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CHEMISTRY

PHYSICAL CHEMISTRY

Level & Board

CIE (A-LEVEL)

TOPIC:

CHEMICAL ENERGETICS

PAPER TYPE:

SOLUTION - 1

TOTAL QUESTIONS

15

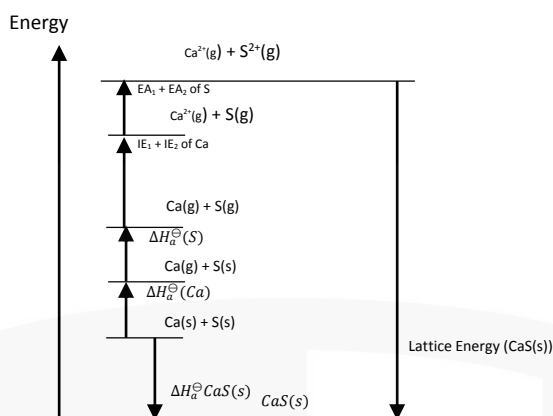
TOTAL MARKS

148

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1)

(a)

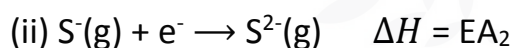


(b) $-487 = 178 + 279 + (590 + 1150) + 337 + \text{Lattice energy}$

$\Rightarrow \text{Lattice energy} = -3021 \text{ KJ mol}^{-1}$

(c) (i) $EA_1 + EA_2 = 337$

$$\begin{aligned} EA_2 &= 337 - EA_1 \\ &= 337 - (-200) \\ &= +537 \text{ KJ mol}^{-1} \end{aligned}$$



EA_2 involves the addition of a negatively charged electron to a negatively charged anion. The like charges repel and this makes the process difficult to take place.

Hence, the process is endothermic, unlike EA_1 .

(d) $|\text{Lattice energy}| = \left| \frac{q_+ q_-}{r_+ + r_-} \right|$

Since O^{2-} is smaller than S^{2-} , the lattice energy of CaO would be more exothermic than that of CaS.

2)

(a) Lattice energy is the energy released when 1 mole of an ionic compound is formed from its constituent gaseous ions.



$$(c) \Delta H_f(\text{MgO}) = \Delta H_{\text{atom}}(\text{Mg}) + \text{IE}_1(\text{Mg}) + \text{IE}_2(\text{Mg}) + \frac{1}{2}\text{BE}(\text{O}_2) + \text{EA}_2(\text{O}) + \text{L.E.}$$

$$= -602 = 148 + 736 + 1450 + \frac{1}{2}(946) - 140 + 798 + \text{L.E.}$$

$$\text{L.E} = -3842 \text{ KJ mol}^{-1}$$

(d) Lattice energy of CaO is less exothermic than that of MgO because Ca^{2+} is larger than Mg^{2+} .

$$|L.E| \propto \left| \frac{q_+q_-}{r_+ + r_-} \right|$$

When the interionic distance is bigger, the ionic bond is weaker and the magnitude of

Lattice energy is smaller.

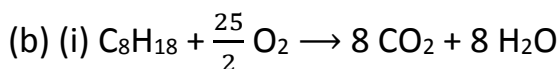
(e) Due to their relatively high magnitude of lattice energy, Group II oxides have high melting

points due to strong ionic bond.

MgO is used in furnace lining.

3)

(a) The bond energy is the average energy required to break 1 mole of a covalent bond.



$$\begin{aligned} \text{(ii) } \Delta H_c &= \left[18 + BE(C-H) + (C-C) + \frac{25}{2} BE(O=O) \right] \\ &= [8 \times 2BE(C=O) + 9 \times 2BE(O-H)] \\ &= \left(18 \times 410 + 7 \times 350 + \frac{25}{2} \times 486 \right) - (16 \times 740 + 18 \times 460) \\ &= -4090 \text{ KJ mol}^{-1} \end{aligned}$$

(c) (i) The bond energies used are only average values.

(ii) ΔH associated with the combustion of a CH_2 unit.

