551534 – Chemistry
Pretest 3.4

1 Experiments show that pure water at 25°C will dissociate as follows:

$$\text{Heat} + H_2O_{(l)} \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$

Which of the following correctly defines $[H^+]$ and $[OH^-]$?

A) $[H^+] = 7$ mol/L $[OH^-] = 7$ mol/L

B) $[H^+] = 14$ mol/L $[OH^-] = 1$ mol/L

C) $[H^+] = 1 \times 10^{-14}$ mol/L $[OH^-] = 1 \times 10^{-1}$ mol/L

D) $[H^+] = 1 \times 10^{-7}$ mol/L $[OH^-] = 1 \times 10^{-7}$ mol/L

2 Experiments show that pure water at 25°C will dissociate as follows:

$$\text{Heat} + H_2O_{(l)} \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$

What would be observed if the Ka was measured at 33 ^oC instead of 25^oC?

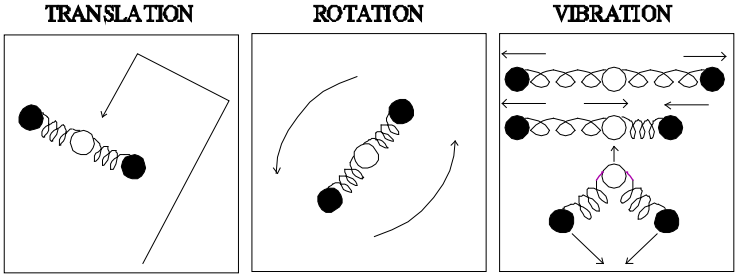
A) There would be no change; it's a constant

B) It would be influenced by the amount of Na^+ in the water

C) The value of K would be lower than 1.0 X 10^{-14}.

D) The pH of water would drop slightly.

3 The following illustrations represent the types of motion exhibited by the different phases of matter.



A block of solid carbon dioxide (dry ice) is heated from -90°C to -70°C.

What **new** molecular motion is produced?

(N.B. : Carbon dioxide sublimes at -78.5°C at standard atmospheric pressure.)

A) Translational motion

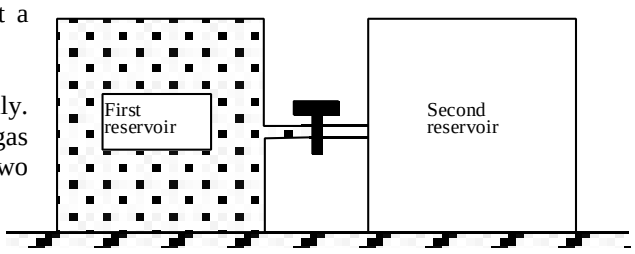
B) Translation and rotation motion

C) Translation, rotation and vibration motion

D) No new motion

4 The first reservoir has a volume of 500 litres. It is filled with gas at a pressure of 510 kPa and a temperature of 20°C.

The second reservoir has a volume of 250 litres and is empty initially. When the valve in the tube connecting the two reservoirs is opened, the gas enters the second reservoir and the temperature of the gas in the two reservoirs drops to 10°C.



What will be the new pressure of the gas in the two reservoirs?

A) 170 kPa

B) 265 kPa

C) 328 kPa

D) 383 kPa

5 Calculate the heat of combustion for ethane (C_2H_6) using the heat of formation reactions provided below:

1) $C + O_2 \longrightarrow CO_2$ $\Delta H = -393$ kJ
2) $2\ H_2 + O_2 \longrightarrow 2\ H_2O$ $\Delta H = -483$ kJ
3) $3\ H_2 + 2\ C \longrightarrow C_2H_6$ $\Delta H = -84$ kJ

The equation for the combustion of ethane is:

$$2\ C_2H_6 + 7\ O_2 \longrightarrow 4\ CO_2 + 6\ H_2O$$

Which of the following correctly identifies the heat of combustion for ethane (C_2H_6)?

A) -1035 kJ

B) -2853 kJ

C) -3189 kJ

D) -3819 kJ

6 A balloon is filled with an ideal gas and the initial pressure is recorded. Then, the absolute temperature is tripled, the volume is tripled, and the number of molecules is also tripled.

Which of the following best describes the final pressure of the gas?

A) The final pressure is 3 times higher.

B) The final pressure is 9 times higher.

