

REVIEW

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Adsorption of some heavy metal ions by used different immobilized substances on silica gel



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KEYWORDS

Poly(8-hydroxyquinoline); Immobilization; Silica gel; Heavy metals; Cu(II); Fe(III) **Abstract** 8-Hydroxyquinoline, HQ, or poly(8-hydroxyquinoline), PHQ, was immobilized on the activated silica gel for extractive concentration of metal ions. FTIR was used to prove the result caused by the immobilization of PHQ on the surface of functionalized silica gel. The thermal gravimetric analysis (TGA) and differential thermal analysis (DTA) prove that Si–PHQ–Cu is more highly thermally stable and strongly adsorbed water than Si–PHQ. Spectra of the solution produced from substrate of PHQ immobilized on silica gel showed record peak at 305 nm was which was maximized at pH 7.2 \pm 0.1 of the universal buffer solution. By the addition of Cu(II) ion solution, a peak at 380 nm was appeared corresponding to formation of HQ–Cu(II) coordinated complex.

Spectra of 100 mg of substrate (Si–HQ, Si–PHQ, or Si–Cu) at pH 7.2 \pm 0.1 universal buffer solution was recorded, solutions of metal ions were added, after contact time, filtrate, dissolve the solid precipitate in pure ethanol and record the spectra of this solution. A peak at 380 nm appeared corresponding to HQ–Cu(II) complex. The capacity of Si–HQ for extraction of Cu(II) ion was 10 mmol/g. Immobilization of Cu(II) metal ion on silica gel (Si–Cu) was studied. The maximum amount of HQ that can be extracted was 7 mmol/g. In the case of Fe(III) ion on Si–HQ, new two peaks appeared at 580 and 455 nm. The capacity of Si–HQ for extraction of Fe(III) ion was 20 mmol/g.

Addition of Cu(II) on Si–PHQ, a new peak at 380 nm was appeared corresponding to PHQ–Cu(II) coordinated complex. The capacity of Si–PHQ for extraction of Cu(II) ion was 40 mmol/g. While, Si–Cu can extract PHQ, the maximum amount of PHQ that can be extracted was 20 mmol/g. Spectra of Fe(III) ion on Si–PHQ was recorded, new two peaks were appeared at 580 and 455 nm corresponding to the formation of PHQ–Fe(III). The capacity of Si–PHQ for extraction of Fe(III) ion was 40 mmol/g. PHQ immobilized on silica gel was useful for removal of Iron from the sytron syrup (anti-anemic). © 2011 Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/3.0/).

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1. Introduction

Hydroxyquinoline is a well-characterized organic chelating ligand, which can form covalent compounds with over 60 metal ions under controlled pH conditions, and its preference for transition and heavy metal cations over alkaline earth cations are well known (Rao and Gladis, 2002). 8-Hydroxyquinoline, 8HQ, and its derivatives as well as related metal complexes are playing a uniquely important role in different disciplines of chemical research and applications. 8HQ, as a complex one or as sequestering reagent, is considered second to EDTA and its analogues in binding with metal ions (Soroka et al., 1967). 8HQ was mainly applied for analytical purposes and separation techniques as an excellent reagent for the extraction of metal ions due to its extraordinary coordinating capabilities (Hollingshead, 1954; Mahmoud, 2006; Mahmoud and Soliman, 2003; Wen and Shan, 2002; Goswami et al., 2003; Firdaus et al., 2007). However, in coordination chemistry, versatile synthetic approaches for the formation of metal complexes of 8HO and its derivatives were extensively used to open a wide range of di and tri-valent metal complexes that can be used as an arsenal for various impacts and applications in different fields.

Ahmed et al. (2003), have prepared spectro analytical solutions and using several spectroscopic techniques, characterized coordination polymer based on poly(8-hydroxyquinoline) complexed to some metal ions. The lowest potential energy and dipole moment of the optimally proposed structure of PHQ that is coordinated to copper ion were estimated by Molecular Mechanics (MM +) calculations.