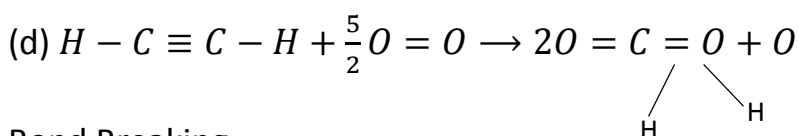
(d) Ethanol: $n = \frac{790}{2 \times 12 + 6 \times 1 + 16} = 17.17 \text{ mol}$

$$\begin{aligned} \text{Heat produced} &= n \times \Delta H_c^\ominus \\ &= 17.17 \times 1367 = 2.35 \times 10^4 \text{ KJ} \end{aligned}$$

Octanol: $n = \frac{700}{8 \times 12 + 18 \times 1 + 16} = 5.385 \text{ mol}$

$$\begin{aligned} \text{Heat produced} &= n \times \Delta H_c^\ominus \\ &= 5.385 \times 5470 = 2.95 \times 10^4 \text{ KJ} \end{aligned}$$

4)



Bond Breaking

Bond Energy of $2 \times C-H = 2 \times 410$

$$\text{Bond Energy of } \text{C} \equiv \text{C} = \frac{5}{2} \times 496$$

$$\text{Total} = 2900 \text{ KJ mol}^{-1}$$

Bond Making

$$\text{Bond Energy of } 4 \times \text{O} = \text{O} = 4 \times 740$$

$$= 2980$$

$$\text{Bond Energy of } 2 \times \text{O} - \text{H} = 2 \times 480$$

$$= 920$$

$$\text{Total} = 3880 \text{ KJ mol}^{-1}$$

$$\Delta H_c = \text{Bond Braking} - \text{Bond Making}$$

$$= 2900 - 3880 = -980 \text{ KJ mol}^{-1}$$

- (e) (i) It is the enthalpy change when one mole of a compound is completely burnt in oxygen at standard conditions of temperature and pressure (298 K and 1 atm.)
- (ii) Calculations in (d) includes water in gaseous form while ΔH_c involves water in liquid form to gaseous state.

5)

- (c) (i) Lattice energy is the heat evolved when one mole of an ionic compound is formed from its gaseous ion (at 298 K, 1 atm).
- (ii) Lattice energy of MgSO_4 is greater as compared to BaSO_4 because of larger ionic radius

Radius of Ba²⁺ ions as compared to Mg²⁺ ions.

$$\text{Lattice Energy} \propto \frac{q^+q^-}{r^++r^-}$$

6)

(c) (i) As the molecular size increase from HCl to HI, the number of electrons per molecule

Increase and the strength of VDW forces between the molecules increases.

Hence, the

Boiling point increases.

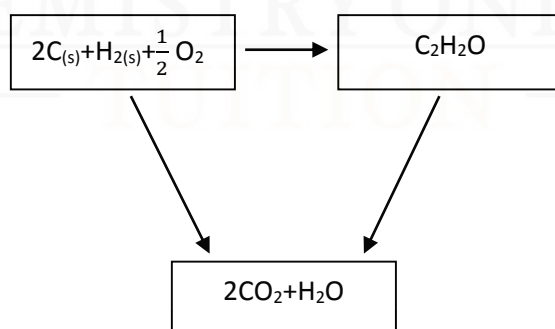
(ii) There is strong intermolecular hydrogen bond between HF molecules.

7)

(c) (i) Enthalpy change when 1 mol of a compound is formed from its constituent elements in

In their standard states under standard conditions.

(ii)



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$$\text{Applying Hess' law } \Delta H_A^\ominus = \Delta H_{B_1}^\ominus + \Delta H_{B_1}^\ominus$$

$$\Delta H_{B_1}^\ominus = \Delta H_A^\ominus - \Delta H_{B_1}^\ominus$$

$$= 2(-395) + (-286) - (-1028) = -49 \text{ KJ mol}^{-1}$$

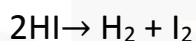
(d) H₂O (g) (steam)

8)

(a) The energy required to break one mole of bonds in the gas phase.

(b) With HCl to change with HI purple forces of iodine are produced.

H— C/bond being strong does not break whereas H— I bond being weaker breaks into its Element.



(c) Bonds broken – Bonds formed = -328

$$\Rightarrow 3\text{BE (F-F)} + \text{BE(Cl-Cl)} - 6\text{BE(Cl-F)} = -328$$

$$(3 \times 158) + 244 - 6 \text{ BE (Cl-F)} = -328$$

$$718 - 6\text{BE(Cl-F)} = -328$$

$$6 \text{ BE (Cl-F)} = 1046$$

$$\text{BE (Cl-F)} = 174.3 = 174$$

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9)

(a) Bonds broken	Bonds formed
4 C – H	5 C – H
1 C = C	1 C – F
1 HF	1 C – C

Let bond energy of C – F bond be x.

$$\therefore \text{Energy required to break bonds} = (4 \times 410) + (1 \times 610) + (1 \times 562) = 2812$$

$$\text{Energy required to form bonds} = (5 \times 410) + (1 \times x) + (1 \times 350) = 2400 + x$$

$$\Delta H_{\text{reaction}}^{\ominus} = 2812 - (2400 + x)$$

$$-73 = 2812 - 2400 - x$$

$$x = 2812 - 2400 + 73$$

$$= 485 \text{ KJ mol}^{-1}$$

(b) 1. They are non – flammable.

