Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2017

PHYSICS AND CHEMISTRY – HIGHER LEVEL

MONDAY, 19 JUNE – MORNING, 9.30 to 12.30

Six questions to be answered.

Answer any **three** questions from **Section I** and any **three** questions from **Section II**.

All questions carry equal marks.

However, in each section, one additional mark will be given to each of the first two questions for which the highest marks are obtained.

N.B. Relevant data are listed in the *Formulae and Tables* booklet, which is available from the superintendent.
Take $g = 9.8 \text{ m s}^{-2}$ as the acceleration due to gravity at the surface of the Earth.

SECTION I – PHYSICS (200 marks)

1. Answer **eleven** of the following items (*a*), (*b*), (*c*), etc. All the items carry equal marks.
Keep your answers short.

(*a*) State the *principle of conservation of momentum*.

(*b*) Define work.

(*c*) **Figure 1** is a graph of the motion of an animal on a straight, horizontal path.
(*i*) Between which two points of **O**, **A**, **B** and **C** on the graph is the animal moving at uniform speed towards the starting point?
(*ii*) What is this speed?

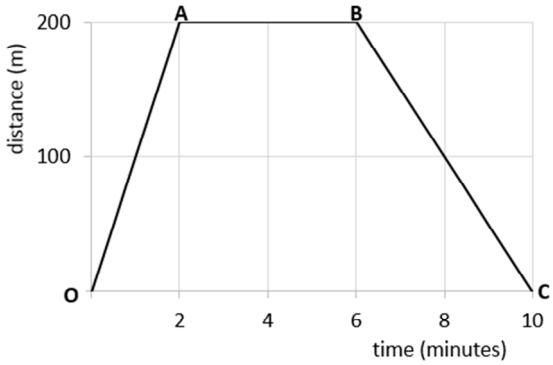

Figure 1

(*d*) State Snell's law of refraction.

(*e*) What term is used for the splitting up of white light into its constituent colours when passed through a prism?
Why does this phenomenon occur?

(*f*) Ultrasound waves, used in prenatal examinations as shown in **Figure 2**, are examples of <u>longitudinal waves</u>.
Explain the underlined term.

Figure 2

(*g*) What is the general name of a property that changes measurably as temperature changes?
What such property is used in a constant volume gas thermometer?

(*h*) Calculate the temperature reading on the Celsius scale when the height of liquid in a liquid-in-glass thermometer is 12 cm; the liquid had heights of 4 cm and 20 cm respectively when placed in ice-water and in steam above boiling water.

(*i*) What are the fixed points (reference points) on the Kelvin scale of temperature?

(*j*) During a thunderstorm, a bolt of lightning resulted in 300 C of charge flowing in a lightning conductor in a time of 2.5×10^{-3} s.
Calculate the average current in the conductor.

(*k*) Explain how a fuse protects an electric circuit.

(*l*) Copy **Figure 3** and sketch the magnetic field pattern around the solenoid when the switch is closed.

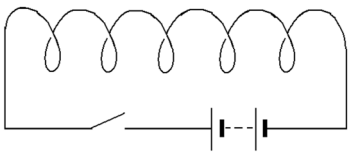

Figure 3

(*m*) What is meant by electromagnetic induction?

(*n*) Why would very high temperatures such as those found in the core of the sun be required to bring about the following nuclear reaction?

$$\mathbf{{}_1^2H + {}_1^3H \longrightarrow {}_2^4He + {}_0^1n + energy}$$

What name is given to this type of nuclear reaction?

(*o*) The energy released in a nuclear reaction is 8.1×10^{-15} J.
Calculate the loss in mass involved.

(11 × 6)

2. (*a*) State *Newton's second law of motion*.

Define the unit of force, i.e. the newton. (12)

(*b*) As part of an experiment to investigate Newton's second law, a constant force *F* was applied to a series of different masses *m* and the corresponding accelerations *a* were measured. The following results were obtained.

a (m s^{-2})	0.75	0.86	1.0	1.2	1.5	2.0
m (kg)	4.0	3.5	3.0	2.5	2.0	1.5
$1/m$ (kg^{-1})	0.25					

(*i*) Draw a labelled diagram of an apparatus used to obtain these data.

