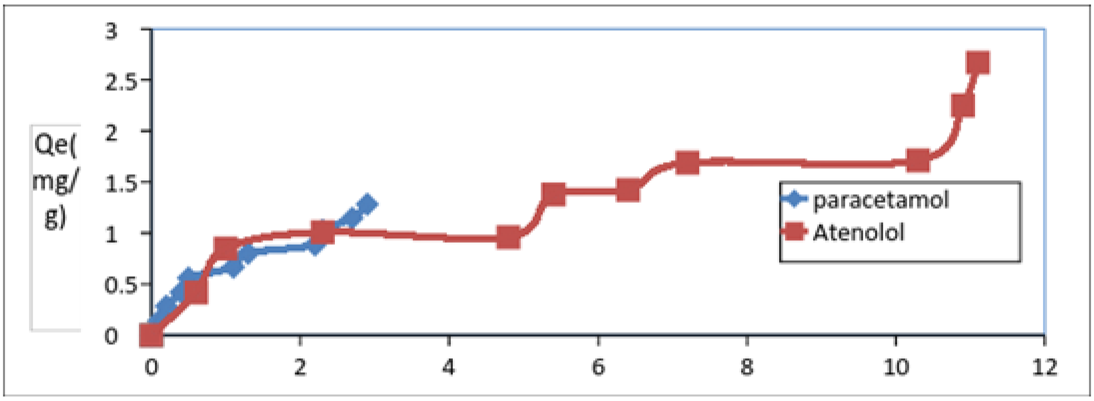

Figure 4: Adsorption isotherm for the adsorption of both the PL and AL from their aqueous solutions on the ICS at 313 K

These results were re-plotted according to Freundlich isotherm (Figure 5) and Langmuir isotherm Figure 6.

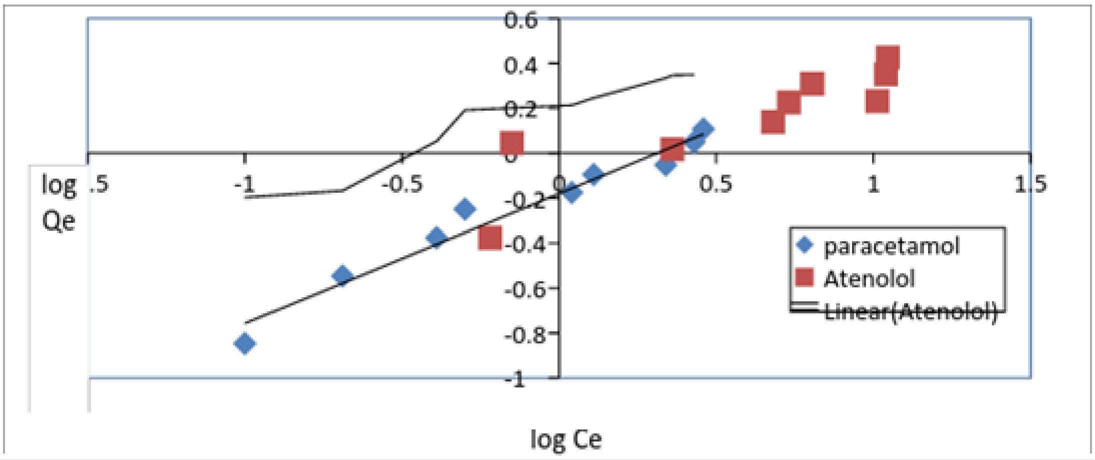

Figure 5: Freundlich adsorption isotherm for the adsorption of PL and AL at 313 K on ICS

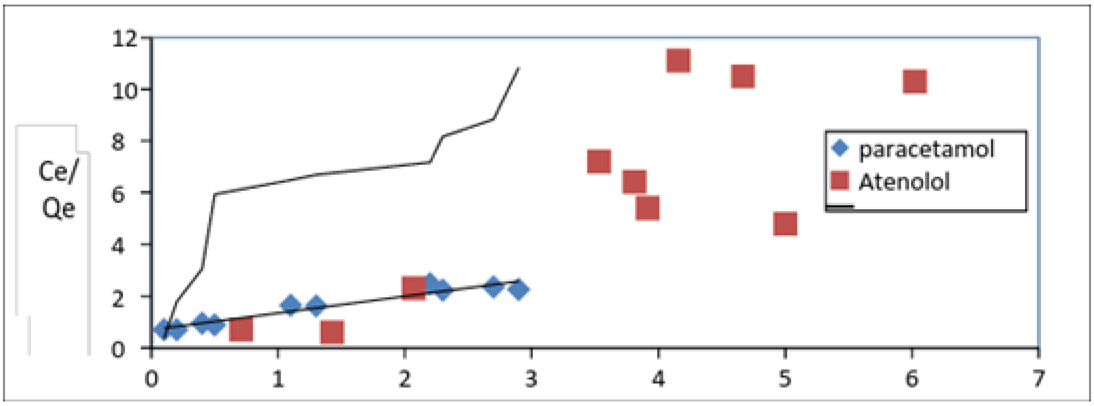

Figure 6: Langmuir adsorption isotherm for the adsorption of PL and AL at 313 K on ICS

3.4 Effects of pH on the adsorption

The effect of pH of solution on the adsorption of each of PL and AL from their aqueous solutions on ICS was studied at different pH values (pH=2-14). It was found that the effect of pH was varied according to the type of the used medicine. The best absorption was obtained at pH =4, this probably arises from the effect of the activity of the basic groups on these medicines. This relatively lower pH value can minimize the repulsion forces between adsorbate molecules

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and the surface. This can promote molecules to adsorb on the surface with high efficiency under this conditions[28-30]. These results are summarized in Figure 7.

