# Chemistry 30
Thermochemistry Review

1. Which of the following statements is **true** for an endothermic reaction?

   A. ΔH_r for the reaction is negative. ✗ exo

   B. Energy is a product in the chemical equation. ✗ exo

   C. The temperature of the surroundings increases. ✗ exo

   (D.) The potential energy of the products is greater than the potential energy of the reactants.

Use the following information to answer the next question.

$$4\ Q(s)\ +\ Z_2(g)\ +\ 100\ kJ\ \rightarrow\ 2\ Q_2Z(g)$$
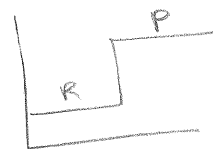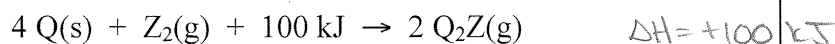
$\Delta H = +100\ kJ$

2. The ΔH_r value for the reverse reaction would be

$\Delta H\ reverse = -100\ kJ$

   A. +100 kJ

   B. +50.0 kJ

   C. −50.0 kJ

   (D.) −100 kJ

Numerical Response

1. Benzene is a gasoline additive. The heat of formation for 1.00 mol of $C_6H_6(l)$ is _____49.1_____ kJ.

   (Record your **three-digit answer** in the numerical-response section on the answer sheet)

   $$\Delta H = (1.00\ mol)\left(\frac{49.1\ kJ}{mol}\right) = 49.1\ kJ$$

Numerical Response

2. An outdoor mercury thermometer contains 1.02 g of mercury. On a winter day, the thermometer records a change in temperature from −38.0°C to −13.0°C. The mercury absorbed ____3.57____ J of energy. The heat capacity of mercury is 0.140 J/g°C.

   (Record your **three-digit answer** in the numerical-response section on the answer sheet)

   $$Q = mc\Delta t$$
   $$= (1.02g)\left(0.140\frac{J}{g\cdot°C}\right)(-13-(-38°C)$$
   $$= 3.57$$

1

3. In the reaction $C_{25}H_{52}(s) + 38\ O_2(g) \rightarrow 25\ CO_2(g) + 26\ H_2O(g) + $ energy, the energy released by the reaction of the paraffin fuel is called the molar enthalpy of

    A. formation

    B. vaporization

    C. combustion

    D. decomposition

Use the following information to answer the next two questions.

> Limestone, mined near Exshaw, Alberta, is used as a raw material in the production of lime, which has a wide range of industrial applications. Lime, $CaO_{(s)}$, in the plant is produced by roasting crushed limestone, $CaCO_{3(s)}$, in kilns. The process of removing carbon dioxide from the limestone is referred to as calcination. The lime can be used to produce slaked lime, $Ca(OH)_{2(s)}$, through the careful addition of liquid water.
>
> The demand for lime and slaked lime has increased in the last few years because it can be used in the treatment of industrial wastes and raw sewage, and in the purification of water.

4. The molar heat of reaction for the production of lime from limestone is

    A. −634.9 kJ/mol

    B. +634.9 kJ/mol

    C. +179.2 kJ/mol

    D. −179.2 kJ/mol

$$CaCO_3 \rightarrow CaO + CO_2 \qquad \Delta H = ?$$

$$\Delta H = \left[\left(1\,mol\left(\frac{-393.5\,kJ}{mol}\right)\right) + 1\,mol\left(\frac{-634.9\,kJ}{mol}\right)\right] -$$

$$\left[1\,mol\left(\frac{-1207.6\,kJ}{mol}\right)\right]$$

5. The production of slaked lime can be classified as an

    A. exothermic phase change

    B. endothermic phase change

    C. exothermic chemical change

    D. endothermic chemical change

$$\underset{\text{lime}}{CaO} + H_2O_{(l)} \rightarrow \underset{\text{slaked lime}}{Ca(OH)_{2\,(s)}} \qquad \Delta H = ?$$

$$\Delta H = \left[1\,mol\left(\frac{-985.2\,kJ}{mol}\right)\right] - \left(1\,mol\left(\frac{-634.9\,kJ}{mol}\right) + 1\,mol\left(\frac{-285.8\,k}{mol}\right)\right.$$

$$= -64.5\,kJ\ (\text{exothermic})$$

2

6. The Euglena is an organism that can produce glucose by photosynthesis when light is present. The major energy conversion in the Euglena, in the presence of light is **best** described as