C) The final pressure is 9 times lower.

D) The final pressure is 27 times higher.

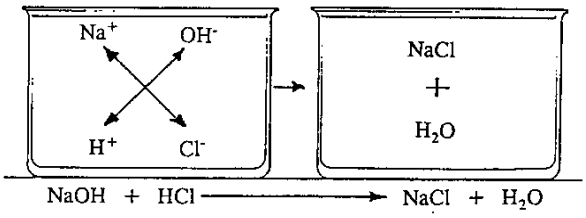
7 The following statements concern the enthalpy of substances :

1. When a chemical bond forms, the enthalpy decreases.
2. When a chemical bond is broken, the enthalpy decreases.
3. When a chemical bond is broken, the enthalpy increases.
4. When a chemical bond forms, the enthalpy increases.

Which of the statements are true?

A) 1 and 3
B) 1 and 4
C) 2 and 3
D) 2 and 4

8 When an acidic solution comes in contact with a basic solution, the hydrogen ions combine with the hydroxide ions, producing water. Also, the metallic ions combine with the non-metallic ions, producing a salt, as in the diagram below :



Given that the neutralizing reaction described above releases heat, which of the following statements is **correct**?

A) The enthalpy of the reactants is greater than the enthalpy of the products.
B) The enthalpy of the reactants is less than the enthalpy of the products.
C) The change in enthalpy (ΔH) is positive.
D) The reaction is endothermic.

9 The molar heat of reactions of various elements are listed below :

Elements			Formula Name		ΔH/kJ	
$H_{2(g)} + 1/2\ O_{2(g)}$	$\rightarrow$	$H_2O_{(g)}$	water vapour			-241.8
$1/8\ S_{8(s)} + O_{2(g)}$	$\rightarrow$	$SO_{2(g)}$	sulfur dioxide		-296.9	
$H_{2(g)} + 1/8\ S_{8(s)} + 2O_{2(g)}$	$\rightarrow$	$H_2SO_{4(l)}$	sulfuric acid			-811.4
$C_{(s)} + 1/2\ O_{2(g)}$	$\rightarrow$	$CO_{(g)}$	carbon monoxide		-110.5	
$C_{(s)} + O_{2(g)}$	$\rightarrow$	$CO_{2(g)}$	carbon dioxide		-393.5	
$C_{(s)} + 2\ H_{2(g)}$	$\rightarrow$	$CH_{4(g)}$	methane		- 74.8	
$2\ C_{(s)} + 3\ H_{2(g)}$	$\rightarrow$	$C_2H_{6(g)}$	ethane			- 84.7
$3C_{(s)} + 4\ H_{2(g)}$	$\rightarrow$	$C_3H_{8(g)}$	propane		-103.8	

The following equation can be used to represent methane combustion :

$$CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$$

What is the molar heat of methane combustion (CH_4)?

Show all you work.

10 Carbonic acid, H_2CO_3, is a weak acid. The dissociation of carbonic acid and the ionization constant, K_a, are shown below.

$$H_2CO_{3(aq)} \leftrightarrow H^+_{(aq)} + HCO_3^-{}_{(aq)} \qquad K_a = 4.3 \times 10^{-7}$$

A chemistry student places 3.1×10^{-2} grams of carbonic acid into 5.0×10^2 mL of distilled water.

What is the pH of this solution?

11 Tim is heating oil in a deep fryer so he can cook some french fries. The telephone rings and he forgets about the oil he is heating. His telephone conversation ends abruptly when he realizes the oil has caught on fire. He reacts quickly and puts the cover on the pot.

Why did Tim place the cover on the pot?

A) To reduce the temperature of the oil below the temperature at which ignition occurs, thereby ending combustion

B) To increase the pressure on the oil, thereby putting out the fire

C) To prevent a required reactant from contacting the oil, thereby ending combustion

D) To prevent a required product from escaping the pot, thereby ending combustion

12 You wish to find the molar heat of combustion of calcium according to the following equation:

$$Ca_{(s)} + ½\ O_{2(g)} \rightarrow CaO_{(s)}$$

Because the results are difficult to obtain directly, you proceed by an indirect method. You carry out the two following experiments:

EXPERIMENT 1:

The reaction of 4.0 g of calcium with 1000 g of water according to the equation:

$$Ca_{(s)} + 2\ H_2O_{(l)} \rightarrow Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$$

