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A REPORT ON THE WORK SUBMITTED BY CANDIDATES IN THE 1967 G.C.E. EXAMINATIONS IN CHEMISTRY AT ORDINARY LEVEL

(ALTERNATIVE SYLLABUS T)

January 1968

REPORT ON ORDINARY LEVEL CHEMISTRY

GENERAL

The syllabus for this examination should be interpreted in the spirit of the Syllabus in Chemistry for Grammar Schools published in 1961 by the S.M.A. and A.W.S.T. The purpose of the course is to develop the students' abilities to draw valid conclusions from evidence, to devise experiments, to investigate simple problems, to understand and not just to memorise definitions and statements of chemical principles, to recall and to use functional information to support simple arguments, to apply a knowledge of facts and chemical principles to novel situations and to discuss simple topics of general chemical interest.

In the five papers set, an attempt has been made to strike a balance between questions designed to test the abilities given above and more conventional 'bookwork' questions. In each paper, enough questions of the latter type have been included to ensure a comfortable pass mark for those who have worked conscientiously through the course but have not been able to acquire any real depth of understanding of the subject.

The general standard of work has been high. There has been an exceptionally low proportion of very poor scripts and the better scripts have shown evidence of real chemical ability and a genuine understanding of the principles of chemistry. In answering the earlier papers, candidates showed an understandable tendency to avoid questions that appeared strange, although excellent answers to questions were written by some quite moderate candidates who were prepared to read these questions carefully and to give them a little thought. Moreover, it was encouraging to find in June 1967 that these simple problems were tackled with much greater confidence by a very high proportion of the candidates.

More detailed comments relating to the various sections of the syllabus are given below.

1. Descriptions of Experimental Work

Descriptions of the preparation, collection and reactions of the common gases and of qualitative tests for the identification of gases, anions and cations were usually very good. Preparations of bases and salts were not so well described: the use of concentrated acids followed by filtration is too common and there is much confusion about the solubilities of common oxides, hydroxides and salts. When candidates are asked to devise simple experiments for a particular purpose, good answers are less frequent. It appears that, in some schools, too little time is being given to simple experimental investigations and possibly too much to standard preparations of gases and to qualitative and volumetric analysis.

2. Chemical Industry

Outlines of manufacturing processes were generally well known and most candidates were able to write short lists of uses of important chemicals. There was, however, a general inability to write convincingly on topics of general chemical interest such as the fixation of atmospheric nitrogen.

3. Theoretical Chemistry

The understanding of chemical principles and the ability to apply these principles has generally fallen behind knowledge of descriptive chemistry, although the work submitted in the June 1967 examination showed a marked improvement in this respect. Many candidates with an extensive knowledge of facts show no real understanding of basic terms such as element, compound, oxidation, atomic weight and molecular weight.

Routine calculations on formulae and corrections to N.T.P. were usually carried out correctly but other calculations involving volumes of gases caused more trouble. Many failed to realise the simplicity of these problems and started all their calculations by writing down reacting weights when these were not required at all. Answers sometimes included obvious contradictions and showed a general lack of common sence. Statements such as 'Atomic weight is the number of times one gram of an element is heavier than one gram of hydrogen' were found, and correct definitions and statements of chemical laws were followed by illustrations showing that these definitions and statements had not been understood.

Too many candidates seem to regard work with standard solutions as a purposeless game during which a tap is turned off when a dye changes colour and the relationships

$$n_1 v_1 = n_2 v_2$$

and

$$\text{concentration} = \text{normality} \times \text{equivalent}$$

are mechanically applied. Volumetric problems that have not conformed to this pattern frequently revealed a complete lack of understanding of the principles on which the work is based.

4. Atomic Structure, Valency and Ionic Theory

The structures of atoms in terms of protons, neutrons and electrons and the ideas of combination by electron transfer or sharing were generally well known. There were, however, many mistakes when examples of electrovalent and covalent compounds were given. Sodium chloride and magnesium oxide were stated to be covalent and compounds such as water and ammonia to be electrovalent.

Questions on the ionic theory and the mechanism of electrolysis have usually been well answered. One of the more important applications of ionic theory in elementary chemistry is the use of ionic equations, but answers to questions involving these equations have been rather disappointing. The symbols Fe^{3+} and H^+ were sometimes thought to represent metallic iron and gaseous hydrogen and formulae such as $C^{4+}O_2^{4-}$ and H_2^+ were often given for carbon dioxide and the hydrogen ion. There appears to be a need for more practice in the use of ionic equations, not as an isolated topic but in the treatment of descriptive chemistry throughout the syllabus.

