CHEMISTRY
MULTIPLE CHOICE
QUESTIONS

E. Chemical Energetics

2002 - 2014
1. Which statement about the standard enthalpy change of formation of carbon dioxide is correct?
   A. It is equal to the standard enthalpy change of combustion of carbon.
   B. It is equal to twice the bond energy of the C=O bond.
   C. It is the energy released when one mole of carbon dioxide is formed from carbon at the
temperature of combustion of the carbon.
   D. It is the same for carbon dioxide produced from graphite and from diamond.
   [2002 M/J (8)]

2. Use of the Data Booklet is relevant to this question.

Hydrazine was used as a fuel for the Messerschmitt 163 rocket fighter in World War II and for the
American Gemini and Apollo spacecraft. It has the following formula.

\[
\text{H} - \text{N} - \text{H}
\]

What is the enthalpy change of atomisation of 1 mol of gaseous hydrazine?
   A. 560 kJ
   B. 1720 kJ
   C. 1970 kJ
   D. 2564 kJ
   [2002 M/J (9)]

3. The following energy cycle represents the enthalpy changes in the formation of carbon dioxide
from its constituent elements in their standard states.

What substances are present at level Y in this diagram?

\[
\begin{align*}
\text{A} & : \text{C}(g) + 2\text{O}(g) \\
\text{B} & : \text{C}(g) + \text{O}_2(g) \\
\text{C} & : \text{C}(s) + \text{O}_2(g) \\
\text{D} & : \text{CO}_2(g)
\end{align*}
\]
   [2002 O/N (9)]

4. At 600 °C oxides of nitrogen react with unburnt hydrocarbons in a catalytic converter in a car
exhaust. The equation using methane as representative of a hydrocarbon molecule would be as
follows:

\[
4\text{NO} + \text{CH}_4 \rightarrow 2\text{N}_2 + \text{CO}_2 + 2\text{H}_2\text{O}
\]

Which statement is likely to be true about the energy change of this reaction?
   A. It is endothermic as heat energy is converted into chemical energy.
   B. It is exothermic as a high temperature is required.
   C. It is exothermic as the triple bond $\text{N} \equiv \text{O}$ is broken.
   D. It is exothermic as the products have large negative enthalpy changes of formation.
   [2002 O/N (10)]
5. Gaseous phosphorus pentachloride can be decomposed into gaseous phosphorus trichloride and chlorine by heating. The table below gives the bond energies.

<table>
<thead>
<tr>
<th>bond</th>
<th>bond energy / kJ mol(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-Cl (in both chlorides)</td>
<td>330</td>
</tr>
<tr>
<td>Cl-Cl</td>
<td>240</td>
</tr>
</tbody>
</table>

What is the enthalpy change in the decomposition of \(\text{PCl}_5\) to \(\text{PCl}_3\) and \(\text{Cl}_2\)?

A. \(-420\) kJ mol\(^{-1}\)  
B. \(-60\) kJ mol\(^{-1}\)  
C. \(-90\) kJ mol\(^{-1}\)  
D. \(-420\) kJ mol\(^{-1}\)  

[2003 M/J (7)]

6. The 'flash' produced by nineteenth century photographers to take indoor photographs was obtained from the following reaction.

\[3\text{Mg} + \text{KClO}_3 \rightarrow 3\text{MgO} + \text{KCl}\]

The standard enthalpy changes of formation are given below.

<table>
<thead>
<tr>
<th>compound</th>
<th>(\Delta H^o ) / kJ mol(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>MgO</td>
<td>(-602)</td>
</tr>
<tr>
<td>KCl</td>
<td>(-437)</td>
</tr>
<tr>
<td>KClO(_3)</td>
<td>(-391)</td>
</tr>
</tbody>
</table>

What is the standard enthalpy change of the 'flash' reaction?

A. \(-3\times(-602) + (-437) - (-391)\)  
B. \((-602) + (-437) - (-391)\)  
C. \(3\times(-602) + (-437) - (-391)\)  
D. \((-602) + 3\times(-437) - 3\times(-391)\)

[2003 O/N (11)]

7. Why does the exothermic reaction

\[\text{C}_{}(\text{diamond}) \rightarrow \text{C}_{}(\text{graphite})\]

\(\Delta H = -3 \text{ kJ mol}^{-1}\)

not occur spontaneously?

A. A tetrahedral configuration is always more stable than a planar one.  
B. Diamond has only strong covalent bonds whereas graphite has both covalent bonds and van der Waals' forces.  
C. The change from diamond to graphite has a high activation energy.  
D. The density of graphite is less than that of diamond.  

[2003 O/N (12)]

8. The standard enthalpy changes of formation of iron(II) oxide, \(\text{FeO(s)}\), and aluminium oxide, \(\text{Al}_2\text{O}_3(s)\), are \(-266\) kJ mol\(^{-1}\) and \(-1676\) kJ mol\(^{-1}\) respectively.

What is the enthalpy change under standard conditions for the following reaction?

\[3\text{FeO(s)} + 2\text{Al(s)} \rightarrow 3\text{Fe(s)} + \text{Al}_2\text{O}_3(s)\]

A. \(+878\) kJ  
B. \(-878\) kJ  
C. \(-1942\) kJ  
D. \(-2474\) kJ  

[2004 M/J (8)]

9. The conversion of graphite has only a small positive value of \(\Delta H\).

\[\text{C}_{}(\text{graphite}) \rightarrow \text{C}_{}(\text{diamond})\]

\(\Delta H = +2.1 \text{ kJ mol}^{-1}\)

However, the production of synthetic diamonds using this reaction is very difficult. Which statements help to explain this?

1. The activation energy of the reaction is large.  
2. An equilibrium exists between diamond and graphite.  
3. Only exothermic reactions can be made to occur readily.  

[2004 M/J (32)]
10. The diagram illustrates the energy changes of a set of reactions.
\[ \Delta H = -134 \text{ kJ mol}^{-1} \]
\[ \Delta H = +92 \text{ J mol}^{-1} \]
\[ \Delta H = -75 \text{ kJ mol}^{-1} \]

Which of the following statements are correct?
1. The enthalpy change for the transformation \( U \rightarrow R \) is +42 kJ mol\(^{-1}\).
2. The enthalpy change for the transformation \( T \rightarrow S \) is endothermic.
3. The enthalpy change for the transformation \( R \rightarrow T \) is -33 kJ mol\(^{-1}\).

