

## Wet synthesis of high purity crystalline urea phosphate from untreated Moroccan industrial phosphoric acid

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### Abstract

The phosphorus-nitrogen fertilizer family improves the availability of phosphorus and nitrogen for efficient crop growth. Urea phosphate 17-44-0 (N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O%) is considered as a binary fertilizer characterized by its high purity and it is easily soluble in water. In addition, urea phosphate can be used in other fields as a high-quality food additive, finishing agent for metals and fermentation food. As a fertilizer, it is suitable for alkaline soils. In this work, a new process for the synthesis of urea phosphate by the wet route is developed. It consists in directly producing crystalline urea phosphate by the chemical reaction between Moroccan industrial phosphoric acid (54 % P<sub>2</sub>O<sub>5</sub>) and solid urea (46 %). The synthesis is carried out by mixing the solid urea with a stoichiometric amount of untreated Moroccan industrial phosphoric acid. The chemical reaction is complete for optimal conditions which are a temperature of 50 °C and a duration of 90 min. After cooling, the urea phosphate crystals are formed without any additional treatment and are easily recovered. Analysis of the residual liquor after recovery of the urea phosphate crystals confirms that the majority of impurities which may be harmful to the environment pass into the liquid phase

**Keywords:** Fertilizer; Urea Phosphate; wet process, phosphoric acid purification.

## 1. Introduction

Today it is very difficult in agriculture to obtain good yields without adding fertilizers (chemical or organic). These fertilizers improve the chemical properties of the soil and offer it the essential plant nutrients to reinforce the growth of plants. However, the applications of these fertilizers are also dangerous for the environment if their use is not optimized. Among the essential nutrients, which supplied the soil systems are: nitrogen (N), phosphorus (P) and potassium (K). These elements are considered as primary or macronutrients and used in large amounts compared to other nutrients (Ca, Mg, S, Zn, ...) [1]. The nitrogen fertilizers derive generally from the oxidation of ammonia by combustion. These types of fertilizers can be produced in three forms: (i) gaseous: anhydrous ammonia; (ii) liquid: a solution of urea and ammonium nitrate in water used as a fertilizer (UAN); or (iii) solid: ammonium nitrate, ammonium sulfate and urea ( $\text{CO}(\text{NH}_2)_2$ ). Due to its low cost and good storage, urea (46 % N) is usually applied in agriculture for different soils needing nitrogen fertilizer. When urea is spread in soil, a series of chemical, physical and biological reactions are occurred. The most significant of these reactions is urea hydrolysis (urea's conversion to  $\text{NH}_4^+$ ) and the volatilization of  $\text{NH}_3$  which causes a loss of nitrogen from the fertilizer [2,3]. In addition, Mikkelsen [2] has indicated that the urea application can generate the formation of Biuret, which is toxic to plants. In the same order, the phosphorus fertilizers are also important in agriculture. They are widely mixed with nitrogen and supplemented by other potassium varieties (potassium sulfate, potassium chloride and potassium nitrate) [4]. Phosphorus fertilizers are subdivided into three types: (i) granular simple: single (SSP) or triple (TSP) superphosphates; (ii): granular mixed such as monoammonium (MAP) and diammonium phosphate (DAP); and (iii) liquids containing mainly ammonium polyphosphate (APP) [5]. Generally, the manufacture of these phosphorus fertilizers is mainly from phosphoric acid ( $\text{H}_3\text{PO}_4$ ) by the wet process. In order to produce phosphoric acid from the phosphate rock, two processes can be envisaged the thermal and the wet. The thermal process consists to produce elemental phosphorus at high-temperature, which is oxidized to  $\text{P}_2\text{O}_5$  then hydrated to phosphoric acid. The obtained phosphoric acid is very pure and intended for the food manufacture and the pharmaceuticals industry [6]. The wet process represents about 90 % of the total production of phosphoric acid. This involves the production of phosphoric acid by attacking the phosphate rock with concentrated sulfuric acid. Also, a by-product called phosphogypsum (mostly calcium sulfate), was generated during this process. Generally, the phosphoric acid composition depends on the phosphate rock origin, the acid strength and the process conditions [7]. In Morocco, phosphoric acid can be produced through two wet processes: the dihydrate and the hemihydrate-dehydrate process. The obtained phosphoric acid contained around 27-29 %  $\text{P}_2\text{O}_5$ , which is concentrated by evaporation to produce merchant-grade phosphoric acid with 52-54 %  $\text{P}_2\text{O}_5$  [8]. In addition, phosphoric acid produced by these processes contains various impurities (effectively Cd and U), which affect the quantity and the quality of this acid. For this reason, numerous patents and techniques have been examined for purifying phosphoric acid, like as: concentration, crystallization, addition of additives, solid-liquid extraction or liquid-liquid extraction. However, the use of these techniques was restricted by several disadvantages such as: limited efficiency, high costs of additives, difficulty to recover the additives and formation of some hazardous by-products [9–11]. In this work, a suitable method is presented to produce high-quality of urea phosphate ( $\text{CO}(\text{NH}_2)_2 \cdot \text{H}_3\text{PO}_4$ ) from urea and untreated Moroccan phosphoric acid. The importance of this process comes from producing the urea phosphate with high efficiency under easier conditions. Thus, after crystallization of the urea phosphate, the majority of the impurities initially contained in the phosphoric acid remain in the liquid phase. Also, the produced urea phosphate could be used as intermediate for purifying Moroccan phosphoric acid [12]. In order to confirm the quality of the urea phosphate synthesized, several technical analyzes were carried out. Due to its physical and chemical proprieties (white crystalline, high solubility in water, acidic pH, content of 17 % N and 44 %  $\text{P}_2\text{O}_5$ ), urea phosphate is classified as a valuable product for the agriculture. It can be used principally as finished fertilizer, intermediate in the production of the polyphosphate fertilizers and as animals feed. In recent years, urea phosphate was also successfully utilized as a special cleaner, a fire retardant and an active component in certain detergents [13–16].

