

1. What energy changes occur when chemical bonds are formed and broken?
- A. Energy is absorbed when bonds are formed and when they are broken.
 - B. Energy is released when bonds are formed and when they are broken.
 - C. Energy is absorbed when bonds are formed and released when they are broken.
 - D. Energy is released when bonds are formed and absorbed when they are broken.

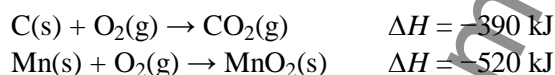
(1)

2. The temperature of a 2.0 g sample of aluminium increases from 25°C to 30°C. How many joules of heat energy were added? (Specific heat of Al = 0.90 J g⁻¹K⁻¹)

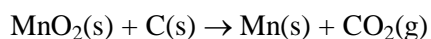
- A. 0.36
- B. 2.3
- C. 9.0
- D. 11

(1)

3. Using the equations below:



what is ΔH (in kJ) for the following reaction?



- A. 910
- B. 130
- C. -130
- D. -910

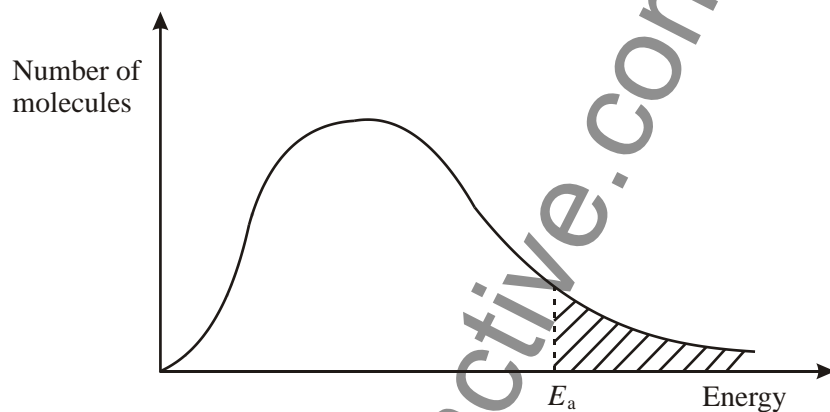
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4. Under what circumstances is a reaction spontaneous at all temperatures?

	ΔH^\ominus	ΔS^\ominus
A.	+	+
B.	+	-
C.	-	-
D.	-	+

(1)

5.



The diagram shows the distribution of energy for the molecules in a sample of gas at a given temperature, T_1 .

- (a) In the diagram E_a represents the *activation energy* for a reaction. Define this term.

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- (b) On the diagram above draw another curve to show the energy distribution for the same gas at a higher temperature. Label the curve T_2 .

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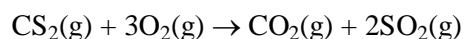
- (c) With reference to your diagram, state and explain what happens to the rate of a reaction when the temperature is increased.

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(2)

(Total 5 marks)

6. What is ΔH for the reaction below in kJ?



$[\Delta H_f / \text{kJ mol}^{-1}: \text{CS}_2(\text{g}) 110, \text{CO}_2(\text{g}) - 390, \text{SO}_2(\text{g}) - 290]$

- A. -570
- B. -790
- C. -860
- D. -1080

(1)

7. Which statements about exothermic reactions are correct?

- I. They have negative ΔH values.
- II. The products have a lower enthalpy than the reactants.
- III. The products are more energetically stable than the reactants.

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

(1)

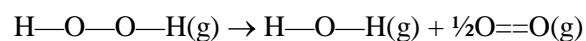
8. A sample of a metal is heated. Which of the following are needed to calculate the heat absorbed by the sample?

- I. The mass of the sample
- II. The density of the sample
- III. The specific heat capacity of the sample

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

(1)

9. The average bond enthalpies for O—O and O==O are 146 and 496 kJ mol⁻¹ respectively. What is the enthalpy change, in kJ, for the reaction below?



- A. - 102
B. + 102
C. + 350
D. + 394

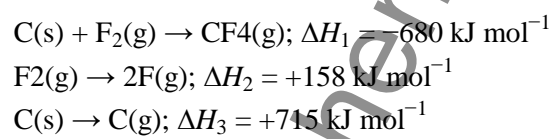
(1)

10. Which reaction has the greatest positive entropy change?

- A. $\text{CH}_4(\text{g}) + 1\frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g}) + 2\text{H}_2\text{O}(\text{g})$
B. $\text{CH}_4(\text{g}) + 1\frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
C. $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$
D. $\text{CH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$

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11. Given the following data:



calculate the average bond enthalpy (in kJ mol^{-1}) for the C—F bond.

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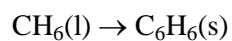
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(Total 4 marks)

12. For the process:



the standard entropy and enthalpy changes are:

$$\Delta H^\ominus = -9.83 \text{ kJ mol}^{-1} \text{ and } \Delta S^\ominus = -35.2 \text{ J K mol}^{-1}.$$

Predict and explain the effect of an increase in temperature on the spontaneity of the process.