2. They are non – toxic.

(c) CCl₂F₂ contains C – Cl bonds which have a bond energy of 340 KJ mol.

From part (a), the

Bond energy of C – F bond is 485 KJ/mol. Hence, C – F bond, having a bond energy of 410

KJ/mol, is also stronger than the C – Cl bond.

Therefore C – Cl bonds are broken by uv light, producing Cl[•] free radicals, which are responsible for damaging the ozone.

(d) (i) The term *enhanced greenhouse effect* refers to the trapping of reflected heat from the Earth in the lower atmosphere, which contributes to global warming.

(ii) Carbon dioxide.

(e) Octahedral

10)

(a) The overall enthalpy change for a reaction is independent of the number of steps that are

Involved in the reaction, provided that the initial and final conditions are kept the same.

(b) (i) $\text{K}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{KCl} + \text{H}_2\text{O} + \text{CO}_2$

(ii) $V_{\text{HCl}} = 30.0 \text{ cm}^3$

\therefore Heat produced, $Q = mc\Delta T$

$$= 30 \times 4.18 \times (26.2 - 21)$$

$$= 652.08 \text{ J per } 0.0200 \text{ moles of } \text{K}_2\text{CO}_3$$

(iii) Heat produced by 0.02 moles of $\text{K}_2\text{CO}_3 = 652.08 \text{ J}$

$$\text{heat produced by } 1 \text{ mol of } \text{K}_2\text{CO}_3 = \frac{652.08}{0.02}$$

$$= 32604 \text{ J} \approx 32.60 \text{ KJ}$$

\therefore enthalpy change per mole of $\text{K}_2\text{CO}_3 = -32.60 \text{ KJ/mol}$

(iv) This is done to ensure that all of the K_2CO_3 is completely neutralized.

(c) (i) $\text{KHCO}_3 + \text{HCl} \rightarrow \text{KCl} + \text{H}_2\text{O} + \text{CO}_2$

(ii) $V_{\text{HCl}} = 30.0 \text{ cm}^3$

∴ Heat absorbed, $Q = mc \Delta T$

$$= 30 \times 4.18 \times (21 - 17.3)$$

$$= 30 \times 4.18 \times 3.7$$

$$= 463.98 \text{ J per } 0.0200 \text{ moles of } \text{KHCO}_3$$

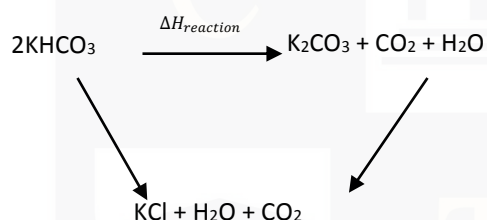
(iii) 0.02 moles of KHCO_3 cause the absorption of 463.98 J of heat

$$\therefore \text{Heat absorbed per mole of } \text{KHCO}_3 = \frac{1}{0.02} \times 463.98$$

$$= 463.98 \text{ J per } 0.0200 \text{ moles of } \text{KHCO}_3$$

Enthalpy change per mole of $\text{KHCO}_3 = + 23.20 \text{ KJ mol}^{-1}$

(d)



Using Hess's law, $\Delta H_{\text{reaction}} + \Delta H_B = \Delta H_A$

$$\Rightarrow \Delta H_{\text{reaction}} = \Delta H_A - \Delta H_B$$

$$= (2 \times +23.20) - (-32.60)$$

$$= 46.40 + 32.60 = + 79.00 \text{ KJ/mol}$$

11)

(a) (i) By shining UV light on the gaseous mixture of hydrogen and chlorine.

(ii) White misty fumes would be produced and reddish brown colour of bromine would disappear.

(iii) $X = \text{Cl}$:

Bond energies, $\text{H} - \text{H} = 436$, $\text{Br} - \text{Br} = 193$, $\text{H} - \text{Br} = 366$

$$\Delta H^\ominus = (436 + 244) - (431 \times 2)$$

$$= 103 \text{ KJ/mol}$$

(iv) $\text{H} - \text{Cl}$ bond is stronger than $\text{H} - \text{Br}$ bond.

