Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2012

Marking Scheme

Physics and Chemistry

Higher Level

General Guidelines

In considering this marking scheme the following points should be noted.

1. In many instances only key words are given, i.e. words that must appear in the correct context in the candidate's answer in order to merit the assigned marks.

2. Marks shown in square brackets represent marks awarded for partial answers as indicated in the scheme.

3. Words, expressions or statements separated by a solidus, /, are alternatives which are equally acceptable.

4. Answers that are separated by a double solidus, //, are answers which are mutually exclusive. A partial answer from one side of the // may not be taken in conjunction with a partial answer from the other side.

5. The descriptions, methods and definitions in the scheme are **not** exhaustive and alternative valid answers are acceptable. Marks for a description may be obtained from a relevant diagram, depending on the context.

6. Where indicated, 1 mark is deducted for incorrect/ no units.

7. Each time an arithmetical slip occurs in a calculation, one mark is deducted.

8. The context and the manner in which the question is asked and the number of marks assigned to the answer in the examination paper determines the detail required in any question. Therefore, in any instance, it may vary from year to year.

Question 1

Any eleven parts **11×6**

(*a*) **Define *displacement*.** **2×3**
distance …3
in a given direction …3

(*b*) **State *the principle of conservation of momentum.*** **2×3**
(in a system of colliding bodies) where no external force acts total momentum //
(in a system of colliding bodies) where no external force acts the total momentum before a collision // (in a system of colliding bodies) where no external force acts $m_1u_1 + m_2u_2 =$ …3

is constant // is equal to total momentum after // $m_1v_1 + m_2v_2$ or $(m_1 + m_2)$v …3
[where no external force omitted …(–1)]

(*c*) **Calculate the work done when a crane lifts a 125 kg object from the ground to a height of 50 m, as shown in Figure 1.** **2×3**
$W = F \times s$ / $W = mgh$ / $W = mg$ = 1226.25 N (1226.25 – 1250 N) …3
(W =) = 125 × 9.8 × 50 = 61250 (J) = 61.250 (kJ) (61250 -62500 J) …3

(*d*) **When an image of an object is formed, what is meant by lateral inversion?** **5, 1**
image appears reversed …5
from left to right …1
[diagram may be used to explain][example …3]

(*e*) **The dotted lines in Figure 2 represent light rays striking three different diamonds, whose shapes are classified as shallow cut, ideal and deep cut.**
What phenomenon occurs at (i) A, (ii) B? **2×3**
A: refraction / bending …3
B: total internal reflection …3
[accept dispersion for A]

(*f*) **Give two properties of ultraviolet radiation.** **5, 1**
causes fluorescence, cannot travel through glass, can travel through quartz, higher frequency than visible light, shorter wavelength than visible light, electromagnetic radiation, travels at 3×10^8 m s^{-1} / causes skin cancer or melanoma or sunburn or suntan, invisible, etc
first correct…5
second correct…1

(*g*) **What is the *photoelectric effect* ?** **2×3**
release of electrons from metal surface / release of electrons from zinc …3
when light or electromagnetic radiation of suitable frequency is incident on it / when ultra-violet light is incident on it …3

(*h*) **Give two examples of a thermometric property.** **5, 1**
volume or height of liquid (in a column), volume of gas (at constant pressure), pressure of gas (at constant volume), product of pressure and volume of a gas, emf (generated in a thermocouple), resistance (of metal or thermocouple), colour, etc.
first correct…5
second correct…1

(*i*) **The equation used to define temperature θ on the Celsius scale is $\frac{\theta}{100} = \frac{X_\theta - X_0}{X_{100} - X_0}$.**

What do X_θ and X_{100} represent? <u>2×3</u>

thermometric property value at temperature θ ºC …3

(thermometric property value) at upper fixed point / boiling point (of water) at 100 ºC …3

[specific thermometric property may be referred to]

(*j*) **State two assumptions of the kinetic theory of gases.** <u>5, 1</u>

large number of particles or molecules, particles or molecules have negligible volume, in constant motion, in rapid motion, in random motion, in straight line motion, collide with one another, collide with walls of the container, collisions elastic or involve neither loss nor gain of energy, collision times of short duration, no interaction between particles or molecules except during collisions, etc

first correct…5

second correct…1

(*k*) **Give one use for a capacitor.** <u>6</u>

tuning radio or TV stations, flash bulb in a camera, timer switches, to separate ac from dc, rectification, smoothing direct current, to reduce interference in radio signal, to prevent sparking in an induction coil, to start a motor, to store charge, etc

any one…6

(*l*) **A student is asked to charge an electroscope positively by induction. A negatively charged rod was brought near the cap of the electroscope as shown in Figure 3.**
What steps must be carried out next to complete the process? <u>2×3</u>

touch cap with finger // earth cap

take away finger // for a moment

take away rod

any two …2×3

(*m*) **Calculate the heat energy produced when a current of 13 A flows through a piece of fuse wire of resistance 0.1 Ω and melts it in 0.2 s.** <u>2×3</u>

heat energy = RI^2t …3

(heat energy =) $0.1 \times 13^2 \times 0.2 = 3.38$ (J) …3

(*n*) **What is meant by *mass-energy conservation* in nuclear reactions?** <u>2×3</u>

when a small amount of mass is destroyed / when mass is lost // mass-energy of products is equal …3

energy is released correspondingly or according to $E = mc^2$// to mass-energy of reactants …3