(*ii*) Calculate the remaining values of $1/m$ and draw a graph of a against $1/m$ (x-axis).

(*iii*) Use your graph to find the constant force *F* applied to all the masses.

(*iv*) What mass would have an acceleration of 1.4 m s^{-2} under this force?

(*v*) Explain how your graph verifies Newton's second law. (39)

(*c*) A drone of mass 1.2 kg, shown in **Figure 4**, is at an altitude of 65 m and has a horizontal velocity in a straight line of 18 m s^{-1}.
Its motors are used to control its motion. Calculate

(*i*) the horizontal force applied by the motors to reduce its velocity to zero in 2 s,

(*ii*) the vertical force applied by the motors to prevent it falling,

(*iii*) the drone's potential energy due to its position 65 m above the ground. (15)

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Figure 4

3. (*a*) State the laws of reflection of light. (6)

(*b*) Describe, with the aid of a diagram, an experiment to verify one of these laws. (12)

(*c*) Distinguish, in terms of light rays, between a real and a virtual image. (6)

(*d*) What is the relationship between the focal length *f* and the radius of curvature *c* of a spherical mirror? (3)

(*e*) Draw a ray diagram to show image formation in a convex mirror.

Give two properties of the virtual images formed in a convex mirror. (15)

(*f*) The table below refers to two spherical mirrors **A** and **B**.

	Object distance, u (cm)	Image distance, v (cm)	Magnification, v/u	Focal length, f (cm)	Nature of image
Mirror **A**	7	– 4.2			virtual
Mirror **B**	5		– 6		virtual

Calculate (*i*) the magnification produced by mirror **A**, (*ii*) the focal length of mirror **A**.

Calculate (*iii*) the distance of the image from mirror **B**, (*iv*) the focal length of mirror **B**.

Which of the two mirrors is a convex mirror?
Give a reason for your answer. (24)

4. (*a*) The data obtained in an experiment to verify Boyle's law were used to draw the graph shown in **Figure 5**.

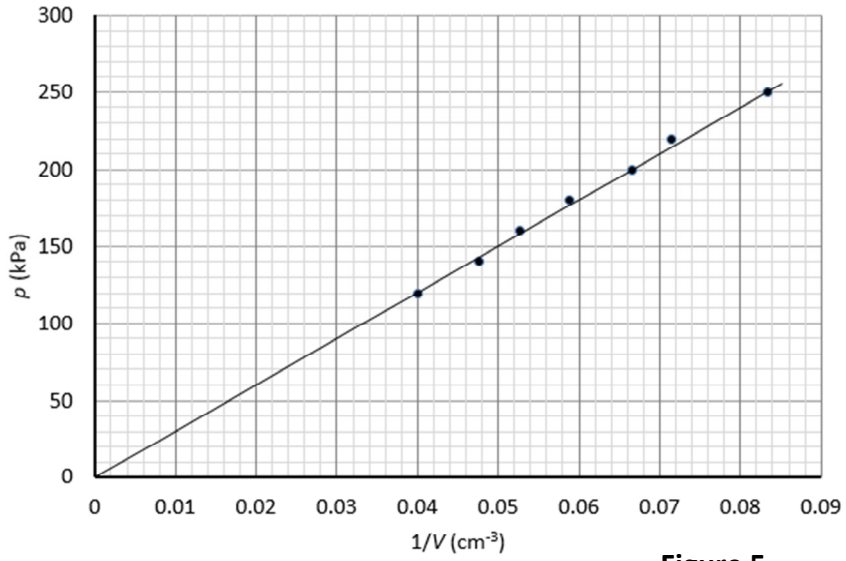

Figure 5

(*i*) Draw a labelled diagram of an apparatus used to carry out this experiment.

(*ii*) What measurements were taken using this apparatus?

(*iii*) What two conditions were kept constant during this experiment? (18)

(*iv*) Use the graph to find the volume of the gas when the pressure was 150 kPa.

