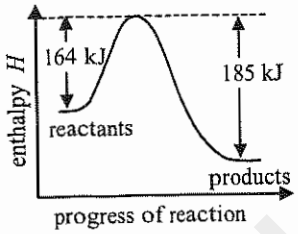
1. The energy profile shown is for the reaction

$$\tfrac{1}{2}H_2(g) + \tfrac{1}{2}I_2(g) \rightarrow HI(g).$$



What conclusions can be drawn from the energy profile?

1 The forward reaction is exothermic.
2 The activation energy for the forward reaction is 164 kJ mol^{-1}.
3 The activation energy for the back reaction is 185 kJ mol^{-1}.

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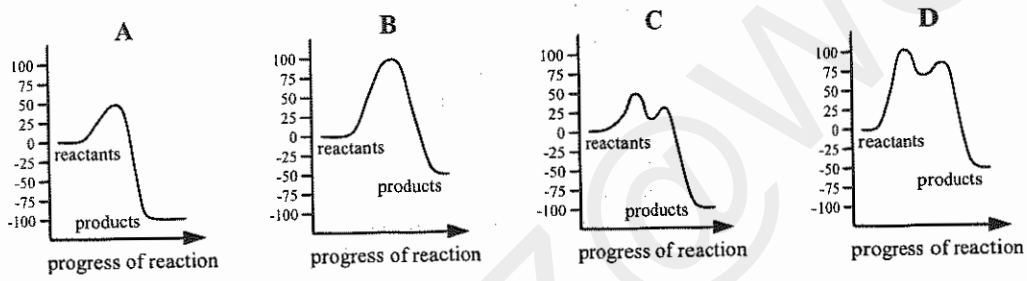
2. An exothermic chemical reaction proceeds in two stages as follows:

$$\text{reactants} \xrightarrow{\textit{stage 1}} \text{intermediate} \xrightarrow{\textit{stage 2}} \text{products}$$

Given that the activation energy of stage 1 is 50 kJ mol^{-1} and the overall enthalpy change of reaction is –100 kJ mol^{-1}, what is the energy level diagram for this reaction?



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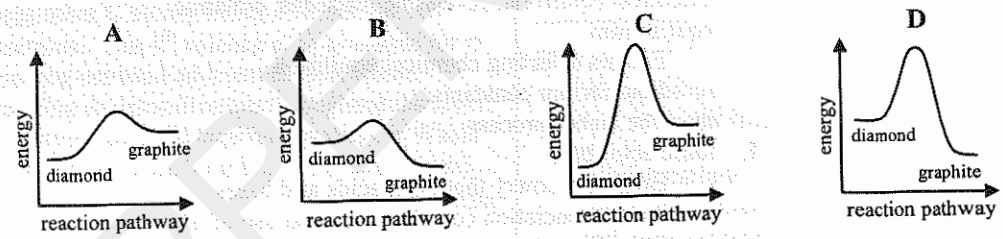
3. Diamond does not readily change into graphite although the conversion of diamond into graphite is exothermic ($\Delta H = -2$ kJ mol^{-1}). What is the energy profile (reaction pathway) for this conversion?



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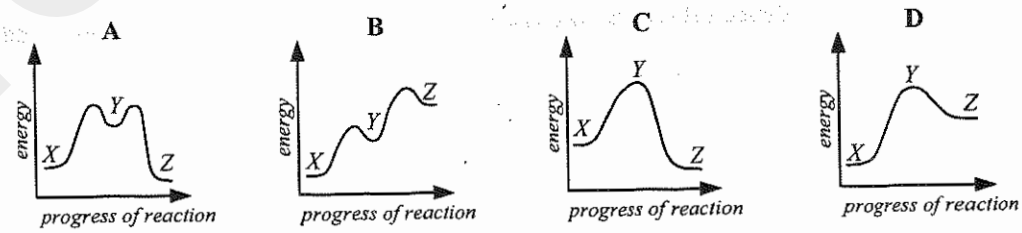
4. Compound X is converted into compound Z in two steps: $X \rightarrow Y$; ΔH, positive
$Y \rightarrow Z$; ΔH, negative

Given that compound Y could be isolated, what is the energy profile for this reaction?