[2004 O/N (31)]

11. Iodine trichloride, \( IC_3 \), is made by reacting iodine with chlorine.
\[ \text{I}_2(s) + 3\text{Cl}_2(g) \rightarrow 2\text{ICl}_3(s) \quad \Delta H^\circ = +14 \text{ kJ mol}^{-1} \]
\[ \text{ICl}_3(s) + \text{Cl}_2(g) \rightarrow 3\text{ICl}(s) \quad \Delta H^\circ = -88 \text{ kJ mol}^{-1} \]

By using the data above, what is the enthalpy change of the formation for solid iodine trichloride?
A. -60 kJ mol\(^{-1}\)
B. -74 kJ mol\(^{-1}\)
C. -81 kJ mol\(^{-1}\)
D. -162 kJ mol\(^{-1}\)

[2005 M/J (7)]

12. Which of the enthalpy changes of the following reactions can only be obtained by application of Hess' Law?
1. The hydration of anhydrous copper sulphate to form crystals of \( \text{CuSO}_4 \cdot 5\text{H}_2\text{O} \).
2. The formation of methane from its elements.
3. The combustion of glucose, \( \text{C}_6\text{H}_{12}\text{O}_6 \).

[2005 M/J (33)]

13. Given \( \text{S(s)} + \text{O}_2(g) \rightarrow \text{SO}_2(g), \quad \Delta H^\circ = -297 \text{ kJ mol}^{-1} \)
and \( \text{S(s)} + \frac{1}{2}\text{O}_2(g) \rightarrow \text{SO}_3(g), \quad \Delta H^\circ = -395 \text{ kJ mol}^{-1} \)
what is the enthalpy change of reaction, \( \Delta H^\circ \), of \( 2\text{SO}_2(g) + \text{O}_2(g) \rightarrow 2\text{SO}_3(g) \)?
A. -198 kJ mol\(^{-1}\)
B. -98 kJ mol\(^{-1}\)
C. +98 kJ mol\(^{-1}\)
D. +198 kJ mol\(^{-1}\)

[2005 O/N (6)]

14. The table shows the enthalpy change of neutralisation per mole of water formed, \( \Delta H \), for various acids and bases.

<table>
<thead>
<tr>
<th>acid</th>
<th>base</th>
<th>( \Delta H / \text{kJ mol}^{-1} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>hydrochloric acid</td>
<td>sodium hydroxide</td>
<td>-57.0</td>
</tr>
<tr>
<td>hydrochloric acid</td>
<td>sodium hydroxide</td>
<td>-54.0</td>
</tr>
<tr>
<td>nitric acid</td>
<td>sodium hydroxide</td>
<td>-52.0</td>
</tr>
<tr>
<td>nitric acid</td>
<td>sodium hydroxide</td>
<td>-57.0</td>
</tr>
</tbody>
</table>

What are \( P, Q \) and \( R \)?

<table>
<thead>
<tr>
<th></th>
<th>( P )</th>
<th>( Q )</th>
<th>( R )</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ethanoic acid</td>
<td>ammonia</td>
<td>potassium hydroxide</td>
</tr>
<tr>
<td>B</td>
<td>ethanoic acid</td>
<td>sodium hydroxide</td>
<td>ammonia</td>
</tr>
<tr>
<td>C</td>
<td>sulphuric acid</td>
<td>ammonia</td>
<td>potassium hydroxide</td>
</tr>
<tr>
<td>D</td>
<td>sulphuric acid</td>
<td>sodium hydroxide</td>
<td>ammonia</td>
</tr>
</tbody>
</table>

[2005 O/N (7)]
15. In the conversion of compound $X$ into compound $Z$, it was found that the reaction proceeded by way of compound $Y$, which could be isolated. The following steps were involved.

$$X \rightarrow Y; \Delta H, \text{ positive}$$

$$Y \rightarrow Z; \Delta H, \text{ negative}$$

Which reaction profile fits these data?

![Reaction profiles A, B, C, D]

16. Sodium ions can be formed from sodium atoms.

$$Na(s) \rightarrow Na^+(g)$$

Which quantities are required to calculate the enthalpy change of formation of gaseous sodium ions?

1. enthalpy change of atomisation of sodium
2. first ionisation energy of sodium
3. enthalpy change of formation of sodium

17. For which equation is the enthalpy change correctly described as an enthalpy change of formation?

A. $2NO(g) \rightarrow N_2(g) + O_2(g)$
B. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$
C. $H_2O(l) + NaCl(s) \rightarrow NaCl(aq)$
D. $K(s) + Mn(s) + 2O_2(g) \rightarrow KMnO_4(s)$

18. Given

$$\text{Given: CO}(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H^\circ = -283 \text{ kJ mol}^{-1}$$

$$\text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) \quad \Delta H^\circ = -286 \text{ kJ mol}^{-1}$$

$$\text{H}_2\text{O}(g) \rightarrow \text{H}_2\text{O}(l) \quad \Delta H^\circ = -44 \text{ kJ mol}^{-1}$$

What is the change in enthalpy, $\Delta H^\circ$, for the following reaction?

$$\text{CO}_2(g) + \text{H}_2(g) \rightarrow \text{CO}(g) + \text{H}_2\text{O}(g)$$

A. $-525 \text{ kJ mol}^{-1}$  
B. $-41 \text{ kJ mol}^{-1}$  
C. $+41 \text{ kJ mol}^{-1}$  
D. $+525 \text{ kJ mol}^{-1}$

19. An exothermic chemical reaction proceeds by two stages.

$$\text{reactants} \rightarrow \text{intermediate} \rightarrow \text{products}$$

The activation energy of stage 1 is $50 \text{ kJ mol}^{-1}$. The overall enthalpy change of reaction is $-100 \text{ kJ mol}^{-1}$.

Which diagram represents the reaction pathway for this reaction?

![Reaction pathways A, B, C, D]
20. Skiers trapped by snowstorms use heat packs to keep warm. The heat may be generated by the reaction below.

\[ 4\text{Fe(s)} + 3\text{O}_2(g) \rightarrow 2\text{Fe}_2\text{O}_3(s) \quad ; \quad \Delta H^\circ = -1648 \text{kJ} \]

What is the standard enthalpy change of formation of iron(III) oxide?

A. 0 kJ mol\(^{-1}\)
B. -824 kJ mol\(^{-1}\)
C. -1648 kJ mol\(^{-1}\)
D. -3296 kJ mol\(^{-1}\)

[2007 M/J (8)]

21. Slaked lime, Ca(OH)\(_2\), may be made from limestone, CaCO\(_3\).

On heating in a lime kiln at 1000°C, limestone decomposes as follows.

\[ \text{reaction 1} \quad \text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g) \]

Water is then reacted with calcium oxide, CaO, as follows.

\[ \text{reaction 2} \quad \text{CaO}(s) + \text{H}_2\text{O}(l) \rightarrow \text{Ca(OH)}_2(s) \]

What are the enthalpy changes of these reactions?

