Define (the term(s)...) is intended literally. Only a formal statement or equivalent paraphrase is required.

Example 1

Bromine exists naturally as a mixture of two stable isotopes, ^{79}Br and ^{81}Br, with relative isotopic masses of 78.92 and 80.92 respectively.

(i) Define the term *relative isotopic mass*.

.....

.....

.....

..... [2]

relative to $\frac{1}{12}$ (the mass) of (an atom of) carbon–12

OR

relative to carbon–12 which is (exactly) 12 (units)

allow a correct expression

Example 2

(a) Define, with the aid of an equation which includes state symbols, the standard enthalpy change of formation of carbon dioxide.

equation .....

definition .....

.....

..... [3]

(a) $C(s) + O_2(g) \rightarrow CO_2(g)$ (1)

the enthalpy change/energy change/heat change when

one mole of a compound/CO_2 (1)

is formed from its elements in their standard states (1)

What do you understand by/What is meant by (the term(s)...) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.

Example 1

(i) What is meant by the term *bond polarity*?

.....

(i) bonding electrons are unequally shared **or**

the molecule has a dipole/δ+ and δ- ends to molecule

Example 2

(a) Explain what is meant by the term *ionisation energy*.

(a)	The amount of energy required / energy change / enthalpy change when one electron is removed	1
	from each atom / (cat)ion in one mol	1
	of gaseous atoms / (cat)ions	1
	OR energy change when 1 mole of electrons is removed from one mole of gaseous atoms / ions	
	$X(g) \rightarrow X^{+}(g) + e^{-}$ gains 2 marks	

[3]

Example 3

(i) What is meant by the term *weak acid*?

(i) an acid that is partially dissociated into ions **(1)**

Example 4

(c) What is meant by the term *nucleophile*?

(c) a species which has a lone pair of electrons
or which reacts with an electron deficient (δ+) centre in a molecule (1)

[1]

State implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained ‘by inspection’.

Example 1

(b) Allyl alcohol undergoes the following reactions.

(i) When reacted with concentrated HC*l* at 100 °C, CH_2=$CHCH_2Cl$ is formed.

State as fully as you can what *type of reaction* this is.

(b) (i) nucleophilic substitution (1)

Example 2

(a) (i) State Le Chatelier's Principle.

.....

.....

2 (a) (i) if the conditions of a system in equilibrium are changed (1)

the position of equilibrium moves so as to reduce that change (1)

.. [2]

Example 3

(b) The reaction of ethane with bromine forms a mixture of products.

(i) State the essential conditions for this reaction to occur.

..... [1]

(b) (i)	UV light / sunlight / high temperature	1

Example 4

(e) Sulfur reacts with fluorine to form SF_6. State the shape and bond angle of SF_6.

shape of SF_6 .....

bond angle of SF_6 .....

[2

(e)	shape of SF_6 = Octahedral bond angle = 90°	1 1

Example 5

(d) Strontium nitrate, $Sr(NO_3)_2$ undergoes thermal decomposition.

(i) State one observation you would make during this reaction.

.....

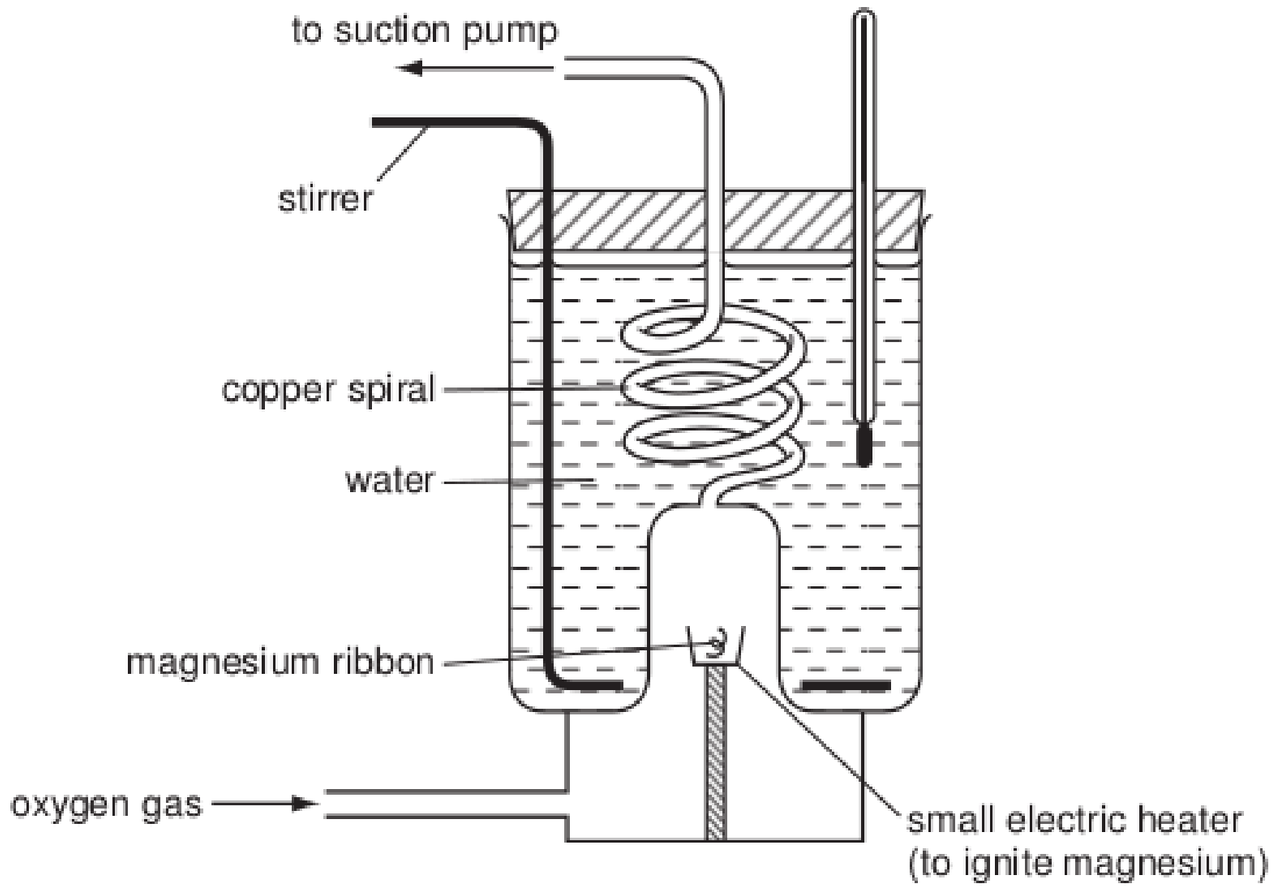
.....

