Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2015

PHYSICS AND CHEMISTRY – HIGHER LEVEL

MONDAY, 15 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 $g = 9.8$ 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 *Newton's first law of motion*.

(*b*) Name the SI unit of measurement defined as *the work done when a force of one newton moves its point of application one metre in the direction of the force*.
What quantity, other than work, is also measured using this unit?

(*c*) What power does a weightlifter develop in a 2.5 m vertical lift of 60 kg completed in 0.12 s?

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

(*e*) **Figure 1** shows a transverse wave drawn to scale. What is
(*i*) the amplitude,
(*ii*) the wavelength, of this wave?

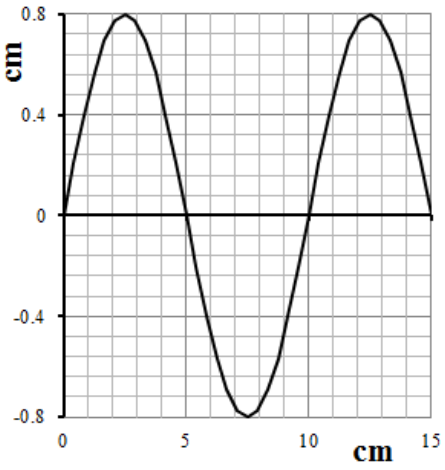


Figure 1

(*f*) What is total internal reflection?

(*g*) What is meant by *complete destructive interference* of waves?

(*h*) A balloon containing helium and a balloon containing carbon dioxide are inflated to the same volume at the same temperature and pressure.
What is the ratio of the number of moles of helium to the number of moles of carbon dioxide present in the two balloons?

(*i*) Under what conditions of temperature and pressure does a real gas behave most like the ideal gas?

(*j*) Deduce the type of charge on (*i*) $\boldsymbol{Q}_1$, (*ii*) $\boldsymbol{Q}_2$, from their electric field pattern when placed close together as shown in **Figure 2**.

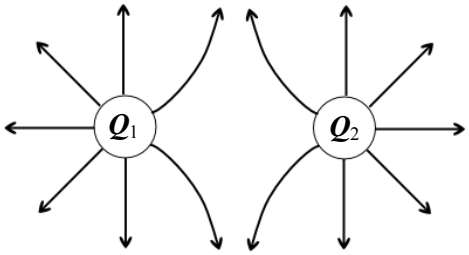


Figure 2

(*k*) Identify the electrical device that
(*i*) generates an electric current from chemical reactions,
(*ii*) stores energy by means of the separation of charges.

(*l*) Define electrical potential difference.

(*m*) A wire carrying current ***I*** passes through a sheet of cardboard as shown in **Figure 3**. Copy the diagram and show the magnetic field lines around the wire.

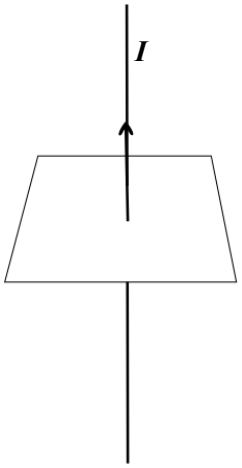


Figure 3

(*n*) A radioactive isotope has a half-life of 3 days. If 2 g of the isotope remained undecayed in a sample after 9 days, what was the original mass of the isotope in the sample?

(*o*) When a beta-particle is emitted from the nucleus of an atom, what change occurs in
(*i*) the number of protons,
(*ii*) the number of neutrons?

(11 × 6)

2. (*a*) Define (*i*) force, (*ii*) momentum. (9)

(*b*) Write a mathematical expression for the relationship between force and the rate of change of momentum. (6)

(*c*) Define the newton. (6)

(*d*) State the *law of conservation of momentum*. (6)

(*e*) Draw a labelled diagram of an arrangement of apparatus used to verify the law of conservation of momentum. (12)

(*f*) Engineers test the effectiveness of the safety features when new vehicles are being designed. In such a test, a car of mass 1500 kg travelling at 20 m s^{-1} struck a block representing a stationary truck of mass 7500 kg head-on and the car and the block moved together after the collision.

(*i*) Calculate the common velocity of the car and the block immediately after the collision.

(*ii*) Does the car or the block experience the greater force during the collision? Justify your answer.

(*iii*) Calculate the ratio of the magnitude of the acceleration of the car to that of the block during the test.

