

AP Chemistry - Unit 4

Wkst: Thermochemistry and energy diagram

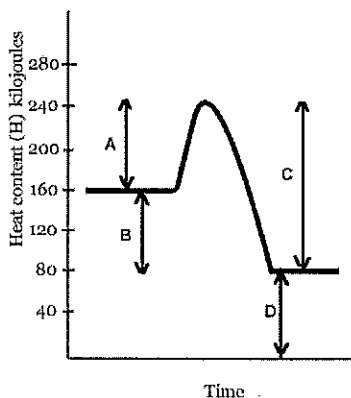


Diagram 1

- If you were holding in your hand a test tube in which the reaction, Diagram 1, is taking place, it would
  - feel cold, because energy is being absorbed
  - feel hot, because energy is being released
  - feel hot, because energy is being absorbed
  - feel cold, because energy is being released
- The reaction whose energy diagram 1 is shown here is
  - exothermic
  - endothermic
  - isothermic
- In the reaction depicted in the diagram 1
  - the energy content of the reactants is greater than the energy content of the products
  - the energy content of the reactants is the same energy content of the products
  - the energy content of the products is greater than the energy content of the reactants

- In the reaction in diagram 2
  - the energy content of the products is greater than the energy content of the reactants
  - the energy content of the reactants is the same as the energy content of the products
  - the energy content of the reactants is greater than the energy content of the products
- The activation energy ( $E_a$ ), diagram 2, of this reaction is
  - 240 KJ
  - 160 KJ
  - 80 KJ
  - 40 KJ
  - 80 KJ

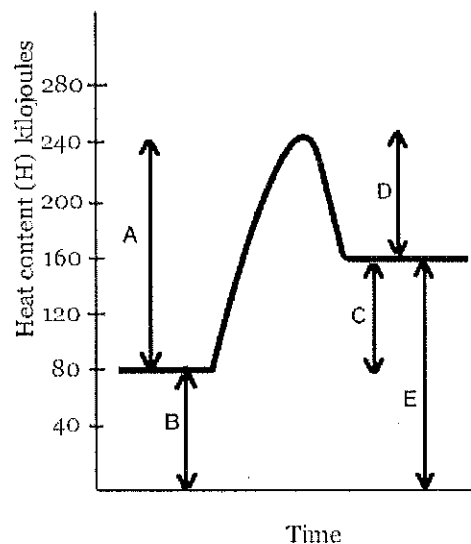


Diagram 2

6. The heat of reaction ( $\Delta H$ , or  $\Delta E$ ), diagram 2, of this reaction is

- a. 160 KJ
- b. -80 KJ
- c. -160 KJ
- d. 240 KJ
- e. 80 KJ

7. The reaction whose energy diagram 2 is

- a. exothermic
- b. endothermic
- c. isothermic

8. If you were holding in your hand a test tube in which the reaction in diagram 2 is taking place, it would feel

- a. feel hot, because energy is being released
- b. feel hot, because energy is being absorbed
- c. feel cold, because energy is being absorbed
- d. feel cold, because energy is being released

9. The line that represents the heat of reaction ( $\Delta H$ , or  $\Delta E$ ), diagram 2, of this reaction is

- a. Line E
- b. Line A
- c. Line B
- d. Line D
- e. Line C

10. The heat of reaction ( $\Delta H$ , or  $\Delta E$ ) of this reaction in diagram 3 is

- a. 80 KJ
- b. 240 KJ
- c. -160 KJ
- d. 160 KJ
- e. -80 KJ

11. The line that represents the heat of reaction ( $\Delta H$ , or  $\Delta E$ ), in diagram 3, of this reaction is

- a. Line B
- b. Line C
- c. Line D
- d. Line A

12. The activation energy ( $E_a$ ) of diagram 3 is

- a. 160 KJ
- b. 240 KJ
- c. 80 KJ
- d. -80 KJ
- e. 40 KJ

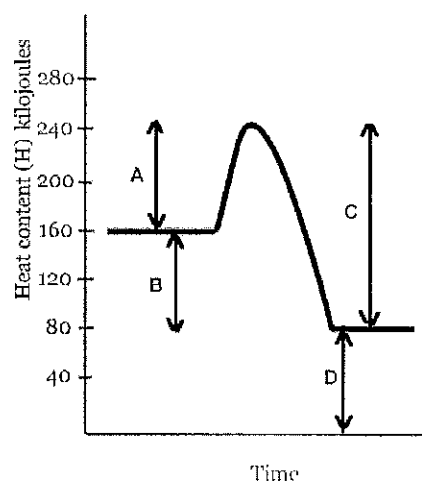
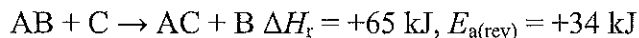


Diagram 3

Consider the following reaction:



Draw and label a potential energy diagram for this reaction. Calculate and label  $E_{a(\text{fwd})}$ .