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5. The standard enthalpy changes of combustion of carbon are: C (graphite) = –393.1 kJ mol^{-1}
C (diamond) = –395.0 kJ mol^{-1}

What can be deduced from the data above?

1 Graphite is more stable than diamond.
2 Graphite has a higher energy content than diamond.
3 Graphite is formed endothermically from diamond.

6. The conversion of graphite into diamond is an endothermic reaction.

C(graphite) → C(diamond) $\Delta H = +3$ kJ mol^{-1}

What can be deduced from the above data?

1 The enthalpy change of atomisation of diamond is smaller than that of graphite.
2 The bond energy of the C–C bonds in graphite is greater than that in diamond.
3 The enthalpy change of combustion of diamond is greater than that of graphite.

7. The production of synthetic diamonds is very difficult although the conversion of graphite into diamond is only very slightly endothermic.

C(graphite) → C(diamond) $\Delta H = +2.1$ kJ mol^{-1}

Which of the following help to explain this observation?

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.

8. Hydrazine, N_2H_4, reacts with oxygen to give 'environmentally friendly' gases and so, is widely used as a rocket fuel.

$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$ $\Delta H = -534$ kJ mol^{-1}

However, hydrazine does not spontaneously burn in oxygen.

Which of the following explains why hydrazine does not burn spontaneously?

1 The activation energy is too high.
2 The N≡N bond is very strong.
3 Hydrazine is a liquid.

9. Which equation correctly defines the enthalpy change of formation of a compound?

A $2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$
B $Na(s) + Cl(g) \longrightarrow NaCl(s)$
C $H_2O(l) + NaCl(s) \longrightarrow NaCl(aq)$
D $K(s) + Mn(s) + 2O_2(g) \longrightarrow KMnO_4(s)$

10. Which equation correctly defines the enthalpy change of formation of carbon monoxide?

A $C(g) + O(g) \longrightarrow CO(g)$
B $C(g) + \frac{1}{2}O_2(g) \longrightarrow CO(g)$
C $C(s) + \frac{1}{2}O_2(g) \longrightarrow CO(g)$
D $C(s) + CO_2(g) \longrightarrow 2CO(g)$

11. Which equation correctly defines the enthalpy change of atomisation of white phosphorus?

A $P(s) \rightarrow P(g)$ **B** $P_4(s) \rightarrow P_4(g)$ **C** $\frac{1}{4}P_4(s) \rightarrow P(g)$ **D** $P_4(s) \rightarrow 4P(g)$

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12. Which equation correctly defines the enthalpy change of atomisation of iodine?

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

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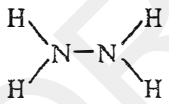
13. *Use of the Data Booklet is relevant to this question.*

Hydrazine (structure shown) was used as a fuel for the American Gemini and Apollo spacecraft.


hydrazine

What is the enthalpy change of atomisation of 1 mol of gaseous hydrazine?

A 550 kJ **B** 1720 kJ **C** 1970 kJ **D** 2554 kJ

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14. Which of the following gives the value of the enthalpy change for the process $Na(s) \rightarrow Na^+(g) + e^-$?

A the electron affinity of sodium.
B the enthalpy change of vaporisation of sodium.
C the sum of the enthalpy change of atomisation and the first ionisation energy of sodium.
D the sum of the enthalpy change of atomisation and the electron affinity of sodium.

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15. Which of the following is a **correct** statement about the standard enthalpy change of formation of carbon dioxide?

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.

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16. Which of the following reactions would have a $\Delta H^{\ominus}$ value that represents **both** a standard enthalpy change of combustion **and** a standard enthalpy change of formation?

