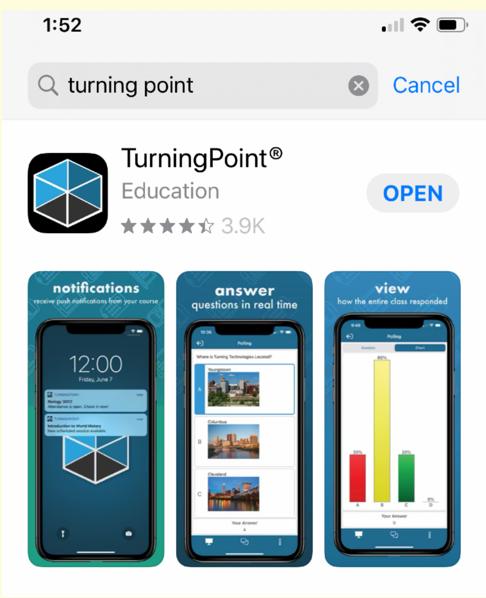
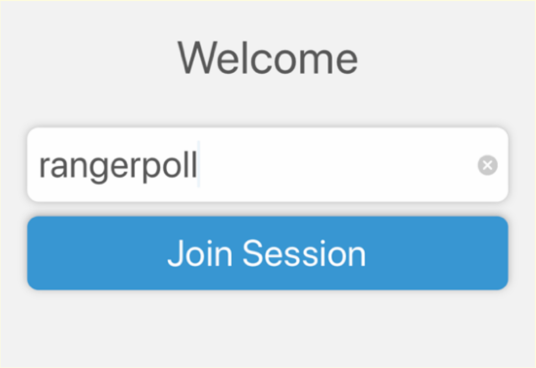
Thermochemical Equations

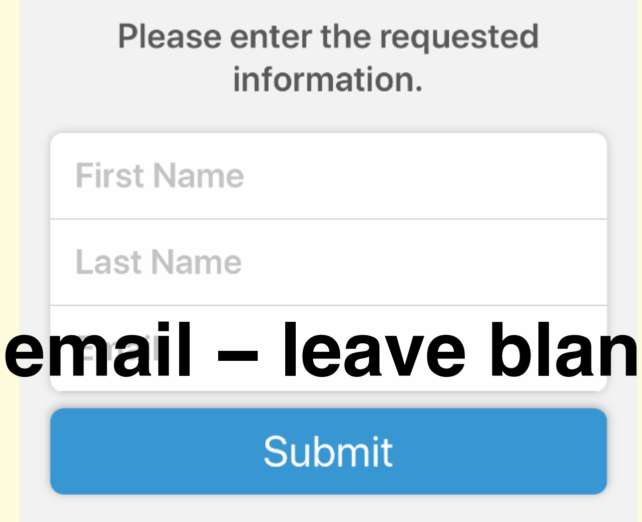
Energy of Reactions

The energy diagram shown below represents which type of reaction?

1. exothermic
2. endothermic







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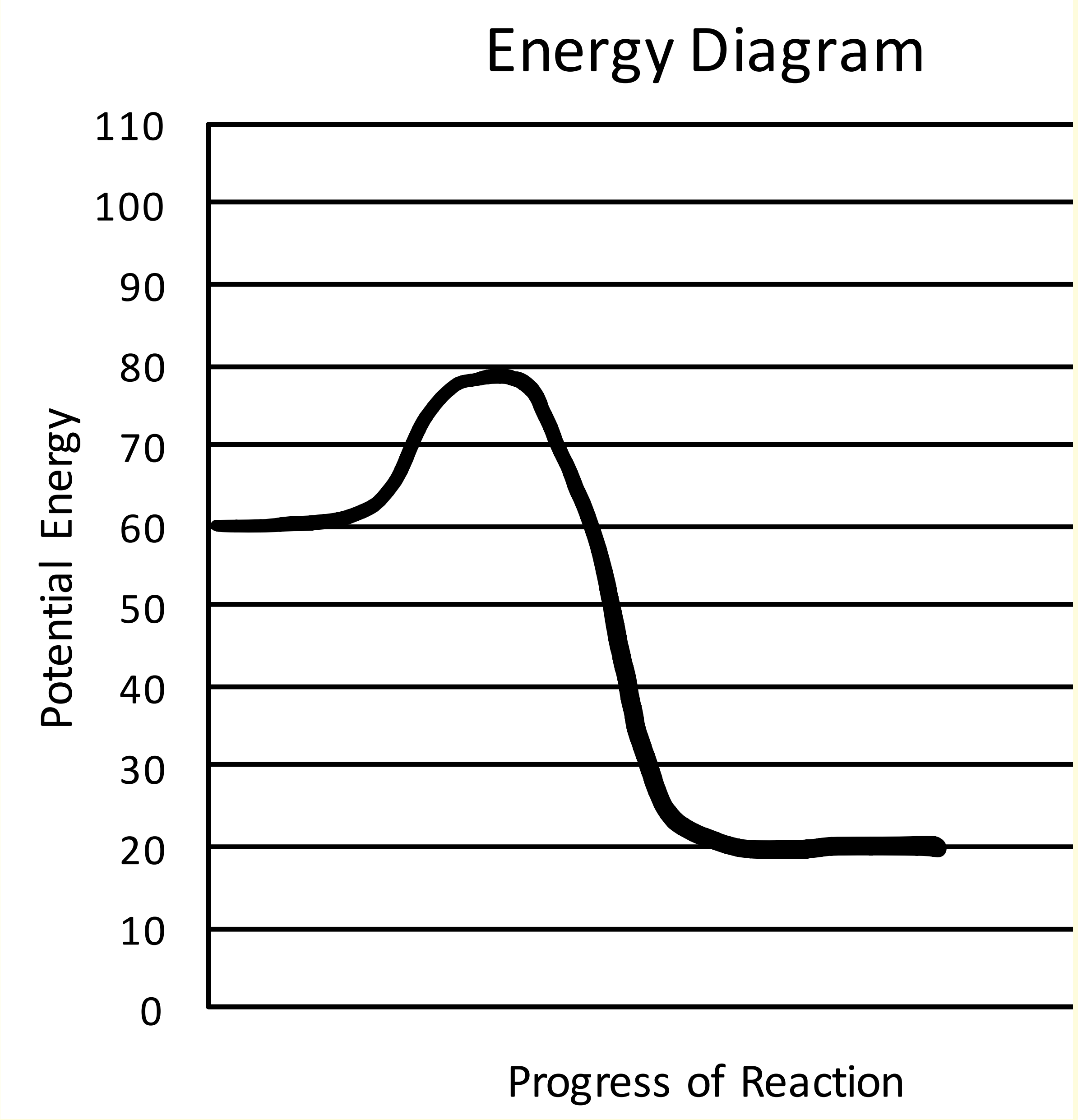

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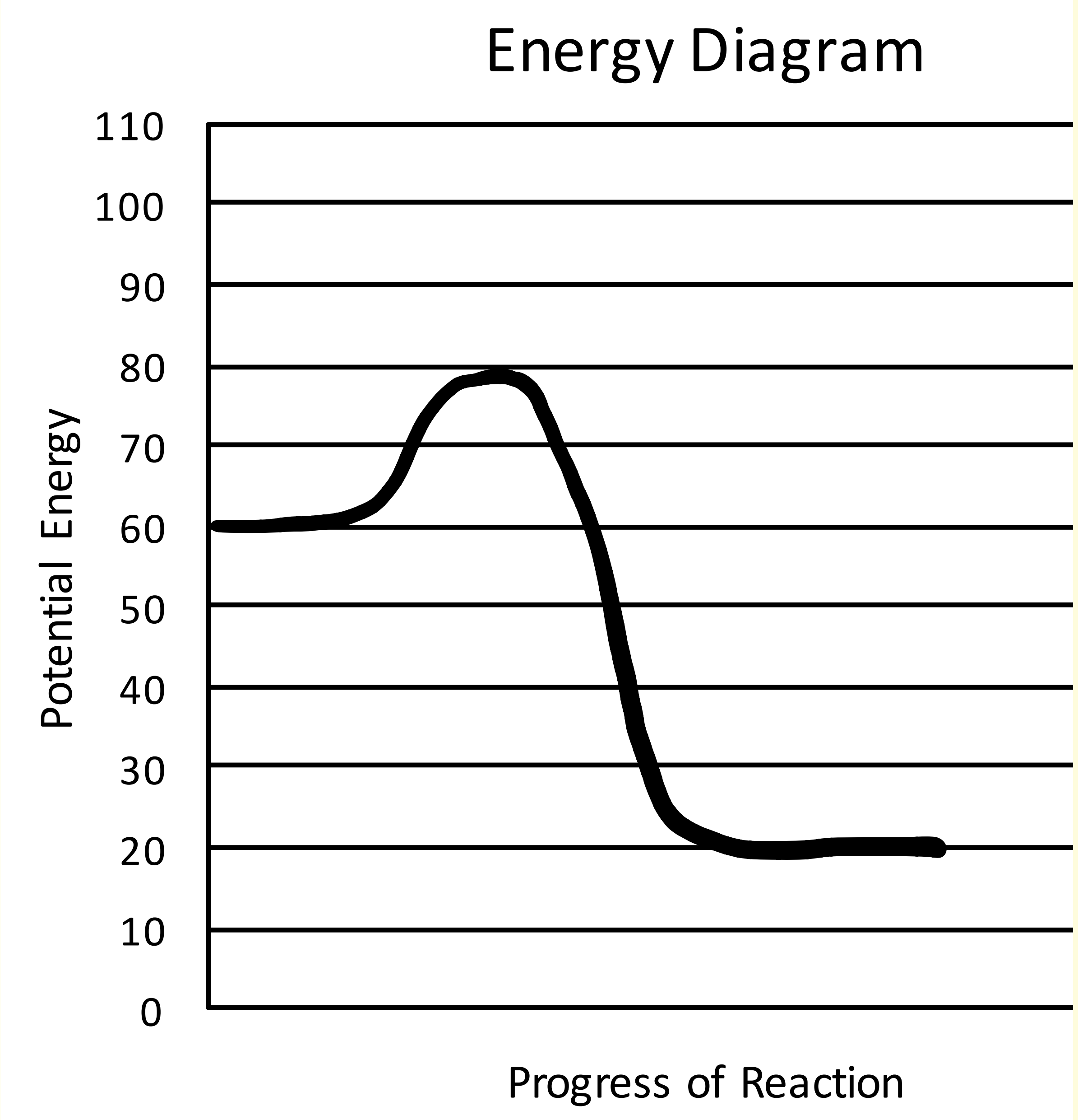
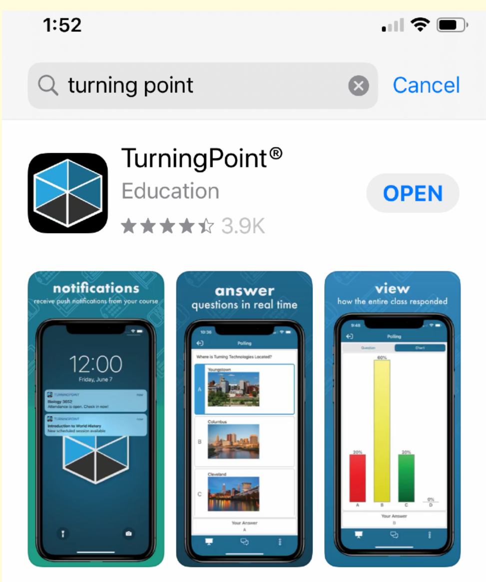
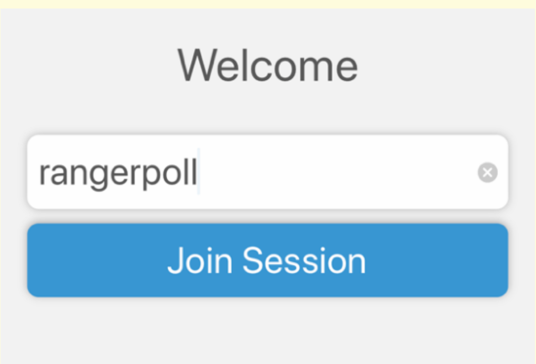
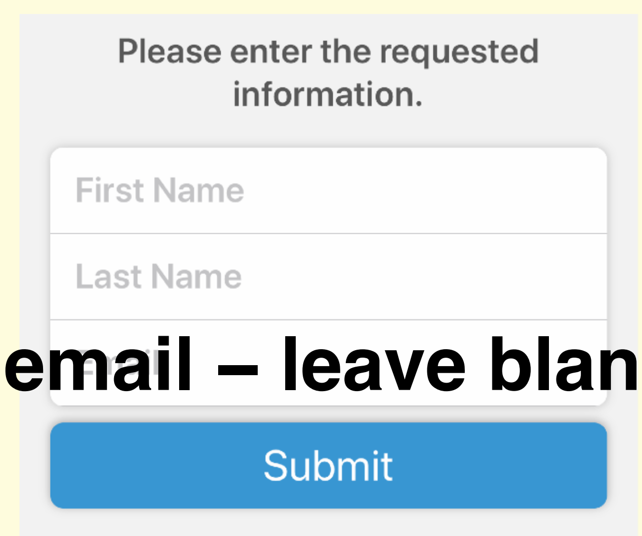


If you were near this reaction, would it feel hot or cold?

