

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

WORKBOOK

Working to Excellence & NCEA Questions



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All NCEA answers
can be found on
C3.4 ppt





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 to 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.



Past NCEA questions Periodic Trends – Electronegativity

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

Atom	Electronegativity
O	3.44
Se	2.55

2015: Question 1b: Define the term electronegativity.

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.



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 to 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



Past NCEA questions Periodic Trends – Ionisation Energy

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

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	$1s^2$	$1s^2 2s^2 2p^1$	$1s^2 2s^2 2p^3$	$1s^2 2s^2 2p^6$

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

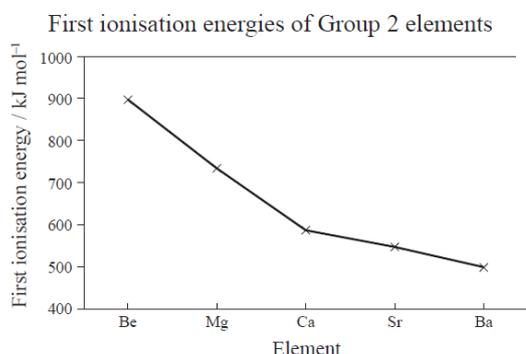
2015: Question 1c: The following table shows the first ionisation energy values for elements in the third period of the periodic table. Justify the periodic trend of first ionisation energies shown by the data in the table beside, and relate this to the expected trend in atomic radii across the third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

Element	First ionisation energy/kJ mol ⁻¹
Na	502
Al	584
Si	793
Ar	1527

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



- (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



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



Chlorine atom
17 protons
17 electrons
99 pm radius



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**

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 Periodic Trends – Atomic and Ionic Radii

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.

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	1 527

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

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:

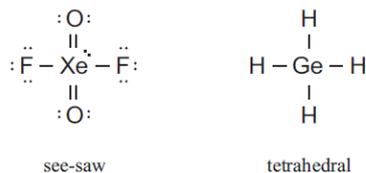
- describe the trends in atomic radius across the second period
- explain the factors influencing the trends in atomic radius across the second period
- relate the trend in first ionisation energy to the trend in atomic radius.



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.



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 <u>AND</u> 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 <u>AND</u> 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 <u>AND</u> 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 <u>AND</u> 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.



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



Past NCEA questions Molecule Shapes and Polarity (and solubility)

2013: Question 1c: (ii) The Lewis diagrams for SF₄ and XeF₄ 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.

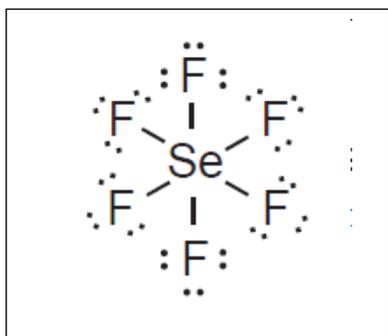
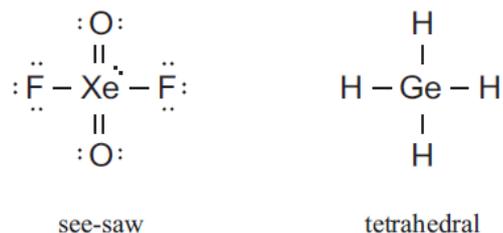


Using this as an example, indicate the polarity of the following bonds by indicating any dipoles present.



(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.

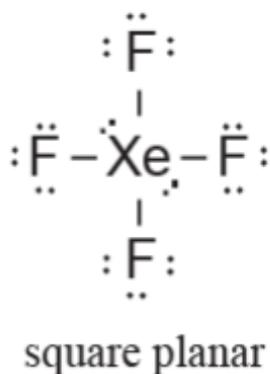
2015: Question 3b: The Lewis diagrams and shapes for XeO₂F₂ and GeH₄ are shown right. Compare and contrast the polarities and shapes of these two molecules.



2016: Question 1c (ii): The Lewis diagram for SeF₆ is shown left. Would you expect SeF₆ to be soluble in water? Explain your answer in terms of the shape and polarity of SeF₆.

2017 Question 3c (ii): Explain why the I³⁻ ion has a linear shape.

2017: Question 3c (iii): IF₅ has a square pyramidal shape. Indicate whether the molecule IF₅ is polar or non-polar. Justify your choice.