<table>
<thead>
<tr>
<th></th>
<th>reaction 1</th>
<th>reaction 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>endothermic</td>
<td>endothermic</td>
</tr>
<tr>
<td>B</td>
<td>endothermic</td>
<td>exothermic</td>
</tr>
<tr>
<td>C</td>
<td>exothermic</td>
<td>endothermic</td>
</tr>
<tr>
<td>D</td>
<td>exothermic</td>
<td>exothermic</td>
</tr>
</tbody>
</table>

[2007 M/J (14)]

22. The standard enthalpy changes of formation of HCl and HI are -92 kJ mol\(^{-1}\) and +26 kJ mol\(^{-1}\) respectively.

Which statement is most important in explaining this difference?

A. Chlorine is more electronegative than iodine.
B. The activation energy for the H\(_2\)/Cl\(_2\) reaction is much less than that for the H\(_2\)/I\(_2\) reaction.
C. The bond energy of HI is smaller than the bond energy of HCl.
D. The bond energy of I\(_2\) is smaller than the bond energy of Cl\(_2\).

[2007 M/J (16)]

23. Which equation represents the standard enthalpy change of atomisation of bromine?

A. Br\(_2\)(l) → 2Br(g)
B. Br\(_2\)(g) → 2Br(g)
C. \(\frac{1}{2}\) Br\(_2\)(l) → Br(g)
D. \(\frac{1}{2}\) Br\(_2\)(g) → Br(g)

[2007 O/N (8)]

24. For which equation does the enthalpy change correspond to the enthalpy change of atomisation of iodine?

A. \(\frac{1}{2}\) I\(_2\)(s) → I(s)
B. \(\frac{1}{2}\) I\(_2\)(s) → I(g)
C. I\(_2\)(g) → 2I(g)
D. I\(_2\)(s) → 2I(g)

[2008 M/J (9)]
25. Titanium occurs naturally as the mineral rutile, TiO₂. One possible method of extraction of titanium is to reduce the rutile by heating with carbon.

\[
\text{TiO}_2(s) + 2\text{C}(s) \rightarrow \text{Ti}(s) + 2\text{CO(g)}
\]

The standard enthalpy changes of formation of TiO₂(s) and CO(g) are \(-940\ \text{kJ mol}^{-1}\) and \(-110\ \text{kJ mol}^{-1}\) respectively.

What is the standard enthalpy change of this reaction?

A. \(-830\ \text{kJ mol}^{-1}\)
B. \(-720\ \text{kJ mol}^{-1}\)
C. \(+720\ \text{kJ mol}^{-1}\)
D. \(+830\ \text{kJ mol}^{-1}\)

[2008 M/J (10)]

26. Red lead oxide, Pb₃O₄, is used in metal priming paints. It can be made by heating PbO in air.

\[
6\text{PbO(s)} + \text{O}_2(g) \rightarrow 2\text{Pb}_3\text{O}_4(s)
\]

Which two values are needed to calculate the enthalpy change for this reaction?

A. enthalpy change of combustion of lead and enthalpy change of formation of Pb₃O₄
B. enthalpy change of combustion of PbO and enthalpy change of formation of Pb₂O₄
C. enthalpy change of formation of PbO and enthalpy change of atomisation of O₂
D. enthalpy change of formation of PbO and enthalpy change of formation of Pb₃O₄

[2008 O/N (8)]

27. The diagram represents the reaction pathway for the following reaction.

\[
W(g) + X(g) \rightarrow Y(g) + Z(g)
\]

What statement can be made about the reverse reaction, \(Y(g) + Z(g) \rightarrow W(g) + X(g)\)?

A. It will have a larger activation energy and a positive \(\Delta H\).
B. It will have a larger activation energy and a negative \(\Delta H\).
C. It will have a smaller activation energy and a positive \(\Delta H\).
D. It will have a smaller activation energy and a negative \(\Delta H\).

[2008 O/N (9)]
28. Hydrogen peroxide slowly decomposes into water and oxygen. The enthalpy change of reaction can be calculated using standard enthalpies of formation.
\[
\Delta H^\circ_{\text{(hydrogen peroxide(l))}} = -187.8 \text{ kJ mol}^{-1}
\]
\[
\Delta H^\circ_{\text{(water(l))}} = -285.8 \text{ kJ mol}^{-1}
\]
Using a Hess cycle, what is the enthalpy change of reaction for this decomposition?
\[
2\text{H}_2\text{O}_2(l) \rightarrow 2\text{H}_2\text{O}(l) + \text{O}_2(g)
\]

A. \(+98\text{ kJ mol}^{-1}\)
B. \(-98\text{ kJ mol}^{-1}\)
C. \(-196\text{ kJ mol}^{-1}\)
D. \(-474.2\text{ kJ mol}^{-1}\)

[2009 M/J (8)]

29. For which reactions does the value of \(\Delta H^\circ\) represent both a standard enthalpy change of combustion and a standard enthalpy change of formation?
1. \(\text{C(s)} + \text{O}_2(g) \rightarrow \text{CO}_2(g)\)
2. \(2\text{C(s)} + \text{O}_2(g) \rightarrow 2\text{CO}(g)\)
3. \(\text{CO}(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{CO}_2(g)\)

[2009 M/J (33)]

30. The first stage in the industrial production of nitric acid from ammonia can be represented by the following equation.
\[
4\text{NH}_3(g) + 5\text{O}_2(g) \rightarrow 4\text{NO}(g) + 6\text{H}_2\text{O}(g)
\]
Using the following standard enthalpy change of formation data, what is the value of the standard enthalpy change, \(\Delta H^\circ\), for this reaction?

<table>
<thead>
<tr>
<th>compound</th>
<th>(\Delta H^\circ/\text{kJ mol}^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{NH}_3(g)</td>
<td>(-46.1)</td>
</tr>
<tr>
<td>\text{NO}(g)</td>
<td>(+90.3)</td>
</tr>
<tr>
<td>\text{H}_2\text{O}(g)</td>
<td>(-241.8)</td>
</tr>
</tbody>
</table>

A. \(+905.2\text{ kJ mol}^{-1}\)
B. \(-105.4\text{ kJ mol}^{-1}\)
C. \(-905.2\text{ kJ mol}^{-1}\)
D. \(-1274.0\text{ kJ mol}^{-1}\)

[2009 O/N-11 (6)]
31. Four reactions of the type shown are studied at the same temperature.

\[ X(g) + Y(g) \rightarrow Z(g) \]

Which is the correct reaction pathway diagram for the reaction that would proceed most rapidly and with the highest yield?