Silica gel is a porous, granular form of silica, synthetically manufactured from sodium silicate or silicon tetrachloride or substituted chlorosilane or the silicate solution. Silica gel synthesis from sodium silicate solution is well documented by (Iler, 1979). Silica particles of small particle size (2-5 nm) have an extraordinarily large surface-to-volume ratio $(\sim 2 \times 10^9 \text{ m}^{-1})$ and a corresponding high specific surface area ($\sim 900 \text{ m}^2/\text{g}$). It is not surprising, therefore, to note that the chemistry of the interior surface of silica gel plays a dominant role in its chemical and physical behavior (El-Nahhal and El-Ashgar, 2007). Silica

can be regarded as a polymer of silicic acid, consisting of interlinked SiO₄ tetrahedral. The structure terminates at the surface in either a siloxane group (=Si-O-Si=) with the oxygen on the surface, or one of several forms of silanol groups (=Si-OH). The silanols can be divided into isolated groups (or free silanols), where the surface silicon atom has three bonds in the bulk structure and the fourth bond is attached to a single OH group, and vicinal silanols (or bridged silanols), where two single silanol groups, attached to different silicon atoms, are close enough to the hydrogen bond. The third type of silanols, geminal silanols, consists of two hydroxyl groups that are attached to one silicon atom and that are too close to form hydrogen bond between each other (Kiselev and Lygin, 1975). The enhanced acidity of the silica surface gives it a high degree of chemical reactivity, so it can react with many coupling agents to immobilize organo-functionalized silanes (Leyden and Luttrell, 1975), in which Lisickin's team and Zaitsev have made an important contribution (Lisickin et al., 2003; Zaitsev, 1997).

Surface modification of silica relates to all the processes that lead to change in chemical composition of the surface. Surface can be modified either by physical treatment (thermal or hydrothermal) that leads to change in ratio of silanol and siloxane concentration of the silica surface or by chemical treatment that leads to change in chemical characteristics of the silica surface. By the modification the adsorption properties are significantly affected. Chemisorptions of chelating molecules on silica surface provides immobility, mechanical stability and water insolubility, thereby increases the efficiency, sensitivity and selectivity of the analytical application (Jal et al., 2001). Essentially all silica-based 8-quinolinol (HQ_x) materials have been prepared utilizing one of two similar procedures described by (Hill (1973) and Sugawara et al. (1974). These immobilization procedures involve a rather lengthy synthesis (3-4 days) consisting of silvlation of the silica surface with an aliphatic amino silane, aromatic nitrogroup introduction, reduction of immobilized ArNO2 to immobilized ArNH2 diazonium salt formation, and finally diazo coupling to (HQ_x) . All the above steps, with the exception of diazo coupling to HQ_x , have been adopted from the procedure described by Weetall (1970).

The low capacity of silica-bound ligands has been one of the major difficulties encountered in their use. High capacities are desirable in terms of both increased preconcentrating ability as well as higher loading ability. In fact, capacities greater than 70 μ mol/g were not observed for silica-immobilized HQ_x. Immobilization of 8-hydroxyquinoline onto the inner wall of silicone tubing and evaluation of its use as a support for the concentration of trace metals from seawater was done. This system offers an alternative to packed columns as it is well-suited to lower pressure flow injection procedure since back pressure problems can be avoided (Willie et al., 1998). A less complicated route to silica-immobilized 8-HQ was described (Zheng et al., 2006), in which the 8-HQ is anchored to the surface of previously aminated silica by a one-step Mannich reaction. This considerably reduced the reaction time, yielding products having relatively high metal-exchange capacities.

2. Experimental

2.1. Materials

8-Hydroxyquinoline (HQ) was obtained from Aldrich (Chemical Co., US). Poly(8-hydroxyquinoline), PHQ, was prepared based on the homo-oxidative polymerization technique of the corresponding monomer, 8-HQ. (Pierre and Baret Serratrice, 2003). Metal ions such as Cu(II) and Fe(III) salts were prepared by dissolving a known amount of chemically pure metal nitrate (Merck) in double distilled water. Silica gel (60–120 mesh size) was obtained from Sigma. It was activated by refluxing with 6 molL⁻¹ HCl for 4 h. Then, the filtrate was washed with double distilled water until free from acid and dried in furnace at 140 °C for 12 h. All other chemicals were of analytical reagent grade.

2.2. Immobilization of 8-hydroxyquinoline (HQ) and its polymer (PHQ)

Weigh about 1 g of 8-hydroxyquinoline (HQ), dissolve it in a small amount of pure ethanol (5 ml), add this solution to 10 g of silica gel and mix well. Add to this swelling 50 ml double distilled water in a 250 ml conical flask and stir for about 4 h. Filter this solution, wash the precipitate with double distilled water and leave it for drying at room temperature. At the third day, collect the solid yield in a closed bottle. HQ was immobilized on silica gel (Si–HQ). FTIR and UV-spectroscopic measurements were carried out on this solid. Poly(8-hydroxyquinoline), PHQ, was immobilized on silica gel in the same way and at the same conditions to form Si–PHQ.