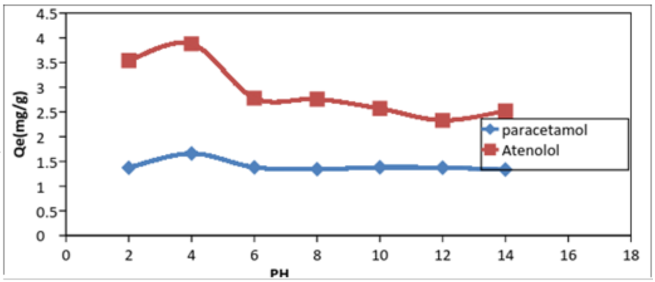

Figure 7: The effect of pH on the adsorption of PL and AL on the surface of ICS

3.5 Effects of temperature on the adsorption of medicines

In this study, it was found that the amount of the adsorbed medicine was reduced with increasing reaction temperature. The negative values of ΔH indicate that, this process is an exothermic reaction. This also means that there is absorption processes beside adsorption processes[31]. Increase in temperature of reaction leads to increase amount of molecules that are adsorbed on the surface and then these molecules are diffused into the internal pores in the surface of the adsorbent[32-35]. The results of effect of temperature on the adsorption are shown in Figure 8.

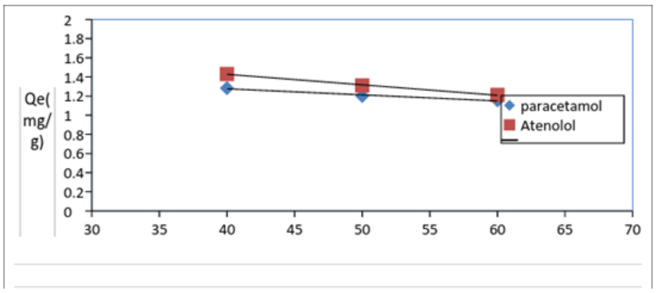

Figure 8: The effect of temperature on the adsorption of the used medicines on the surface of ICS

The values of ΔH were obtained using Van -Hoff equation as follows[31, 36]:

Plotting log $_{Xm}$ against 1/T gives linear relationship as shown in Figure 9.

$$\log Xm = \frac{-\Delta H}{2.303RT} + con$$

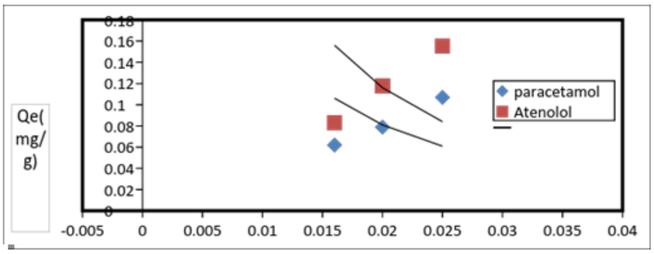

Figure 9: Plotting log Xm versus 1/T for adsorption of PL and AL on ICS at 313 K and pH=4.

Gibbs free energyΔG was calculated from the following equation[42]:

$$\Delta G = -RT.Ln\left(\frac{Q_e}{C_e}\right)$$

Entropy change ΔS for adsorption process can be calculated using the following equation[43]:

$$\Delta G = \Delta H - T\Delta S$$

Generally, positive values of ΔS indicate that the adsorption of these medicines on the surface leads to reduce the entropy due to adsorb these molecules on the surface and form bonding with the surface as well as electrostatic attraction between molecules and the surface of the adsorbent molecules. The values of Freundlich constants at 313 K are shown in Table 1.

Table 1: Freundlich adsorption constants calculated at 313 K

Dyes	K_f	n	R^2	a	k	R^2
Paracetamol	0.661	1.736	0.966	0.649	1.436	0.927
Atenolol	0.791	2.3148	0.799	1.970	0.975	0.692

Table 2: Thermodynamics values for adsorption of AL and PL medicines on ICS at 313 K

Dyes	ΔH($Kj.mol^{-1}.k^{-1}$)-	ΔG($Kj.mol^{-1}.k^{-1}$)+	ΔS($j.mol^{-1}.k^{-1}$)-
Paracetamol	1.5319	2.124	11.68
Atenolol	0.962	3.708	14.92

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4. Conclusions

This study showed that both paracetamol and atenolol can be removed from their aqueous solutions by adsorption over Iraqi cherry seeds. Also it was found that removal of atenolol over ICS was more efficient than that for paracetamol under the same conditions. Also the adsorption of these medicines over ICs was exothermic process and it possessing reduction in the entropy upon adsorption.

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