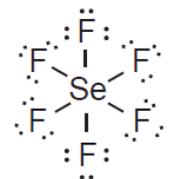
2018: Question 1c (ii): The Lewis diagram and shape for XeF₄ are given to the right. Elaborate on the shape and polarity of XeF₄.



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	

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 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	$\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{OH}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{CH}_2 - \text{OH} \\ \\ \text{CH}_3 \end{array}$
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



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 ₂ H ₄	114
Fluoromethane, CH ₃ F	-78.4
Decane, C ₁₀ H ₂₂	174

2014: 2a. The boiling points of ammonia, NH₃, fluorine, F₂, 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	

2014: 2b. Discuss the differences between the boiling points of NH₃ and HCl, in terms of the strength of the attractive forces between the particles involved. Then describe why F₂ has the lowest boiling point.

2015: 3c. The two molecules below have the same molecular formula (C₅H₁₂O) but have different boiling points.

Name	Pentan-1-ol	Dimethylpropan-1-ol
Structure	CH ₃ -CH ₂ -CH ₂ -CH ₂ -CH ₂ -OH	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3-\text{C}-\text{CH}_2-\text{OH} \\ \\ \text{CH}_3 \end{array}$
Boiling point	138°C	113°C

- List all the forces of attraction between these molecules in each of their liquid states.
- 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	$\Delta_{\text{vap}}H^\circ / \text{kJ mol}^{-1}$	Attractive forces
NaCl	194	
HCl	16.0	
CH ₃ Cl	22.0	



Past NCEA questions Intermolecular Forces (TWO)

2016: Question 2b (i) : The standard enthalpy of vaporisation, $\Delta_{\text{vap}}H^\circ$, of sodium chloride, NaCl, hydrogen chloride, HCl, and chloromethane, CH₃Cl, are given in the table below. Explain why $\Delta_{\text{vap}}H^\circ(\text{NaCl})$ is significantly higher than both $\Delta_{\text{vap}}H^\circ(\text{HCl})$ and $\Delta_{\text{vap}}H^\circ(\text{CH}_3\text{Cl})$.

Compound	$\Delta_{\text{vap}}H^\circ / \text{kJ mol}^{-1}$
NaCl	194
HCl	16.0
CH ₃ Cl	22.0

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

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

Molecule	Boiling Point / °C	$M / \text{g mol}^{-1}$
Hydrazine, N ₂ H ₄	114	32
Iodomethane, CH ₃ I	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, Cl₂, bromine, Br₂, and iodine, I₂, 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, $\Delta_{\text{vap}}H^\circ$, 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.

Molecule	$\Delta_{\text{vap}}H^\circ / \text{kJ mol}^{-1}$	$M / \text{g mol}^{-1}$	Attractive forces
Methanol CH ₃ -OH	38	32	
Propan-1-ol CH ₃ CH ₂ CH ₂ -OH	47	60	
Propanal CH ₃ CH ₂ C(=O)H	30	58	

Question 2a (ii): The standard enthalpy of vaporisation, $\Delta_{\text{vap}}H^\circ$, of methanol, propan-1-ol, and propanal, are given in the table below.

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.



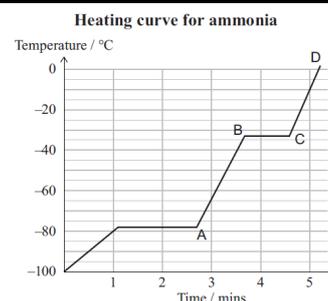
Writing Excellence answers to Enthalpy and State change questions

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 $\Delta_{\text{fus}}H^\circ(\text{NH}_3)$ and discuss why is $\Delta_{\text{vap}}H^\circ(\text{NH}_3)$ greater than $\Delta_{\text{fus}}H^\circ(\text{NH}_3)$?



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 $\Delta_{\text{fus}}H^\circ(\text{NH}_3)$	
6. compare the $\Delta_{\text{fus}}H^\circ(\text{NH}_3)$ linked to energy to overcome/break some bonds to $\Delta_{\text{vap}}H^\circ(\text{NH}_3)$ to overcome/break all bonds	

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.