(*iv*) Modern cars have 'crumple zones' built in to reduce injury to the occupants in the event of a collision. The crumple zones are designed to be able to fold up like an accordion, as shown in **Figure 4**, leaving the cabin relatively intact.

Explain in terms of force how crumple zones can help reduce injuries in a collision. (27)

Figure 4

3. A beam of monochromatic light undergoes refraction when it passes through a triangular glass prism. A beam of white light undergoes refraction *and* dispersion when it passes through the same prism.

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

(*b*) State one property of a wave

(*i*) that changes,

(*ii*) that does not change when it is refracted. (6)

(*c*) Describe with the aid of a labelled diagram how you would use a prism and lenses to project a spectrum of white light onto a screen.

Show on your diagram where you would expect to be able to detect infrared radiation.

How could you detect the presence of this invisible radiation? (15)

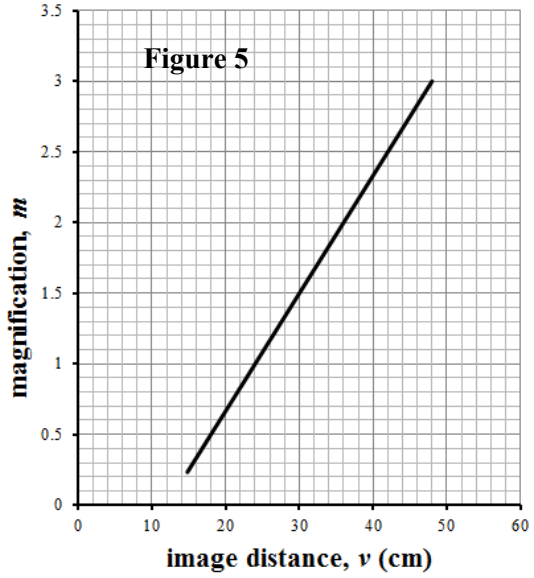
(*d*) The graph in **Figure 5** shows the relationship between image distance *v* and magnification *m* for a concave mirror.

(*i*) Use the graph to find the image distance when the magnification is exactly 1.

(*ii*) What is the object distance when the magnification is 1?

(*iii*) Calculate the focal length of the mirror.

(*iv*) What is the magnification when the object is placed 18 cm from the mirror? (21)



(*e*) Use a ray diagram to show how a magnified erect image is produced by a concave mirror.

Give a use for a concave mirror based on its magnifying ability. (12)

4. (*a*) State *Charles' law*. (6)

(*b*) What property of the molecules of a gas determines the temperature of the gas?
At what temperature on the Kelvin scale is the value of this property theoretically zero? (9)

(*c*) The volumes of a fixed mass of gas at various temperatures are shown in the table below.

Temperature (°C)	–13	17	37	57	87	117
Volume (cm^3)	800	900	960	1020	1110	1200

(*i*) Draw a suitable graph of volume *versus* temperature to verify Charles' law.

(*ii*) Explain how your graph verifies Charles' law. (21)

(*d*) The constant volume gas thermometer is used as a standard thermometer.

(*i*) On what thermometric property is the constant volume gas thermometer based?

(*ii*) Why are standard thermometers necessary?

(*iii*) Give two reasons why constant volume gas thermometers are *not* in common use. (18)

(*e*) (*i*) How can the temperatures 0 °C and 100 °C be generated in the laboratory to establish the fixed points for the Celsius scale?

(*ii*) Write an equation that can be used to calculate temperature on the Celsius scale from measurements taken using a constant volume gas thermometer. (12)

5. (*a*) What is electric current?
State *Ohm's law*. (12)

(*b*) Describe, with the aid of a labelled diagram, the apparatus and electrical circuit used in an investigation into the heating effect of an electric current in a coil of wire.
What relationship was established? (18)

(*c*) State the principle of operation of a moving-coil galvanometer in detecting a small current.
Explain how a moving-coil galvanometer can be converted into an ammeter to measure larger currents. (12)

(*d*) A circuit designer has proposed an improved surgically-implantable electronic device to prevent snoring.
The wiring and electronic circuits of any medically implanted device are required to have minimal heating effects inside the body.

Calculate, assuming Ohm's law applies,

(*i*) the current drawn from a 2.8 V battery when the device is in use if the combined resistance of the wiring and circuits is 64 Ω,

(*ii*) the electrical energy that would be used by the device during a sleep period of 8 hours. (12)

(*e*) Energy loss due to heating must be minimised when transmitting electricity from generating stations to the point of use.
Explain how this is achieved.
Why is alternating current used in the transmission of electricity? (12)

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

(*a*) What is a photon? (6)

A negatively-charged zinc plate rests on the cap of an electroscope as shown in **Figure 6**.