(*v*) Boyle's law may be represented by the equation $pV = k$ where k is a constant.

How does the graph verify Boyle's law?

Use the graph to find the value for k. (15)

(*b*) (*i*) Describe Brownian movement.

Explain how it provides evidence for the kinetic theory of gases. (12)

(*ii*) What term is used to describe a gas that obeys all the assumptions of the kinetic theory of gases at all temperatures and pressures?

State two of these assumptions. (9)

(*c*) Calculate the number of moles of helium gas in a large foil balloon inflated to a volume of 0.072 m^3 at a pressure of 1.05×10^5 Pa and at room temperature of 20 °C.

Helium gas escaped from the foil balloon over time. How many moles of gas were left in the balloon when the inflated volume was reduced to 0.018 m^3 at the same temperature and at a pressure of 1.03×10^5 Pa? (12)

5. (*a*) (*i*) Define the unit of current, i.e. the ampere. (9)

(*ii*) State Ohm's law. (6)

(*iii*) Heating is one possible effect of an electrical current.
What are the other two? (6)

(*iv*) Classify each of the following as having a direct current (d.c.) or an alternating current (a.c.) *output*:

battery **transformer** **battery charger** (6)

(*b*) The USB ports on computers can be used as power 'sources' to supply small electrical currents to operate various gadgets with motors or heating elements or to charge batteries in phones, etc.
A USB supplies a current of 0.5 A at 5 V to the heating element in a mini-hotplate warmer, like that shown in **Figure 6**.
Calculate

(*i*) the resistance of the heating element,

(*ii*) the power rating of the heater,

(*iii*) the heat energy supplied when the heater operates for 20 minutes. (18)

Figure 6

(*c*) **Figure 7** shows an apparatus used to demonstrate the principle on which the moving-coil galvanometer is based.
An aluminium strip lies loosely between the poles of a magnet as shown.
Electric current passes through the aluminium when the switch is closed.

(*i*) What is observed when the switch is closed?

(*ii*) State the principle demonstrated. (9)

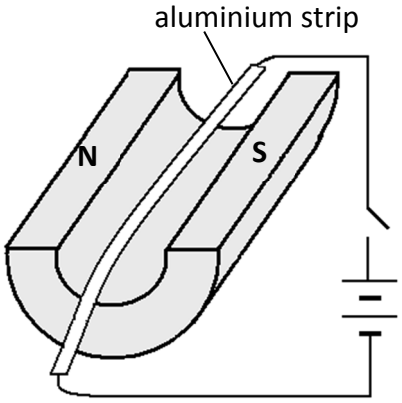

Figure 7

(*d*) A moving-coil galvanometer, with an internal resistance of 150 Ω, gives a full-scale deflection of 10 mA.

(*i*) Calculate the resistance of the shunt required to enable the galvanometer to measure currents up to 2 A.

(*ii*) How can a resistor be used to convert the galvanometer into a voltmeter capable of reading voltages up to about 50 V? (12)

6. Answer any **two** of the following parts (*a*), (*b*), (*c*), (*d*). Each part carries 33 marks.

(*a*) Identify the attractive force that a mass in the Universe exerts on every other mass.

Write an equation for the size of this force in terms of the two masses and the distance between them.

Explain how weight at the surface of the Earth is a specific example of this force. (15)

The Hubble Space Telescope, shown in **Figure 8**, has a mass of 11,110 kg. The radius of the Earth is 6.4×10^6 m. Calculate

(*i*) the weight the telescope had at the surface of the Earth before it was launched into space,

(*ii*) the mass of the Earth,

(*iii*) the acceleration due to Earth's gravity at the orbit of Hubble, 541 km above the surface of the Earth. (18)

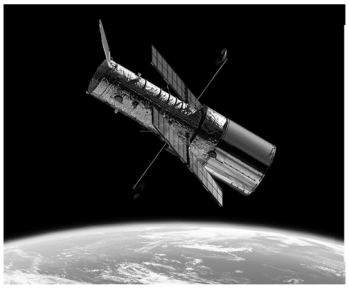

Figure 8

(*b*) What is (*i*) a photon, (*ii*) the photoelectric effect? (9)

Describe an experiment to demonstrate the photoelectric effect. (12)

Monochromatic light of wavelength 375 nm was used to demonstrate the photoelectric effect.

