

on chemical kinetics you know this is lecture number twelve we have been on this for the past eleven lectures

so ah just quickly to remind you of what we were doing in the last class

so we had talked about this one very briefly where we said that this is the kinetic energy distribution right of molecules say in gas phase in a reaction vessel and these are the fraction of molecules having the respective kinetic energy as plotted on the x axis the main point for a particular distribution is that not all molecules will be having the same kinetic energy there is a distribution of kinetic energies then each at each temperature the kinetic energy peaks at a certain value and this value this value this ah where it peaks this value we say is the most probable kinetic energy now how do we bring it ah how related to the activation energy

so we say that suppose we take two different temperatures three and kelvin and nine iron kelvin just as examples

so what happens is when you increase the temperature nine and kelvin two things happen one is see this black curve this is at higher temperature has become broader broader means that you have more molecules with higher kinetic energies right and the value of the most probable kinetic energy has also gone up that means the value has increased

as compared to that at 300 kelvin now suppose you say that ok at this point this is the  $E_a$  the activation energy that means the energy it needs to go over the energy over the barrier and to the product side

so the energy the reactant molecules will need to go to the top of the hill which is the barrier and then the top of the barrier and go over to the product side

so if you say that this is  $E_a$  and you say that  $E_a$  is constant right and you just draw a vertical line parallel to the y axis

so what you see is at the lower temperature is 300 kelvin this blue shaded region is the one which tells you that these are the fraction of molecules having energy in

excess of  $E_a$  if this fraction molecules are having energy and excess of  $E_a$  then what is going

to happen these fractional molecules are going to readily go over to the product side because

they already have the energy which is close to  $E_a$  or more now what happens when you increase the

temperature is as this pictorially tells you or in terms of figure it tells you in terms of a

diagram see when i increase it to 900 kelvin now you look at this black curve the black curve

now is shifted that means it shifted above that means there is more area more

area under the black curve above  $e_a$  so the area what is so if you look at the area that means the fraction of molecules for the black curve that is the curve at 900 kelvin what you would understand that there are more molecules more many more molecules as compared to that at 300 kelvin so that means you have more molecules which have higher energy more than the energy of activation right at least as much of energy of activation or more than the range of activation so at 900 kelvin the fraction of molecules having energy higher than the energy of activation is more than the fraction of molecules having energy higher than the energy activation at three hundred kelvin as is available from the shaded regions so for nine hundred kelvin the shaded region would be the green one plus the blue one while for at 300 kelvin the shaded region would be only the blue one right and this directly tells you what happens when i increase the temperature right hence going back to again what we wrote we said that the area of the shaded portion right increases as the temperature is increased right so the area of the shaded portion increases as the temperature is increased then then what we had already mentioned as the temperature was increased the distribution became broader and the peak of the distribution shifted to higher values of kinetic energy so this we had already mentioned so now what i just told you was that the fraction of molecules having energy excess  $e_a$  excess that means over and above that of  $e_a$  is given by  $e^{-e_a/RT}$  and then this relates you to the arrhenius expression for the temperature dependence of reaction rates which says  $k$  is equal to  $A e^{-e_a/RT}$  so then what is this factor telling you this factor the exponential factor tells you is what fraction of molecules would be having energy in excess of  $e_a$  so that they can easily pass on to the product side in other words higher the temperature right more is a shaded portion under the curve that means more is the number of molecules having energy equal to  $e_a$  or greater that means more than that and hence there is a greater chance of the reaction happening that means the reaction happens faster at higher temperature and this was the idea behind the discussion of this distribution of energies this distribution of energies as a function of temperature and seeing how the shape of the distribution changes as i change my temperature that means go from a lower temperature to higher temperature and what it leads to right ok