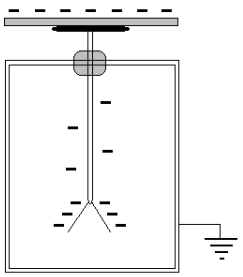


Figure 6

Describe and explain what you would expect to observe if the zinc plate were illuminated with

(*i*) ultraviolet light from a lamp placed 50 cm from the zinc plate,

(*ii*) ultraviolet light from the same lamp placed 10 cm from the zinc plate,

(*iii*) infrared radiation from a lamp placed 10 cm from the zinc plate. (15)

Calculate the frequency of radiation of wavelength 2.0×10^{-7} m.

What is the energy of a photon of ultraviolet radiation of this frequency? (12)

(*b*) State *Newton's law of universal gravitation*.

Using this law, derive the relationship between g the acceleration due to the Earth's gravity and G the gravitational constant. (15)

The acceleration due to gravity at the orbit of the international space station (ISS) around the Earth is 8.61 m s^{-2}. Calculate the distance of the space station from the surface of the Earth. Take the mass of the Earth as 5.97×10^{24} kg and the radius of the Earth as 6.37×10^{6} m.

If an astronaut's mass decreased by 3.50 kg while living for a few months in the ISS, how would this affect the acceleration due to gravity he or she experienced? Explain your answer. (18)

(*c*) State *Faraday's law of electromagnetic induction*.

Describe an experiment to demonstrate electromagnetic induction. (15)

Figure 7 shows a generator in which coil **C** rotates inside a magnetic field.

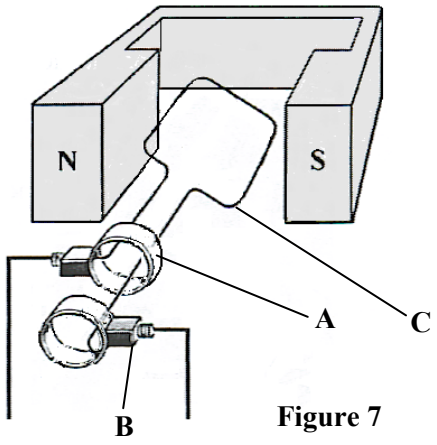


Figure 7

Name the parts labelled **A** and **B**.

State the functions of **A** and **B**. (9)

Sketch the variation of the output voltage with time.

Give one way of increasing the output voltage from a generator. (9)

(*d*) In a nuclear reactor uranium–235 is bombarded with neutrons and the following is a typical energy releasing reaction that occurs.

$$^{235}_{92}\mathbf{U} + {}^{1}_{0}\mathbf{n} \rightarrow {}^{141}_{56}\mathbf{Ba} + {}^{92}_{36}\mathbf{Kr} + 3{}^{1}_{0}\mathbf{n} + \textbf{Energy}$$

State one feature of generating electricity using this type of reaction that is

(*i*) advantageous to the environment,

(*ii*) harmful to the environment. (6)

What name is given to the type of nuclear reaction represented by the following equation?

$$^{3}_{1}\mathbf{H} + {}^{2}_{1}\mathbf{H} \rightarrow {}^{4}_{2}\mathbf{He} + {}^{1}_{0}\mathbf{n} + \textbf{Energy}$$

Why is it difficult to bring about such a reaction? (6)

What is meant by *mass-energy conservation* in a nuclear reaction? (6)

In 1932 Cockroft and Walton verified, for the first time, the principle of mass-energy conservation in nuclear reactions by bombarding lithium atoms with protons as follows.

$$^{7}_{3}\mathbf{Li} + {}^{1}_{1}\mathbf{H} \rightarrow {}^{4}_{2}\mathbf{He} + {}^{4}_{2}\mathbf{He} + \textbf{Energy}$$

Use data from pages 47 and 83 of the *Formulae and Tables* booklet to calculate the number of joules of mass-energy released when two helium nuclei are produced in this reaction. (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*) Give the symbol, atomic number and mass number for a neutral atom that contains 12 neutrons and 11 electrons.

(*b*) Why is the first ionisation energy value of boron less than that of carbon?

(*c*) What are *isotopes*?