5. Organic Chemistry

Organic questions have not been popular nor particularly well answered. Formulae of organic compounds in general and structural formulae in particular have caused a lot of trouble and the valencies shown for oxygen and carbon have varied seemingly at random from 1 to 6.

6. Time wasting in Examination

It is understandable for a weak candidate to pad out with irrelevancies answers to those questions that he can attempt, but this practice was not uncommon in the scripts of those who showed a wide knowledge of chemistry. Detailed descriptions of preparations were given when they were not asked for and answers were illustrated by carefully drawn but unhelpful diagrams of beakers, filter funnels, test-tubes, pipettes and even human hands. While marks are not usually deducted for the inclusion of the unnecessary material, there is evidence that some good candidates waste so much time in this way that they lose marks by having to hurry through the remainder of their work.

THEORY PAPER

In answers to Question 1(*a*),

[Give the names of: (i) **three** gases, other than oxygen and nitrogen, that are present in the atmosphere, (ii) **two** compounds that, when dissolved in water, make the water hard.]

hydrogen was named far too often as an atmospheric gas.

Question 1(*b*) asked for equations for the action of heat on sodium bicarbonate, lead carbonate, lead nitrate and ferric hydroxide. The equations given were generally correct, the commonest mistake being

$$NaHCO_3 = NaOH + CO_2.$$

Statements of Boyle's law in answer to Question 1(*d*) frequently contained no reference to a fixed mass of gas.

In the calculation of the formula of ferric sulphide from its percentage composition in Question 1(*e*), nearly all candidates found the correct atomic ratio of 0·96:1·44 but at this stage a surprisingly large number, apparently not knowing how to proceed, wrote FeS as the formula of the only sulphide known to them.

Answers to Question 1(*f*)

[State briefly why each of the following statements is false.
(i) 'If 112·5 gm. of an element combine with 16 gm. of oxygen, the atomic weight of the element must be 112·5.'
(ii) 'Isotopes are atoms of different elements having the same atomic weight.'
(iii) 'Rusting is the combination of iron with the combined oxygen in water.']

showed that the meaning of 'isotope' was well known and that ideas about rusting were usually correct, but there was much confusion about combining weights. Answers such as

'The equivalent weight must be 112·5';

'The atomic weight of an element combines with 32 grams of oxygen';

and

'The atomic weight of an element will increase when it combines with oxygen' were common.

The terms 'diffusion' and 'osmosis' were frequently confused in answers to Question 1(*g*)

[Define or explain the meaning of the following terms: '*diffusion*', '*molecule*', '*saturated solution*'.]

and there were few precise answers involving definitions or explanations of a saturated solution.

Descriptions of the contact process asked for in Question 2(*a*) frequently included elaborate diagrams that did not help in any way to clarify the answers.

Question 3(*a*) provided a few easy marks for those with a little knowledge of the ionic theory.

[Dilute sulphuric acid is electrolysed in a beaker, using copper electrodes. Answer the following questions about this electrolysis.
(i) Give the formulae of **all** the ions present in the solution before electrolysis starts.
(ii) Give the formula(e) of any new ion (or ions) which will be present in the solution after electrolysis has been taking place for a few minutes.
(iii) Draw a simple diagram to indicate the direction of migration of the ions mentioned in (i) and (ii), and also the direction of flow of electrons in the circuit outside the beaker.
(iv) What changes, if any, would you **observe** at the anode, at the cathode, and in the solution?
(v) Explain the chemical change occurring at the anode (positive electrode).]

Really good answers, revealing a deeper understanding of the principles of electrolysis, were not uncommon. The problem in Question 3(*b*)

[Draw a labelled diagram of the apparatus you would use to electroplate a small object with a coating of a metal such as nickel or silver.
Do you think it would be possible to electroplate an object with magnesium? Give briefly the reasons for your answer.]

had the candidates thinking hard and there were many good, well-reasoned answers. Too often, however, statements such as 'Magnesium is high in the activity series and so will not ionise' or 'Magnesium will not conduct electricity' were encountered.

Question 4 was of an unfamiliar type but it produced many admirable answers. It was most encouraging to find many confident attempts.