2.3. Instrumentation

A perkin-Elmer Lambada 35 spectrophotometer with 1.0 cm quartz cells (scan speed, 8 nm/sec) was used for spectrophotometric measurements. The pH measurements were made using Jenway 3305 pH-meter accurate to ± 0.01 pH unit with glass calomel electrode assembly. The pH-meter was standardized against pH values 4.0 and 10.0 buffers (prepared by dissolving buffer capsules in definite amount of second de-ionized water). Magnetic stirrer Jenway 1000 was used for stirring the



Figure 1 FTIR of: (a) Activated silica gel free, (b) PHQ, (c) Si-PHQ, (d) Cu(II) and (e) Si-PHQ-Cu(II).

solutions. FTIR spectroscopic measurements on KBr pellets were scanned on a Shimadzu (type 470) spectrometer.

3. Results and discussion

3.1. FTIR spectroscopic studies

FTIR was used to provide information on the total or partial loss of silanol group bonds of silica and to prove the result caused by the immobilization of PHQ on the surface of functionalized silica. As shown in Fig. 1:



Figure 2 Thermo gravimetric analysis curve (TGA) of: (a) Si–PHQ, and (b) Si–PHQ–Cu(II) matrix.



Figure 3 Differential Thermal analysis (DTA) of: (a) Si–PHQ, and (b) Si–PHQ–Cu(II) matrix.

- (a) The main characteristic peaks were assigned as: 1100–1000, 950–900 and 800–700 cm⁻¹ could be attributed to v(Si-O-Si), v(Si-OH) and $\delta(Si-O-Si)$, respectively. The peak at 3430 cm⁻¹ was assigned to v(C=C).
- (b) The absorption bands at 1430, 1500, 1550 and 1600 cm⁻¹ are characteristic of the HQ moiety in PHQ polymer chain.
- (c) Compared with the spectrum of original silica, (a), and spectrum of PHQ, (b), the C=C was presented and the amplitudes of silanol groups bonds of silica were decreased. Also, the amplitudes of (Si–O–Si) between 800 and 700 cm⁻¹ were increased than the original silica because PHQ had coupled with silica. These features confirmed that the original silica had reacted with PHQ.
- (d) Spectrum of Cu(II) has a main characteristic peak at 1100 cm^{-1} .
- (e) The peak was appearing at about 1460 cm⁻¹ due to the formation of a metal oxygen bond. A strong band at 1100 cm⁻¹, which corresponds to C–O–Cu stretching vibration, confirms the presence of metal coordination (Ahmed et al., 2003). Also, the band at 1650 cm⁻¹ appeared. This should be a characteristic peak of v(O=C). In the frequency range from 3000 to 3500 cm⁻¹ related to hydroxyl groups, a broad band

was noted for Si-PHQ-Cu(II) spectrum because silica appended at side chain and hampered the formation of hydrogen bond between PHQ chain. This proved that silica had successfully copolymerized with PHQ-Cu(II).

3.2. Thermal behavior of Si-PHQ and Si-PHQ-Cu(II) matrix

Thermal behavior of Si–PHQ and Si–PHQ–Cu(II) were obtained from Thermo gravimetric analysis (TGA) and differential thermal analysis (DTA). The TGA thermogram, Fig. 2, shows a one step decomposition at about 150 °C and reveals the thermal degradation of PHQ while Si remains stable until 400 °C.

The TGA proves that Si–PHQ in the presence of Cu(II) ion as Si–PHQ–Cu is more thermally stable more than Si–PHQ. The thermal degradation of Si–PHQ–Cu reveals many steps for its decomposition. The first step in Si–PHQ–Cu thermogram is the weight loss below 100 °C, due to the loss of matrix water molecules. The second stage temperature of more than 100 °C indicates that the Si–PHQ–Cu(II) matrix remains stable to 250 °C after the loss of water and that the complexed polymer is more thermally stable than the polymer itself. The last stage temperature of ~370 °C corresponds to the decomposition of Si.

In Fig. 3, it is shown that the DTA of Si–PHQ, shows a peak at about 70 °C which is assigned to the release of the water bonded to Si–PHQ. While, in the DTA of Si–PHQ–Cu the release of water is shown as a peak at 90 °C indicating strongly adsorbed water than Si–PHQ. The other peaks represent of decomposition of each Si–PHQ and Si–PHQ–Cu(II) as explained previously.



