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Compositien and solvation chemic al problems with two correct answers

Abstract: Our aim is: to develop the ability to implement the knowledge on constructing graphs of linear function in chemical problem solution. Solution to chemical problems is considered by the graphic method, for which it is necessary to use the knowledge on construction of a linear function graph **Proportional dependence between the known quantities and unknow**n **quantities** serves as a mathematical base for the value of solution to problems on chemical formulas of substances or equation of chemical reactions. **Dependence of one variable on another is called functional dependence** or **function** the value of which can be illustrated graphically.

Keywords: Functional dependence, calculation problems, interdisciplinary links, graph of a direct proportionality, graphic method of solution, linear function, amphoteric hydroxide.

Introduction

The role of mathematics is traditionally great in teaching natural scientific disciplines including chemistry. Skills of mathematical analysis enable pupils to interprete the changes occurring in chemical compounds and to identify their patterns of change Problem solution is an important component in the process of teaching chemistry [1].

Problem solving is an important component in the process of teaching chemistry, using a variety of methods for solving chemical problems (comparison methods, bringing to unit, tabulation, algebraic Ерыгин, as well as graphic Э.Г. Злотников), which, without any exception, are based on the definite mathematical knowledge and logics of the learners. In this sense we can state that the interdisciplinary links of chemistry and mathematics are applied and used practically during all the lessons of chemistry.

The solution to calculation problems is the utmost important part of the subject “chemistry” at school, as it is one of the ways of teaching, which provides a deeper and fuller mastering of teaching material on chemistry and helps to work out the skills of independent use of the obtained knowledge Пузаков. To study chemistry efficiantly, a regular learning of the truth universally acknowledged in chemistry combined with independent search for the solutions to the problems starting from the smaller and later passing to the greater ones is necessary. No matter how interesting the theoretical parts of the text-book and qualitative experiments of the practical training are, they are not enough without the numerical conformation of the theory conclusions and experiment results: chemistry is a quantitative subject, isn’t it? Inclusion of problems into the teaching process allows to realize the following didactic principles of teaching: 1. obtaining firm knowledge and abilities; 2) provision of learners with independence and activity; 3) implementation of teaching-life link.

In the process of teaching chemistry you can often meet complicated problems which have a very interesting way of solution. However, you can rarely meet such problems when the solution brings to two correct answers, i.e. two answers simultaneously meet the demand of the problem and they both are right [2]. As an example of such problems, let us consider the chemical reaction of carbon-dioxide gas absorbtion by solution of barium hydroxide. In this problem dependence of variable m($BaCO_3$) on variable n(CO_2) is a linear function as a definite value of m($BaCO_3$) corresponds to each value of n(CO_2)

$$M(BaCO_3) = k \cdot n(CO_2) \quad \Longrightarrow \quad k=197 \text{ g/moles}$$

On the basis of the reaction equation it is obvious to anticipate that along with the increase of carbon dioxide blown into the solution the mass of the formed sediment i.e., barium carbonate increases. However, this process will last until all the calcium hydroxide turns into calcium carbonate.

$$Ba(OH)_2+CO_2=BaCO_3\downarrow +H_2O \qquad (1)$$

Let us suppose that carbon dioxide gradually and proportionally passes into solution containing 171 g (1 moles) barium hydroxide. At the beginning of the process when there is a great abundance of hydroxide in the solution, the carbon dioxide, introduced into the solution, changes into barium carbonate, which is discharged from the solution in the form of sediment and the mass of which gradually increases. It's obvious, that maximal quantity of the sediment corresponds to the complete binding of the barium in the form of carbonate, i.e., when the whole barium hydroxide enters the reaction with one mole of carbon oxide. We form a segment corresponding to picture 1 (pic. 1, segment OA). From the point, stating the mass of barium carbonate, we draw an additional **y**-axis for constructing a segment characterizing the second reaction, and by means of the latter to find the mass of the sediment, taking into consideration that the beginning of the second segment coincides with the end of the first one.

When increasing the quantity of carbon dioxide, the process of barium carbonate dissolution begins which takes place according to the following reaction equation:

$$BaCO_3\downarrow + H_2O + CO_2 = Ba(HCO_3)_2 \qquad (2)$$

According to this reaction the linear function is expressed by the following equation:

$$m(BaCO_3) = 197 \cdot k\ (2 - n\ (CO_2)\ )$$

Under the influence of carbone dioxide abundance, the mass of the sediment gradually decreases, and, eventually, the moment comes when the solution again becomes transparent due to the transfer of barium carbonate into soluble hydrocarbonate. After conducting the mentioned operations two segments are achieved (pic. 1, segment OA and AB).