A. endothermic, with an increase in potential energy
B. exothermic, with a decrease in potential energy
C. endothermic, with an increase in kinetic energy
D. exothermic, with a decrease in kinetic energy

6 $CO_{2(g)}$ + 6 $H_2O_{(l)}$ + energy →
$C_6H_{12}O_6$ + $O_{2(g)}$
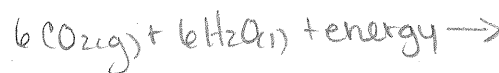
Use the following information to answer the next question.

Molar Heats of Formation for Silicon Halides

$SiF_4(g)$	−1 617 kJ/mol
$SiCl_4(g)$	−688 kJ/mol
$SiBr_4(g)$	−458 kJ/mol
$SiI_4(g)$	−190 kJ/mol

$\Delta_d H_m$
= +1617 ← *most stable*
= +688 *(takes the*
= +458 *most energy*
= +190 *to decompose*

7. The silicon halide that is most stable is

A. $SiF_4(g)$
B. $SiCl_4(g)$
C. $SiBr_4(g)$
D. $SiI_4(g)$

_____

8. For which fossil fuel was the Sun the original source of energy?

A. $O_2(g)$
B. $CH_4(g)$ *fossil fuel originates w/ Sun*
C. $H_2(g)$
D. $UF_6(s)$

Numerical Response

3. The amount of energy released by the **formation** of 0.100 mol of propane under standard conditions is _____10.4_____ kJ.

$\Delta H = n\Delta_r H_m$
= (0.100 mol)(−103.8 kJ) = −10.38 kJ
mol
= −10.4 kJ

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

3
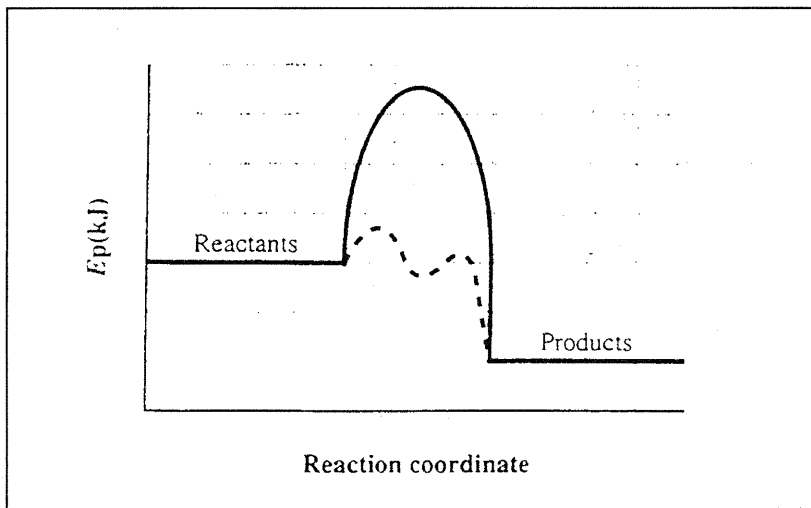
9. The broken line on the energy diagram indicates that

   A. the temperature of the reaction has increased

   B. the pressure of the system has decreased

   C. more reactants have been added

   D. a catalyst has been added *(lower E_a, same ΔH)*

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10. Compound X has a molar mass of 75.0 g/mol. The combustion of 300.0 g of compound X causes the temperature of 1000 g of water to rise 3.00°C. The molar heat of combustion for compound X is

   A. -3.14 kJ/mol

   B. -3.77 kJ/mol

   C. -12.6 kJ/mol

   D. -50.3 kJ/mol

$$n \Delta_r H_m = -mc\Delta t$$

$$(300.0\,g)\left(\frac{mol}{75.0\,g}\right)(\Delta_c H_m) = -(1.0\,kg)\left(\frac{4.19\,J}{g\cdot°C}\right)(3.00°C)$$

$$\Delta_c H_m = -3.14\,kJ/mol$$

11. Pure copper can be obtained by roasting copper ore with carbon monoxide. The heat of reaction for $CuO(s) + CO(g) \rightarrow Cu(s) + CO_2(g)$ is

