



**IB Chemistry HL**  
**Topic 5 Answers**

1. B

2. B

3. B

4. A

5. A

6. C

7. D

8. A

9. B

10. D

11. C

12. C

13. D

14. B

15. B

16. C

17. B

18. D

19. (a) (cannot be  $\ominus$  as) conditions are not standard/at 500 K/*OWTTE*;  
(cannot be f as) not formation from elements/is decomposition/*OWTTE*; 2

(b) change in entropy/degree of (dis)order (of system); 1

(c)  $\Delta G = 177000 - (500 \times 161) = +96500$ ;  
reaction is not spontaneous;  
 $\Delta G$  is positive; 3

*Allow ECF from calculation for last two marks.*

[6]

20. (a)  $\text{C}_6\text{H}_5\text{OH} + 7\text{O}_2 \rightarrow 6\text{CO}_2 + 3\text{H}_2\text{O}$ ; 1  
*Ignore state symbols.*

(b)  $\Delta H_r^\ominus = \Sigma \Delta H_f^\ominus \text{ products} - \Sigma \Delta H_f^\ominus \text{ reactants}$ ;



$$-3050 = (6(-394) + 3(-286) - (\Delta H_f^\ominus \text{ phenol} + \text{O}));$$

$$\Delta H_f^\ominus \text{ phenol} = -172 \text{ kJ mol}^{-1};$$

*Award [3] for correct final answer.*

*Apply -1 (U) if appropriate.*

*Award [2 max] for  $\Delta H_f^\ominus \text{ phenol} = +172 \text{ kJ mol}^{-1}$ .*

3

- (c) appropriate conversion of units;

$$\Delta G = -172 - 298(-0.385)$$

$$= -57.3 \text{ kJ mol}^{-1} / -57\,300 \text{ J mol}^{-1};$$

*Award [3] for correct final answer.*

*Accept answers in range  $-57.0$  to  $-57.3 \text{ kJ mol}^{-1}$ .*

*Accept 3 sig. fig. only.*

*Allow ECF from (b).*

*Apply -1 (U) if appropriate.*

3

- (d) spontaneous;

since  $\Delta G$  is negative;

*Allow ECF from (c).*

2

- (e) reaction becomes less spontaneous;

$\Delta G$  becomes less negative/more positive;

*Accept a suitable calculation.*

*Allow ECF from (c).*

2

[11]

21. a reaction is spontaneous when  $\Delta G^\ominus$  is negative;

at high T,  $\Delta G^\ominus$  is negative;

$-\text{T}\Delta S^\ominus$  is larger/greater than  $\Delta H^\ominus$ ;

at low T,  $\Delta G^\ominus$  is positive because  $-\text{T}\Delta S^\ominus$  is smaller than  $\Delta H^\ominus$ /OWTTE;

4

[4]

22. (i)  $\Delta H = (\text{sum of energies of bonds broken}) - (\text{sum of energies of bonds formed});$   
*Can be implied by working.*

Correct substitution of values and numbers of bonds broken;

Correct substitution of values and numbers of bonds made;

$$(\Delta H = (\text{N}\equiv\text{N}) + 3(\text{H}-\text{H}) - 6(\text{N}-\text{H}) = 944 + 3(436) - 6(388) = -76 \text{ (kJ)});$$

4

*Allow ECF.*

*Do not penalize for SF or units.*

- (ii)  $\Delta S^\ominus = (\text{sum of entropies of products}) - (\text{sum of entropies of reactants});$   
*Can be implied by working.*

3

$$(\Delta S^\ominus = 2 \times 192 - (193 + 3 \times 131) = -202 \text{ (J K}^{-1} \text{ mol}^{-1});$$

four molecules make two molecules/fewer molecules of gas;

- (iii)  $(\Delta G^\ominus = \Delta H^\ominus - \text{T}\Delta S^\ominus = -76.0 - 300(-0.202)) = -15.4 \text{ (kJ mol}^{-1});$   
*Do not penalize for SF.*

1

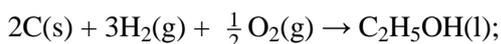


- (iv)  $\Delta H^\ominus$  becomes more negative;  
heat released when gas  $\rightarrow$  liquid;

2

[10]

23. enthalpy change associated with the formation of one mole of a compound/substance; from its elements;  
in their standard states/under standard conditions;

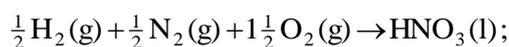


5

*Award [1] for formulas and coefficients, [1] for state symbols.*

[5]