## 2. Materials and methods

The phosphoric acid used in this work is merchant-grade (52 % as  $\text{P}_2\text{O}_5$ ). It's produced by the wet process from the fertilizer plant Maroc Phosphore. This phosphoric acid was used directly without any treatment to remove the

impurities that it contains. Urea in the granular form is obtained from the local market. The urea phosphate was prepared by mixing stoichiometric amounts of phosphoric acid and urea (1:1) in aqueous solution under constant stirring (150 tr/min). The chemical reaction of this process can be expressed as following:



Generally, the reaction of the phosphoric acid and urea is exothermic, but the complete dissolution of the urea grains takes a very long time. For this reason we heated the mixture to accelerate this reaction. After a necessary reaction time, the reactional mixture was cooled at room temperature to precipitate the urea phosphate. Then, this obtained urea phosphate crystals was filtered through a Buchner and dried in the ambient area in a desiccator for enough time until they get dry. The residual liquor is recovered for chemical analysis. In order to define the optimum conditions for the urea phosphate process, a design of experiments "DOE" (Software Nemrodw) was used. The chemical elements concentrations of urea, phosphoric acid, produced urea phosphate and residual liquor were determined by inductively coupled plasma mass spectrometry (ICP-OES ICAP 7400 DUO used standard NF EN ISO 11885). The total  $\text{P}_2\text{O}_5$  and N contents of the all samples were determined by using colorimetric technic (standard NF U42-246, spectrophotometer UV-1900 SHIMADZU) and the Kjeldahl method (standard U42-118) respectively after necessary calibration. The density of phosphoric acid was measured by water psychometry technique, while the rate of solid (ROS) in this acid was deduced by centrifugation technic (standard NF T90-105-2). The acid was centrifuged and the retained solid materials are washed in order to remove the impregnating phosphoric acid then dried and weighed. The mineralogical composition of the urea phosphate crystals was carried out using X-ray powder diffraction (XRD diffractometer BRUKER D8 Eco with  $\text{CuK}\alpha$  radiation  $\lambda=1.5418 \text{ \AA}$ ). Infrared spectrum was performed by Fourier transform infrared spectroscopy (Thermo Scientific Nicolet iS10 FT-IR Spectrometer) using ATR technique. The thermal behavior of the produced sample was investigated by differential thermal analysis (DTA) and thermogravimetric analysis (TGA) (DTG-60 type SHIMADZU).

