Coimisiún na Scrúduithe Stáit
State Examinations Commission

LEAVING CERTIFICATE EXAMINATION, 2014

PHYSICS AND CHEMISTRY – HIGHER LEVEL

MONDAY, 16 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 the acceleration due to gravity, $g = 9.8 \text{ m s}^{-2}$.

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*) Which of the following are vector quantities?

force **energy** **momentum** **mass** **speed**

(*b*) What quantity is defined as *the change in velocity per unit time*?

What unit is assigned to this quantity?

(*c*) A body moving in a straight line with a speed of 10 m s^{-1} had kinetic energy of 1500 J. When its speed increased to 40 m s^{-1}, what was its new kinetic energy?

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

(*e*) Copy **Figure 1** and complete it as a ray diagram showing the formation of the image of an object **O** placed between the focus **F** and the centre of curvature **C** of a concave mirror.

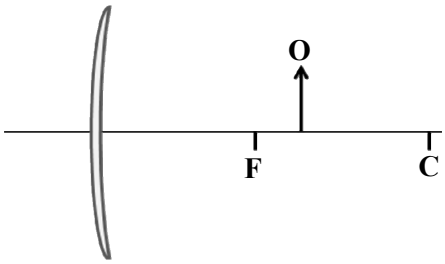

Figure 1

(*f*) What is meant by the *dispersion* of white light?

(*g*) What is the *photoelectric effect*?

(*h*) Calculate the energy of a photon of gamma radiation that has a frequency of 3.9×10^{22} Hz.

(*i*) What is *Brownian motion (movement)*?

(*j*) What is a *thermometric property*? Give an example.

(*k*) A sample of gas had an initial volume of 213 cm^3 at a temperature of 300 K. The temperature of the gas fell to 200 K without change of pressure.

What was the new volume of the gas?

(*l*) State *Coulomb's law* of force between electric charges.

(*m*) Two long, light wires **A** and **B** hang freely, side by side, but not touching as shown in **Figure 2**.

Why do the wires move when parallel currents *I* are passed through the wires?

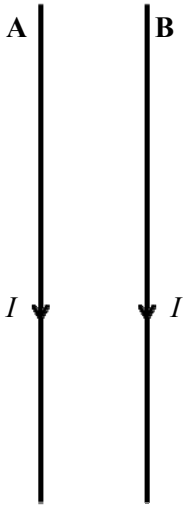

Figure 2

(*n*) What is meant by *nuclear fission*?

(*o*) Give **two** properties of a beta-particle.

(11 × 6)

2. (*a*) Define (i) work, (ii) power. (12)

(*b*) State *Newton's second law of motion*. (6)

(*c*) Draw a labelled diagram of an apparatus used to measure the acceleration caused by an applied force.
State
(i) one precaution taken to minimize the effects of friction,
(ii) how the applied force was measured,
(iii) how the timing system was used to measure the initial velocity. (24)

(*d*) The motion of an object of mass 1.5 kg on a smooth horizontal surface is represented by the graph in **Figure 3** and consists of two parts **A** (first 3 seconds) and **B** (final 2 seconds), as indicated.

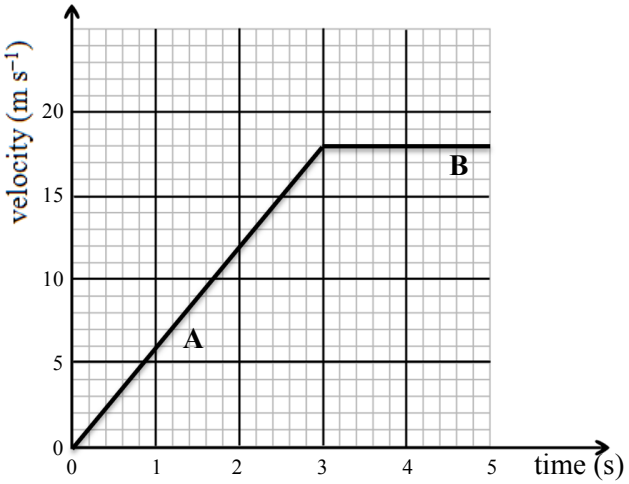

Figure 3

For part **A** of the motion, use the data in **Figure 3** and the equations of motion, to calculate
(i) the acceleration of the object,
(ii) the force applied to the object,
(iii) the work done,
(iv) the power developed.