24. (a) the enthalpy/energy/heat change for the formation of one mole of a compound/substance from its elements;  
in their standard states/under standard conditions/at 298 K and 1 atm;



4

*Award [1] for correctly balanced equation, [1] for all state symbols correct.*

*Do not award equation mark if  $2\text{HNO}_3$  formed.*

- (b)  $\Delta H_r = \sum \Delta H_f^\ominus$  (products)  $- \sum \Delta H_f^\ominus$  (reactants)/suitable cycle;

$$= 3(-394) + 2(-286) - 185;$$

*Award [1] for correct coefficients of  $\text{CO}_2$  and  $\text{H}_2\text{O}$  values, [1] for correct value for  $\text{C}_3\text{H}_4$  from Data Booklet.*

$$= -1939 \text{ or } -1940 \text{ kJ};$$

4

*Ignore units.*

*Award [4] for correct final answer.*

*Award [3] for +1939 or -1569.*

- (c) negative;  
decrease in disorder/increase in order;  
5 mol of gas  $\rightarrow$  3 mol of gas/reduction in number of gas moles;

3

*Award [1] for answer of close to zero based on use of  $\text{H}_2\text{O(g)}$ .*

[11]

25. (a)  $\Delta S = \sum S^\ominus$  (products)  $- \sum S^\ominus$  (reactants)/suitable cycle;

$$= 270 - 248 - 2 \times 131;$$

$$= -240 \text{ (J K}^{-1}\text{)};$$

3

*Units not needed for mark, but penalize incorrect units.*

*Award [3] for correct final answer.*

- (b)  $\Delta G^\ominus = -287 - (298 \times -0.240);$



Award [1] for correct substitution of values and [1] for conversion of units.

= -215 kJ;

3

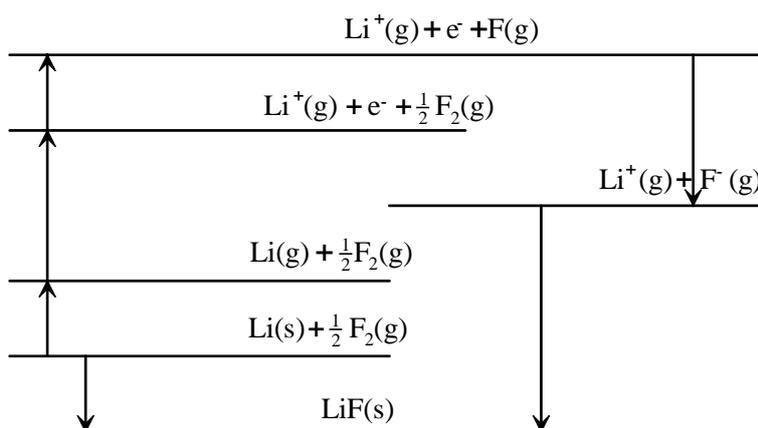
Units needed for mark.

Apply ECF from -360 kJ or incorrect answer from (a).

[6]

26. (a)

6



Award [6] for completely correct cycle, with endothermic processes in any order.

Deduct [1] for each line in which species symbol and/or state symbol is incorrect or missing.

Penalize missing electrons once only.

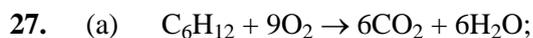
- (b) bonding in AgF more ionic than in AgI/bonding in AgI more covalent than in AgF;

Accept AgF is ionic and AgI is covalent.

values closer/in better agreement in AgF/big(ger) difference in values for AgI/OWTTE;

2

[8]



1

(b) (i)  $(\Delta H^\ominus = \sum \Delta H_f^\ominus \text{ products} - \sum \Delta H_f^\ominus \text{ reactants})$

$\Delta H^\ominus = (6 \times -394 + 6 \times -242) - (-43)$ ;

$\Delta H_c^\ominus = -3773 / -3.8 \times 10^3 \text{ (kJ mol}^{-1}\text{)}$ ;

2

Accept 2, 3 or 4 sig. fig..

Award [1] for + 3773/+  $3.8 \times 10^3 \text{ (kJ mol}^{-1}\text{)}$ .

Allow ECF from (a) only if coefficients used.

(ii)  $\Delta S^\ominus = (S_p^\ominus - S_r^\ominus) = (6 \times 189 + 6 \times 214) - (385 + 9 \times 205)$ ;

$\Delta S^\ominus = 188 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$ ;

2

Accept only 3 sig. fig..



Award [1] for -188.

Allow ECF from (a) only if coefficients used.

