Chemistry 3.4 AS 91390

GZ Science Resources

Demonstrate understanding of thermochemical principles and the properties of particles and substances

WORKBOOK

Working to Excellence & NCEA Questions

All NCEA answers can be found on C3.4 ppt

CONTENTS

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Past NCEA questions SPD Configurations – Complete the following table

Year	Symbol	Electron Configuration		
2013	Se			
	V			
	V^{3+}			
2014	K			
	Cr			
	As			
2015	Al			
	Cu^{2+}			
	Se			
2016	Cl			
	Zn			
	Cr^{3+}			
2017		Electron Configuration	Charge	Atomic Number
	Cl		0	
			+2	20
	Mn^{2+}			
2018	V			
	Cu^+			
	Br^-			
2019	Cr			
	Fe^{3+}			
	Ge			
2020	Mn			
	As			
	Cu^{2+}			

Writing Excellence answers to Periodic Trends - Electronegativity questions

Periodic Trends – Electronegativity QUESTION

Question: Explain the factors influencing the trends in electronegativity down a group and across a period of the periodic table.

In your answer you should:
- ❑ define electronegativity
- ❑ explain the trend for electronegativity down a group AND across a period
- ❑ Use the data for the following atoms as examples

Atom	Electronegativity
Ca	1.00
O	3.44
Se	2.55

ANSWER	
1. Give the **definition** for electronegativity	
2. link **electronegativity decreasing down a group** *with* the atomic radius increasing as more energy levels are added *Give your example of energy levels for O and Se*	
3. **compare** the larger attractive force of the increasing nuclear charge down a group <u>to</u> the increasing repulsion force (shielding) of more energy levels of electrons	
4. **link** the further distance of the valence electrons down a group to the nuclear charge *with* less electrostatic attraction to other bonding electrons *Give your example of electronegativity for O and Se*	
5. link **electronegativity increasing across a period** *with* the larger attractive force of the increasing nuclear charge **AND** greater electrostatic attraction to other bonding electrons *Give your example of position across table for Ca and Se*	
6. **summarize** the two trends *with examples of data from Ca, O and Se*	

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

Writing Excellence answers to Periodic Trends – Ionisation Energy questions

Periodic Trends – Ionisation Energy QUESTION

Question: The following table shows the first ionisation energy values for elements in the third period of the periodic table. Justify the periodic trend of **first ionisation energies** shown by the data in the table above, and relate this to the expected trend in **atomic radii** across the third period.

Element	First ionisation energy / kJ mol⁻¹
Na	502
Al	584
Si	793
Ar	1 527

ANSWER

1. Give the **definition** for first ionisation energy	
2. write the **equation** showing first ionisation energy for your atom *(if needed)*	
3. state the trend of **first ionisation energy** from data in the table	
4. link **first ionisation energy increasing across a period** *with* the nuclear charge increasing and therefore attractive charge so valence electrons are held closer	
5. **compare** the larger attractive force of the increasing nuclear charge down a group <u>to</u> the same repulsion force (shielding) of the same number of energy levels of electrons	
6. **link** the increasing nuclear charge to increasing attraction and first ionisation energy	
7. state the trend of **atomic radii** across the table and **link** to increasing ionisation energy	
8. **summarize** the two trends and common influences	

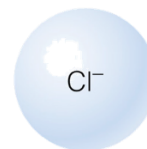## Writing Excellence answers to Periodic Trends – Atomic and Ionic Radii questions

Periodic Trends – Atomic and Ionic Radii (Anion)

Question: Explain why the radius of the Cl atom and the radius of the Cl⁻ ion are different.

	Radius (pm)
Cl atom	99
Cl⁻ ion	181

Cl

Chlorine atom
17 protons
17 electrons
99 pm radius

Cl⁻

Chloride ion
17 protons
18 electrons
181 pm radius

ANSWER

1. State the data from the table. *(if given)*	
2. explain the **gain or loss** of electrons to form the ion and link to the same nuclear charge	
3. link **increasing electron repulsion** to valence electrons (by having more electrons) moving further from the nucleus	
4. link to which particle has the **largest radii**	

Periodic Trends – Atomic and Ionic Radii (Cation)

Question: Explain the difference between the radii of the K atom and the K^+ ion.

ANSWER

|	
1. explain the **gain or loss** of electrons to form the ion and loss of energy level AND link to the same nuclear charge	
2. link **decreasing electron repulsion** to valence electrons (by having less energy levels and electrons) moving closer to the nucleus	
3. link to which particle has the **largest radii**	

Periodic trends (E1 – can often be 2E or M + E)

- ❑ Always include both NUCLEAR CHARGE (across) and ENERGY LEVELS (down) as part of your discussion
- ❑ Also include attraction (+/-) /repulsion (-/-) to explain NET attractive force
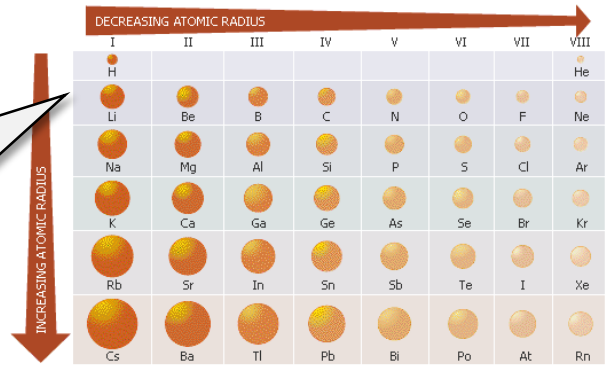
- ❑ Make sure you can write an ionisation equation (with states!)
- ❑ Use the equation to remember your definitions

quick tip

Periodic trends Summary

	Electronegativity	1st ionisation energy	Atomic radii
Across a Period	The greater the nuclear charge, the easier it is to obtain more electrons from other atoms > more p+ to pull with INCREASES	As the nuclear charge is larger it requires more energy to remove an electron as they are stronger attracted (and closer) to the nucleus INCREASES	Across a period, the energy level numbers stay the same, but proton numbers increase attraction of the valence electrons DECREASES
Down a group	The larger the number of energy levels the less net electrostatic attraction so the less ability an atom has to remove the valance electrons of another atom (and further away) DECREASES	As the energy level numbers increase the easier it is to remove electrons as the valence electrons are further from the 'pull' of the protons and more electron repulsion by other electrons in inner energy levels DECREASES	Down a group the energy levels become further away from the nucleus therefore the valence electrons repel more, less attraction to nucleus, taking up more space and increasing the size INCREASES

Past NCEA questions Periodic Trends

2013: Question 1b: Discuss the data for each of the following pairs of particles.

Atom	Electronegativity
O	3.44
Se	2.55

Past NCEA questions Periodic Trends

2013: Question 1b: Discuss the data for each of the
following pairs of particles.

Atom	First ionisation energy/kJ mol^{-1}
Li	526
Cl	1257

2013: Question 1b: Discuss the data for each of the following pairs of particles

Atom or ion	Radius/pm
Cl	99
Cl$^-$	181

2014: Question 1b: Explain the difference between the radii of the K atom and the K$^+$ ion.

2014: Question 1c: The following table shows the electron configurations of four atoms, He, B, N, and Ne. Arrange these atoms in order of increasing first ionisation energy by writing the symbol of the appropriate atom in the boxes below.

Atom	He	B	N	Ne
Electron configuration	$1s^2$	$1s^22s^22p^1$	$1s^22s^22p^3$	$1s^22s^22p^6$

2015: Question 1c: The following table shows the first ionisation energy values for elements in the third period of the periodic table. Justify the periodic trend of first ionisation energies shown by the data in the table beside, and relate this to the expected trend in atomic radii across the third period.

Element	First ionisation energy/kJ mol^{-1}
Na	502
Al	584
Si	793
Ar	1527

2015: Question 1b: Define the term electronegativity.

2015/2017: Question 1b: Define the term first ionisation energy.

2015: Question 1c: The following table shows the first ionisation energy values for elements in the third period of the periodic table. Justify the periodic trend of first ionisation energies shown by the data in the table above, and relate this to the expected trend in atomic radii across the third period.

Element	First ionisation energy/kJ mol^{-1}
Na	502
Al	584
Si	793
Ar	1527

Past NCEA questions Periodic Trends

2016: Question 1b (i) : Explain why the radius of the Cl atom and the radius of the Cl⁻ ion are different.

|	Radius (pm)
Cl atom	99
Cl⁻ ion	181

2016: Question 1b (ii): Explain the factors influencing the trends in electronegativity and first ionisation energy down a group of the periodic table.
In your answer you should:
❑ define both electronegativity and first ionisation energy
❑ explain the trend in both electronegativity and first ionisation energy down a group
❑ compare the trend in electronegativity and first ionisation energy down a group.

2017: Question 1b(ii): Explain why the electronegativity of chlorine is greater than that of phosphorus.

2017: Question 1c: The following graph shows the first ionisation energies of the Group 2 elements from Be to Ba.

First ionisation energies of Group 2 elements
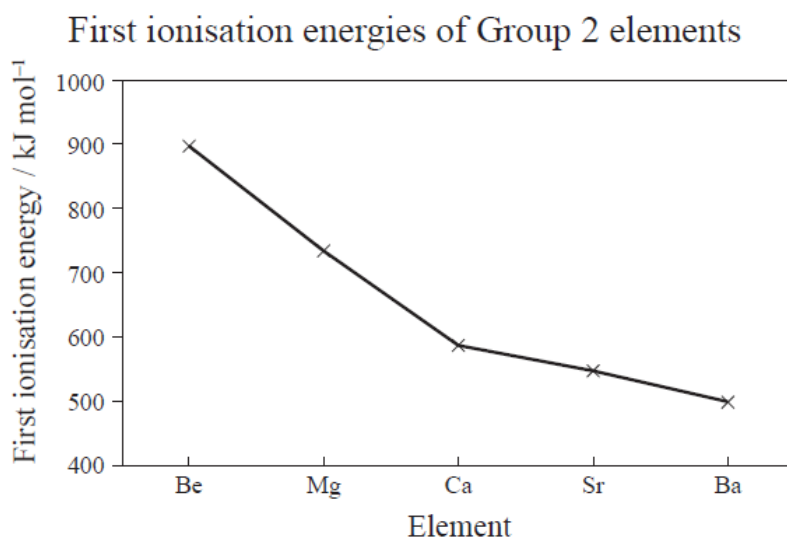
(i)   Write an equation to show the first ionisation energy for the element calcium.
(ii)   Explain the trend shown of first ionisation energies of the Group 2 elements

2018: Question 1b: Explain the factors influencing the trends in first ionisation energy and atomic radius across the second period of the periodic table.
In your answer, you should:
• describe the trends in both first ionisation energy
• explain the factors influencing the trends in first ionisation energy

Past NCEA questions Periodic Trends

2018: Question 1b: Explain the factors influencing the trends in first ionisation energy and atomic radius across the second period of the periodic table.
In your answer, you should:
• describe the trends in atomic radius across the second period
• explain the factors influencing the trends in atomic radius across the second period
• relate the trend in first ionisation energy to the trend in atomic radius.

2019: Question 1c: (i) Explain why the radii of the S atom and the S^{2-} ion are different.

2019: Question 1c: (ii) Justify the difference in electronegativities for oxygen, sodium, and sulfur.

Element	Electronegativity
Oxygen, O	3.44
Sodium, Na	0.93
Sulfur, S	2.58

2020: Q 3a: (ii) Explain why the radii of the Mg atom and the Mg^{2+} ion are different

	Radius/pm
Mg atom	160
Mg^{2+} ion	72

2020: Q 3c:(i) Write the equation to show the reaction that has an enthalpy change equal to the first ionisation energy for the element arsenic, As.

2020: Q 3c:(ii) Justify the difference in first ionisation energies for nitrogen, potassium, and arsenic.

Element	First ionisation energy/kJ mol^{-1}
Nitrogen, N	1407
Potassium, K	425
Arsenic, As	953

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Writing Excellence answers to Molecule shapes and Polarity questions

Molecule Shapes and Polarity QUESTION
Question: The Lewis diagrams and shapes for XeO_2F_2 and GeH_4 are shown below. Compare and contrast the polarities and shapes of these two molecules.

see-saw   tetrahedral
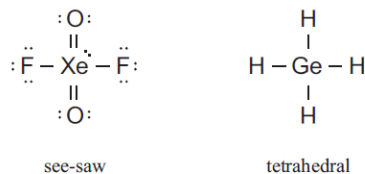
ANSWER	
1. state the **polarity** of first molecule (name)	
2. state number of regions of negative charge around the central atom (name central atom)	
3. state the **Valence shell electron pair repulsion (VSEPR) theory** and link to the base arrangement of negative regions	
4. state the number of **bonded** and **non-bonded** regions AND the final shape of the first molecule	
5. 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 the **shape** of your molecule to being symmetrical or not AND resulting in dipole moments cancelling (or not) and link to final **polarity** of molecule	
7. state the **polarity** of second molecule (name)	
8. state number of regions of negative charge around the central atom (name central atom)	
9. state the **Valence shell electron pair repulsion (VSEPR) theory** and link to the base arrangement of negative regions	
10. state the number of **bonded** and **non-bonded** regions AND the final shape of the first molecule	
11. State the **types of bonds** present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	
12. link the **shape** of your molecule to being symmetrical or not AND resulting in dipole moments cancelling (or not) and 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 shaded area is just to help you structure your answer and would not appear in the question.