For part **B** of the motion, what is
(v) the distance travelled,
(vi) the force acting on the object? (24)

3. (*a*) What is *refraction* of light?
State *Snell's law of refraction*. (12)

(*b*) Light travels along perspex optical fibres by *total internal reflection*.
(i) Define total internal reflection.
(ii) Give one application of optical fibres. (9)

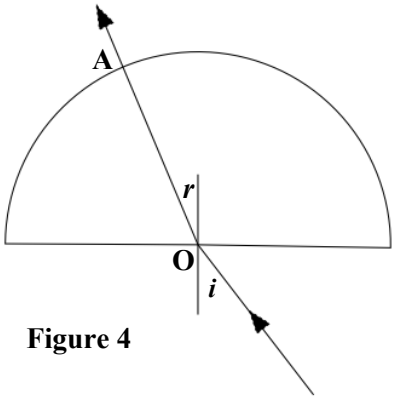

Figure 4

A student measured the angle of incidence *i* and the corresponding angle of refraction *r* for a ray of light entering a semi-circular perspex block at **O** and emerging again at **A** as shown in **Figure 4**.
This procedure was repeated for different angles of incidence *i* and the following results were obtained.

i (degrees)	5	15	25	35	45	54	63
r (degrees)	3	10	17	23	28	33	36

(*c*) Using the data above, draw a suitable graph to verify Snell's law.
Explain how the graph verifies Snell's law. (18)

(*d*) Use your graph to find the refractive index of the perspex. (9)

(*e*) Calculate the critical angle for the perspex. (6)

(*f*) Calculate the speed of light in the perspex. (6)

(*g*) Why does refraction **not** occur at **A** as the ray emerges from the perspex? (6)

4. (*a*) State *Boyle's law*.

Draw a labelled diagram of an apparatus used to investigate Boyle's law.

What measurements were taken?

How were these measurements used to verify Boyle's law? (21)

(*b*) Define the ideal gas.

State one way that the behaviour of a real gas differs from the behaviour of the ideal gas.

Under what conditions does a real gas behave most like the ideal gas?

What property of a gas is related to the average kinetic energy of its molecules? (18)

(*c*) Explain the terms (i) *absolute zero* of temperature, (ii) *triple point of water*.

What value is assigned to the triple point of water on the Kelvin temperature scale?

The pressure recorded using a constant volume gas thermometer at the triple point of water was 8.25 kPa. The pressure recorded at room temperature was 9.00 kPa.

What was the temperature in the room?

Give one advantage of a constant volume gas thermometer compared to other thermometers. (27)

5. (*a*) State *Ohm's law*.

Distinguish between alternating current (a.c.) and direct current (d.c.). (12)

(*b*) What is *electromagnetic induction*?

Fleming's right hand generator rule is used to determine the direction of the induced current in a conductor as shown in **Figure 5**.

Name the quantities represented by the arrows **A**, **B** and **C**. (15)

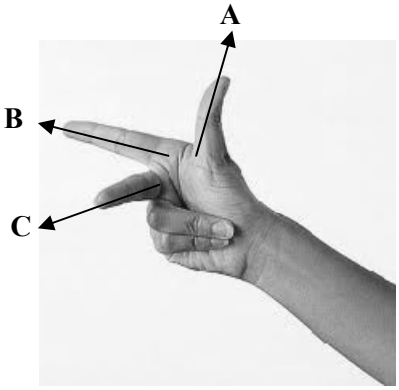

Figure 5

(*c*) **Figure 6** shows a step-down transformer.

Explain the operation of a transformer.

State one cause of energy loss in a transformer. (12)

(*d*) The step-down transformer in a mobile phone charger converts a 230 V a.c. mains supply to a 5 V a.c. output.