(i) gas evolved [1]
gas is brown [1]

List requires a number of points with no elaboration. If a specific number of points is requested, this number should not be exceeded.

Example 1

(b) The apparatus shown in the diagram can be used to measure the enthalpy change of formation of magnesium oxide, $\Delta H_f^{\ominus}$(MgO).



List the measurements you would need to make using this apparatus in order to calculate $\Delta H_f^{\ominus}$(MgO).

(b) measurements needed:
volume/mass/weight of water (in calorimeter) [1]
initial + final temperature/temperature change/temperature rise (of the water) [1]
mass of Mg (used)/mass MgO [1]
Not *volume/moles/mass of oxygen used*

[3]

..... [3]

<u>Deduce/Predict</u> implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question.

Example 1

(iv) .....C_xH_y + ...O_2 → .....CO_2 + zH_2O

(v) Deduce the values of *x*, *y* and *z* in the equation in **(iv)**.

x = ...

y = ...

z = ...

[3]

(v)	$x = 2$; $y = 2$; $z = 2$ (or $z = 1$ if $C_xH_y + 2.5O_2 \rightarrow 2CO_2 + zH_2O$)	(1+1+1)

Example 2

(d) Deduce the oxidation state of nitrogen in hydrazine.

.....

(d) –2 (1) [1]

Example 3

(e) Carbon disulphide reacts with nitrogen monoxide, NO, to form a yellow solid and two colourless gases which are produced in a 1:1 molar ratio.

Deduce the identity of **each** gas

gases ..... and .....

(e) CO_2 (1)

N_2 (1)

Example 4

(ii) Predict the shape of the H_2S molecule.

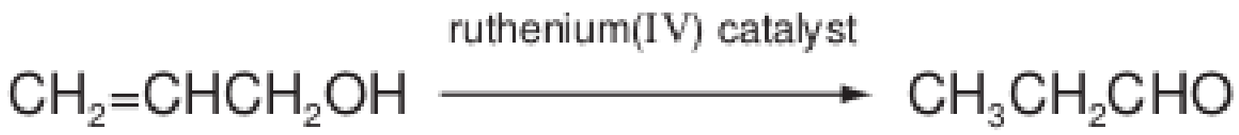
..

(ii) non-linear/bent/V-shaped **(1)**

Suggest is used in two main contexts. It may imply either that there is no unique answer (e.g. in chemistry, two or more substances may satisfy the given conditions describing an 'unknown'), or that candidates are expected to apply their general knowledge to a new situation (one that may not formally be in the syllabus).

Example 1

(d) Allyl alcohol may also be converted into propanal by using a ruthenium(IV) catalyst in water.



Suggest what is unusual about this single step reaction.

.....

[1]

(d) **both** oxidation **and** reduction have occurred **or**

disproportionation has taken place (1)

Example 2

(e) Pent-2-ene decolourises aqueous bromine. Suggest the structural formula of an isomer of C_5H_{10} which does **not** decolourise aqueous bromine.

(e) 

e.g. cyclopentane structure

allow methylcyclobutane **or** dimethylcyclopropane

Example 3

(iii) Oxygen and sulphur are both in Group VI of the Periodic Table.

Suggest why the melting and boiling points of water, H_2O, are much higher than those of H_2S.

(iii) H_2O has hydrogen bonds/H_2S does not <u>or</u>
H_2S has van der Waals' forces only **(1)**

.....

hydrogen bonds are stronger
than van der Waals' forces <u>or</u>
H_2S has weaker intermolecular bonds
than H_2O **(1)**

.....

.....

Calculate is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

Example 1

(i) Calculate the amount, in moles, of H_2SO_4 present in the 25.0 cm^3 of 1.00 mol dm^{-3} H_2SO_4.

(a) (i) $n(H_2SO_4) = \dfrac{25.0 \times 1.00}{1000} = 0.025$ mol (1)

Example 2

(e) Compound **P**, another unsaturated compound, is found in some blue cheeses.
The percentage composition by mass of compound **P** is C: 73.7%; H: 12.3%; O: 14.0%.