1. feel hot
2. feel cold







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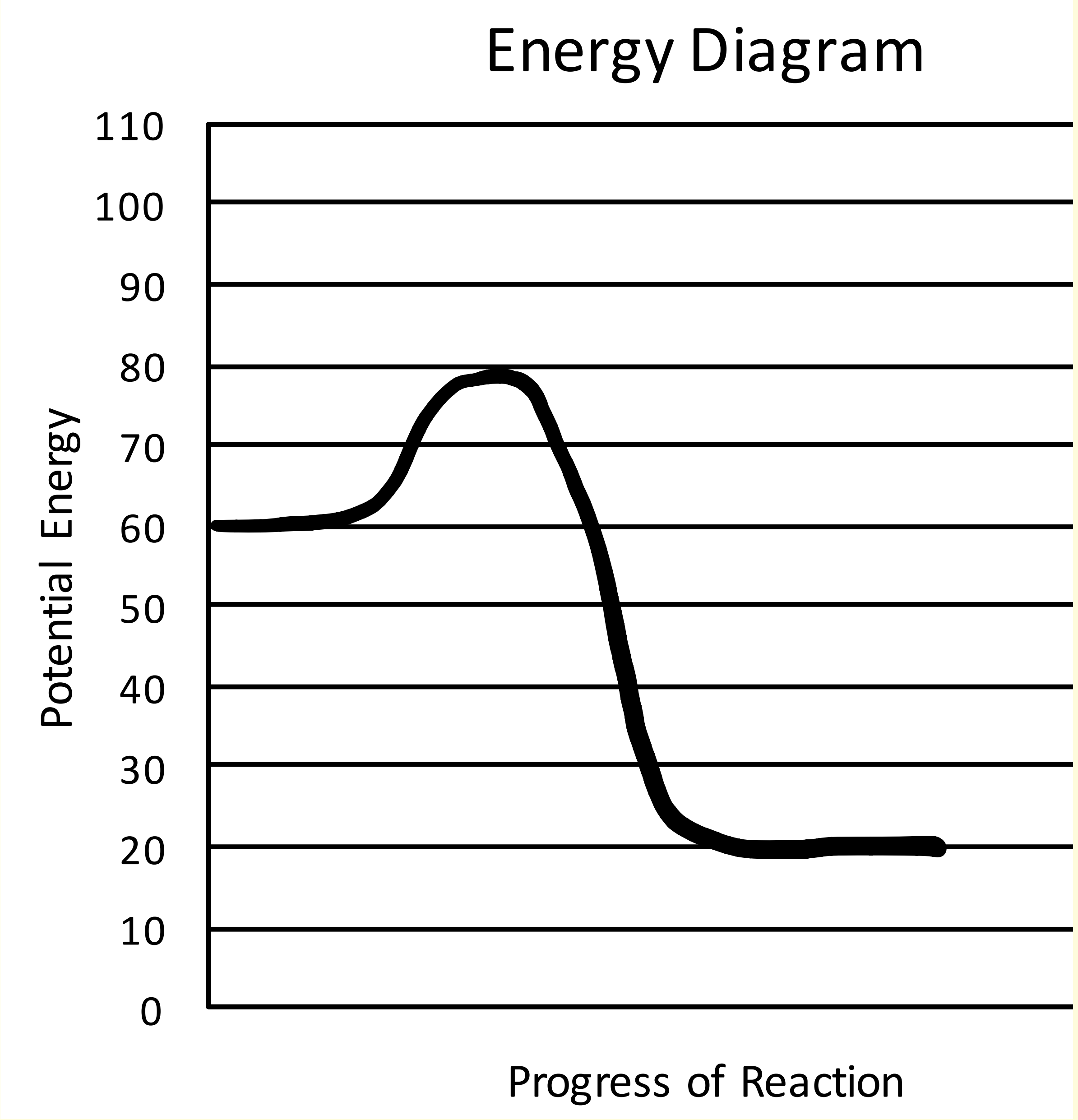

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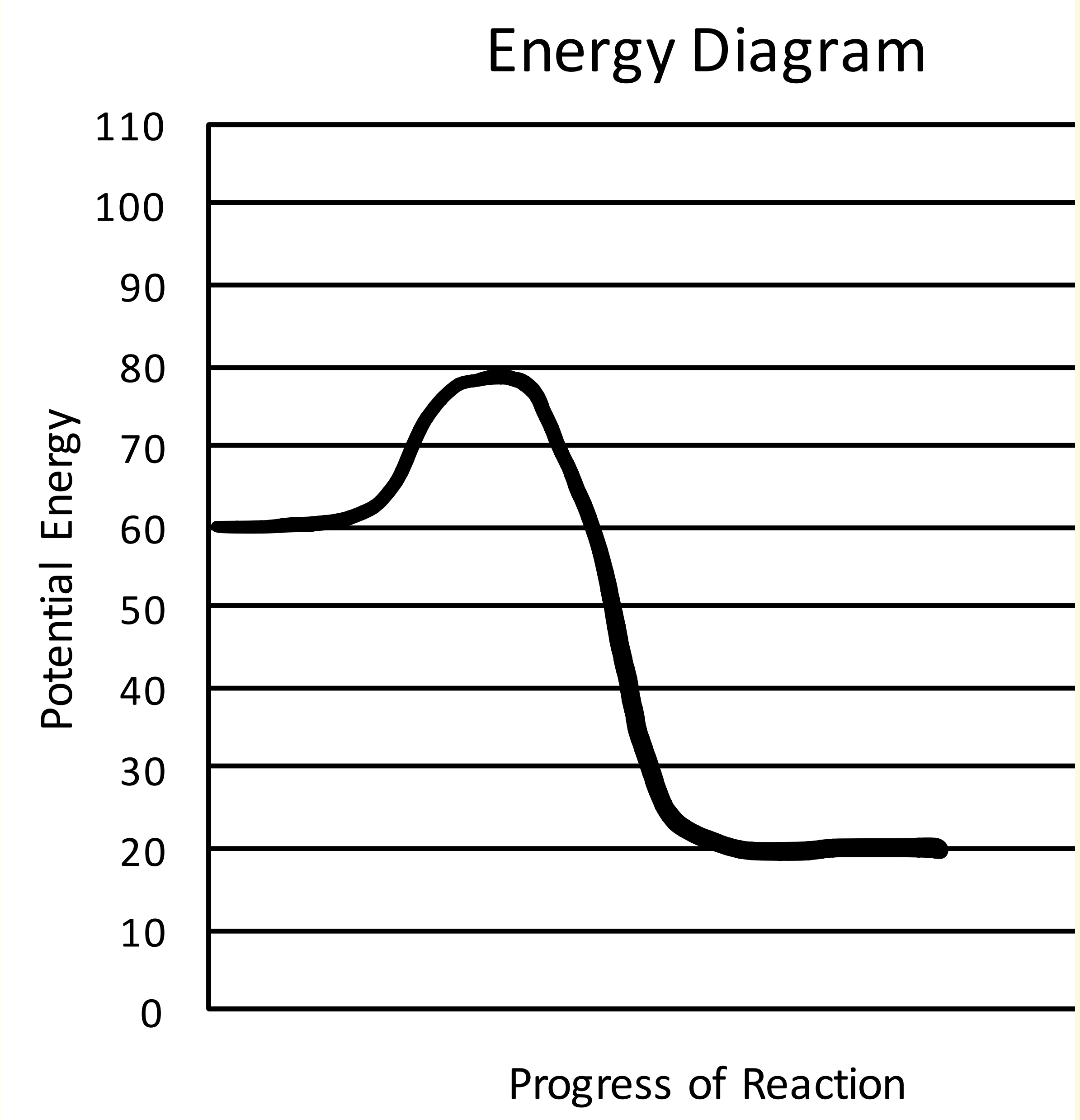
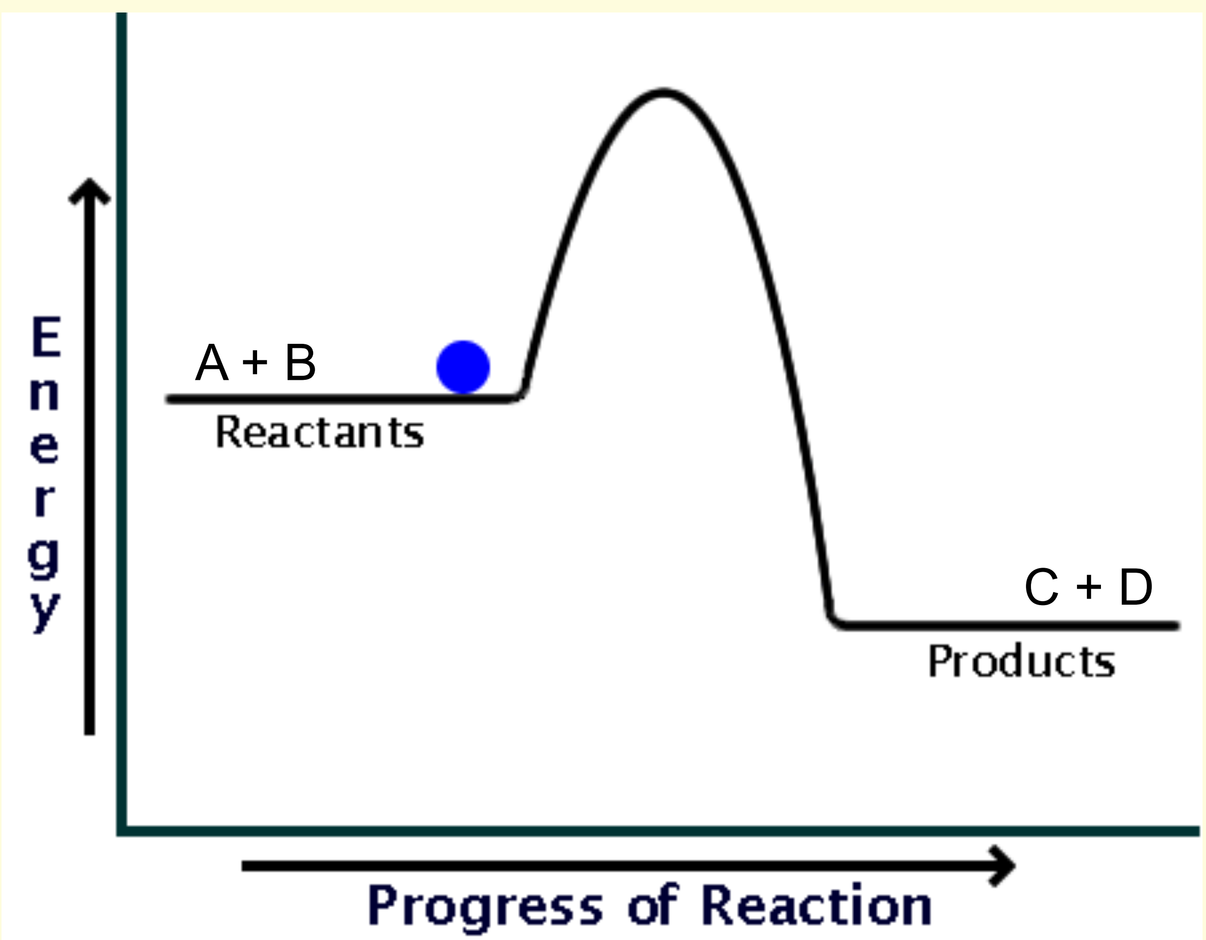
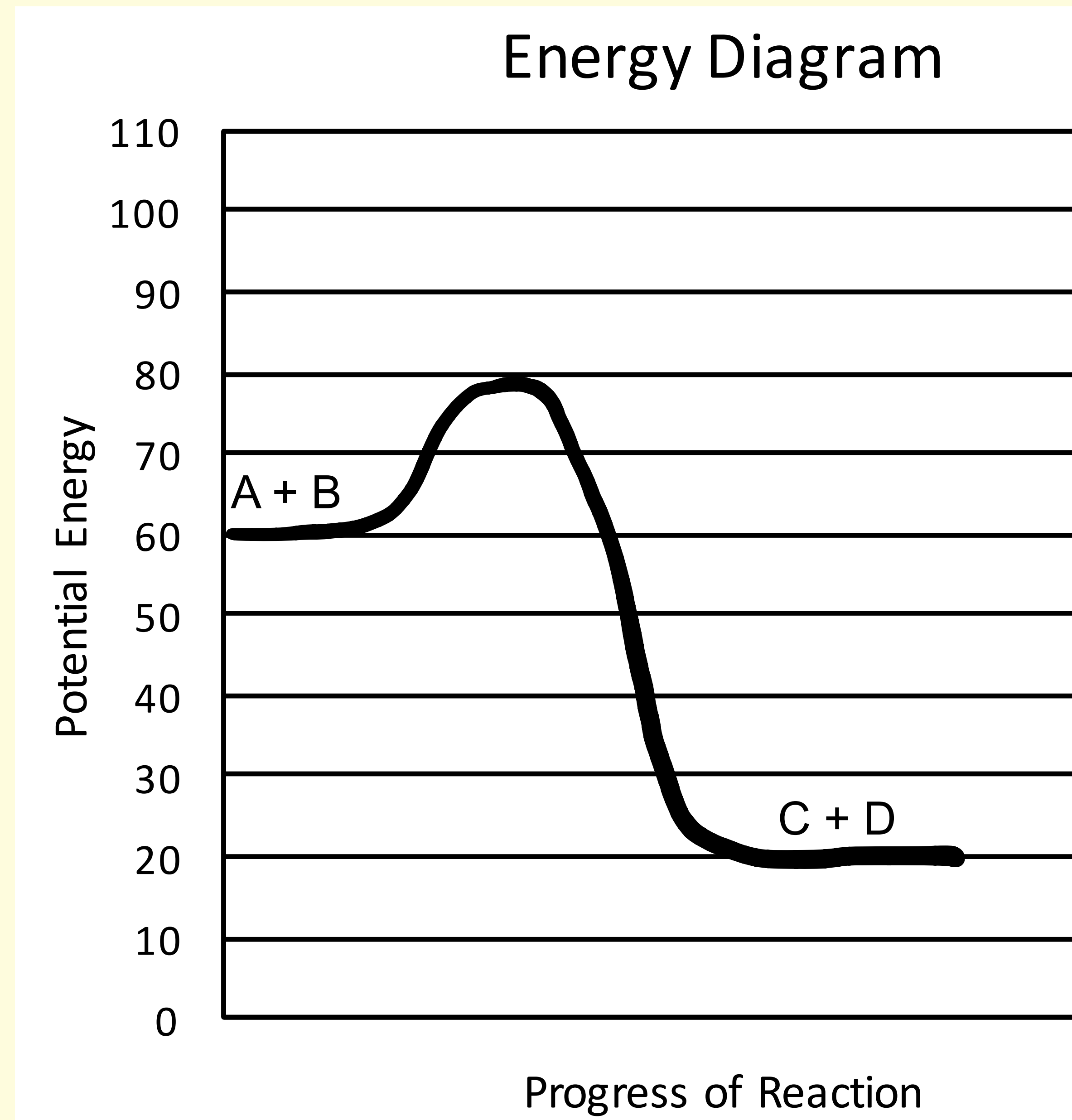