![Graph A] ![Graph B] ![Graph C] ![Graph D]

[2009 O/N-11 (10)]

33. Some bond energy values are listed below.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Bond Energy/kJ·mol(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>C–H</td>
<td>410</td>
</tr>
<tr>
<td>C–Cl</td>
<td>340</td>
</tr>
<tr>
<td>Cl–Cl</td>
<td>244</td>
</tr>
<tr>
<td>Br–Br</td>
<td>193</td>
</tr>
</tbody>
</table>

These bond energy values relate to the following four reactions.

P. \( \text{Br}_2 \rightarrow 2\text{Br} \)
Q. \( 2\text{Cl}_2 \rightarrow \text{Cl}_4 \)
R. \( \text{CH}_4 + \text{Cl} \rightarrow \text{CH}_3\text{Cl} \)
S. \( \text{CH}_4 \rightarrow \text{CH}_2 + \text{H} \)

What is the order of enthalpy changes of these reactions from most negative to most positive?

A. P \(\rightarrow\) Q \(\rightarrow\) R \(\rightarrow\) S
B. Q \(\rightarrow\) R \(\rightarrow\) S \(\rightarrow\) P
C. R \(\rightarrow\) Q \(\rightarrow\) P \(\rightarrow\) S
D. S \(\rightarrow\) P \(\rightarrow\) Q \(\rightarrow\) R

[2010 M/J-13 (5)]

32. Given the following enthalpy changes,

\[ \text{I}_2(g) + 3\text{Cl}_2(g) \rightarrow 2\text{ICl}(s) \quad \Delta H^\circ = -214 \text{kJ·mol}^{-1} \]

\[ \text{I}_2(s) \rightarrow \text{I}_2(g) \quad \Delta H^\circ = +38 \text{kJ·mol}^{-1} \]

What is the standard enthalpy change of formation of iodine trichloride, \(\text{ICl}_3(s)\)?

A. +176 kJ·mol\(^{-1}\)
B. -88 kJ·mol\(^{-1}\)
C. -176 kJ·mol\(^{-1}\)
D. -214 kJ·mol\(^{-1}\)

[2010 M/J-11 (5)]

34. Equations involving four enthalpy changes are shown.

\[ \text{Na}(g) \rightarrow \text{Na}^+(g) + e^- \quad \Delta H = W \]
\[ \text{Na}(g) \rightarrow \text{Na}^{2+}(g) + 2e^- \quad \Delta H = X \]
\[ \text{Ne}(s) \rightarrow \text{Ne}(g) \quad \Delta H = Y \]
\[ \text{Na}(s) \rightarrow \text{Na}^{2+}(g) + 2e^- \quad \Delta H = Z \]

What is the second ionisation energy of sodium?

A. 2W
B. X - W
C. Y - W
D. Z - Y

[2010 O/N-11 (3)]
35. Enthalpy changes of combustion can be used to determine enthalpy changes of formation. The following equation represents the enthalpy change of formation of butane.

$$4C(s) + 5H_2(g) \rightarrow C_4H_{10}(g)$$

By using the following standard enthalpy of combustion data, what is the value of the standard enthalpy change of formation, $\Delta H^\circ_r$, for this reaction?

<table>
<thead>
<tr>
<th>compound</th>
<th>$\Delta H^\circ_r$kJ mol$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>carbon</td>
<td>-5883</td>
</tr>
<tr>
<td>hydrogen</td>
<td>-286</td>
</tr>
<tr>
<td>butane</td>
<td>-2877</td>
</tr>
</tbody>
</table>

A. $-5883\text{kJ mol}^{-1}$  
B. $-129\text{kJ mol}^{-1}$  
C. $+129\text{kJ mol}^{-1}$  
D. $+2197\text{kJ mol}^{-1}$

[2010 O/N-11 (8)]

36. In a calorimetric experiment, 1.60g of a fuel is burnt. 45% of the energy released is absorbed by 200g of water whose temperature rises from 18°C to 66°C. The specific heat capacity of water is 4.2 J g$^{-1}$ K$^{-1}$.

What is the total energy released per gram of fuel burnt?

A. 25 200 J  
B. 56 000 J  
C. 89 600 J  
D. 143 360 J

[2010 O/N-11 (9)]

37. Which equation represents the change corresponding to the enthalpy change of atomisation of iodine?

A. $\frac{1}{2}I_2(g) \rightarrow I(g)$  
B. $I_2(g) \rightarrow 2I(g)$  
C. $\frac{1}{2}I_2(s) \rightarrow I(g)$  
D. $I_2(s) \rightarrow 2I(g)$

[2010 O/N-11 (11)]

38. Methanol may be prepared by the reaction between carbon monoxide and hydrogen.

$$\text{CO}(g) + 2\text{H}_2(g) \rightarrow \text{CH}_3\text{OH}(g)$$

The relevant average bond energies are given below.

$$
\begin{align*}
E(\text{C}=\text{O}) & : 1077\text{kJ mol}^{-1} \\
E(\text{C}−\text{O}) & : 360\text{kJ mol}^{-1} \\
E(\text{C}−\text{H}) & : 410\text{kJ mol}^{-1} \\
E(\text{H}−\text{H}) & : 436\text{kJ mol}^{-1} \\
E(\text{O}−\text{H}) & : 460\text{kJ mol}^{-1}
\end{align*}
$$

What is the enthalpy change of this reaction?

A. $-537\text{kJ mol}^{-1}$  
B. $-101\text{kJ mol}^{-1}$  
C. $+101\text{kJ mol}^{-1}$  
D. $+537\text{kJ mol}^{-1}$

[2010 O/N-12 (4)]

39. The reaction pathway diagram below illustrates the energies of reactants, products and the transition state of a reaction.

Which expression represents the activation energy of the forward reaction?

A. $E_1 - E_2$  
B. $E_1 - E_3$  
C. $E_2 - E_3$  
D. $(E_1 - E_2) - (E_3 - E_3)$

[2010 O/N-12 (6)]
40. Use of the Data Booklet is relevant to this question.

The enthalpy change of formation, \( \Delta H_f \), of hydrated calcium ions is the enthalpy change of the following reaction.

\[
\text{Ca(s) + aq} \rightarrow 2e^- \rightarrow \text{Ca}^{2+}(\text{aq})
\]

The following enthalpy changes are **not** quoted in the Data Booklet.

\[
\begin{align*}
\text{Ca(s)} & \rightarrow \text{Ca(g)} \quad \Delta H_f = 177 \text{kJ mol}^{-1} \\
\text{Ca}^{2+}(\text{aq}) + \text{aq} & \rightarrow \text{Ca}^{2+}(\text{aq}) \quad \Delta H_{\text{hydr}} = -1565 \text{kJ mol}^{-1}
\end{align*}
\]

What is the enthalpy change of formation of hydrated calcium ions?

