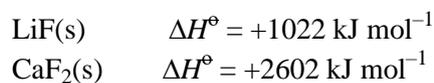**IB Chemistry HL**
Topic5 Questions

1. Which combination of ionic charge and ionic radius give the largest lattice enthalpy for an ionic compound?

	Ionic charge	**Ionic radius**
A.	high	large
B.	high	small
C.	low	small
D.	low	large

2. The lattice enthalpy values for lithium fluoride and calcium fluoride are shown below.

$$LiF(s) \qquad \Delta H^\ominus = +1022 \text{ kJ mol}^{-1}$$
$$CaF_2(s) \qquad \Delta H^\ominus = +2602 \text{ kJ mol}^{-1}$$

Which of the following statements help(s) to explain why the value for lithium fluoride is less than that for calcium fluoride?

I. The ionic radius of lithium is less than that of calcium.

II. The ionic charge of lithium is less than that of calcium.

A. I only

B. II only

C. I and II

D. Neither I nor II

3. Which reaction has the most negative $\Delta H^\ominus$ value?

A. $LiF(s) \rightarrow Li^+(g) + F^-(g)$

B. $Li^+(g) + F^-(g) \rightarrow LiF(s)$

C. $NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$

D. $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$

4. Which type of reaction is referred to in the definition of *standard enthalpy change of formation*?

A. the formation of a compound from its elements

B. the formation of a crystal from its ions

C. the formation of a molecule from its atoms

D.   the formation of a compound from other compounds

5.   What is the correct order of decreasing entropy for a pure substance?

A.   gas > liquid > solid

B.   solid > liquid > gas

C.   solid > gas > liquid

D.   liquid > solid > gas

6.   Which reaction has the largest positive value of $\Delta S^{\ominus}$?

A. $CO_2(g) + 3H_2(g) \rightarrow CH_3OH(g) + H_2O(g)$

B. $2Al(s) + 3S(s) \rightarrow Al_2S_3(s)$

C. $CH_4(g) + H_2O(g) \rightarrow 3H_2(g) + CO(g)$

D. $2S(s) + 3O_2(g) \rightarrow 2SO_3(g)$

7.   Which is a correct equation to represent the lattice enthalpy of magnesium sulfide?

A. $MgS(s) \rightarrow Mg(s) + S(s)$

B. $MgS(s) \rightarrow Mg(g) + S(g)$

C. $MgS(s) \rightarrow Mg^+(g) + S^-(g)$

D. $MgS(s) \rightarrow Mg^{2+}(g) + S^{2-}(g)$

8.   Which equation represents a change with a negative value for ΔS?

A. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

B. $H_2O(s) \rightarrow H_2O(g)$

C. $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

D. $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$

9.   The expression for the standard free energy change of a reaction is given by

$$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$$

What are the signs for $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for a reaction that is spontaneous at all temperatures?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
A.	+	−

B.	−	+
C.	+	+
D.	−	−

10. Which are characteristics of ions in an ionic compound with a large lattice enthalpy value?

    A.   Large ionic radius and high ionic charge

    B.   Small ionic radius and low ionic charge

    C.   Large ionic radius and low ionic charge

    D.   Small ionic radius and high ionic charge

11. The following reaction is spontaneous only at temperatures above 850°C.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Which combination is correct for this reaction at 1000°C?

	ΔG	ΔH	ΔS
A.	−	−	−
B.	+	+	+
C.	−	+	+
D.	+	−	−

12. Consider the following information.

Compound	$C_6H_6(l)$	$CO_2(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	+49	-394	−286

$$C_6H_6(l) + 7\tfrac{1}{2} O_2(g) \rightarrow 6CO_2(g) + H_2O(l)$$
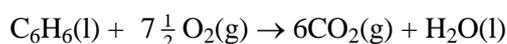
Which expression gives the correct value of the standard enthalpy change of combustion for benzene (l), in kJ mol^{-1}?

    A.   12(−394) + (−286) −2(49)

    B.   12(394) + 6(286) −2(−49)

    C.   6(−394) + 1(−286) − (+49)

    D.   6(394) + 3(286) − (−49)

13. Which equation represents the lattice enthalpy of magnesium oxide?

A. $Mg(s) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$

B. $Mg^{2+}(g) + O^{2-}(g) \rightarrow MgO(g)$

C. $Mg^{2+}(g) + \frac{1}{2}O_2(g) \rightarrow MgO(s)$

D. $Mg^{2+}(g) + O^{2-}(g) \rightarrow MgO(s)$

14. The $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ values for a reaction are both negative. What will happen to the spontaneity of this reaction as the temperature is increased?