1 $C(s) + O_2(g) \rightarrow CO_2(g)$
2 $2C(s) + O_2(g) \rightarrow 2CO(g)$
3 $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$

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17. Which ion is likely to have the most exothermic enthalpy change of hydration?

	ion	*charge on ion*	*ionic radius / nm*
A		–1	0.181
B		+1	0.169
C		+2	0.065
D		+2	0.135

18. Given that the enthalpy change for the neutralisation given below is –114 kJ,

$$2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

what is the most likely value for the enthalpy change in the following neutralisation?

$$Ba(OH)_2(aq) + 2HCl(aq) \longrightarrow BaCl_2(aq) + 2H_2O(l)$$

A –57 kJ mol^{-1} **B** –76 kJ mol^{-1} **C** –114 kJ mol^{-1} **D** –228 kJ mol^{-1}

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19. When 20 cm^3 of aqueous potassium hydroxide (containing 0.04 mol of KOH) is added to 20 cm^3 of a solution con ining 0.04 mol in a plastic cup of negligible heat capacity, the temperature s

Given that the heat capacity of the final solution is 4.2 J K^{-1} cm^{-3}, what is the enthalpy change of neutralisation of hydrochloric acid?

A $\frac{20 \times 4.2 \times 15}{0.04}$ J mol^{-1} **B** $40 \times 4.2 \times 15 \times 0.08$ J mol^{-1}

C $\frac{40 \times 4.2 \times 15}{0.04}$ J mol^{-1} **D** $\frac{20 \times 4.2 \times 15}{0.08}$ J mol^{-1}

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20. Which of the following are **correct** statements about the neutralisation of a strong acid by a strong alkali in aqueous solution at 25 °C?

1 It is an endothermic process.

2 It can be represented as $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$.

3 The enthalpy change per mole of H_2O formed is independent of the acid or alkali used.

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21. Which equation correctly defines the lattice energy of an ionic compound *XY*?

A $X(s) + Y(s) \rightarrow XY(s)$ **B** $X(g) + Y(g) \rightarrow XY(s)$

C $X^+(s) + Y^-(s) \rightarrow XY(s)$ **D** $X^+(g) + Y^-(g) \rightarrow XY(s)$

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22. For the hypothetical ionic compound MgH, which value is needed to estimate its lattice energy?

A the electron affinity of hydrogen

B the first ionisation energy of hydrogen

C the magnesium–hydrogen bond energy

D the standard enthalpy change of formation of MgH_2

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3. Calcium reacts with chlorine to form $CaCl_2$ rather than $CaCl$.

Which statement explains this observation?

A Less energy is required to remove one electron from the calcium atom than to remove two electrons.

B More energy is released in forming chloride ions from chlorine molecules in the formation of $CaCl_2(s)$ than in the formation of $CaCl(s)$.

C The lattice energy of $CaCl(s)$ is less exothermic than that of $CaCl_2(s)$.

D When $CaCl(s)$ is formed from its elements, more energy is released than when $CaCl_2(s)$ is fo from its elements.

24. The lattice energies of rubidium fluoride, RbF, and caesium chloride, CsC*l*, are:

RbF, -760 kJ mol^{-1}; CsC*l*, -650 kJ mol^{-1}

What is the lattice energy of caesium fluoride, CsF, likely to be?

A -620 kJ mol^{-1} **B** -720 kJ mol^{-1} **C** -800 kJ mol^{-1} **D** -900 kJ mol^{-1}

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25. Which compound is likely to have the greatest lattice energy (i.e. greatest magnitude, ignoring sign)?

A lithium fluoride **B** lithium iodide **C** rubidium chloride **D** sodium chloride

26. The radius and charge of six ions are given in the table below:

ion	M^{2+}	X^-	Y^-	Z^{2-}
radius / nm	0.15	0.14	0.18	0.15

Given that the ionic solids *JX*, *LY* and *MZ* are of the same lattice type, what is the order of their lattice energies (placing the most exothermic first)?

