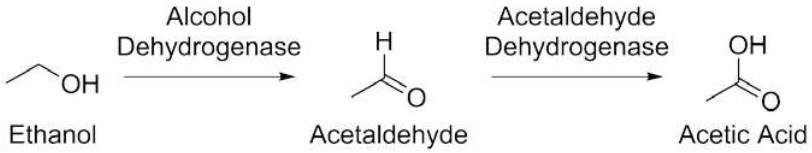
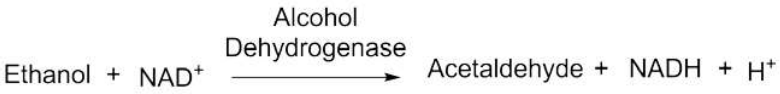
4. This question is about hangovers

After the consumption of too much alcoholic beverage, people sometimes experience a hangover the following day. There are a variety of causes of a hangover, one of these is the accumulation of the toxic metabolites of ethanol in the body.

In the body, ethanol is first converted into acetaldehyde by the enzyme alcohol dehydrogenase and then into acetic acid by the enzyme acetaldehyde dehydrogenase.



In the first step, ethanol reacts with nicotinamide adenine dinucleotide (NAD+) to form acetaldehyde, a compound called NADH and H^+.



(a) What happens to the NAD^+ in this reaction? Circle the correct answer.

it is oxidised	it is reduced	it is hydrolysed	it is isomerised	it remains chemically unchanged

In most parts of the UK, the legal drink drive limit is 80 mg of ethanol per 100 ml of blood.

(b) What concentration of ethanol does this correspond to (in mol dm^{-3})? (1 ml = 1 cm^3)

After drinking it is not permitted to drive until the concentration of ethanol has fallen below this level. The reaction to remove ethanol involves the initial combination of the ethanol and the alcohol dehydrogenase to form an enzyme-substrate complex, followed by the conversion of this complex into products. The rate of this reaction (the rate of production of acetaldehyde) has a complicated rate law (as shown below).

$$\text{rate} = \frac{k_{\text{cat}}[\text{AD}][\text{C}_2\text{H}_5\text{OH}]}{K_{\text{M}} + [\text{C}_2\text{H}_5\text{OH}]}$$

where [AD] is the concentration of the alcohol dehydrogenase enzyme

k_{cat} = 1.33 s^{-1} and is the rate constant for the conversion of the enzyme substrate complex to products

K_M = 1.00 × 10^{-3} mol dm^{-3} and is a measure of the ease of dissociation of the enzyme substrate complex back to reactants. It has the units of concentration.

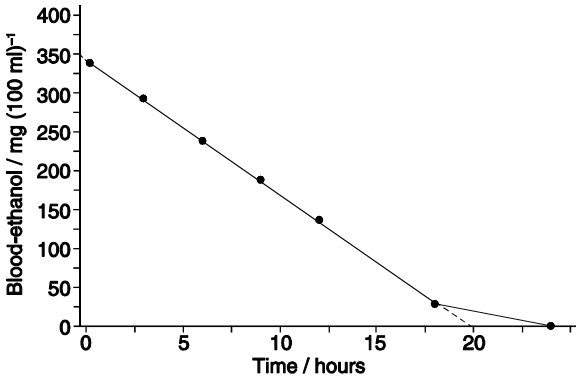
It is often the case that the rate law above simplifies to a much simpler form.

(c) **(i)** Write down the simplified form of this rate law when the concentration of ethanol is very much **larger** than the value of K_M.

(ii) Write down the simplified form of this rate law when the concentration of ethanol is very much **smaller** than the value of K_M.

(d) Hence, or otherwise, write down the order of this reaction with respect to ethanol at around or above the UK drink drive limit.

The graph shows how the blood ethanol concentration of someone who has drunk a lot of alcohol varies over time.



(e) For the majority of the time that this person is sobering up, what is the rate of loss of ethanol?

(i) In (mg / 100 ml) h^{-1}

(ii) In mol dm^{-3} s^{-1}

(f) What concentration of alcohol dehydrogenase enzyme does this person have?

(g) The half-life of this reaction is the time taken for the concentration of ethanol to fall to half of its initial value. From the graph, how does the half-life vary over the majority of the period this person is sobering up?

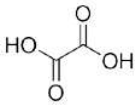
it increases | it is constant | it decreases | it is impossible to determine from the graph

(h) As well as ethanol, alcohol dehydrogenase will also metabolise other alcohols. The following metabolites are highly toxic. For each of these suggest which highly poisonous alcohol they came from.

(i)

Formic Acid

(ii)



Oxalic Acid

(i) For one of these poisonous alcohols, alcohol dehydrogenase has a $k_{cat} = 1.10\ s^{-1}$ and a $K_M = 3.2 \times 10^{-2}$ mol dm^{-3}. What can be concluded about the metabolism of this alcohol? Tick all that apply.

- The maximum rate of metabolism is faster for ethanol
- The maximum rate of metabolism is faster for the poisonous alcohol
- The maximum rate of metabolism is the same for both
- A higher concentration of ethanol is needed for the reaction to proceed at half of its maximum rate
- A higher concentration of the poisonous alcohol is needed for the reaction to proceed at half of its maximum rate
- The same concentration of ethanol and the poisonous alcohol are needed for the reactions to proceed at half of their maximum rate
- The metabolism of the poisonous alcohol follows a rate law different from that of ethanol