How many turns are required in the secondary coil of the transformer to give the 5 V output if the 230 V mains supply flows through 460 turns in the primary coil? (6)

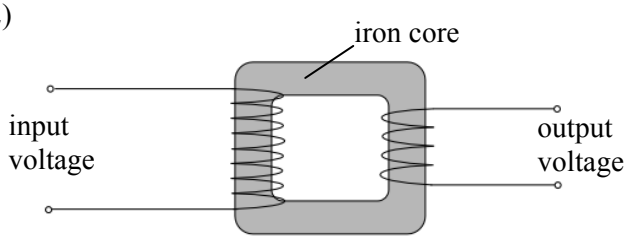

Figure 6

The transformer output is then converted to a 5 V direct current in order to charge the battery of the phone. The circuits of the charger and the connected phone have a *combined* resistance of 4.5 Ω.

Calculate

(i) the current flowing in the circuits of the charger and connected phone,

(ii) the power used when the phone is connected and charging,

(iii) the energy wasted in one week by a charger left on 'stand-by' 80% of the time while still using 0.125 W. (21)

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

(*a*) State *Newton's law of universal gravitation*. (6)

Two uniform lead spheres **A** and **B**, of different sizes and whose surfaces touch, are shown in **Figure 7**. The mass of **A** is 64 times the mass of **B** and the density of lead is 1.13×10^4 kg m^{-3}. Calculate

(i) the mass of sphere **A** whose volume is 0.0042 m^3,

(ii) the gravitational force between the two spheres when they are in contact. (21)

How would you expect the gravitational force between the two spheres to change as they are moved apart? Justify your answer. (6)

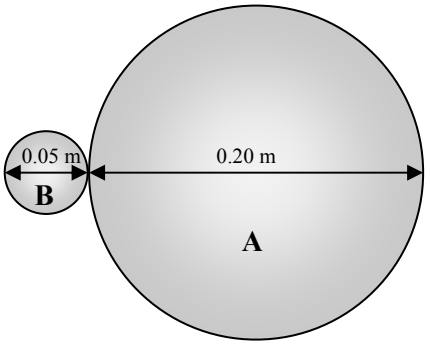

Figure 7

(*b*) Define *capacitance*. (6)

Describe an experiment to investigate how the capacitance of a parallel-plate capacitor depends on the distance between its plates. (9)

Calculate the effective capacitance of the combination of capacitors shown in **Figure 8**. (6)

The charge stored in the capacitor in a defibrillator can be used to shock the heart of a person in cardiac arrest back into a normal rhythm.

What charge is stored in a 32 μF capacitor in a defibrillator when it is connected to a 500 V supply? (6)

Give one other use for a capacitor. (6)

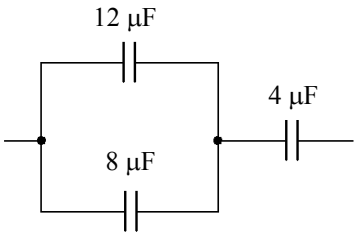

Figure 8

(*c*) Diffraction and interference both occur when a narrow beam of red monochromatic light passes through a pair of narrow slits whose separation is 0.3 mm. The light then strikes a screen 2.4 m from the slits forming a pattern of bright and dark images. The distance from the central bright image to the 6th bright image is 3.12 cm as shown in **Figure 9**.

Explain the underlined terms. (15)

Calculate the wavelength of the red light used. (12)

What did Thomas Young conclude about the nature of light, when he pioneered this experiment in 1801? (6)

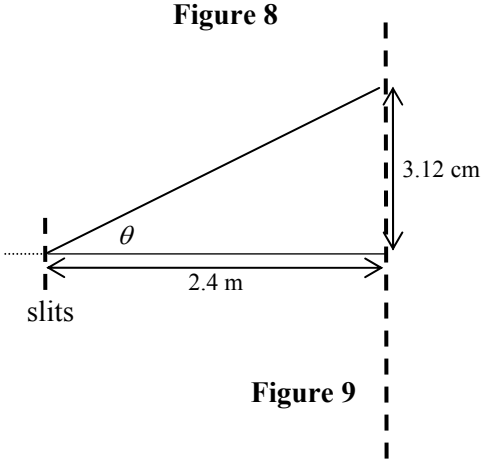

Figure 9

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

Use the graph in **Figure 10** to estimate the half-life of radon–222, an alpha-particle emitter. (6)

What is an alpha-particle? (6)

Fracking is the process of drilling and injecting fluid at high pressure into the ground to release natural gas and oil trapped in rock. Radon–222 sometimes occurs in rocks as a result of the radioactive decay of uranium–238. Radon–222 gas could be released into the environment as a result of fracking.