Determining Molecular Shapes and Polarity

The central atom (*name*) has (*number*) regions of negative charge around the central atom.

Since regions of electrons are negatively charged, they repel each other as far apart as possible (**VSEPR**) into a (*name*) **geometry / arrangement**.

EITHER
All of the regions are bonding pairs, therefore the final shape of the molecule is also (*name*)
OR
(*number*) of the central regions is a non-bonding pair. Therefore, the overall shape formed from bonded regions is a (*name*)
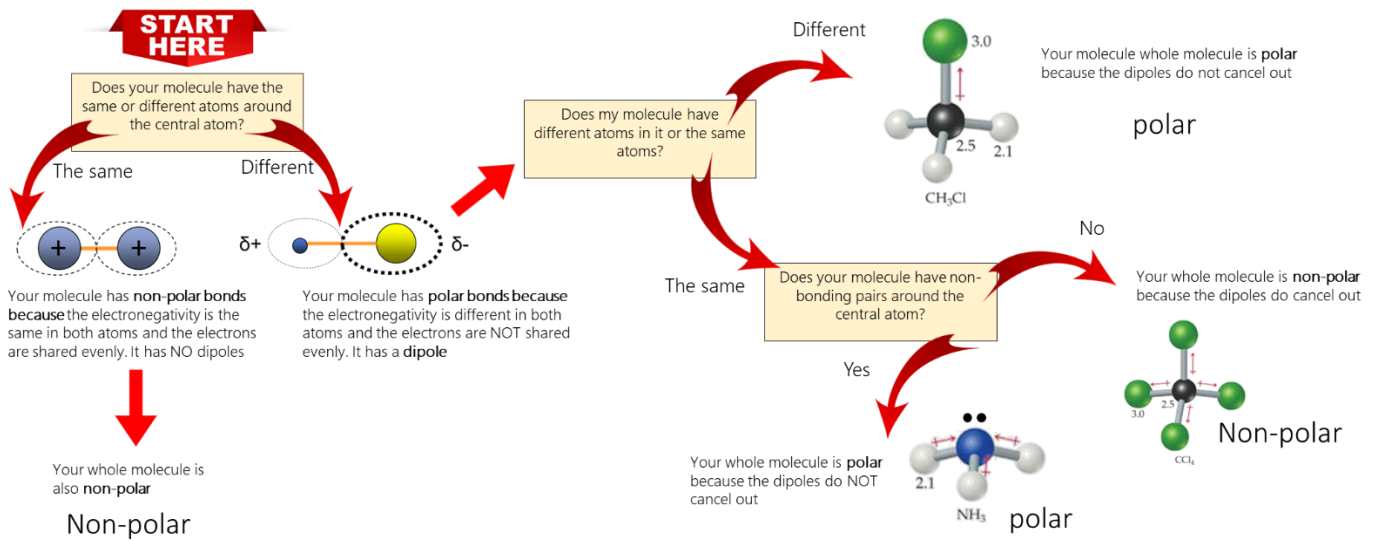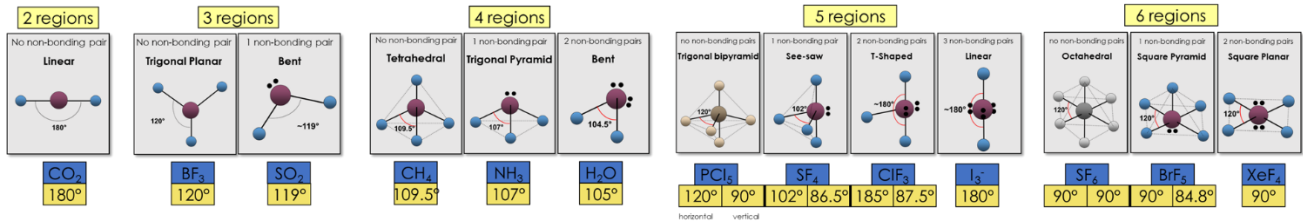
Past NCEA questions Lewis Diagrams and Molecular shape names

Year	Name of shape	Lewis diagram	Name of shape	Lewis Diagram
2013		BrF_3		PCl_6^-
2014		SiF_6^{2-}		

2015		AsF_5		SeF_6
2016		ICl_4^-		ClF_3
2017	linear	I_3^-		
2018		ArF_5		AsF_5
2019		SF_4		SF_3^-
2020		BrF_3		PCl_6^-

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and the properties of particles and substances

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Writing Excellence answers to Molecule Polarity and Solubility questions

Molecule Polarity and solubility QUESTION

Question: The Lewis diagram for SeF_6 is shown beside.
Would you expect SeF_6 to be soluble in water? Explain your
answer in terms of the shape and polarity of SeF_6.
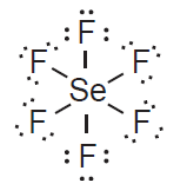
ANSWER

1. state if the molecule is soluble or not	
2. state the **polarity** of the molecule (name)	
3. state number of regions of negative charge around the central atom (name central atom)	
4. state the **Valence shell electron pair repulsion (VSEPR) theory** and link to the base arrangement of negative regions	
5. state the number of **bonded** and **non-bonded** regions <u>AND</u> the final shape of the molecule	
6. State the **types of bonds** present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	
7. link the **shape** of your molecule to being symmetrical or not <u>AND</u> resulting in dipole moments cancelling (or not) and link to final **polarity** of molecule	
8. state the polarity of water and **link** to attraction between non-polar (or polar) molecule above	
9. link the intermolecular attraction between water and your molecule as being insufficient (or sufficient) to **overcome attraction** between water molecules	
10. link to **solubility**	

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Past NCEA questions Molecule Shapes and Polarity (and solubility)

2013: Question 1c: (ii) The Lewis diagrams for SF_4 and XeF_4 are shown below.
Compare and contrast the polarities and shapes of these two molecules.

2014: Question 1d: The halogens make up Group 17 of the periodic table.
(i) The polarity of the HBr molecule is shown below.
$\delta+$ $\delta-$
H — Br
Using this as an example, indicate the polarity of the following bonds by indicating any dipoles present.
1. F — Cl   2. At — Cl
(ii) Using your knowledge of trends in the periodic table, circle the atom below that has the greater electronegativity
value.   Br   I   Justify your answer.

2015: Question 3b: The Lewis diagrams and shapes for XeO_2F_2 and GeH_4 are shown right. Compare and contrast the
polarities and shapes of these two molecules.

see-saw   tetrahedral
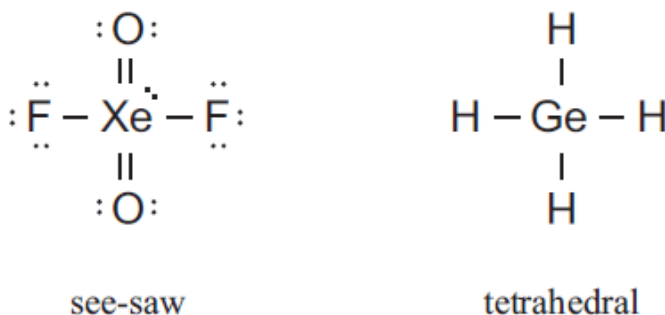
2016: Question 1c (ii): The Lewis diagram for SeF_6 is shown left. Would you expect SeF_6 to be soluble in water? Explain your
answer in terms of the shape and polarity of SeF_6.
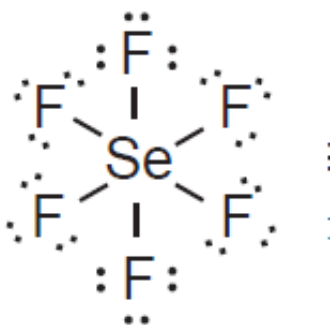
2017 Question 3c (ii): Explain why the I_3^- ion has a linear shape.

2017: Question 3c (iii): IF_5 has a square pyramidal shape. Indicate whether the molecule IF_5 is polar or non-polar. Justify
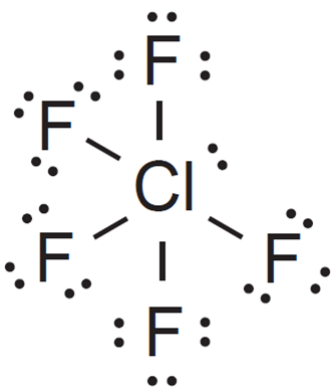your choice.

Past NCEA questions Molecule Shapes and Polarity (and solubility)

2018: Question 1c (ii): The Lewis diagram and shape for XeF_4 are given to the right. Elaborate on the shape and polarity of XeF_4.
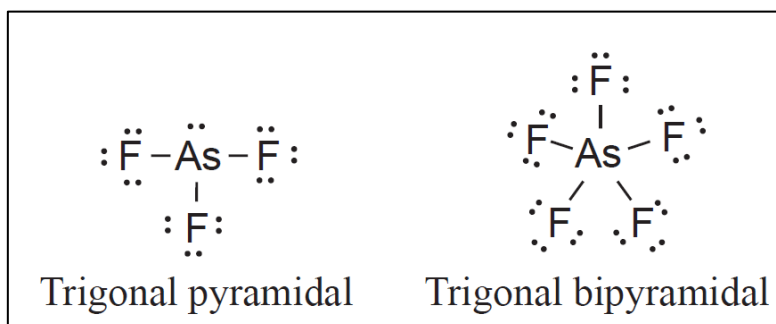

square planar
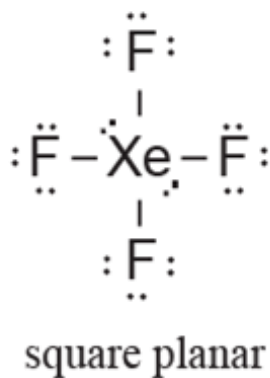
2019: Question 1d: The Lewis structure of ClF_5 is given below.

Identify and explain the shape and polarity of ClF_5.

2020: Question 3b: (ii) The Lewis structures and shape names for AsF_3 and AsF_5 are shown below. Compare and contrast the shapes and polarities of AsF_3 and AsF_5.

Trigonal pyramidal   Trigonal bipyramidal

Writing Excellence answers to Intermolecular Forces questions

Intermolecular Forces QUESTION

Question: The two molecules below have the same molecular formula ($C_5H_{12}O$) and one Decane ($C_{10}H_{22}$) has a different molecular formula but all have different boiling points.

(i) List all the forces of attraction between these molecules in each of their liquid states.

(ii) Use the information above to explain the difference in the boiling points of decane, pentan-1-ol and dimethylpropan-1-ol by comparing and contrasting the relative strengths of the attractive forces between the molecules involved.

Decane is straight chained with a boiling point of 174°C

Name	Pentan-1-ol	Dimethylpropan-1-ol
Structure	$CH_3-CH_2-CH_2-CH_2-CH_2-OH$	$CH_3-\overset{\overset{CH_3}{\vert}}{\underset{\underset{CH_3}{\vert}}{C}}-CH_2-OH$
Boiling point	138°C	113°C

ANSWER

1. List the forces of attraction in all three molecules *(some questions have a table to fill in)* ID-ID, PD-PD , HB	
2. explain the relative strengths of the forces in molecules of similar molar mass	
3 compare the type of attractive forces of **decane** to the other two molecules and link the high boiling point to the molar mass (and instantaneous dipoles)	
4. compare the **same attractive forces** for pentan-1-ol and dimethylpropan-1-ol linked to their polarity and groups attached	
5. compare the **same strength** of attractive forces for pentan-1-ol and dimethylpropan-1-ol linked to molar mass	
6. contrast the structure of pentan-1-ol and dimethylpropan-1-ol and link to how close they can pack and therefore to steric hindrance (interfere with bonding), greater surface area	
7. link closer packing (structure) to stronger instantaneous dipoles and therefore increased boiling point	
8. summarize all 3 molecules in regards to boiling point and attractive forces	

NOTE: The white column is how your answer would appear on your test paper so make sure you **write out complete sentences**. The shaded area is just to help you structure your

Non-Polar Temporary (Instantaneous) dipoles ID - ID	Polar Permanent dipoles +temporary dipoles PD – PD + ID - ID	Polar (H-O, H-N, H-F) Hydrogen Bonding (permanent dipoles) + temporary dipoles HB – HB + ID – ID
The (.........) molecular solid is non-polar and so the only intermolecular forces would be due to temporary dipole interactions. This type of intermolecular bonding is the weakest of the three so these molecular solids will have the lowest boiling point. Generally as the molar mass increases there are more electrons and more temporary dipole-dipole interactions so all things being equal, the boiling points would increase.	The (.....) molecular solid is polar and contains both Permanent dipole and temporary dipole interactions. The permanent dipole is generally the stronger force and will be the dominant force found in the molecular solid and therefore these substances tend to have a higher boiling point than the non-polar substances. The temporary dipole forces will become more significant if the molar mass of the molecule becomes greater.	The (.......) molecular solid has the highest boiling point of the three. This is because it has hydrogen bonds which are very strong intermolecular forces. The electronegativity difference between the H-.... Bond creates a very polar molecule which takes a lot of energy to break the intermolecular bond between molecules hence a high boiling point. These molecular substances also contain temporary dipoles which only become significant when the molar mass is large.

