (state at room temperature) in your question for the first substance	Therefore, chlorine is a gas at room temperature.
5. For the second substance (name) state the type of solid that it is	Copper chloride is an ionic substance.
6. describe the structure of this type of substance using the *terms* above in the table	It is composed of a lattice of positive copper ions and negative chloride ions held together by electrostatic attraction (ionic bonds) between these positive and negative ions.
7. explain how the bonding relates to the energy required to break bonds of your substance	These are strong forces; therefore they require considerable energy to disrupt them and melt the copper chloride;
8. link to the observation (state at room temperature) in your question for the first substance	Hence, copper chloride is a solid at room temperature.

Writing Excellence answers to Solids – Conductivity (Ductility) questions

Structure and Bonding – Conductivity (Ductility) QUESTION

Question: Using your knowledge of structure and bonding, explain why, although both graphite and copper are good conductors of electricity, copper is suitable for electrical wires, but graphite is not. (note two properties to discuss)
(you will need to fill in the chart below correctly as part of the question and use the terms in your answer)

Substance	Type of substance	Type of particle	Attractive forces between particles
$C_{(s)}$ Graphite	Covalent network	Atom	Covalent (and weak intermolecular forces)
$Cu_{(s)}$ copper	metal	Atom / cations and electrons	Metallic bonds / electrostatic attraction

ANSWER

1. For the first substance (name) state the type of solid that it is	Graphite is a covalent network solid
2. describe the structure of this type of substance using the *terms* above in the table	composed of layers of C atoms covalently bonded to three other C atoms. The remaining valence electron is delocalised (i.e. free to move) between layers;
3. explain how the bonding relates to the present of free moving charged particles to conduct electricity in your substance (property 1)	The delocalised electrons are able to carry an electrical charge
4. link to the observation (conductivity) in your question for the first substance	Therefore, graphite is able to conduct electricity
5. explain how the bonding relates to ductility in your substance (property 2)	In graphite, the attractive forces holding the layers together are very weak and are broken easily, so the layers easily slide over one another,
6. link to the observation (forming wires) in your question for the first substance	but the attraction is not strong enough to hold the layers together and allow it to be drawn into wires or although the layers can slide due to weak forces, if graphite was to be made into a wire the very strong covalent bonds within the layers would have to be broken. Graphite cannot form wires.
7. For the second substance (name) state the type of solid that it is	Copper is a metallic substance
8. describe the structure of this type of substance using the *terms* above in the table	composed of copper atoms packed together. Valence electrons are loosely held and are attracted to the nuclei of the neighbouring Cu atoms;i.e. the bonding is non-directional.
9. explain how the bonding relates to the present of free moving charged particles to conduct electricity in your substance (property 1)	These delocalised valence electrons are free moving and can carry a charge
10. link to the observation (conductivity) in your question for the second substance	Therefore, copper is able to conduct electricty
11. explain how the bonding relates to ductility in your substance (property 2)	In copper, the non-directional metallic bonding holds the layers together, allowing it to be stretched without breaking.
12. link to the observation (forming wires) in your question for the second substance	Therefore, Copper metal is malleable and can easily be drawn into wires since, as it is stretched out,

NOTE: The white column is how your answer would appear on your test paper so make sure you **write out complete sentences**. The grey area is just to help you structure your answer and would not appear in the question.

Writing Excellence answers to Structure and Bonding – Solubility questions

Solids – Solubility QUESTION

Question: Justify this statement in terms of the particles, structure, and bonding of these solids. You may use diagrams in your justification.
Potassium chloride is soluble in water while Silicon dioxide and copper are insoluble in water
(you will need to fill in the chart below correctly as part of the question and use the terms in your answer)

Substance	Type of substance	Type of particle	Attractive forces between particles
$KCl_{(s)}$ potassium chloride	ionic	ion	Ionic bonds / electrostatic attraction
$SiO_{2(s)}$ silicon dioxide	Covalent network	atoms	covalent
Cu(s) copper	metal	atom	Metallic bonds / electrostatic attraction