[(*a*) 'Non-metallic elements of valency *n* usually form with hydrogen compounds of formula XH_n. These compounds, called hydrides, are generally covalent and gaseous. They vary from being very soluble to insoluble in water and may be acidic, basic or neutral in character.'
Illustrate these statements by reference to the simple hydrides of chlorine, sulphur, nitrogen and carbon.
(*b*) Aluminium forms the compounds $AlCl_3$ and Al_2S_3 with chlorine and sulphur. These compounds react with water as indicated by the following equations

$$AlCl_3 + 3H_2O = Al(OH)_3 + 3HCl,$$
$$Al_2S_3 + 6H_2O = 2Al(OH)_3 + 3H_2S.$$

(i) Write formulae for the compounds you would expect aluminium to form with nitrogen and with carbon.
(ii) Write equations for the reactions you would expect when the compounds in (i) are treated with water.

(iii) Suggest simple qualitative experiments by which you would attempt to confirm your expectations in (ii).]

Answers to Question 4(*a*) revealed, in some cases, an inability to set out information in an orderly way. Part (*b*) tested the candidates ability to reason by analogy. The poorer candidates were quite lost here, failing to see the point of the question. Many gave formulae for carbonates and nitrates in part (*b*) (i). The better candidate, however, scored high marks quite easily.

The inorganic sections of Question 5

[For each of the following, name the reagents used, give the conditions of reaction and write the equations:
(*a*) the preparation of oxygen from hydrogen peroxide,
(*b*) the conversion of ethylene into ethane,
(*c*) the preparation of concentrated nitric acid from a nitrate,
(*d*) the preparation of ethylene from ethanol (ethyl alcohol),
(*e*) the liberation of hydrogen from ethanol.
Diagrams, and details of collection and purification of products are **not** required.]

were generally well answered although reaction conditions were frequently omitted in the preparation of nitric acid. The organic sections were, as usual, less well known and some candidates could not even write correct formulae for ethanol, ethylene and ethane.

Question 6 was attempted by the great majority of candidates, but good answers were rare.

[(*a*) Crystals of naphthalene melt on heating to give liquid naphthalene and the liquid boils at a higher temperature to give gaseous naphthalene. Describe, in terms of naphthalene molecules, the differences between the solid, liquid and gaseous states.]

Ideas about the kinetic theory were often vague or badly expressed. A more careful reading of the question would have helped, since many of the answers discussed changes of state rather than differences between the three states of matter.

Answers to part (*b*)

[(*b*) Explain the following facts.
(i) Sulphur will not conduct electricity in the solid or the liquid state.
(ii) Copper will conduct electricity in both the solid and liquid states.
(iii) Sodium chloride will not conduct electricity in the solid state but will conduct electricity when molten.
(iv) Pure liquid hydrogen chloride and a solution of hydrogen chloride in toluene are non-conductors but a solution of hydrogen chloride in water will conduct electricity.]

revealed much confusion about metallic and electrolytic conduction. There were many references to the carrying of current by ions in

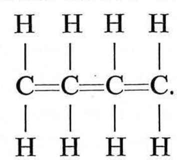
metallic copper and by electrons flowing between the 'molecules' of sodium chloride. Few candidates knew anything about the interaction between water and hydrogen chloride.

Question 7 was largely numerical and seemed rather difficult at first sight.

[It is found that 4 gm. of oxygen, 7 gm. of the gaseous compound butylene and 10·5 gm. of the gaseous element krypton all occupy the same volume at the same temperature and pressure.
(i) What fraction of a gram-molecule is 4 gm. of oxygen?
(ii) Calculate the molecular weights of butylene and krypton.
(iii) The empirical (simplest) formula of butylene is CH_2. What is its molecular formula?
(iv) The atomic weight of krypton is 84. What is the atomicity of krypton?
(v) Write a possible structural formula for butylene.
(vi) Give the name and structural formula of another compound having the empirical formula CH_2.
(vii) Write the equation for the burning of butylene in oxygen to give carbon dioxide and water.
(viii) If 10 ml. of butylene are burnt according to your equation, calculate the volume of oxygen used and the volume of carbon dioxide formed (all volumes at the same temperature and pressure).]