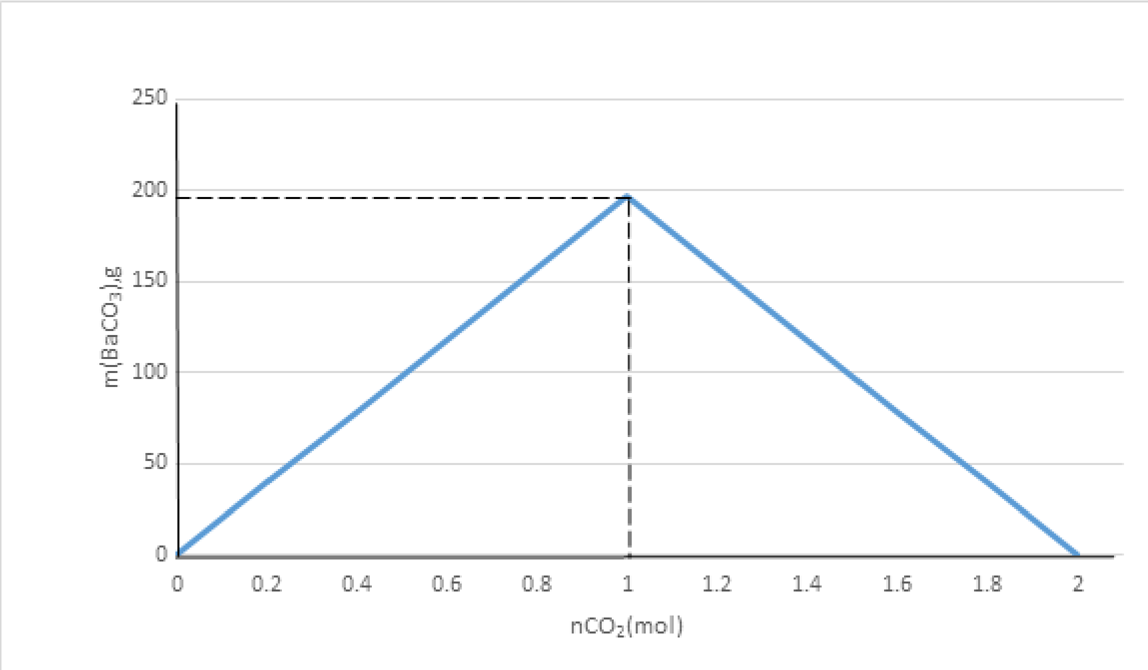
To construct a graph of a direct proportionality a table of several values of $m(BaCO_3) = 197 \cdot n(CO_2)$ and by (1) reaction

$m(BaCO_3) = 197 \cdot K \cdot (n(CO_2)-1)$ function is created. by (2) reaction

Table 1. Masses of the formed sediment of $BaCO_3$ depending on the quantity of CO_2 (mole) added (introduced) into the solution

$m(BaCO_3)$, g	0	39,4	78,8	118,2	157,6	197	157,6	118,2	78,8	39,4	0
$n(CO_2)$, мole	0	0,2	0,4	0,6	0,8	**1**	1,2	1,4	1,6	1,8	**2**

We will present the data in the form of a chart adding along the ordinate axis the formed barium carbonate mass (g), and along the abscissa axis quantity of carbon oxide (IV) (mole).



Pic. 1. Dependence of $BaCO_3$ mass on carbon oxide quantity (IV)

Any straight line is defined by its own two points. This is why the construction of a chart of a direct proportional dependence in solving chemical problems will be enough to find the coordinates of the two points of the graph. As one of such points is expedient to take the beginning of the coordinate, and the second point is defined by corresponding quantities (segment OA), found by the formula of the matter or equation reaction.