   A. -125.7 kJ

   B. -236.2 kJ

   C. -504.0 kJ

   D. -661.3 kJ

$$\Delta H = \left[1\,mol\left(\frac{-393.5\,kJ}{mol}\right) + 0\right] - \left[1\,mol\left(\frac{-157.3\,kJ}{mol}\right) + 1\,mol\left(\frac{-110.5\,kJ}{mol}\right)\right]$$

$$= -125.7\,kJ$$
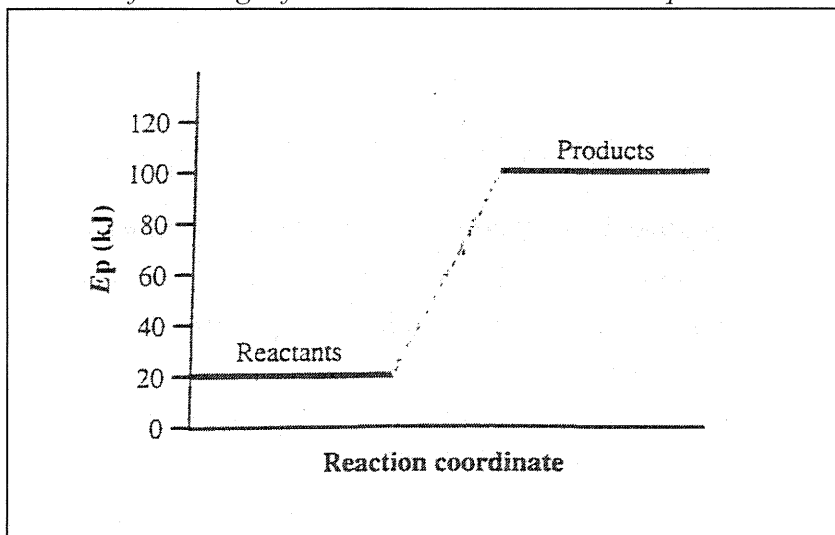
12. The heat of reaction is

    A. −100 kJ

    B. −80 kJ

    C. +80 kJ

    D. +100 kJ

$\Delta H = \Sigma p - r$

$= 100 - 20\,kJ = +80\,kJ$

I.	$3\,B + X_2 + 31.1\,kJ \rightarrow B_3X_2$	✗ endo
II.	$A_2 + 4\,B \rightarrow 2\,AB_2 + 42.5\,kJ$	✓ exo
III.	$X_2 + Y_2 \rightarrow 2\,XY \qquad \Delta H = -40.9\,kJ$	✓ exo
IV.	$C_4 + 5\,G_2 \rightarrow 2\,C_2G_5 \qquad \Delta H = +22.6\,kJ$	✗ endo
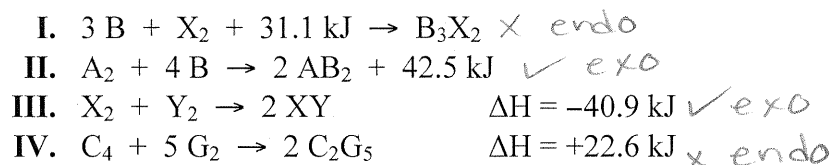
13. Which of the above reactions is/are exothermic?

    A. II only

    B. III only

    C. I and IV only

    D. II and III only

The combustion of fossil fuels such as propane, plays and important role in our daily lives and affects the economic and environmental climate in Alberta. The balanced chemical reaction for this combustion is

$$C_3H_8(g) + 5 O_2(g) \rightarrow 3 CO_2(g) + 4 H_2O(g)$$
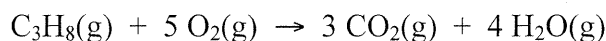
14. The original source of the energy stored in fossil fuels such as propane was