Calculate the empirical formula of compound **P**.

(e) C : H : O $= \dfrac{73.7}{12} : \dfrac{12.3}{1} : \dfrac{14.0}{16}$

$= 6.14 : 12.3 : 0.875$ (1)

$= 7.01 : 14.1 : 1$

gives $C_7H_{14}O$

formula must be given (1)

[2]

Example 3

(c) Calculate the standard enthalpy change of formation of CS_2 from the following data. Include a sign in your answer.

standard enthalpy change of combustion of CS_2 = $-1110\,kJ\,mol^{-1}$

standard enthalpy change of formation of CO_2 = $-395\,kJ\,mol^{-1}$

standard enthalpy change of formation of SO_2 = $-298\,kJ\,mol^{-1}$

(c)

	CS_2	+	$3O_2$	$\rightarrow$	CO_2	+	$2SO_2$	
$\Delta H_f^{\ominus}/kJ\,mol^{-1}$	x				–395		2(–298)	(1)

$\Delta H_{reaction} = -395 + 2(-298) - x = -1110\,kJ\,mol^{-1}$ (1)

gives $x = -395 + (-596) + 1110 = +119\,kJ\,mol^{-1}$ (1)

Example 4

(c) Bromine reacts with the element **A** to form a compound with empirical formula **A**Br_3. The percentage composition by mass of **A**Br_3 is **A**, 4.31; Br, 95.69.

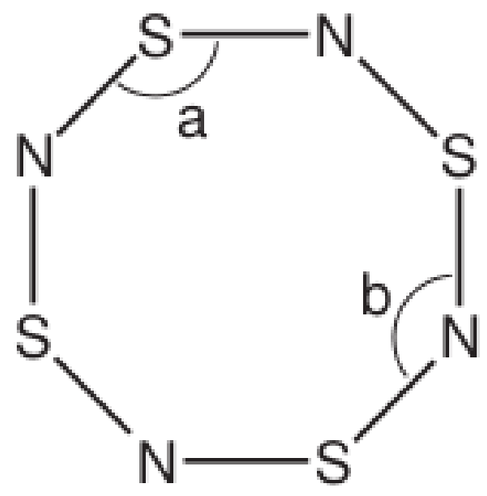
Calculate the relative atomic mass, A_r, of **A**.
Give your answer to **three** significant figures.

(c)	A Br $\frac{4.31}{A_r}$ $\frac{95.69}{79.9}$ = 1 : 3	
	So $\frac{95.69/79.9}{4.31/A_r} = 3$	1
	$A_r = \frac{3 \times 4.31 \times 79.9}{95.69}$ = 10.796 = 10.8 to 3 s.f.	1
	3 sig figs	1
	allow alternative correct methods	

<u>Determine</u> often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, e.g. relative molecular mass.

Example 1

(c) Sulfur forms the compound S_4N_4 with nitrogen. The structure of S_4N_4 is shown below. Assume all bonds shown are single bonds.



(i) Determine the number of lone pairs of electrons around a nitrogen atom and a sulfur atom in S_4N_4.

nitrogen atom .....

sulfur atom .....

(c) (i) around the N atom there is only one lone pair
around the S atom there are two lone pairs **both** (1)

Example 2

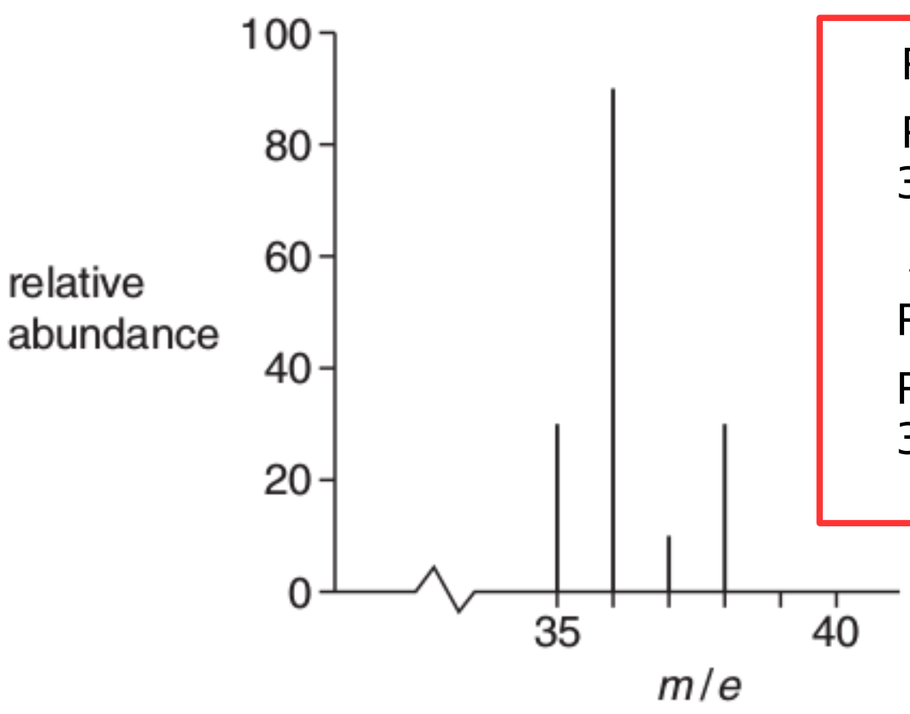
(ii) The empirical formula of **W** is $C_4H_6O_5$.