ANSWER

1. For the first substance (name) state the type of solid that it is	$KCl_{(s)}$ potassium chloride is an ionic solid.
2. describe the structure of this type of substance using the *terms* above in the table	KCl is made up of positive K^+ ions, and negative Cl^- ions, ionically bonded in a 3D lattice.
3. explain how the bonding relates to the attraction between particles in your substance and water particles	When added to water, polar water molecules form electrostatic attractions with the K^+ and Cl^- ions. The partial negative charge, δ^-, on oxygen atoms in water are attracted to the K^+ ions and the partial positive, δ^+, charges on the H's in water are attracted to the Cl^- ions,
4. link to the observation (solubility) in your question for the first substance	causing KCl to dissolve in water, and therefore be soluble
5. For the second substance (name) state the type of solid that it is	$SiO_{2(s)}$ silicon dioxide is a covalent network solid.
6. describe the structure of this type of substance using the *terms* above in the table	$SiO_{2(s)}$ is made up of atoms covalently bonded together in a 3D lattice structure.
7. explain how the bonding relates to the attraction between particles in your substance and water particles	(Covalent bonds are strong), Polar water molecules are not strong / insufficiently attracted to the Si and O atoms,
8. link to the observation (solubility) in your question for the second substance	therefore, SiO_2 is insoluble in water.
9. For the third substance (name) state the type of solid that it is	$Cu_{(s)}$ copper is a metallic solid.
10. describe the structure of this type of substance using the *terms* above in the table	$Cu_{(s)}$ is made up of an array of atoms (or ions) held together by non-directional forces between the positive nuclei of the atoms and the delocalised / free moving valence electrons.
11. explain how the bonding relates to the attraction between particles in your substance and water particles	There is no attraction between the copper atoms and the (polar) water molecules,
12. link to the observation (solubility) in your question for the third substance	therefore, Cu is insoluble in water.

NOTE: The white column is how your answer would appear on your test paper so make sure you **write out complete sentences**. The grey area is just to help you structure your answer and would not appear in the question.

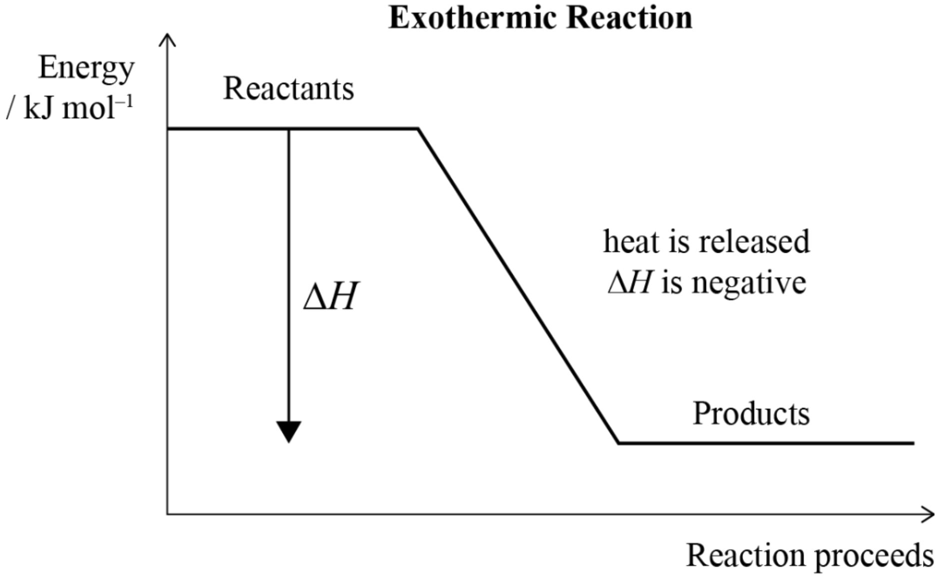
Writing Excellence answers to Enthalpy questions

Enthalpy QUESTION

Question: Pentane, C_5H_{12}, is a liquid at room temperature. It evaporates at 36.1°C in an endothermic process.
(i) Explain why the evaporation of pentane is an endothermic process.

(ii) Draw, including labels, the energy diagram for the combustion of pentane, $C_5H_{12(l)}$.
Pentane combustion: $C_5H_{12(l)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(l)}$ $\Delta_r H^\circ = -3509 \text{ kJ mol}^{-1}$
Include in your diagram the reactants, products, and change in enthalpy.

ANSWER

1. define an endothermic process	An Endothermic process is one where heat / energy has been absorbed and the enthalpy of the products is higher than the reactants
2. For the substance (name) state the type of "solid" that it is	Pentane is a molecular "solid" made up of molecules held together by weak intermolecular bonds.
3. link state change (liquid to gas) to breaking bonds requiring energy	Energy is required to change pentane from a liquid to a gas. The energy / heat is used to break weak intermolecular forces / bonds / attraction between pentane molecules. (not the strong covalent bonds between atoms in the molecule)
3. link state change to endothermic process	Because energy is needed to be absorbed by the pentane to break the bonds then this process of evapouration is endothermic.
4. draw labelled diagram including labelled axis's, reactants H_R, products H_P and change in enthalpy ΔH	

Writing Excellence answers to Thermochemical Calculations questions

Thermochemical Calculations QUESTION

Question: Hexane, C_6H_{14}, like pentane, will combust (burn) in sufficient oxygen to produce carbon dioxide gas and water.