Calculate (*iii*) the frequency, (*iv*) the energy of a photon, of this light. (12)

(*c*) What is radioactivity? (6)

Define the half-life of a radioactive isotope. (6)

Krypton–85 is a beta-particle emitter.

Write a nuclear equation to represent the beta-decay of **Kr**–85. (6)

After 21.5 years 75% of a sample of **Kr**–85 has decayed.

Calculate the half-life of the isotope. (6)

Kr–85 is used industrially to monitor the thickness of sheets of paper, plastic and metal. A sample containing **Kr**–85 is placed on one side of the sheet and a beta-radiation detector on the other. The thicker the sheet the less intense the stream of beta-particles that reaches the detector. Why are alpha-particle sources unsuitable for thickness monitoring in this way? (3)

When an alpha-particle source was brought close to the cap of a negatively-charged electroscope as shown in **Figure 9**, the electroscope lost its charge. Explain why this happened. (6)

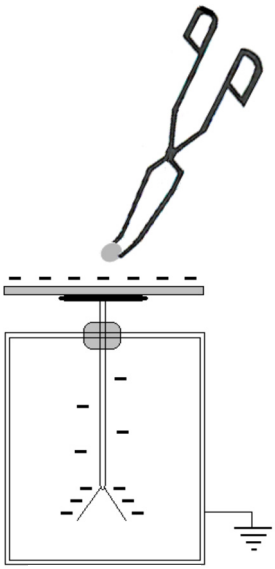

Figure 9

(*d*) State Coulomb's law of force between electrical charges.

F is the electrostatic force between two particles, each carrying a positive charge of 4 μC when their centres are 6 cm apart in air. What is the electrostatic force, in terms of *F*, when the distance between them is 3 cm?

Draw a diagram to show the electrical field around these two positive charges. (18)

What is a capacitor?

State two factors on which the capacitance of a parallel-plate capacitor depends.

What charge is transferred when a 4 μF parallel-plate capacitor is connected to a 9 V battery? (15)

SECTION II – CHEMISTRY (200 marks)

7. Answer **eleven** of the following items (*a*), (*b*), (*c*), etc. All the items carry equal marks. *Keep your answers short*.

(*a*) A tripositive ion, $\mathbf{M^{3+}}$, has 10 electrons and 14 neutrons.
What is (*i*) the atomic number, (*ii*) the identity, of element **M**?

(*b*) The set of quantum numbers {2, 1, 0, +½} identifies an electron in an atom.
(*i*) What main energy level does the electron occupy?
(*ii*) What shape does the orbital occupied by the electron have?

(*c*) In terms of atomic structure, how is a transition metal defined?

(*d*) **Figure 10** shows an electron transition from the third shell to the second shell in a hydrogen atom that results in the emission of a photon of red light according to $E_3 - E_2 = hf$. What do E_3 and h represent?

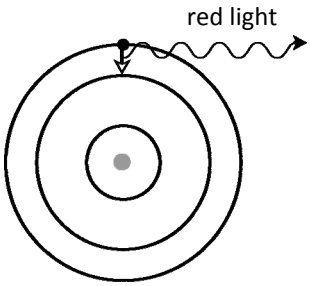

Figure 10

(*e*) Explain why ammonia is very soluble in water but methane is virtually insoluble.

(*f*) State (*i*) the number of electrons in the valence shell of a halogen atom,
(*ii*) the valency of chlorine in sodium chloride.

(*g*) What are the possible shapes of a covalent molecule with the general formula $\mathbf{QH_2}$?

(*h*) What is the conjugate base of each of the following species: (*i*) $\mathbf{H_3O^+}$, (*ii*) $\mathbf{HCO_3^-}$?

(*i*) Explain why boron trifluoride ($\mathbf{BF_3}$) does **not** have a dipole moment.