so now lets look at our  
ah kinetic you know this rna expression a little more closely  
so remember  
so this was  $k_a$  minus  
 $e^{-a}$  over  $r t$   
so this was our rate expression so i think this was equation number  
one please go and cross check now what you do is trying to look at the  
details  
so we know what  $a$  is right  
so  $a$  well will you know talk about  $a$  later but  
before that let us look at the this this form the factor in the exponent  
remember  
the factor in the exponent has to be dimensionless right  
so that means  $e^{-a}$   
 $a$  over  $r t$  has to be a pure number right that is no dimension is that what it is  
so let us  
check that out  
so generally  $e^{-a}$  is expressed in kilo joules per mole  
which i can write as  
so kilo mil thousand or  $10^3$  joule mole inverse  
right i can write like in that form what about ah the denominator now  
so  $r$  let us see  $r$   
is your universal gas constant it is 8.  
314 joule kelvin per mole right  
so this is  $r$   
so and these are the units right and then  
obviously temperature is having the unit of  $k$  that is kelvin ok  
so now what we know is  
we know the units of the denominator of the exponent  $e^{-a}$  that is activation  
energy and also  
we know the units of  $r$  and  $t$  respectively so lets quickly do  $e^{-a}$  by  $r t$  in  
terms of units so  
then  $e^{-a}$  by  $r t$  in terms of units would give us  
so  $e^{-a}$  over  $r t$  in terms of  
units would give us joule per mole right i am keeping thousand aside  
because thousand is just in ten to the power three right its kilo joules thats  
why ah in this general  
way of expressing activation energy then i have  $r$  which is having the units of  
joule per mole per  
kelvin or per kelvin per mole or and then i have  $k$  right and the moment i do  
this you have  
understood what has happened  
so the kelvin  
so kelvin gets cancelled out i am left with  
this and then the units also get cancelled out  
so what i am having is i am having a pure i am having a pure number if i am  
having  
a pure number  
so i am absolutely fine with this expression because this is the power of  
the  
exponent this has to be dimensionless that is a pure number and we just proved  
that it is indeed  
a pure number right what is the importance of this why why are we doing this  
you know i could

have not done this and just moved on  
 so that i could have you know finished of the lecture  
 earlier but the point is the following see a you do not try to memorize these  
 equations you have to understand what the equation means what the equation  
 is trying to tell you second if this is you know this this  $e^{-a} / r t$  is the  
 power in  
 the exponent what you immediately keep in mind is that this has to be  
 dimensionless  
 now for some reason suppose your you know you are doing ah something ah very  
 hurriedly you are rushing through and you write down the expression somewhere  
 where you say  
 that  $k$  is equal to  $a e^{-a} / r t$  or  $e^{-a} / t$  and say you  
 have forgotten you are  
 wondering whether this equation is right or wrong immediately what you do is  
 you go and check that  
 whatever i have written if i if it is  $e^{-a} / r t$  or if you have written  $e^{-a} / t$   
 then it does  
 not become dimensionless right as you have seen you only it only becomes  
 dimensionless  
 if i have  $e^{-a} / r t$  where  $r t$  is in the new denominator and  $e^{-a}$  is in the  
 numerator  
 expressed in their conventional units right this is that's why it also becomes  
 a very important  
 check point for you to see whether you actually have written the equation  
 correctly or even if you  
 do forget even if you do forget you would always remember that i need to have  
 a dimensionless power  
 that means exponent i need to have a dimensionless unit of the dimensionless  
 quantity out  
 there and hence it has to be  $e^{-a} / r t$  now once that is cell you come back  
 to this  
 equation its  $k$  is equal to  $a e^{-a} / r t$   
 so this  $a$  then what is going to  
 happen because this  $e^{-a} / r t$  is a pure number right  $a$  has to be  
 equal to  
 $k$  the units of  $ok$   
 so i can write now then units of  $a$  should be equal to units  
 of  $k$  which means which means if for a first order reaction  
 so for a first order reaction remember  
 what was  $k$  for a first order reaction  
 so  $k$  was time inverse right and this would also be the  
 unit of  $a$  right for a first order reaction then recall what it would be for a  
 second order reaction  
 so for a second order reaction  
 so  $k$  means the unit of  $k$  says liter per  
 mole inverse time inverse and this again is a unit of  $k$   
 so again what it means  
 is that because the exponential form because this exponential form is  
 a few pure number then the units of  $a$  will have to be that of the units of  
 $k$  if for a first order reaction then  $a$  is just the inverse of time if it is  
 for a  
 second order reaction then it goes like this and  
 so on  
 so this is liter per mole per time

so this was about the expression or the in terms of the units just to cross check now

let us talk about the next part under this temperature dependence which is determining the arrhenius parameters let us do this we are determining the original parameters

so determining sorry this will be i out here ok again let us go back to the arrhenius red equation

so which is  $k$  is equal to  $a \cdot e^{-E_a / RT}$

so now what

i can do is i can take natural logarithm on both sides

so i can say that natural

log of  $k$  is equal to natural log of  $a$  minus natural log of  $e^{-E_a / RT}$  ok

so let this be equation number two now see that this equation its not a continuation of ah you know the previous lecture because i am you know

talking about the temperature dependence today i have started with the new set of equation