A *JX* > *MZ* > *LY* **B** *LY* > *MZ* > *JX* **C** *MZ* > *JX* > *LY* **D** *MZ* > *LY* > *JX*

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27. The lattice energy of calcium chloride is numerically greater than that of potassium bromide.

Which of the following help to explain this observation?

1 The radius of the chloride ion is smaller than that of the bromide ion.
2 The charge on the calcium ion is greater than that on the potassium ion.
3 Chlorine is more highly electronegative than bromine.

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28. The lattice energy of magnesium oxide is four to five times that of sodium fluoride although both compounds are isoelectronic (i.e. they have the same number of electrons).

Which of the following help to explain this observation?

1 the higher enthalpy change of hydration of the doubly charged cations
2 the higher electrostatic attraction between the doubly charged ions
3 the shorter internuclear distance between the doubly charged ions

29. The lattice energies of sodium fluoride, NaF, and magnesium oxide, MgO, are:

NaF, -915 kJ mol^{-1}; MgO, -3933 kJ mol^{-1}

Which of the following help to explain the difference between these two values?

1 The two ions in each compound are isoelectronic (have the same number of electrons).
2 The attraction between doubly charged ions is about four times that between singly charged ions.
3 The interionic distance in NaF is 0.102 nm and that in MgO is 0.074 nm.

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30. Which one of the following is an **endothermic** process?

A the condensation of steam **B** the electrolysis of water
C the freezing of water **D** $Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$

31. Which of the following processes are always endothermic?

1 the hydration of a gaseous cation
2 the dissociation of a diatomic molecule into atoms
3 the sublimation of a solid

32. Which of the following classes of reaction always give an endothermic enthalpy change?

1 atomisation 2 neutralisation 3 solution

33. From which equation can the bond energy of the C—F bond be determined by using **only** the standard enthalpy change of the reaction?

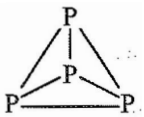
A $CF_4(g) \rightarrow C(g) + 4F(g)$
B $CF_4(g) \rightarrow CF_2(g) + F_2(g)$
C $CF_4(s) \rightarrow CF_4(g)$
D $2F_2(g) + C(s) \rightarrow CF_4(g)$

34. On heating, gaseous phosphorus pentachloride (PCl_5) is decomposed into gaseous phosphorus trichloride (PCl_3) and chlorine (Cl_2).

Given bond energy of P–Cl (in both chlorides) = 330 kJ mol^{-1}, and that of Cl–Cl = 240 kJ mol^{-1}, what is the enthalpy change in the thermal decomposition of PCl_5?

A –420 kJ mol^{-1} **B** –90 kJ mol^{-1} **C** +90 kJ mol^{-1} **D** +420 kJ mol^{-1}

35. Nitrogen exists as the molecule N≡N, phosphorus as the molecule shown below.



If nitrogen were to form a similar molecule N_4; i.e. $2N_2(g) \rightarrow N_4(g)$ what would be the value of ΔH for this reaction?

[Bond energies: N–N, 160 kJ mol^{-1}; N≡N, 994 kJ mol^{-1}]

A 1028 kJ mol^{-1} **B** 1348 kJ mol^{-1} **C** 1954 kJ mol^{-1} **D** 2628 kJ mol^{-1}

36. Nitrogen, being an unreactive gas, is frequently used as an inert atmosphere.

Which of the following gives the best explanation for its unreactivity?

A Its molecule contains a triple bond.
B The bond energy of the molecule is high (994 kJ mol^{-1}).
C The bond in its molecule is very short (0.110 nm).
D The three p orbitals of nitrogen are half-filled.

37. The gaseous oxides of nitrogen have positive enthalpy changes of formation.

Which of the following is likely to make the most significant contribution to these enthalpy changes?

A the high bond energy of the nitrogen molecule, N_2
B the high electron affinity of nitrogen atoms
C the high electron affinity of oxygen atoms
D the similarity of the electronegativities of oxygen and nitrogen