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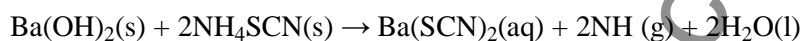
(Total 3 marks)

13. What is the energy change (in kJ) when the temperature of 20 g of water increases by 10°C?

- A. $20 \times 10 \times 4.18$
- B. $20 \times 283 \times 4.18$
- C. $\frac{20 \times 10 \times 4.18}{1000}$
- D. $\frac{20 \times 283 \times 4.18}{1000}$

(1)

14. When the solids $\text{Ba}(\text{OH})_2$ and NH_4SCN are mixed, a solution is produced and the temperature drops.

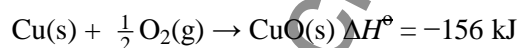


Which statement about the energetics of this reaction is correct?

- A. The reaction is endothermic and ΔH is negative.
- B. The reaction is endothermic and ΔH is positive.
- C. The reaction is exothermic and ΔH is negative.
- D. The reaction is exothermic and ΔH is positive.

(1)

15. Using the equations below



what is the value of ΔH° (in kJ) for the following reaction?



- A. 142
- B. 15
- C. -15
- D. -142

(1)

16. Which reaction occurs with the largest increase in entropy?

- A. $\text{Pb}(\text{NO}_3)_2(\text{s}) + 2\text{KI}(\text{s}) \rightarrow \text{PbI}_2(\text{s}) + 2\text{KNO}_3(\text{s})$
- B. $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- C. $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$
- D. $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g})$

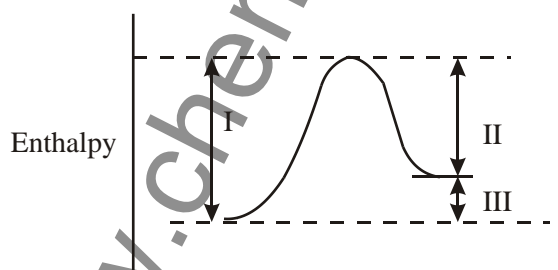
(1)

17. The ΔH° and ΔS° values for a certain reaction are both positive. Which statement is correct about the spontaneity of this reaction at different temperatures?

- A. It will be spontaneous at all temperatures.
- B. It will be spontaneous at high temperatures but not at low temperatures.
- C. It will be spontaneous at low temperatures but not at high temperatures.
- D. It will not be spontaneous at any temperature.

(1)

18. Which of the quantities in the enthalpy level diagram below is (are) affected by the use of a catalyst?

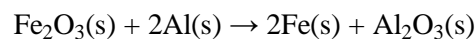


- A. I only
- B. III only
- C. I and II only
- D. II and III only

(1)

19. The standard enthalpy change of formation of $\text{Al}_2\text{O}_3(\text{s})$ is $-1669 \text{ kJ mol}^{-1}$ and the standard enthalpy change of formation of $\text{Fe}_2\text{O}_3(\text{s})$ is -822 kJ mol^{-1} .

- (i) Use these values to calculate ΔH^\ominus for the following reaction.



State whether the reaction is exothermic or endothermic.

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- (ii) Draw an enthalpy level diagram to represent this reaction. State the conditions under which standard enthalpy changes are measured.

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- (iii) Estimate, without doing a calculation, the magnitude of the entropy change for this reaction. Explain your answer.

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(3)

(Total 8 marks)

20. Explain in terms of ΔG^\ominus , why a reaction for which both ΔH^\ominus and ΔS^\ominus values are positive can sometimes be spontaneous and sometimes not.

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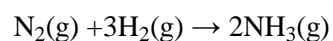
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(Total 4 marks)

21. Consider the following reaction.



- (i) Use values from Table 10 in the Data Booklet to calculate the enthalpy change, ΔH^\ominus , for this reaction.

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- (ii) The magnitude of the entropy change, ΔS , at 27 °C for the reaction is 62.7 J K⁻¹ mol⁻¹. State, with a reason, the sign of ΔS .

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- (iii) Calculate ΔG for the reaction at 27 °C and determine whether this reaction is spontaneous at this temperature.

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(3)

(Total 8 marks)

22. Explain in terms of ΔG^\ominus , why a reaction for which both ΔH^\ominus and ΔS^\ominus are positive is sometimes spontaneous and sometimes not.

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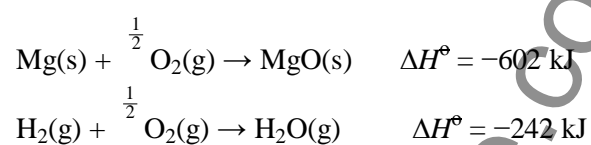
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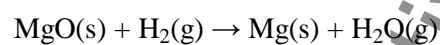
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(Total 4 marks)

23. Consider the following equations.



What is the ΔH° value (in kJ) for the following reaction?