For the reaction: A + B → C + D
The energy should be represented on which side of the chemical equation?

1. left
2. right





For the reaction: A + B → C + D
The energy should be represented on which side of the chemical equation?

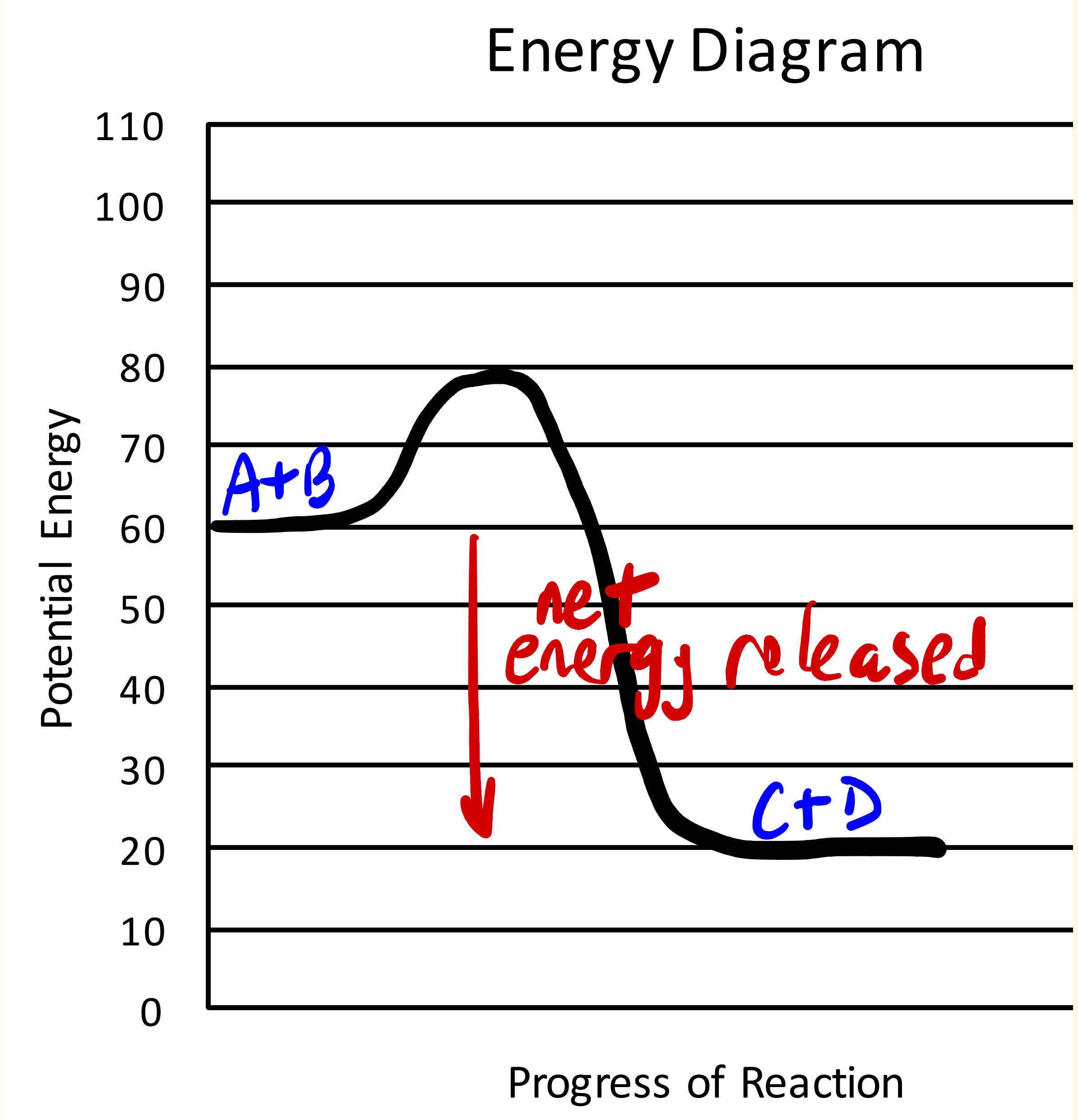
1. left
2. right

feels hot if you are nearby

A + B → C + D + Energy

energy = energy

Law of Conservation of Energy



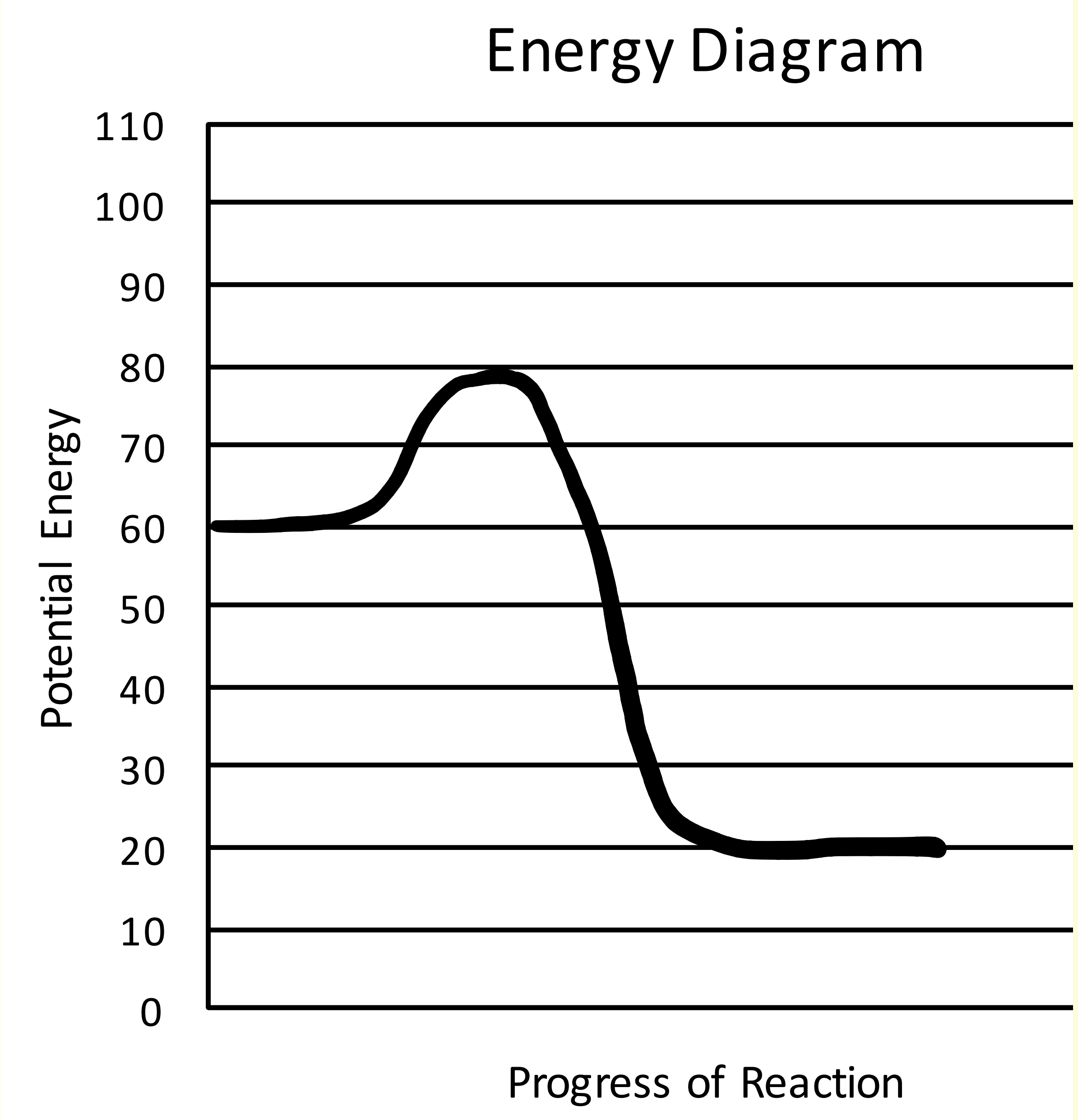
Δ *to ipad*

For the reaction: A + B → C + D

Using the graph below, what value of ΔH_{rxn} would be recorded in the table below?

