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Level 2 Chemistry 2021

91164 Demonstrate understanding of bonding, structure, properties and energy changes

Credits: Five

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of bonding, structure, properties and energy changes.	Demonstrate in-depth understanding of bonding, structure, properties and energy changes.	Demonstrate comprehensive understanding of bonding, structure, properties and energy changes.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table is provided in the Resource Booklet L2–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (▨). This area may be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

QUESTION ONE

Rocket Lab is an aerospace company that launches satellites into orbit from the Māhia Peninsula in New Zealand, using their *Electron* rocket.

Some substances used in the *Electron* rocket are shown in the table below.

www rnz.co nz/news/business/437449/rocket-lab-confirms-public-listing-through-merger-deal

(a) Complete the following table for these substances in their solid states.

Solid	Type of solid	Type of particle	Attractive forces between particles
Oxygen $O_2(s)$			
Copper $Cu(s)$			
Graphite $C(s)$			

(b) Copper, $Cu(s)$, is used for electrical wiring in the rocket, due to its ability to conduct electricity and be stretched into wires (ductility).

Use your knowledge of structure and bonding to explain BOTH of these properties.

(c) Liquid oxygen, $O_2(\ell)$, is stored in the oxygen tank of the rocket. This tank is made of a carbon composite material, which contains graphite, $C(s)$.

Under atmospheric pressure, oxygen turns from a liquid into a gas at –183 °C, while graphite must be heated to around 3600 °C in order to turn from a solid into a gas.

Using your knowledge of structure and bonding, explain the large difference between the temperatures at which each substance turns into a gas.

QUESTION TWO

The *Electron* rocket uses RP-1 fuel, which is a high-grade kerosene. Kerosene is a mixture of hydrocarbons that can be represented by the molecular formula $C_{12}H_{26}$.

(a) Gaseous kerosene, $C_{12}H_{26}(g)$, reacts with oxygen gas, $O_2(g)$, in the combustion chamber of the rocket, as shown in the equation below:

$$2C_{12}H_{26}(g) + 37O_2(g) \rightarrow 24CO_2(g) + 26H_2O(\ell) \qquad \Delta_r H^\circ = -15\,800 \text{ kJ mol}^{-1}$$

(i) Which diagram below best represents the reaction profile for this chemical reaction?

Diagram A

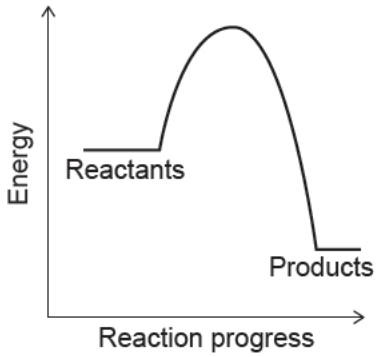
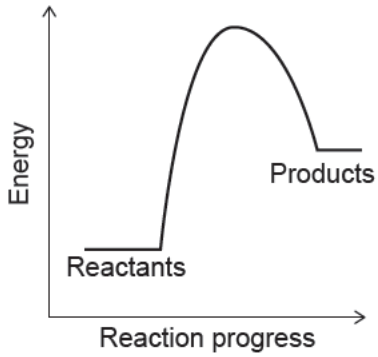


Diagram B



Circle one: **Diagram A** **Diagram B**

Explain your answer.

(ii) On the diagram that you chose above, clearly label the change in enthalpy ($\Delta_r H$).

(b) Many rocket engines run fuel-rich, which means they do not use all of the kerosene ($C_{12}H_{26}$) fuel that passes through them. 2560 kg (2.56×10^6 g) of kerosene fuel is loaded into the first stage of the rocket; however only 75.0% of this is combusted (burned).

$$2C_{12}H_{26}(g) + 37O_2(g) \rightarrow 24CO_2(g) + 26H_2O(\ell) \qquad \Delta_r H^\circ = -15\,800 \text{ kJ mol}^{-1}$$

Calculate the energy produced by the combustion of this amount of kerosene fuel.

$M(C_{12}H_{26}) = 170 \text{ g mol}^{-1}$

(c) Kerosene, $C_{12}H_{26}(\ell)$, is a non-polar substance.

Use your knowledge of structure and bonding to identify and explain the solubility of kerosene in both water and cyclohexane solvents.

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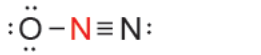
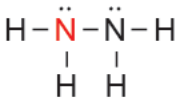
The examination continues on the following page.

QUESTION THREE

(a) Draw the Lewis diagram (electron dot diagram) for the following molecules and name their shapes.

Molecule	AsF_3	H_2S	F_2CO
Lewis diagram			
Name of shape			

(b) The Lewis diagrams and bond angles of two different propellants that have been used in rocket engines are shown below.

Lewis diagram		
Name	Nitrous oxide (N_2O)	Hydrazine (N_2H_4)
Bond angle about red N atom	180°	109.5°

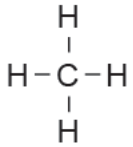
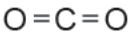
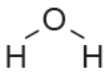
Explain the difference in the shapes and bond angles about the nitrogen atoms that are **coloured red** in each molecule.

Question Three continues on the next page.

(c) Another fuel that can be used in rocket engines is methane, $CH_4(g)$. It reacts with oxygen, $O_2(g)$, as shown by the reaction below.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \quad \Delta_r H^\circ = -802 \text{ kJ mol}^{-1}$$

(i) Use the change in enthalpy ($\Delta_r H^\circ$) for the combustion of methane and the bond energies listed in the table below to calculate the average bond energy of the C–H bond in methane.

 CH_4	 O_2	 CO_2	 H_2O

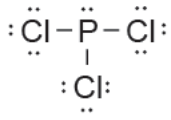
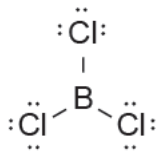
Bond	Average bond energy (kJ mol^{-1})
C=O	805
O=O	495
O–H	463

(ii) Calculate the mass of methane, $CH_4(g)$, required to react in order to release 1660 kJ of energy.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g) \quad \Delta_r H^\circ = -802 \text{ kJ mol}^{-1}$$

$$M(CH_4) = 16.0 \text{ g mol}^{-1}$$

(d) The Lewis diagrams of phosphorus trichloride (PCl_3) and boron trichloride (BCl_3) are shown below.

	
Phosphorus trichloride (PCl_3)	Boron trichloride (BCl_3)

Both molecules contain three chlorine atoms around a central atom, yet have different polarities.

(i) Circle the word that describes the polarity of each molecule below.

Phosphorus trichloride (PCl_3) **Polar** **Non-polar**

Boron trichloride (BCl_3) **Polar** **Non-polar**

(ii) Compare and contrast the factors that influence the polarity of these two molecules.

Extra space if required.
Write the question number(s) if applicable.

QUESTION NUMBER