    A. protozoa

    B. plants

    C. animals

    D. the Sun

15. When propane is burned in a barbeque, the molar heat of reaction is

    A. −103.8 kJ/mol

    B. +103.8 kJ/mol

    C. +2 043.9 kJ/mol

    D. −2 043.9 kJ/mol

$$\Delta H = \left[4\,mol\left(\frac{-241.8\,kJ}{mol}\right) + 3\,mol\left(\frac{-393.5\,kJ}{mol}\right) \right] - \left[1\,mol\left(\frac{-103.8\,kJ}{mol}\right) \right]$$

$$= -2043.9\,kJ$$

$$= -2043.9\,kJ/mol\ C_3H_8$$

*Use the value selected in **Multiple Choice 15** to answer **Numerical Response 4**.*

Numerical Response

$$\Delta H = n\Delta_r H_m$$
$$= \left(449g \times \frac{mol}{44.11g} \right)\left(\frac{-2043.9\,kJ}{mol} \right)$$

4. If 449 g of propane are burned in a barbeque, the amount of energy released is

_____20.8_____ MJ.

$$= -20805\,kJ = -20.8\,MJ$$

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

16. When the combustion of fuels, such as propane, is compared to cellular respiration,

    A. combustion is exothermic and respiration is *exo* ~~endothermic~~

    B. combustion is *exo* ~~endothermic~~ and respiration is exothermic

    C. respiration requires the presence of ~~light~~ and combustion does not

    D. both produce carbon dioxide gas

Use the following information to answer the next question.

$$K(s) + \tfrac{1}{2} Br_2(l) \rightarrow KBr(s) \qquad \Delta_fH° = -393.8 \text{ kJ/mol}$$
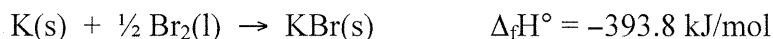
17. Using only the information given above, which valid interpretation can be made?

    A. The equation represents a phase change.

    B. The dissolving of KBr(s) is an exothermic process.

    C. The decomposition of KBr(s) is an endothermic process. ✓ $\Delta_dH = +393.8 \text{ kJ/mol}$

    D. KBr(s) is ~~less~~ more stable than its constituent elements.

Use the following information to answer the next question.

A student was asked to determine the molar enthalpy of neutralization of KOH(aq). She recorded the average initial temperature of the KOH(aq) and the H_2SO_4(aq), then poured 50.0 mL of sulphuric acid into an insulated cup. She then added 100 mL of KOH(aq) to the acid, stirred the solution, and recorded the highest temperature reached. Her analysis of the data resulted in an answer of -46 kJ/mol.

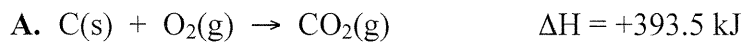**18.** If the student had used 100 mL of H_2SO_4(aq) and 200 mL of KOH(aq), then

    A. temperature change would double and the molar heat of reaction would double

    B. heat released would be the same but the moles of KOH would double

    C. heat released would double but the molar heat of reaction would remain the same

    D. temperature would double and, because the volume of KOH had doubled, the <u>molar</u> heat of reaction would be four times as great

$$\ast \text{ moles of KOH } \left(\frac{\text{double}}{\text{would double volume}} \right) \qquad \ast \Delta_rH_m \text{ unique/mol}$$