Starting with one U–238 nucleus, how many (i) alpha-particles, (ii) beta-particles, are released in the production of one Rn–222 nucleus by radioactive decay? Refer to pages 79 and 82 of the *Formulae and Tables* booklet.

State one way that a radioactive gas like radon–222 can damage human tissue. (15)

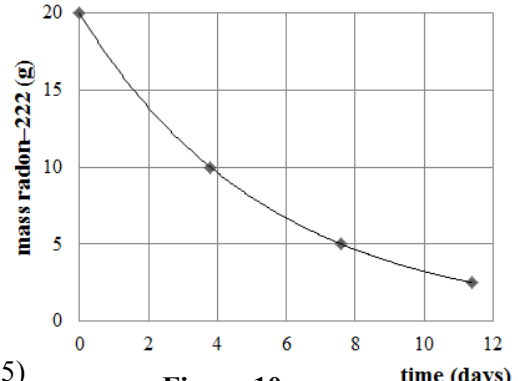

Figure 10

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*) In a crystal of potassium chloride (**KCl**), an ionic compound, identify (i) the particles that occupy the lattice points, (ii) the forces that bind these particles together.

(*b*) What name is given to the energy change represented by the following equation?

$$\mathbf{X_{(g)} \rightarrow X^{+}_{(g)} + e^{-}}$$

(*c*) Define a *mole* of a chemical.

(*d*) Give a reason why the atomic radii of the elements in the periodic table (i) decrease across a period, (ii) increase down a group.

(*e*) Balance the following chemical equation.

$$\mathbf{Al + HCl \rightarrow AlCl_3 + H_2}$$

(*f*) Explain why boron trifluoride (**BF_3**) does **not** have a dipole moment.

(*g*) *Superglue* is the trade name for methyl-2-cyanoacrlyate (**$C_5H_5NO_2$**). It is used in forensic science to help make hidden fingerprints visible as shown in **Figure 11**.
Calculate the percentage by mass of the element oxygen in methyl-2-cyanoacrylate.
[**H** = 1; **C** = 12; **N** = 14; **O** = 16]

Figure 11

(*h*) Give two chemical properties associated with transition metals or their compounds.

(*i*) Write the names or formulae of **two** compounds that contain both hydrogen and oxygen only.

(*j*) Identify (i) the conjugate acid of **NH_2^-** (ii) the conjugate base of **H_3O^+**.

(*k*) Distinguish between an *exothermic* and an *endothermic* reaction.

(*l*) Define *heat of formation* of a substance.

(*m*) What is the functional group in (i) an aldehyde, (ii) a ketone?

(*n*) Name **two** of the aromatic compounds labelled **A**, **B**, **C** in **Figure 12**.

A	B	C
CH_3	OH	NO_2

Figure 12

(*o*) Propyl ethanoate (**$CH_3COOC_3H_7$**) is an ester that has the odour of pears. What two substances react to form propyl ethanoate?

(11 × 6)

8. Atoms of carbon exist as isotopes, e.g. carbon–12, carbon–14. The element carbon occurs in different allotropic forms, e.g. graphite, diamond.