The M_r of **W** is 134. Use this value to determine the molecular formula of **W**.

(ii) $C_4H_6O_5 = 12 \times 4 + 1 \times 6 + 16 \times 5 = 134$
molecular formula of **W** is $C_4H_6O_5$ (1)

Example 3

In a mass spectrometer some hydrogen chloride molecules will split into atoms. The mass spectrum of HC*l* is given. Chlorine has two isotopes. The hydrogen involved here is the isotope $^{1}_{1}H$ only.



Relative abundance of $H^{35}Cl$ = 90
Relative abundance of $H^{37}Cl$ = 30
$^{35}Cl : {}^{37}Cl$ = 90:30 = 3:1
or
Relative abundance of ^{35}Cl = 30
Relative abundance of ^{37}Cl = 10
$^{35}Cl : {}^{37}Cl$ = 30:10 = 3:1

(c) Use the relative heights of the peaks to determine the proportions of the two isotopes of chlorine.

Explain may imply reasoning or some reference to theory, depending on the context.

Example 1

(ii) Explain why the HC*l* molecule is polar.

.....

(ii) the H and C*l* atoms have different electronegativities

or chlorine is more electronegative than hydrogen

.....

[2

Example 2

(a) The MnO_4^- ions in the potassium manganate(VII) *oxidise* the Fe^{2+} ions in the acidified solution.

(i) Explain, in terms of electron transfer, the meaning of the term *oxidise* in the sentence above.

(i)	(The MnO_4^- ions cause the Fe^{2+} ions to) lose electrons owtte/ora	1

..... [1]

Example 3

(c) The melting points of the elements Si to C*l* are given in the table.

element	Si	P	S	C*l*
m.p./°C	1414	44	115	–102

(i) Explain why the melting point of Si is very much greater than those of the other three elements.

(c) (i) Si is giant molecular/giant covalent **or**

P, S, and C*l* are simple molecular (1)

Example 4

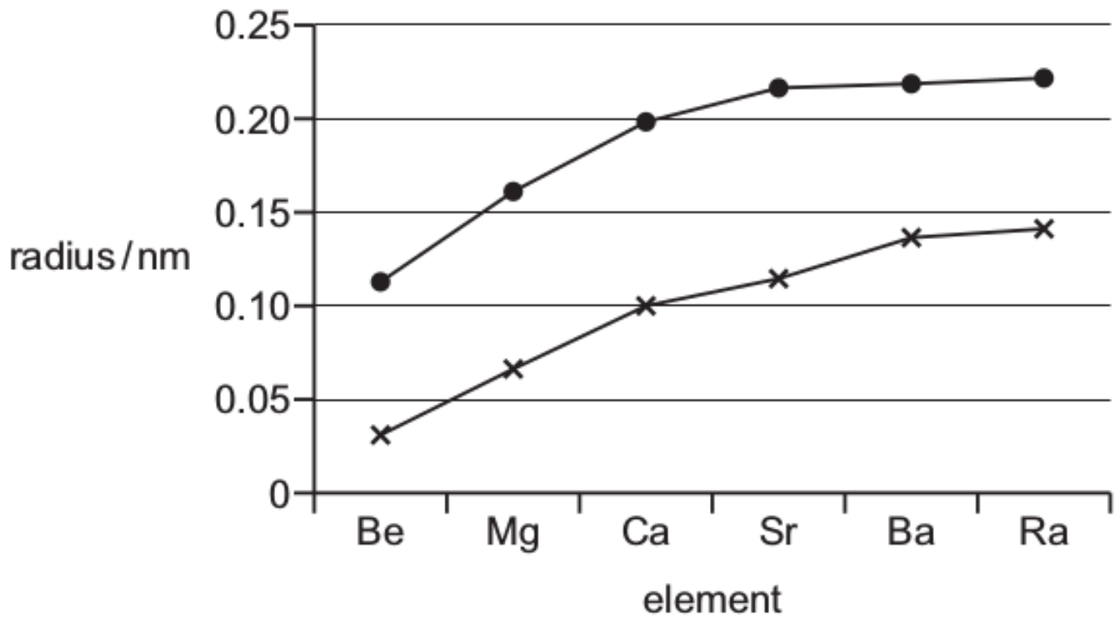
(a) Explain what is meant by the term *ionisation energy*.

(a)	The amount of energy required/energy change/enthalpy change when one electron is removed from each atom/(cat)ion in one mol of gaseous atoms/(cat)ions **OR** energy change when 1 mole of electrons is removed from one mole of gaseous atoms/ions $X(g) \rightarrow X^{+}(g) + e^{-}$ gains 2 marks	1 1 1

[3]

Example 5

(a) The graph below shows the radius values of the atoms and 2+ ions of the elements in Group 2.



(i) Explain why both lines show a steady increase in the values of the radii down the group.

.....