numbers ok now when i have this i can write again then that  $\ln k$  is equal to  $\ln a$

so this

is  $\log_{10} k$  anyway

so i can

so this one sorry this is plus this is plus

so this

one would become  $-E_a / RT$  ok or

so go over to the next page natural log of  $k$

is equal to natural log of  $a$  minus  $E_a / RT$  let this be three i can also express it in terms of log base ten

so then it would be two point three zero

three  $\log_{10} k$  is equal to two point three zero three natural log of  $a$  minus  $E_a / RT$  see this would be  $\log_{10} a$

so let me write again it would be two

point three zero three  $\log_{10} k$  is equal to two point three zero three  $\log_{10} a$  minus  $E_a$

over  $RT$  and then what i can do is i can write  $\log k$  which is  $\log_{10} k$  is equal to

$\log_{10} a$  which is  $\log_{10} a$  minus  $E_a$  by two point three zero three  $RT$  ok

so what i have done is i have replaced

this  $\ln k$  over by  $\log_{10}$ .

so this is the conversion factor then i have taken and have divided the equation throughout by 2.

303

so 2.

302.

303 gets cancelled and i have a factor of 2.

303 out here and this is my equation in terms of  $\log_{10}$ .

so this is  $\log_{10}$

this  $\log_{10}$  okay again you look at equation 3 out here if i write this equation a little little

different form

so i can write this like this natural log of k is equal to minus  $e_a$  over  $rT$  plus  $\ln a$  let this be four i just switched the order of the terms and once i have written this you immediately understand this is the equation of

a straight line if this is the equation of a straight line what i get is i should be getting

a straight line if i plot natural log against one by t and the type of plot should be a linear plot the type of plot should be a linear plot ok

so let's see what we get out here

so what

we get is here in terms of plot

so let this be the plot right

so here what i have is i have natural log of k and here i will be having one by t that is the inverse of

temperature ok

so the moment i have this say these are my experimental points at certain temperatures right and i get a straight line through the experimental points

so this remember what the equation was right the equation was let me write the equation again the equation was natural log of k is equal

to a minus  $e_a$  over  $rT$  which we rewrote as  $\ln k$  is equal to minus  $e_a$  over  $rT$  plus

$\ln a$  right and what we are doing is you you are plotting  $\ln k$  against one by t so

then what is the intercept the intercept is natural log of a and whatever the slope now the slope is equal to minus  $e_a$  over  $r$  right this

found the arrhenius equation tells you what is how you can calculate the  $r$  and  $a$  parameters so

what are the parameters the parameters are a the exponential rate constant right ah sorry a is the

pre exponential factor there is arrhenius factor and then  $e_a$  which is the activation energy

how do you do it

so what you do is do is that see these different points correspond to different

temperatures

so different one by t values because these are different one by t values

so what essentially doing is that suppose you have taken a reaction right you have taken a reaction you are not changing anything in the reaction but the only thing

you are changing is the temperature see let us take a temperature of three hundred kelvin

right when we take the temperature can we say you ah start ah the reaction with an initial

concentration of say ah one mole per liter ok now if you go if you now raise the temperature

you raise the temperature to whatever say from 300 to say 320 kelvin but everything else remains

the same you cannot change anything else because you know that rates also depend upon what the

concentrations

so the initial concentration remains the same the only thing you vary is the temperature

so once you vary the temperature what you do is you then go to different temperature

say 320 kelvin 340 kelvin you know 360 kelvin

so on as the reaction would permit right

and based on this you generate these points one by one

so at respective temperatures what you

do is you have the corresponding rate constants ok

so once you have the rate constants right

from the rates of the equation once you have the rate constants then you are plotting

this natural log of the rate constant versus one by t and from this and from the Arrhenius equation

which you already know you are getting the natural log of A as the intercept from which you can get

A by doing an anti log and the slope it gives you minus E over R

so this is how you determine

the Arrhenius parameters by any reaction you are working on or you are focusing

on or you are studying in the lab right I hope uh now it is clear to you the significance of the Arrhenius rate equation right especially of that the exponential factor

over R T that E over R T factor and also given a reaction how you can design your experiment to

figure out the Arrhenius parameters A which is the pre exponential factor or the frequency factor

and then the E which is the activation energy ok one big assumption out here has been if you

would notice that see I have done this over a range of temperatures right and I have said

that the only thing you change is temperature you do not change anything else in the reaction

this is extremely important but there is one very clear assumption out here the assumption is that

so if we write what the assumption is

that A which is the pre exponential factor and E A which is the activation energy are independent of temperature ok that means that means A and E are constants over the temperature range you have studied

so if your temperature range uh you know goes from say

three hundred kelvin or say you know two hundred eighty kelvin to four hundred kelvin then when you are

doing this plot your assumption is that the pre exponential factor A which is this and the activation energy E

they are constant that means they are not changing with the change in temperature right

so having now made this point clear and again to show you this is the plot you are looking at let us move on to this significance of the activation energy what does you know this activation energy tell you

in terms of its magnitude

so let us talk about the magnitude of activation energy E A ok lets talk about this right now what does E

