5. This is a question about arsenic.

Arsenic, As, atomic number 33, is an element infamous for its toxic compounds. The presence of naturally occurring arsenic compounds in groundwater currently affects millions of people throughout the world.
A number of different techniques for removing arsenic compounds from water have been developed, but research to improve these methods is ongoing.

Marsh gas test

In 1836 British chemist James Marsh developed the first reliable test for the detection of arsenic(III) oxide. In the Marsh test arsenic(III) oxide is first converted to arsine gas (AsH_3) which is then ignited leaving a silvery-black deposit of arsenic.

a) **i)** Draw the structure of arsine indicating the geometry.

ii) Write a balanced equation for the combustion of arsine as used in this test.

Arsine is formed when arsenic(III) oxide is reacted with zinc and sulfuric acid.

b) **i)** Give the formula for arsenic(III) oxide.

ii) Write a balanced equation for the reaction of arsenic(III) oxide with zinc and sulfuric acid.

The Marsh test is no longer used to detect arsenic; today spectroscopic methods allow the concentration of arsenic in a sample to be determined rapidly and with great sensitivity.

In groundwater the most prevalent arsenic species at high pH is $HAsO_4^{2-}$.

c) **i)** What is the oxidation number of arsenic in $HAsO_4^{2-}$?

ii) Draw a diagram to show the three-dimensional structure of $HAsO_4^{2-}$.

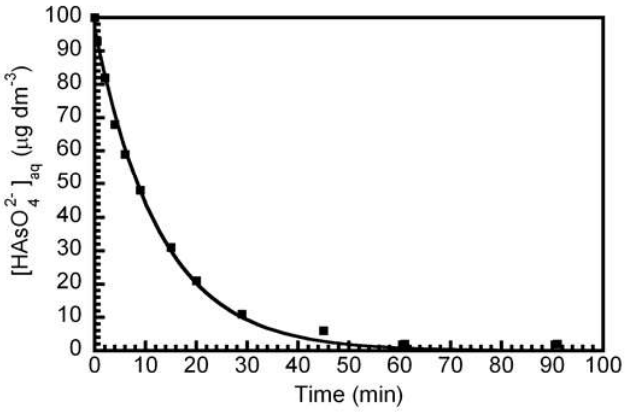
$HAsO_4^{2-}$ can be removed from water by adsorption on to particles of iron(III) hydroxide. The variation in the concentration of aqueous $HAsO_4^{2-}$ with adsorption time can be described by the equation:

$$[HAsO_4^{2-}{}_{(aq)}]_t = [HAsO_4^{2-}{}_{(aq)}]_0 \, e^{-(kt)}$$

where $[HAsO_4^{2-}{}_{(aq)}]_t$ is the concentration of aqueous $HAsO_4^{2-}$ at time t, $[HAsO_4^{2-}{}_{(aq)}]_0$ is the initial concentration of aqueous $HAsO_4^{2-}$ and k is the rate constant for the adsorption reaction. The rate constant is related to the half-life of the reaction ($t_{1/2}$) by the equation:

$$t_{1/2} = \frac{\ln 2}{k}$$

The graph to the right shows how the concentration of aqueous $HAsO_4^{2-}$ varies with adsorption time at 40 °C. According to the World Health Organization the safe level for dissolved arsenic species in water is < 10μg dm^{-3}.



d) **i)** Using the graph, determine the rate constant for the adsorption of $HAsO_4^{2-}$ on to iron(III) hydroxide particles stating the units.

ii) In a different water sample it took 55 minutes for the concentration of aqueous arsenic to reach the safe level. What was the initial concentration of aqueous $HAsO_4^{2-}$?

Under certain conditions the equilibrium constant, K, for the adsorption of $HAsO_4^{2-}$ can be defined as:

$$K = \frac{[HAsO_{4\,(adsorbed)}^{2-}]}{[HAsO_{4\,(aq)}^{2-}]}$$

At 20 °C the value of K is 186.

e) If the initial concentration of aqueous $HAsO_4^{2-}$ was 30 μg dm^{-3}, what is the concentration of aqueous $HAsO_4^{2-}$ at equilibrium at 20 °C?