(*d*) Define relative atomic mass.

(*e*) Balance the following chemical equation.

$$\mathbf{Na_2S_2O_3 + HCl \rightarrow NaCl + H_2O + S + SO_2}$$

(*f*) The eye make-up effect illustrated in **Figure 8** was achieved using a black iron oxide pigment in the mascara and eyeliner.
Calculate the percentage by mass of iron in this iron(III) oxide (**Fe_2O_3**) pigment.
[O = 16; Fe = 56]

Figure 8

(*g*) What are *allotropes*?

(*h*) What is (*i*) the shape of, (*ii*) the value of the bond angle in, an ammonia (**NH_3**) molecule?

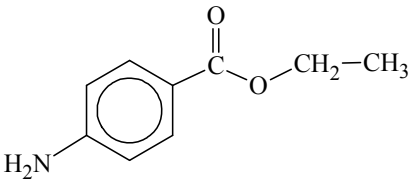
(*i*) What mass of magnesium will contain the same number of atoms as 8 g of calcium?
[Mg = 24; Ca = 40]

(*j*) Identify (*i*) the conjugate acid of $\mathbf{HS^-}$ (*ii*) the conjugate base of $\mathbf{H_2NO_3^+}$.

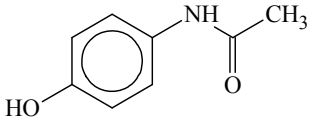
(*k*) Name or give the formula of an oxide that is (*i*) basic, (*ii*) amphoteric.

(*l*) Define the *heat of combustion* of a substance.

(*m*) Consider the structures of the two pain-relievers benzocaine and paracetamol shown in **Figure 9**.



benzocaine



paracetamol

Figure 9

Copy the structure that has an ester functional group into your answerbook and circle its carbonyl group.

(*n*) Name two products formed when sunlight falls on an equimolar mixture of methane and chlorine.

(*o*) Give a common everyday use for each of the organic chemicals:
(*i*) **CH_3COOH**, (*ii*) **CH_3COCH_3**.

(11 × 6)

8. (*a*) **Figure 10** shows how Bohr, in 1913, used the coloured lines in the hydrogen line emission spectrum to provide evidence for the existence of energy levels in the atom. We now understand that electrons in atoms actually occupy orbitals with defined energy values.

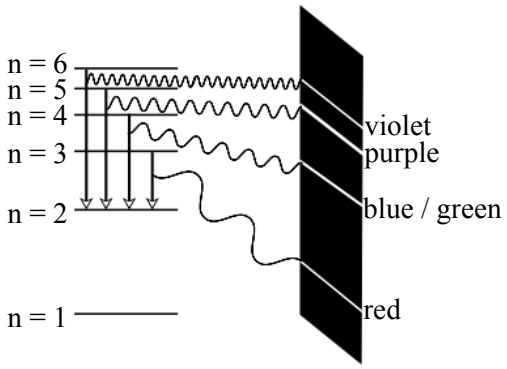


Figure 10

(*i*) Distinguish between the *ground state* and an *excited state* for an electron in a hydrogen atom.

(*ii*) Give two ways that an electron in a hydrogen atom can be excited.

(*iii*) To which two energy levels in **Figure 10** does the expression $E_a - E_b = hf$ refer in the case of the blue / green line on the line emission spectrum of hydrogen?

(*iv*) Explain why there is no yellow line in the hydrogen emission spectrum. (24)

(*b*) Flame tests also provide evidence for the existence of energy levels in atoms.

Describe how you would confirm the presence of lithium in a salt sample using a flame test. (12)

(*c*) Define an *atomic orbital*.

What is the maximum number of electrons that can occupy any atomic orbital?

Sketch the shape of (*i*) an *s* orbital, (*ii*) a *p* orbital. (15)

(*d*) Write the electron configuration of a nitrogen atom showing the arrangement of electrons in orbitals in the ground state.

How many (*i*) main energy levels, (*ii*) orbitals, are occupied by electrons in a nitrogen atom?