Pentane combustion: $C_5H_{12(l)} + 8O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(l)}$ $\Delta_rH^\circ = -3509$ kJ mol^{-1}

Hexane combustion: $2C_6H_{14(l)} + 19O_{2(g)} \rightarrow 12CO_{2(g)} + 14H_2O_{(l)}$ $\Delta_rH^\circ = -8316$ kJ mol^{-1}

Justify which alkane – pentane or hexane – will produce more heat energy when 125 g of each fuel is combusted in sufficient oxygen.

$M(C_5H_{12}) = 72.0$ g mol^{-1} $M(C_6H_{14}) = 86.0$ g mol^{-1}

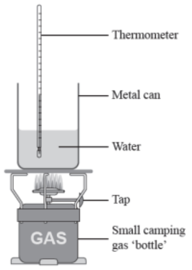
(An equation and n=m/M are required for this type of thermochemical calculation)

ANSWER	
1. Calculate the amount of energy per mol from the equation (divide Δ_rH° by number mol of substance in equation) – substance 1	1 mole of pentane releases 3509 kJ energy $\frac{1}{1} : \frac{3509}{1}$
2. calculate the number of mols of the known (K) n = m/M	n (pentane) = m / M n (pentane) = 125 g / 72.0 g mol^{-1} = 1.74 mol
3. multiply amount of energy per mol (step 1) by number of mols calculated (step 2) to get energy per mass *Answer with units plus 3sgf*	1.74 × 3509 = 6106 kJ energy released.
4. Calculate the amount of energy per mol from the equation (divide Δ_rH° by number mol of substance in equation) – substance 2	If 2 moles of hexane release 8316 kJ energy, then 1 mole of hexane releases 4158 kJ energy. $\frac{2}{2} : \frac{8316}{2}$
5. calculate the number of mols of the known (K) n = m/M	n (hexane) = m / M n (hexane) = 125 g / 86.0 g mol^{-1} = 1.45 mol
6. multiply amount of energy per mol (step 4) by number of mols calculated (step 5) to get energy per mass *Answer with units plus 3sgf*	1.45 × 4158 = 6029 kJ energy released
7. compare both substances with summary statement	Pentane releases 6106 kJ of energy and Hexane releases 4158 kJ of energy, therefore, pentane releases more energy (77.0 kJ) than hexane, per 125 g of fuel.

Writing Excellence answers to Specific Heat Capacity questions

Specicific Heat Capacity QUESTION

Question: The accepted enthalpy change for the combustion reaction of butane gas, $C_4H_{10(g)}$, is $\Delta r\ H = -5754$ kJ mol^{-1}.
Explain why calculated enthalpy is different to the accepted value.
In your answer, you should include at least TWO reasons.



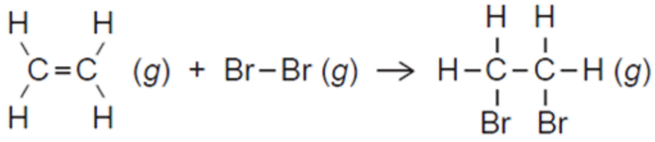
ANSWER

1. state values for both calculated data (worked out from a previous question on experimental data) and accepted data *Units, sign and 3sgf*	The value for calculated data worked out from a previous question on experimental data for the combustion reaction of butane gas is $\Delta_rH = -3370$ kJ mol^{-1} The accepted enthalpy changes for the combustion reaction of butane gas, $C_4H_{10(g)}$, is $\Delta r\ H = -5754$ kJ mol^{-1}.
2. link results from experimental data to errors in experimental design	The results from this experiment are less than the accepted results, due to errors in the experimental design. The errors could include:
3. explain error number 1.	Some energy is used to heat the metal can and the air surrounding the experiment / the experiment was not conducted in a closed system, therefore not the entire amount is heating the water
4. explain error number 2.	Incomplete combustion of butane, which releases less energy per mol of heat, to transfer to the water
5. explain error number 3.	Some butane may have escaped before being ignited and therefore not all of the fuel is combusted with the heat energy transferred
6. explain error number 4. (may need only 2 or 3 in answer)	Some energy was converted to light and sound OR The butane in the gas canister was impure OR Not carried out under standard conditions etc
7. make summary statement linking that not energy released is transferred to heating the water	Therefore, not all of the energy released by the combustion of butane was transferred to heating the water, and the experimental data was calculated to be less than the actual data (carried out under error free conditions)

Writing Excellence answers to Bond enthalpy questions

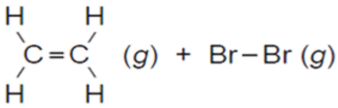
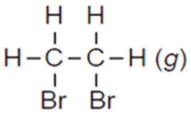
Bond enthalpy QUESTION

Question: Ethene gas, $C_2H_{4\,(g)}$, reacts with bromine gas, $Br_{2(g)}$, as shown in the equation below. Calculate the enthalpy change, $\Delta_r H°$, for the reaction between ethane and bromine gases, given the average bond enthalpies in the table below. Show your working and include appropriate units in your answers.