Past NCEA questions Intermolecular Forces (ONE)

2013: 3a. Use the information in the table below to compare and contrast the boiling points of hydrazine, fluoromethane, and decane in terms of the relative strengths of the attractive forces between the particles involved.

Molecule	Boiling point/ °C
Hydrazine, N_2H_4	114
Fluoromethane, CH_3F	−78.4
Decane, $C_{10}H_{22}$	174

2014: 2a. The boiling points of ammonia, NH_3, fluorine, F_2, and hydrogen chloride, HCl, are given in the table below. Complete the table to identify the attractive forces between the molecules in their liquid state.

Molecule	Boiling point/°C	Attractive forces
Ammonia, NH_3	−33	
Fluorine, F_2	−188	
Hydrogen chloride, HCl	−85	

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Past NCEA questions Intermolecular Forces (TWO)

2014: 2b. Discuss the differences between the boiling points of NH_3 and HCl, in terms of the strength of the attractive forces between the particles involved. Then describe why F_2 has the lowest boiling point.

2015: 3c. The two molecules below have the same molecular formula ($C_5H_{12}O$) but have different boiling points.

Name	Pentan-1-ol	Dimethylpropan-1-ol
Structure	$CH_3-CH_2-CH_2-CH_2-CH_2-OH$	$CH_3-\overset{\overset{\displaystyle CH_3}{\textstyle\vert}}{\underset{\underset{\displaystyle CH_3}{\textstyle\vert}}{C}}-CH_2-OH$
Boiling point	138°C	113°C

(i) List all the forces of attraction between these molecules in each of their liquid states.
(ii) Use the information above to explain the difference in the boiling points of pentan-1-ol and dimethylpropan-1-ol by comparing and contrasting the relative strengths of the attractive forces between the molecules involved.

2016: 2a. Identify all the attractive forces between particles of the following compounds in their liquid state.

Compound	$\Delta_{vap}H°$ / kJ mol^{-1}	Attractive forces
NaCl	194	
HCl	16.0	
CH_3Cl	22.0	

2016: Question 2b (i): The standard enthalpy of vaporisation, $\Delta_{vap}H°$, of sodium chloride, NaCl, hydrogen chloride, HCl, and chloromethane, CH_3Cl, are given in the table below. Explain why $\Delta_{vap}H°$(NaCl) is significantly higher than both $\Delta_{vap}H°$(HCl) and $\Delta_{vap}H°$(CH$_3$Cl).

Compound	$\Delta_{vap}H°$ / kJ mol^{-1}
NaCl	194
HCl	16.0
CH_3Cl	22.0

Question 2b:(ii) Explain why $\Delta_{vap}H°$(CH$_3$Cl) is greater than $\Delta_{vap}H°$(HCl).

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Past NCEA questions Intermolecular Forces (THREE)

2017: 2a. Use the information in the table below to compare and contrast the boiling points of the substances below.

Molecule	Boiling Point / °C	M / g mol^{-1}
Hydrazine, N_2H_4	114	32
Iodomethane, CH_3I	42.4	142
Decane, $C_{10}H_{22}$	174	142

In your answers, you should:
• list the types of intermolecular forces present for each substance
• explain the relative strength between the particles involved.
(i) Hydrazine and iodomethane. (ii) Iodomethane and decane.

2017: Question 2b: Explain why the solubility of hydrazine in water is greater than that of decane in water.

2017: 3a. Chlorine, Cl_2, bromine, Br_2, and iodine, I_2, are all halogens.
Bromine is a liquid at room temperature.
(i) Indicate the type(s) of intermolecular attractions in liquid bromine.
(ii) Explain why bromine is a liquid at room temperature, whereas chlorine is a gas.

2018: Question 2a (i): The standard enthalpy of vaporisation, $\Delta vapH°$, of methanol, propan-1-ol, and propanal, are given in the table below.
List all the forces of attraction between the molecules in their liquid state.

Question 2a (ii): The standard enthalpy of vaporisation, $\Delta vapH°$, of methanol, propan-1-ol, and propanal, are given in the table below.

Molecule	$\Delta_{vap}H°$ /kJ mol^{-1}	M /g mol^{-1}	Attractive forces
Methanol CH_3-OH	38	32	
Propan-1-ol $CH_3CH_2CH_2-OH$	47	60	
Propanal $CH_3CH_2C\overset{O}{\underset{H}{<}}$	30	58	

Compare and contrast the enthalpy of vaporisation of methanol, propan-1-ol, and propanal. Your answer should include an explanation of the relative strength of the attractive forces between the molecules

Past NCEA questions Intermolecular Forces (FOUR)

2019: Question 3a: List all the forces of attraction between the following molecules in their liquid state.

Molecule	Boiling point/ °C	Attractive forces
Ammonia, $NH_3(\ell)$	−33.3	
Ethane, $C_2H_6(\ell)$	−88.6	
Methanamine, $CH_3NH_2(\ell)$	−6.3	

Question 3b:(i) Using the data in the above table, identify the molecule that has the strongest forces of attraction between its molecules.
(ii) Justify why methanamine has a higher boiling point than ethane.
(iii) Justify why methanamine has a higher boiling point than ammonia.

2020: Question (a) (i) Identify all types of attractive forces between particles of the following substances in their liquid state.

Substance	Boiling point/ °C	Attractive forces
Bromomethane, $CH_3Br(\ell)$	3.6	
Bromine, $Br_2(\ell)$	59	
Calcium bromide, $CaBr_2(\ell)$	1815	

Question (a) With reference to the relative strength of the attractive forces between the particles in each substance, justify the following:
(ii) Calcium bromide has a higher boiling point than both bromomethane and bromine.
(iii) Bromine has a higher boiling point than bromomethane.

Writing Excellence answers to Enthalpy and State change questions

Enthalpy and State Change QUESTION
Question: The following graph shows the change in temperature over a five-minute period for a sample of ammonia, where a constant amount of heat was applied per minute. ❑ Using the graph below, justify the physical changes occurring to ammonia between points A and D, in terms of the energy of the particles and the intermolecular forces of attraction. ❑ Define $\Delta_{fus}H°(NH_3)$ and discuss why is $\Delta_{vap}H°(NH_3)$ greater than $\Delta_{fus}H°(NH_3)$?

Heating curve for ammonia

Temperature / °C

Time / mins
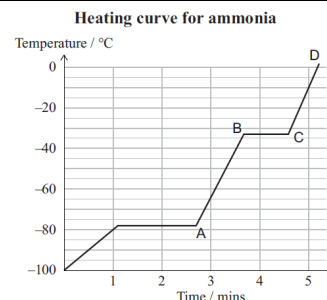
ANSWER	
1. Give the state and link **A – B** to gain in kinetic energy and temperature	
2. link **B– C** to gain in breaking bonds and state change	
3. explain why B-C does not gain in temperature	
4. Give the state and link **C– D** to gain in kinetic energy and temperature	
5. give the **definition** for $\Delta_{fus}H°(NH_3)$	
6. **compare** the $\Delta_{fus}H°(NH_3)$ linked to energy to overcome/break some bonds to $\Delta_{vap}H°(NH_3)$ to overcome/break all bonds	

Chemistry 3.4 AS 91390 Demonstrate understanding of thermochemical principles and the properties of particles and substances

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Enthalpy Changes

Standard Enthalpy of combustion ($\Delta_cH°$)
1 mol of substance combusted completely in oxygen

Standard Enthalpy of formation ($\Delta_fH°$)
1 mol of substance formed from constituent elements

Enthalpy of reaction (Δ_rH) for any given reaction

Standard conditions ($\Delta_rH°$)   1 atmosphere of pressure, 25°C

Enthalpy of fusion ($\Delta_{fus}H°$)   1 mol solid to liquid state

Enthalpy of vapourisation ($\Delta_{vap}H°$)   1 mol liquid to gas state

Enthalpy of sublimination ($\Delta_{sub}H°$)   1 mol solid to gas state

solid

$\Delta_{sub}H°$ $\Delta_{fus}H°$

gas   liquid
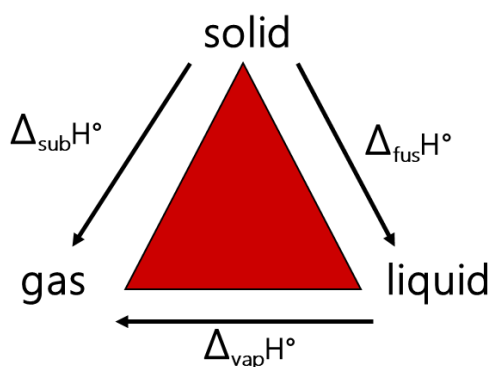
$\Delta_{vap}H°$

Past NCEA Questions Enthalpy and State change

2013: 2a: (i) Explain what is meant by the term $\Delta_{vap}H$ −($H_2O_{(\ell)}$).
(iii) Explain why the temperature of liquid water does not change when it is heated at 100°C.

2014: 2d. The following graph shows the change in temperature over a five-minute period for a sample of ammonia, where a constant amount of heat was applied per minute. Using the graph below, justify the physical changes occurring to ammonia between points A and D, in terms of the energy of the particles and the intermolecular forces of attraction.

Heating curve for ammonia

Temperature / °C

Chemistry 3.4 AS 91390 Demonstrate understanding of thermochemical principles and the properties of particles and substances

GZ Science Resources
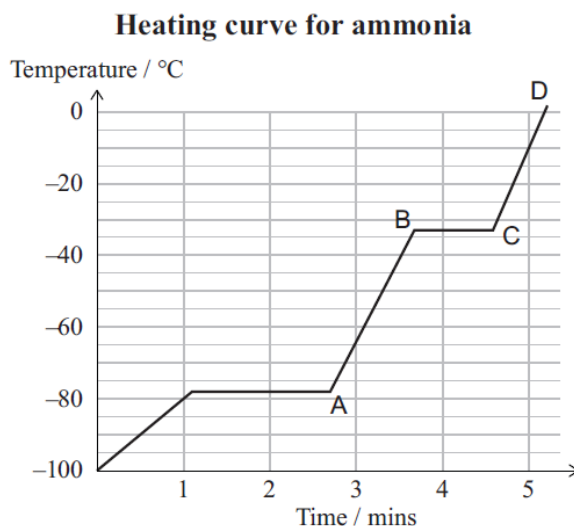
Past NCEA Questions Enthalpy and State change

2015: 2a. (i): The equation for $\Delta_f H°$ of $H_2O_{(l)}$ is: $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)}$ -286 kJ mol^{-1}
Write the equation for $\Delta_c H°$ ($H_{2(g)}$).
(ii): Using the equations above, explain why $\Delta_c H°$ (H_2) and $\Delta_f H°$(H_2O) have the same value of -286 kJ mol^{-1}.

2015: 2b. The enthalpy of formation would change if the water was formed as a gas rather than a liquid.
(i) Circle the correct phrase to complete the sentence below. $\Delta_f H°$ ($H_2O_{(g)}$) is:
less negative than / the same as / more negative than $\Delta_f H°$ ($H_2O_{(l)}$). (ii) Justify your choice.

2016: 2c. (i): Define $\Delta_{fus}H°$(NaCl).
(ii): Why is $\Delta_{vap}H°$(NaCl) greater than $\Delta_{fus}H°$(NaCl)?

2017: 3b. (i): Write an equation for the sublimation of iodine below.
(ii): Define the enthalpy of sublimation for iodine.

2018: 3a: (i) Write an equation to represent the enthalpy of fusion (melting), $\Delta_{fus}H°$, of water.
(ii) Why is the enthalpy of vaporisation of water larger than its enthalpy of fusion?