Figure 4 Effect of different concentrations of Cu(II) ion on 100 mg of Si–HQ, at universal buffer (pH 7.2), different Cu(II) concentrations are: [(a): 0.02, (b): 0.04, (c): 0.06, (d): 0.1, (e): 0.14, (f): 0.2, (g): 0.3, (h): 0.4, (i): 0.7, and (j): 1.0 mmolL^{-1}], after precipitation, filtrate, and the ppt. dissolved in 5 ml pure ethanol.



Figure 5 Effect of different concentrations of Cu(II) on 100 mg of Si–PHQ, at universal buffer (pH 7.2), different Cu(II) concentrations are: [(a): 0.02, (b): 0.06, (c): 0.2, (d): 0.4, (e): 0.5, (f): 0.8, (g): 1.7, (h): 3.0 and (i): 4.0 mmolL⁻¹] of Cu(II).

3.3. UV-visible spectroscopic studies of HQ and PHQ immobilized on Si [Si-HQ and Si-PHQ]

3.3.1. Effect of contact time

The time required for extraction of maximum amount of metal ion from the solution by Si–HQ, called contact time, was studied. Spectra of 50 mg of Si–HQ at universal buffer solution (pH 7.2 \pm 0.1), 0.5 mmolL⁻¹ of Cu(II) ion solution was added. Record the spectra of this solution at different times (min). The contact time of the experiment calculated from the addition of metal ion to the filtrate of the solution. The different times of the spectra were recorded as: 0.166, 0.5, 1, 10, 20 and 60 min. The best contact time was about 1 min, This means that the time of more than 1 min has no effect for the extraction of metal ions from the solution. Also, a long time that reached up to 24 h was recorded which gave the same absorbance peak for time of more than 1 min.

3.3.2. UV-visible absorption spectra of Cu(II) ion on Si-HQ and on Si-PHQ

Spectra of 100 mg of Si–HQ after different additions of Cu(II) ion added at universal buffer solution (pH 7.2) were recorded as shown in Fig. 4. In each experiment, solution of Cu(II) ion was added to the solution containing Si–HQ, after contact time, filter the content, dissolve the solid precipitate in 5 ml pure ethanol and record the spectra of that solution. A peak at 380 nm appeared corresponding to the peak of HQ–Cu(II)

complex. The formation of this coordination complex indicates that the solid of HQ immobilized into silica gel can extract the metal of Cu(II) ion from the solution to form Si–HQ–Cu(II). But ethanol can dissolve the coordination complex HQ–Cu(II) and give the peak at 380 nm.

The maximum absorbance of this peak as shown in Fig. 4(j) corresponds to the added Cu(II) concentration of 1 mmolL⁻¹. This Cu(II) ion concentration represents the capacity of Si–HQ solid for extraction of Cu(II) ion from the solution.

This capacity measured as (concentration of metal ion by mmol/weight of substrate Si–HQ by g). So, the capacity of Si–HQ for extraction of Cu(II) ion from solution is 10 mmol/g, compared to the capacity in old studies which was 70 µmol/g (Willie et al., 1998).

By the same way, and in the same conditions, Spectra of 20 mg of Si–PHQ after different additions of Cu(II) ion added at universal buffer solution (pH 7.2) was recorded as shown in Fig. 5.

The maximum absorbance peak as shown in Fig. 5(i) corresponds to the addition of 4 mmolL⁻¹ of Cu(II) ion. This Cu(II) ion concentration represents the capacity of Si–PHQ solid for extraction of Cu(II) ion from the solution which was 40 mmol/g.



Figure 6 Filtrate of different concentrations of Cu(II) on 100 mg of Si–PHQ, at universal buffer (pH 7.2), different concentrations are: [(a): 0.02, (b): 0.06, (c): 0.2, (d): 0.4, (e): 0.5, (f): 0.8, (g): 1.7, (h): 3.0 and (i): 4.0 mmolL⁻¹] of Cu(II).

Table 1 gel.	Capao	Capacity of different immobilized substrate on silica								
Substrate		Capacity of substrate (mmol/g)								
		Cu(II)	F	e(III)		HQ		PHQ	2	
Si-HQ		10	2	0		_		-		
Si-PHQ		40	4	0		_		_		
Si-Cu(II)		_	_			7		20		

If the spectra of the filtrate, produce from addition of Cu(II) ion at universal buffer (pH 7.2), was recorded. The excess of free PHQ which was not coordinated with added Cu(II) appears as peak at 305 nm, as shown in Fig. 6.