19. Hydrogen peroxide slowly decomposes to water and oxygen. A small amount, 0.010 g, of black MnO_2(s) is added to a test tube containing hydrogen peroxide. As a result, the rate of bubble formation increases, the temperature increases more rapidly, a glowing splint relights above the liquid, and 0.010 g of black residue remains. These results indicate that MnO_2(s)
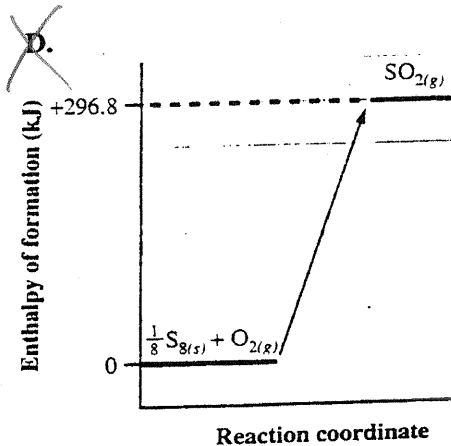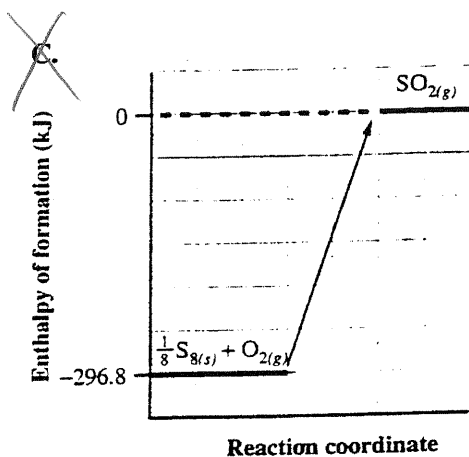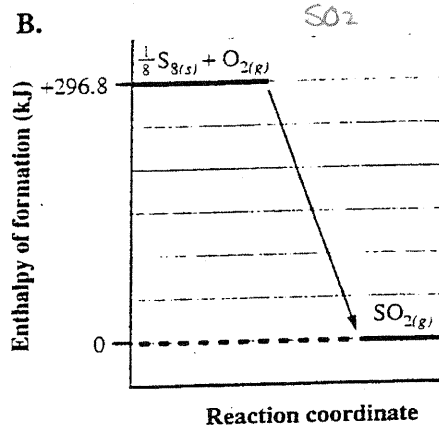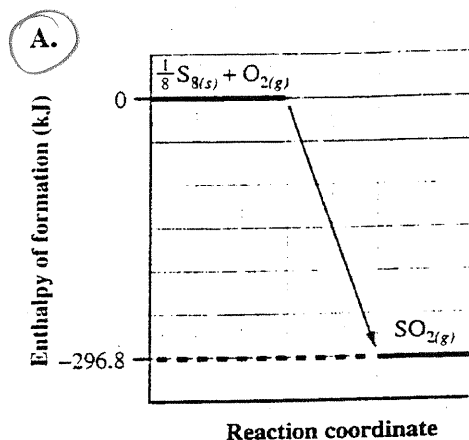
    A. reacts with peroxide to form O_2(g)

    B. decomposes to produce O_2(g)

    C. reacts with peroxide to form H_2(g)

    D. acts as a catalyst in the reaction

20. Coal is composed mainly of carbon. The thermochemical equation that correctly represents the complete combustion of carbon is
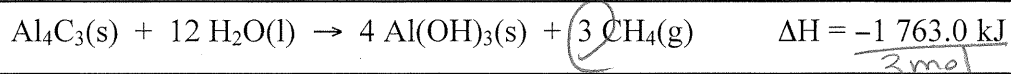
    A. $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = +393.5$ kJ

    B. $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ kJ ✓

    C. $2\,C(s) + O_2(g) \rightarrow 2\,CO(g)$ $\Delta H = -221.0$ kJ

    D. $2\,C(s) + O_2(g) \rightarrow 2\,CO(g)$ $\Delta H = +221.0$ kJ
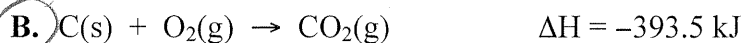
21. Sulphur, $S_8(s)$, is present in coal. When coal is burned, $SO_2(g)$ is formed. The potential energy diagram that **best** represents this reaction is

$\Delta_f H_m = -296.8\ kJ/mol$
SO_2

8

$$Al_4C_3(s) + 12\ H_2O(l) \rightarrow 4\ Al(OH)_3(s) + 3\ CH_4(g) \qquad \Delta H = -1\ 763.0\ kJ$$

$\dfrac{}{3\ mol}$

22. If this equation is rewritten to show the production of one mole of $CH_4(g)$ and the energy is expressed as a term in the equation, then the energy will be

   A. 587.7 kJ on the reactant side

   B. 1763.0 kJ on the reactant side

   C. 587.7 kJ on the product side

   D. 1763.0 kJ on the product side

   $\dfrac{-1763.0\ kJ}{3\ mol} = -296.8\ kJ$

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23. When a 25.0 g sample of a metal is heated from 20.0°C to 50.0°C, 178 J of energy is absorbed from the surroundings. The specific heat capacity of the metal is

   A. 7.12 J/g°C

   B. 0.356 J/g°C

   C. 0.237 J/g°C

   D. 0.142 J/g°C

   $c = \dfrac{Q}{m\Delta t} = \dfrac{178\ J}{(25.0g)(50.0-20.0°C)}$

   $= 0.237\ J/g\cdot°C$

Cold packs are used to treat sprains and bruises. A chemical commonly used in cold packs is ammonium nitrate, $NH_4NO_{3(s)}$, which can produce a cooling effect.