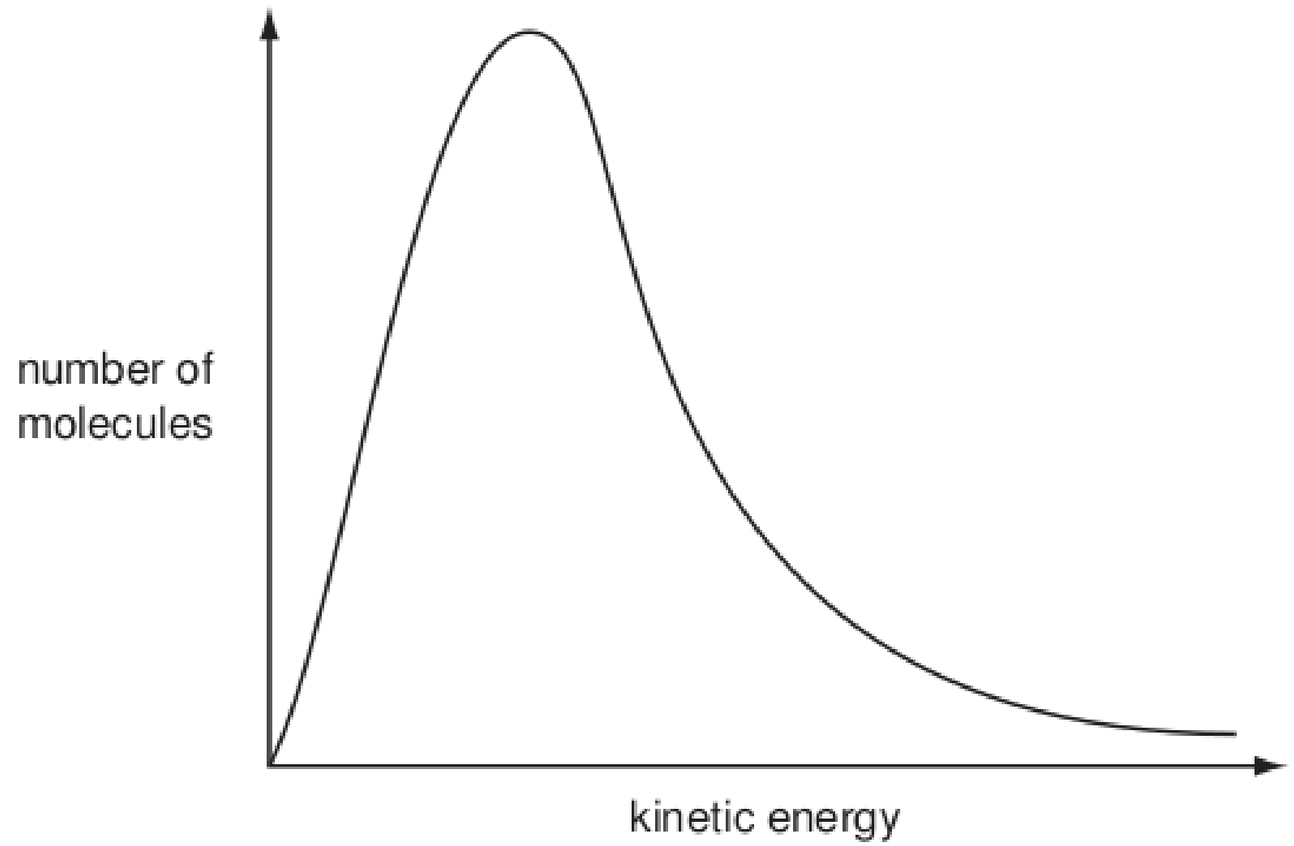
.....

..... [2]

3(a)(i)	(Atoms/ ions become larger as) the number of (electron) shells increases (down the group)	1
	Increased distance of (outer) electrons (from the nucleus) OR Increased shielding results in weaker (nuclear) attraction / pull	1

Example 6

(b) Use the Boltzmann distribution shown to explain why a catalyst increases the rate of this reaction.



(b)	Label on graph indicating catalysed and uncatalysed Ea OR statement Ea catalysed is lower (than Ea uncatalysed) owtte	1
	Reference to catalyst creating alternative mechanism / reaction pathway / route	1
	Idea that more molecules have sufficient energy (to react)	1
	so greater chance / frequency of successful collisions	1

Describe requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. For particular phenomena, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. In other contexts, describe and give an account of should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. Describe and explain may be coupled in a similar way to state and explain.

Example 1

Aluminium is a metal in Period 3 and Group III of the Periodic Table.

(a) Describe the structure of solid aluminium.

(a)	regular arrangement/lattice of cations/positive ions surrounded by delocalised electrons	[1] [1]

.....

.....

[2]

Example 2

Oxides are classified as follows.

acidic alkaline amphoteric basic

(a) Using these terms only, complete the table to describe the oxides of the elements o the third period of the Periodic Table sodium to sulfur.

Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	Cl_2O_7
						acidic

(a)

Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_2	Cl_2O_7
alkaline	basic	amphoteric	acidic	acidic	acidic	acidic

Na_2O is alkaline – allow basic (1)

MgO is basic – allow alkaline (1)

Al_2O_3 is amphoteric (1)

SiO_2, P_4O_{10}, and SO_2 are **all** acidic (1)

Example 3

(d) Sodium and silicon also react directly with chlorine to produce the chlorides shown.

chloride	melting point/°C	difference between the electronegativities of the elements
NaCl	801	2.2
$SiCl_4$	–69	1.3

(i) Describe what you would **see** during the reaction between sodium and chlorine.

.....