2018: 2b (ii): The equation for the combustion of propan-1-ol is:
$C_3H_7OH_{(l)} + 4.5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$
Explain how $\Delta_c H°$(propan-1-ol) would differ if water was produced as a gas rather than a liquid.
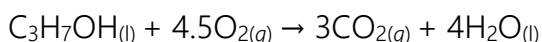
2019: Question 2a: The equation for the vaporisation of hexane is: $C_6H_{14(l)} \rightarrow C_6H_{14(g)}$

What term that best describes this process? Give a reason for your choice.

2020: Question 2a: The heating curve below shows the change in temperature as a sample of stibine, SbH_3, is supplied with a constant amount of heat over a time period of six minutes. (i) Write the equation for the reaction that has an enthalpy change equal to the standard enthalpy of vaporisation, $\Delta_{vap}H°$, of SbH_3.

Question 2a: (ii) With reference to the heating curve for stibine, explain the physical changes between points A and D. Your answer should refer to: • energy and movement of particles • intermolecular forces of attraction.

Chemistry 3.4 AS 91390 Demonstrate understanding of thermochemical principles
and the properties of particles and substances

GZ Science Resources

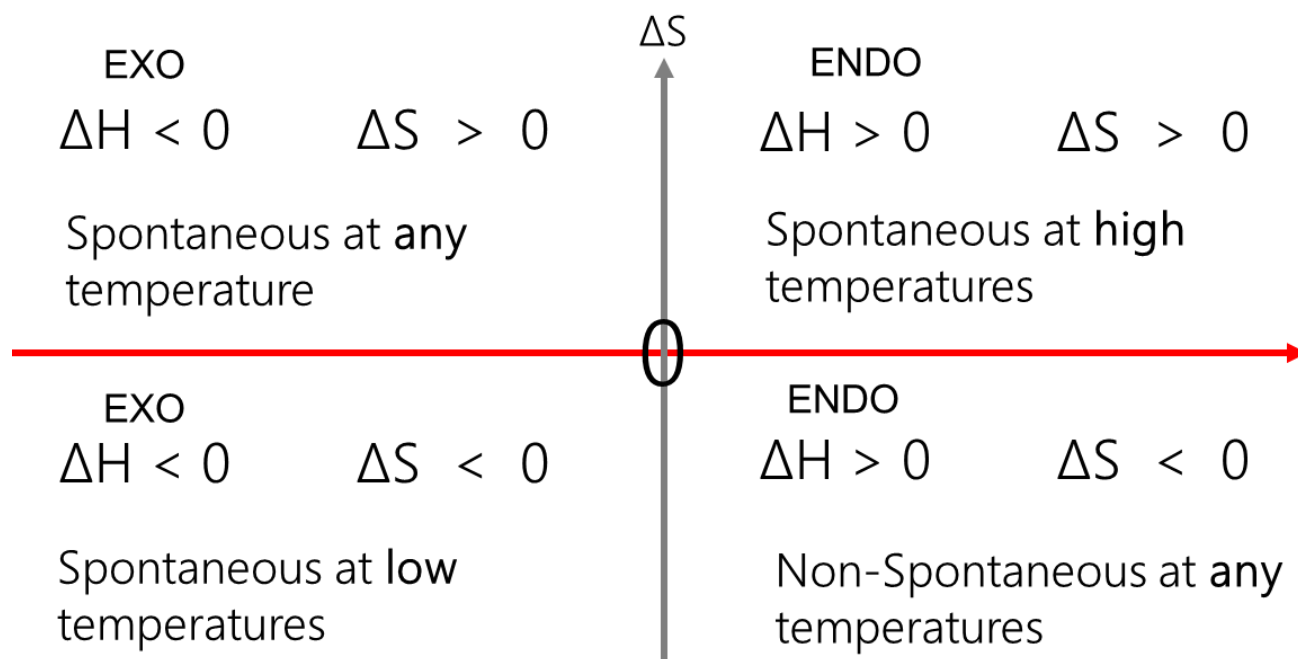## Writing Excellence answers to Entropy and Spontaneity questions

Entropy and Spontaneity QUESTION
Question: The equation for the evaporation of liquid methanol is: $CH_3OH_{(l)} \rightarrow CH_3OH_{(g)}$ The evaporation of methanol is spontaneous, despite being endothermic. ❑ Explain why this is so, in terms of the entropy change for the reaction system. ❑ Explain the entropy changes of the system and surroundings for the evaporation of methanol.

ANSWER	
1. Give the **definition** for entropy	
2. link the **increase in entropy** change for the reaction system to the state change (and increase in disorder)	
3. link the **increase in enthalpy** change for the reaction system to an endothermic reaction	
4. compare the tendency towards minimum enthalpy entropy change to tendency towards maximum entropy and therefore **spontaneity**	
5. explain whether the **enthalpy AND entropy of the surroundings** decreases or increases as the alcohol evaporates AND link to energy absorption/release	

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

ΔS

EXO

$\Delta H < 0 \qquad \Delta S > 0$

Spontaneous at **any**
temperature

ENDO

$\Delta H > 0 \qquad \Delta S > 0$

Spontaneous at **high**
temperatures

EXO

$\Delta H < 0 \qquad \Delta S < 0$

Spontaneous at **low**
temperatures

ENDO

$\Delta H > 0 \qquad \Delta S < 0$

Non-Spontaneous at **any**
temperatures

Past NCEA Questions Entropy and Spontaneity

2013: 3c. Hydrazine is often used as a rocket fuel. When liquid hydrazine undergoes combustion, it forms
nitrogen and water:
$N_2H_{4(\ell)} + O_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$ $\Delta cH°(N_2H_{4\ (\ell)}) = -624$ kJ mol^{-1}
Explain why liquid hydrazine readily burns in oxygen.
Your answer should consider both enthalpy and entropy changes.
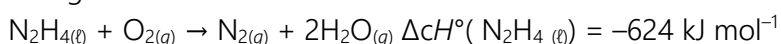
2014: 3b. Ammonium nitrate is used in 'cold packs' to relieve symptoms of a sports injury. The dissolving of the
solid crystals of ammonium nitrate (shown in the equation below) is spontaneous, despite being endothermic.
$NH_4NO_{3(s)} \rightarrow NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$
Explain why this is so, in terms of the entropy change for the reaction system.
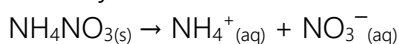
2014: 3c. Ammonium nitrate dissociates in an endothermic reaction, as shown in the equation below.
$NH_4NO_{3(s)} \rightarrow NH_{3(g)} + HNO_{3(g)}$
Below is a table outlining four statements about changes in entropy that may occur during any reaction.
Tick (P) to the left of any statement that is correct for the above reaction.

Tick (✓)	Entropy statement
	The entropy of the system increases.
	The entropy of the surroundings increases.
	The entropy of the system decreases.
	The entropy of the surroundings decreases.

Past NCEA Questions Entropy and Spontaneity

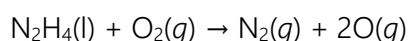2016: 2c. Why does NaCl readily dissolve in water, even though the process is slightly endothermic?
$NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$ $\Delta_rH° = +3.90$ kJ mol^{-1}
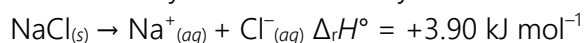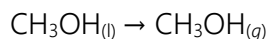
2016: 3c. The equation for the evaporation of liquid methanol is:
$CH_3OH_{(l)} \rightarrow CH_3OH_{(g)}$
Explain the entropy changes of the system and surroundings for the evaporation of methanol.

2017: 2d. The reaction for the complete combustion of hydrazine is shown in the equation below.
$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2O(g)$
This is an exothermic reaction.
Explain the entropy changes associated with this reaction.

2017: 3b. Explain why the sublimation of iodine is spontaneous, even though the enthalpy of sublimation is a positive Value

2018:
The dissolving of ammonium chloride in water is an endothermic process, but ammonium chloride readily dissolves in water.

$NH_4Cl_{(s)} \rightarrow NH_4^+_{(aq)} + Cl^-_{(aq)}$ Justify, in terms of the entropy changes of the system and the surroundings, why ammonium chloride readily dissolves in water.

2019: Question 3d: Ammonia reacts with oxygen according to the equation below.

$4NH_{3(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}$ $\Delta_rH° = -906$ kJ mol^{-1}
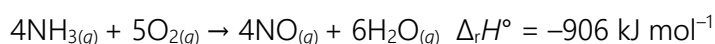
Justify, in terms of the entropy changes of the system and surroundings, why the reaction is spontaneous.

2020: Question 2c: When solid calcium, $Ca_{(s)}$, is added to a test tube of hydrochloric acid solution, $HCl_{(aq)}$, the calcium reacts vigorously. The test tube becomes hot, and bubbles of hydrogen gas, $H_{2(g)}$, are released. The reaction can be represented by the equation below:

$Ca_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_{2(g)}$

Justify, in terms of the entropy changes of the system and the surroundings, why the reaction is spontaneous.

Chemistry 3.4 AS 91390 Demonstrate understanding of thermochemical principles and the properties of particles and substances

GZ Science Resources

Writing Excellence answers to Specific Heat Capacity questions

Specific Heat Capacity QUESTION

Question: When 25.0 mL of a 1.00 mol L^{-1} hydrochloric acid solution, HCl, is added to 25.0 mL of a 1.00 mol L^{-1} ammonia solution(NH_3) a temperature rise of 6.50°C is recorded, as a neutralisation reaction occurs producing aqueous ammonium chloride and water. Assume specific heat capacity of the aqueous ammonium chloride = 4.18 J g^{-1} °C^{-1}

(i) Calculate $\Delta_r H$ ° for this neutralisation reaction. The mass of the mixture is 50.0 g.

(ii) When the $\Delta_r H$° for the neutralisation above was found experimentally in a school laboratory, the value obtained was lower than the theoretical value.

Account for the difference in values, and suggest how this difference could be minimised.

ANSWER

1. calculate the energy change *with units and sign* $q = m \, c \, \Delta T$ (Every 1mL of water can be taken as 1g due to its density)	
2. calculate the number of mols (of 1 substance) *with units and 3sgf* $n = c \cdot v$ (remember v is in L)	
3. Calculate $\Delta_r H$ ° *with units, sign and 3sgf* $\Delta_r H° = -q / n$ (remember to convert J to kJ)	
4. **link** results from experimental data to errors in experimental design	
5. **explain error number 1.** and suggest how this difference could be minimised	
6. **explain error number 2.** and suggest how this difference could be minimised	
7. **explain error number 3**. and suggest how this difference could be minimised	
8. 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 shaded area is just to help you structure your answer and would not appear in the question.