A  \(-1388 \text{kJ mol}^{-1}\)  \\
B  \(-798 \text{kJ mol}^{-1}\)  \\
C  \(-383 \text{kJ mol}^{-1}\)  \\
D  \(+352 \text{kJ mol}^{-1}\)

[2010 O/N-12 (8)]

41. The equation below represents the combination of gaseous atoms of non-metal X and of hydrogen to form gaseous \( X_2H_5 \) molecules.

\[
2X(g) + 6H(g) \rightarrow X_2H_5(g) \quad \Delta H = -2775 \text{kJ mol}^{-1}
\]

The bond energy of an X–H bond is 395 kJ mol\(^{-1}\).

What is the bond energy of an X–X bond?

A  \(-405.0 \text{kJ mol}^{-1}\)  \\
B  \(-202.5 \text{kJ mol}^{-1}\)  \\
C  \(+202.5 \text{kJ mol}^{-1}\)  \\
D  \(+405.0 \text{kJ mol}^{-1}\)

[2011 M/J-11 (8)]

42. Titanium occurs naturally as the mineral rutile, \( \text{TiO}_2 \). One possible method of extraction of titanium is to reduce the rutile by heating with carbon.

\[
\text{TiO}_2(s) + 2C(s) \rightarrow \text{Ti}(s) + 2\text{CO}(g)
\]

The standard enthalpy changes of formation of TiO\(_2\)(s) and CO(g) are \(-940 \text{kJ mol}^{-1}\) and \(-110 \text{kJ mol}^{-1}\) respectively.

What is the standard enthalpy change of this reaction?

A  \(-830 \text{kJ mol}^{-1}\)  \\
B  \(-720 \text{kJ mol}^{-1}\)  \\
C  \(+720 \text{kJ mol}^{-1}\)  \\
D  \(+830 \text{kJ mol}^{-1}\)

[2011 M/J-12 (7)]

43. Which reaction has an enthalpy change equal to the standard enthalpy change of formation of propane?

A  \(3\text{C}(g) + 4\text{H}_2(g) \rightarrow \text{C}_3\text{H}_8(g)\)  \\
B  \(3\text{C}(g) + 8\text{H}(g) \rightarrow \text{C}_3\text{H}_8(g)\)  \\
C  \(3\text{C}(s) + 4\text{H}_2(g) \rightarrow \text{C}_3\text{H}_8(g)\)  \\
D  \(3\text{C}(s) + 4\text{H}_2(g) \rightarrow \text{C}_3\text{H}_8(l)\)

[2011 M/J-12 (8)]
44. In the conversion of compound X into compound Z, it was found that the reaction proceeded by way of compound Y, which could be isolated. The following steps were involved.

\[ X \rightarrow Y; \Delta H, \text{positive} \]
\[ Y \rightarrow Z; \Delta H, \text{negative} \]

Which reaction profile fits these data?

A

\[
\begin{array}{c}
\text{progress of reaction} \\
X \rightarrow Y \rightarrow Z
\end{array}
\]

B

\[
\begin{array}{c}
\text{progress of reaction} \\
X \rightarrow Y \rightarrow Z
\end{array}
\]

C

\[
\begin{array}{c}
\text{progress of reaction} \\
X \rightarrow Y \rightarrow Z
\end{array}
\]

D

\[
\begin{array}{c}
\text{progress of reaction} \\
X \rightarrow Y \rightarrow Z
\end{array}
\]

45. The standard enthalpy change for the reaction

\[ 2\text{NF}_3(g) \rightarrow 2\text{N}(g) + 6\text{F}(g) \quad \Delta H^\circ = +1668 \text{kJ} \]

What is the bond energy of the N–F bond?

A \(-556 \text{kJ mol}^{-1}\)
B \(-278 \text{kJ mol}^{-1}\)
C \(+278 \text{kJ mol}^{-1}\)
D \(+556 \text{kJ mol}^{-1}\)
48. The equation for a reaction is shown.

\[ \text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) \quad \Delta H = x \text{ kJ mol}^{-1} \]

Which pair of descriptions is fully correct for this reaction?

<table>
<thead>
<tr>
<th>type(s) of enthalpy change</th>
<th>value of x</th>
</tr>
</thead>
<tbody>
<tr>
<td>A  formation only</td>
<td>positive</td>
</tr>
<tr>
<td>B  formation only</td>
<td>negative</td>
</tr>
<tr>
<td>C  combustion, formation</td>
<td>positive</td>
</tr>
<tr>
<td>D  combustion, formation</td>
<td>negative</td>
</tr>
</tbody>
</table>

[2012 M/J-11 (3)]

49. Propanone has the molecular formula \( \text{C}_3\text{H}_6\text{O} \).

The enthalpy change of combustion of hydrogen is \(-286 \text{ kJ mol}^{-1}\).
The enthalpy change of combustion of carbon is \(-394 \text{ kJ mol}^{-1}\).
The enthalpy change of combustion of propanone is \(-1786 \text{ kJ mol}^{-1}\).

Using this information, what is the enthalpy change of formation of propanone?

A \(-1106 \text{ kJ mol}^{-1}\)
B \(-540 \text{ kJ mol}^{-1}\)
C \(-254 \text{ kJ mol}^{-1}\)
D \(+1106 \text{ kJ mol}^{-1}\)

[2012 M/J-11 (7)]

50. Red lead oxide, \( \text{Pb}_2\text{O}_4 \), is used in metal priming paints. It can be made by heating PbO in air.

\[ 6\text{PbO(s)} + \text{O}_2(\text{g}) \rightarrow 2\text{Pb}_2\text{O}_4(\text{s}) \]

Which two values are needed to calculate the enthalpy change for this reaction?

A enthalpy change of atomisation of \( \text{O}_2 \) and enthalpy change of formation of \( \text{Pb}_2\text{O}_4 \)
B enthalpy change of formation of \( \text{O}_2 \) and enthalpy change of formation of \( \text{Pb}_2\text{O}_4 \)
C enthalpy change of formation of PbO and enthalpy change of atomisation of \( \text{O}_2 \)
D enthalpy change of formation of PbO and enthalpy change of formation of \( \text{Pb}_2\text{O}_4 \)

[2012 M/J-12 (12)]

51. *Use of the Data Booklet is relevant to this question.*

A reaction which causes the presence of oxides of nitrogen in car exhausts is the formation of NO.

\[ \text{N}_2 + \text{O}_2 \rightarrow 2\text{NO} \quad \Delta H = +180 \text{ kJ mol}^{-1} \]

What is the bond energy in kJ mol\(^{-1}\) of the bond between the atoms in NO?

