Westminster School

Sixth Form Entrance Examination

CHEMISTRY

Sample structured questions

Worked Answers

Where appropriate, further information is given in each answer – for example, common mistakes and misconceptions, or where extra credit may have been awarded.

These extended notes are written in *blue*.

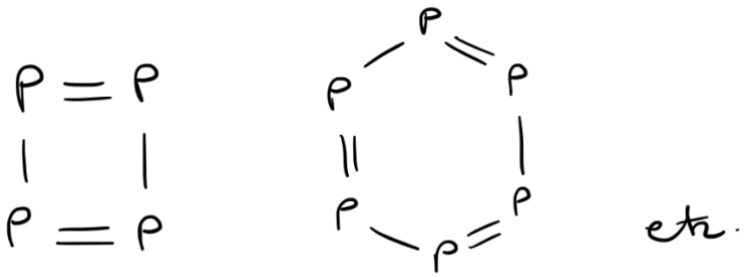
Question 1

a) Allotropes are different structural forms of the same element. [1]

Extra credit can be gained here by stating that the elements must be in the same physical state. Solid magnesium is not an allotrope of liquid magnesium, for example, even though the structures are different.

b) *The key here is to note that phosphorus must form three bonds. Any structure for which this is the case gains credit.*

Some possible answers:



[1 mark each – max 2]

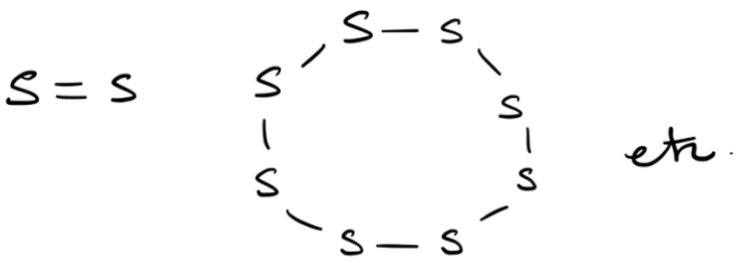
c)

(i) Sulphur is in group 6 (same as oxygen) so we should expect 2 bonds to each sulphur atom [1]

(ii) *There are a huge number of options here, many of which actually exist. As long as each S atom has two bonds, credit whould be awarded.*

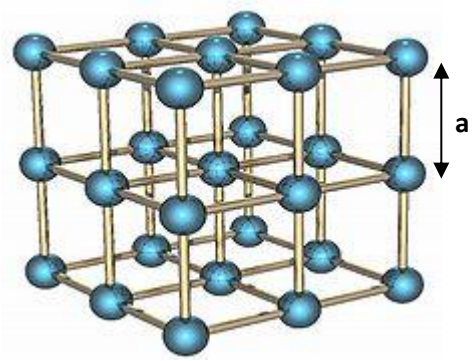
S_8 rings are commonly found in nature, but polymeric, orthorhombic and monoclinic forms exist too.

Some possible answers:



[1 mark each – max 2]

d)



a	3.35 x 10^{-8} cm
density	9.20 g/cm^3

(i) $volume = a^3 = (3.35 \times 10^{-8})^3 = 3.76 \times 10^{-23} cm^3$ [1]

(ii) *Careful consideration of segments of spheres gives us that 1/8 of each Po atom is **inside** the cube. Common wrong answers are to say ¼.*

1/8 of an atom on each corner [1]
8 corners in a cube, so each cube contains 1 equivalent single atom. [1]

(iii) $density = \frac{mass}{volume}$
$\therefore mass = volume \times density = 3.76 \times 10^{-23} \times 9.20 = 3.46 \times 10^{-22} g$ [1]

The total of 4 marks in this question was allocated generously across all parts. It is possible to carry through an incorrect value and still gain credit later on.

Question 2

This question takes some of the core principles from GCSE organic chemistry and asks about them in a novel context. It would be expected that candidates who chose to answer this question would have covered the core principles of alkanes, alkenes, carboxylic acids and polymers. Those who had not covered organic chemistry would be advised to pick a different question.

a) There are no double bonds (C=C) in the compound owtte [1]

Candidates will have met the fact that alkanes are saturated hydrocarbons and therefore, by extension, recognise that the compound given falls into a similar category.

b) *The chemical tests for chloride ions and chlorine gas are routinely confused and this can be an issue at A-Level also. This question rewards those that have the right attention to detail.*

(i) Add silver nitrate solution (and nitric acid). The positive result would be the formation of a white precipitate (AgCl).

Not necessary for the answer, but candidates might have mentioned also that the precipitate would be soluble in dilute ammonia solution.

(ii) Bleaches <u>damp</u> (blue) litmus paper.

Use of blue litmus paper often gives an intermediate result of red due to the acids formed when Cl_2 dissolves in water. This isn't always observed though as it does depend on the concentration of the chlorine gas and the subsequent rate of reaction.

c) *This is another question that seeks to draw out some common misconceptions – this time around electrolysis of aqueous solutions.*

(i) Cathode

(ii) Anode / electrode A

(iii) Hydrogen

(iv) Oxygen [1]

$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$
or
$2H_2O \rightarrow 4H^+ + O_2 + 4e^-$

d)

(i) Compounds with the <u>same molecular formula</u> but different <u>structural formula</u>.

It is common, but incorrect, for candidates to say chemical formula instead of molecular formula – they need to distinguish between the different types.

Pupils often struggle with what to put at the start of this definition – terms like 'substance' are a bit vague here, but 'species' is a good catch-all.