### 3. Results and Discussions

#### 1) Chemical analysis of the phosphoric acid and the urea

The chemical analyses of the phosphoric acid ( $\rho=1.664 \text{ g/cm}^3$ ) and urea are shown in Table 1. In the light of these analyses, we can notice clearly that the composition of the phosphoric acid was dominated by  $\text{P}_2\text{O}_5$  (52.23 wt%) beside various impurities (S, Mg, Na, Ca, Zn...). This composition remains closer to that obtained by Aboulhassane et al [10] for a phosphoric acid ( $\rho=1.681 \text{ g/cm}^3$ ) issued from the same fertilizer plant. Several impurities in phosphoric acid are dissolved initially and rest unstable or subsequently precipitate. Generally, the presence of these impurities can be originated from: (i) the phosphate rock; (ii) the sulfuric acid used; (iii) the corrosion in the process plant; (iv) the water used during the various stages of phosphate rock digestion; (v) the compounds (effectively the organic matter) introduced during filtration. Thus, the existence of this several impurities affects rigorously on the color, density, viscosity, turbidity, and filterability of the acid [17]. For urea, the chemical analysis shows well that this sample contains about 45.89 % N. The content of nitrogen in this urea is almost closer than that of other urea in the world, which is generally almost 46 % N [18,19]. Urea contained also a low amount of some impurities such as P, Na, Ca, S and Mg. The presence of these impurities is due essentially to the initial reagents or to the different agents supplied to the synthesise of urea [19].

**Table 1.** Chemical analysis of Moroccan wet process phosphoric acid and urea.

Composition (wt %)	$\text{P}_2\text{O}_5$	N	$\text{SO}_4^{2-}$	CaO	$\text{Na}_2\text{O}$	$\text{K}_2\text{O}$	$\text{SiO}_2$	MgO	$\text{Fe}_2\text{O}_3$	$\text{Al}_2\text{O}_3$	ROS	Zn (ppm)	Cd (ppm)
Phosphoric acid	52.33	--	3.12	0.04	0.15	0.01	0.12	1.23	0.26	0.10	0.53	366.1	9.56
Urea	0.45	45.89	0.05	0.07	0.20	0.01	0.01	0.06	0.00	0.01	--	10.96	0.00

#### 2) Optimization of the urea phosphate production

In order to define the optimum conditions to synthesise Moroccan urea phosphate, we have established a design of experiments "DOE" (Software Nemrodw). Several factors can influence the chemical reaction, so we agreed to vary

two factors (chemical reaction temperature and chemical reaction time) while operating with the Nemrodw software an experimental plan at three levels which are presented in Table 2. The response values observed with different combinations of the two factors with three levels are listed in

We can conclude from  $R^2$  and  $R^2_{\text{Adjusted}}$  that the quality of our model is good. The coefficients  $b_{1(3-1)}, b_{2(2-1)}, b_{2(3-1)}$  are almost have no significant effects they showed that these factors have no influence on the synthesis of urea phosphate since its risk of significance v-sign successively equal 92.5 % ; 9.7 % ; 7.7 % is more than 0.05 with a low contribution of the factors compared to other 0 to 8 % (

Table 5 ), on the other hand the coefficients  $b_{1(2-1)}, b_{1(3-2)}, b_{2(3-2)}$  have a significant influence on the %  $P_2O_5$  because the meanings of the v-sign risks are less than 0.05 (

Table 5). The graphical study of the effects and the pareto approach clearly presents the contribution percentages of the factors and their effects in the influence on the %  $P_2O_5$  response (Figure 1).  $b_{2(3-2)}$  is the factor of the reaction time during 90 min, it is the factor most influencing the synthesis of urea phosphate with a contribution alone by 32.38 % in the variability of the studied response. Then the factor  $b_{1(3-2)}$  of the reaction temperature 50 °C come in second place with a contribution of 26.33 %. Also the graphs of total effects and cumulative Pareto effects confirmed the optimal time and temperature of the reaction (50 °C; 90 min) to obtain the best %  $P_2O_5$  of urea phosphate production (Figure 2).