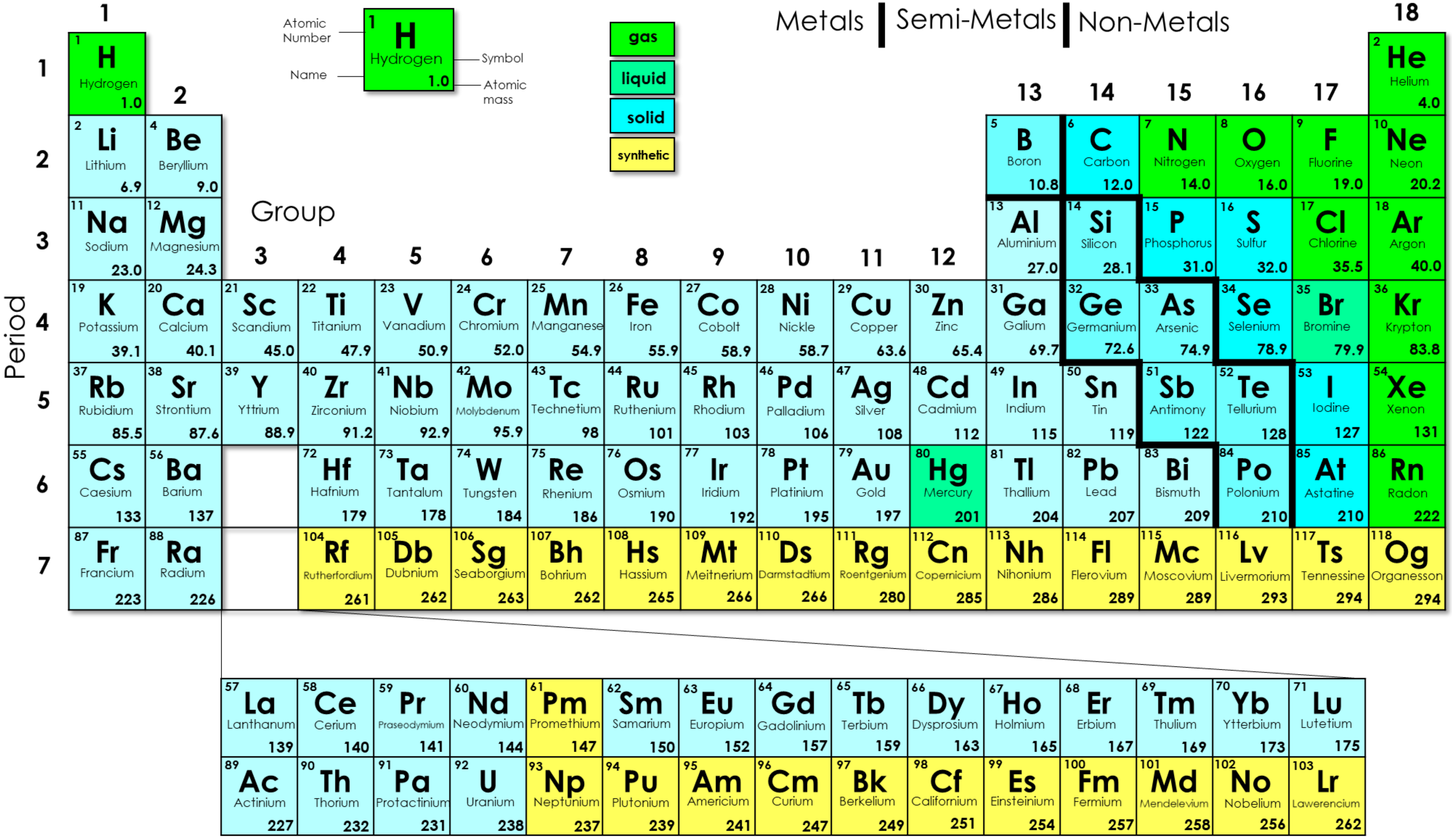


Bond	Average bond enthalpy/kJ mol^{-1}
Br–Br	193
C–C	346
C=C	614
C–Br	285
C–H	414