### What Is Required?

You need to draw a potential energy diagram labelling the x-axis and y-axis, the transition state, and  $E_{a(\text{fwd})}$ .

### What Is Given?

You know the balanced chemical equation for the reaction.

You know the activation energy of the reverse reaction:  $E_{a(\text{rev})} = +34 \text{ kJ}$

You know the enthalpy change of the forward reaction  $\Delta H_r = +65 \text{ kJ}$

Note:

→ Fwd

← rev

$E_{a(\text{rev})}$  = Activation Energy Reverse direction

$E_{a(\text{fwd})}$  = A.E Forward Direction

Plan Your Strategy	Act on Your Strategy
Use the formula $\Delta H_r = E_{a(\text{fwd})} - E_{a(\text{rev})}$ to calculate $E_{a(\text{fwd})}$ .	$\Delta H_r = E_{a(\text{fwd})} - E_{a(\text{rev})}$ $+65 \text{ kJ} = E_{a(\text{fwd})} - (+34 \text{ kJ})$ $E_{a(\text{fwd})} = +99 \text{ kJ}$
Draw and label the potential energy diagram.	<p>The diagram shows a curve starting at a baseline for reactants (AB + C), rising to a peak (transition state), and then falling to a higher baseline for products (AC + B). The energy difference between the reactants and the transition state is labeled <math>E_{a(\text{fwd})} = 99 \text{ kJ}</math>. The energy difference between the products and the transition state is labeled <math>E_{a(\text{rev})} = 34 \text{ kJ}</math>. The energy difference between the reactants and products is labeled <math>\Delta H_r = 65 \text{ kJ}</math>.</p>

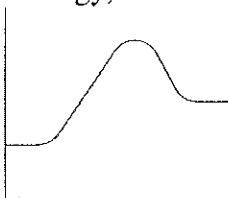
### Check Your Solution

Since the sign of  $\Delta H_r$  is positive, the reaction is endothermic and the potential energy diagram shows the reactants at a lower energy than the products.

## Representing a Reaction with a Potential Energy Diagram

Complete the following potential energy diagram by adding the following labels: an appropriate label for the  $x$ -axis and  $y$ -axis,  $E_{a(\text{fwd})}$ ,  $E_{a(\text{rev})}$ ,  $\Delta H_r$ .

- Is the forward reaction endothermic or exothermic?
- Which has the higher potential energy, the reactants or the products?



### What Is Required?

You need to label the given potential energy diagram, determine if the reaction is exothermic or endothermic and indicate which has the higher potential energy, reactants or products.

### What Is Given?

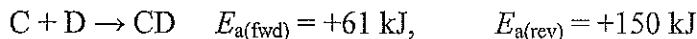
You have an unlabelled potential energy diagram.

Plan Your Strategy	Act on Your Strategy
<p>The <math>y</math>-axis is an energy scale, and the <math>x</math>-axis follows the reaction progress. The reactants will be shown as the first level portion, and the products will be the second level portion of the diagram. The activation energy in the forward direction, <math>E_{a(\text{fwd})}</math>, is the difference between the reactant energy and the transition state at the peak of the diagram. The activation energy for the reverse reaction, <math>E_{a(\text{rev})}</math>, is the difference between the product energy and transition state at the peak of the diagram. <math>\Delta H_r</math> is the difference between the potential energy of the reactant and the potential energy of the product.</p>	<p>a. The reaction is endothermic. b. The products have a higher potential energy than the reactants.</p>

### Check Your Solution

The potential energy of the reactant is lower than the potential energy of the product. This corresponds to an endothermic reaction.

13. Consider the reaction below:



Draw and label a potential energy diagram for this reaction. Calculate and label  $\Delta H_r$ .

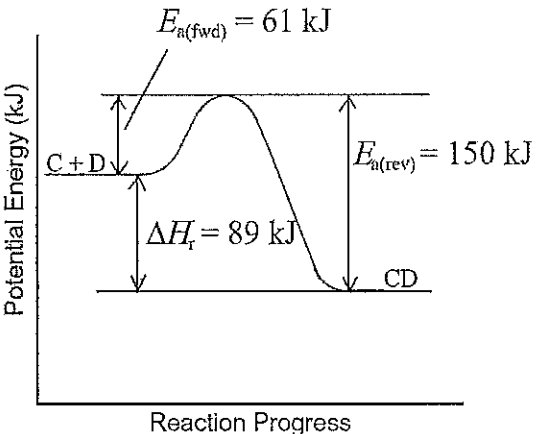
### What Is Required?

You need to draw and label a potential energy diagram for this reaction and calculate and label  $\Delta H_r$ .