Negative if temp decrease and positive if temp increase

Mass (in g) of solid reactant

units in kJmol^{-1} +ve if endothermic and −ve if exothermic

Total mass of solution 1mL = 1g

$$n = m / н$$

$$q = m c \Delta T$$

$$\Delta_r H° = -q / n$$

$$n = c.v$$

Concentration and volume of one reactant only

Convert from J to kJ and add −ve sign
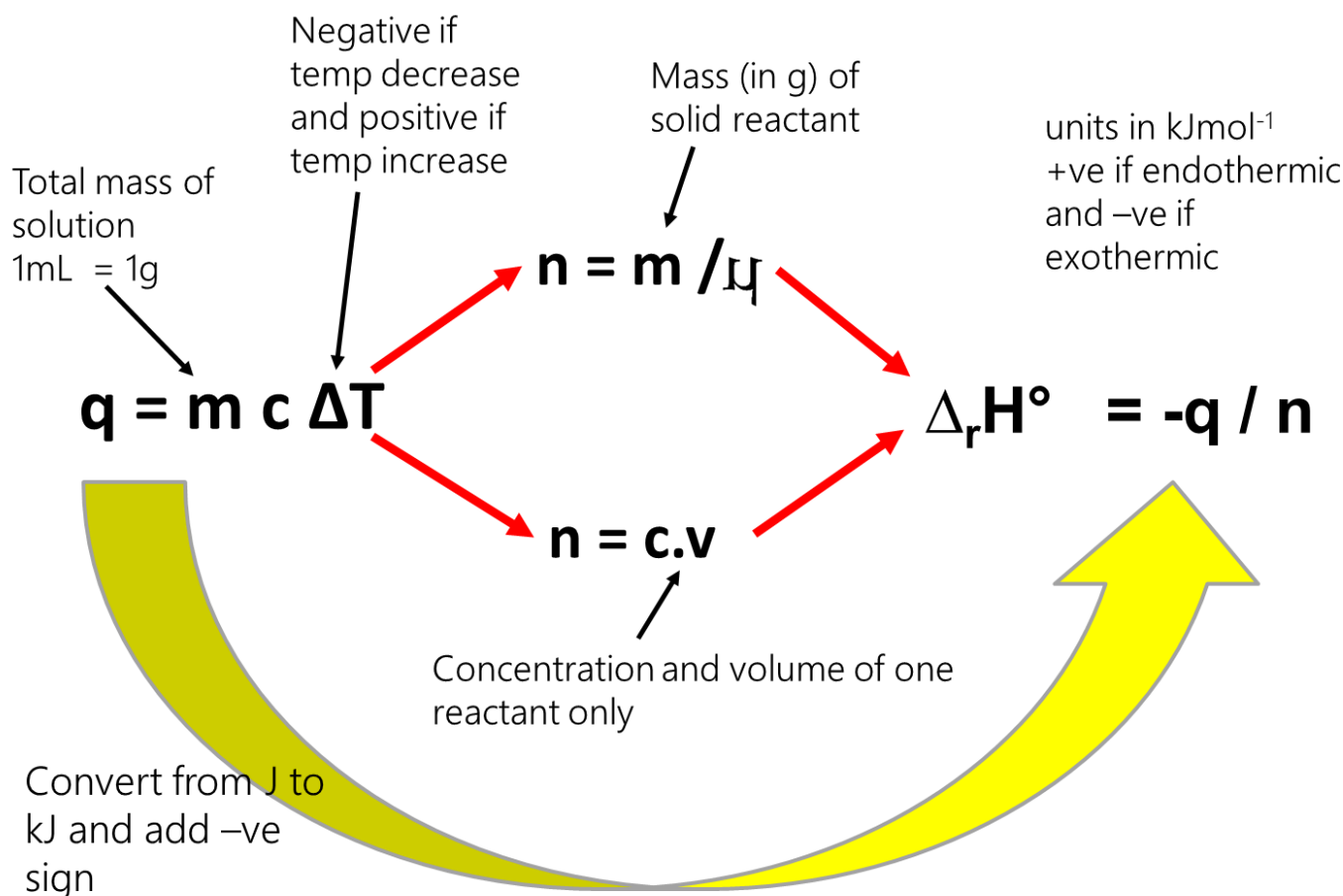
Past NCEA questions Specific Heat Capacity

2013: 2b (i). When 25.0 mL of a 1.00 mol L^{-1} hydrochloric acid solution, HCl, is added to 25.0 mL of a 1.00 mol L^{-1} ammonia solution, NH3, a temperature rise of 6.50°C is recorded, as a neutralisation reaction occurs to produce aqueous ammonium chloride and water.
Calculate $\Delta_r H$ ° for this neutralisation reaction. The mass of the mixture is 50.0 g.
Assume specific heat capacity of the aqueous ammonium chloride = 4.18 J g^{-1} °C^{-1}

2013: 2b (ii). When the Δ_r H° for the neutralisation above was found experimentally in a school laboratory, the value obtained was lower than the theoretical value.
Account for the difference in values, and suggest how this difference could be minimised.

2016: 3b(i) The enthalpy of combustion of liquid methanol, $\Delta_c H$ °(CH$_3$OH$_{(l)}$), can also be determined by burning a known mass of methanol and measuring the temperature change in a known mass of water above the burning methanol. If 2.56 g of methanol is burned, the temperature of 500 g water increases from 21.2°C to 34.5°C.
Using these results, calculate the experimental value of $\Delta_c H$ °(CH$_3$OH$_{(l)}$).

The specific heat capacity of water is 4.18 J °C^{-1} g^{-1}.
M(CH$_3$OH) = 32.0 g mol^{-1}

Past NCEA questions Specific Heat Capacity

2016: 3b (ii). Why is the experimental value obtained in the enthalpy of formation question less negative than the theoretical value determined in the specific heat capacity question?

glass beaker

water

methanol burner
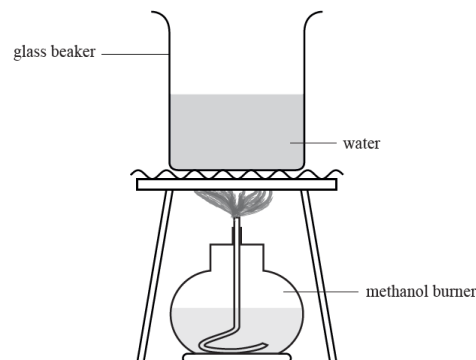
2018: 3b: When 10.6 g of ammonium chloride, NH_4Cl, is dissolved in 65.0 mL of water, the temperature of the water changes from 20.9°C to 11.5°C. The mass of the final solution is 75.6 g

Assume specific heat capacity of aqueous ammonium chloride = 4.18 J $g^{-1}°C^{-1}$

$M(NH_4Cl)$ = 53.5 g mol–1

Calculate the enthalpy change, $\Delta_rH°$, for dissolving ammonium chloride in water.

2019: Question 2c: The enthalpy of combustion of liquid hexane, $\Delta_cH(C_6H_{14(l)})$, can be determined by burning a known mass of hexane and measuring the temperature change in a known mass of water above the burning hexane.

(i) If 5.22 g of hexane is burned, the temperature of 400 g of water increases from 20.5°C to 36.7°C.

Using these results, calculate an experimental value of $\Delta_cH(C_6H_{14(l)})$.

The specific heat capacity of water is 4.18 J $g^{-1}°C^{-1}$. $M(C_6H_{14})$ = 86.0 g mol^{-1}

(ii) Explain why the experimental value obtained in part (c)(i) [=-446 kJ mol^{-1}] is less negative than the theoretical value of – 4163 kJ mol^{-1}, given in part (b).

2020: Question 1b: Solid sodium hydroxide, $NaOH_{(s)}$, readily dissolves in water:

$NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$ $\Delta_rH°$ = −44.5 kJ mol^{-1}
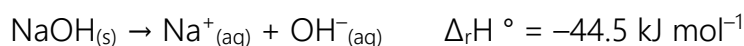
Calculate the temperature change when 1.70 g of solid sodium hydroxide is dissolved in 35.0 g of water. Assume the specific heat capacity of the sodium hydroxide solution is 4.18 J $g^{-1}°C^{-1}$.

Assume the mass of the sodium hydroxide solution is 36.7 g.

$M(NaOH)$ = 40.0 g mol^{-1}

Writing Excellence answers to Formation Enthalpy Calculations questions

Formation Enthalpy Calculations QUESTION 1. (Excellence)

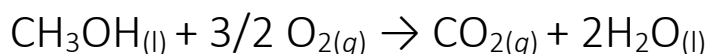**Question:** The equation for the combustion of liquid methanol is:

$CH_3OH_{(l)} + 3/2\ O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

Calculate the standard enthalpy of combustion of liquid methanol, $\Delta_cH°(CH_3OH_{(l)})$, using the information in the table below.

Compound	kJ mol^{-1}
$\Delta_cH°(C(s))$	-394
$\Delta_cH°(H_2(g))$	-286
$\Delta_fH°(CH_3OH(\ell))$	-240

ANSWER

1. Write all available formation enthalpy above each substance in the equation. (elements will be 0)	$CH_3OH_{(l)} + 3/2\ O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$
2. check to see if any of the combustion enthalpy equations could be used a formation energy equation. Write out equation. $\Delta_cH°(C) = \Delta_fH°(CO_2)$ $\Delta_cH°(H_2) = \Delta_fH°(H_2O)$	
3. Calculate $\Delta_r H °$ with units, sign and 3sgf $\Delta_rH° = \Sigma\Delta_fH°$ products $- \Sigma\Delta_fH°$ reactants	

Formation Enthalpy Calculations QUESTION 2. (Merit)

Decane is a component of petrol. Carbon dioxide and water are formed when decane burns completely in oxygen.

$C_{10}H_{22(\ell)} + 15.5O_{2(g)} \rightarrow 10CO_{2(g)} + 11H_2O_{(\ell)}$

Calculate $\Delta_cH^{-}(C_{10}H_{22\ (\ell)})$, given the following data:
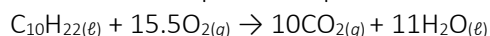
$\Delta_fH^{-}(C_{10}H_{22(\ell)}) = -250$ kJ mol^{-1}
$\Delta_fH^{-}(CO_{2(g)}) = -393$ kJ mol^{-1}
$\Delta_fH^{-}(H_2O_{(\ell)}) = -286$ kJ mol^{-1}

ANSWER
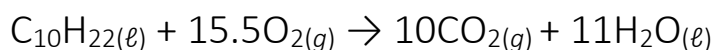
|	
1. Write all available formation enthalpy above each substance in the equation. (elements will be 0)	$C_{10}H_{22(\ell)} + 15.5O_{2(g)} \rightarrow 10CO_{2(g)} + 11H_2O_{(\ell)}$
2. Calculate $\Delta_r H °$ with units, sign and 3sgf $\Delta_rH° = \Sigma\Delta_fH°$ products $- \Sigma\Delta_fH°$ reactants	

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

Past NCEA questions Formation Enthalpy Calculations

$\Delta_r H^o = \sum n \, \Delta_f H^o{}_{products} - \sum n \, \Delta_f H^o{}_{reactants}$

2013: 3b. Decane is a component of petrol. Carbon dioxide and water are formed when decane burns completely in oxygen.

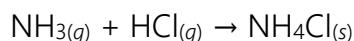$C_{10}H_{22(\ell)} + 15.5O_{2(g)} \rightarrow 10CO_{2(g)} + 11H_2O_{(\ell)}$
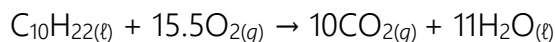
Calculate $\Delta_c H^- (C_{10}H_{22\ (\ell)})$, given the following data:

$\Delta_f H^- (C_{10}H_{22(\ell)}) = -250 \text{ kJ mol}^{-1}$

$\Delta_f H^- (CO_{2(g)}) = -393 \text{ kJ mol}^{-1}$

$\Delta_f H^- (H_2O_{(\ell)}) = -286 \text{ kJ mol}^{-1}$

2014: 2c. An equation for the reaction of ammonia gas with hydrogen chloride gas is:

$NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$

Calculate the standard enthalpy change, $\Delta_r H^\circ$, for this reaction, using the following data.

$\Delta_f H^\circ (NH_{3(g)}) = -46 \text{ kJ mol}^{-1}$

$\Delta_f H^\circ (HCl_{(g)}) = -92 \text{ kJ mol}^{-1}$

$\Delta_f H^\circ (NH_4Cl_{(s)}) = -314 \text{ kJ mol}^{-1}$

2015: 3d. The equation for the combustion of pentan-1-ol is:

$C_5H_{12}O_{(l)} + 7½ O_{2(g)} \rightarrow 5CO_{2(g)} + 6H_2O_{(l)}$
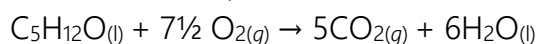
Calculate $\Delta_c H^\circ$ for pentan-1-ol, given the following data:

$\Delta_f H^\circ (C_5H_{12}O_{(l)}) = -295 \text{ kJ mol}^{-1}$

$\Delta_f H^\circ (CO_{2(g)}) = -394 \text{ kJ mol}^{-1}$

$\Delta_f H^\circ (H_2O_{(l)}) = -286 \text{ kJ mol}^{-1}$

2016: 3a. The equation for the combustion of liquid methanol is:
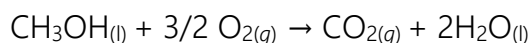
$CH_3OH_{(l)} + 3/2 \, O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$
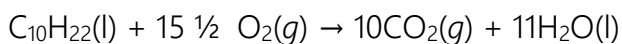
Calculate the standard enthalpy of combustion of liquid methanol, $\Delta_c H^\circ (CH_3OH_{(l)})$, using the information in the table below.