A 655  B 835  C 1310  D 1670

[2012 O/N-11 (4)]
52. In the table below,
- ‘+’ means that this type of standard enthalpy change can only have positive values,
- ‘−’ means that this type of standard enthalpy change can only have negative values,
- ‘+/−’ means that either positive or negative values are possible.
Which row is correct?

<table>
<thead>
<tr>
<th></th>
<th>atomisation</th>
<th>formation</th>
<th>solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+</td>
<td>+</td>
<td>+/-</td>
</tr>
<tr>
<td>B</td>
<td>+</td>
<td>+/−</td>
<td>−/−</td>
</tr>
<tr>
<td>C</td>
<td>−</td>
<td>+/−</td>
<td>−</td>
</tr>
<tr>
<td>D</td>
<td>−</td>
<td>−</td>
<td>+</td>
</tr>
</tbody>
</table>

53. A student calculated the standard enthalpy change of formation of ethane, $\text{C}_2\text{H}_6$, using a method based on standard enthalpy changes of combustion.

He used correct values for the standard enthalpy change of combustion of ethane ($-1560 \text{ kJ mol}^{-1}$) and hydrogen ($-286 \text{ kJ mol}^{-1}$) but he used an incorrect value for the standard enthalpy change of combustion of carbon. He then performed his calculation correctly. His final answer was $-168 \text{ kJ mol}^{-1}$.

What did he use for the standard enthalpy change of combustion of carbon?

A $-1432 \text{ kJ mol}^{-1}$
B $-860 \text{ kJ mol}^{-1}$
C $-480 \text{ kJ mol}^{-1}$
D $-272 \text{ kJ mol}^{-1}$

54. Which process could be used to calculate the bond energy for the covalent bond $X-Y$ by dividing its $\Delta H$ by $n$?

A $XY(g) \rightarrow X(g) + nY(g)$
B $2XY(g) \rightarrow 2XY_n(g) + Y(g)$
C $Y(g) + XY_n(g) \rightarrow XY(g)$
D $nXY(g) \rightarrow nX(g) + \frac{n}{2}Y(g)$

55. Ethyne, $\text{C}_2\text{H}_2$, completely combusts, as shown in the equation.

$$\text{H} = \text{C} = \text{C} - \text{H} + 2 \frac{1}{2} \text{O} \rightarrow \text{H}_2\text{O} + 2\text{CO}_2$$

Using the average bond enthalpies in the table, what is the enthalpy change of combustion of ethyne?

<table>
<thead>
<tr>
<th>Bond</th>
<th>Average Bond Enthalpy $/\text{kJ mol}^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{C-H}$</td>
<td>410</td>
</tr>
<tr>
<td>$\text{C=C}$</td>
<td>840</td>
</tr>
<tr>
<td>$\text{O=O}$</td>
<td>496</td>
</tr>
<tr>
<td>$\text{C-O}$</td>
<td>740</td>
</tr>
<tr>
<td>$\text{O-H}$</td>
<td>480</td>
</tr>
<tr>
<td>$\text{C-O}$</td>
<td>360</td>
</tr>
</tbody>
</table>

A $-980 \text{ kJ mol}^{-1}$
B $-540 \text{ kJ mol}^{-1}$
C $+540 \text{ kJ mol}^{-1}$
D $+980 \text{ kJ mol}^{-1}$
56. The enthalpy change of the neutralisation given below is $-114 \text{ kJ mol}^{-1}$.

$$2\text{NaOH(aq)} + \text{H}_2\text{SO}_4(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + 2\text{H}_2\text{O(l)}$$

By using this information, what is the most likely value for the enthalpy change of the following neutralisation?

$$\text{Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl}_2(aq) + 2\text{H}_2\text{O(l)}$$

A $-57 \text{ kJ mol}^{-1}$  B $-76 \text{ kJ mol}^{-1}$  C $-114 \text{ kJ mol}^{-1}$  D $-228 \text{ kJ mol}^{-1}$

[2012 O/N-13 (10)]

57. The reaction pathway for a reversible reaction is shown below.

![Reaction Pathway](image)

Which statement is correct?

A The activation energy of the reverse reaction is $+80 \text{ kJ mol}^{-1}$.
B The enthalpy change for the forward reaction is $+30 \text{ kJ mol}^{-1}$.
C The enthalpy change for the forward reaction is $+50 \text{ kJ mol}^{-1}$.
D The enthalpy change for the reverse reaction is $+30 \text{ kJ mol}^{-1}$.

[2013 M/J-11 (7)]

58. Use of the Data Booklet is relevant to this question.

This question should be answered using bond enthalpy data. The equation for the complete combustion of methane is given below.

$$\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$$

What is the enthalpy change of combustion of methane?

A $-1530 \text{ kJ mol}^{-1}$  B $-1184 \text{ kJ mol}^{-1}$  C $-770 \text{ kJ mol}^{-1}$  D $-688 \text{ kJ mol}^{-1}$

[2013 M/J-11 (12)]

59. Equations involving four enthalpy changes are shown.

$$\text{Na(g)} \rightarrow \text{Na}^{+}(g) + e^{-} \quad \Delta H = W$$
$$\text{Na(g)} \rightarrow \text{Na}^{2+}(g) + 2e^{-} \quad \Delta H = X$$
$$\text{Na(s)} \rightarrow \text{Na}(g) \quad \Delta H = Y$$
$$\text{Na(s)} \rightarrow \text{Na}^{2+}(g) + 2e^{-} \quad \Delta H = Z$$

What is the second ionisation energy of sodium?

A $X$  B $X - W$  C $Y - W$  D $Z - Y$

[2013 M/J-12 (2)]
60. Use of the Data Booklet is relevant to this question.

A student mixed 25 cm$^3$ of 0.10 mol dm$^{-3}$ sodium hydroxide solution with 25 cm$^3$ of 0.10 mol dm$^{-3}$ hydrochloric acid and noted a temperature rise of 2.5 °C.

What is the enthalpy change of the reaction per mole of NaOH?
A $-209 \text{ kJ mol}^{-1}$
B $-104.5 \text{ kJ mol}^{-1}$
C $-209 \text{ J mol}^{-1}$
D $-522.5 \text{ J mol}^{-1}$

[2013 M/J-12 (10)]

61. Which energy change corresponds to the enthalpy change of atomisation of hydrogen at 298 K?
A the bond energy of a H–H bond
B half the bond energy of a H–H bond
C minus half the bond energy of a H–H bond
D minus the bond energy of a H–H bond

[2013 M/J-12 (11)]

62. Propanone has molecular formula C$_3$H$_6$O.

The enthalpy change of combustion of hydrogen is $-286 \text{ kJ mol}^{-1}$.