   A. The reaction will become more spontaneous as the temperature is increased.

   B. The reaction will become less spontaneous as the temperature is increased.

   C. The reaction will remain spontaneous at all temperatures.

   D. The reaction will remain non-spontaneous at any temperature.

15. Which reaction has the most negative $\Delta H^{\ominus}$ value?

   A. $LiF(s) \rightarrow Li^+(g) + F^-(g)$

   B. $Li^+(g) + F^-(g) \rightarrow LiF(s)$

   C. $NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$

   D. $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$

16. Which equation represents the electron affinity of calcium?

   A. $Ca(g) \rightarrow Ca^+(g) + e^-$

   B. $Ca(g) \rightarrow Ca^-(g) + e^-$

   C. $Ca(g) + e^- \rightarrow Ca^-(g)$

   D. $Ca^+(g) + e^- \rightarrow Ca(g)$

17. Which reaction causes a decrease in the entropy of the system?

   A. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

   B. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

   C. $2C(s) + O_2(g) \rightarrow 2CO(g)$

   D. $2SO_3(g) \rightarrow 2SO_2(g) + O_2(g)$

18. What are the signs of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for a reaction that is non-spontaneous at low temperature but spontaneous at high temperature?

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
A.	−	−
B.	+	−
C.	−	+
D.	+	+

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

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

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

(a) Explain why ΔH for the reaction above cannot be described as $\Delta H_f^{\ominus}$.

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(2)

(b) State the meaning of the term ΔS.

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(1)

(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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(3)
(Total 6 marks)

20. The standard enthalpy change for the combustion of phenol, $C_6H_5OH(s)$, is –3050 kJ mol^{-1} at 298 K.

(a) Write an equation for the complete combustion of phenol.

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(1)

(b) The standard enthalpy changes of formation of carbon dioxide, $CO_2(g)$, and of water, $H_2O(l)$, are –394 kJ mol^{-1} and –286 kJ mol^{-1} respectively.

Calculate the standard enthalpy change of formation of phenol, $C_6H_5OH(s)$.

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(3)

(c) The standard entropy change of formation, $\Delta S^\ominus$, of phenol, $C_6H_5OH(s)$ at 298 K is –385 J K^{-1} mol^{-1}. Calculate the standard free energy change of formation, $\Delta G^\ominus$, of phenol at 298 K.

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(3)

(d) Determine whether the reaction is spontaneous at 298 K, and give a reason.

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(2)

(e) Predict the effect, if any, of an increase in temperature on the spontaneity of this reaction.

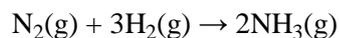..

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(Total 11 marks)

21. Explain in terms of $\Delta G^{\ominus}$, why a reaction for which both $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ are positive is sometimes spontaneous and sometimes not.

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(Total 4 marks)

22. Consider the following reaction.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

(i) Using the average bond enthalpy values in Table 10 of the Data Booklet, calculate the standard enthalpy change for this reaction.

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(ii) The absolute entropy values, S, at 300 K for $N_2(g)$, $H_2(g)$ and $NH_3(g)$ are 193, 131 and 192 JK^{-1} mol^{-1} respectively. Calculate $\Delta S^{\ominus}$ for the reaction and explain the sign of $\Delta S^{\ominus}$.

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(3)

(iii) Calculate $\Delta G^{\ominus}$ for the reaction at 300 K.

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(1)

(iv) If the ammonia was produced as a **liquid** and not as a gas, state and explain the effect this would have on the value of $\Delta H^{\ominus}$ for the reaction.

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(2)
(Total 10 marks)

23. Define the term *standard enthalpy of formation*, and write the equation for the standard enthalpy of formation of ethanol.

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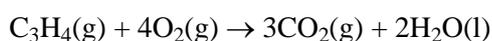……

(Total 5 marks)

24. Throughout this question, use relevant information from the Data Booklet.

(a) Define the term *standard enthalpy change of formation,* and illustrate your answer with an equation, including state symbols, for the formation of nitric acid.

