Chem Factsheet

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How To Answer AS Exam Questions On Atomic Structure

You need to know and understand all related ideas before you can gain maximum credit when answering exam questions on any particular topic. To help you, the following provides a summary of the essential ideas under the topic heading, "**atomic structure**". However, **applying** these correctly to exam questions is really what this FactSheet is about. After studying this FactSheet you should be able to pick up a few more marks – or a lot!

Sub-atomic Particle	Relative Mass	Relative Charge	Position in Atom	Deflection by Electrical Field
Proton	1	1+	In central, very mass-dense nucleus	Slight, towards negative
Neutron	1	1-	In central, very mass-dense nucleus	None
Electron	1/1840	0	In orbit around the nucleus in energy levels	Great, towards positive

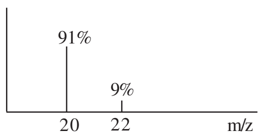
Mass Spectrometer = device for determining (a) isotopic distribution, and hence A_r, for an element (b) M_r for a molecular substance (c) molecular formula. [Also (d) molecular structure – A2]

Operation of Mass Spectrometer (ms) – be familiar with actual diagram!

1. **Vaporisation** : Very low pressure ensures sample → gas
2. **Ionisation** : Electron gun fires high energy e- →collide with sample → knock electron out of sample → positive ions ; X(g) + e- → X+(g) + 2e-. Some 2+ ions may form but this is much less likely.
3. **Acceleration** : +ve ions are accelerated by an electric field and focused into a beam as they pass through slits.
4. **Deflection** : Variable magnetic field. Deflection increases as relative mass / relative charge ratio (m/z) decreases. m/z halved if 2+ ion formed.
5. **Detection** : Metal plate collects ions → e- taken from plate → electric current in plate → proportional to % abundance of ion

Relative Atomic Mass, A_r - evaluated using mass spectrum of element.

$$A_r = \frac{\text{the average mass of one atom of an element}}{\text{the mass of one atom of C-12}} \times 12$$

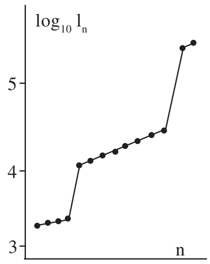


$$A_r = \frac{(91 \times 20) + (9 \times 22)}{(91 + 9)} = 20.2$$

For a compound, HIGHEST m/z = M_r : high resolution M_r (e.g. 4 dec. pl.) can be used to deduce molecular formula.

How Science Works :
Ideas about atomic structure (and most other scientific ideas) come from experimental evidence. This is used to generate a model which can explain and predict properties. However, the model may be rejected or modified as more experimental data becomes available.

Atomic Number (Z) = number of protons per atom
Mass Number (A) = number of protons + neutrons in an atom
Isotopes = atoms of same element having the same number of protons (Z) but different numbers of neutrons (A-Z).



n^{th} **Ionisation Energy** (I_n) of an atom = the energy required to remove the n^{th} electron from each atom in one mole of gaseous atoms to form n+ ions

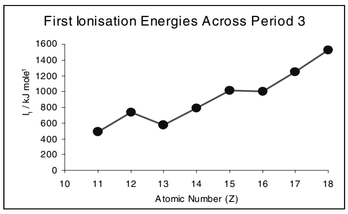
$X^{(n-1)+}(g) \rightarrow X^{n+}(g) + e-$

e.g. I_1 : $X(g) \rightarrow X^+(g) + e-$

I_n increases as n increases because +ve charge increasing but sudden increase as electron removed from energy level much nearer, and less shielded from, nucleus.

Number of plateaus and number of points in each plateau in I_n vs n graphs → number of principle e- energy levels and number e- in each eg 2,8,4 for Si above

1. Increases in I_1 caused by no. of p+ increasing → greater force of attraction
2. Decrease gp 2 to 3 as e- in more distant, more shielded p orbital → weaker force of attraction
3. Decrease gp 5 to 6 as e- spins pair, ↑↓ ↑ ↑ for S, causing repulsions → weaker force of attraction.



Electron Configurations:

e Level	No. sub-levels	s level	p-level	d-level	f-level
1	1	1s			
2	2	2s	2p		
3	3	3s	3p	3d	
4	4	4s	4p	4d	4f

Order for filling sub-levels is
1s → 2s → 2p → 3s → 3p → 4s → 3d → 4p → 5s …
e.g. $_3$Li $1s^2 2s^1$; $_7$N $1s^2 2s^2 2p^3$
s-block elements have 1 or 2 e^- in the outer s sub-level
p-block elements have 1 to 6 e^- in the outer p sub-level
s-block elements have 1 to 10 e^- in the outer d sub-level

General

When answering any examination question it is essential to read the question carefully and fully appreciate what you are being asked to do. Most importantly, you must respond appropriately to the "key words / phrases" used in questions that are designed to get you to respond as required by the examiners. The "key words" used most often in AS chemistry "atomic structure" questions and their expected type of response are summarised as follows:

Compare	Show *both* the differences and the similarities.
Define	Give the *precise meaning* to distinguish it from related terms.
Describe	*Write an account* in a logical sequence.
Explain	Use *appropriate theories* to account for.
Illustrate	Use concrete examples, comparisons or analogies to *explain*.
Justify	State what you think and *give reasons* for your statement.
Name	Give the *word(s) used to identify* something.
State	*Give information* using single words / brief, clear sentences and omitting details and examples.