.....

[2]

(c) **(i)** any **three** from:
floats
vigorous/violent reaction occurs
melts/forms a sphere
moves
disappears – allow dissolves
effervescence/gas produced (any 3)

Example 4

(d) Sodium and silicon also react directly with chlorine to produce the chlorides shown.

chloride	melting point / °C	difference between the electronegativities of the elements
Na*Cl*	801	2.2
$SiCl_4$	–69	1.3

(i) Describe what you would **see** during the reaction between sodium and chlorine.

....

(d) (i)	Yellow / orange flame White fumes / solid Yellow / green gas disappears	[1] [1] [1]

.... [2]

<u>Outline</u> implies brevity, i.e. restricting the answer to giving essentials.

Example 1

In many countries, new cars have to comply with regulations which are intended to reduce the pollutants coming from their internal combustion engines.

Two pollutants that may be formed in an internal combustion engine are carbon monoxide, CO, and nitrogen monoxide, NO.

(e) **(i)** Outline how **each** of these pollutants may be formed in an internal combustion engine.

CO .....

.....

NO .....

.....

(i) CO by incomplete combustion of the hydrocarbon fuel (1)

NO by reaction between N_2 and O_2 in the engine (1)

Example 2

(ii) Outline briefly how the cracking of hydrocarbons would be carried out.

..

.....

(ii) using high temperatures/thermal cracking **or**
using catalysts/catalytic cracking (1)

Example 3

Aluminium reacts with chlorine.

(b) **(i)** Outline how, starting from aluminium powder, this reaction could be carried out in a school or college laboratory to give a small sample of aluminium chloride. A diagram is not necessary.

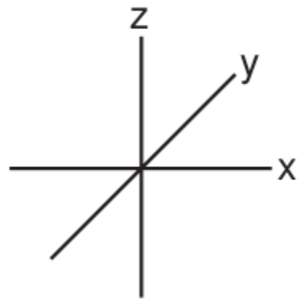
(i) pass chlorine gas (1)
over heated aluminium (1)

.....

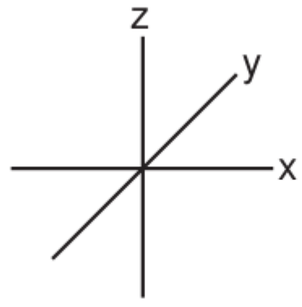
Sketch, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value. In diagrams, sketch implies that a simple, freehand drawing is acceptable though care should be taken over proportions and the clear exposition of important details.

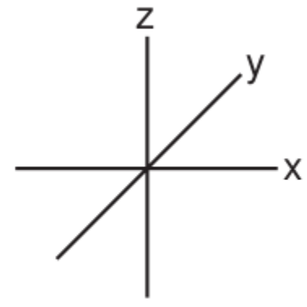
Example 1

(a) On the axes below, sketch the shapes of a 1s, a 2s, and a $2p_x$ orbital.

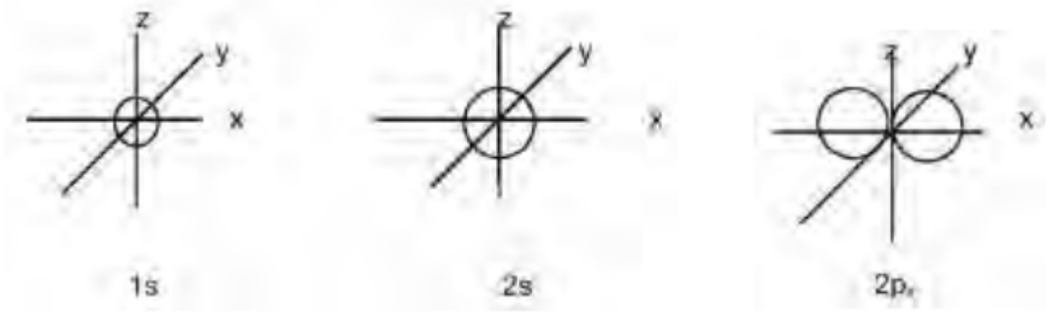


1s





(a)



spherical (1)

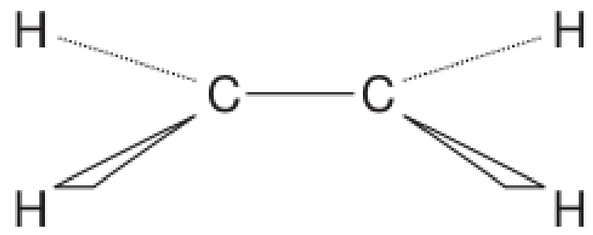
larger spherical (1)