(*j*) Define a mole of a substance in terms of the Avogadro constant.

(*k*) Titanium metal, used in the type of replacement joint shown in **Figure 11**, can be extracted from an ore called ilmenite ($\mathbf{FeTiO_3}$). Calculate the percentage by mass of oxygen in this ore.
(**O** = 16, **Ti** = 48, **Fe** = 56)

Figure 11

(*l*) When 0.8 g of sodium hydroxide (**NaOH**) dissolves in a large quantity of water, 890 J of energy are released. Calculate the heat of solution of sodium hydroxide.
(**H** = 1, **O** = 16, **Na** = 23)

(*m*) Distinguish between aliphatic and aromatic organic compounds.

(*n*) Copy **Figure 12**, the structure of vanillin which is the main ingredient in the flavouring vanilla, into your answer book.
(*i*) Circle the carbonyl group in your structure.
(*ii*) What is the molecular formula of vanillin?

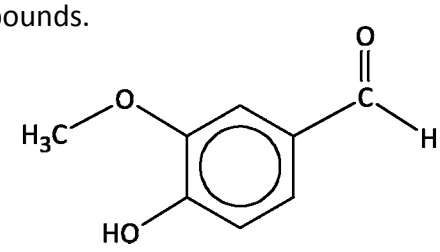

Figure 12

(*o*) Write a balanced equation for the complete combustion of benzene ($\mathbf{C_6H_6}$) in oxygen.

(11 × 6)

8. (*a*) Distinguish between mass number and relative atomic mass. (9)

Atoms of the element boron that have either 5 or 6 neutrons in their nuclei exist in nature.

State the mass number of each of these two different kinds of boron atom.

Explain why both types of boron atom have the same chemical properties.

What term is used to describe atoms of the same element that have different numbers of neutrons? (12)

19.9% of the atoms in a sample of boron have 5 neutrons and 80.1% of the atoms in the sample have 6 neutrons.
Calculate the relative atomic mass of boron. (9)

(*b*) Define electronegativity.

Use electronegativity values to predict the type of bonding you would expect to find in (*i*) **CaO**, (*ii*) **HBr**. (12)

(c) The table below shows the electronegativity value and the atomic radius for each of the elements in the second period of the Periodic Table, excluding neon.

Element	**Li**	**Be**	**B**	**C**	**N**	**O**	**F**
Atomic number (*Z*)	3	4	5	6	7	8	9
Electronegativity	0.98	1.57	2.04	2.55	3.04	3.44	3.98
Atomic radius (pm)	128	96	84	76	71	66	57

Draw a graph to show the relationship between electronegativity value and atomic number (***Z***) for elements 3 to 9. (9)

Why is there a decrease in atomic radius from element 3 to element 9?

Explain (*i*) how, and (*ii*) why, electronegativity values across the second period are influenced by atomic radius.

Why do the electronegativity values of the alkali metals decrease as their atomic numbers increase? (15)

9. Propanoic acid (**C_2H_5COOH**) is a weak acid and it is monoprotic. It has antibacterial and antifungal properties and can be used as a food preservative.
A solution of propanoic acid was titrated against 25.0 cm^3 portions of a standard solution of 0.10 M sodium hydroxide (**NaOH**) using a suitable indicator.
The balanced equation for the reaction is:

$$C_2H_5COOH + NaOH \rightarrow C_2H_5COONa + H_2O$$

(*a*) Explain the underlined terms. (12)

(*b*) Identify the hazard symbol in **Figure 13** used on bottles of acids and bases.
State one precaution taken to handle these solutions safely. (6)

Figure 13

(*c*) The equipment in **Figure 14** is used to deliver 25.0 cm^3 of the **NaOH** solution into a titration flask.
Name **X**.
Describe how **X** was rinsed before use.
What is the advantage of attaching a suction device like **Y** to the top of **X**? (12)

(*d*) Name a suitable indicator for this titration.
Justify your choice.
State the colour change observed at the end point. (12)