A tell you lets go through few equations and then we will understand what E A

is telling us

but to start with just let me mention because this was the slope this was a slope right you know this was

ah the plot of  $\ln k$  versus  $1/T$  what the inherent message you get from here is the slope is equal to  $-E_a/R$  is a constant

so the slope is going to depend

upon the activation energy  $E_a$  right hence the slope will depend upon this  $E_a$  now obviously depending upon  $E_a$  the slope will change either

the slope will increase or the slope will decrease right if that happens it tells you that means  $E_a$

the activation energy tells you how sensitive a particular reaction is to the temperature that

means when you change the temperature this slope or  $E_a$  will determine the degree to which the

rate of reaction will be affected

so let me write that down but before i do that i forgot to write here one thing

so this plot is referred to as the arrhenius plot right just something i thought i would mention but anyway

so what i was saying was that

then  $E_a$  for a particular reaction the magnitude of the activation energy  $E_a$  will determine or tell you the degree to which the

degree to which the rate of reaction is increased is increased under similar under similar concentration conditions when the temperature is increased

ok when the temperature is increased

so again lets go through this

so what is the magnitude of  $v_a$  tell you so

the magnitude of  $E_a$  will determine the degree the degree to which the rate of reaction is increased if i put a comma out here under similar concentration conditions

so this is extremely important under similar concentration that means you're not changing the concentrations right you cannot change everything because

rates also depend on concentrations right

so then the determine the degree to which

the rate of reaction is increased under similar concentration conditions when the temperature

is increased

so this is what the magnitude of  $E_a$  tries to deliver to you the message it tries to deliver ok

so can we look at some mathematical interpretation of the same so

what will do is again we will start with our equation  $k$  is equal to  $A \exp(-E_a/RT)$

so this was equation one now lets take two temperatures ok let us take two temperatures

so two temperatures are  $T_1$  and  $T_2$  and it is given and is given

so both the temperatures are in kelvin both the terminals are in kelvin remember

always temperatures are unknown please take temperature in kelvin do not by mistake put in degree celsius please no

so  $T_1$  and  $T_2$  then i say that  $T_2$  is greater than  $T_1$  ok

so  $t_2$  is higher than  $t_1$  that is  $t_2$  is telling that its a higher temperature than  $t_1$  you are running the reaction at a higher temperature okay now let us come back and look at one

so what i will do is for  $t_1$  the rate constant will be referred to as  $k_1$  and for  $t_2$  the rate constant will refer to as  $k_2$

so what i can say is that here for  $t_1$  the rate constant is  $k_1$  for  $t_2$  the

rate constant is  $k_2$  ok once that is clear let me write down the expressions

so i have then based

on Arrhenius equation  $\ln k_1$  is equal to  $\ln A - \frac{E_a}{R T_1}$  let this be five next  $\ln k_2$  which is the

rate constant temperature  $t_2$  is equal to  $A - \frac{E_a}{R T_2}$  this is x again please see that both  $A$  and  $E_a$  have been kept the same we have not changed that two things are changing one is the rate constant and obviously the other

one is the temperature right

so again assumptions the same assumptions remember  $A$  and  $E_a$  are constant ok

so this is a assumption

so then what you

can do is now i will subtract equation five from equation six

so then i can write six minus five equation six

minus equation five will give me  $\ln k_2 - \ln k_1 = \ln A - \frac{E_a}{R T_2} - \ln A + \frac{E_a}{R T_1}$  ok

so these

are  $R T_1$

so  $\ln A - \frac{E_a}{R T_2}$

so this is  $\ln A - \frac{E_a}{R T_1}$  again

so once we

have this

so you can immediately realize that  $\ln A$  will cancel out why because  $A$  is a constant anyway didn't change in temperature and then  $E_a$  is also constant it is independent