(c)  $(\Delta G_c^\ominus = \Delta H_c^\ominus - T\Delta S_c^\ominus) = -3800 - (298 \times 0.188);$

$= -3900 \text{ kJ mol}^{-1}.$

2

Accept -3800 to -3900.

Accept 2, 3 or 4 sig. fig.

Allow ECF from (b).

Units needed for second mark.

(d) spontaneous and  $\Delta G^\ominus$  negative;

1

Allow ECF from (c).

[8]

28.  $-1 \times \Delta H_1 / 676;$

$1 \times \Delta H_2 / -394;$

$2 \times \Delta H_3 / -484;$

$\Delta H_4 = -202 \text{ (kJ mol}^{-1}\text{);}$

4

Accept alternative methods.

Correct answers score [4].

Award [3] for (+)202 or (+)40 (kJ/kJ mol<sup>-1</sup>).

[4]

29. (a) enthalpy/energy change for the formation of 1 mol of a compound from its elements;

*Do not accept heat needed to form 1 mol...*

in their standard states/under standard conditions/at 298 K and 1 atm;

2

(b) greater value/more negative value;

energy given out when steam condenses/turns to water;

2

(c)  $\Delta H^\ominus = \sum \Delta H_f^\ominus \text{ (products)} - \sum \Delta H_f^\ominus \text{ (reactants) / suitable cycle};$

$= (-28 - 242) - (-201 - 46);$

$= -23 \text{ kJ/kJ mol}^{-1};$

3

Units needed for 3rd mark.

Correct final answer scores [3].

23 or +23 kJ/kJ mol<sup>-1</sup> scores [2].

If -239 used instead of -201 for CH<sub>3</sub>OH, award [2] for +15 kJ.

[7]

30. (a) the enthalpy change when one mole of compound is formed from its elements in their (standard state);

at (standard conditions of) 298 K/25°C and 101 325 Pa/1 atm;

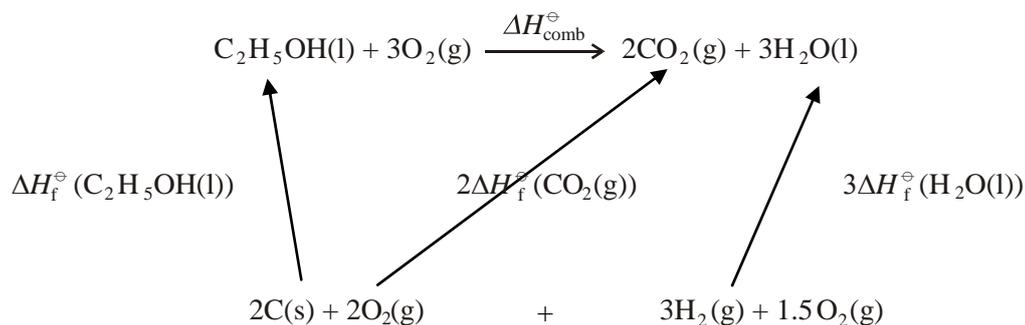
2



- (b) (i)  $\Delta H_p = (4 \times -242 + 4 \times -394) \text{ kJ mol}^{-1}$ ;  
 $\Delta H_R = 1 \text{ kJ mol}^{-1}$ ;  
 $\Delta H^\ominus = (\sum \Delta H_p^\ominus - \sum \Delta H_R^\ominus) = -2545 / -2.55 \times 10^3 / -2550 \text{ (kJ mol}^{-1}\text{)}$ ; 3  
*Allow ECF.*
- (ii) products more stable than reactants;  
 bonds are stronger in products than reactants/ $H_p < H_R$ /enthalpy/stored  
 energy of products less than reactants; 2
- (iii) same/equal, because the same bonds are being broken and formed; 1

[8]

31. (i) change in energy for the formation of (1 mol) of a substance from its  
 elements; under standard conditions/1 atm pressure or 101 kPa and  
 298 K/25°C; 2
- (ii)



*States not required.*

*Correct cycle showing:*

$$\Delta H_{\text{comb}}^\ominus$$

$$\Delta H_f^\ominus(\text{C}_2\text{H}_5\text{OH(l)});$$

$$2\Delta H_f^\ominus(\text{CO}_2\text{(g)}) \text{ and } 3\Delta H_f^\ominus(\text{H}_2\text{O(l)});$$

$$(\Delta H_f^\ominus(\text{C}_2\text{H}_5\text{OH(l)}) = (2\Delta H_f^\ominus(\text{CO}_2\text{(g)}) + 3\Delta H_f^\ominus(\text{H}_2\text{O(l)}) - \Delta H_{\text{comb}}^\ominus)$$

$$= 2(-394) + 3(-286) + 1371;$$

$$= -275 \text{ kJ mol}^{-1};$$

5

*If values are substituted for symbols in the enthalpy cycle diagram to give correct answer, award last [2] marks.*