(4)

(b) Propyne undergoes complete combustion as follows:

$$C_3H_4(g) + 4O_2(g) \rightarrow 3CO_2(g) + 2H_2O(l)$$

Calculate the enthalpy change of this reaction, given the following additional values:

$$\Delta H_f^{\ominus} \text{ of } CO_2(g) = -394 \text{ kJ mol}^{-1}$$

$$\Delta H_f^{\ominus} \text{ of } H_2O(l) = -286 \text{ kJ mol}^{-1}$$

(4)

(c) Predict and explain whether the value of $\Delta S^{\ominus}$ for the reaction in part (b) would be negative, close to zero, or positive.

(3)
(Total 11 marks)

`25. (a) Propyne reacts with hydrogen as follows:

$$C_3H_4(g) + 2H_2(g) \rightarrow C_3H_8(g) \qquad \Delta H^{\ominus} = -287 \text{ kJ}$$

Calculate the standard entropy change of this reaction, given the following additional information:

$$S^{\ominus} \text{ of } H_2(g) = 131 \text{ J K}^{-1} \text{ mol}^{-1}$$

(3)

(b) Calculate the standard free energy change at 298 K, $\Delta G^{\ominus}$, for the reaction in part (a). Use your answer and relevant information from part (d). If you did not obtain an answer to part (a), use $\Delta S^{\ominus} = -360 \text{ J K}^{-1}$ (this is not the correct value).

(3)
(Total 6 marks)

26. (a) The lattice enthalpy of an ionic compound can be calculated using a Born-Haber cycle. Using lithium fluoride as the example, construct a Born-Haber cycle, labelling the cycle with the formulas and state symbols of the species present at each stage.

(6)

(b) Two values of the lattice enthalpies for each of the silver halides are quoted in the Data Booklet. Discuss the bonding in silver fluoride and in silver iodide, with reference to these values.

(2)
(Total 8 marks)

27. Hex-1-ene gas, C_6H_{12}, burns in oxygen to produce carbon dioxide and water vapour.

(a) Write an equation to represent this reaction.

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(1)

(b) Use the data below to calculate the values of $\Delta H_c^{\ominus}$ and $\Delta S_c^{\ominus}$ for the combustion of hex-1-ene.

Substance	$O_2(g)$	$C_6H_{12}(g)$	$CO_2(g)$	$H_2O(g)$
Standard enthalpy of formation, $\Delta H_f^{\ominus}$ / kJ^{-1} mol	0.0	–43	–394	–242
Entropy, $S^{\ominus}$ / J K^{-1} mol^{-1}	205	385	214	189

(i) Value of $\Delta H_c^{\ominus}$

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(2)

(ii)   Value of $\Delta S_c^{\ominus}$

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(2)

(c)   Calculate the standard free energy change for the combustion of hex-1-ene.

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(2)

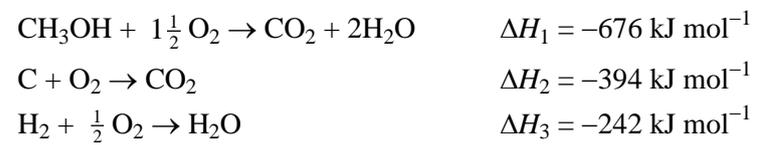(d)   State and explain whether or not the combustion of hex-1-ene is spontaneous at 25°C.

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(1)
(Total 8 marks)

28.   Calculate the enthalpy change, ΔH_4 for the reaction

$$C + 2H_2 + \tfrac{1}{2} O_2 \rightarrow CH_3OH \qquad \Delta H_4$$
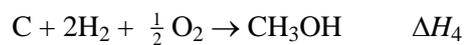
using Hess's Law, and the following information.

$$CH_3OH + 1\tfrac{1}{2} O_2 \rightarrow CO_2 + 2H_2O \qquad \Delta H_1 = -676 \text{ kJ mol}^{-1}$$
$$C + O_2 \rightarrow CO_2 \qquad \Delta H_2 = -394 \text{ kJ mol}^{-1}$$
$$H_2 + \tfrac{1}{2} O_2 \rightarrow H_2O \qquad \Delta H_3 = -242 \text{ kJ mol}^{-1}$$

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(Total 4 marks)

29. Methylamine can be manufactured by the following reaction.

$$CH_3OH(g) + NH_3(g) \rightarrow CH_3NH_2(g) + H_2O(g)$$
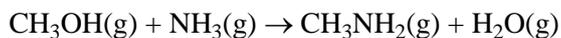
(a) Define the term *standard enthalpy change of formation*.