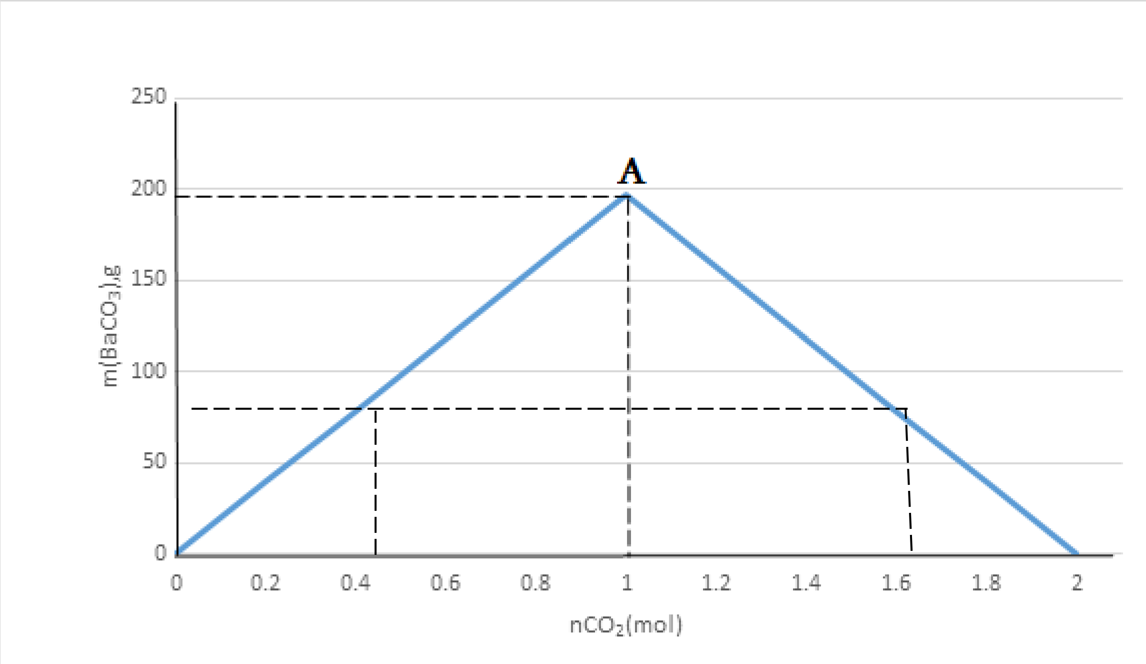
The obtained chart serves as a base for solving problems. Let's review the course of the solution of such a problem.

Problem 1

In adding of what quantity of CO_2 (mole) into unimolar water solution of $Ba(OH)_2$ is obtained identical mass of $BaCO_3$ sediment equal to 78,8 gr?

Solution

From the obtained chart (pic. 1) it is obvious that the vertical, going down along the oordinate axe, crosses the drawn curved line in two points, showing on the absciss axe two possibly different quantities added into the carbon dioxide alkaline solution. To one of these values corresponds the barium carbonate mass in the phase of its formation, and the second value is conditioned by the partial dissolution of the sediment after its quantitative precipitation, which takes place under the influence of carbon dioxide gas excess. The same mass of barium carbonate, i.e., 78,8 gr, is formed in case when 0,4 mole CO_2 is transmitted through $Ba(OH)_2$ solution. In another case such a mass of barium carbonate is obtained when after the complete conversion of entire 171 gr (1 mole) of $Ba(OH)_2$ into such a quantity of $BaCO_3$, additional 0,6 mole is added through the obtained solution, i.e., only 1,6 mole CO_2.



Pic. 2. Dependence of barium carbonate mass on carbon oxide (IV) quantity

I.e., the same quantity of calcium carbonate is obtained in two different quantities of CO_2, hence, two right answers meet the demand of the question: the formation of 78,8 gr $BaCO_3$ takes place if in one case 0,4 mole CO_2 and in the other case 1,6 mole CO_2 passes through the solution containing 171 gr (1 mole) $Ba(OH)_2$.

It should be mentioned that from the base of the obtained OAB triangle to the top, to its maximal point, two separate quantities absorbed by the carbon dioxidesolution will meet any value of the sediment mass. Hence, the obtained results can be ofered as one of the methods of solving analogous problems, mainly, as a graphic method of problem solving.

Problem 2.