(b) (i) Ultraviolet light

(ii) Bond energies: C – H = 410, 1 – 1 = 151, H– 1 = 299, C – 1 = 240

energy gained for breaking bonds = $(410 \times 4) + 151 = 1791 \text{ J}$

energy lost in forming bonds = $(410 \times 3) = 240 + 299 = 1769 \text{ J}$

$$\Delta H^{\ominus} = 1791 - 1769 = + 22 \text{ KJ/mol}$$

(iii) $\text{CH}_3 \text{I}$ cannot be made as the overall reaction is endothermic.

(c) (i) Homolytic fission is the breaking of a bond to form two radicals.

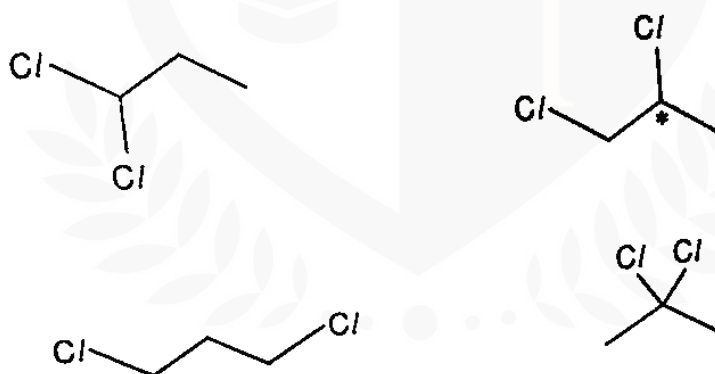
(ii) CH_2Cl .

C – Br bond with Bond energy of 280 KJ/mol is the weakest bond as compared to C – C

And C – Cl bonds with bond energies of 410 KJ/mol and 340 KJ/mol respectively. Hence

C – Br bond will break most easily.

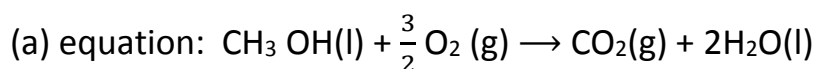
(d)



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12)

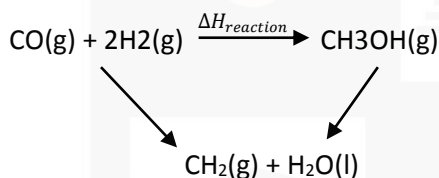


Definition: Standard enthalpy change of combustion of a substance is the heat evolved

When 1 mole of a substance, at its standard state, is completely burned in oxygen under

Standard state, is completely burned in oxygen under standard conditions of 1 atm and 298 K.

(b)



$$\Delta H_{\text{reaction}} + (-726) = (-283) + (-286 \times 2)$$

$$\Delta H_{\text{reaction}} = -283 - 572 + 726$$

$$= 129 \text{ KJ/mol}$$

(c) **Pressure:** increasing the pressure will increase the rate of formation of methanol due to the

Fact that the frequency of collisions will increase, thereby leading to more fruitful collisions.

Temperature: Increasing the temperature will increase methanol's rate of formation as

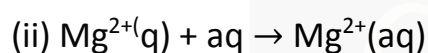
Mole molecules would have energy greater than the activation energy, and thus more

Successful collisions will take place.

Catalyst: The use of a catalyst would increase the rate of formation of methanol By providing an alternative route of lower activation energy to the reaction pathway.

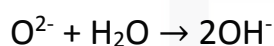
13)

(a) (i) The enthalpy change when 1 mol of gaseous ions dissolve in sufficient water to give an infinitely dilute solution.



(iii) Mg^{2+} has greater charge density than Ca^{2+}

(iv) This is because the oxide ion reacts with water to give OH^- .



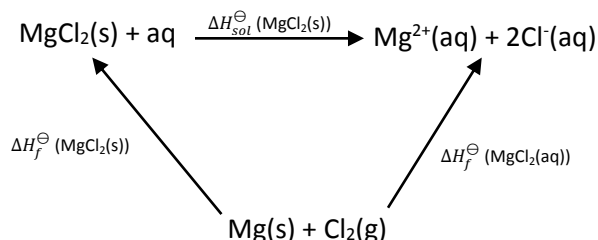
(b) Apparatus: Insulated Calorimeter, water, Thermometer. Pour a known volume of water,

Add a known mass of MgCl_2 into the water, and record the highest temperature change of

Change of the solution. These measurements would be sufficient for determining a value for $\Delta H_{\text{sol}}^\ominus$ ($\text{MgCl}_2(\text{s})$).