ANSWER

1. list types of bonds for reactants (bonds broken) and products (bonds formed) AND number of each, in a table. Watch for double or triple bonds as these are separate (Draw Lewis structures if not given)	Bonds broken (reactants) 				Bonds formed (products) 			
2. write bond type for each reactant (bonds broken) and product (bonds formed). Watch for double and triple bonds as they are different. Cross off on lewis diagram as you go	Bond type	number	enthalpy	Total enthalpy	Bond type	number	enthalpy	Total enthalpy
3. write the number of each bond type beside 4. multiply bond enthalpy by number of each bond	C=C	1	614	614	C-C	1	346	346
	C-H	4	414	1656	C-H	4	414	1656
	Br-Br	1	193	193	C-Br	2	285	570
5. total reactant bond enthalpy and total product enthalpy	Total Enthalpy (bonds broken)			2463kJ	Total enthalpy (bonds broken)			2572kJ
6. calculate enthalpy change *(sign, units and 3sgf)* $\Delta_r H^o = \Sigma$Bond energies (bonds broken) – ΣBond energies(bonds formed)	Total enthalpy = 2463 – 2572 = -109kJ mol^{-1}							
7. you may have to rearrange equation if enthalpy for a bond is required $\Delta_r H^o = \Sigma$Bond enthalpy (bonds broken) – ΣBond enthalpy (bonds formed)	Not needed							

Periodic Table of the Elements



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
2	2 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
3	11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminium 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulfur 32.0	17 **Cl** Chlorine 35.5	18 **Ar** Argon 40.0
4	19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.9	27 **Co** Cobolt 58.9	28 **Ni** Nickle 58.7	29 **Cu** Copper 63.6	30 **Zn** Zinc 65.4	31 **Ga** Galium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 78.9	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
5	37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium 98	44 **Ru** Ruthenium 101	45 **Rh** Rhodium 103	46 **Pd** Palladium 106	47 **Ag** Silver 108	48 **Cd** Cadmium 112	49 **In** Indium 115	50 **Sn** Tin 119	51 **Sb** Antimony 122	52 **Te** Tellurium 128	53 **I** Iodine 127	54 **Xe** Xenon 131
6	55 **Cs** Caesium 133	56 **Ba** Barium 137		72 **Hf** Hafnium 179	73 **Ta** Tantalum 178	74 **W** Tungsten 184	75 **Re** Rhenium 186	76 **Os** Osmium 190	77 **Ir** Iridium 192	78 **Pt** Platinium 195	79 **Au** Gold 197	80 **Hg** Mercury 201	81 **Tl** Thallium 204	82 **Pb** Lead 207	83 **Bi** Bismuth 209	84 **Po** Polonium 210	85 **At** Astatine 210	86 **Rn** Radon 222
7	87 **Fr** Francium 223	88 **Ra** Radium 226		104 **Rf** Rutherfordium 261	105 **Db** Dubnium 262	106 **Sg** Seaborgium 263	107 **Bh** Bohrium 262	108 **Hs** Hassium 265	109 **Mt** Meitnerium 266	110 **Ds** Darmstadtium 266	111 **Rg** Roentgenium 280	112 **Cn** Copernicium 285	113 **Nh** Nihonium 286	114 **Fl** Flerovium 289	115 **Mc** Moscovium 289	116 **Lv** Livermorium 293	117 **Ts** Tennessine 294	118 **Og** Organesson 294

57 **La** Lanthanum 139	58 **Ce** Cerium 140	59 **Pr** Praseodymium 141	60 **Nd** Neodymium 144	61 **Pm** Promethium 147	62 **Sm** Samarium 150	63 **Eu** Europium 152	64 **Gd** Gadolinium 157	65 **Tb** Terbium 159	66 **Dy** Dysprosium 163	67 **Ho** Holmium 165	68 **Er** Erbium 167	69 **Tm** Thulium 169	70 **Yb** Ytterbium 173	71 **Lu** Lutetium 175
89 **Ac** Actinium 227	90 **Th** Thorium 232	91 **Pa** Protactinium 231	92 **U** Uranium 238	93 **Np** Neptunium 237	94 **Pu** Plutonium 239	95 **Am** Americium 241	96 **Cm** Curium 247	97 **Bk** Berkelium 249	98 **Cf** Californium 251	99 **Es** Einsteinium 254	100 **Fm** Fermium 257	101 **Md** Mendelevium 258	102 **No** Nobelium 256	103 **Lr** Lawerencium 262