Table 3. Since we used a screening plan on a first degree mathematical model without interaction, the model will be as follows:

$$Y = b_0 + b_{1(2-1)}X_1 + b_{1(3-1)}X_2 + b_{1(3-2)}X_3 + b_{2(2-1)}X_4 + b_{2(3-1)}X_5 + b_{2(3-2)}X_6 + \varepsilon$$

$b_0$  Represents the theoretical mean value of the response

$b_{1(2-1)}, b_{1(3-1)}, b_{1(3-2)}, b_{2(2-1)}, b_{2(3-1)}, b_{2(3-2)}$  the main effects of factors  $X_1, X_2, X_3, X_4, X_5$  and  $X_6$  respectively.

Statistical significance and the quality of the model (

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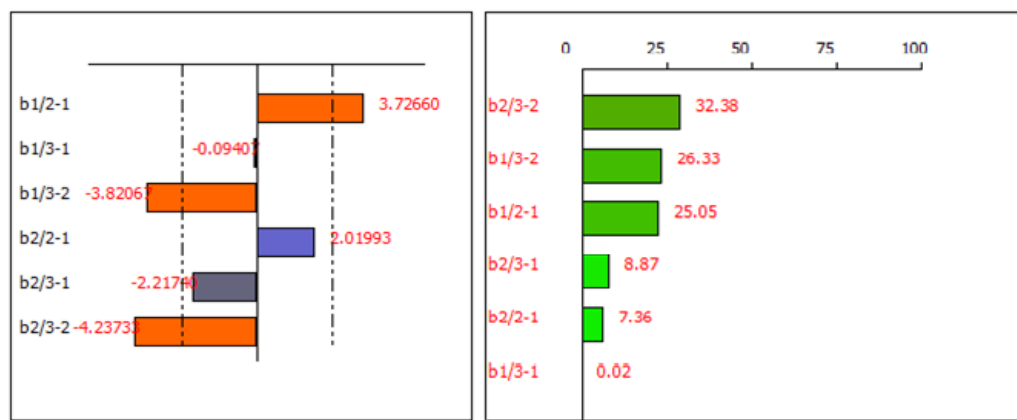
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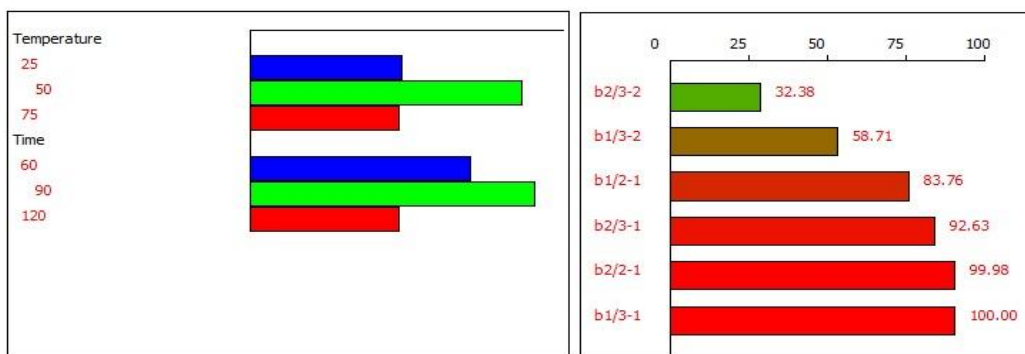
Table 3) was successively checked by the analysis of variance at the level of significance  $2.12\% < 5\%$  [20,21] and by  $R^2=0.913$  which makes possible to conclude that the model explains the 91.3% of the phenomenon studied.  $R^2_{\text{Adjusted}}$  gives us an idea on the quality of adjustment and the choice of the model (Table 4).