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(2)

(b) The values of standard enthalpy changes of formation for some compounds are shown in the table.

Compound	ΔH_f^{Θ} / kJ mol^{-1}
$NH_3(g)$	-46
$H_2O(g)$	-242

Predict, with a reason, whether the value of ΔH_f^{Θ} for $H_2O(l)$ is less than, greater than, or equal to, the value of ΔH_f^{Θ} for $H_2O(g)$.

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(2)

(c) Use information from the table in (b) and from Table 11 of the Data Booklet to calculate the enthalpy change for the reaction used to manufacture methylamine.
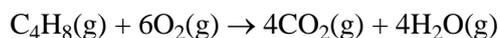
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(3)
(Total 7 marks)

30. **(a)** Define the term *standard enthalpy change of formation*, $\Delta H_f^{\ominus}$.

(2)

(b) **(i)** Use the information in the following table to calculate the enthalpy change for the complete combustion of but-1-ene according to the following equation.

$$C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$$

Compound	$C_4H_8(g)$	$CO_2(g)$	$H_2O(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	+ 1	− 394	− 242

(3)

(ii) Deduce, giving a reason, whether the reactants or the products are more stable.

(2)

(iii) Predict, giving a reason, how the enthalpy change for the complete combustion of but-2-ene would compare with that of but-1-ene based on average bond enthalpies.

(1)

(Total 8 marks)

31. **(i)** Define the term *standard enthalpy change of formation, $\Delta H_f^{\ominus}$.*

(2)

(ii) Construct a simple enthalpy cycle and calculate the value of $\Delta H_f^{\ominus}$ ($C_2H_5OH(l)$) given the following data.

Compound	$\Delta H_f^{\ominus}$ / kJ mol^{-1}	$\Delta H^{\ominus}_{comb}$/ kJ mol^{-1}
$H_2O(l)$	−286	
$CO_2(g)$	−394	
$C_2H_5OH(l)$		−1371

(5)

(Total 7 marks)

32. Consider the following reaction:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$
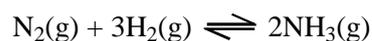
(i) Suggest why this reaction is important for humanity.

(1)

(ii) Using the average bond enthalpy values in Table 10 of the Data Booklet, calculate the standard enthalpy change for this reaction.

(4)

(iii) The absolute entropy values, S, at 238 K for $N_2(g)$, $H_2(g)$ and $NH_3(g)$ are 192, 131 and

193 J K^{-1} mol^{-1} respectively. Calculate $\Delta S^\ominus$ for the reaction and explain the sign of $\Delta S^\ominus$.

(2)

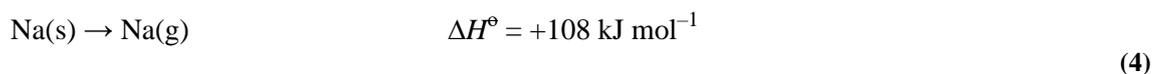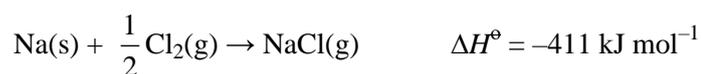(iv) Calculate $\Delta G^\ominus$ for the reaction at 238 K. State and explain whether the reaction is spontaneous.

(3)

(v) If ammonia was produced as a liquid and not as a gas, state and explain the effect this would have on the value of $\Delta H^\ominus$ for the reaction.

(2)

(Total 12 marks)

33. (i) Define the terms *lattice enthalpy* and *electron affinity*.

(2)

(ii) Use the data in the following table and from the data booklet to construct the Born-Haber cycle for sodium chloride, NaCl, and determine the lattice enthalpy of NaCl(s).

$$Na(s) + \frac{1}{2}Cl_2(g) \rightarrow NaCl(g) \qquad \Delta H^\ominus = -411 \text{ kJ mol}^{-1}$$

$$Na(s) \rightarrow Na(g) \qquad \Delta H^\ominus = +108 \text{ kJ mol}^{-1}$$

(4)

(iii) Describe the structure of sodium chloride.

(2)

(Total 8 marks)