Results:

Calcium	Water	Initial Temperature	Final Temperature
4 g	1000 g	19.0°C	29.3°C

EXPERIMENT 2:

The reaction of 5.6 g calcium oxide with 1000 g of water according to the equation:

$$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)}$$

Results:

Calcium oxide	Water	Initial Temperature	Final Temperature
5.6 g	1000 g	21.0°C	22.9°C

Consulting your chemistry text, you then find the molar heat of combustion of hydrogen, H_2:

$$H_{2(g)} + ½\ O_{2(g)} \rightarrow H_2O_{(l)} + 286\ kJ$$

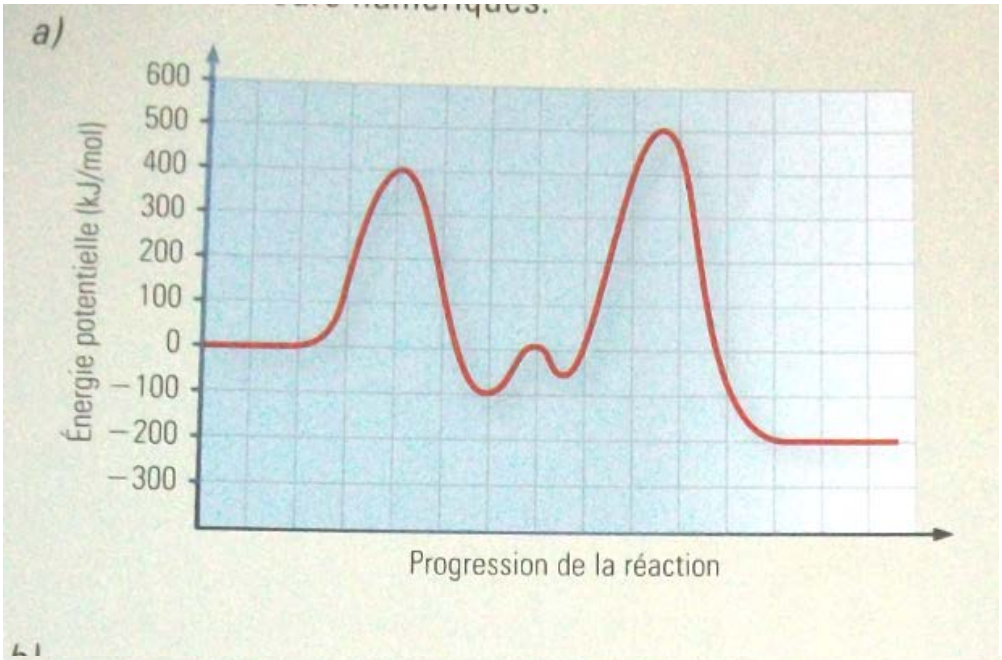
How can you determine the molar heat of combustion of calcium from the results that you have obtained?

Show all your work.