1. +20
2. −20
3. +40
4. −40
5. +60
6. −60

Energy of Rxn	ΔH (kJ/mol)
A + B → C + D	?
melting ice	
decomposition of H_2O_2	
ATP→ ATP	



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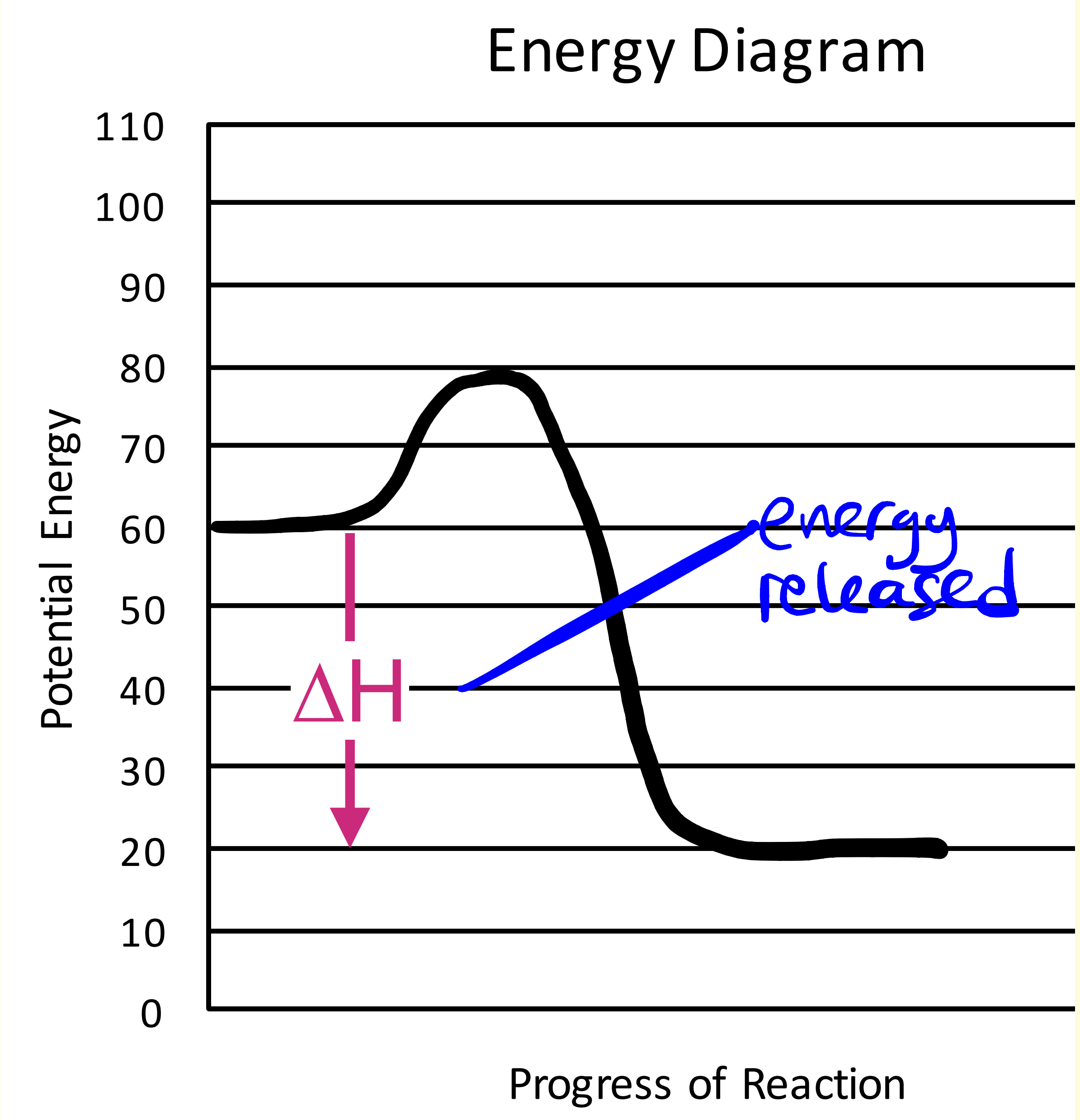


Connections to Unit C

Phase Changes

"bond" breaking	"bond" forming
endothermic	exothermic
melting ice	freezing water
ΔH_{fusion} (334 J/g)	ΔH_{fusion} (334 J/g)
boiling water	condensing steam
$\Delta H_{vaporization}$ (2250 J/g)	$\Delta H_{vaporization}$ (2250 J/g)

energy + $H_2O_{(solid)} \rightarrow H_2O_{(liquid)}$

energy + $H_2O_{(liquid)} \rightarrow H_2O_{(gas)}$

$H_2O_{(liquid)} \rightarrow H_2O_{(solid)}$ + energy

$H_2O_{(gas)} \rightarrow H_2O_{(liquid)}$ + energy

Connections to Unit C

Units?

"bond" breaking	"bond" forming
endothermic	exothermic
melting ice	freezing water
ΔH_{fusion} (334 J/g)	$-\Delta H_{fusion}$ (334 J/g)
boiling water	condensing steam
$\Delta H_{vaporization}$ (2250 J/g)	$-\Delta H_{vaporization}$ (2250 J/g)

$$334\ \frac{J}{g} \times \frac{18.02\ g}{1\ mol} = 6019\ \frac{J}{1\ mol} \Rightarrow 6.02\ \frac{kJ}{1\ mol}$$

$$2250\ \frac{J}{g} \times \frac{18.02\ g}{1\ mol} = 40545\ \frac{J}{1\ mol} \Rightarrow 40.5\ \frac{kJ}{1\ mol}$$

6.02 kJ + $H_2O_{(solid)} \rightarrow H_2O_{(liquid)}$

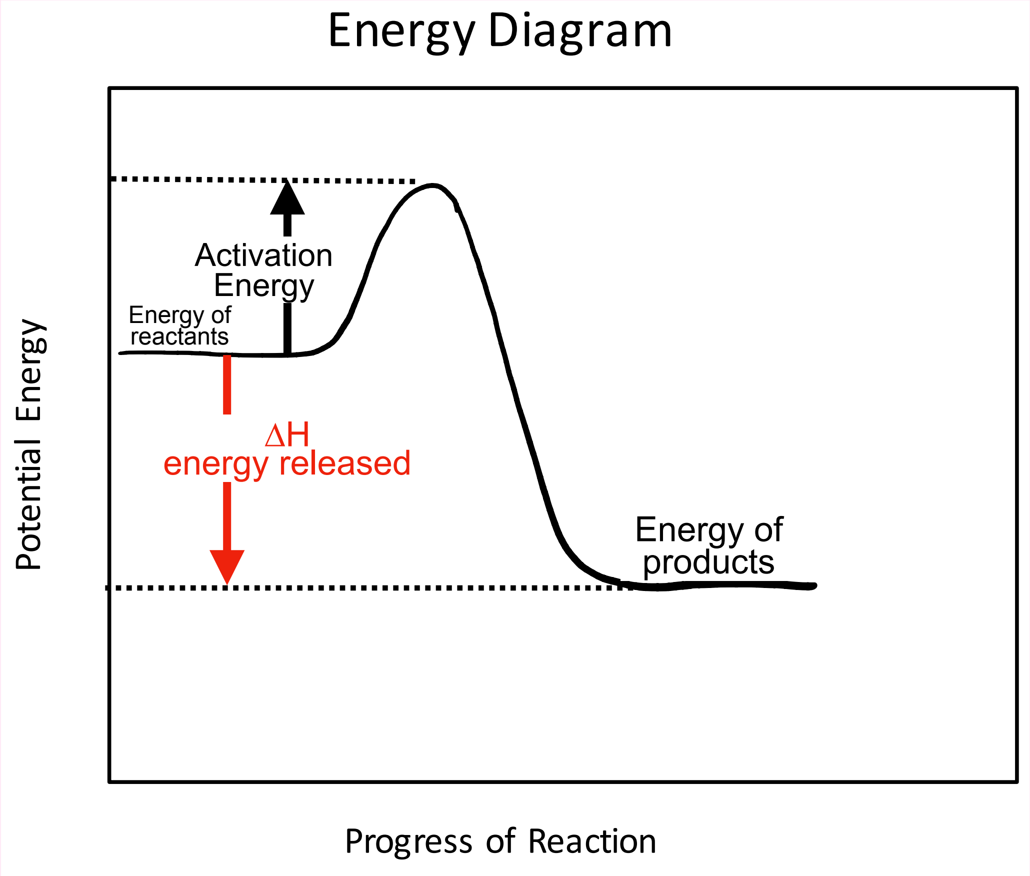
40.5 kJ + $H_2O_{(liquid)} \rightarrow H_2O_{(gas)}$

$H_2O_{(liquid)} \rightarrow H_2O_{(solid)}$ + 6.02 kJ

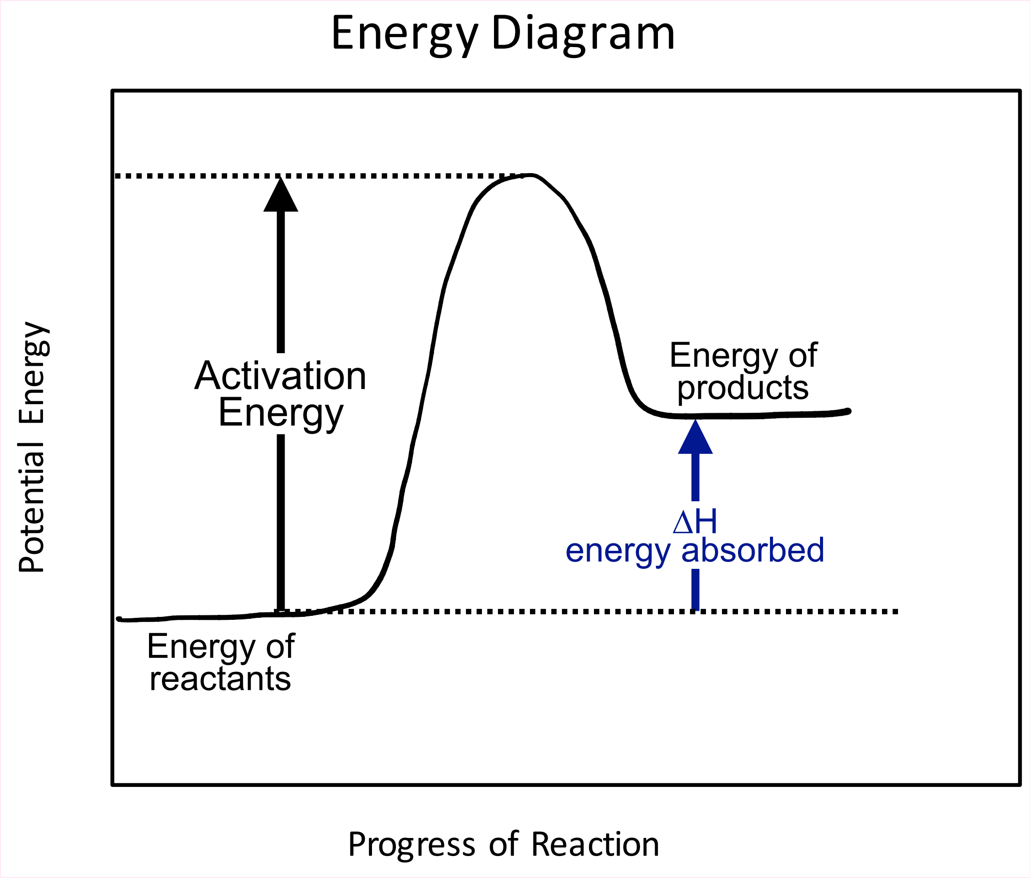
$H_2O_{(gas)} \rightarrow H_2O_{(liquid)}$ + 40.5 kJ

Sign of ΔH: + or – ?