### What Is Given?

You know the activation energy of the forward reaction:  $E_{a(\text{fwd})} = +61 \text{ kJ}$

You know the activation energy of the reverse reaction:  $E_{a(\text{rev})} = +150 \text{ kJ}$

Plan Your Strategy	Act on Your Strategy
Use the formula $\Delta H_r = E_{a(\text{fwd})} - E_{a(\text{rev})}$ to calculate $\Delta H_r$ .	$\begin{aligned} \Delta H_r &= E_{a(\text{fwd})} - E_{a(\text{rev})} \\ &= +61 \text{ kJ} - (+150 \text{ kJ}) \\ &= -89 \text{ kJ} \end{aligned}$
Draw and label the potential energy diagram.	 <p><math>E_{a(\text{rev})}</math> is the energy difference between the transition state and the products (+150 kJ). <math>\Delta H_r</math> is the enthalpy of reaction between the reactants and the products (-89 kJ).</p>

### Check Your Solution

Since the sign of  $\Delta H_r$  is negative, the reaction is exothermic. The diagram correctly shows the potential energy of the product lower than the potential energy of the reactant.

14. In the upper atmosphere, oxygen exists as  $O_2(g)$ , as ozone,  $O_3(g)$ , and as individual oxygen atoms,  $O(g)$ . Ozone and atomic oxygen react to form two molecules of oxygen gas. The enthalpy change is  $-392 \text{ kJ}$  and the activation energy is  $+19.0 \text{ kJ}$ . Draw and label a potential energy diagram. Include a value for  $E_{a(\text{rev})}$ .

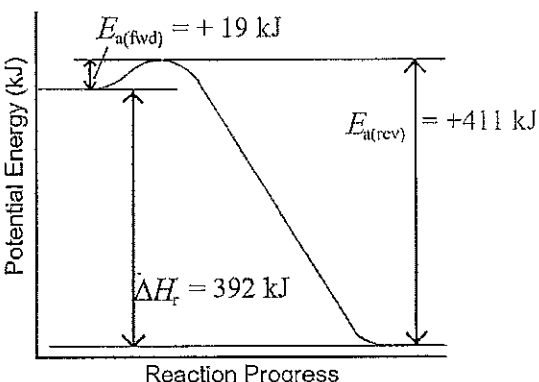
### What Is Required?

You need to determine the value of  $E_{a(\text{rev})}$  for a reaction and draw and label a potential energy diagram.

### What Is Given?

You know the activation energy of the forward reaction:  $E_{a(\text{fwd})} = +19 \text{ kJ}$

You know the enthalpy change of the forward reaction:  $\Delta H_r = -392 \text{ kJ}$

Plan Your Strategy	Act on Your Strategy
Use the formula $\Delta H_r = E_{a(\text{fwd})} - E_{a(\text{rev})}$ to determine $E_{a(\text{rev})}$ .	$\Delta H_r = E_{a(\text{fwd})} - E_{a(\text{rev})}$ $-392 \text{ kJ} = +19 \text{ kJ} - E_{a(\text{rev})}$ $E_{a(\text{rev})} = +411 \text{ kJ}$
Draw and label a potential energy diagram.	

### Check Your Solution

Since the sign of  $\Delta H_r$  is negative, the reaction is exothermic. The diagram correctly shows the potential energy of the product lower than the potential energy of the reactant.

15 For a reaction, on an arbitrary scale, the potential energies are as follows: activated complex, +112 kJ; reactants, +36 kJ; products, +78 kJ.

- Determine the activation energy and the enthalpy change for the reaction.
- Draw a labelled potential energy diagram for the reaction, indicating the relative energies of the reactants, products, and activated complex.

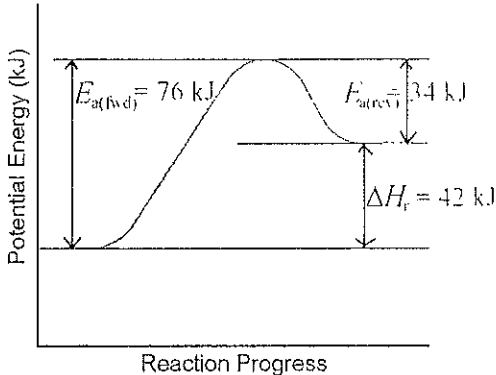
### What Is Required?

You need to determine the activation energy,  $E_a$ , and the enthalpy change,  $\Delta H_r$ , for the reaction.

You need to draw a potential energy diagram for the reaction.

### What Is Given?

You know the potential energies: activated complex, +112 kJ; reactants, +36 kJ; products, +78 kJ.

Plan Your Strategy	Act on Your Strategy
<p>a. The activation energy is the difference between the potential energy of the activated complex and the potential energy of the reactants. The enthalpy change is the difference in potential energy between the products and reactants. Estimate the energy scale (y-axis) that will include the calculated differences in energy.</p>	$E_a = 112 \text{ kJ} - 36 \text{ kJ}$ $= +76 \text{ kJ}$ $\Delta H = 78 \text{ kJ} - 36 \text{ kJ}$ $= +42 \text{ kJ}$
<p>b. Draw and label the potential energy diagram.</p>	

### Check Your Solution

The sign of the enthalpy change is positive, and the diagram will show the potential energy of the reactants lower than the potential energy of the products.