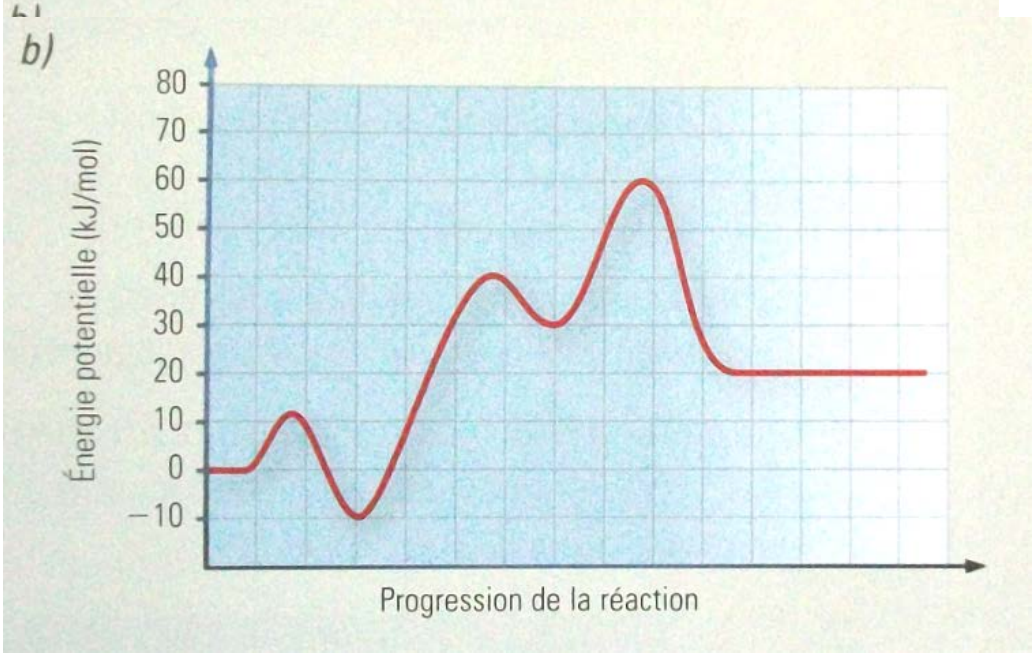
Part 2 Offbeat and Easier Questions

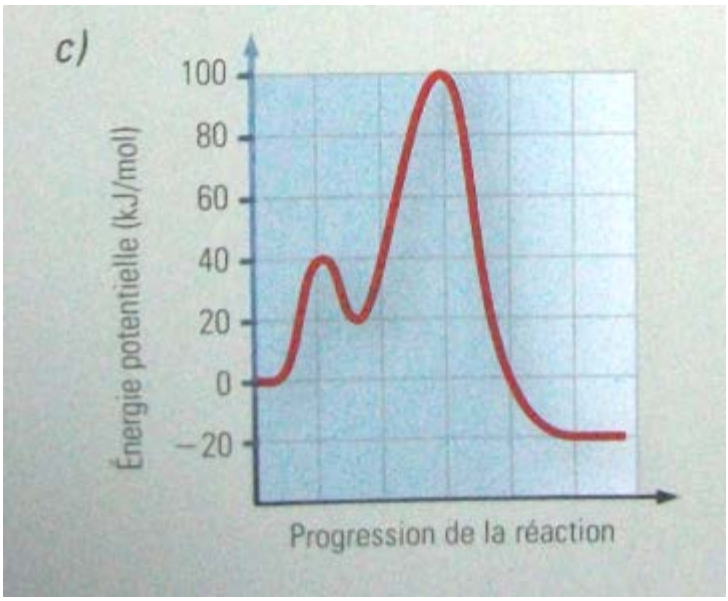
1. For each of the following reactions:
   (1) Give the number of steps in each reaction. (each step has its own activation energy)
   (2) Find the value of the highest activation energy.
   (3) Out of the two or three steps that each reaction has, which is most likely to be the slowest?
   (4) Is the overall reaction exothermic? What is the overall $\square H$?

a)



b)





2. The May 6th 2013 edition of the Economist ran an interesting story about the American chestnut which was almost wiped out in the 20th century. A fungus infecting Chinese chestnuts spread to indigenous trees, killing almost 2 billion of them.

The story goes on to report about how a combination of hybridization and genetic engineering may allow the American chestnut to make a comeback.

The fungus kills because it secretes oxalic acid.

Oxalic (1)	$H_2C_2O_4$	Oxalate ion $HC_2O_4^-$	$K_A = 5.9 \times 10^{-2}$

a) Write an equation and calculate the pH of a 1.0 M solution of $H_2C_2O_4$

b) Biologists have isolated a gene from wheat which produces and enzyme than then converts oxalate to carbon dioxide.

Show a distribution of kinetic energies for the breakdown of oxalate with and without the enzyme.

c) They have also incorporated the oxalate gene into a plasmid and have fooled the American chestnut into incorporating the gene into its own DNA.

What will the chestnut start doing? How will this help it survive the fungus?

d) By the way, is the conversion of $HC_2O_4^-$ to CO_2 an oxidation? Show why or why not.

e) If another acid has a K_A of 5.1×10^{-3}, how does its strength compare to that of oxalic acid?

f) Why can't pH be used to compare the relative strengths of two different acids?

3. a) How many grams of $Tl(OH)_3$ will you find in 50.0 ml of a saturated solution? Its Ksp is a whoppingly-low 1.68 X 10^{-44}.

b) What effect will the addition of acid have on the above equilibrium?

Part 1 Answers

1. D 2 . D 3. B 4. C 5. B 6. A 7. A 8. A

9.