**Table 2.** Description of factors and response

	Unit	Level 1	Level 2	Level 3
Temperature	°C	25	50	75
time	min	60	90	120



**Figure 1.** Graphic Study of the effects at the approach of Pareto



**Figure 2.** Total effects and cumulative Pareto effects

We can conclude from  $R^2$  and  $R^2_{\text{Adjusted}}$  that the quality of our model is good. The coefficients  $b1_{(3-1)}$ ,  $b2_{(2-1)}$ ,  $b2_{(3-1)}$  are almost have no significant effects they showed that these factors have no influence on the synthesis of urea phosphate since its risk of significance  $v$ -sign successively equal 92.5 % ; 9.7 % ; 7.7 % is more than 0.05 with a low contribution of the factors compared to other 0 to 8 % (

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**Table 3.** Design of experiments "DOE"

N° d'Exp	Temperature °C	time (min)	P <sub>2</sub> O <sub>5</sub> %
9	25	60	42.2082
7	25	90	43.0120
2	25	120	39.2520
6	50	60	44.3840
1	50	90	43.9600
3	50	120	44.1820
8	75	60	41.2600
4	75	90	44.7140
5	75	120	38.2160

**Table 4.** Analysis of variance

Source of variation	Sum of squares	Degrees of free	Medium square	Report	Signif (5%)
<b>Regression</b>	55.4459	4	13.8615	10.5402	2.12 *
<b>Residues</b>	5.2604	4	1.3151	/	/
<b>Total</b>	60.7063	8	/	/	/
<b>R<sup>2</sup></b>	0,913				
<b>R<sup>2</sup><sub>Adjusted</sub></b>	0,827				

**Table 5.** Effects of the model coefficients for the % P<sub>2</sub>O<sub>5</sub> response

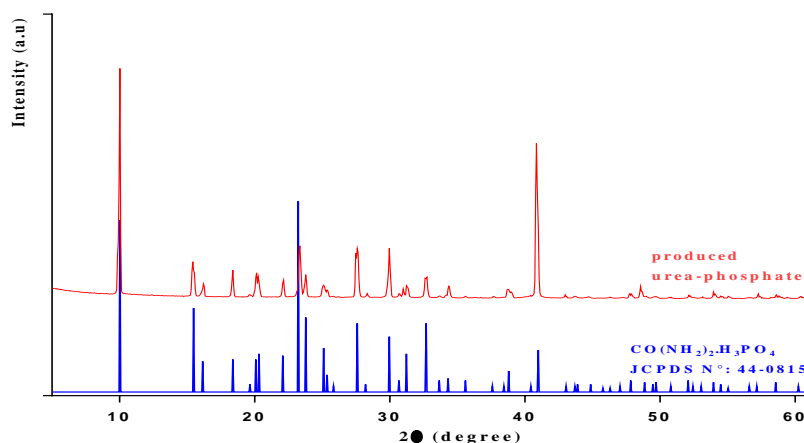
Coefficient	Effect	v-sign %
<b>b0</b>	-39.24509	< 0.01 ***
<b>b1<sub>(2-1)</sub></b>	3.72660	1.64 *
<b>b1<sub>(3-1)</sub></b>	-0.09407	92.5
<b>b1<sub>(3-2)</sub></b>	-3.82067	1.51 *
<b>b2<sub>(2-1)</sub></b>	2.01993	9.7
<b>b2<sub>(3-1)</sub></b>	-2.21740	7.7
<b>b2<sub>(3-2)</sub></b>	-4.23733	1.06 *