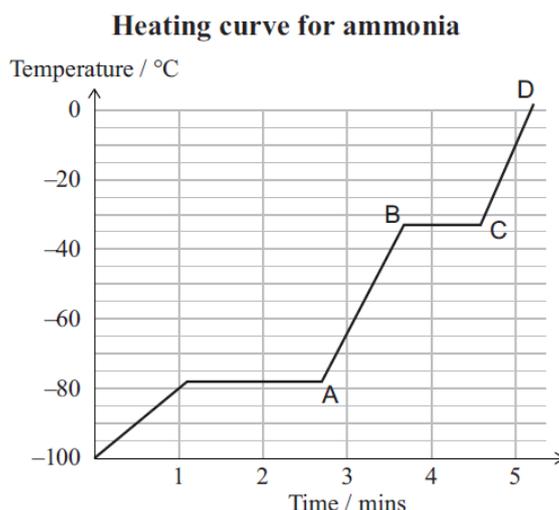


Past NCEA questions Enthalpy and State Change

2013: 2a. : (i) Explain what is meant by the term $\Delta_{\text{vap}}H^\circ(\text{H}_2\text{O}(\text{l}))$.

(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.



2015: 2a. (i): The equation for $\Delta_f H^\circ$ of $\text{H}_2\text{O}(\text{l})$ is: $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) - 286 \text{ kJ mol}^{-1}$

Write the equation for $\Delta_c H^\circ$ ($\text{H}_2(\text{g})$).

(ii) : Using the equations above, explain why $\Delta_c H^\circ$ (H_2) and $\Delta_f H^\circ$ (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. $\Delta_f H^\circ$ ($\text{H}_2\text{O}(\text{g})$) is:

less negative than / the same as / more negative than $\Delta_f H^\circ$ ($\text{H}_2\text{O}(\text{l})$).

(ii) Justify your choice.

2016: 2c. (i) : Define $\Delta_{\text{fus}}H^\circ(\text{NaCl})$.

(ii) : Why is $\Delta_{\text{vap}}H^\circ(\text{NaCl})$ greater than $\Delta_{\text{fus}}H^\circ(\text{NaCl})$?

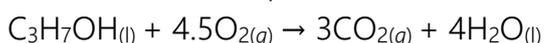
2017: 3b. (i): Write an equation for the sublimation of iodine below.

(ii) : Define the enthalpy of sublimation for iodine.

2018: 3a: (i) Write an equation to represent the enthalpy of fusion (melting), $\Delta_{\text{fus}}H^\circ$, 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:



Explain how $\Delta_c H^\circ$ (propan-1-ol) would differ if water was produced as a gas rather than a liquid.



Writing Excellence answers to Entropy and Spontaneity questions

Entropy and Spontaneity QUESTION

Question: The equation for the evaporation of liquid methanol is: $\text{CH}_3\text{OH}_{(l)} \rightarrow \text{CH}_3\text{OH}_{(g)}$
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

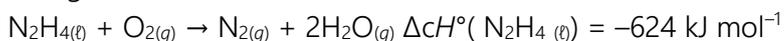
1. Give the definition for entropy	
2. link the increase in entropy change for the reaction system to the state change (and increase in disorder)	
3. link the increase in enthalpy change for the reaction system to an endothermic reaction	
4. compare the tendency towards minimum enthalpy entropy change 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.



Writing Excellence answers to Entropy and Spontaneity questions

2013: 3c. Hydrazine is often used as a rocket fuel. When liquid hydrazine undergoes combustion, it forms nitrogen and water:



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.



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.

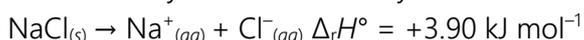


Below is a table outlining four statements about changes in entropy that may occur during any reaction.

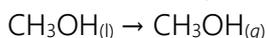
Tick (P) to the left of any statement that is correct for the above reaction.

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.

2016: 2c. Why does NaCl readily dissolve in water, even though the process is slightly endothermic?

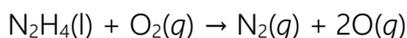


2016: 3c. The equation for the evaporation of liquid methanol is:



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.



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: 3c: The dissolving of ammonium chloride in water is an endothermic process, but ammonium chloride readily dissolves in water.