- Energy out, A + B → C + D + energy
  - ✓ Exothermic
  - ✓ ΔH negative sign
  - ✓ nearby thermometer, temp goes up



- Energy in, energy + C + D → A + B
  - ✓ Endothermic
  - ✓ ΔH positive sign
  - ✓ nearby thermometer, temp goes down

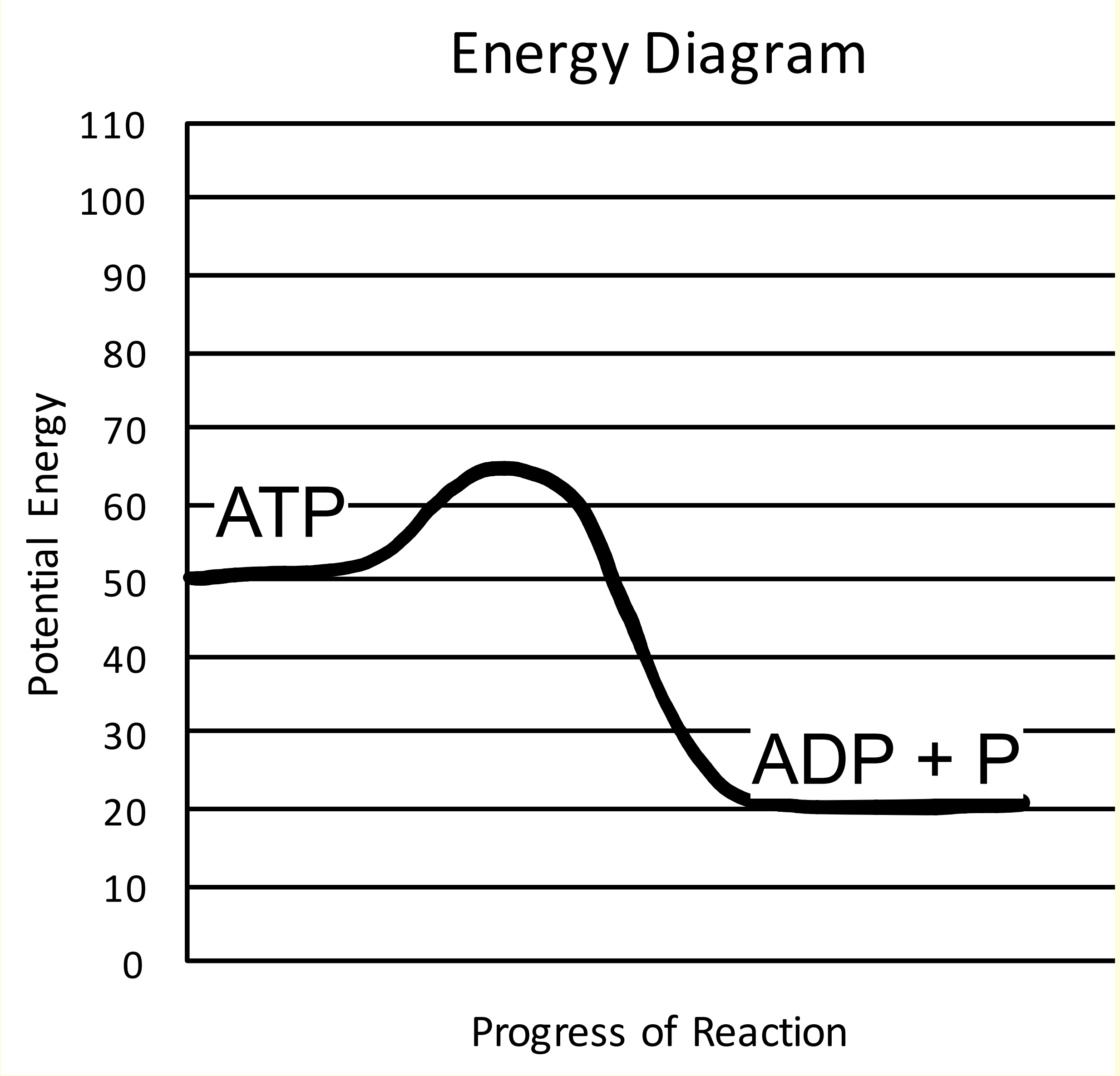


For the reaction: ATP → ADP + P

Using the graph below, what value of ΔH_{rxn} would be recorded in the table below?

1. +15
2. −15
3. +30
4. −30
5. +45
6. −45

Energy of Rxn	ΔH (kJ/mol)
A + B → C + D	
melting ice	
decomposition of H_2O_2	
ATP→ ATP	?

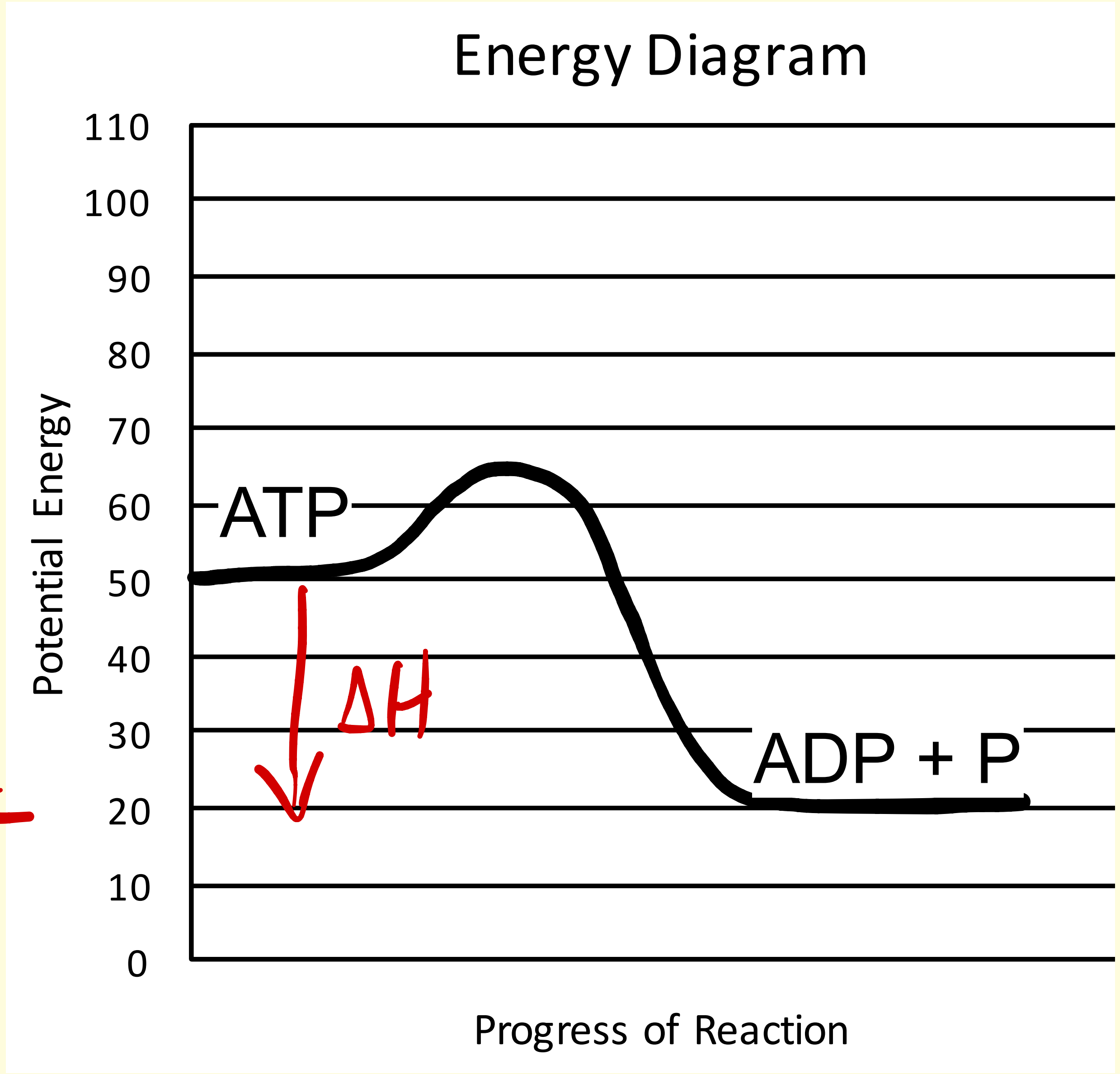


For the reaction: ATP → ADP + P Using the graph below, the ΔH of the reaction that sould be recorded in Energy of reaction table would be

1. +15
2. −15
3. +30
4. −30
5. +45
6. −45

Energy of Rxn	ΔH (kJ/mol)
A + B → C + D	
melting ice	
decomposition of H_2O_2	
ATP→ ATP	?

exothermic



The Energy of Bonds

Bond breaking	Bond forming
Endothermic	Exothermic
+	–

$$ATP \rightarrow ADP + P + E$$

but wait….

this looks like bond breaking is exothermic

so why do I say bond breaking is endothermic??

hold on, the equation above does not tell the whole story…

Connections to Biology

the Energy of Bonds

Bond breaking
Endothermic

Bond Forming
Exothermic

15 energy in

$$ATP \rightarrow ADP + P + E$$

45 energy out

$$C_{10}H_{16}N_5O_{13}P_3 + H_2O \rightarrow C_{10}H_{15}N_5O_{10}P_2 + HPO_4^{2-} + 2H^+ + 30kJ$$

- ✓ Less energy in to break the bonds compared with more energy out when bonds formed
- ✓ Net result? Exothermic, −30 kJ/mol$_{ATP\ reacted}$