### 3) Physical and chemicals analysis of the produced phosphate urea

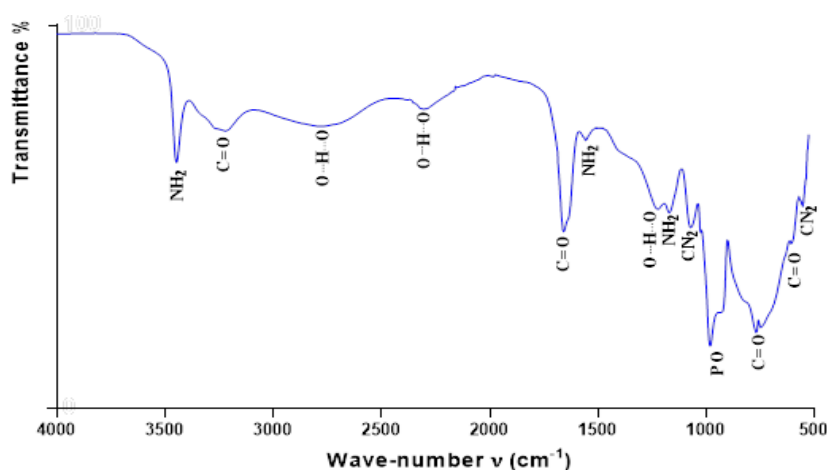
In the following paragraphs, the urea phosphate recovered under the optimal conditions, namely reaction temperature of 50 °C, reaction time of 90 minutes, crystallization at room temperature until the total decantation of the crystals and ratio Urea / H<sub>3</sub>PO<sub>4</sub> of 1: 1, was chosen for all the other tests in order to determine its quality and its physical and chemical properties. The XRD diffractogram of the produced urea phosphate is represented in Figure 3. The identification of peaks of this sample shows a consistency with that of the standard card of urea phosphate (CO(NH<sub>2</sub>)<sub>2</sub>.H<sub>3</sub>PO<sub>4</sub>, JCPDS N°: 44-0815). Zhang et al [22] have mentioned that the impurities present initially in the phosphoric acid and urea cannot affect on the crystal structure of the synthesized urea phosphate. The obtained urea phosphate was also identified by FTIR. The infrared spectrum of this sample is displayed in Figure 4. It shows clear that all characteristic bands correspond to urea phosphate are present [22–24]. According to Ilczyszko et al [24], the characteristic bands of the urea phosphate can be attributed to 3 types of vibrations: urea vibration (NH<sub>2</sub>, C=O and CN<sub>2</sub> species), phosphate vibration (PO group) and hydrogen bond vibrations (O—H·····O bond).

Vibration band frequencies and assignments for the produced urea phosphate are listed in Table 6.





**Figure 3.** XRD diffractogram of the produced urea phosphate.



**Figure 4.** FTIR spectrum of the produced urea phosphate.

**Table 6.** Infrared frequencies of the produced urea phosphate.

Assignment	Wave number $\nu$ ( $\text{cm}^{-1}$ )
NH <sub>2</sub> $\nu_{\text{as}}$	3448
NH <sub>2</sub> $\delta$	1558
NH <sub>2</sub> $\rho$	1170
C=O $2\nu$	3243
C=O $\nu$	1660
C=O $\nu$	760
C=O $\delta$	606
CN <sub>2</sub> $\nu_{\text{s}}$	1060
CN <sub>2</sub> $\delta$	554
PO $\nu$	983
PO $\nu$	927
O—H...O $\nu$	2760
O—H...O $\nu$	2310
O—H...O $\delta$	1220

$\nu$ : stretching;  $\delta$ : in-plane bending;  $\rho$ : wagging;  $\nu_{\text{s}}$ : symmetric stretching;  $\nu_{\text{as}}$ : antisymmetric stretching.

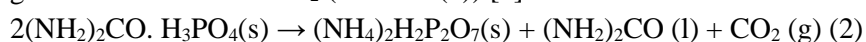
In the light of these results, the phosphorus and nitrogen content of urea phosphate is about 44 and 17 % respectively. Also, about 84 % of P<sub>2</sub>O<sub>5</sub> originally contained in the initial acid is recovered. These rational percentages are important and reply to the requirements (standard GBT 27805-2011) for using this produced urea phosphate in the national

industry [25]. Compared to other work realized by Gittenait [14], Hodge et al [5] and Greidinger et al [13], these obtained results rest almost the same to that showed by these researchers. Ding et al [26] and Zhang et al [22] have indicated that the impurities have slight influence on phosphorus and nitrogen content of urea phosphate. We can conclude from Table 7 that the elements  $\text{Si}^{4+}$ ,  $\text{Al}^{3+}$  and  $\text{Fe}^{3+}$  cannot generally exist in the produced urea phosphate. These chemicals elements have a big and similar ionic radius.  $\text{Si}(\text{H}_2\text{O})_6^{4+}$ ,  $\text{Al}(\text{H}_2\text{O})_6^{3+}$  and  $\text{Fe}(\text{H}_2\text{O})_6^{3+}$  existing in the mixture prefer to rest into mother liquor [27]. The produced urea phosphate contained about 1.05 % of sulfate  $\text{SO}_4^{2-}$ . In fact,  $\text{SO}_4^{2-}$  is tetrahedral such as  $\text{PO}_4^{3-}$  and can substitute the phosphate ion in the urea phosphate crystal.  $\text{Mg}^{2+}$  is originally contained in the initial phosphoric acid. However, the presence of  $\text{Mg}^{2+}$  in the urea phosphate is due to the viscosity of mixture solution [22].