Work : (example)

$CH_{4(g)} \rightarrow C_{(s)} + 2\ H_{2(g)}$		74.8
$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$		-393.5
$2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(g)}$		-483.6
$CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$		-802.3

Result : -802.3 kJ

With sig figs: -8.02 X 10^2 kJ or 802 kJ

10 **Example of an appropriate procedure**

Find the concentration of the H_2CO_3

$$\text{Moles of } H_2CO_3 = \frac{3.1 \times 10^{-2}\ \text{g}}{62\ \frac{\text{g}}{\text{mol}}} = 5.0 \times 10^{-4}\ \text{mol}$$

$$\text{Molarity} = \frac{5.0 \times 10^{-4}\ \text{mol}}{0.500\text{L}} = 1.0 \times 10^{-3}\ \frac{\text{mol}}{\text{L}}$$

Find the concentration of the $H^+_{(aq)}$

	$H_2CO_{3(aq)}$	$\leftrightarrow$	$H^+_{(aq)}$ +	$HCO_3^-{}_{(aq)}$	$K_a = 4.3 \times 10^{-7}$
Initial	$1.0 \times 10^{-3}\frac{\text{mol}}{\text{L}}$		0	0	
Change	$-x$		$+x$	$+x$	
Equilibrium	$1.0 \times 10^{-3}\ \frac{\text{mol}}{\text{L}} - x$		$0 + x$	$0 + x$	

$$K_a = \frac{[H^+_{(aq)}][HCO_3^-{}_{(aq)}]}{[H_2CO_{3(aq)}]}$$

$$4.3 \times 10^{-7} = \frac{(x)(x)}{1.0 \times 10^{-3}\ \frac{\text{mol}}{\text{L}} - x} = \frac{x^2}{1.0 \times 10^{-3}\ \frac{\text{mol}}{\text{L}}}$$

(note : assume x is negligible when subtracted from $1.0 \times 10^{-3}\ \frac{\text{mol}}{\text{L}}$)

$4.3 \times 10^{-10} = x^2$

$2.1 \times 10^{-5}\ \frac{\text{mol}}{\text{L}} = x = [H^+_{(aq)}]$

$\text{pH} = -\log[H^+_{(aq)}] = -\log(2.1 \times 10^{-5}) = 4.68$

Answer : The pH of this solution is 4.68.

11.C

12 Work is complete and the result is correct. Example :

♦ From the experimental results, the molar heat of reaction 1 and 2 must be determined.

REACTION 1 :

- Heat absorbed by the water from the reaction of 4 g of calcium.
  $Q_{(water)} = m_{(water)} \bullet c_{(water)} \bullet \Delta T_{(water)}$
  $Q_{(water)} = 1.000\ kg \bullet 4.19\ kJ/kg \bullet °C \times 10.3°C$
  $Q_{(water)} = 43.2\ kJ$
- Heat for one mole of calcium
  43.2 kJ/4.0 g × 40 g/mol = 432 kJ/mol

REACTION 2 :

- Heat absorbed by the water from the reaction of 5.6 g calcium oxide
  $Q_{(water)} = m_{(water)} \bullet c_{(water)} \bullet \Delta T_{(water)}$
  $Q_{(water)} = 1000\ kg \bullet 4.19\ kJ/kg \bullet °C \bullet 1.9°C$
  $Q_{(water)} = 8.0\ kJ$
- Heat for one mole of calcium oxide
  8.0 kJ/5.6 g × 56 g/mol = 80 kJ/mol

▸ Using these three equations the molar heat of combustion of calcium can be calculated :

(1) $Ca_{(s)} + 2\ H_2O_{(l)} \rightarrow Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)} + H_{2(g)}$ $\Delta H =$ -432 kJ

(2) $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)}$ $\Delta H =$ -80 kJ

(3) $H_{2(g)} + 1/2\ O_{2(g)} \rightarrow H_{(2)}O_{(l)}$ $\Delta H =$ -286 kJ

Inverting equation 2 to give (2a) :

(2a) $Ca^{2+}_{(aq)} + 2\ OH^-_{(aq)} \rightarrow CaO_{(s)} + H_2O_{(l)}$ $\Delta H =$ +80 kJ

Addition of equations 1, 2a and 3 gives the equation for the combustion of calcium :