One of the electrons in a nitrogen atom is described by the set of quantum numbers {2, 0, 0, +½}. Specify the orbital occupied by this electron. (15)

9. A student titrated an ammonium hydroxide (**NH_4OH**) solution against 25.0 cm^3 volumes of a 0.10 M solution of hydrochloric acid (**HCl**). Ammonium hydroxide solution is a weak base. On average, 12.25 cm^3 of the ammonium hydroxide solution was required for neutralisation.
The equation for the titration reaction is as follows.

$$\mathbf{NH_4OH + HCl \rightarrow NH_4Cl + H_2O}$$

(*a*) Describe how a burette was prepared and filled for use in this titration. (12)

(*b*) Why is a conical flask usually preferable to a beaker as the container for a titration reaction? (6)

(*c*) Name a suitable indicator for this titration.
State the colour change observed at the end point of the titration.
Why should only one or two drops of indicator be used? (12)

(*d*) Calculate the concentration of the ammonium hydroxide solution in
(*i*) moles per litre,
(*ii*) grams per litre. (12)

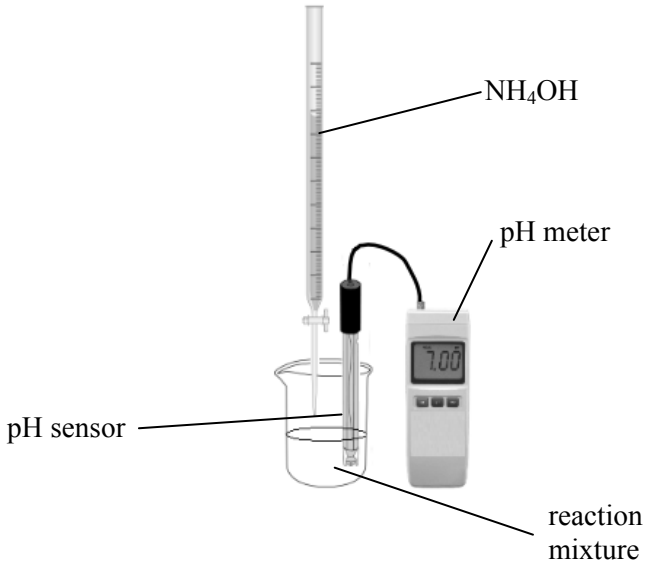


Figure 11

In one of these titrations the student also measured the pH of the contents of the beaker, as the ammonium hydroxide solution was added from the burette as shown in **Figure 11**. The data in the table were obtained.

Volume (cm^3) of **NH_4OH** added	0.0	6.0	10.0	11.0	11.7	12.0	12.2	12.4	12.9	15.0	20.0	22.0
pH	1.0	1.2	1.5	1.7	2.0	2.7	4.7	7.2	8.0	8.6	8.8	9.0

(*e*) Define pH.
Use the data in the table above to plot a graph of pH (*y*-axis) *versus* volume of ammonium hydroxide added (*x*-axis).
Use the volume of ammonium hydroxide solution required for neutralisation to estimate the pH at neutralisation from your graph. (24)

10. The following is a list of metals arranged in the order of their decreasing ease of oxidation: **K**, **Na**, **Ca**, **Mg**, **Al**, **Zn**, **Fe**, **Sn**, **Cu**, **Ag**.

(*a*) Define oxidation in terms of electron transfer.
What is the electrochemical series? (9)

(*b*) **Figure 12** shows two iron objects, one protected from corrosion by a zinc coat and the other by a coating of tin (**Sn**).
Explain how zinc and tin can protect iron from corrosion. (9)

Figure 12

(*c*) Explain which, if any, of the following is / are redox reactions.

$$2Al + 6H^+ \rightarrow 2Al^{3+} + 3H_2$$

$$2NaF + CaCl_2 \rightarrow 2NaCl + CaF_2$$

$$SnO_2 + 2C \rightarrow Sn + 2CO$$

Identify clearly any substance acting as an oxidising reagent in the reactions above. (18)

(*d*) Write a balanced equation for the reaction that occurs when a magnesium rod is dipped into a solution of zinc sulfate.
Why is there no reaction when a silver (**Ag**) rod is dipped into a solution of zinc sulfate? (9)

(*e*) During the electrolysis of molten potassium iodide (**KI**), purple iodine (I_2) vapour was observed at the anode and molten potassium metal was produced at the cathode.
Write a balanced equation for the reaction that took place at the anode.
What mass of potassium metal was produced when a current of 5 A flowed through the electrolyte for 6 minutes?
Explain how the current was conducted through the electrolyte. (21)

11. (*a*) (*i*) What name is given to 'families' of organic compounds that have the same functional group and the same general formula?
(*ii*) Explain the term *functional group*.
(*iii*) What general name is given to compounds that contain carbon and hydrogen only?
(*iv*) Distinguish between aliphatic and aromatic compounds.
(*v*) Name three families of aliphatic compounds that contain carbon and hydrogen only.
Draw the structural formula and give the IUPAC name for the second member of any two of the families you name. (39)

(*b*) Study the reaction scheme in **Figure 13** below and answer the questions that follow.