The enthalpy change of combustion of carbon is $-394 \text{ kJ mol}^{-1}$.

The enthalpy change of formation of propanone is $-254 \text{ kJ mol}^{-1}$.

Using this information, what is the enthalpy change of combustion of propanone?
A $-264.4 \text{ kJ mol}^{-1}$
B $-2294 \text{ kJ mol}^{-1}$
C $-1786 \text{ kJ mol}^{-1}$
D $-428 \text{ kJ mol}^{-1}$

[2013 M/J-12 (12)]

63. Use of the Data Booklet is relevant to this question.

This question should be answered using bond enthalpy data. The equation for the complete combustion of methanal is given below.

$$\text{H}_2\text{C}=\text{O} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$$

What is the enthalpy change of combustion of methanal?
A $+416 \text{ kJ mol}^{-1}$
B $+396 \text{ kJ mol}^{-1}$
C $-344 \text{ kJ mol}^{-1}$
D $-690 \text{ kJ mol}^{-1}$

[2013 M/J-13 (11)]

64. The reaction pathway for a reversible reaction is shown below.

Which statements are correct?
1 The enthalpy change for the backward reaction is $-20 \text{ kJ mol}^{-1}$.
2 The forward reaction is endothermic.
3 The activation energy for the forward reaction is $+70 \text{ kJ mol}^{-1}$.

[2013 M/J-13 (33)]
65.
Use of the Data Booklet is relevant to this question.

A student carried out an experiment to determine the enthalpy change for the combustion of methanol.

The following results were obtained by the student:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>start temperature of the water</td>
<td>20°C</td>
</tr>
<tr>
<td>final temperature of the water</td>
<td>53°C</td>
</tr>
<tr>
<td>mass of alcohol burner before burning</td>
<td>259.65 g</td>
</tr>
<tr>
<td>mass of alcohol burner after burning</td>
<td>259.15 g</td>
</tr>
<tr>
<td>mass of glass beaker plus water</td>
<td>150.00 g</td>
</tr>
<tr>
<td>mass of glass beaker</td>
<td>50.00 g</td>
</tr>
</tbody>
</table>

How much of the heat energy produced by the burning of methanol went into the water?

A 209 J  B 13794 J  C 20691 J  D 22154 J

[2013 O/N-11 (11)]

66.
Enthalpy changes that are difficult to measure directly can often be determined using Hess' Law to construct an enthalpy cycle.

Which enthalpy change is indicated by X in the enthalpy cycle shown?

\[
\begin{align*}
\text{C(s) + 2H}_2(g) + 2\text{O}_2(g) & \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O(l)} \\
\Delta H^\circ & \\
\text{CH}_4(g) + 2\text{O}_2(g) & \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O(l)} \\
\Delta H^\circ &
\end{align*}
\]

A  $-4 \times$ the enthalpy of combustion of hydrogen  
B  $+4 \times$ the enthalpy of combustion of hydrogen  
C  $-2 \times$ the enthalpy of formation of water  
D  $+2 \times$ the enthalpy of formation of water

[2014 M/J-11 (3)]

67.
A student mixed 25.0 cm$^3$ of 0.350 mol dm$^{-3}$ sodium hydroxide solution with 25.0 cm$^3$ of 0.350 mol dm$^{-3}$ hydrochloric acid. The temperature rose by 2.50°C. Assume that no heat was lost to the surroundings.

The final mixture had a specific heat capacity of 4.20 J cm$^{-3}$ K$^{-1}$.

What is the molar enthalpy change for the reaction?

A  $-150$ kJ mol$^{-1}$  
B  $-60.0$ kJ mol$^{-1}$  
C  $-30.0$ kJ mol$^{-1}$  
D  $-0.150$ kJ mol$^{-1}$

[2014 M/J-11 (5)]
68. **Use of the Data Booklet is relevant to this question.**

When the liquid $\text{N}_2\text{F}_4$ is heated, it decomposes into a single product, $X$.

Which statements are correct?

1. N–F bonds are broken during this decomposition.
2. The enthalpy change when $\text{N}_2\text{F}_4$ decomposes into $X$ is approximately $+180 \text{ kJ mol}^{-1}$.
3. Molecules of $X$ are non-linear.

[2014 M/J-11 (31)]

69. The enthalpy change of formation of carbon dioxide is $-394 \text{ kJ mol}^{-1}$.
The enthalpy change of formation of water is $-288 \text{ kJ mol}^{-1}$.
The enthalpy change of formation of methane is $-74 \text{ kJ mol}^{-1}$.

What is the enthalpy change of combustion of methane?

A. $-892 \text{ kJ mol}^{-1}$
B. $-806 \text{ kJ mol}^{-1}$
C. $+606 \text{ kJ mol}^{-1}$
D. $+892 \text{ kJ mol}^{-1}$

[2014 M/J-12 (3)]

70. Which equation represents the standard enthalpy change of formation of ethanol, $\text{C}_2\text{H}_5\text{OH}$?

A. $2\text{C}(g) + 3\text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{C}_2\text{H}_5\text{OH}(l)$
B. $2\text{C}(s) + 3\text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{C}_2\text{H}_5\text{OH}(l)$
C. $2\text{C}(s) + 3\text{H}_2(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{C}_2\text{H}_5\text{OH}(g)$
D. $2\text{C}(g) + 6\text{H}(g) + \text{O}(g) \rightarrow \text{C}_2\text{H}_5\text{OH}(l)$

[2014 M/J-12 (8)]

71. The diagram shows the skeletal formula of cyclopropane.

The enthalpy change of formation of cyclopropane is $+53.3 \text{ kJ mol}^{-1}$ and the enthalpy change of atomisation of graphite is $+717 \text{ kJ mol}^{-1}$.
The bond enthalpy of $\text{H–H}$ is $436 \text{ kJ mol}^{-1}$ and of $\text{C–H}$ is $410 \text{ kJ mol}^{-1}$.

What value for the average bond enthalpy of the $\text{C–C}$ bond in cyclopropane can be calculated from this data?

A. $187 \text{ kJ mol}^{-1}$  B. $315 \text{ kJ mol}^{-1}$  C. $351 \text{ kJ mol}^{-1}$  D. $946 \text{ kJ mol}^{-1}$

[2014 M/J-12 (11)]

72. A reaction pathway diagram is shown.

Which enthalpy change could the diagram not apply to?