double lobes along the *x*-axis (1

Example 2

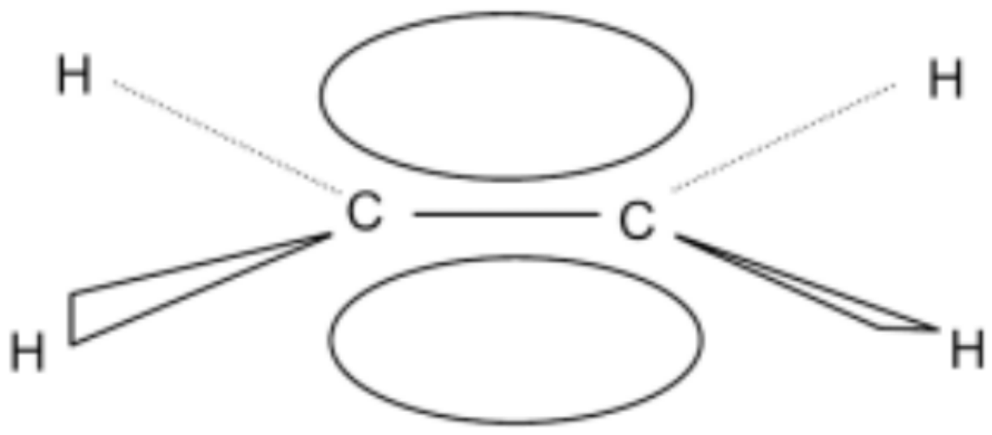
(d) The bonding in ethene may be described as a mixture of σ and π bonding.

Each carbon atom in ethene forms three σ bonds as shown below.



On the diagram, sketch the π bond that is also present in ethene. [1]

(d)



allow two 'sausages' above **and** below the C-C axis

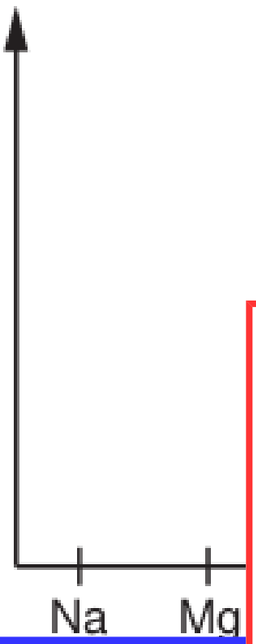
or two p orbitals **overlapping** sideways
to form one (localised) π bond over two carbon atoms (1)

Example 3

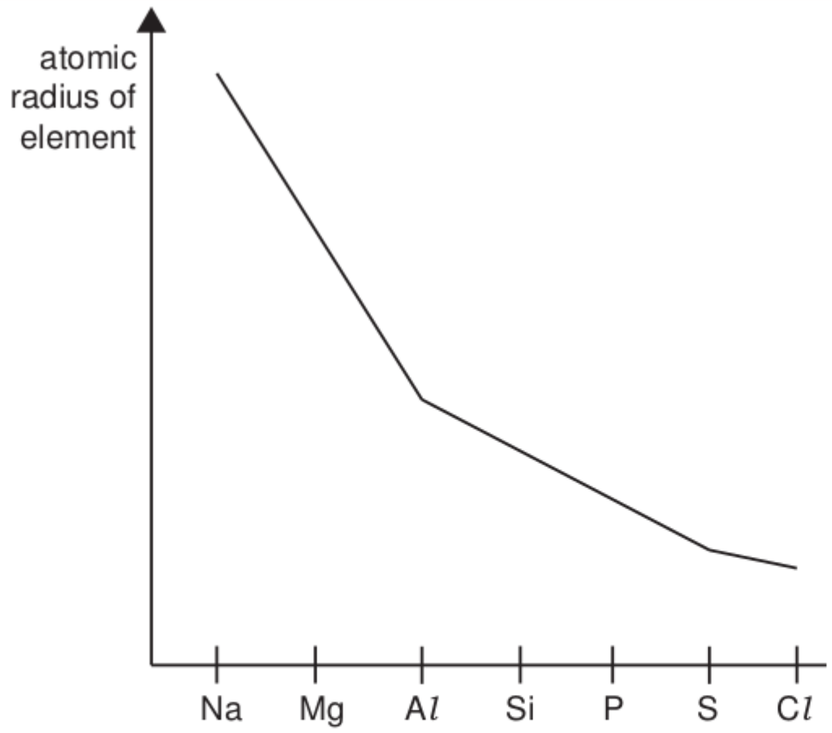
3 Elements in the same period of the Periodic Table show trends in physical and chemica properties. The grids on this page and on the opposite page refer to the elements of the third period, Na to C*l*.

On **each** of these grids, draw a clear sketch to show the variation of the stated property.

(a)