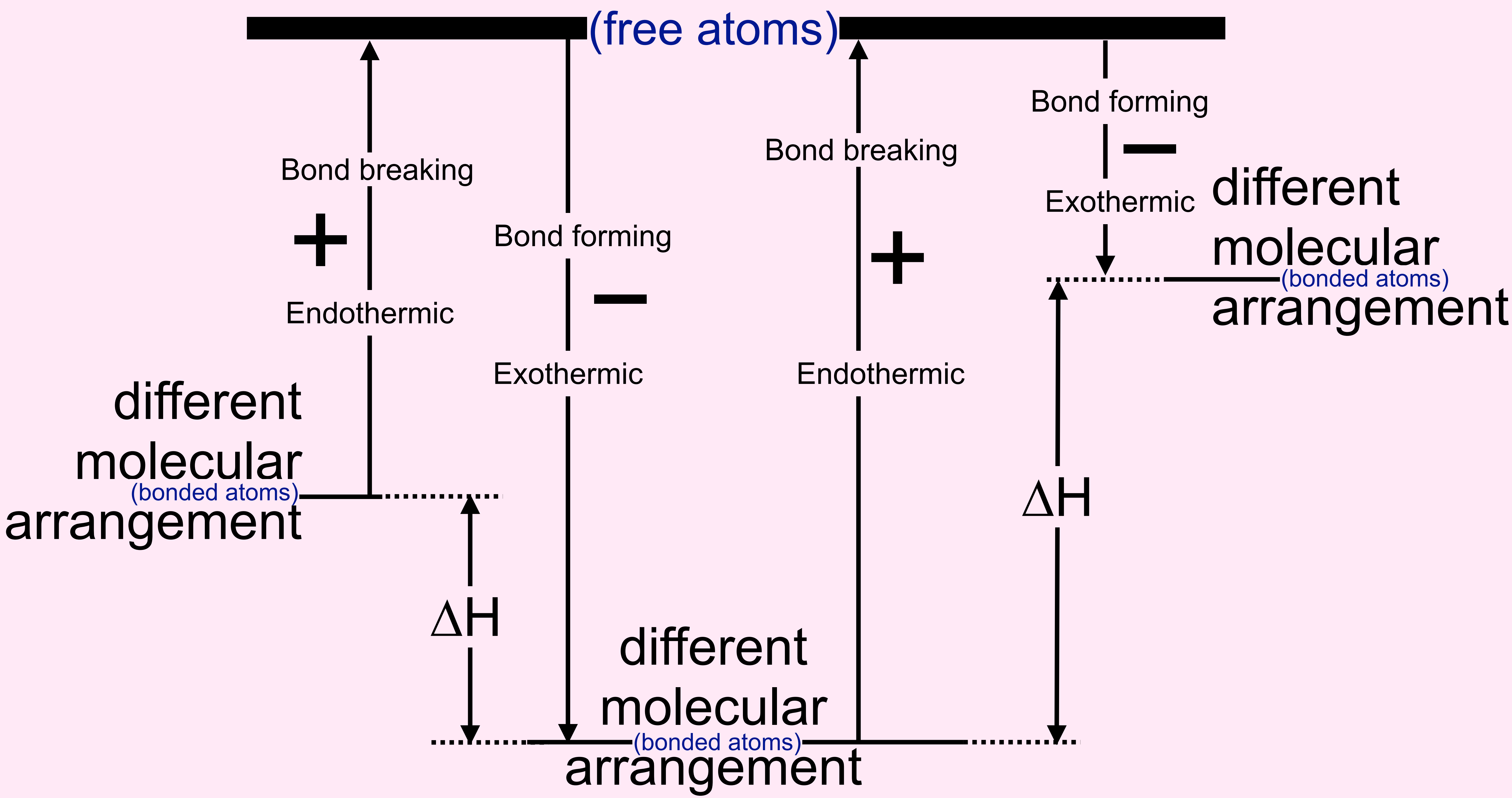
45 energy in 15 energy out

and the reverse… $ADP + P + E \rightarrow ATP \quad \Delta H = +30\ kJ/mol$

(free atoms) (bonded atoms)

Parts vs molecules

A group of atoms can be arranged into different molecules.
Those arrangments will have different potential energy.



ATP $\rightarrow$ ADP + P + 30 kJ

In one day, your body cycles 2×10^{26} ATP molecules each day. Calculate the amount of energy transfer.

Enter your answer on your clicker.

$ATP \rightarrow ADP + P + 30\ kJ$

In one day, your body cycles 2×10^{26} ATP molecules each day. Calculate the amount of energy transfer.

Enter your answer on your clicker.

$$\frac{2 \times 10^{26}\ \text{ATP}}{\text{day}} \times \frac{1\ \text{mol ATP}}{6.02 \times 10^{23}\ \text{ATP}} \times \frac{30\ \text{kJ}}{1\ \text{mol ATP}} = -9967\ \text{kJ}$$

SF

$$-10{,}000\ \text{kJ/day}$$

Photosynthesis

$$2800\ \text{kJ} + 6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

The ΔH for this thermochemical reaction is

1. negative
2. positive

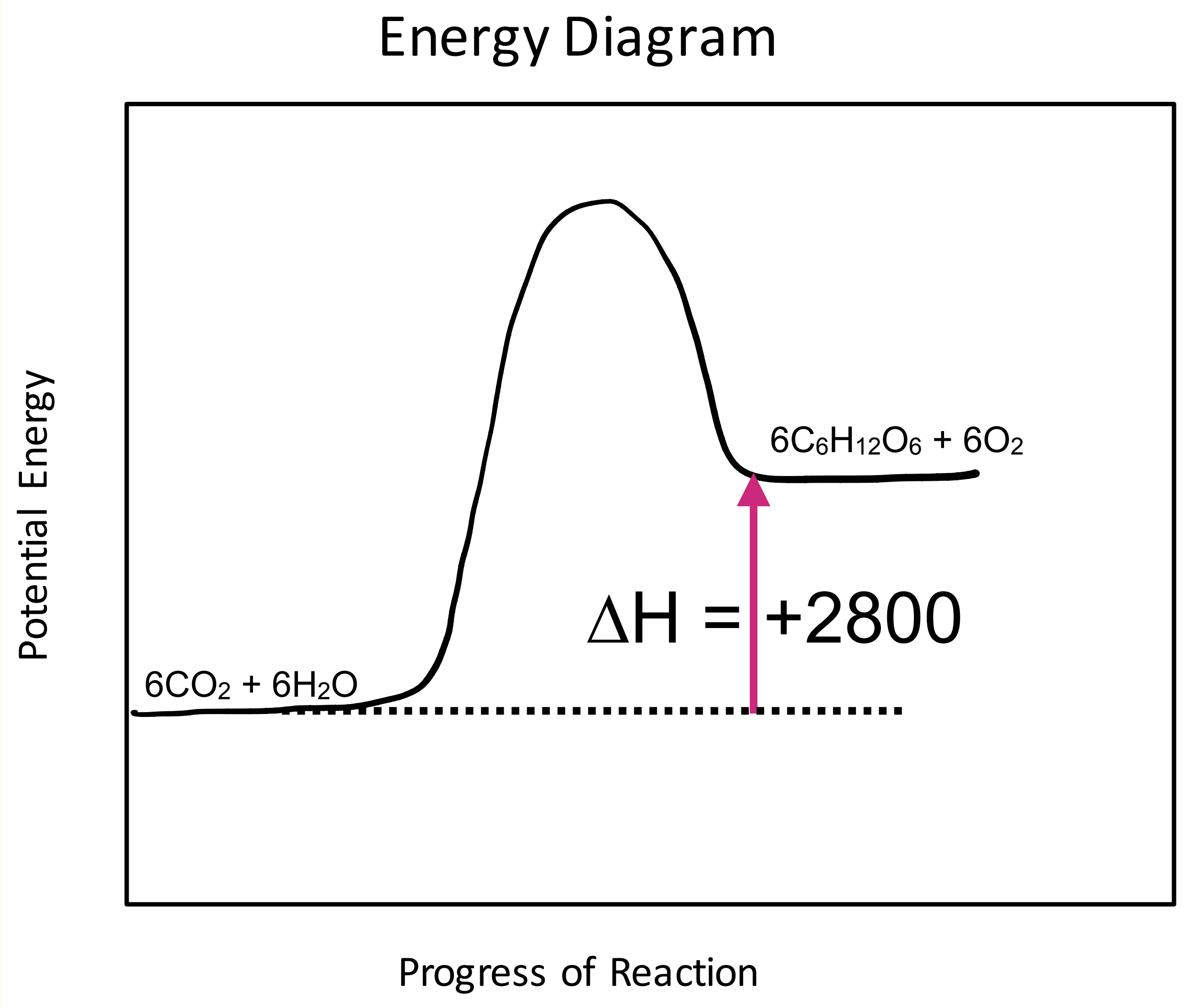
Photosynthesis

$2800\ kJ + 6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$

The ΔH for this thermochemical reaction is

$\Delta H = +2800\ kJ/mol_{rxn}$

1. negative
2. positive



Connections to Biology

Photosynthesis

Bond breaking — Endothermic

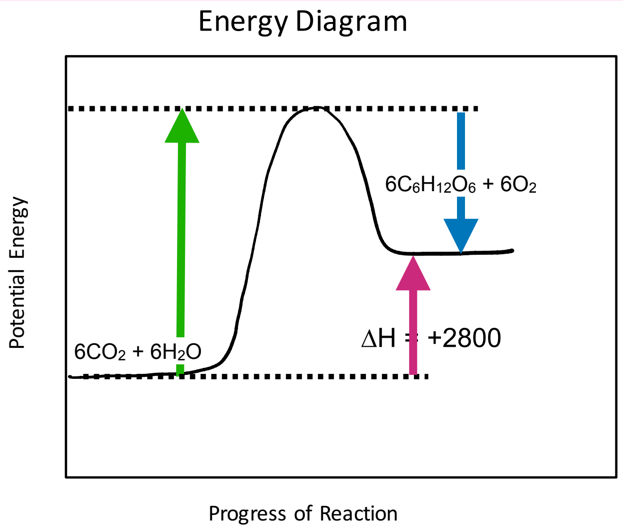
Bond Forming — Exothermic

6600 energy in

3800 energy out

$$2800\ kJ + 6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

- ✓ More energy in to break the bonds compared with less energy out when bonds formed
- ✓ Net result? Endothermic



$$2800\ kJ + 6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

The thermochemical equation for photosynthesis:

$$2800\ kJ + 6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

The ΔH for cellular respiration is

1. $+2803\ kJ/mole_{rxn}$
2. $-2803\ kJ/mole_{rxn}$

The thermochemical equation for photosynthesis:

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The ΔH for cellular respiration is