(*a*) Define (i) *mass number*, (ii) *relative atomic mass*.
Explain why the relative atomic mass of naturally occurring carbon is **not** a whole number. (15)

(*b*) Write the electron configuration (*s*, *p*) for a carbon atom. (6)

(*c*) Use dot and cross diagrams to show the bonding in a molecule of methane (**CH_4**).
State and explain the bond angle in a methane molecule. (12)

(*d*) Define *electronegativity*.
Identify the type of bond that occurs in a water molecule.
Predict the solubility or otherwise of methane in water, justifying your answer in terms of bonding. (15)

(*e*) **Figure 13** shows parts of the crystal structures of diamond (**A**) and graphite (**B**).
What type of bond holds the carbon atoms together in diamond?
In graphite, what type of bonding force holds
(i) the carbon atoms together within each layer,
(ii) the layers together?
Which of these two allotropes is a good electrical conductor?
Explain how electricity is conducted through this allotrope. (18)

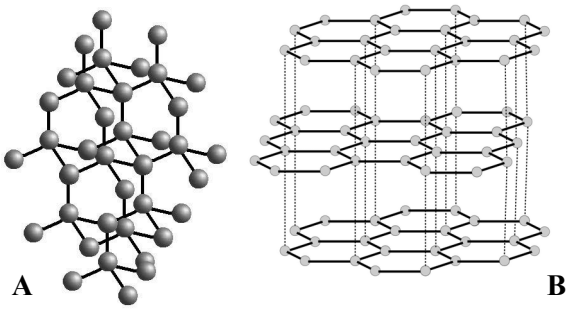

Figure 13

9. To determine the concentration of a barium hydroxide (**$Ba(OH)_2$**) solution, a student titrated it in 25.0 cm^3 volumes against a 0.18 M solution of hydrochloric acid (**HCl**). On average, 23.08 cm^3 of the hydrochloric acid solution was required for neutralisation. Because hydrochloric acid is not a primary standard, it had been previously standardised by titrating it with a suitable primary standard base.

(*a*) Explain the underlined term.
Name a suitable primary standard used to standardise the hydrochloric acid solution. (9)

(*b*) Having rinsed a 25.0 cm^3 pipette with deionised water for use in the titration, why was it then rinsed with a little of the solution it was to deliver?

Figure 14 shows the level of solution in the pipette before it was released into a titration flask. Explain whether the pipette had been filled correctly or incorrectly to 25.0 cm^3.

Describe the procedure for transferring exactly 25.0 cm^3 of solution to a titration flask from this pipette, assuming it has been correctly filled. (15)

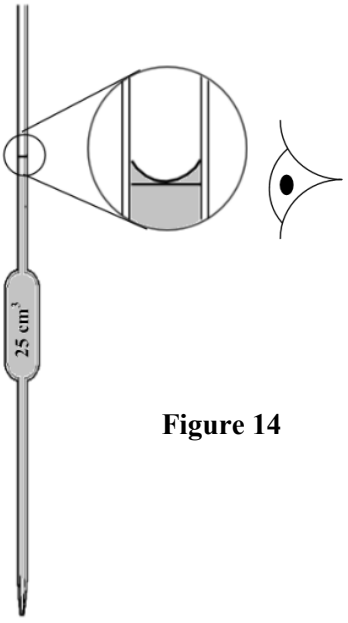

Figure 14

(*c*) Give a reason why
(i) a *conical* flask is suitable for use as the titration flask,
(ii) the sides of the conical flask were washed down with deionised water a few times during the titration,
(iii) the conical flask may have been placed on a white tile during the titration. (15)

(*d*) Barium hydroxide is a strong base.
Name an indicator suitable for this titration.
State the colour change observed at the end point. (9)

(*e*) Write a balanced equation for the titration reaction. (6)

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

10. (*a*) Define (i) oxidation, (ii) reduction, in terms of electron transfer. (6)

(*b*) When lead sulfide (**PbS**) is roasted in air, lead oxide (**PbO**) is formed. When lead oxide is heated with coke (**C**), lead (**Pb**) metal is obtained.

Identify the oxidising agent in each of these reactions given by the following equations.

$$\mathbf{2PbS + 3O_2 \rightarrow 2PbO + 2SO_2}$$

$$\mathbf{2PbO + C \rightarrow 2Pb + CO_2}$$

(6)

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

gold **sodium** **copper** **aluminium** **lead**

Which of these metals may be found free in nature? (12)

(*d*) What is *electrolysis*?

State *Faraday's first law of electrolysis*. (12)

(*e*) Lead(II) bromide (**$PbBr_2$**) is an ionic compound that has a low melting point. **Figure 15** shows the electrolysis of molten lead(II) bromide using inert electrodes **X** and **Y**.