[$E = mc^2$ only ....3]

(*o*) **What conditions are required for nuclear fusion to occur?** <u>5, 1</u>

(joining together of two) small nuclei or light nuclei, at very high temperatures, overcoming nuclear repulsive forces

first correct…5

second correct…1

[‘energy required’ not sufficient]

Question 2

Define

(i) kinetic energy <u>6</u>

energy due to motion / (KE =)$\frac{1}{2}mv^2$ …6

[omit to explain m, v (–1)]

(ii) power. <u>2×3</u>

rate of // W ÷ or E ÷ // work done or energy used // F × …3

doing work / using energy // t // per unit time // v …3

[definition of Watt or (P) = VI …3] [omit to explain W or E, t or F, v or V, I (–1)]

State *Newton's second law of motion*. <u>2×3</u>

rate of change of momentum is proportional …3

to applied force and in same direction …3

[$F = ma$ …3, omit to explain F, m, a (–1)]

How is the unit of force, the newton, derived from Newton's second law of motion? <u>2×3</u>

rate of change of momentum ∝ applied force /

$(\frac{mv - mu}{t}) \propto F$ …3

$m \times (\frac{v - u}{t}) \propto F$

⇒ ($kma = F$) ⇒ $F = ma$, (where k = 1 when units of force are newtons) …3

or

$F = m \times a = m \times (\frac{v - u}{t})$ …3

$m \times (\frac{v - u}{t}) = (\frac{mv - mu}{t})$ = rate of change of momentum …3

[definition of a newton …3]

A student carried out an experiment to show that the acceleration of a moving body is proportional to the force applied.

Draw a labelled diagram of a suitable apparatus. <u>3×3</u>

trolley on sloped track or on a smooth frictionless horizontal track, e.g. air track …3

attached to weights or masses by string (passing over pulley) / attached to spring balance …3

timing using ticker tape timer, light gates, Fletchers trolley, timer, etc …3

[no labels (–3)]

[ticker tape instead of ticker (tape) timer (–1)]

State what measurements were made and how the relationship between acceleration and applied force was established. <u>3×3</u>

initial distance, final distance and interval distance or interval time / time through two light gates, distance between gates / calculate acceleration …3

note applied force / read weights or get mass × g for each run …3

graph (of acceleration versus (applied) force) is a straight line through origin/ graph shows they are directly proportional …3

transfer weights from trolley to end of string (to keep mass accelerated constant) …3

any three …3×3

[dots instead of spaces (–1)]

The driver of a Formula 1 racing car of laden mass 640 kg was travelling at 75 m s^{-1} along a straight, horizontal stretch of a racing circuit, as shown in Figure 4. The driver applied the brakes over the last 25 m to reduce the speed to 60 m s^{-1} to negotiate the next bend of the circuit.

Calculate

(i) the acceleration of the car approaching the bend **2×3**

$v^2 = u^2 + 2as$ / 3600 = 5625 + (2× a × 25) …3

a = – 40.5 m s^{-2} …3

[allow positive or negative sign or 40.54]

[no unit or incorrect unit (–1)]

(ii) the time spent braking **2×3**

$v = u + at$ / $t = (\frac{v-u}{a})$ …3

$(t =)\ (\frac{60-75}{-40.5}) = 0.37$ s …3

[no unit or incorrect unit (–1)]

[accept $s = ½(v + u)$ t followed by $v = u + at$ to give answers to (i) and (ii) in reverse order]

(iii) the force applied by the brakes **3**

$F = ma$ = 640 × (– 40.5) = – 25 920 N …3

[no unit or incorrect unit (–1)]

[allow positive or negative sign]

(iv) the power required generated during braking **2×3**

$P = (\frac{W}{t}) = \frac{F \times s}{t}$ / $P = (\frac{W}{t}) = \frac{1}{2}\frac{m(v^2 - u^2)}{t}$ …3

$(P =)\ \frac{25920 \times 25}{0.37}$ / $P = \frac{1}{2}\frac{640(75^2 - 60^2)}{0.37}$ = 1 751 351.35 W …3

[no unit or incorrect unit (–1)]

[negative sign(–1)]

What energy conversion takes place during braking? **3**

kinetic (energy) to sound or heat or vibration …3

Question 3

(*a*) State the laws of refraction of light. **4×3**

the incident ray, the refracted ray and the normal …3

all lie in the same plane …3

[reflection instead of refraction (– 3)]

sine angle of incidence / sin*i* // (ratio of) sine angle of incidence to sine angle of refraction / $\frac{\sin i}{\sin r}$ …3

is proportional to sine angle of refraction / ∝ sin*r* // is constant or equal to refractive index or *n* or *μ* 3