Compound	kJ mol^{-1}
$\Delta_c H^\circ (C(s))$	−394
$\Delta_c H^\circ (H_2(g))$	−286
$\Delta_f H^\circ (CH_3OH(\ell))$	−240

Past NCEA questions Formation Enthalpy Calculations

2017: 2c. Carbon dioxide and water are formed when decane burns completely in oxygen. The reaction is shown in the equation below.
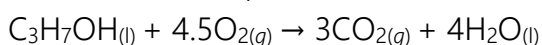
$C_{10}H_{22}(l) + 15\frac{1}{2} O_2(g) \rightarrow 10CO_2(g) + 11H_2O(l)$

Calculate the enthalpy of combustion for decane, given the following data:

$\Delta_fH° (C_{10}H_{22}(\ell)) = -301$ kJ mol^{-1}

$\Delta_cH° (C) = -393$ kJ mol^{-1}

$\Delta_cH° (H_2) = -286$ kJ mol^{-1}

2018: 2b (i): The equation for the combustion of propan-1-ol is:

$C_3H_7OH_{(l)} + 4.5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$

Calculate the standard enthalpy of combustion, $\Delta_cH°$, of propan-1-ol, given the following data:

$\Delta_f H°(C_3H_7OH_{(l)}) = -255$ kJ mol^{-1}

$\Delta_f H°(CO_{2(g)}) = -394$ kJ mol^{-1}

2019: Question 3c: Ammonia, NH_3, reacts with methane, CH_4, in the following reaction:
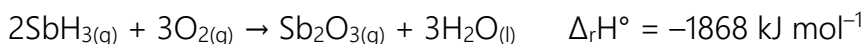
$CH_{4(g)} + NH_{3(g)} \rightarrow HCN_{(g)} + 3H_{2(g)}$
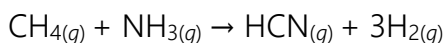
Calculate the enthalpy change, $\Delta_rH°$, for this reaction using the following data.

$\Delta_fH°(NH_{3(g)}) = -45.9$ kJ mol^{-1}

$\Delta_fH°(CH4(g)) = -74.9$ kJ mol^{-1}

$\Delta_fH°(HCN(g)) = +135$ kJ mol^{-1}

2020: Question 2b: (i) Stibine can be oxidised according to the following reaction:

$2SbH_{3(g)} + 3O_{2(g)} \rightarrow Sb_2O_{3(g)} + 3H_2O_{(l)}$ $\Delta_rH° = -1868$ kJ mol^{-1}

Calculate the standard enthalpy of formation of stibine, $\Delta_fH°(SbH_3)$.

$\Delta_fH°(Sb_2O_3) = -720$ kJ mol^{-1} $\Delta_fH°(2O) = -286$ kJ mol^{-1}

(ii) Explain how the $\Delta_rH°$ provided in (i) would differ if the water was produced as a gas rather than a liquid.

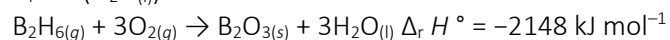$\Delta_f H°(H_2O_{(l)}) = -286$ kJ mol^{-1}

Writing Excellence answers to Hess's Law questions

Hess's Law QUESTION
Question: Calculate the $\Delta_f H°$ for $B_2H_{6(g)}$, given the following data: $\Delta_f H° (B_2O_{3(s)}) = -1255$ kJ mol^{-1} $\Delta_f H° (H_2O_{(l)}) = -286$ kJ mol^{-1} $B_2H_{6(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(l)}$ $\Delta_r H° = -2148$ kJ mol^{-1} The melting point of boron is 2300°C.

| ANSWER	
1. Write out the equation for the $\Delta_f H°$ for $B_2H_{6(g)}$ underline May need to expand it	
2. write/expand out the first equation given and the enthalpy value to right. *Check to see which substances match those in the top equation* *- may need to multiply (or divide) so multiply enthalpy* *- may need to reverse reaction so reverse sign on enthalpy*	
3. write/expand out the second equation given and the enthalpy value to right.	
4. write/expand out the third equation given and the enthalpy value to right.	
5. cancel same substances on both side of each equation -check they are the same number of mols and same state	
6. re-write the remaining substances below as an equation	
7. If they match the original equation – total the enthalpies	

NOTE: The white column is how your answer would appear on your test paper so make sure you **write out complete sentences**. The shaded area is just to help you structure your answer and would not appear in the question.
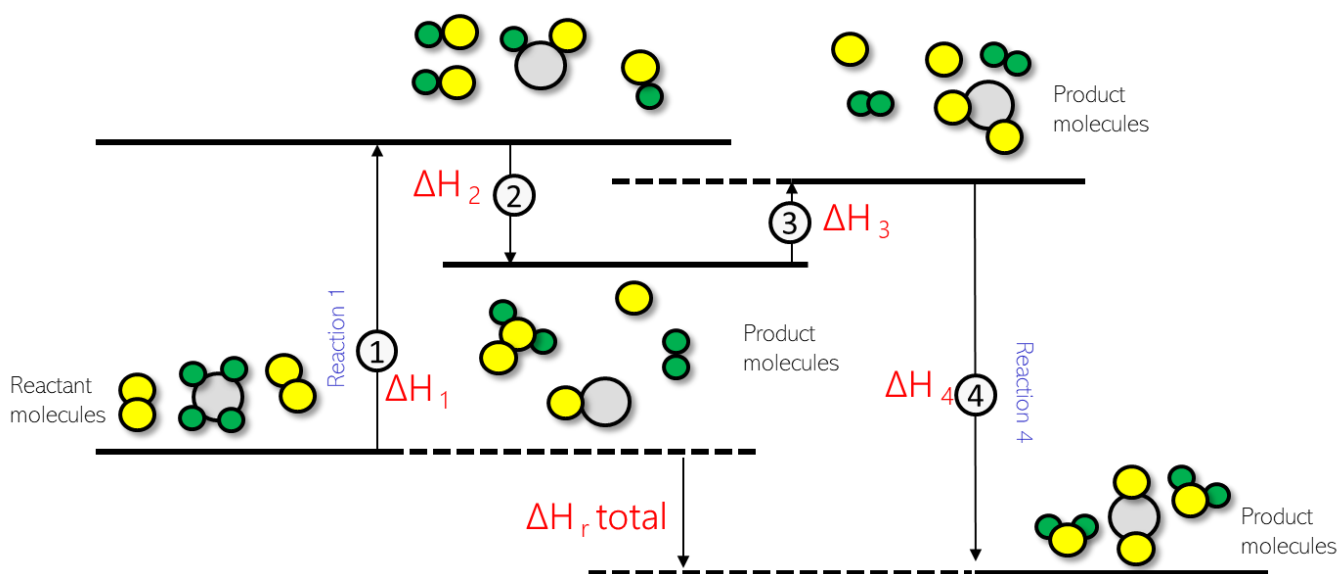
Past NCEA questions Hess's Law

2013: 3a. When gaseous hydrogen and oxygen are heated in a test tube, droplets of liquid water form on the sides of the test tube. Calculate $\Delta_f H^-(H_2O_{(\ell)})$, given the following data:

$\Delta_f H^-(H_2O_{(g)}) = -242$ kJ mol^{-1}

$\Delta_{vap}H^-(H_2O_{(\ell)}) = +44$ kJ mol^{-1}

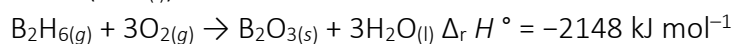**2014: 3d (i)** Calculate the standard enthalpy of formation of liquid ethanol using the information given below.

Compound	kJ mol^{-1}
$\Delta_c H^\circ (C(s))$	−394
$\Delta_f H^\circ (H_2O(\ell))$	−286
$\Delta_c H^\circ (C_2H_5OH(\ell))$	−1367

2014: 3d (ii) Discuss how the value of the enthalpy change would differ if the ethanol product formed was a gas rather than a liquid.

2015: 2c. Calculate the $\Delta_f H^\circ$ for $B_2H_{6(g)}$, given the following data:

$\Delta_f H^\circ (B_2O_{3(s)}) = -1255$ kJ mol^{-1}

$\Delta_f H^\circ (H_2O_{(l)}) = -286$ kJ mol^{-1}

$B_2H_{6(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(l)}$ $\Delta_r H^\circ = -2148$ kJ mol^{-1}

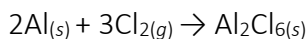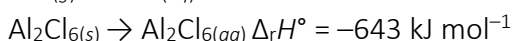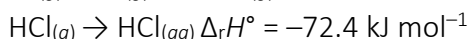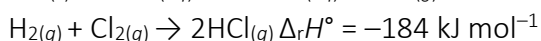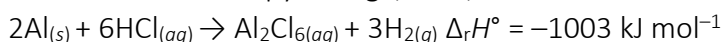The melting point of boron is 2300°C.

Past NCEA questions Hess's Law

2018: 2c: The equation for the formation of $Al_2Cl_{6(s)}$ is:

$2Al_{(s)} + 3Cl_{2(g)} \rightarrow Al_2Cl_{6(s)}$

Calculate the enthalpy change, $\Delta_r H°$, for this reaction using the following data:

$2Al_{(s)} + 6HCl_{(aq)} \rightarrow Al_2Cl_{6(aq)} + 3H_{2(g)}$ $\Delta_r H° = -1003$ kJ mol^{-1}

$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$ $\Delta_r H° = -184$ kJ mol^{-1}

$HCl_{(g)} \rightarrow HCl_{(aq)}$ $\Delta_r H° = -72.4$ kJ mol^{-1}

$Al_2Cl_{6(s)} \rightarrow Al_2Cl_{6(aq)}$ $\Delta_r H° = -643$ kJ mol^{-1}

2019: Question 2b: The equation for the formation of liquid hexane is:

$6C_{(s)} + 7H_{2(g)} \rightarrow C_6H_{14(l)}$
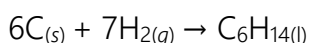
Calculate the standard enthalpy of formation for liquid hexane, $\Delta_f H°(C_6H_{14(l)})$, using the following data:

$C_6H_{14(l)} + 9.5O_{2(g)} \rightarrow 6CO_{2(g)} + 7H_2O_{(l)}$ $\Delta_c H°(C_6H_{14(l)}) = -4163$ kJ mol^{-1}

$\Delta_c H°(C_{(s)}) = -394$ kJ mol^{-1}

$\Delta_c H°(H_{2(g)}) = -286$ kJ mol^{-1}
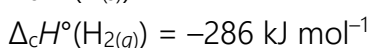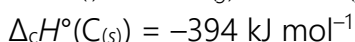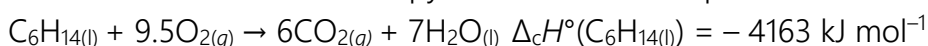
Periodic Table of the Elements

Writing Excellence answers to Periodic Trends - Electronegativity questions

Periodic Trends – Electronegativity QUESTION

Question: Explain the factors influencing the trends in electronegativity down a group and across a period of the periodic table.

In your answer you should:
- ❑ define electronegativity
- ❑ explain the trend for electronegativity down a group AND across a period
- ❑ Use the data for the following atoms as examples

Atom	Electronegativity
Ca	1.00
O	3.44
Se	2.55

ANSWER

1. Give the **definition** for electronegativity	Electronegativity is a measure of how strongly an atom attracts bonding electrons to itself. The nuclear charge of an atom attracts electrons from another bonding atom.
2. link **electronegativity decreasing down a group** *with* the atomic radius increasing as more energy levels are added *Give your example of energy levels for O and Se*	**Electronegativity decreases down a group** on the periodic table as the atomic radius increases down a group because more energy levels are added. For example O and Se are in the same group but O has 2 energy levels compared to Se with 4
3. **compare** the larger attractive force of the increasing nuclear charge down a group <u>to</u> the increasing repulsion force (shielding) of more energy levels of electrons	Although the nucleus will become increasingly positive down a group (number of protons and therefore nuclear charge increases), as more energy levels are added and shielding / repulsion from inner shells of electrons increases.
4. **link** the further distance of the valence electrons down a group to the nuclear charge *with* less electrostatic attraction to other bonding electrons *Give your example of electronegativity for O and Se*	Therefore, the bonding electrons in the valence shell will be further from the positive nucleus, resulting in a weaker electrostatic attraction between the nucleus and the bonding electrons. For example; as Se is further down a group with a more energy levels it has a electronegativity of 2.55 compared to O with fewer energy levels and a greater electronegativity value of 3.44
5. link **electronegativity increasing across a period** *with* the larger attractive force of the increasing nuclear charge **AND** greater electrostatic attraction to other bonding electrons *Give your example of position across table for Ca and Se*	**Electronegativity** increases as you move from left to right across a period. As an atoms nuclear charge increases there is a stronger pull on electrons of another atom by electrostatic attraction. Ca and Se are in the same period and therefore have the same number of energy levels but Ca has an atomic number of 20 (20 protons) compared to Se which has an atomic number of 34 (34 protons), so Se has a greater electronegativity value (2.55 compared to 1.00 of Ca)
6. **summarize** the two trends *with examples of data from Ca, O and Se*	Electronegativity increases across a period, and decreases down a group *There is a difference of nuclear charge of 26 protons between O and Se with a E difference of 0.89 but a smaller nuclear charge difference of 14 between Ca and Se and a E difference of 1.55 (as Se has a smaller radius and bonding electrons can be closer)*

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Chemistry 3.4 AS 91390 Demonstrate understanding of thermochemical principles
and the properties of particles and substances

GZ Science Resources

Writing Excellence answers to Periodic Trends – Ionisation Energy questions

Periodic Trends – Ionisation Energy QUESTION
Question: The following table shows the first ionisation energy values for elements in the third period of the periodic table. Justify the periodic trend of **first ionisation energies** shown by the data in the table above, and relate this to the expected trend in **atomic radii** across the third period.