*If no enthalpy cycle drawn but equation written and Hess's Law applied or calculated as follows, then [3 max]*

$$(\Delta H_f = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants}))$$

$$-1371 = (-394 \times 2) + (-286 \times 3) - \Delta H_f(\text{ethanol});$$

$$\Delta H_f(\text{ethanol}) = -788 - 858 + 1371;$$

$$= -275 \text{ (kJ mol}^{-1}\text{)};$$



*Award [2] for correct answer without enthalpy cycle and without working and [1] for 275 or + 275.*

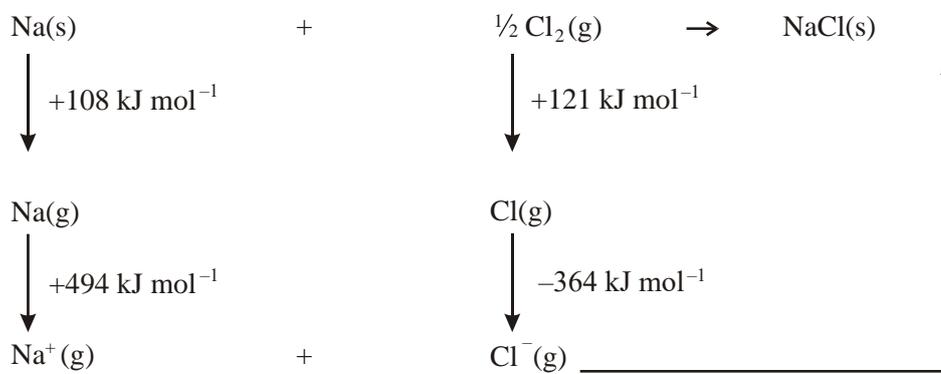
[7]

32. (i) fertilizers/increasing crop yields;  
production of explosives for mining;  
max 1
- (ii)  $\Delta H = (\text{sum of energies of bonds broken}) - (\text{sum of energies of bonds formed})$ ;  
*Can be implied by working.*
- correct substitution of values and numbers of bonds broken;  
correct substitution of values and numbers of bonds made;  
 $(\Delta H = (\text{N}\equiv\text{N}) + 3(\text{H}-\text{H}) - 6(\text{N}-\text{H}) = 944 + 3(436) - 6(388) = -76.0 \text{ (kJ)})$ ; 4  
*Allow ECF.*  
*Do not penalize for sig. fig. or units.*  
*Award [4] for correct final answer.*
- (iii)  $(\Delta S^\circ [2 \times 193] - [192 + 3 \times 131]) = -199 \text{ (J K}^{-1} \text{ mol}^{-1})$ ; 2  
*Allow ECF.*  
*four gaseous molecules generating two gaseous molecules/fewer molecules of gas;*
- (iv)  $(\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = -76.0 - 298(-0.199)) = -16.7 \text{ (kJ)}$ ;  
Spontaneous;  
 $\Delta G$  is negative; 3  
*Do not penalize for SF.*
- (v) heat released when gas  $\rightarrow$  liquid;  
 $\Delta H^\circ$  becomes more negative; 2
- [12]
33. (i) lattice enthalpy for a particular ionic compound is defined as  $\Delta H$  for the  
process,  $\text{MX(s)} \rightarrow \text{M}^+(\text{g}) + \text{X}^-(\text{g})$ ;  
*Accept definition for exothermic process*
- electron affinity is the energy change that occurs when an electron is added  
to a gaseous atom or ion; 2



(ii)

$$\Delta H_f^\ominus = -411 \text{ kJ mol}^{-1}$$



$$\text{lattice enthalpy} = -[(-411) - (+108) - (+494) - (+121) - (-364)]$$

$$= 770 \text{ (kJ mol}^{-1}\text{)}$$

*Award [2] for all correct formulas in correct positions on cycle diagram.*

*1 incorrect or missing label award [1].*

*Award [1] for all correct values in correct positions on cycle diagram.*

calculation of lattice enthalpy of NaCl(s) = 770 (kJ mol<sup>-1</sup>);

4

*Allow ECF.*

*Accept alternative method e.g. energy level diagram.*

(iii) lattice/network/regular structure;

each chloride ion is surrounded by six sodium ions and each sodium ion is surrounded by six chloride ions/6:6 coordination;

2

[8]