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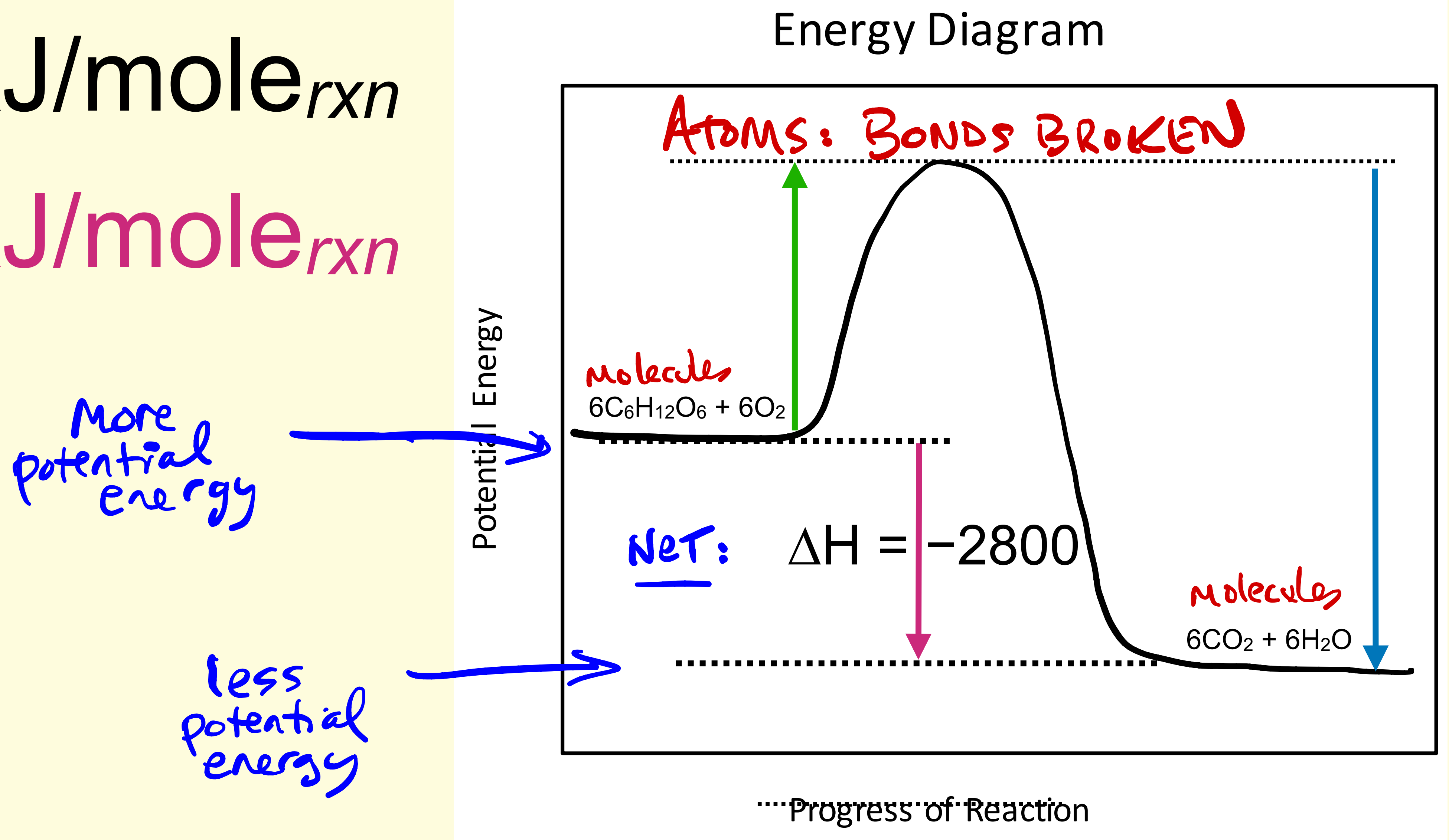


Connections to Biology

Cellular Respiration

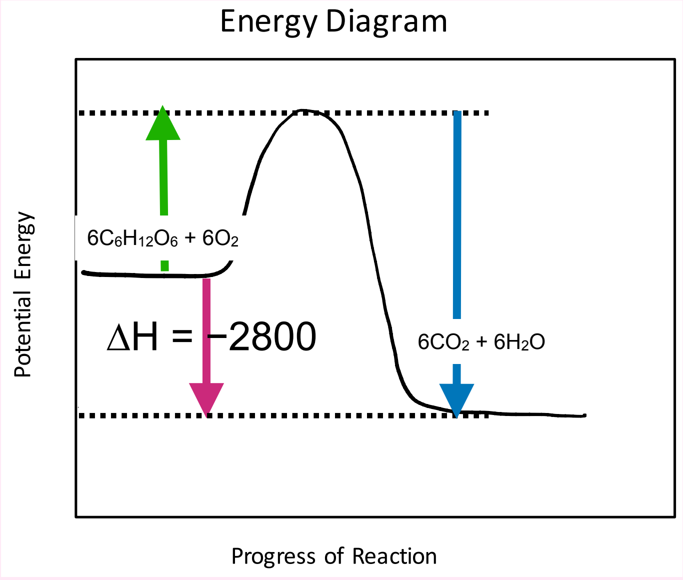
Bond breaking	Bond Forming
Endothermic	Exothermic

3800 energy in

6600 energy out

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 2800\ kJ$$

- ✓ Less energy in to break the bonds compared with more energy out when bonds formed
- ✓ Net result? Exothermic



$2H_2O_2 \rightarrow 2\ H_2O + O_2$

$\Delta H = -108\ kJ/mol_{rxn}$ MM H_2O_2 = 34.0 g/mol

Calculate the energy change when 25.0 g of hydrogen peroxide is decomposed.

$2H_2O_2 \rightarrow 2\ H_2O + O_2$

$\Delta H = -108\ kJ/mol_{rxn}$ MM H_2O_2 = 34.0 g/mol

−39.7 kJ for 25.0 g of hydrogen peroxide.

$$25\ g\ H_2O_2 \times \frac{1\ mol}{34\ g} \times \frac{-108\ kJ}{2\ mol\ H_2O_2} = -39.7\ kJ$$

Is the energy released or absorbed?

1. energy released
2. energy absorbed

$2H_2O_2 \rightarrow 2\ H_2O + O_2$

$\Delta H = -108$ kJ/mol$_{rxn}$

−39.7 kJ for 25.0 g of hydrogen peroxide.

The 39.7 kJ is released.

Does the container warm up or cool down?

1. The container warms
2. The container cools

$2H_2O_2 \rightarrow 2\ H_2O + O_2$

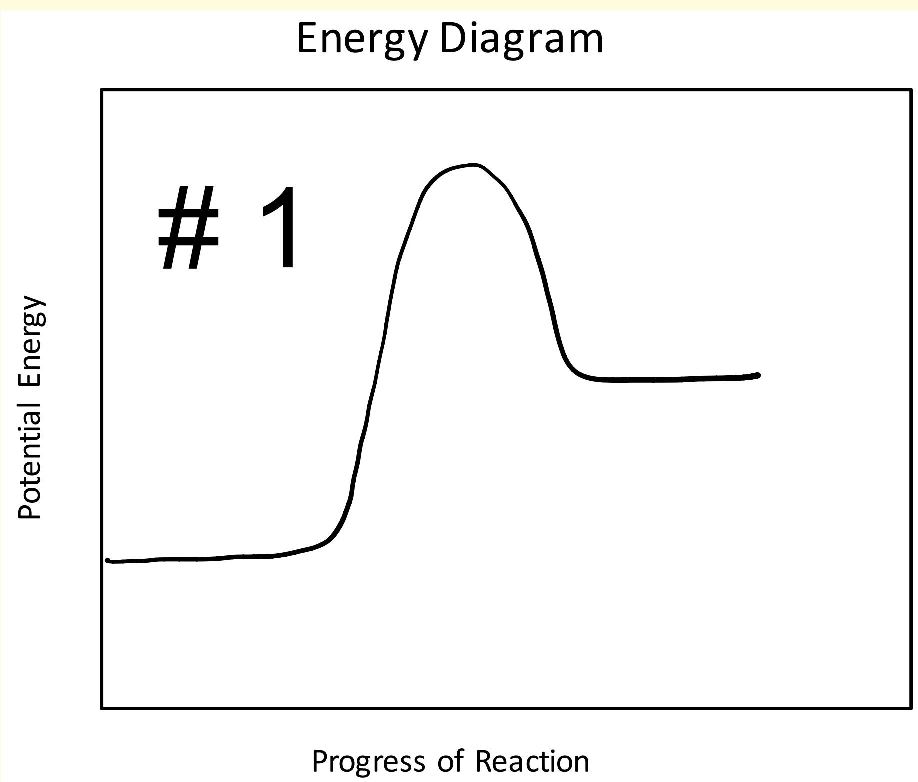
$\Delta H = -108\ kJ/mol_{rxn}$

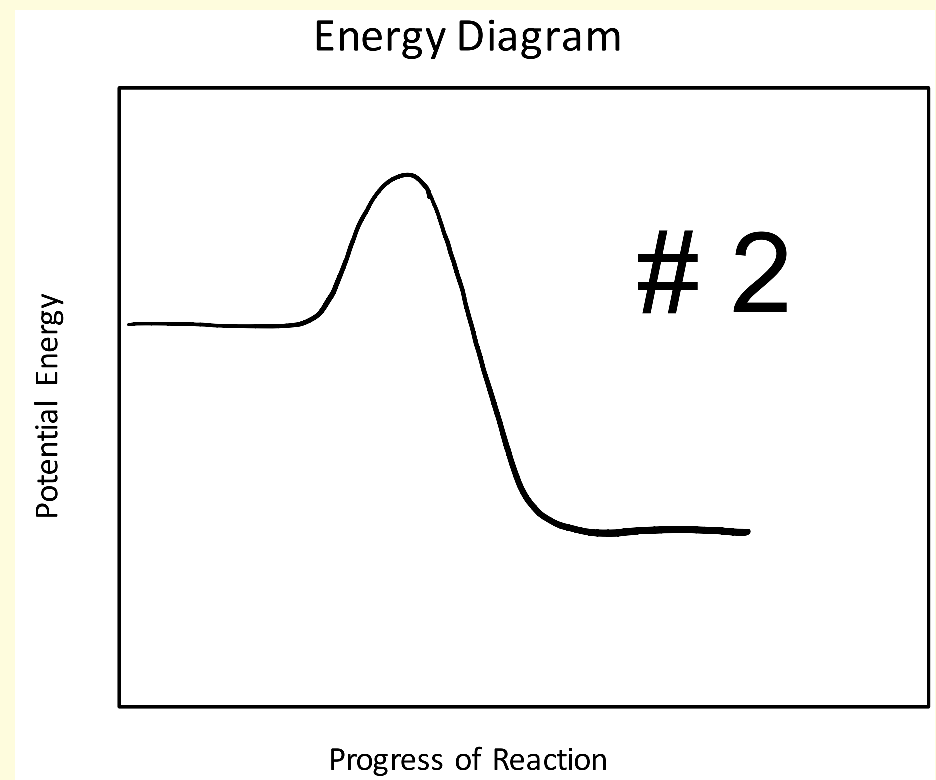
−39.7 kJ for 25.0 g of hydrogen peroxide.

The 39.7 kJ is released, and the container warms up.

energy released as heat warms up the container and the molecules still in the container

Which diagram is most appropriate?