Element	First ionisation energy / kJ mol^{-1}
Na	502
Al	584
Si	793
Ar	1 527

ANSWER	
1. Give the **definition** for first ionisation energy	First ionisation energy is the minimum energy required to **remove one mole of electrons from one mole of gaseous atom**s.
2. write the **equation** showing first ionisation energy for your atom *(if needed)*	
3. state the trend of **first ionisation energy** from data in the table	First ionisation energy increases from 502 in Na to 1527 in Ar as you move from left to right across the third period.
4. link **first ionisation energy increasing across a period** *with* the nuclear charge increasing and therefore attractive charge so valence electrons are held closer	There is an increase in the number of protons and thus the nuclear charge / attractive force of the nucleus, moving from left to right across the periodic table and so valence electrons are held closer.
5. **compare** the larger attractive force of the increasing nuclear charge down a group <u>to</u> the same repulsion force (shielding) of the same number of energy levels of electrons	As the electrons are added to the same energy level from left to right, there is no increase in repulsion between energy levels.
6. **link** the increasing nuclear charge to increasing attraction and first ionisation energy	The nuclei with a greater number of protons have a stronger electrostatic attraction for the valence electrons in the third shell, thus the energy to remove an electron is greater and the first ionisation energy increases across a period.
7. state the trend of **atomic radii** across the table and **link** to increasing ionisation energy	The larger the ionisation energy, the more strongly the valence electrons are held. Thus atomic radii across Period 3 decrease as outer electrons are held closer to the nucleus.
8. **summarize** the two trends and common influences	Both periodic trends are influenced by nuclear charge and the number of energy levels and distance to the nucleus, so the ionisation energy increases while the atomic radii decrease.

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Writing Excellence answers to Periodic Trends – Atomic and Ionic Radii questions

Periodic Trends – Atomic and Ionic Radii (Anion)

Question: Explain why the radius of the Cl atom and the radius of the Cl^- ion are different.

	Radius (pm)
Cl atom	99
Cl⁻ ion	181

Cl
Chlorine atom
17 protons
17 electrons
99 pm radius

Cl^-
Chloride ion
17 protons
18 electrons
181 pm radius

ANSWER

1. State the data from the table. *(if given)*	The chlorine atom has a radius of 99 pm and the chloride ion has a radius of 181 pm
2. explain the **gain or loss** of electrons to form the ion and link to the same nuclear charge	The Cl atom gains one electron to complete its valence shell to form the Cl^- ion, the nuclear charge remains the same.
3. link **increasing electron repulsion** to valence electrons (by having more electrons) moving further from the nucleus	The increased inter-electron repulsion in the outer energy level causes the valence electrons to move further from the nucleus,
4. link to which particle has the **largest radii**	so the Cl^- ion is larger than the Cl atom.

Periodic Trends – Atomic and Ionic Radii (Cation)

Question: Explain the difference between the radii of the K atom and the K^+ ion.

ANSWER

1. explain the **gain or loss** of electrons to form the ion and <u>loss of energy level</u> AND link to the same nuclear charge	The K atom loses an electron from the valence/outer energy level to form the K+ ion, and therefore has fewer energy levels. Both the K atom and K+ ion have the same number of protons / amount of nuclear charge.
2. link **decreasing electron repulsion** to valence electrons (by having less energy levels and electrons) moving closer to the nucleus	This results in greater attraction between the nucleus and the valence electrons, as the outer electrons are now closer to the nucleus. There is less repulsion between the remaining electrons
3. link to which particle has the **largest radii**	Therefore The K^+ ion has a smaller radius than the K atom

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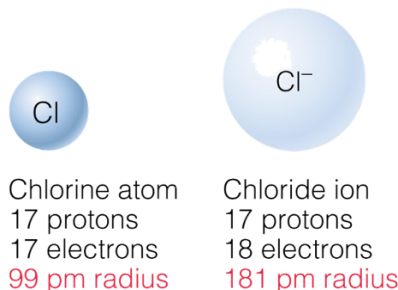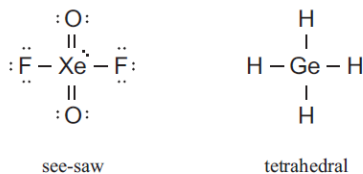
Writing Excellence answers to Molecule shapes and Polarity questions

Molecule Shapes and Polarity QUESTION	
Question: The Lewis diagrams and shapes for XeO_2F_2 and GeH_4 are shown below. Compare and contrast the polarities and shapes of these two molecules.	

$$:O:$$
$$\|$$
$$:F - Xe - F:$$
$$\|$$
$$:O:$$

see-saw

$$H$$
$$|$$
$$H - Ge - H$$
$$|$$
$$H$$

tetrahedral

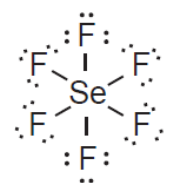| ANSWER	
1. state the **polarity** of first molecule (name)	XeO_2F_2 is polar.
2. state number of regions of negative charge around the central atom (name central atom)	It has 5 regions of electron density around the central Xe atom,
3. state the **Valence shell electron pair repulsion (VSEPR) theory** and link to the base arrangement of negative regions	These regions of negative charge repel each other as far away from each other as possible - Maximum separation for minimum repulsion to form a square pyramid arrangement.
4. state the number of **bonded** and **non-bonded** regions AND the final shape of the first molecule	However, there are 4 bonding regions and 1 non-bonding region resulting in a final **see-saw shape**
5. State the **types of bonds** present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	The Xe=O bonds are polar, due to the greater electronegativity of O, and the Xe-F bonds even more polar, due to the F atom having the highest electronegativity on the periodic table.
6. link the **shape** of your molecule to being symmetrical or not AND resulting in dipole moments cancelling (or not) and link to final **polarity** of molecule	The molecule is **not symmetrical being a see-saw shape**, and so the dipole moments cannot cancel, making the **molecule polar.**
7. state the **polarity** of second molecule (name)	GeH_4 is non-polar.
8. state number of regions of negative charge around the central atom (name central atom)	It has 4 regions of electron density around the central Ge atom
9. state the **Valence shell electron pair repulsion (VSEPR) theory** and link to the base arrangement of negative regions	These regions of negative charge repel each other as far away from each other as possible - Maximum separation for minimum repulsion to form a tetrahedral arrangement.
10. state the number of **bonded** and **non-bonded** regions AND the final shape of the first molecule	And all 4 regions are bonding regions resulting in a final **tetrahedral shape as well**
11. State the **types of bonds** present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	The Ge - H bonds are polar, due to the (Slightly) greater electronegativity of Ge.
12. link the **shape** of your molecule to being symmetrical or not AND resulting in dipole moments cancelling (or not) and link to final **polarity** of molecule	The molecule is **symmetrical being a tetrahedral shape**, and so the dipole moments do cancel, making the **molecule non-polar.**

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

Writing Excellence answers to Molecule Polarity and Solubility questions

Molecule Polarity and solubility QUESTION	
Question: The Lewis diagram for SeF_6 is shown beside. Would you expect SeF_6 to be soluble in water? Explain your answer in terms of the shape and polarity of SeF_6.	
ANSWER	
1. state if the molecule is soluble or not	SeF_6 is not soluble in water
2. state the **polarity** of the molecule (name)	As SeF_6 is a non-polar molecule
3. state number of regions of negative charge around the central atom (name central atom)	It has 6 regions of electron density around the central Xe atom,
4. state the **Valence shell electron pair repulsion (VSEPR) theory** and link to the base arrangement of negative regions	These regions of negative charge repel each other as far away from each other as possible - Maximum separation for minimum repulsion to form an Octohedral arrangement.
5. state the number of **bonded** and **non-bonded** regions AND the final shape of the molecule	And all 4 regions are bonding regions resulting in a final **Octahedral shape as well**
6. State the **types of bonds** present (name atoms) and state whether they are polar (form a dipole) or non-polar due to electronegativity.	The Se-F bonds are polar, due to the greater electronegativity of F,
7. link the **shape** of your molecule to being symmetrical or not AND resulting in dipole moments cancelling (or not) and link to final **polarity** of molecule	The molecule is **symmetrical being a Octahedral shape**, and so the dipole moments do cancel, making the **molecule non-polar.**
8. state the polarity of water and **link** to attraction between non-polar (or polar) molecule above	Water is a polar solvent. Non-polar molecules like SeF_6 are not attracted to polar molecules like water,
9. link the intermolecular attraction between water and your molecule as being insufficient (or sufficient) to **overcome attraction** between water molecules	i.e. the intermolecular attraction between the water molecules and the SeF_6 molecules is insufficient to overcome the attraction between the water molecules.
10. link to **solubility**	Therefore, SeF_6 is insoluble in water.

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Writing Excellence answers to Intermolecular Forces questions

Intermolecular Forces QUESTION
Question: The two molecules below have the same molecular formula ($C_5H_{12}O$) and one Decane ($C_{10}H_{22}$) has a different molecular formula but all have different boiling points. (i) List all the forces of attraction between these molecules in each of their liquid states. (ii) Use the information above to explain the difference in the boiling points of decane, pentan-1-ol and dimethylpropan-1-ol by comparing and contrasting the relative strengths of the attractive forces between the molecules involved. Decane is straight chained with a boiling point of 174°C

Name	Pentan-1-ol	Dimethylpropan-1-ol
Structure	$CH_3—CH_2—CH_2—CH_2—CH_2—OH$	$CH_3—\overset{\overset{CH_3}{\|}}{\underset{\underset{CH_3}{\|}{C}}}—CH_2—OH$
Boiling point	138°C	113°C

ANSWER	
1. List the forces of attraction in all three molecules *(some questions have a table to fill in)* ID-ID, PD-PD , HB	**Decane:** ID-ID (temporary dipole) only **pentan-1-ol:** ID-ID + PD-PD (permanent dipole) leading to hydrogen bonding **dimethylpropan-1-ol:** ID-ID + PD-PD leading to hydrogen bonding
2. explain the relative strengths of the forces in molecules of similar molar mass	In molecules of the same molar mass temporary dipole are the weakest attractive force, Permanent dipoles are a stronger attractive force and hydrogen bonding is stronger again (although all three are classified as weak intermolecular forces)
3 compare the type of attractive forces of **decane** to the other two molecules and link the high boiling point to the molar mass (and instantaneous dipoles)	$C_{10}H_{22}$ is a non-polar molecule. The only attractive forces between the $C_{10}H_{22}$ molecules are due to temporary dipoles. However, since $C_{10}H_{22}$ is a significantly larger molecule than pentan-1-ol and dimethylpropan-1-ol, it has more electrons / greater molar mass, so its temporary dipole attractions are even stronger than the hydrogen bonds in both of the others. As a result, $C_{10}H_{22}$ requires the most heat energy to break its intermolecular forces and therefore has the highest boiling point.
4. compare the **same attractive forces** for pentan-1-ol and dimethylpropan-1-ol linked to their polarity and groups attached	The attractive forces due to the **hydrogen bonding and permanent dipoles are similar** between the molecules in both pentan-1-ol and dimethylpropan-1-ol, as they both have one OH group, which causes the molecule to be polar and take part in hydrogen bonding.
5. compare the **same strength** of attractive forces for pentan-1-ol and dimethylpropan-1-ol linked to molar mass	The **two molecules have the same mass**, and so the same number of electrons involved in the weak temporary (instantaneous) dipoles.
6. contrast the structure of pentan-1-ol and dimethylpropan-1-ol and link to how close they can pack and therefore to steric hindrance (interfere with bonding), greater surface area	However, the **pentan-1-ol molecule has no side chains compared to** dimethylpropan-1-ol and so the main chains can get closer to each other (less steric hindrance, greater surface area),
7. link closer packing (structure) to stronger instantaneous dipoles and therefore increased boiling point	thus the temporary dipoles are stronger / greater in pentan-1-ol, than dimethylpropan-1-ol and therefore the boiling point is higher. Decane also has no side chains.
8. summarize all 3 molecules in regards to boiling point and attractive forces	So **decane has the highest boiling point** and temporary dipoles, followed by pentan-1-ol with no side chains and finally dimethylpropan-1-ol with side chains, both having ID-ID, PD-PD leading to hydrogen bonding

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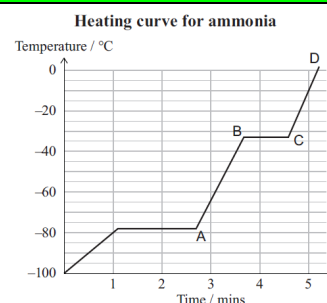
Writing Excellence answers to Enthalpy and State change questions