of temperature we said assumption  $R$  obviously is constant ok

so then we can write that

$\ln k_2 - \ln k_1 = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$  ok

so this is

a very important expression or this is a very important equation what is it telling you it is

telling you that depending upon depending upon what your temperatures are depending

upon what your temperatures are with the assumption that the Arrhenius factor  $A$  and the activation energy  $E_a$  are constant it will tell you it will tell you that

means the activation energy will tell you to what extent  $k_1$  and  $k_2$  would vary that means

to what extent  $k_1$  would increase to  $k_2$  if the temperature is increased from  $t_1$  to  $t_2$

and we can easily find this if we know what the activation energy is for the specific reaction

hence you go back to our initial statement that means the magnitude of the activation energy what did we say we said that the magnitude of  $e_a$  will the degree that means the extent to which the rate of the reaction is increased when the temperature is increased but make sure that concentration conditions are kept the same ok so this was about the magnitude of the activation energy so now i will close this discussion on the temperature dependence of reaction rates by just looking at this final thing let us talk about our reaction which has the rate expression  $r$  is equal to  $k$  that means rate law  $a$  to the power  $\alpha$   $b$  to the power  $\beta$  and for this what i can write is  $k$  follows  $a - e_a$  over  $r t$  and we know that from the Arrhenius equation but think about this at a given temperature so that means at a given temperature if i look at this equation then i can say the reaction rate  $k$  will depend upon so look at this and i also look at this rate law will depend upon one what will it depend upon it will depend upon  $A$  which is the Arrhenius factor which is this  $k$  it will depend upon magnitude of  $e_a$  reactivation energy also also based on this the rate law it will depend upon what it will depend upon the initial concentration of the reactants right it will depend upon the initial concentration of reactants which are  $a_0$  and  $b_0$  because these are the initial concentrations after that depending upon the reaction  $a_0$  and  $b_0$  will start decreasing so you understand that at the initial conditions as we had discussed before you will anyway be having the maximum rate so that is why you say it will depend on the initial conditions but now we are talking about a fixed temperature see we are talking about a fixed temperature at a given temperature so if you are talking about a given temperature now so temperature is out of the equation right because temperature is constant so  $k$  is depending upon its depending upon  $A$  which is the frequency factor or Arrhenius factor or the pre exponential factor then  $e_a$  which is what the activation energy or the magnitude of the activation energy and then also upon the initial concentrations of  $a$  and  $b$  ok then the question that comes to your mind is which one is more dominant isn't it that's the logical thing because if it is depend upon all these three then which one would be more dominant so then we you you pose the question the post what you pose the question is the question you pose is that which of these factors will influence will

influence or affect the reaction rate or or which one will be the most influential

one let us look at a small table to find out the answer for this now follow the table carefully

so just let me give you some time to write the table down then i can ah you know

explain the same to you

so what i am doing is

so lets this be  $e_a$  a activation energy given in kilo joule per mole ok then what i am plot then i am what i am writing in the table is exponential minus  $e_a$  over  $r \cdot t$  ok so

i am calculating this factor what is this factor remember this factor is the factor which was

written out here  $e^{-\frac{e_a}{r \cdot t}}$

so i am writing is exponential minus  $e_a$  by  $r \cdot t$  okay and

what i am doing is i am calculating it say if i draw a line out here and if i draw another line out here i am calculating for two different temperatures what are the temperatures one is  $t_1$  is equal to three hundred kelvin and the other one is  $t_2$

is equal to six hundred kelvin ok

so these are my two different temperatures ok

so lets go ahead and complete the table ok now let us write down the values so what are you doing out here again

so what you are doing is you are having different activation energies which i will put in right now say for i put in three values one activation energy is 11.

5 kilo joule per mole once you are given this activation energy once you know this

temperature right i can easily calculate minus exponential minus  $e_a$  over  $r \cdot t$  so that is  $10^{-\frac{5}{8.314 \cdot 300}}$

kelvin when i go to six hundred kelvin it becomes  $10^{-\frac{5}{8.314 \cdot 600}}$  ok lets take

another  $e_a$  activation energy which is 51.