Increases in the concentration of Cu(II) ion with increasing the formation of Si-PHQ-Cu(II) coordinated complex was observed, that could be confirmed by the increases of the absorbance peak at 380 nm. But in the filtration the peak at 305 nm decreased because the noncoordinated PHO decreased, until the peak corresponding to maximum concentration as shown in Fig. 6(i) disappeared then, there is no free PHQ because all PHQ coordinate with Cu(II) ion to form Si-PHQ-Cu(II) coordinated complex.

Comparing between capacity of Si-PHQ for extraction of Cu(II) ion and the capacity of Si-HQ, it was observed that



Figure 7 Effect of different concentrations of HQ on 100 mg of Si-Cu, at universal buffer (pH 7.2), different HQ concentrations are: [(a): 0.0, (b): 0.1, (c): 0.2, (d): 0.3, (e): 0.5, and (f): 0.7 mmolL^{-1}] of HQ.



Figure 8 Effect of different concentrations of (PHQ) on 100 mg of SiCu, at universal buffer (pH 7.2), different PHQ concentrations are: [(a): 0.1, (b): 0.2, (c): 0.3, (d): 0.5, (e): 0.7, (f): 1.0, (g): 1.5, and (h): 2.0 mmolL^{-1} of PHQ.

the Si-PHQ has the ability about four times greater than Si-HQ. The ability of Si-Cu to coordinate with PHQ was about three times greater than HQ, Table 1.

3.3.3. UV-visible absorption spectra of HQ and PHQ on Si-Cu(II)

Immobilization of Cu(II) metal ion itself on silica gel (Si-Cu) was studied the capacity of it was calculated, then compared with the capacity of Si-HQ. Spectra of 100 mg of Si-Cu at universal buffer solution (pH 7.2) were recorded as shown in Fig. 7. A series of different concentrations of HQ were added to the solution containing Si-Cu, after contact time, filter the content, dissolved the solid precipitate in 5 ml pure ethanol and recorded the spectra of each addition. After the first addition of HQ to the solution containing Si-Cu, a peak that appeared at 380 nm represented the formation of HQ-Cu coordinated complex. The formation of this complex indicated that the solid of Cu(II) ion immobilized on silica gel can extract HQ from the solution to form Si-HQ-Cu(II).

Also, ethanol can dissolve the coordination complex HO-Cu(II) and gives the appeared absorbance peak at 380 nm. By increasing the concentration of HQ added, increase in the absorbance peak of formation of HQ-Cu(II) was seen, until the Cu(II) ion from Si-Cu was consumed, then the peak of HQ-Cu complex disappeared and the peak corresponding to

HQ itself at 305 nm, appeared, as shown in Fig. 7(f). This absorbance represents the maximum amount of HQ that can be extracted from the solution that is expressed as the capacity of Si–Cu solid was 7 mmol/g.

Comparing between capacity of Si–HQ for extraction of Cu(II) ion and the capacity of Si–Cu for extraction of HQ, it is observed that Si–HQ has ability about 1.5 times greater than Si–Cu. So the immobilization of HQ on silica gel is better than immobilization of Cu(II) ion alone.

Also, The capacity of Si–PHQ was compared with the immobilized Cu(II) metal ion on silica gel (Si–Cu). Increasing the concentration of PHQ added, and increase of the absorbance peak of formation of PHQ–Cu(II), as shown in Fig. 8, until the Cu(II) ion from Si–Cu was consumed, Fig. 8(h). The absorbance represents the maximum amount of PHQ that can be extracted from the solution that was expressed, as the capacity of SiCu solid was 20 mmol/g.

Comparing between capacity of Si–PHQ for extraction of Cu(II) ion and the capacity of Si–Cu for extraction of PHQ, it is observed that Si–PHQ has ability about two times greater than Si–Cu. So the immobilization of PHQ on silica gel is better than immobilization of Cu(II) ion on it.

From the previous comparison, it is observed that, PHQ has the ability to be immobilized on silica gel and coordinated

with metal Cu(II) ion four times more than the ability of HQ to do that.