$\text{NH}_4\text{Cl}(\text{s}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{Cl}^-(\text{aq})$ Justify, in terms of the entropy changes of the system and the surroundings, why ammonium chloride readily dissolves in water.



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(NH₃) 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 $\Delta_r H^\circ$ for this neutralisation reaction. The mass of the mixture is 50.0 g.

(ii) When the $\Delta_r H^\circ$ 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 $\Delta_r H^\circ$ *with units, sign and 3sgf*

$$\Delta_r H^\circ = -q / n$$

(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.



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 $\Delta_r H^\circ$ 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 $\Delta_r H^\circ$ for the neutralisation above was found experimentally in a school laboratory, the value obtained was lower than the theoretical value.

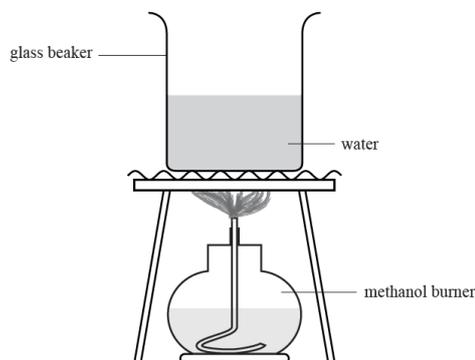
Account for the difference in values, and suggest how this difference could be minimised.

2016: 3b(i) The enthalpy of combustion of liquid methanol, $\Delta_c H^\circ(\text{CH}_3\text{OH}_{(l)})$, 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 $\Delta_c H^\circ(\text{CH}_3\text{OH}_{(l)})$.

The specific heat capacity of water is 4.18 J °C⁻¹ g⁻¹.

$M(\text{CH}_3\text{OH}) = 32.0 \text{ g mol}^{-1}$



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?

2018: 3b: When 10.6 g of ammonium chloride, NH₄Cl, 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

$M(\text{NH}_4\text{Cl}) = 53.5 \text{ g mol}^{-1}$

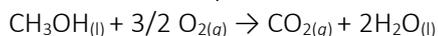
Calculate the enthalpy change, $\Delta_r H^\circ$, for dissolving ammonium chloride in water.



Writing Excellence answers to Formation Enthalpy Calculations questions

Formation Enthalpy Calculations QUESTION 1. (Excellence)

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



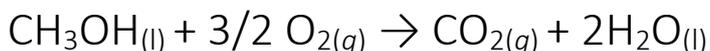
Calculate the standard enthalpy of combustion of liquid methanol, $\Delta_c H^\circ(\text{CH}_3\text{OH}(\text{l}))$, using the information in the table below.

Compound	kJ mol^{-1}
$\Delta_c H^\circ(\text{C}(\text{s}))$	-394
$\Delta_c H^\circ(\text{H}_2(\text{g}))$	-286
$\Delta_f H^\circ(\text{CH}_3\text{OH}(\text{l}))$	-240

ANSWER

1. Write all available formation enthalpy above each substance in the equation.

(elements will be 0)



2. check to see if any of the combustion enthalpy equations could be used a formation energy equation. Write out equation.

$$\Delta_c H^\circ(\text{C}) = \Delta_f H^\circ(\text{CO}_2)$$

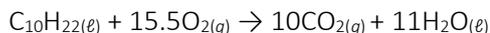
$$\Delta_c H^\circ(\text{H}_2) = \Delta_f H^\circ(\text{H}_2\text{O})$$

3. Calculate $\Delta_r H^\circ$ with units, sign and 3sgf

$$\Delta_r H^\circ = \sum \Delta_f H^\circ \text{ products} - \sum \Delta_f H^\circ \text{ reactants}$$

Formation Enthalpy Calculations QUESTION 2. (Merit)

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



Calculate $\Delta_c H^\circ(\text{C}_{10}\text{H}_{22}(\text{l}))$, given the following data:

$$\Delta_f H^\circ(\text{C}_{10}\text{H}_{22}(\text{l})) = -250 \text{ kJ mol}^{-1}$$

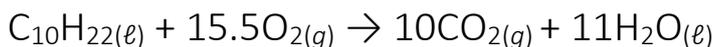
$$\Delta_f H^\circ(\text{CO}_2(\text{g})) = -393 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{H}_2\text{O}(\text{l})) = -286 \text{ kJ mol}^{-1}$$