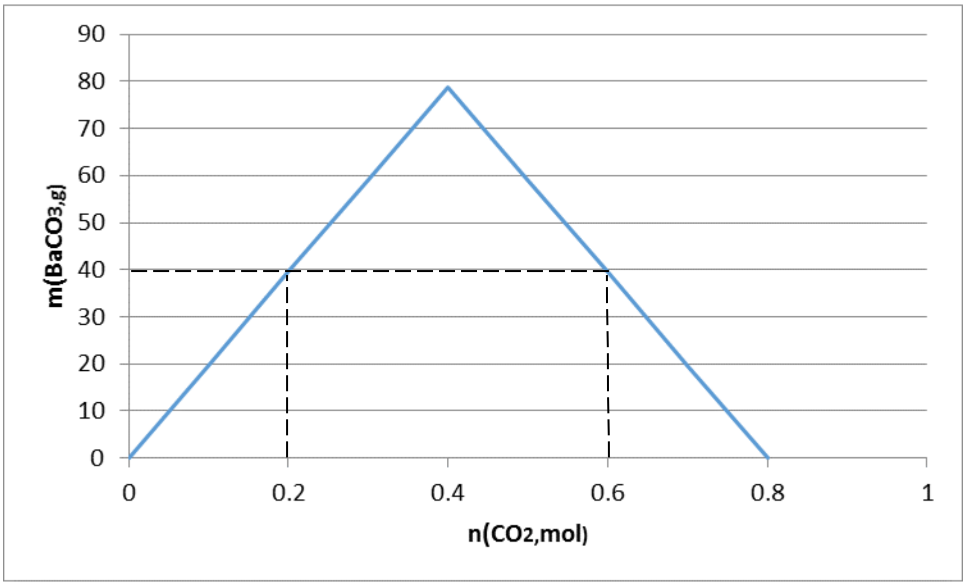
1. What volume of carbon oxide (IV) was absorbed by 200 gr barium hydrocide solution with the 34,2 % mass portion, if the mass of the formed sediment is 39,4 gr, and the final (finite) solution doesn't contain alkali?

Solution

The solution contains (200·34,2)/100 = 68,4 gr $Ba(OH)_2$ which composes 68,4/ 171 = 0,4 mole ($M_{Ba(OH)2}$ =171 g/moles). According to the equation reaction (1) with the increase of the quantity of carbonate gas blown into the solution,the mass of the formed barium carbonate sediment increases up to its complete formation,after which in case of excess carbone gas, according to the equation reaction (2) dissolution of the sediment starts. Taking into account the conditions of the problem, once more we define the possible quantities of carbonate gas necessary ffor obtaining 39,4 gr sediment of $BaCO_3$ and present the data in the form of table (table 2).

Table 2. Masses of obtained $BaCO_3$ in different quantities of CO_2 added into solution

n(CO_2), (мole)	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8
m($BaCO_3$), (g)	19,7	39,4	59,1	78,8	59,1	39,4	19,7	0



Pic. 3. Dependence of barium carbonate mass on carbon oxide quantity (IV)

The data presented in table 2, we will present in the form of a chart, arranging along the oordinate axe the mass of formed barium carbonate (gr), and along the absciss axe – the quantity of carbonate gas (mole) (pic. 3).

And now, on the oordinate axe showing the $BaCO_3$ mass, we shall note the point corresponding to 39.4 g mass and it will assure us once more that the vertical going down from that point will cross the drawn curved line in two points showing two different and necessary for obtaining 39,4 g $BaCO_3$ quantity of carbone gas, mainly: in the first case, when 0,2 mole passes through $Ba(OH)_2$ solution or 0,2.22,4 = 4,48 l CO_2 (table 2). The same amount, i.e.,39,4 gr $BaCO_3$ remains in the sediment, if after the complete precipitation of $BaCO_3$ by reaction (1), i.e., after complete convertion of the entire $Ba(OH)_2$ (0,4 mole) into $BaCO_3$, additional 0,2 mole is added into the solution, i.e., on the whole 0,6 mole or 0,6.22,4 =13,44 l CO_2 (table 2). Thus, the same mass of barium carbonate is obtained in one case when 4,48 l CO_2 is absorbed by $Ba(OH)_2$ solution, and in the other case in presence of 13,44 l CO_2 in the solution (pic. 3).

The answer is 13,44 l CO_2.

If the metal hydroxide doesn't possess amphoteric properties, hydroxides, formed from the aqueous salt solutions of corresponding metals under the influenceof alkalines, are discharged in the form of sediment and they don't undergo any further changes under the inluence of excess alkaline. This is typical of many hydroxides that are difficult to dissolve, e.g.

$$MgCl_2+2NaOH=Mg(OH)_2\downarrow+2NaCl \qquad (3)$$

Problem 3.