(ii) *The easiest approach here is not to change too many things at the same time. It would be possible to draw isomers that have a sulphur atom elsewhere (i.e. as part of a thiol -SH) but it is easiest simply to change the carbon chain lengths.*

Example answers:

[insert diagrams]

e) *This question is a veiled alkane question and doesn't require any additional knowledge.*

(i) Substitution

(ii) HCl / hydrogen chloride

*Hydrochloric acid would **not** be a viable answer here since there is no water present for the HCl to dissociate. It would therefore be present as a gaseous covalent molecule.*

(iii) UV light

f) *This question requires some careful thought and builds on what pupils learn about general formulae when studying hydrocarbons. The question is made easier if candidates realise that there will always be 1 x S and 2 x Cl atoms.*

Since the molecules are symmetrical, an increase in the value of n by 1, will lead to 2 x 1 increase in the number of carbon atoms.

(i) General formula: $C_{2n}H_{4n}SCl_2$

(ii) Similar/same chemical properties
Trend in physical properties

The common mistake here is to state that members have the same physical properties, which can't be true since they wouldn't all have the same boiling point. Another common error is to restate a previous property in other terms – e.g. 'all contain single bonds' is encompassed by 'similar chemical properties'.

Question 3

This question was designed to tempt those who have studied any qualitative analysis at GCSE. Much of the content is the same, but the presentation of the data in a single table is at first quite daunting. The key here is not to try to work out too much at once, and to apply small bits of knowledge.

The question is made harder by not making it clear which tests are for anions and which for cations. This means that candidates have to recall and apply the tests out of the context in which they were learned.

a) Ca^{2+} / calcium (ion)

b) Anion in C = chloride / Cl^-
Anion in D = carbonate / CO_3^{2-}

Even though the nitric acid is added after the silver nitrate, this is the usual familiar test. The white ppte for C would suggest AgCl has been formed. The white ppte with silver nitrate and D is due to silver carbonate also being insoluble. Normally pupils wouldn't see this as they are used to adding the acid first – hence the effervescence that follows.

Candidates are advised to give names rather than formulae, particularly for the tricker ions, where an incorrect formula would be penalised. A common mistake is to refer to chlorine ions, rather than chloride ions.

c) $BaSO_4$

d) Ammonia / NH_3

Test for this by using damp red litmus paper – it should turn blue.

Be careful not to state or imply that the litmus paper is added to the solution. This would give a false positive result since sodium hydroxide has been added, which will also turn the litmus blue. We are testing for the presence of a basic gas, so the litmus must be held above the test tube.

e) Solution would turn cloudy.

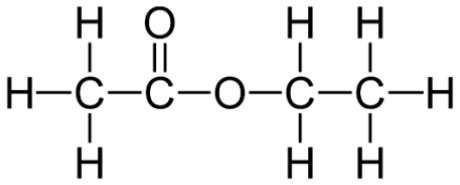
Solution made from Test 1 with C is $Ca(OH)_2$, otherwise known as limewater. Only the strongest candidates would be expected to know the identity of limewater.

f) *The information in the question is telling us that the organic compound must be a carboxylic acid – from the formation of an ester, as well as its reaction with a carbonate.*

(i) B is acidic / a carboxylic acid.

(ii) *There are only a limited number of options here, despite the question seeming quite open-ended, since the carboxylic acid must have empirical formula CH_2O.*

The likely identity is therefore ethyl ethanoate (since we are asked to draw the product and not the original acid).



Question 4

This question was designed to tempt those who have studied moles but could in fact be attempted by anyone, given the information in the question.

a) d

Symbol	Protons	Neutrons	Electrons
^{10}B	5	5	5
$^{16}O^{2-}$	8	8	10
$^{7}Li^{+}$	3	4	2

b) To have the same number of electrons as protons, the species must be neutrally charged – hence the answer must be Al.

c) To get the number of neutrons, we need to subtract the number of protons (the atomic number) from the mass number – the charges here are irrelevant.

The only one that works here is ^{13}C – 7 neutrons and 6 protons.

d) This question is designed to see whether candidates have an intuitive sense of orders of magnitude. A typical size for an atom is on the nm (10^{-9},)/Angstrom (10^{-10}m) scale.

e)

(i) The correct answer here comes from multiplying the number of moles by the number of H atoms. B gives 4.5 moles of hydrogen atoms; whereas all of the others give fewer.

(ii) Looking at the balancing numbers in the equation, we see that the ratio of oxygen to water is 1:2. Hence if 1.5 moles of oxygen are used, we should expect to form 3 moles of water.

(iii) From the equation we see that the ratio of hydrogen to oxygen is 2:1, hence 3 moles of hydrogen will have reacted. This is equivalent to $3 \times 6 \times 10^{23} = 18 \times 10^{23}$ molecules.

(iv) By the conservation of mass, there must be 18g of water produced (since there are no other products).

(v) Anhydrous copper (II) sulphate will turn from white to blue; or anhydrous cobalt (II) chloride from blue to pink.

f) It is important to recognise that the sum of the abundances must be 100%, hence we can express them as:

Isotope	Abundance
^{32}S	95.02%
^{33}S	x/100
^{34}S	(100 – 95.02 – x)/100 = (4.98 – x) /100

This allows us to create an expression for the RAM:

$$\left(\frac{95.02}{100} \times 32\right) + \left(\frac{x}{100} \times 33\right) + \left(\frac{100 - 95.02 - x}{100} \times 34\right) = 32.092$$

Solving this gives x = 0.76
And therefore:

Isotope	Abundance
^{32}S	95.02%
^{33}S	0.76%
^{34}S	4.22%

g)

(i) Counting along the Periodic Table, puts Lv in group 6 (or 16).

(ii) H_2Lv

(iii) Calcium has atomic number 20, so it must be the case that the element with atomic number 116 – 20 = 96 was collided with it. This gives us the answer Curium (Cm).