ANSWER

1. Write all available formation enthalpy above each substance in the equation.

(elements will be 0)



2. Calculate $\Delta_r H^\circ$ with units, sign and 3sgf

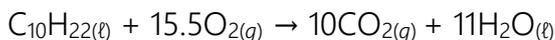
$$\Delta_r H^\circ = \sum \Delta_f H^\circ \text{ products} - \sum \Delta_f H^\circ \text{ reactants}$$

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

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



Calculate $\Delta_c H^\circ$ ($\text{C}_{10}\text{H}_{22}(\ell)$), given the following data:

$$\Delta_f H^\circ(\text{C}_{10}\text{H}_{22}(\ell)) = -250 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{CO}_2(\text{g})) = -393 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{H}_2\text{O}(\ell)) = -286 \text{ kJ mol}^{-1}$$

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



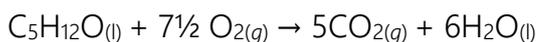
Calculate the standard enthalpy change, $\Delta_r H^\circ$, for this reaction, using the following data.

$$\Delta_f H^\circ(\text{NH}_3(\text{g})) = -46 \text{ kJ mol}^{-1}$$

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

$$\Delta_f H^\circ(\text{NH}_4\text{Cl}(\text{s})) = -314 \text{ kJ mol}^{-1}$$

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



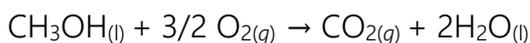
Calculate $\Delta_c H^\circ$ for pentan-1-ol, given the following data:

$$\Delta_f H^\circ(\text{C}_5\text{H}_{12}\text{O}(\text{l})) = -295 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{CO}_2(\text{g})) = -394 \text{ kJ mol}^{-1}$$

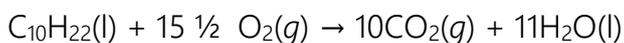
$$\Delta_f H^\circ(\text{H}_2\text{O}(\text{l})) = -286 \text{ kJ mol}^{-1}$$

2016: 3a. The equation for the combustion of liquid methanol is:



Calculate the standard enthalpy of combustion of liquid methanol, $\Delta_c H^\circ(\text{CH}_3\text{OH}(\text{l}))$, using the information in the table below.

2017: 2c. Carbon dioxide and water are formed when decane burns completely in oxygen. The reaction is shown in the equation below.



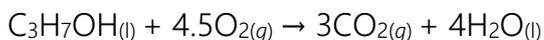
Calculate the enthalpy of combustion for decane, given the following data:

$$\Delta_f H^\circ(\text{C}_{10}\text{H}_{22}(\ell)) = -301 \text{ kJ mol}^{-1}$$

$$\Delta_c H^\circ(\text{C}) = -393 \text{ kJ mol}^{-1}$$

$$\Delta_c H^\circ(\text{H}_2) = -286 \text{ kJ mol}^{-1}$$

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



Calculate the standard enthalpy of combustion, $\Delta_c H^\circ$, of propan-1-ol, given the following data:

$$\Delta_f H^\circ(\text{C}_3\text{H}_7\text{OH}(\text{l})) = -255 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{CO}_2(\text{g})) = -394 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{H}_2\text{O}(\text{l})) = -286 \text{ kJ mol}^{-1}$$



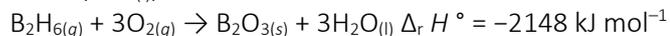
Writing Excellence answers to Hess's Law questions

Hess's Law QUESTION

Question: Calculate the $\Delta_f H^\circ$ for $B_2H_6(g)$, given the following data:

$$\Delta_f H^\circ (B_2O_3(s)) = -1255 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ (H_2O(l)) = -286 \text{ kJ mol}^{-1}$$



The melting point of boron is 2300°C .