3.3.4. UV-visible absorption spectra of Fe(III) ion on the immobilized substrate, Si-HQ or Si-PHQ

Spectra of different concentrations of Fe(III) ion on 100 mg of Si–HQ at universal buffer solution (pH 7.2) was recorded as shown in Fig. 9. Solution of Fe(III) ion was added to the solution containing Si–HQ; after contact time, filter the content, dissolve the solid precipitate in 5 ml pure ethanol and record the spectra of that solution. Two new peaks appeared at 580 and 455 nm corresponding to the formation of HQ–Fe(III) complex. The formation of this coordination complex indicates that the solid of HQ immobilized on silica gel can extract the metal of Fe(III) ion from the solution to form Si–HQ–Fe(III).

The maximum absorbance peak as shown in Fig. 9(g) which corresponds to the added Fe(III) concentration of 2 mmolL⁻¹. This Fe(III) ion concentration represents the capacity of Si–HQ solid for extraction of Fe(III) ion from the solution which was 20 mmol/g.

Ethanol can dissolve the coordination complex HQ–Fe(III) and give the two appeared absorbance peaks at 580 and 455 nm. The spectra of the filtrate, produced from the addition

1.5

1

0.5

0 **+** 380 С

b

480

Absorbance



Figure 10 Effect of different concentrations of Fe(III) ion on 100 mg of Si–PHQ, at universal buffer (pH 7.2). Different Fe(III) concentrations are: [(1): 0.1, (2): 0.2, (3): 0.3, (4): 0.5, (5): 0.7, (6): 1.0, (7): 1.5, (8): 1.7, (9): 2.0, (10): 3.0 and (11): 4.0 mmolL⁻¹ of Fe(III) ion], after precipitation, filtrate, and the ppt. dissolved in pure ethanol.

580

Wavelength (nm)

780

680





Figure 11 Effect of different concentration of Fe(III) ion and real sample on 100 mg of Si–PHQ, at universal buffer (pH 7.2), as: (a) one addition of Sytron syrup sample,(b): 0.3, and (c) 1.0 mmolL^{-1} of Fe(III) ion], after precipitation, filtrate, and the ppt. dissolved in pure ethanol.

of Fe(III) ion at universal buffer (pH 7.2), was recorded. The excess of HQ free which did not coordinate with added Fe(III) appears as a peak at 305 nm. Increases of the concentration of Fe(III) ion with increasing the formation of Si–HQ–Fe(III) coordinated complex was observed, then increase of the absorbance peaks.

By the same way, and in the same conditions, spectra of different concentrations of Fe(III) ion with 20 mg of Si–PHQ at universal buffer solution (pH 7.2) was recorded as shown in Fig. 10.

The maximum absorbance peaks are shown in Fig. 10(k) which correspond to the addition of $4 \text{ mmol}L^{-1}$ of Fe(III) ion. This Fe(III) ion concentration represent the capacity of Si–PHQ solid for extraction of Fe(III) ion from the solution which was 40 mmol/g.

Comparison between capacity of Si–PHQ and Si–HQ for the extraction of Fe(III) ion from the solution observed that Si–PHQ has the capacity for the extraction of Fe(III) about two times greater than Si–HQ, as shown in Table 1.

4. Determination of ferric ion from sytron syrup sample

Immobilized PHQ on silica gel (Si–PHQ) is useful for several applications such as: removal of metal ions from solution in different fields. For example, of these samples, Sytron syrup is used as anti-anemic which contains Iron as Sodium Iron

edetate (each 5 ml equivalent to 27.5 mg of iron). One addition of real sample (0.3 ml) added to solution contains 100 mg of Si–PHQ at universal buffer solution (pH 7.2), after contact time, filter the content, the solid dissolved in 5 ml pure ethanol, the spectra was recorded as shown in Fig. 11(a). To ensure that the peak for extraction of Fe(III) and at which range the amount was extracted, add 0.3 and 1.0 mmol L^{-1} of synthetic Fe(III) ion solution as shown in Fig. 11(b and c), respectively.

Atomic Absorption Spectroscopy (AAS) also determined the recovery of this extraction and it was found to be 67.38%. This observation evaluated that the solid of Si–PHQ can extract Fe(III) from the sample of Sytron syrup.

5. Conclusions

The surface of Silica gel can be modified with organic functional groups as 8-hydroxyquinoline (HQ) or its polymer, poly(8-hydroxyquinoline) (PHQ), and provide access stability. Immobilization of 8-hydroxyquinoline (HQ) or its polymer (PHQ) on the surface of silica gel, was prepared by easier methods than the previous methods. The capacity for the extraction of heavy metal ions from solutions is also greater than the other methods. It was used for the extraction of some heavy metal ions such as: Fe(III) and Cu(II) from its solutions in different fields and has a capacity as shown in Table 1.

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