Enthalpy and State Change QUESTION	
Question: The following graph shows the change in temperature over a five-minute period for a sample of ammonia, where a constant amount of heat was applied per minute. ❑ Using the graph below, justify the physical changes occurring to ammonia between points A and D, in terms of the energy of the particles and the intermolecular forces of attraction. ❑ Define $\Delta_{fus}H°(NH_3)$ and discuss why is $\Delta_{vap}H°(NH_3)$ greater than $\Delta_{fus}H°(NH_3)$?	Heating curve for ammonia

ANSWER	
1. Give the state and link **A – B** to gain in kinetic energy and temperature	The state of NH_3 between A-B is a liquid. Between A and B, molecules of ammonia are gaining kinetic energy, and hence the temperature increases.
2. link **B– C** to gain in breaking bonds and state change	Between B and C, molecules of ammonia change from liquid to gas. Bonds are broken completely in the gas.
3. explain why B-C does not gain in temperature	Energy supplied is used to overcome the intermolecular forces rather than increase the kinetic energy of the particles; thus the temperature does not increase until all the NH_3 is in the gas phase.
4. Give the state and link **C– D** to gain in kinetic energy and temperature	The state of NH_3 between C-D is a gas. Between C and D, the molecules of ammonia gas are again gaining kinetic energy, and so the temperature increases.
5. give the **definition** for $\Delta_{fus}H°(NH_3)$	Enthalpy of fusion is the energy required to change 1 mol of a substance (NH_3) from a solid to a liquid.
6. **compare** the $\Delta_{fus}H°(NH_3)$ linked to energy to overcome/break some bonds to $\Delta_{vap}H°(NH_3)$ to overcome/break all bonds	Fusion of NH_3 only requires sufficient heat energy to break / overcome some of the ionic bonds, whereas vaporisation requires much more heat energy to overcome all the ionic bonds, therefore the $\Delta_{vap}H°$ of NH_3 is much greater than its $\Delta_{fus}H°$.

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Writing Excellence answers to Entropy and Spontaneity questions

Entropy and Spontaneity QUESTION	
Question: The equation for the evaporation of liquid methanol is: $CH_3OH_{(l)} \rightarrow CH_3OH_{(g)}$ The evaporation of methanol is spontaneous, despite being endothermic. ❑ Explain why this is so, in terms of the entropy change for the reaction system. ❑ Explain the entropy changes of the system and surroundings for the evaporation of methanol.	
ANSWER	
1. Give the **definition** for entropy	Entropy increases the "disorderedness" of a system.
2. link the **increase in entropy** change for the reaction system to the state change (and increase in disorder)	When solid NH_3 evapourates, there is an increase in the entropy of the system since the gas particles have greater entropy than in the liquid state, due to a more random / disordered arrangement.
3. link the **increase in enthalpy** change for the reaction system to an endothermic reaction	When solid NH_3 evapourates from a liquid to a gas the particles absorb energy from the surrounds and this is an endothermic reaction.
4. compare the tendency towards minimum enthalpy entropy change to tendency towards maximum entropy and therefore **spontaneity**	While the majority of spontaneous reactions are exothermic due to a natural tendency towards minimum enthalpy. Some endothermic reactions do occur spontaneously because of a different tendency towards maximum entropy. This endothermic reaction is **spontaneous as the** tendency towards maximum entropy **is a greater magnitude than** tendency towards minimum enthalpy
5. explain whether the **enthalpy AND entropy of the surroundings** decreases or increases as the alcohol evaporates AND link to energy absorption/release	The enthalpy of the surroundings decreases as the alcohol evaporates as energy is absorbed from the surroundings to break the intermolecular forces between methanol molecules; thus the entropy of the surroundings decreases.

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Writing Excellence answers to Specific Heat Capacity questions

Specific Heat Capacity QUESTION
Question: When 25.0 mL of a 1.00 mol L^{-1} hydrochloric acid solution, HCl, is added to 25.0 mL of a 1.00 mol L^{-1} ammonia solution(NH_3) a temperature rise of 6.50°C is recorded, as a neutralisation reaction occurs producing aqueous ammonium chloride and water. Assume specific heat capacity of the aqueous ammonium chloride = 4.18 J g^{-1} °C^{-1} (i) Calculate $\Delta_r H$ ° for this neutralisation reaction. The mass of the mixture is 50.0 g.   (ii) When the $\Delta_r H$° for the neutralisation above was found experimentally in a school laboratory, the value obtained was lower than the theoretical value.   Account for the difference in values, and suggest how this difference could be minimised.

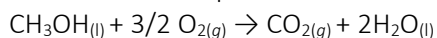| ANSWER	
1. calculate the energy change *with units, sign and 3sgf* q = m c ΔT (Every 1mL of water can be taken as 1g due to its density)	q = m c ΔT q = 50 x 4.18 x 6.5 q = 1358.5 J q = 1.3585 kJ
2. calculate the number of mols (of 1 substance) *with units and 3sgf* n = c . v (remember v is in L)	n = c . v n = 1 x 0.025 mL n = 0.025 mol
3. Calculate $\Delta_r H$ ° *with units, sign and 3sgf* $\Delta_r H°$ = -q / n (remember to convert J to kJ)	$\Delta_r H°$ = -q / n $\Delta_r H°$ = -1.3585 kJ / 0.025 mol $\Delta_r H°$ = -54.3 kJ mol^{-1}
4. **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:
5. **explain error number 1.** and suggest how this difference could be minimised	Incomplete combustion of butane, which releases less energy per mol of heat, to transfer to the water – so ensure the experiment is carried out in a well ventilated area with sufficient oxygen
6. **explain error number 2.** and suggest how this difference could be minimised	The experiment was not carried out under standard conditions -so ensure a repeat is carried out under standard conditions
7. **explain error number 3**. and suggest how this difference could be minimised	Heat lost to atmosphere / beaker / surroundings - so Insulate equipment; ensure all / as much of the energy produced as possible is collected and measured.
8. 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)

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Writing Excellence answers to Formation Enthalpy Calculations questions

Formation Enthalpy Calculations QUESTION 1. (Excellence)

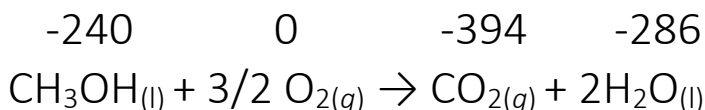**Question:** The equation for the combustion of liquid methanol is:

$CH_3OH_{(l)} + 3/2\ O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

Calculate the standard enthalpy of combustion of liquid methanol, $\Delta_cH°(CH_3OH_{(l)})$, using the information in the table below.

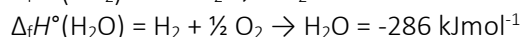| Compound	kJ mol⁻¹
$\Delta_cH°(C(s))$	−394
$\Delta_cH°(H_2(g))$	−286
$\Delta_fH°(CH_3OH(\ell))$	−240

ANSWER

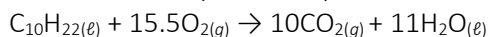|	
1. Write all available formation enthalpy above each substance in the equation. (elements will be 0)	$\begin{array}{cccc} -240 & 0 & -394 & -286 \end{array}$ $CH_3OH_{(l)} + 3/2\ O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$
2. check to see if any of the combustion enthalpy equations could be used a formation energy equation. Write out equation. $\Delta_cH°(C) = \Delta_fH°(CO_2)$ $\Delta_cH°(H_2) = \Delta_fH°(H_2O)$	$\Delta_fH°(CO_2) = C + O_2 \rightarrow CO_2 = -394\ kJmol^{-1}$ $\Delta_fH°(H_2O) = H_2 + ½\ O_2 \rightarrow H_2O = -286\ kJmol^{-1}$
3. Calculate $\Delta_r H°$ with units, sign and 3sgf $\Delta_rH° = \Sigma\Delta_fH°$ products $- \Sigma\Delta_fH°$ reactants	$\Delta_rH° = \Sigma\Delta_fH°$ products $- \Sigma\Delta_fH°$ reactants $\Delta_cH° = -394 + (2 \times -286) - (-240)$ $\Delta_cH° = -966 + 240$ **$\Delta_cH° = -726\ kJ\ mol^{-1}$** ($H_2O$ is 2 mol so x 2)

Formation Enthalpy Calculations QUESTION 2. (Merit)

Decane is a component of petrol. Carbon dioxide and water are formed when decane burns completely in oxygen.

$C_{10}H_{22(\ell)} + 15.5O_{2(g)} \rightarrow 10CO_{2(g)} + 11H_2O_{(\ell)}$

Calculate $\Delta_cH\ -(C_{10}H_{22\ (\ell)})$, given the following data:

$\Delta_fH\ -(C_{10}H_{22(\ell)}) = -250\ kJ\ mol^{-1}$

$\Delta_fH\ -(CO_{2(g)}) = -393\ kJ\ mol^{-1}$

$\Delta_fH\ -(H_2O_{(\ell)}) = -286\ kJ\ mol^{-1}$

ANSWER
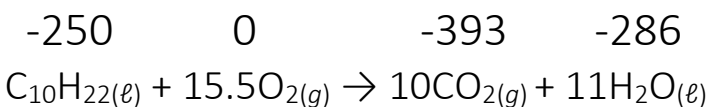
1. Write all available formation enthalpy above each substance in the equation. (elements will be 0)	$\begin{array}{cccc} -250 & 0 & -393 & -286 \end{array}$ $C_{10}H_{22(\ell)} + 15.5O_{2(g)} \rightarrow 10CO_{2(g)} + 11H_2O_{(\ell)}$
2. Calculate $\Delta_r H°$ with units, sign and 3sgf $\Delta_rH° = \Sigma\Delta_fH°$ products $- \Sigma\Delta_fH°$ reactants	$\Delta_rH° = \Sigma\Delta_fH°$ products $- \Sigma\Delta_fH°$ reactants $\Delta_rH° = [(10 \times -393) + (11 \times -286)] - (-250)$ $\Delta_rH° = -6\ 826\ kJ\ mol^{-1}$ or $-6\ 830\ kJ\ mol^{-1}$ 3sgf

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Writing Excellence answers to Hess's Law questions

Hess's Law QUESTION
Question: Calculate the $\Delta_f H°$ for $B_2H_{6(g)}$, given the following data: $\Delta_f H° (B_2O_{3(s)}) = -1255$ kJ mol^{-1} $\Delta_f H° (H_2O_{(l)}) = -286$ kJ mol^{-1} $B_2H_{6(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(l)}$ $\Delta_r H° = -2148$ kJ mol^{-1} The melting point of boron is 2300°C.

ANSWER	
1. Write out the equation for the $\Delta_f H°$ for $B_2H_{6(g)}$ underline May need to expand it	$2B_{(s)} + 3H_{2(g)} \rightarrow B_2H_{6(g)}$
2. write/expand out the first equation given and the enthalpy value to right. *Check to see which substances match those in the top equation* *- may need to multiply (or divide) so multiply enthalpy* *- may need to reverse reaction so reverse sign on enthalpy*	$\Delta_f H° (B_2O_{3(s)}) = -1255$ kJ mol^{-1} $2B_{(s)} + 1½O_{2(g)} \rightarrow B_2O_{3(s)}$ $= -1255$ kJ mol^{-1}
3. write/expand out the second equation given and the enthalpy value to right.	$\Delta_f H° (H_2O_{(l)}) = -286$ kJ mol^{-1} $H_{2(g)} + ½O_{2(g)} \rightarrow H_2O_{(l)}$ $= -286$ kJ mol^{-1} $3H_{2(g)} + 1½O_{2(g)} \rightarrow 3H_2O_{(l)}$ $= -858$ kJ mol^{-1}
4. write/expand out the third equation given and the enthalpy value to right.	$B_2H_{6(g)} + 3O_{2(g)} \rightarrow B_2O_{3(s)} + 3H_2O_{(l)}$ $\Delta_r H° = -2148$ kJ mol^{-1} $3H_2O_{(l)} + B_2O_{3(s)} \rightarrow B_2H_{6(g)} + 3O_{2(g)}$ $= +2148$ kJ mol^{-1}
5. cancel same substances on both side of each equation -check they are the same number of mols and same state	
6. re-write the remaining substances below as an equation	$2B_{(s)} + 3H_{2(g)} \rightarrow B_2H_{6(g)}$
7. If they match the original equation – total the enthalpies	$\Delta_f H° B_2H_{6(g)}, = -1255$ kJ mol^{-1} $+$ -858 kJ mol^{-1} $+$ $+2148$ kJ mol^{-1} $\Delta_f H° B_2H_{6(g)}, = +35$ kJ mol^{-1}

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