Of course, more than one key words are often used e.g. "state and explain" or "explain and illustrate". You must be sure to identify all of them and respond to each.

Note: the number of "key words" is often closely related to the mark scheme!

In the examples that follow, "key words" have been highlighted. It is a good idea to do this when reading a question for the first time. Simply underline them!

Q1 The two isotopes normally found in a sample of nitrogen are ^{14}N and ^{15}N. **Compare** these two isotopes in terms of their fundamental particles.

Be careful to refer to both isotopes and be specific in terms of ***numbers*** *of particles .*

A1 *Both* have 7 protons (✓) ; *Both* have 7 electrons (✓) ; ^{14}N has 7neutrons **but** ^{15}N has 8neutrons (✓)

Q2 **Define** the term *relative atomic mass, A_r.*

This requires a precise definition. – The word "relative" shows that it refers to a ***ratio*** *of masses. – Always try to use "clues" like this.*

A2

$$A_r = \frac{\text{the average mass of one atom of an element}}{\text{the mass of one atom of } ^{12}C} \times 12$$ (✓) (✓)

The word "average" is essential because it allows for the fact that elements consist of mixtures of isotopes.

This can be expressed in words (e.g. the relative atomic mass of an element is the average mass of one atom of an element measured relative to 1/12th of the mass of one atom of carbon12) *but (a) this takes longer to write (b) it involves repeating the question and (c) it often seems to lead to imprecision or ambiguities, depending how clearly candidates express themselves. – Learn the formula – also, understand it!*

Q3 Define, in terms of the fundamental particles present, the meaning of the term *isotopes*.

This must be answered "in terms of the fundamental particles". Atomic number and mass number differences are NOT appropriate to answer this question. Also, electrons are not relevant because their gain or loss does not change isotopic nature.

A3 Isotopes are atoms with **same number of protons** (✓) but **different numbers of neutrons** (✓).

Q4 Describe briefly **how** positive ions are formed from gaseous chromium atoms in a mass spectrometer.

This requires a description of "how", not "what". Hence, "by an electron gun" is not sufficient. Also, do not forget to refer to a chromium atom.

A4 High speed electrons, [$*e^-$] (✓) are caused to collide (✓) with gaseous Cr atoms resulting in an electron being knocked out (✓) of outer shell.

$Cr(g) + *e^- \rightarrow Cr^+(g) + 2e^-$ (✓)

Q5 Explain why the first ionisation energy of neon and that of magnesium are both higher than that of sodium.

Tackle the 2 parts separately – neon vs sodium and then magnesium vs sodium. Don't compare neon with magnesium!

This is really a "comparison" so you must take care to mention both sides of the argument e.g. neon and sodium.

Such "explanations" must be in terms of differences in (a) distance from nucleus, (b) shielding from the nucleus, (c) number of nuclear protons and (d) electron spin pairings where appropriate.

In questions of this type, it is good idea to write down the electron configuration(s) of the atom(s) concerned. This may not attract specific marks but it can help to make descriptions clearer and differences in these configurations are good "prompts" for differences in atomic structure and hence differences in ionisation energy values.

A5 Na : $1s^2\ 2s^2\ 2p^6\ 3s^1$; Ne : $1s^2\ 2s^2\ 2p^6$; Mg : $1s^2\ 2s^2\ 2p^6\ 3s^2$.

I_1[Ne] > I_1[Na] because neon's outer electron is much closer to, (✓) and less shielded from, (✓) the nucleus because it is in the 2p shell rather than 3s. Hence, it is attracted to the nucleus more strongly (✓) and will be more difficult to remove.

I_1[Mg] > I_1[Na] because, even though their outer electrons are in the same shell (3s) with similar shielding (✓), magnesium has one extra proton in the nucleus (✓) which causes its outer electron to be attracted to the nucleus more strongly (✓) and be more difficult to remove.

Q6 There is a general trend in the first ionisation energies of the Period 3 elements, Na–Ar
(i) State and explain this general trend.
(ii) Explain why the first ionisation energy of sulphur is lower than would be predicted from the general trend.

Another question about variations in ionisation energies! See general comments after Q5.

A6 (i) Trend : increases.
Explanation : nuclear attraction on the outer electrons increases as the number of nuclear protons increases (✓) with distance and shielding from the nucleus being almost constant (✓).

(ii) In S ($1s^2\ 2s^2\ 2p^6\ 3s^2 3p^4$), 2 of the outer 3p electrons are spin-paired (✓) [↑↓↑↑]. The electrons in this pair repel each other (✓) making it unusually easy to remove an electron.

Q7 **State** the block in the Periodic Table in which sulphur is placed and **explain** your answer.

Remember to use your Periodic Table to answer this type of question!

A7 S = $1s^2\ 2s^2\ 2p^6\ 3s^2 3p^4$.

S belongs to the p-block (✓).
Its highest occupied orbital is a p-type (3p) (✓).

Q8 **State** any differences and similarities in the atomic structure of the isotopes of an element. **State** the difference, if any, in the chemistry of these isotopes. **Explain** your answer.

Compare the answer to Q3 which "seems" very similar. Here, because of the way the question is phrased, different answers are allowable.

A8

Similarities	Differences
Same number of protons / proton number / atomic number (✓)	Different numbers of neutrons / mass numbers (✓)

Isotopes have identical (✓) chemical properties since they have the same electron configuration (✓) – this alone controls an atom's chemical properties.

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