In spite of this, it was gratifying to find a large number of attempts. The better candidates scored very high marks while the weaker ones usually found some parts that they were able to answer. A common error was the use of 16 as the molecular weight of oxygen. This, of course, led to wrong answers to the other parts of the question but this mistake was not too heavily penalised and respectable marks could be obtained by those who showed an understanding of the chemical principles involved in the later sections. The meaning of 'atomicity' was not always known and structural formulae for the olefines often showed valencies of 5 or 6 for carbon. The formulae of unsaturated hydrocarbons have given trouble in previous papers, a very common error being the writing of formulae with all the carbon atoms joined by double bonds,

e.g.



In Question 9(*a*), many marks were lost through lack of care in reading the question.

[Name **three** gases that can be prepared by the action of a dilute acid on a solid **compound**. For **each** gas, name the acid and solid compound used, and write an equation for the reaction.

If you found, on carrying out one of these preparations, that the reaction was too slow, suggest **two** ways, other than the use of a catalyst, by which you could make it faster.]

Apart from this, the gas preparations were generally well known. The problem in the second part of the question

[Dilute sulphuric acid was added to an excess of granulated zinc. It was noticed that hydrogen was evolved very slowly at first. The rate of evolution of gas increased rapidly for about two minutes and then gradually decreased until the reaction stopped. Attempt to explain these observations.]

produced many good well-reasoned answers. Credit was given for any plausible explanation of the observations. However, it was not always realised that an acid must become progressively less concentrated as it reacts with metal. The slowing-down of the reaction was frequently attributed to the formation of a coating of 'insoluble' zinc sulphate on the granules of metal.

THE PRACTICAL TEST

The average level of attainment seems to remain fairly constant. There are fewer completely worthless scripts than formerly but there does not appear to have been a corresponding improvement at the upper end of the mark range.

Volumentric Analysis

Changes take place in the type of calculations asked for in the volumetric analysis question, though of course the practical work involved does not alter. Accuracy is the essence of quantitative analysis, and errors made in the answers to this question suggest that teachers do not sufficiently drive home the need for accuracy in both titration and calculation. This is shown in the following ways.

(i) What is sought in titration is a small number of concordant burette readings. Candidates should be warned that taking the average of a number of widely varying results is not acceptable and will be penalised. A recent paper produced the most extreme example of this practice yet found—a candidate who repeated the titration ten times, obtained values varying by up to 2 ml., and averaged them all!

(ii) Candidates are too ready to approximate their figures. They should be told that repeated approximation decreases, not increases, accuracy.

(iii) Burette readings should be given to the nearest tenth of a millilitre. Attempts at this level to estimate the second place of decimals are valueless.

Changes in the form of calculation have involved, for example, asking for gram-formula weights or molar quantities instead of equivalents, or asking for volumes of reacting solution equivalent to these quantities. Those candidates who are able to attempt the calculation at all have no difficulty in adapting to the slightly unfamiliar form of calculation. Indeed it was refreshing to see by what varied methods candidates were able to work out from first principles the results required. The weak candidate, on the other hand, is exposed. He can use the stock formula

$$n_1 v_1 = n_2 v_2$$

but he cannot go further than that into unfamiliar ground.

There is much incidental error in computation such as wrongly placed decimal points. Again and again in one recent paper the value $\frac{12}{40}$ was cancelled down to $\frac{3}{10}$ and then down to $\frac{1}{3}$ or 0·33; in many cases logarithms were used to work out the first stage. A correct value for the final answer was often obtained by a double error in placing decimal points.

Observational Experiments

The observation question earns high marks for those who can observe and record with care. Candidates should not approach this question with preconceived ideas as to what the substance is. This leads them to record (or to observe) only what fits in with their ideas. The errors which lead to the greatest loss of marks in this question are

(i) failure to add reagents in excess, and to mix the solutions thoroughly on addition.

(ii) failure to detect gases, usually by not testing for them in time, but waiting until all the gas has been evolved.

Qualitative Analysis

The third question—on qualitative analysis—is often answered very well. It is not difficult to obtain full marks on this question. The great stumbling-block for the weaker candidates is in preparing a true solution for the tests. A suspension is often called a solution; this suspension is filtered, and then there is confusion between filtrate and residue, so that the examiner cannot be sure what is being tested. As well as stating how a solution was made, it is necessary to describe (briefly) the test done, and the result observed. To say 'carbon dioxide test: positive, therefore carbonate' is valueless; this is not an adequate description. Many candidates show lack of thought, or just plain foolishness, e.g. in adding hydrochloric acid and detecting a chloride, or ammonia solution and then discovering ammonia gas, among the products.