7 here it is  $10^{-\frac{51}{8.314 \cdot 300}}$  and here it is  $10^{-\frac{51}{8.314 \cdot 600}}$

2 times ten the per minus five ok and one more one zero three point four

kilo joule per mole is the activation energy now in this case it is  $10^{-\frac{10}{8.314 \cdot 300}}$

18 and this is  $10^{-\frac{10}{8.314 \cdot 600}}$  okay

so again what have you done is if i draw these lines in between to make it a little more clear

so i have taken three activation energies i have two temperatures 300 and 600 kelvin right

then i say that for a given activation energy i am calculating this exponential factor

exponential minus  $e_a$  over  $r \cdot t$  where i know  $e_a$  from here and i know  $t$  from here so at three hundred

kelvin for eleven one one five eighteen minus two at three hundred kelvin for fifty one point seven

being the activation adjacent minus nine then at three hundred kelvin for one zero three point four

kilo joule per mole being the activation energy so minus eighteen you go to

six hundred kelvin now  
for the same for the same  $e$  a values eleven point five it gives to the minus one fifty one point seven it gives three point two times minus five at one zero three point four it gives  $10$  to the minus nine ok  
so you have this table in front of you now look at let us take example the 300 kelvin table which is this one the three hundred kelvin  
so see what has happened at eleven point five the exponential factor is turned to minus two the moment you increase your activation energy by close to ten times its not exactly  $10$  times in  $10$  times would have been 115 but this is close  
so one zero three point four you see the extent to which this exponential factor has changed it has gone from the minus two to the minus eighteen ok  
so lets not consider ten times even lets consider close to something as roughly five times that is eleven point five to fifty one point seven  
at three hundred kelvin what does happen i go from value of ten to the minus two for this exponential factor to value to the minus nine  
so realize now for a ten times change sorry factor of ten change the activation energy changes by so many orders of magnitude do you think that concentration or even the other factor which is a would be able to keep up no  
so then  
the bottom line is that if i write it again at 300 kelvin which is very close to room temperature  
so when we say room temperature we are saying you know 300 minus 273 which is about 27 degree celsius okay at 300 kelvin which is very close to room temperature thats the traditional room temperature that we take a change in  $e$  by this is by a factor by a factor of approximately  $10$  leads leads to an enormous change least an enormous change in the exponential term covering covering over 16 orders of magnitude  
so here the enormous change just by a factor of ten leads to an enormous change and what is the anonymous change it is sixty in orders of magnitude ok lets revisit the table this is what we are talking about at eleven point five it is telling the minus two i go to one zero three point four it is ten to the power minus eighteen ten minus two raise the minus eighteen factor of ten minus sixteen that is the change i am looking at just by a simple change in  $e$  a by a factor of ten because  
this is such an enormous change thus you know within the temperature range just within the temperature range which we have said 300 to 600 kelvin it is generally valid to compare rates of rates of different reactions rates of different reactions solely on the basis of their values of activation energy solely based on the values of activation energy right and this why because any effect any effects due to changes in

concentration due to changes in concentration or  
a the pre exponential factor are virtually swamped out they are completely  
masked ok are virtually swamped out i can say solely on the basis of their  
activation energies why because these are then their effects are negligible  
so the effects of a  
or concentration are negligible as compared to the influence that  $E_a$  has on  
the reaction rate now  
hopefully having done this discussion this gives this gives you a better  
feeling of what this  
activation energy is telling you in terms of a reaction a chemical reaction  
that  
you might be studying or doing in lab  
so we will come back to this activation energy  
concept when we talk about elementary reactions right that would be a next  
topic but before  
i go to the next topic what i will do is i ah you know just do a simple ah  
example of  
this ah relay to this ah you know arrhenius equation for the on the dependence  
of temperature  
ah of reaction rates right and then again reach another general conclusion as  
you will see  
so the problem is our example is you are having cyclobutene in the gas phase  
these are hydrogens ok obviously these corners are your carbon  
atoms and then you have a hydrogen out here your hydrogen out here ok then  
the  
gas phase in the gas phase ok  
so this goes to butadiene  $H_2C=CH-CH=CH_2$  double bond c  
 $H_2C=CH-CH=CH_2$  double bond c h right  
so you have butter iron out here and here you have cyclo  
butane what you are told what you are told is that the activation energy  $E_a$   
for this  
reaction is one thirty seven kilo joule per mole what you are also told is  
or what you have been asked now if i change temperature from four twenty kelvin  
to four  
thirty kelvin that is a ten k change there is a 10 k change by what factor will  
reaction rate increase ok by what factor will the  
reaction rate increase so it is a very easy straight forward question i  
have changed the temperature from four twenty to four thirty kelvin for this  
transformation of  
cyclic beauty and debutadine in the gas phase ok the activation energy is  
given as one thirty  
seven kilojoules per mole please work it out next class i will start with this  
and then  
move on to elementary reactions ok thank you you