**Table 7.** The produced urea phosphate impurity reduction,  $\text{P}_2\text{O}_5$  recovery compared to the initial phosphoric acid and the chemical composition of liquor.

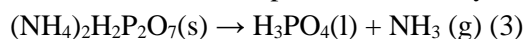
	Phosphoric Acid		Urea		Urea Phosphate			Liquor	
	Impurity/ wt %		wt %		Impurity/ $\text{P}_2\text{O}_5$ ratio		Impurity Reduction		$\text{P}_2\text{O}_5$ Recovery
	wt %	$\text{P}_2\text{O}_5$ ratio	wt %	$\text{P}_2\text{O}_5$ ratio	wt %	$\text{P}_2\text{O}_5$ ratio	n wt%	y wt%	wt %
$\text{P}_2\text{O}_5$	52.33	**	0.45	**	43.96	**	**	84	16.99
N	**	**	45.89	**	17.01	**	**	**	1.96
$\text{SO}_4$	3.12	5.7629	0.05	0.095	0.64	1.05	82,5	**	7.25
CaO	0.04	0.0765	0.07	0.133	0.06	0.01	53	**	0.09
$\text{Na}_2\text{O}$	0.15	0.2871	0.2	0.379	0.09	0.148	73	**	0.3
$\text{K}_2\text{O}$	0.01	0.0191	0.01	0.019	0.02	0.033	13	**	0.01
$\text{SiO}_2$	0.12	0.2297	0.01	0.019	0.00	0	100	**	0.05
MgO	1.23	2.3549	0.06	0.114	0.27	0.443	82	**	1.95
$\text{Fe}_2\text{O}_3$	0.26	0.4977	0	0	0.01	0.016	97	**	0.35
$\text{Al}_2\text{O}_3$	0.1	0.1914	0.01	0.019	0.00	0	100	**	0.19
Zn									
(ppm)	366.1	$693.63 \cdot 10^{-6}$	10.96	$2 \cdot 10^{-5}$	64.32	$105.53 \cdot 10^{-6}$	85	**	465.68
Cd									
(ppm)	9.56	$18.113 \cdot 10^{-6}$	0	0	0.32	$5.25 \cdot 10^{-7}$	97	**	17.06

The obtained urea phosphate contained also  $\text{Ca}^{2+}$ ,  $\text{K}^+$  and  $\text{Na}^+$ . The presence of these elements is originally linked to urea not to the phosphoric acid. For this reason, the content of these elements in the residual liquor remains almost identical to that of the initial phosphoric acid. For the trace element  $\text{Zn}^{2+}$  and  $\text{Cd}^{2+}$ , around 85 and 97 % of these elements are removed in to residual liquor respectively. Owing to its toxicity to animals and humans,  $\text{Cd}^{2+}$  is a hazardous heavy metal that is of great concern for the environment. Cd prefers habitually to pass into liquid phase, this can be explained by the strong affinity between Cd and  $\text{P}_2\text{O}_5$  [28]. Also, Cd and Zn may be eliminated with other element such as silica and sulfur respectively [29,30]. From these results we can concluded that the proposed process (reaction 1) is effective and permits producing a relatively pure urea phosphate from unpurified phosphoric acid. In addition, this produced urea phosphate is non-toxic product, which could be used directly in the agriculture. We conclude from Table 7 that the majority of the impurities initially contained in technical phosphoric acid are strongly reduced in urea phosphate and pass into the liquor. Thus, the goal of having a good quality of a binary fertilizer is achieved A thermal analysis was realized on the produced urea phosphate to study its pyrolysis. The TGA-DTA curves of the produced urea phosphate are represented in Figure 5. The thermic behavior of this sample can be described as follow: (i): A small weight loss (~1 %) was observed around 100 °C, which could be attributed to the elimination of the adsorbed water. (ii): An endothermic peak at 122 °C indicating the start of the pyrolysis of urea phosphate which generates a release of  $\text{CO}_2$  (reaction (2)) [5].