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(c) (i)



$$\Delta H_f^{\ominus}(\text{MgCl}_2(\text{s})) + \Delta H_{\text{sol}}^{\ominus}(\text{MgCl}_2(\text{s})) = \Delta H_f^{\ominus}(\text{MgCl}_2(\text{aq}))$$

$$-641 + \Delta H_{\text{sol}}^{\ominus}(\text{MgCl}_2(\text{s})) = -801$$

$$\Delta H_{\text{sol}}^{\ominus}(\text{MgCl}_2(\text{s})) = -801 + 641$$

$$-160 \text{ KJ/mol}$$

$$(ii) \Delta H_{\text{hyd}}^{\ominus}(\text{Mg}^{2+}(\text{g})) + 2\Delta H_{\text{hyd}}^{\ominus}(\text{Cl}^{-}(\text{g})) = \Delta H_{\text{sol}}^{\ominus}(\text{MgCl}_2(\text{s})) + \text{L.E of MgCl}_2(\text{s})$$

$$-1890 + 2\Delta H_{\text{hyd}}^{\ominus}(\text{Cl}^{-}(\text{g})) = -160 - 2526$$

$$2\Delta H_{\text{hyd}}^{\ominus}(\text{Cl}^{-}(\text{g})) = -160 - 2526 + 1890$$

$$2\Delta H_{\text{hyd}}^{\ominus}(\text{Cl}^{-}(\text{g})) = -796$$

$$2\Delta H_{\text{hyd}}^{\ominus}(\text{Cl}^{-}(\text{g})) = -\frac{796}{2} = -398 \text{ KJ/mol}$$

(d) Magnesium sulfate is more soluble than barium sulfate because ΔH_{sol}

is more exothermic

For magnesium sulfate than barium sulfate. Increasing the ionic radius, leads

to a smaller

Than magnesium sulfate and the hydration enthalpy of Ba^{+2} is lesser than

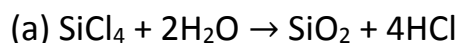
Mg^{+2} . however,

The change in hydration enthalpy is more dominant and hydration

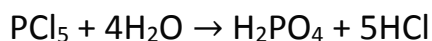
enthalpy decreases

More than L.E, causing magnesium sulfate to be more soluble than barium sulfate.

14)



Observation: White / steamy fumes of HCl are produced.



Observation: Fizzing occurs and white / steamy fumes are produced.

(c) Bond energy of Si – Si Bond = 222 KJ/mol

Bond energy of Si – Cl Bond = 359 KJ/mol

Bond energy of Cl – Cl Bond = 244 KJ/mol

bonds broken = (Si – Si) + 6(Si – Cl) + (Cl – Cl)

$$= 222 + 6(359) + 244$$

$$= 2620$$

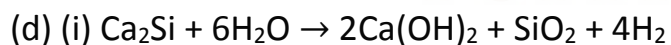
bonds formed = 2 × (4 × Si – Cl)

$$= 8(\text{Si} - \text{Cl})$$

$$= 2872$$

$$\therefore \Delta H^\ominus = 2620 - 2872$$

$$= -252 \text{ KJ/mol}$$

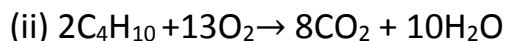


(ii) Silicon is oxidized

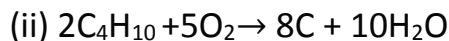
Hydrogen has been reduced

15)

(a) (i) Alkanes.



(b) (i) Carbon



(c) The enthalpy changes when 1 mole of a substance is completely burnt in an excess of

Oxygen under standard conditions of 298 K and 1 atm.

(d) (i) $pV = nRT \Rightarrow n = \frac{pV}{RT}$

As $n = \frac{\text{mass in grams}}{M_r}$

$$\Rightarrow \frac{\text{mass of propane used}}{M_r \text{ of propane}} = \frac{pVM_r}{RT}$$

$$= \frac{(101 \times 10^3) \times (125 \times 10^{-6}) \times (12 \times 3) + (1 \times 8)}{8.31 \times (273.15 + 20)}$$