ANSWER

1. Write out the equation for the $\Delta_f H^\circ$ 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 $\Delta_f H^\circ(\text{H}_2\text{O}(\ell))$, given the following data:

$$\Delta_f H^\circ(\text{H}_2\text{O}(\text{g})) = -242 \text{ kJ mol}^{-1}$$

$$\Delta_{\text{vap}} H^\circ(\text{H}_2\text{O}(\ell)) = +44 \text{ kJ mol}^{-1}$$

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

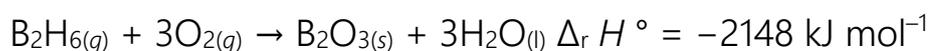
Compound	kJ mol^{-1}
$\Delta_c H^\circ(\text{C}(\text{s}))$	-394
$\Delta_f H^\circ(\text{H}_2\text{O}(\ell))$	-286
$\Delta_c H^\circ(\text{C}_2\text{H}_5\text{OH}(\ell))$	-1367

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 $\text{B}_2\text{H}_6(\text{g})$, given the following data:

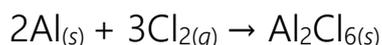
$$\Delta_f H^\circ(\text{B}_2\text{O}_3(\text{s})) = -1255 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{H}_2\text{O}(\ell)) = -286 \text{ kJ mol}^{-1}$$

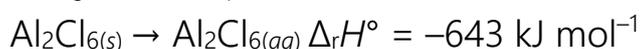
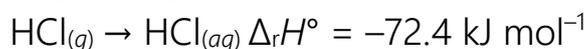
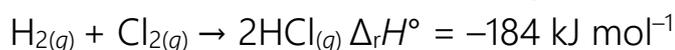
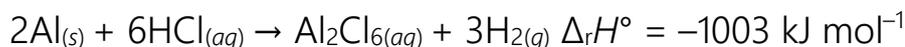


The melting point of boron is 2300°C .

2018: 2c: The equation for the formation of $\text{Al}_2\text{Cl}_6(\text{s})$ is:



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





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 <i>Give your example of energy levels for O and Se</i>	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 <i>Give your example of electronegativity for O and Se</i>	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 <i>Give your example of position across table for Ca and Se</i>	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 <i>with examples of data from Ca, O and Se</i>	Electronegativity increases across a period, and decreases down a group <i>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)</i>

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	First ionisation energy is the minimum energy required to remove one mole of electrons from one mole of gaseous atoms.
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.

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.

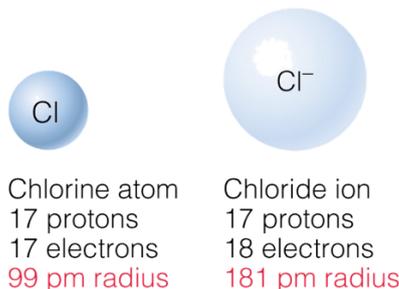


Writing Excellence answers to Periodic Trends – Atomic and Ionic Radii questions

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



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 <u>and</u> loss of energy level 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

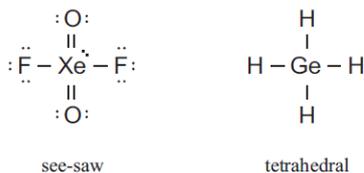
NOTE: The white column is how your answer would appear on your test paper so make sure you **write out complete sentences**. The shaded area is just to help you structure your answer and would not appear in the question.



Writing Excellence answers to Molecule 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.



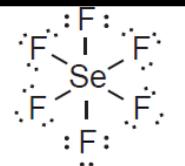
ANSWER

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 <u>AND</u> 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 <u>AND</u> 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 <u>AND</u> 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 <u>AND</u> resulting in dipole moments cancelling (or not) and link to polarity of molecule	The molecule is symmetrical being a tetrahedral shape , and so the dipole moments do cancel, making the molecule non-polar .





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 <u>AND</u> 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 <u>AND</u> 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.

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.



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	$\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{OH}$	$\begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{CH}_2 - \text{OH} \\ \\ \text{CH}_3 \end{array}$
Boiling point	138°C	113°C

ANSWER

1. List the forces of attraction in all three molecules <i>(some questions have a table to fill in)</i> 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	So decane has the highest boiling point and temporary dipoles followed

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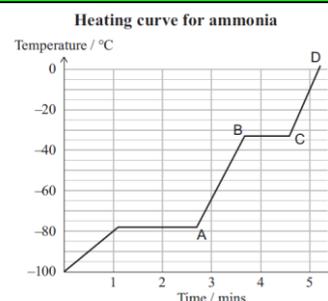


Enthalpy and State Change QUESTION

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 $\Delta_{\text{fus}}H^\circ(\text{NH}_3)$ and discuss why is $\Delta_{\text{vap}}H^\circ(\text{NH}_3)$ greater than $\Delta_{\text{fus}}H^\circ(\text{NH}_3)$?