(*e*) On average, 19.55 cm^3 of propanoic acid solution was required to neutralise 25.0 cm^3 of 0.10 M **NaOH** solution.
Calculate the concentration of propanoic acid in
(*i*) moles per litre,
(*ii*) grams per litre. (12)

(*f*) Define pH.
Calculate the pH of the 0.10 M **NaOH** solution. (12)

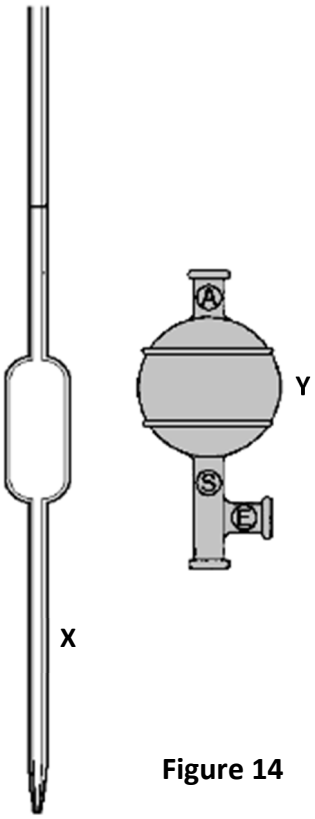

Figure 14

10. (*a*) Define reduction in terms of electron transfer.

Identify the reducing agent in each of the following reactions.

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

$$Al_2O_3 + 3Mg \rightarrow 3MgO + 2Al$$ (9)

(*b*) Arrange the following metals in order of *decreasing* ease of oxidation.

gold magnesium iron aluminium copper (6)

(*c*) What is a sacrificial anode?
Give an example of the use of a sacrificial anode. (6)

(*d*) What is electrolysis?
State *Faraday's first law of electrolysis*. (9)

(*e*) **Figure 15** shows an arrangement for the electrolysis of molten lithium chloride (**LiCl**) using graphite electrodes.

(*i*) Which of the electrodes **X** or **Y** is the anode?
(*ii*) At which electrode does oxidation occur?
Justify your answer.
(*iii*) Write a balanced equation for the oxidation reaction.
(*iv*) Suggest a reason why this electrolysis should only be carried out in a fume cupboard.
(*v*) Explain why the bulb does not light until the lithium chloride has been heated strongly for several minutes using the Bunsen burner.
(*vi*) Calculate the mass of metal produced in this electrolysis when a current of 3 A flows for 24 minutes. (36)

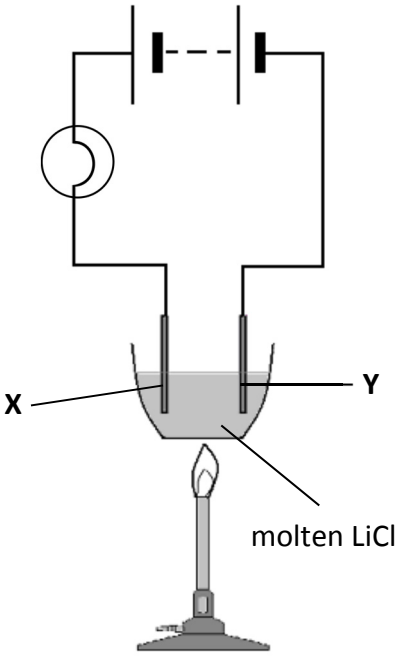

Figure 15

11. Study the reaction scheme in **Figure 16** and answer the questions that follow.

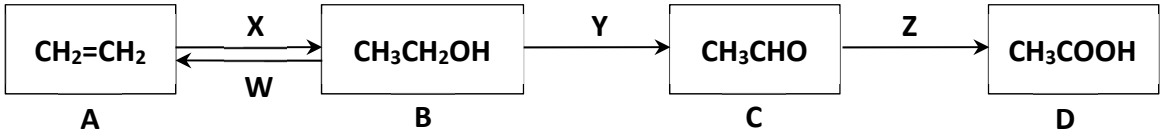

Figure 16

(*a*) (*i*) Name the compounds **A**, **B**, **C** and **D**. (12)
(*ii*) **A** is a hydrocarbon and is unsaturated. Explain the underlined terms. (12)
(*iii*) Describe how to test a sample of **A** for unsaturation. (9)
(*iv*) To what homologous series does **B** belong? (3)
(*v*) Describe a chemical test you would carry out on a sample of **C** to confirm that it is an aldehyde. (6)