A. enthalpy of atomisation
B. enthalpy of combustion
C. enthalpy of formation
D. enthalpy of neutralisation

[2014 M/J-13 (3)]
73. The enthalpy change of formation of \( \text{Mn(NO}_3\text{)}_2\text{(s)} \) is \(-696\text{ kJ mol}^{-1}\).
   The enthalpy change of formation of \( \text{MnO}_2\text{(s)} \) is \(-520\text{ kJ mol}^{-1}\).
   The enthalpy change of formation of \( \text{NO}_2\text{(g)} \) is \(+33\text{ kJ mol}^{-1}\).

   On heating, \( \text{Mn(NO}_3\text{)}_2\text{(s)} \) decomposes into \( \text{MnO}_2\text{(s)} \) and \( \text{NO}_2\text{(g)} \).
   \[
   \text{Mn(NO}_3\text{)}_2\text{(s)} \rightarrow \text{MnO}_2\text{(s)} + 2\text{NO}_2\text{(g)}
   \]

   What is the value of the standard enthalpy change of this reaction?
   
   A. \(-242\text{ kJ mol}^{-1}\)
   B. \(-209\text{ kJ mol}^{-1}\)
   C. \(+209\text{ kJ mol}^{-1}\)
   D. \(+242\text{ kJ mol}^{-1}\)

   [2014 M/J-13 (9)]

74. Which reaction has an enthalpy change equal to the standard enthalpy change of formation of propane?
   
   A. \(3\text{C(g)} + 4\text{H}_2\text{(g)} \rightarrow \text{C}_3\text{H}_8\text{(g)}\)
   B. \(3\text{C(g)} + 8\text{H}_2\text{(g)} \rightarrow \text{C}_3\text{H}_8\text{(g)}\)
   C. \(3\text{C(s)} + 4\text{H}_2\text{(g)} \rightarrow \text{C}_3\text{H}_8\text{(g)}\)
   D. \(3\text{C(s)} + 4\text{H}_2\text{(g)} \rightarrow \text{C}_3\text{H}_8\text{(l)}\)

   [2014 M/J-13 (11)]

75. Ethanol is increasingly being used as a fuel for cars.
   
   The standard enthalpy change of formation of carbon dioxide is \(-393\text{ kJ mol}^{-1}\).
   The standard enthalpy change of formation of water is \(-286\text{ kJ mol}^{-1}\).
   The standard enthalpy change of formation of ethanol is \(-277\text{ kJ mol}^{-1}\).

   What is the standard enthalpy change of combustion of ethanol?
   
   A. \(-1921\text{ kJ mol}^{-1}\)
   B. \(-1367\text{ kJ mol}^{-1}\)
   C. \(-956\text{ kJ mol}^{-1}\)
   D. \(-402\text{ kJ mol}^{-1}\)

   [2014 O/N-11 (3)]

76. In an experiment to calculate the enthalpy change of combustion of a fuel, 1.5 g (0.0326 mol) of the fuel was used to heat 200 g of water. The temperature of the water rose from 23 °C to 55 °C. The specific heat capacity of water is 4.18 J g \(^{-1}\) K\(^{-1}\).

   There is significant heat loss in this experiment. Therefore, the experimental value for the enthalpy change of combustion, \(\Delta H_{\text{exp}}\), of the fuel will be different from the theoretical value.

   Using the information above, what is the experimental value for the enthalpy change of combustion, \(\Delta H_{\text{exp}}\), of the fuel?
   
   A. \(-1410\text{ kJ mol}^{-1}\)
   B. \(-769\text{ kJ mol}^{-1}\)
   C. \(-30.7\text{ kJ mol}^{-1}\)
   D. \(-16.7\text{ kJ mol}^{-1}\)

   [2014 O/N-11 (7)]

77. The reaction pathway diagram below illustrates the energies of the reactants, the products and the transition state of a reaction.

   ![Reaction Pathway Diagram]

   Which expression represents the activation energy of the forward reaction?
   
   A. \(E_1 - E_2\)
   B. \(E_2 - E_1\)
   C. \(E_2 - E_3\)
   D. \(E_3 - E_2\)

   [2014 O/N-11 (8)]
78. Use of the Data Booklet is relevant to this question.
The bond energy of the Br–O bond is 235 kJ mol$^{-1}$.

Which reactions are exothermic?
1. OH$^*$ + HBr → H$_2$ + BrO$^*$
2. OH$^*$ + HBr → H$_2$O + Br$^*$
3. H$^*$ + HBr → H$_2$ + Br$^*$

[2014 O/N-11 (32)]

79. Hydrogen sulfide, H$_2$S, is released from volcanoes. It reacts with oxygen in the air to form sulfur dioxide.

\[ 2\text{H}_2\text{S}(g) + 3\text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(l) + 2\text{SO}_2(g) \]

\[ \Delta H^o[\text{H}_2\text{S}(g)] = -21 \text{kJ mol}^{-1} \]
\[ \Delta H^o[\text{H}_2\text{O}(l)] = -286 \text{kJ mol}^{-1} \]
\[ \Delta H^o[\text{SO}_2(g)] = -297 \text{kJ mol}^{-1} \]

What is the standard enthalpy change of this reaction?
A. -1208 kJ mol$^{-1}$
B. -1124 kJ mol$^{-1}$
C. -562 kJ mol$^{-1}$
D. -541 kJ mol$^{-1}$

[2014 O/N-13 (5)]

80. Nitrogen monoxide is an atmospheric pollutant that is formed inside car engines by an endothermic reaction between nitrogen and oxygen.

\[ \text{N}_2(g) + \text{O}_2(g) \rightarrow 2\text{NO}(g) \quad \Delta H = +66 \text{kJ mol}^{-1} \]

Which labelled diagram correctly represents the energy profile for this reaction?

[Diagram A]

[Diagram B]

[Diagram C]

[Diagram D]

[2014 O/N-13 (10)]

81. Use of the Data Booklet is relevant to this question.

When 0.47 g of a hydrocarbon was completely burnt in air, the energy released heated 200 g of water from 23.7°C to 41.0°C.

What was the amount of energy absorbed by the water?

A. \(0.47 \times 4.18\times 17.3\) J
B. \(0.47 \times 4.18\times (273 + 17.3)\) J
C. \(200 \times 4.18 \times 17.3\) J
D. \(200 \times 4.18 \times (273 + 17.3)\) J

[2014 O/N-13 (11)]
82.
Which names can be applied to the enthalpy change of the reaction shown?

\[ \text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) \]

1. enthalpy change of formation
2. enthalpy change of combustion
3. enthalpy change of hydration

[2014 O/N-13 (34)]