Determination of the gelification kinetics of a correction gel of injection profiles by ultraviolet-visible spectroscopy

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Abstract. Mature wells in which, for a long time, water injection has been used, as a method of recovery they reach a point where the water cut increases or remains constant; thus decreasing the recovered hydrocarbon factor. This phenomenon occurs because the water injected, has preferential recordings in the porous medium, and does not reach the hydrocarbon available in other areas of the formation, in this type of deposits the injection of polyacrylamide gels, crosslinked with acetate of chromium, these gels make a plugging, in areas of high water permeability, causing the change of path of the same, as well as move the hydrocarbon in other areas of the porous medium. At present, the kinetics of gelation of this type of substances is monitored qualitatively by means of the "Syddansk" code, which analyzes its consistency and elasticity, only by observation. Although this method is practical, it is not very descriptive and depends a lot on the opinion and criteria of the observer, being little reproducible. Given this situation, and the increase in chemical recovery projects in the country, a methodology is described that describes the moment of gelation, reproducibly and without the injection of the analyst. During the gelation process, different polyacrylamide-chromium gels were monitored in relationships used in field operations, using ultraviolet-visible spectroscopy, detecting a change in absorbances, of the spectra, which were analyzed to plant a kinetic model of gelation, in addition to generating the approach of a method, to identify the state of gelation based on the variation in absorbance.

1. Introduction
The technique of water injection in mature reservoir, allows obtaining hydrocarbon, because this type of deposits, do not have the natural pressure to be this process naturally, after many volumes of water injected into a reservoir, The hydrocarbon shorts are very low, these because the injected water takes preferential paths, sweeping the oil only in certain parts of the deposit, which after a long time will be found, without any type of oil, but leaves sites of the reservoir without affecting [1,2]. To correct these problems, polyacrylamide gels crosslinked with chromium acetate, are used to generate large macromolecular networks that plug these areas, thus forcing the injected water to take other directions in the formation, and thus make contact with new areas and therefore other hydrocarbon banks, increased hydrocarbon production.

Currently, the best method to analyze the gelation process of polyacrylamide and chromium acetate is by the "Syddansk" method, this method allows to analyze the mechanical characteristics of the gel, from a qualitative point of view, in which the operator appreciation greatly influences the result, making it a very imprecise and poorly reproducible method.

This research proposes the monitoring of polyacrylamide-chromium acetate gels, at different concentrations and two types of water, by determining the absorbance at a wavelength of the visible
spectrum. Thus, obtaining a more systematic and dependable way to analyze and determine the degree of gelation of a polyacrylamide-chromium acetate, formulation to be injected into a reservoir [3-7].

2. Materials and methods
The components of the gels, polyacrylamide and chromium acetate were characterized, the gels were subsequently prepared at different polymer-crosslinker ratios, and absorbance was measured at different wavelengths.

2.1. Polymer and crosslinker characterization
The polyacrylamide and chromium acetate were characterized by infrared (IR) spectroscopy using Bruker Tensor 27 equipment with ATR cell.

2.2. Preparation of gels
Gels with a polyacrylamide concentration of 1500 ppm, derived from an initial solution of 5000 ppm, were prepared. They were crosslinked in 20:1 and 60:1 ratios polyacrilamide: chromium acetate from a 10% solution of chromium acetate. The gels were prepared in two types of water, distilled and a brine with a concentration of 15000 ppm of NaCl.

2.3. Determination of absorbance
The absorbance behavior at 400 nm, 500 nm, 600 nm and 700 nm was analyzed for all gels, for a zero time, for 24 hours, up to 700 hours, using a HACH 2800 spectrophotometer. The results were analyzed and what were the better wavelengths to perform the analysis of gelation kinetics.

3. Results and discussion

3.1. Polymer and crosslinker characterization
Figure 1 shows the infrared spectrum for polyacrylamide, where the corresponding signals can be observed: to the OH group, at 3420 cm⁻¹, at 3200 cm⁻¹ for the NH bond, at 2930 cm⁻¹ for the CH bond, the carbonyl group It is observed in 1670 cm⁻¹ and 1130 cm⁻¹ corresponding to the C=O link. Figure 2 shows the signal around 3500 cm⁻¹ corresponding to the OH group of the alcohol in which the chromium acetate is dissolved. In the 1600 cm⁻¹ and 1400 cm⁻¹ signals characteristic of the C=O bond are observed [8].

![Figure 1. IR spectrum of polyacrylamide.](image-url)
Figure 2. IR spectrum of chromium acetate.

3.2. Determination of absorbance

After an analysis of the absorbances obtained for gels at different wavelengths, the data was taken at 400 nm, because they were the best trend, and in all cases showed valid values for absorbance. Figure 3 shows the absorbance values for the gels of 1500:20:1 and 1500:60:1 in distilled water at 30 °C and 60 °C, it is observed how the gels of 60:1 ratio, show an increase of the absorbance until 200 hours, where the values begin to stabilize, it can be concluded that at 200 hours these gels have already reached a total gelation, and the temperature does not influence considerably, on the other hand, the gels of relation 20:1 show an increase in its absorbance up to 400 hours, thereafter the reaction is stabilized, according to the invariability of the absorbances, although there is more crosslinker, the reaction is slower.

On the other hand, gels made in brine of 15000 ppm of NaCl, Figure 4 of ratio 60:1 at 30 °C stabilizes at 400 hours, while that of 60 °C does it at 200 hours, it is in the only case in which observe that the temperature catalyzes the gelation reaction, on the other hand the gels of 20: 1 ratio obtain their total stabilization and gelation at 400 hours, regardless of the temperature at which they are.

Figure 3. Absorbance of gels in distilled water at 400 nm.
Analyzing the behavior of the absorbance evolution curves as a function of time and the nature of the reaction, it can be estimated that it is a zero order reaction, where the concentration of one of its reagents is very high and during the reaction it is invariably, in this case the concentration of both reagents remains stable, as it is an intermolecular cross-linking process [9-12].

4. Conclusions
According to the absorbance vs. time graphs, for polyacrylamide-chromium acetate gels, if it is possible to use the absorbance determination of the material at a given wavelength, for monitoring the kinetics of the gels, thus achieving the development of a methodology based on this parameter, avoiding falling into qualitative approximations or dependent on the assessment of the operator.

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