(*b*) (*i*) Which one of the conversions **W**, **X**, **Y** and **Z** is an addition reaction?
(*ii*) Classify any one of the conversions **W**, **X**, **Y** and **Z** as an oxidation reaction. (6)

(*c*) Draw a labelled diagram of a suitable arrangement of apparatus and chemicals you would use to prepare and collect **A**. (9)

(*d*) Which two of the compounds in the scheme react together to form an ester?
Give the name of this ester *or* draw its structure. (9)

12. Answer any **three** of the following parts (*a*), (*b*), (*c*), (*d*). Each part carries 22 marks.

(*a*) A coal contains 2.5% sulfur by mass. When the coal is burned at a power plant the sulfur in it is converted to gaseous sulfur dioxide. Scrubbers in the power plant chimneys act as filters, continuously removing this sulfur dioxide from emission gases by reaction with calcium carbonate. These reactions are described by the following balanced equations.

$$\mathbf{S_{(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)}}$$

$$\mathbf{CaCO_{3\,(s)} + SO_{2\,(g)} \rightarrow CaSO_{3\,(s)} + CO_{2\,(g)}}$$

(*i*) Classify sulfur dioxide as an amphoteric, an acidic, a basic or a neutral oxide.

What environmental problem would result from the release of $\mathbf{SO_2}$ into the atmosphere?

(*ii*) What mass of sulfur is in 5.12×10^6 kg of this coal, burned in one day at the power plant?

How many moles of $\mathbf{SO_2}$ are produced from this sulfur?

What volume of oxygen gas reacts with this sulfur at s.t.p.?

What mass of $\mathbf{CaSO_3}$ is produced per day by the scrubbers?

(*b*) Define an atomic orbital.

Write the *s*, *p* electron configuration of (*i*) a silicon atom, (*ii*) a phosphorus atom.

Which electron configuration is more stable? Explain your answer.

What species is represented by the electron configuration $[1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6]^{2+}$?

(*c*) Silicon and diamond have similar crystalline structures.
What type of crystal structure is present in diamond?

Explain in terms of its bonding
(*i*) the hardness of a diamond,
(*ii*) diamond's inability to conduct electricity.

Figure 17 shows table salt (**NaCl**), an ionic crystal, and rock candy (sugar), a molecular crystal. What are the bonding forces
(*iii*) in an ionic crystal,
(*iv*) that hold a molecular crystal together?

Explain why molecular crystals usually have lower melting points than ionic crystals.

What type of crystal is characterised by a solid having a lustre and a very high mobility of electrons throughout its structure?

Figure 17

(*d*) Define heat of formation.

$$\mathbf{\tfrac{1}{2}H_{2\,(g)} + \tfrac{1}{2}Cl_{2\,(g)} \rightarrow HCl_{(g)} \qquad \Delta H = -92.3\ kJ\ mol^{-1}}$$

$$\mathbf{C_{(s)} + 2H_{2\,(g)} \rightarrow CH_{4\,(g)} \qquad \Delta H = -74.6\ kJ\ mol^{-1}}$$

$$\mathbf{C_{(s)} + 1\tfrac{1}{2}H_{2\,(g)} + \tfrac{1}{2}Cl_{2\,(g)} \rightarrow CH_3Cl_{(g)} \qquad \Delta H = -81.9\ kJ\ mol^{-1}}$$

Use the heats of formation above to calculate ΔH for the substitution reaction of methane with chlorine according to the following equation.

$$\mathbf{CH_{4\,(g)} + Cl_{2\,(g)} \rightarrow CH_3Cl_{(g)} + HCl_{(g)}}$$

Is this reaction exothermic or endothermic?

Why is ultraviolet light needed for this reaction to happen?

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