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 $\Delta_{\text{fus}}H^\circ(\text{NH}_3)$	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 $\Delta_{\text{fus}}H^\circ(\text{NH}_3)$ linked to energy to overcome/break some bonds to $\Delta_{\text{vap}}H^\circ(\text{NH}_3)$ to overcome/break all bonds	Fusion of NH_3 only requires sufficient heat energy to break / overcome some of the intermolecular bonds, whereas vaporisation requires much more heat energy to overcome all the intermolecular bonds, therefore the $\Delta_{\text{vap}}H^\circ$ of NH_3 is much greater than its $\Delta_{\text{fus}}H^\circ$.

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Entropy and Spontaneity QUESTION

Question: The equation for the evaporation of liquid methanol is: $\text{CH}_3\text{OH}_{(l)} \rightarrow \text{CH}_3\text{OH}_{(g)}$
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 evaporates, 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 evaporates 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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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 (NH₃) 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 $\Delta_r H^\circ$ for this neutralisation reaction. The mass of the mixture is 50.0 g.

(ii) When the $\Delta_r H^\circ$ 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.

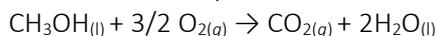
ANSWER

1. calculate the energy change <i>with units, sign and 3sgf</i> $q = m c \Delta T$ (Every 1mL of water can be taken as 1g due to its density)	$q = m c \Delta T$ $q = 50 \times 4.18 \times 6.5$ $q = 1358.5 \text{ J}$ $q = 1.3585 \text{ kJ}$
2. calculate the number of mols (of 1 substance) <i>with units and 3sgf</i> $n = c \cdot v$ (remember v is in L)	$n = c \cdot v$ $n = 1 \times 0.025 \text{ mL}$ $n = 0.025 \text{ mol}$
3. Calculate $\Delta_r H^\circ$ <i>with units, sign and 3sgf</i> $\Delta_r H^\circ = -q / n$ (remember to convert J to kJ)	$\Delta_r H^\circ = -q / n$ $\Delta_r H^\circ = -1.3585 \text{ kJ} / 0.025 \text{ mol}$ $\Delta_r H^\circ = -54.3 \text{ kJ mol}^{-1}$
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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Formation Enthalpy Calculations QUESTION 1. (Excellence)

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



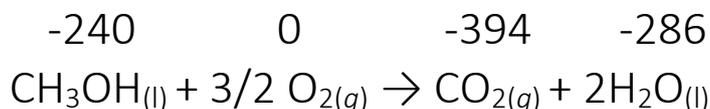
Calculate the standard enthalpy of combustion of liquid methanol, $\Delta_c H^\circ(\text{CH}_3\text{OH}(\text{l}))$, using the information in the table below.

Compound	kJ mol^{-1}
$\Delta_c H^\circ(\text{C}(\text{s}))$	-394
$\Delta_c H^\circ(\text{H}_2(\text{g}))$	-286
$\Delta_f H^\circ(\text{CH}_3\text{OH}(\text{l}))$	-240

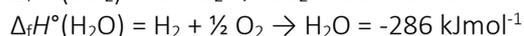
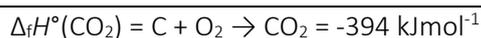
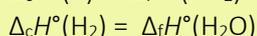
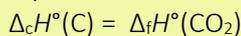
ANSWER

1. Write all available formation enthalpy above each substance in the equation.

(elements will be 0)



2. Check to see if any of the combustion enthalpy equations could be used a formation energy equation. Write out equation.



3. Calculate $\Delta_r H^\circ$ with units, sign and 3sgf

$$\Delta_r H^\circ = \sum \Delta_f H^\circ \text{ products} - \sum \Delta_f H^\circ \text{ reactants}$$

$$\Delta_r H^\circ = \sum \Delta_f H^\circ \text{ products} - \sum \Delta_f H^\circ \text{ reactants}$$

$$\Delta_c H^\circ = -394 + (2 \times -286) - (-240)$$

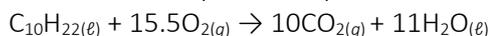
$$\Delta_c H^\circ = -966 + 240$$

$$\Delta_c H^\circ = -726 \text{ kJ mol}^{-1}$$

(H₂O 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.