$$2H_2O_2 \rightarrow 2\,H_2O + O_2$$

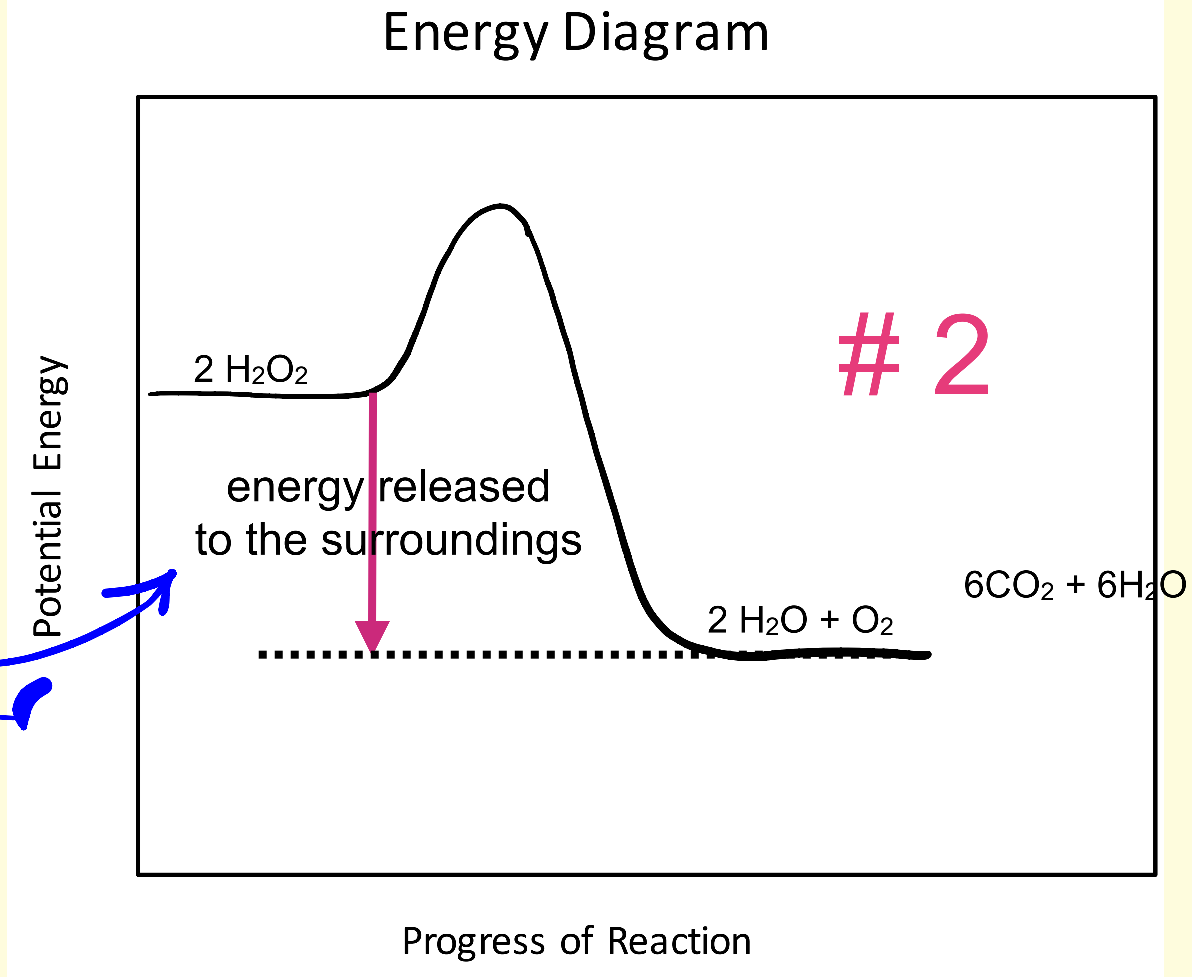
$$\Delta H = -108 \text{ kJ/mol}_{rxn}$$

−39.7 kJ for 25.0 g of hydrogen peroxide.

The 39.7 kJ is released,

and the container warms up.

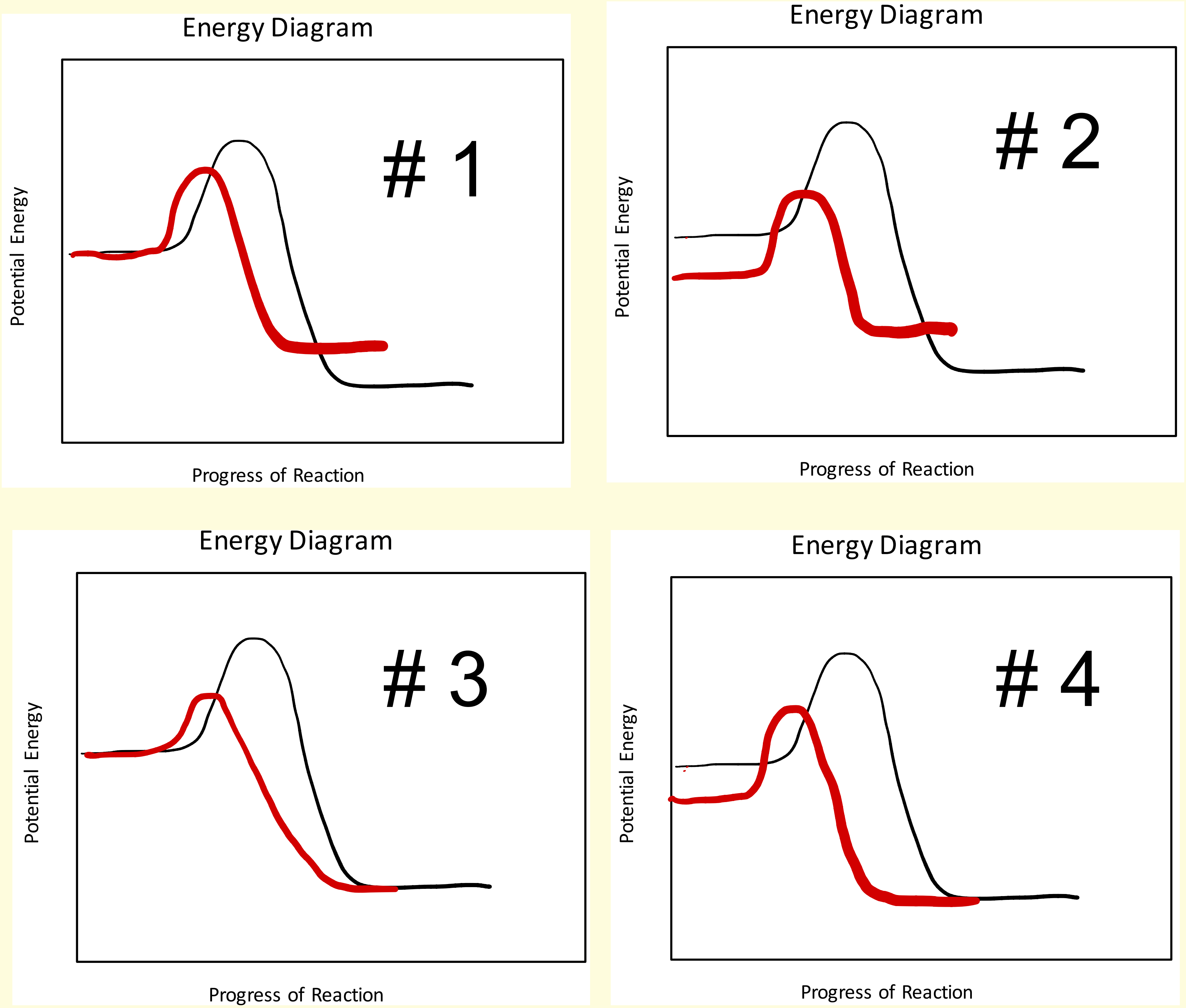
Energy released warms up any molecules in the container



$2H_2O_2 \rightarrow 2\ H_2O + O_2$

$\Delta H = -108\ kJ/mol_{rxn}$

How would the graph change if a catalyst were added?



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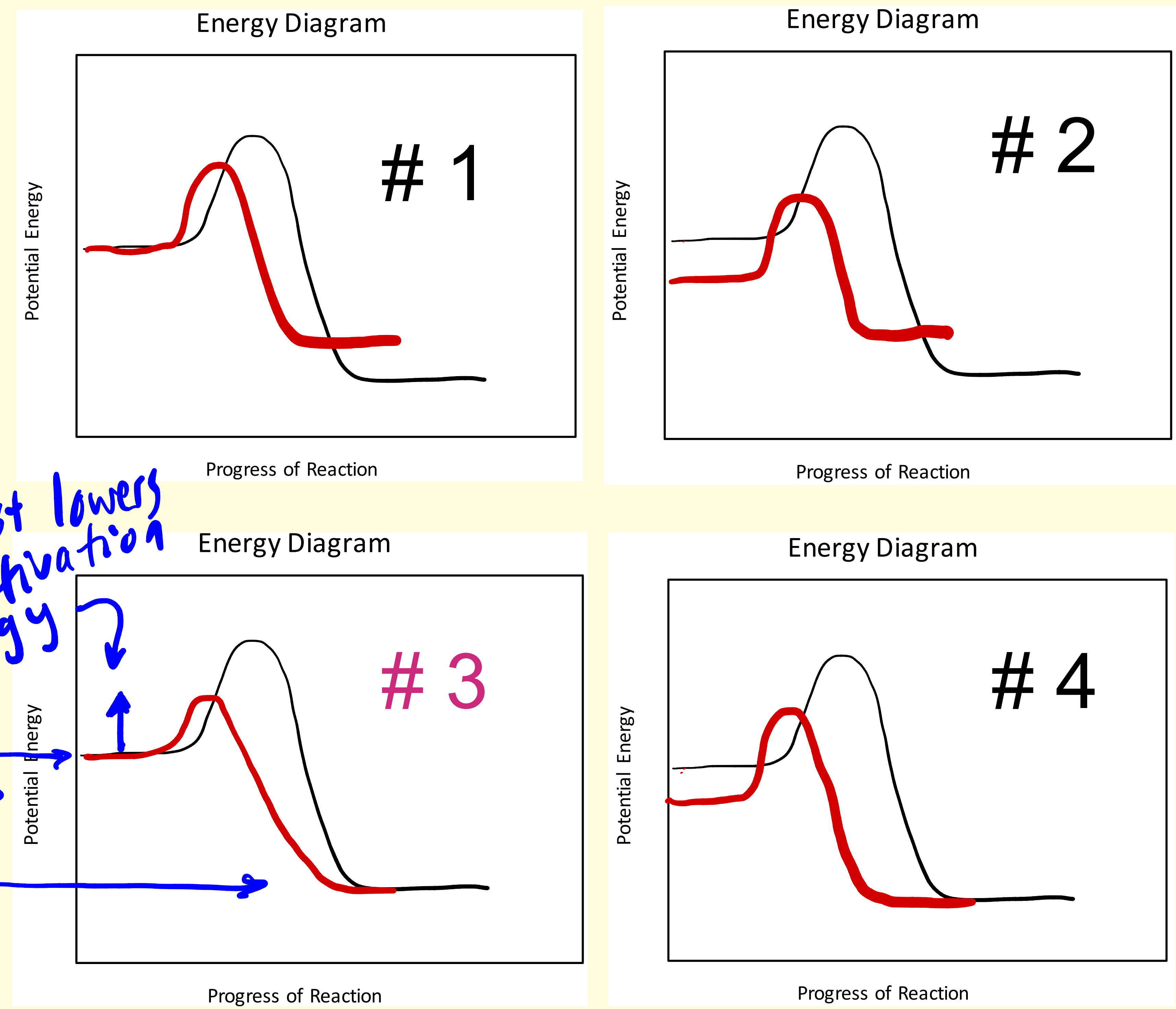

catalyst lowers the activation energy

potential energy of reactants and products does NOT change

$C_{12}H_{22}O_{11} + 6\ O_2 \rightarrow 12\ CO_2 + 11\ H_2O$

$\Delta H = -5645\ kJ/mol_{rxn}$ MM = 342 g/mol

One bottle (20 ounces, 570 g) of Gatorade contains 34 g of sucrose. Calculate the amount of heat released by "burning" 34.0 g of sucrose, $C_{12}H_{22}O_{11}$.

$C_{12}H_{22}O_{11} + 6\ O_2 \rightarrow 12\ CO_2 + 11\ H_2O$

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$$34\text{g sucrose} \times \frac{1\text{mol}}{342\text{g}} \times \frac{-5645\text{ kJ}}{1\text{mol sucrose}} = -561\text{ kJ}$$

$C_{12}H_{22}O_{11} + 6\ O_2 \longrightarrow 12\ CO_2 + 11\ H_2O$

$\Delta H = -5645\ \text{kJ/mol}_{rxn}$

Burning 34.0 g of sucrose releases 561 kJ

If you used that energy to heat up 570. g of 20.ºC Gatorade, would the Gatorade reach boiling temp?

$C_{12}H_{22}O_{11} + 6\ O_2 \rightarrow 12\ CO_2 + 11\ H_2O$

$\Delta H = -5645\ kJ/mol_{rxn}$

Burning 34.0 g of sucrose releases 561 kJ

If you used that energy to heat up 570. g of 20.ºC Gatorade, would the Gatorade reach boiling temp?

$q = mc\Delta T$

560 kJ → $560{,}000\ J = 570g \times \frac{4.18\ J}{g\ °C} \times \Delta T$

$\Delta T = 235°C$ Yikes! way above boiling temp

Yes the Gatorade would reach boiling Temp ~100° Then energy would be used to vaporize while maintaining 100°

That’s all for now