24. The change that occurs in this cold pack is an

   A. endothermic change, which results in an increase in temperature

   B. exothermic change, which results in an increase in temperature

   C. endothermic change, which results in a decrease in temperature

   D. exothermic change, which results in a decrease in temperature

A student designed a calorimetry experiment to determine the molar enthalpy of reaction of hydrochloric acid when it reacts with ammonium hydroxide. The following results were recorded:

heat capacity of calorimeter and water	228 J/°C
initial temperature of water	21.6°C
final temperature of water	16.4°C
concentration of HCl(aq)	0.0500 mol/L
volume of HCl(aq)	50.0 mL
concentration of NH₄OH(aq)	0.0500 mol/L
volume of NH₄OH(aq)	75.0 mL

Numerical Response

5. The molar enthalpy of reaction of the hydrochloric acid is

If + record **1**
If – record **2**

4   7   4   kJ/mol

first column   second column   third column   fourth column

(Record your **four-digit answer** in the numerical-response section on the answer sheet)

$n\Delta_r H_m = -C\Delta t$

$(0.050 \text{ mol})(0.050 L)(\Delta_r H_m) = -(228 J)(-5.2°C)$

$\Delta_r H_m = +474240 J/mol$
$= +474 kJ/mol$

25. The calculated energy change represents the enthalpy of

A. decomposition
B. combustion
C. neutralization (acid + base)
D. formation

Numerical Response

6. In organisms, the reaction of sucrose and oxygen produces carbon dioxide, water and energy. The energy available may be estimated using the reaction for the combustion of sucrose:
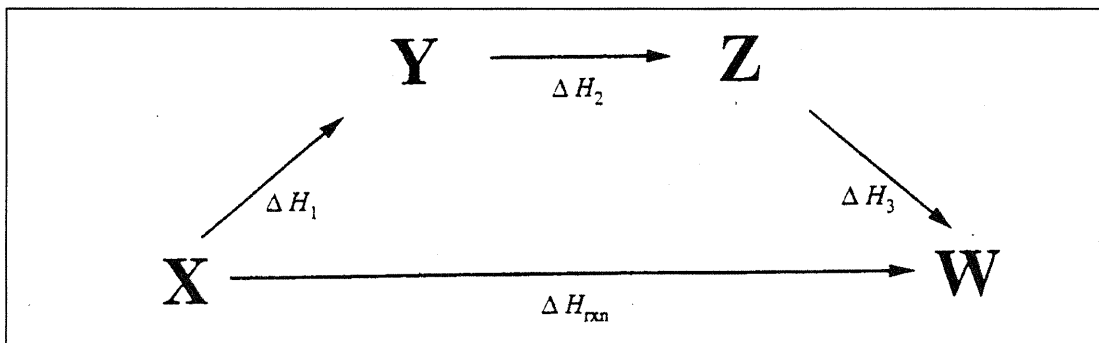
$C_{12}H_{22}O_{11(aq)} + 12 O_{2(g)} \rightarrow 12 CO_{2(g)} + 11 H_2O_{(l)} + 5\,640.3 \text{ kJ}$
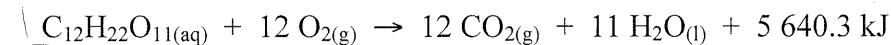
The quantity of energy available when 1.00 g of sucrose reacts is ___16.5___ kJ.

(Record your **three-digit answer** in the numerical-response section on the answer sheet)

$\Delta H = (1.00g)\left(\frac{mol}{342.34g}\right)\left(\frac{-5640.3 kJ}{mol}\right) = -16.475 kJ$
$= -16.5 kJ$

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26. This diagram illustrates

   A. the Law of Conservation of Mass

   B. an exothermic reaction

   C. an endothermic reaction

   D. Hess's Law

27. When phosphorus, $P_{4(s)}$, is exposed to air, it ignites spontaneously and rapidly releases 2 940 kJ/mol. Which of the following potential energy diagrams best represents this reaction?