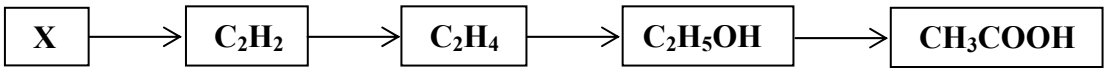


Figure 13

(*i*) Name the inorganic compound **X** and the compounds C_2H_2 and CH_3COOH.
(*ii*) Explain why C_2H_5OH is very soluble in water.
(*iii*) Name the type of reaction involved in converting C_2H_2 to C_2H_4.
(*iv*) Draw a labelled diagram to show how C_2H_2 is prepared by adding water to compound **X**.
(*v*) C_2H_2 and C_2H_4 both decolourise bromine water.
What information does this fact give about these compounds? (27)

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

(*a*) Define transition elements in terms of electron configuration.
Give a property characteristic of a transition metal compound.

Copper is a transition metal. A small part of its crystal structure is shown in **Figure 14**.
Describe the bonding within this metallic crystal.

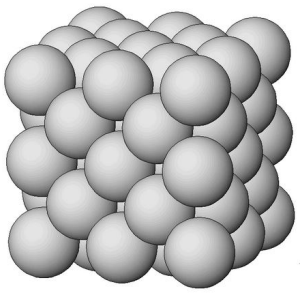


Figure 14

Explain in terms of the crystal structure and bonding why copper is
(*i*) an excellent electrical conductor,
(*ii*) a good conductor of heat.

(*b*) Describe the bonding in a chlorine ($\mathbf{Cl_2}$) molecule.
Define electronegativity.
Give a reason why electronegativity values increase across the third period of the periodic table.
Simple compounds of chlorine can have ionic or covalent bonding.
Referring to the electronegativity values of any of the first 18 elements, give the formula of a compound of chlorine that has (*i*) ionic bonding, (*ii*) polar-covalent bonding.
Explain whether you would expect **HCl** or **HBr** to have the stronger bond.

(*c*) Iron disulfide or iron pyrite ($\mathbf{FeS_2}$) was sometimes present in the building material that was used to fill spaces under floors. As described in the following chemical reactions, the iron disulfide reacted with oxygen and water to produce sulfuric acid; the sulfuric acid then reacted with calcium carbonate ($\mathbf{CaCO_3}$) present in concrete to produce calcium sulfate ($\mathbf{CaSO_4}$).

$$\mathbf{2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4}$$
$$\mathbf{CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2}$$

The subsequent expansion of the calcium sulfate crystals resulted in cracks in floors and walls. As a result of these reactions some buildings in Ireland suffered the kind of severe structural damage shown in **Figure 15**.

Figure 15

Calculate
(*i*) the number of moles contained in 3.6 kg of iron disulfide,
(*ii*) the number of moles of sulfuric acid formed when 3.6 kg of iron disulfide reacted,
(*iii*) the volume of oxygen, measured at s.t.p., required for this reaction,
(*iv*) the number of moles of calcium carbonate that reacted with the sulfuric acid formed,
(*v*) the mass of calcium sulfate formed.

(*d*) Define *heat of formation*.

Consider the following three heats of formation.

$$\mathbf{S_{(s)} + O_{2\,(g)} \rightarrow SO_{2\,(g)} \qquad \Delta H = -297.2\ kJ\ mol^{-1}}$$
$$\mathbf{H_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow H_2O_{(l)} \qquad \Delta H = -285.8\ kJ\ mol^{-1}}$$
$$\mathbf{H_{2\,(g)} + S_{(s)} \rightarrow H_2S_{(g)} \qquad \Delta H = -20.6\ kJ\ mol^{-1}}$$

Use Hess's law and the heats of formation above to calculate the heat change for the following reaction used to desulfurise fuels in oil refineries.

$$\mathbf{SO_{2\,(g)} + 2H_2S_{(g)} \rightarrow 3S_{(s)} + 2H_2O_{(l)}}$$

Why is it desirable to remove sulfur compounds from fuels as part of oil refining?

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