(1) $Ca_{(s)} + 2\ \cancel{H_2O_{(l)}} \rightarrow \cancel{Ca^{2+}_{(aq)}} + \cancel{2\ OH^-_{(aq)}} + \cancel{H_{2(g)}}$ $\Delta H =$ -432 kJ

(2a) $\cancel{Ca^{2+}_{(aq)}} + \cancel{2\ OH^-_{(aq)}} \rightarrow CaO_{(s)} + \cancel{H_2O_{(l)}}$ $\Delta H =$ -80 kJ

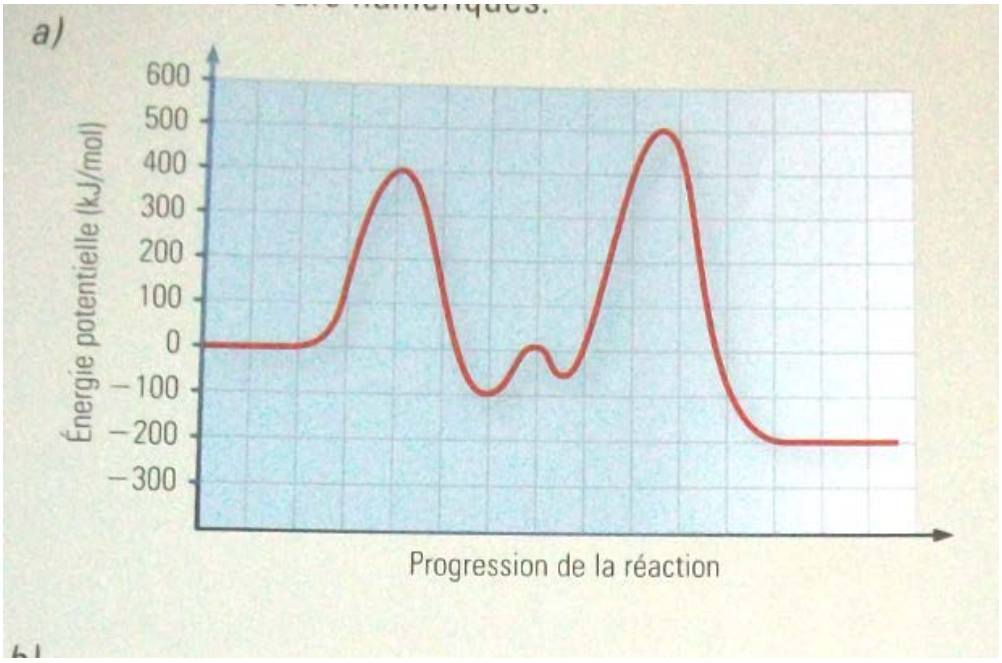
(3) $\cancel{H_{2(g)}} + 1/2\ O_{2(g)} \rightarrow \cancel{H_{(2)}O_{(l)}}$ $\Delta H =$ -286 kJ

$Ca_{(s)} + 1/2\ O_{2(g)} \rightarrow CaO_{(s)}$ $\Delta H =$ -638 kJ

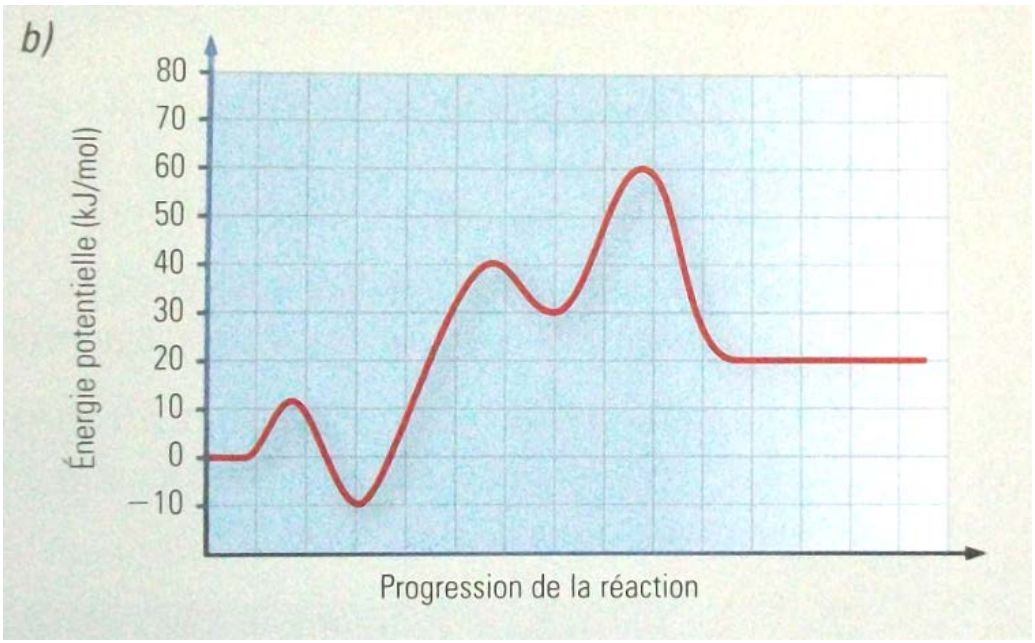
Other complete work to give the correct answer.