- A. -844
- B. -360
- C. +360
- D. +844

(1)

24. For which of the following is the sign of the enthalpy change different from the other three?

- A. $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO(s)} + \text{CO}_2(\text{g})$
- B. $\text{Na(g)} \rightarrow \text{Na}^+(\text{g}) + \text{e}^-$
- C. $\text{CO}_2(\text{s}) \rightarrow \text{CO}_2(\text{g})$
- D. $2\text{Cl(g)} \rightarrow \text{Cl}_2(\text{g})$

(1)

25. Which reaction has a positive entropy change, ΔS^\ominus ?

- A. $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$
- B. $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$
- C. $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
- D. $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$

(1)

26. Separate solutions of $\text{HCl}(\text{aq})$ and $\text{H}_2\text{SO}_4(\text{aq})$ of the same concentration and same volume were completely neutralized by $\text{NaOH}(\text{aq})$. X kJ and Y kJ of heat were evolved respectively. Which statement is correct?

- A. $X = Y$
- B. $Y = 2X$
- C. $X = 2Y$
- D. $Y = 3X$

(1)

27. (a) Define the term *average bond enthalpy*, illustrating your answer with an equation for methane, CH_4 .

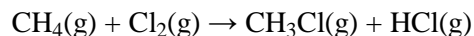
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(3)

- (b) The equation for the reaction between methane and chlorine is



Use the values from Table 10 of the Data Booklet to calculate the enthalpy change for this reaction.

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- (c) Explain why no reaction takes place between methane and chlorine at room temperature unless the reactants are sparked, exposed to UV light or heated.

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- (d) Draw an enthalpy level diagram for this reaction.

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(Total 10 marks)

28. The equation for the decomposition of calcium carbonate is given below.



At 500 K, ΔH for this reaction is $+177 \text{ kJ mol}^{-1}$ and ΔS is $161 \text{ J K}^{-1} \text{ mol}^{-1}$.

- (a) Explain why ΔH for the reaction above cannot be described as ΔH_f^\ominus .

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- (b) State the meaning of the term ΔS .

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- (c) Calculate the value of ΔG at 500 K and determine, giving a reason, whether or not the reaction will be spontaneous.

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(Total 6 marks)

29. Which statements are correct for an endothermic reaction?

- I. The system absorbs heat.
- II. The enthalpy change is positive.
- III. The bond enthalpy total for the reactants is greater than for the products.

- A. I and II only
- B. I and III only
- C. II and III only
- D. I, II and III

(1)

30. The mass m (in g) of a substance of specific heat capacity c (in $\text{J g}^{-1} \text{K}^{-1}$) increases by t °C . What is the heat change in J?

- A. mct (
B. $mc(t + 273)$
C. $\frac{mct}{1000}$
D. $\frac{mc(t + 273)}{1000}$

(1)

31. The average bond enthalpy for the C–H bond is 412 kJ mol^{-1} . Which process has an enthalpy change closest to this value?

- A. $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{s}) + 2\text{H}_2(\text{g})$
B. $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 2\text{H}_2(\text{g})$
C. $\text{CH}_4(\text{g}) \rightarrow \text{C}(\text{s}) + 4\text{H}(\text{g})$
D. $\text{CH}_4(\text{g}) \rightarrow \text{CH}_3(\text{g}) + \text{H}(\text{g})$

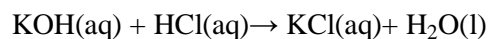
(1)

32. For a certain reaction at 298 K the values of both ΔH° and ΔS° are negative. Which statement about the sign of ΔG° for this reaction must be correct?

- A. It is negative at all temperatures.
B. It is positive at all temperatures.
C. It is negative at high temperatures and positive at low temperatures.
D. It cannot be determined without knowing the temperature.

(1)

33. In aqueous solution, potassium hydroxide and hydrochloric acid react as follows.



The data below is from an experiment to determine the enthalpy change of this reaction.

50.0 cm^3 of a $0.500 \text{ mol dm}^{-3}$ solution of KOH was mixed rapidly in a glass beaker with 50.0 cm^3 of a $0.500 \text{ mol dm}^{-3}$ solution of HCl.

Initial temperature of each solution = 19.6°C

Final temperature of the mixture = 23.1°C

- (a) State, with a reason, whether the reaction is exothermic or endothermic.

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- (b) Explain why the solutions were mixed rapidly.

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- (c) Calculate the enthalpy change of this reaction in kJ mol^{-1} . Assume that the specific heat capacity of the solution is the same as that of water.

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- (d) Identify the **major** source of error in the experimental procedure described above. Explain how it could be minimized.

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- (e) The experiment was repeated but with an HCl concentration of $0.510 \text{ mol dm}^{-3}$ instead of $0.500 \text{ mol dm}^{-3}$. State and explain what the temperature change would be.

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(Total 10 marks)

34. Some chlorine gas is placed in a flask of fixed volume at room temperature. Which change will cause a decrease in entropy?

- A. adding a small amount of hydrogen
- B. adding a small amount of chlorine
- C. cooling the flask
- D. exposing the flask to sunlight

(1)

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