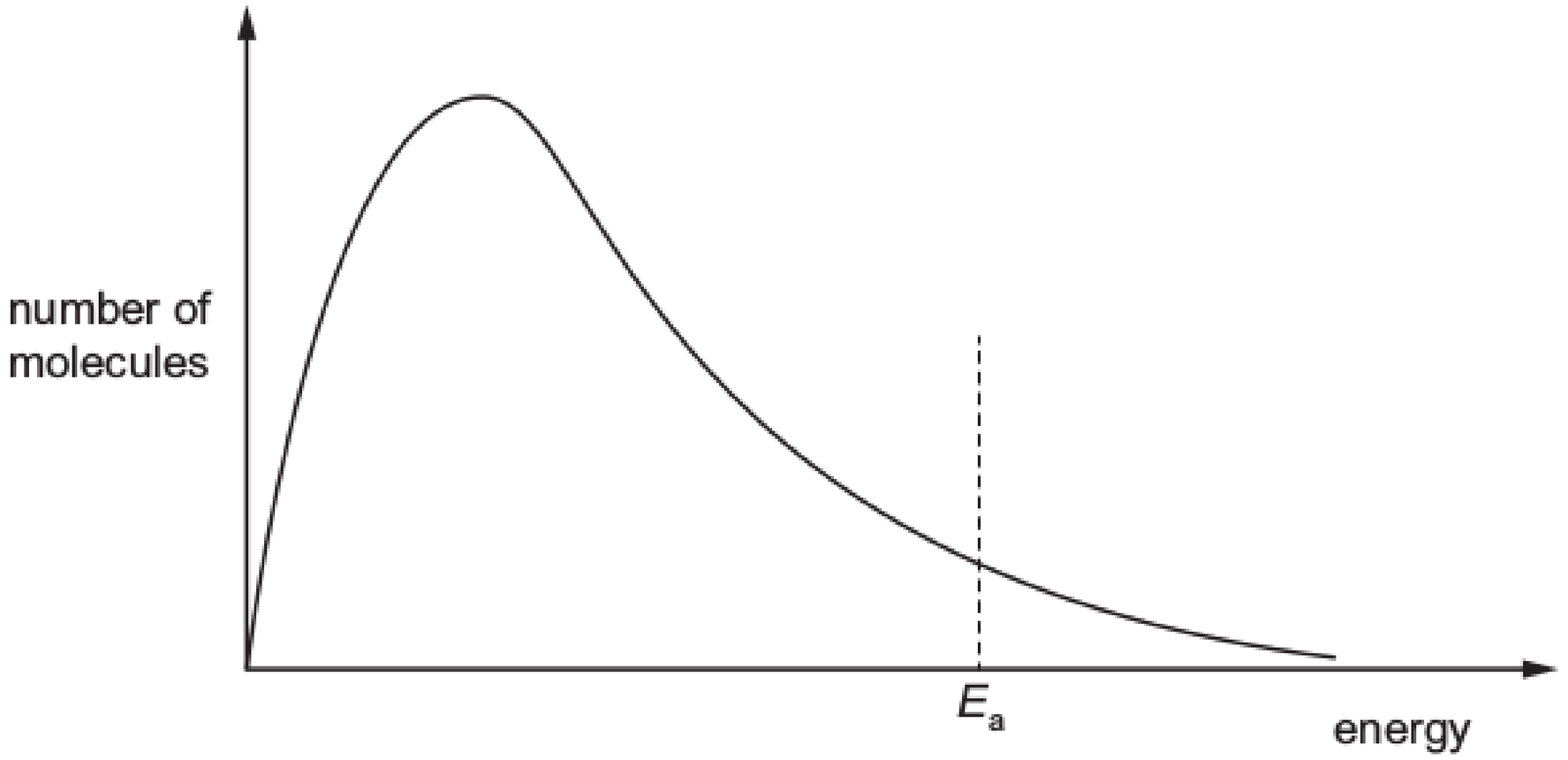
(a)



general shape of curve (1)
for Na → Ar
nuclear charge increases (1)
electrons are added to same shell (1) [3]

Example 4

The Boltzmann distribution curve shows the distribution of energies in a mixture of nitrogen and hydrogen at 450 °C.



(i) Sketch a second line onto the axes above to show the distribution of energies in the same mixture of gases at a higher temperature. [2]

(b)	**(i)**	line from origin AND below left-hand end of original with peak to right of and lower than original crosses original once AND above right-hand end of original AND above energy axis	[1] [1]

Construct is often used in relation to chemical equations where a candidate is expected to write a balanced equation, not by factual recall but by analogy or by using information in the question.

Example 1

(iii) Construct a balanced equation for the reaction of S_2Cl_2 with water.

(iii) $2S_2Cl_2 + 3H_2O \rightarrow 3S + H_2SO_3 + 4HCl$

correct products (1)

balanced equation (1)

Example 2

(d) Carbon disulfide reacts with nitrogen monoxide, NO, in a 1:2 molar ratio.
A yellow solid and two colourless gases are produced.

(i) Construct a balanced equation for the reaction.

.....

(d) **(i)** $CS_2 + 2NO \rightarrow CO_2 + 2S + N_2$
or
$CS_2 + 2NO \rightarrow CO + 2S + N_2O$

correct products (1)

correct equation (1)

Example 3

When carbon and silicon(IV) oxide are heated together at about 2000 °C, silicon carbide, SiC, is formed. Silicon carbide is a hard material which is widely used as an abrasive and in ceramics.

(e) (i) Construct an equation for the reaction of carbon and silicon(IV) oxide.

.....

(e) (i) $SiO_2 + 2C \rightarrow SiC + CO_2$ **or**
$SiO_2 + 3C \rightarrow SiC + 2CO$ (1)

<u>Compare</u> requires candidates to provide both the similarities and differences between things or concepts.

Compare has never appeared on a CIE chemistry exam

Classify requires candidates to group things based on common characteristics.

Classify has never appeared on a CIE chemistry exam

<u>Discuss</u> requires candidates to give a critical account of the points involved in the topic.

Discuss has never appeared on a CIE chemistry exam

Comment is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.

Comment has never appeared on a CIE chemistry exam

Estimate implies a reasoned order of magnitude statement or calculation of the quantity concerned. Candidates should make any necessary simplifying assumptions about points of principle and about the values of quantities not otherwise included in the question.

Estimate has never appeared on a CIE chemistry exam

<u>Find</u> is a general term that may variously be interpreted as calculate, measure, determine, etc.

Find has never appeared on a CIE chemistry exam

<u>Measure</u> implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.

Measure has never appeared on a CIE chemistry exam