Offbeat Answers

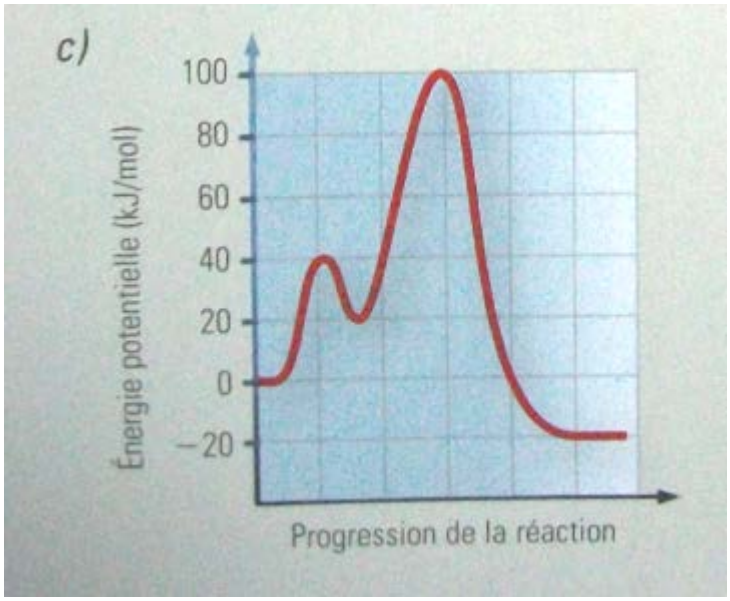
1. For each of the following reactions:
   (1) Give the number of steps in each reaction. (each step has its own activation energy)
   (2) Find the value of the highest activation energy.
   (3) Out of the two or three steps that each reaction has, which is most likely to be the slowest?
   (4) Is the overall reaction exothermic? What is the overall ΔH?



(1) 3 steps
(2) A_e= 500-(-50) = 550 kJ (sig figs: when subtracting(or adding) only, you apply the decimal rule)
(3) Step number 3(the one with the highest activation energy)
(4) Exo: $\Delta H = H_{final} - H_{initial} = -200 - 0 = -200$ kJ



(1) 3 steps
(2) A_e= 40 –(-10) = 50 kJ (sig figs: when subtracting(or adding) only, you apply the decimal rule)
(3) Step number 2 (the one with the highest activation energy)
(4) Endothermic: ΔH = 20 – 0 = 20 kJ



(1) 2 steps
(2) A_e= 100 –20 = 80 kJ (sig figs: when subtracting(or adding) only, you apply the decimal rule)
(3) Step number 2 (the one with the highest activation energy)
(4) Exothermic: ΔH = -20 – 0 = -20 kJ

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The story goes on to report about how a combination of hybridization and genetic engineering may allow the American chestnut to make a comeback.

The fungus kills because it secretes oxalic acid.