Calculate $\Delta_c H^\circ(\text{C}_{10}\text{H}_{22}(\text{l}))$, given the following data:

$$\Delta_f H^\circ(\text{C}_{10}\text{H}_{22}(\text{l})) = -250 \text{ kJ mol}^{-1}$$

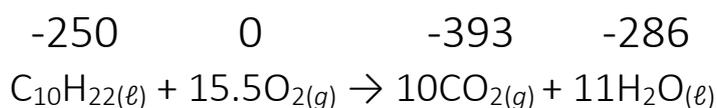
$$\Delta_f H^\circ(\text{CO}_2(\text{g})) = -393 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ(\text{H}_2\text{O}(\text{l})) = -286 \text{ kJ mol}^{-1}$$

ANSWER

1. Write all available formation enthalpy above each substance in the equation.

(elements will be 0)



2. Calculate $\Delta_r H^\circ$ with units, sign and 3sgf

$$\Delta_r H^\circ = \sum \Delta_f H^\circ \text{ products} - \sum \Delta_f H^\circ \text{ reactants}$$

$$\Delta_r H^\circ = \sum \Delta_f H^\circ \text{ products} - \sum \Delta_f H^\circ \text{ reactants}$$

$$\Delta_r H^\circ = [(10 \times -393) + (11 \times -286)] - (-250)$$

$$\Delta_r H^\circ = -6826 \text{ kJ mol}^{-1} \text{ or } -6830 \text{ kJ mol}^{-1} \quad 3\text{sgf}$$

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.

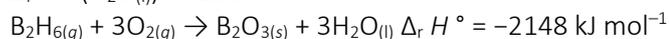
Writing Excellence answers to Hess's Law questions

Hess's Law QUESTION

Question: Calculate the $\Delta_f H^\circ$ for $B_2H_6(g)$, given the following data:

$$\Delta_f H^\circ (B_2O_3(s)) = -1255 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ (H_2O(l)) = -286 \text{ kJ mol}^{-1}$$



The melting point of boron is 2300°C .

ANSWER

1. Write out the equation for the $\Delta_f H^\circ$ 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. <i>Check to see which substances match those in the top equation</i> - may need to multiply (or divide) so multiply enthalpy - may need to reverse reaction so reverse sign on enthalpy	$\Delta_f H^\circ (B_2O_3(s)) = -1255 \text{ kJ mol}^{-1}$ <u>$2B(s) + 1\frac{1}{2}O_2(g) \rightarrow B_2O_3(s) = -1255 \text{ kJ mol}^{-1}$</u>
3. write/expand out the second equation given and the enthalpy value to right.	$\Delta_f H^\circ (H_2O(l)) = -286 \text{ kJ mol}^{-1}$ $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) = -286 \text{ kJ mol}^{-1}$ <u>$3H_2(g) + 1\frac{1}{2}O_2(g) \rightarrow 3H_2O(l) = -858 \text{ kJ mol}^{-1}$</u>
4. write/expand out the third equation given and the enthalpy value to right.	$B_2H_6(g) + 3O_2(g) \rightarrow B_2O_3(s) + 3H_2O(l) \quad \Delta_r H^\circ = -2148 \text{ kJ mol}^{-1}$ <u>$3H_2O(l) + B_2O_3(s) \rightarrow B_2H_6(g) + 3O_2(g) = +2148 \text{ kJ mol}^{-1}$</u>
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	$\Delta_f H^\circ B_2H_6(g), = -1255 \text{ kJ mol}^{-1} + -858 \text{ kJ mol}^{-1} + +2148 \text{ kJ mol}^{-1}$ $\Delta_f H^\circ B_2H_6(g), = +35 \text{ kJ mol}^{-1}$

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Periodic Table of the Elements

		Metals										Semi-Metals						Non-Metals		18
Period	Group	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		3 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 Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.6	30 Zn Zinc 65.4	31 Ga Gallium 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 Platinum 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 Oganesson 294	

gas
liquid
solid
synthetic

Atomic Number	1	H	Symbol
Name	Hydrogen	1.0	Atomic mass

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 Lawrencium 262