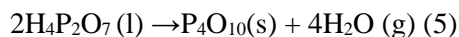
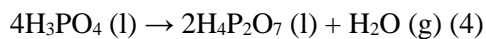


(iii): At about 157 °C, an exothermic peak was observed, which is due to the release of NH<sub>3</sub>. Siwen Bi et al [31] have observed the liberation of CO<sub>2</sub> and NH<sub>3</sub> at 126 and 153 °C respectively. Marcilla A et al explained the delay of the liberation of NH<sub>3</sub> compared with CO<sub>2</sub> by the fixation of NH<sub>3</sub> by phosphoric acid (reaction 3) [32].

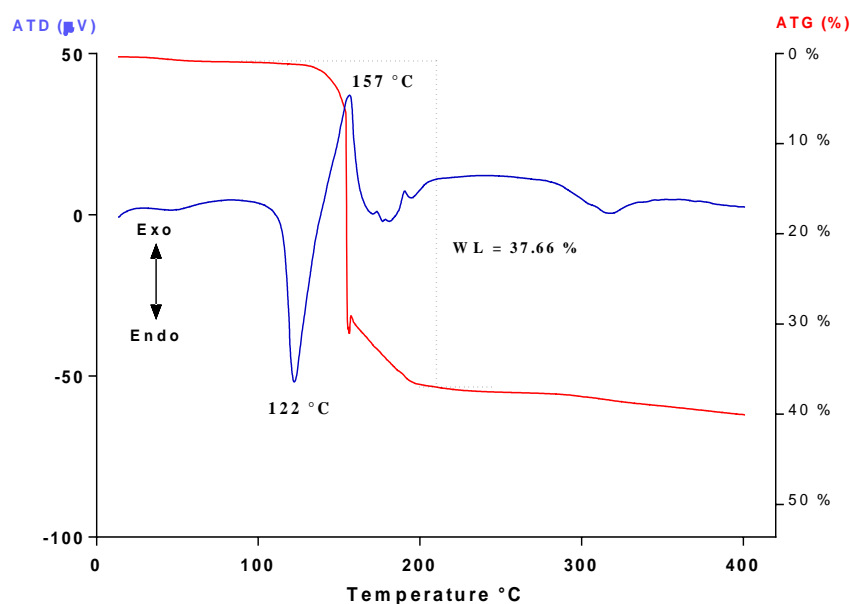


Generally, the release of CO<sub>2</sub> and NH<sub>3</sub> at 205 °C accompanied by a weight loss of 37.66 % indicates that all of the urea in this sample is decomposed.

(iv): Above 205 °C, a slow dehydration of phosphoric acid was occurred to forms the pyrophosphoric acid (reaction 4), until a rapid P<sub>4</sub>O<sub>10</sub> formation at 579 °C (reaction 5) [31,32].



On the basis of these results, the pyrolysis of the produced urea phosphate releases gaseous CO<sub>2</sub> at low temperature, which has the advantage of using this urea phosphate as a fire retardant [33]. In addition, we can use urea phosphate to synthesize ammonium pyrophosphate (NH<sub>4</sub>)<sub>2</sub>H<sub>2</sub>P<sub>2</sub>O<sub>7</sub> and pyrophosphoric acid H<sub>4</sub>P<sub>2</sub>O<sub>7</sub>, which are mainly used in the urea-ammonium polyphosphate (UAPP) liquid fertilizer industry [5,14].



**Figure 5.** TGA-DTA curves of the produced urea phosphate (WL: weight loss).

## Conclusion

As a result of our work, we can produce a high purity of Moroccan urea phosphate from the chemical reaction between technical Moroccan phosphoric acid and urea with heating the mixture at 50 °C for a reaction time 90 min. The urea phosphate crystals are recovered after cooling and filtration.

In addition, we were able to recover 84 % of the mass of P<sub>2</sub>O<sub>5</sub> in the form of urea phosphate. The rest can be recovered by recycling the filtrate. Chemical analyses of the residual liquor have clearly shown that most of the impurities pass through the filtrate and justify that the urea phosphate produced is of high purity.

The quality of this product makes it suitable for use as a fertilizer providing the two nutrients N and P without harming the environment

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