Oxalic (1)	$H_2C_2O_4$	Oxalate ion $HC_2O_4^-$	$K_A = 5.9 \times 10^{-2}$

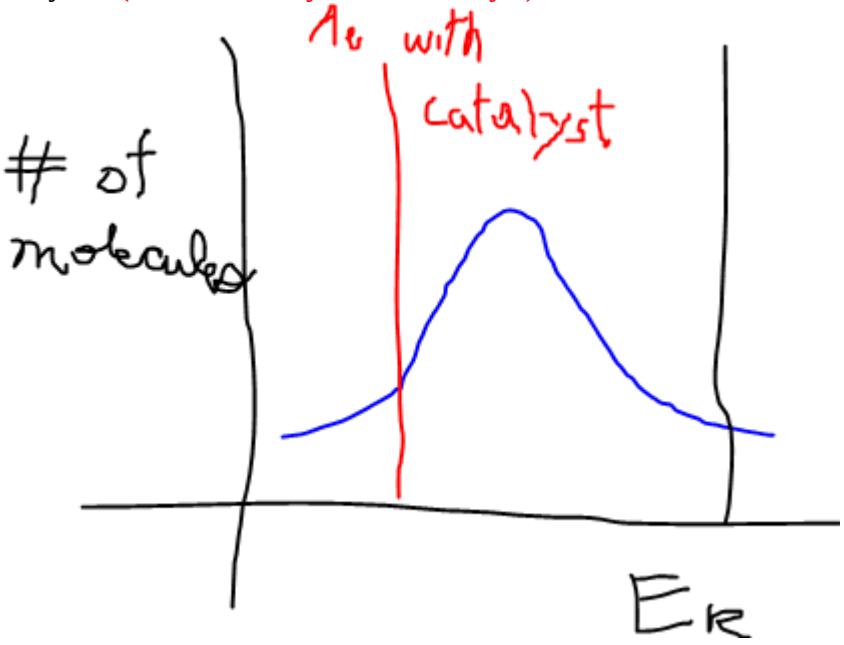
a) Write an equation and calculate the pH of a 1.0 M solution of $H_2C_2O_4$

	$H_2C_2O_4$ =	H^+ +	$HC_2O_4^-$
I	1.0	0	0
C	x	x	x
E	1.0 - x	x	x

$x^2/(1.0 - x) = 5.9 \times 10^{-2}$
$x^2 = 5.9 \times 10^{-2}(1-x)$
$x^2 + 5.9 \times 10^{-2} x - 5.9 \times 10^{-2} = 0.$
$x = .2151839799\ M = [H^+]$
$pH = -\log [H^+] = -\log [.2151839799] = 0.67$

b) Biologists have isolated a gene from wheat which produces and enzyme than then converts oxalate to carbon dioxide.

Show a distribution of kinetic energies for the breakdown of oxalate with and without the enzyme. (note-- the enzyme is a catalyst)



c) They have also incorporated the oxalate gene into a plasmid and have fooled the American chestnut into incorporating the gene into its own DNA.

What will the chestnut start doing? How will this help it survive the fungus?

With the enzyme(catalyst)the chestnut will start breaking down the acid produced by the fungus and have a better chance of surviving the disease.

d) By the way, is the conversion of $HC_2O_4^-$ to CO_2 an oxidation? Show why or why not.

$2C + 1+(-2)(4) = -1$
$C = 6$ in $HC_2O_4^-$
But in CO_2, $C = 4$, so it's a reduction.

e) If another acid has a K_A of 5.1×10^{-3}, how does its strength compare to that of oxalic acid?

Since this other acid has a lower K_A, it is considered a weaker acid.

f) Why can't pH be used to compare the relative strengths of two different acids?

The initial concentration will affect pH, so a weak acid with a very high initial concentration can end up with the same pH as a stronger acid that's prepared with a lot more water. K_A takes both initial concentration and pH into account, so it's the better way of comparing acidic strength.

3. a) How many grams of $Tl(OH)_3$ will you find in 50.0 ml of a saturated solution? Its Ksp is a whoppingly-low 1.68×10^{-44}.

	$Tl(OH)_3$ =	Tl^{+3} +	$3\ OH^-$
I		0	0
C	x= solubility in mol/L	x	3x
E		x	3x

$Ksp = [Tl^{+3}][OH^-]^3 = x(3x)^3 = 1.68 \times 10^{-44}$.
$27x^4 = 1.68 \times 10^{-44}$.
$X = 4.99 \times 10^{-12} M =$
In 50.0 ml there will be: 4.99×10^{-12} mol/L *0050 L *255.4 g/mole = 6.38×10^{-11} g. (3 SF)

b) What effect will the addition of acid have on the above equilibrium?

It will discourage the reverse reaction by consuming base, so there will be more Tl^{+3} produced. The solubility of $Tl(OH)_3$ will increase.