Calculate the mass (g) of magnesium hydroxide, which is precipitated when 800 ml unimolar solution of sodium hydroxide is added to 375 g 19% solution of magnesium chloride.

Such problems are solved by different methods, but they are easily solved by the graphic method [1].

Graphic method of solution

In problem 3 dependence of variable $m(Mg(OH)_2)$ on n(NaOH) variable quality is a function. For our example $m(Mg(OH)_2)$ = k.m(NaOH), k = 58/2 = 29.

To draw a chart of direct proportionality, we make up a table of somel values of the function $m(Mg(OH)_2)$ = 29.n(NaOH).

Table 3. The masses of formed sediment of ($Mg(OH)_2$ depending on the quality of NaOH(mole) added into solution

n (NaOH), mole	0	0,25	0,5	0,75	1	1,5	2
m($Mg(OH)_2$), g	0	7,25	14,5	21,75	29	43,5	58

We are drawing a graph of direct proportionality dependence according to the table (fig. 4).

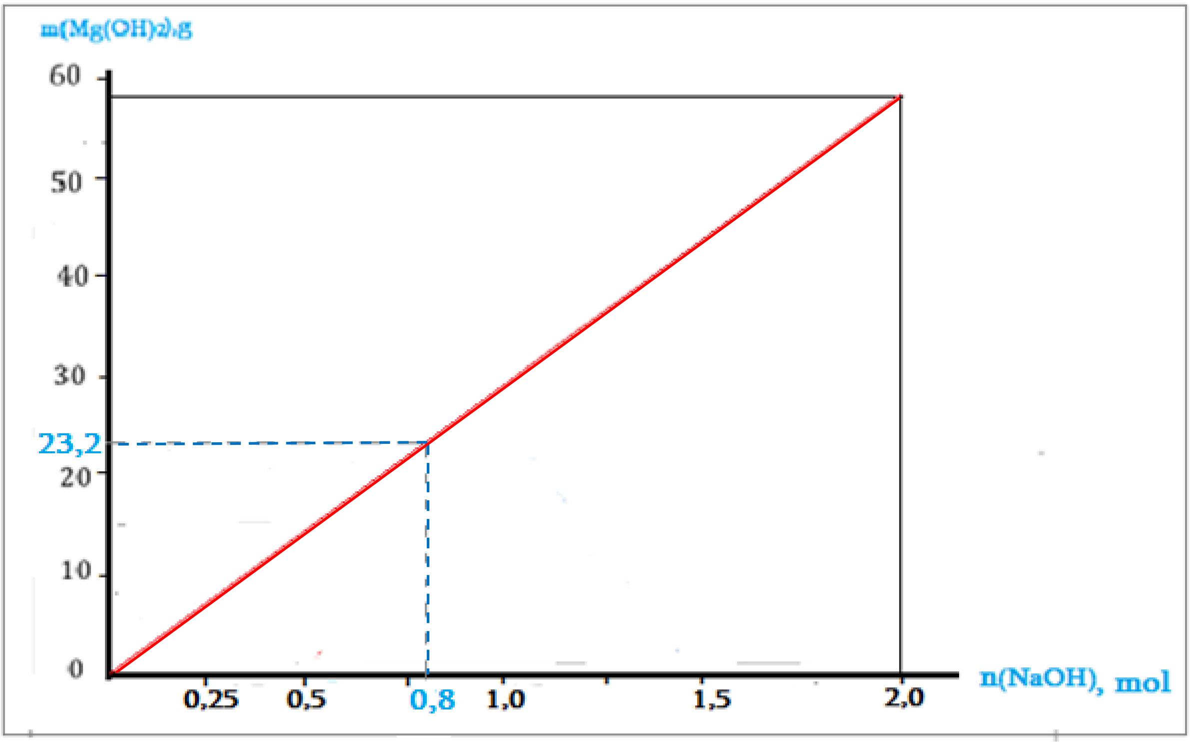


Fig. 4. The dependence of the mass quality of magnesium hydroxide, sodium hydroxide

To solve this problem from the point corresponding to number 0.8 (n)NaOH)=0.8) on the absciss axe is conducted perpendicular up to the intersection with the straight line OA. From the point of intersection a straight line is drawn parallel to the absciss axe and an ordinate point is obtained which shows the quantity of the magnesium hydroxide mass equal to 23.2 g. The answer is 23.2 g $Mg(OH)_2$. Graphical solution of problems of this type are described in the book of D.P. Erygina [1].

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