(i) Suggest a material suitable for the electrodes.

(ii) How is the current conducted through the molten electrolyte?

(iii) At which electrode does oxidation occur?

(iv) Write a balanced equation for the reaction that occurs at the cathode. (15)

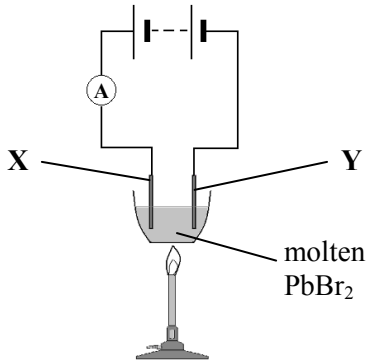

Figure 15

(*f*) When a current of 5.00 A was passed through molten lead(II) bromide for *t* seconds, 4.14 g of lead was deposited.

Calculate

(i) the number of moles of lead produced,

(ii) the number of electrons transferred to produce this lead,

(iii) the value of *t*. (15)

11. Ethene is a small hydrocarbon molecule and is the first member of the alkene homologous series.

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

(*b*) Draw the structure of the ethene molecule.

Give the names and structural formulae of **two** members of the alkene family that have four carbon atoms. (15)

(*c*) Describe, with the aid of a labelled diagram, an experiment to prepare ethene gas.

How could the gas be tested for unsaturation? (18)

(*d*) Name the reagent required, in each case, to convert ethene to

(i) ethane

(ii) chloroethane

(iii) 1,2-dichloroethane

(iv) ethanol.

What is the common type of reaction that occurs in each of these conversions? (15)

(*e*) Ethene burns in air with a luminous flame. Write a balanced equation for the complete combustion of ethene. (6)

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

(*a*) What is an atomic orbital?

Sketch the shape of a *p*-orbital.

What is the maximum number of electrons that can occupy a single *p*-orbital?

What information about an electron in an atom is given by

(i) the first (principal) quantum number,

(ii) the fourth quantum number?

What happens to an electron in an atom when it gains energy?

(*b*) Sulfuric acid (**H_2SO_4**) is a strong acid that is used in car batteries like that shown in **Figure 16**. The sulfuric acid is concentrated when the battery is fully charged. When the battery is 'flat' the sulfuric acid in the battery is very dilute.

Define *an acid* according to Brønsted-Lowry theory.

Distinguish between a *concentrated* solution and a *dilute* solution of an acid.

Distinguish between a *strong* acid and a *weak* acid.

Calculate the pH of a 0.06 M solution of sulfuric acid.

Figure 16

(*c*) The following balanced equation shows the reaction that occurs when ammonium nitrate (**NH_4NO_3**) decomposes when heated to form nitrogen(I) oxide (**N_2O**).

$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

Nitrogen(I) oxide gas is frequently used to anaesthetise patients during dental surgery and is sometimes known as 'laughing gas' because of the behaviour of many patients as they recover from its anaesthetic effects.

Would you expect nitrogen(I) oxide to be acidic, basic or neutral? Justify your answer.

A cylinder of nitrogen(I) oxide for use in a dental surgery contained 2200 g of the gas. Calculate

(i) the number of moles of nitrogen(I) oxide contained in the cylinder,

(ii) the volume that this gas would occupy at s.t.p.,

(iii) the mass of ammonium nitrate that decomposed to produce this quantity of gas,

(iv) the number of water molecules formed in this reaction.

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

Consider the following three heats of reaction.

$$2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)} \qquad \Delta H = -566.0 \text{ kJ}$$
$$CO_{(g)} + 2H_{2(g)} \rightarrow CH_3OH_{(l)} \qquad \Delta H = -128.1 \text{ kJ}$$
$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)} \qquad \Delta H = -571.6 \text{ kJ}$$

Use Hess's law and the heats of reaction above to calculate the heat change for the following reaction.

$$2CO_{2(g)} + 4H_2O_{(l)} \rightarrow 2CH_3OH_{(l)} + 3O_{2(g)}$$

Hence find the heat of combustion of methanol (**CH_3OH**).

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