$$= \frac{555.5}{2436.08}$$

$$= 0.228 \approx 0.23 \text{ g}$$

(ii) Heat Released = $mc\Delta T$

$$= 200 \times 4.18 \times 13.8$$

$$= 11536.8 \text{ J} \approx 11.5 \text{ KJ}$$

(iii) Moles of propane = $\frac{0.228}{44} = 0.005182$

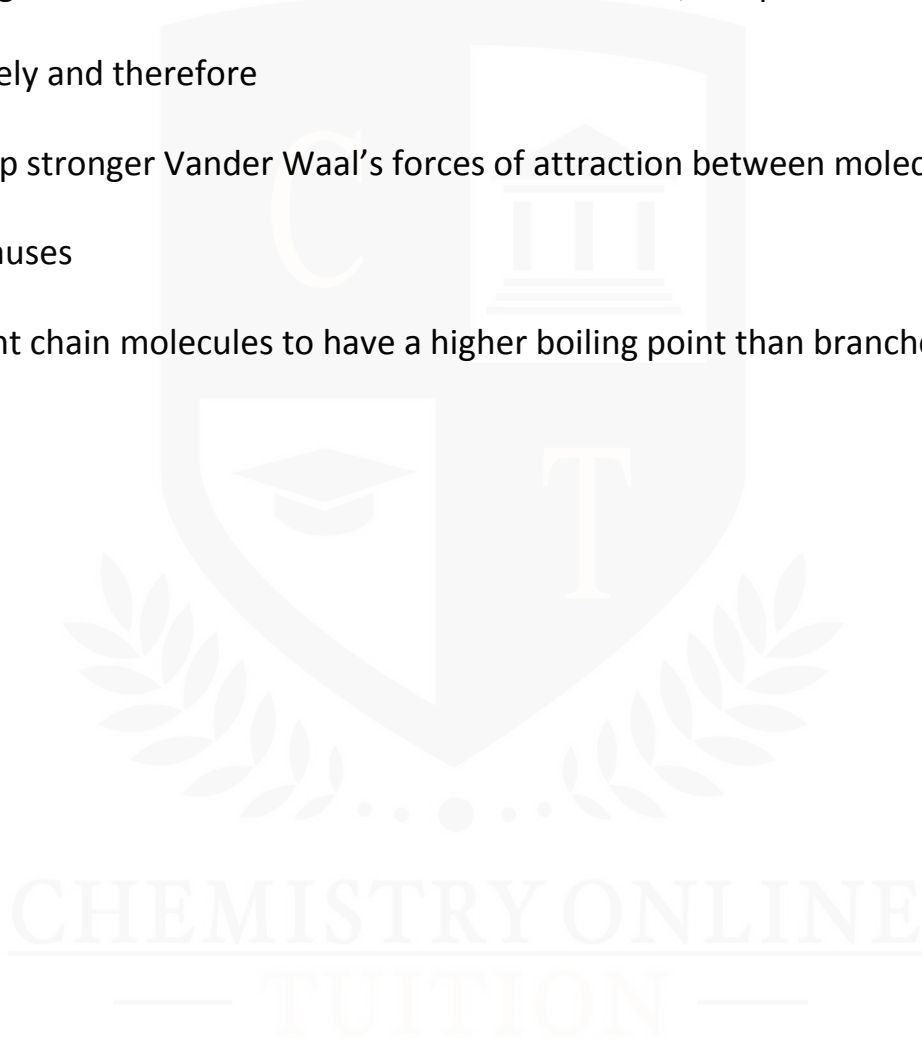
energy produced by 0.00518 moles of propane = 11536.8 J

$$\therefore \text{energy produced by 1 mole of propane} = \frac{11536.8}{0.00518}$$

$$= 2226321.9 \text{ J mol}^{-1}$$

$$= 2226.3219 \text{ KJ mol}^{-1}$$

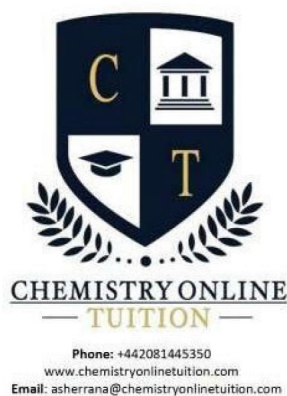
- (e) (i) From methane to butane, there are more number of electrons in the molecule. This causes more stronger Vander Waal's forces of attraction to develop between the molecules leading to an increase in boiling points.
- (ii) Straight Chain molecules such as CH₃CH₂CH₂CH₃, can pack more closely and therefore develop stronger Vander Waal's forces of attraction between molecules. This causes straight chain molecules to have a higher boiling point than branched molecules.



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- Founder & CEO of Chemistry Online Tuition Ltd.
- Completed Medicine (M.B.B.S) in 2007
- Tutoring students in UK and worldwide since 2008
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