[sines omitted (– 3), reflection instead of refraction (– 3)] [no need to explain *i*, *r* etc]

(*b*) In terms of light rays, distinguish between a real image and a virtual image. **6**

real image formed by (actual) intersection of light rays / virtual image formed by apparent intersection of light rays …6

[real image inverted or can be formed on a screen / virtual image upright or cannot be formed on a screen …3]

(*c*) Describe, with the aid of a labelled diagram, an experiment to measure the focal length of a convex (converging) lens. **5×3**

convex lens, ray box, screen // convex lens, pin and search pin // convex lens, pins or ray box and screen and plane mirror …3

correctly arranged in labelled diagram …3

move screen to locate sharply focussed image / find image by no parallax …3

measure object distance and image distance // measure *u* and *v* (if marked on diagram) …3

use formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ / use intercepts of graph of $\frac{1}{u}$ versus $\frac{1}{v}$ / where object and image reflected by plane mirror are equidistant from lens, this distance is focal length …3

[approximate method …6 max]

(*d*) An object is placed 30 cm in front of a convex lens of focal length 12 cm.
Calculate (i) the distance of the image of this object from the lens **2×3**

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}, \ \frac{1}{12} = \frac{1}{30} + \frac{1}{v}$ …3

$\frac{1}{v} = \frac{1}{12} - \frac{1}{30} = \frac{1}{20} \Rightarrow v = 20 \text{ cm}$ …3

[–20 cm (–1)] [no unit or incorrect unit (–1)]

[treat errors with fractions as mathematical slip]

(ii) the magnification of the image relative to the object. **2×3**

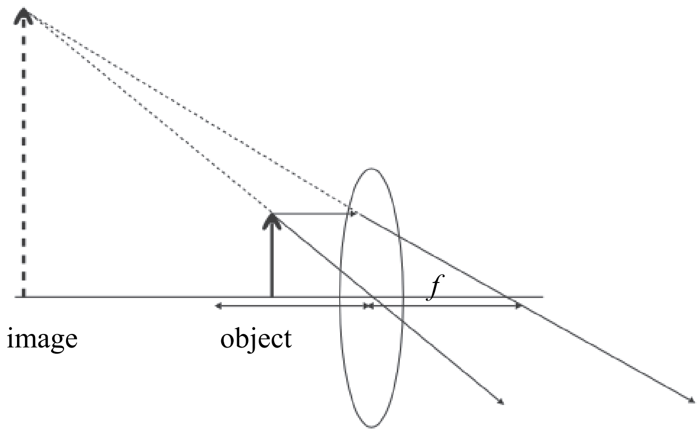
$m = \frac{v}{u}$ …3

$m = \frac{20}{30} = \frac{2}{3}$ or 0.67 …3

[inverted *m* = 1.5 …3]

(*e*) **Draw a diagram to show the formation of an image in a convex lens when it is used as a simple microscope (magnifying glass).** <u>**3×3**</u>

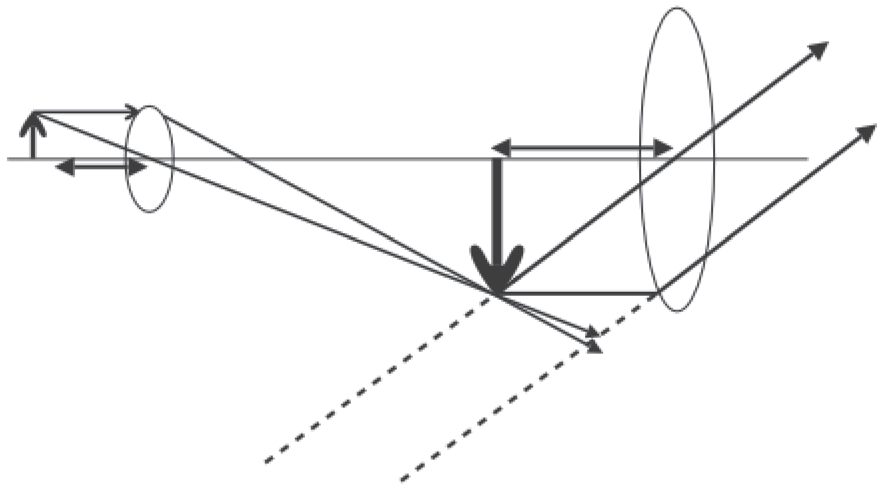
object shown inside focus labelled (on either side) of convex lens …3
one ray refracted correctly …3
ray(s) projected back to form upright magnified image on same side of lens as object …3



[concave lens with image drawn correctly using two rays …6]

(*f*) **A compound microscope consists of two convex lenses A and B of focal lengths f_A and f_B, respectively. An object O is placed just outside the focus of the objective lens A and its image I is formed at the focus of the eyepiece lens B as shown in Figure 5. Copy the diagram into your answer book and show the formation of the final image by the eyepiece lens B.** <u>**2×3**</u>

one ray refracted correctly …3
two parallel rays …3
[objective lens acting like simple microscope (–1)]



Describe the final image. <u>**6 or 2×3**</u>

at infinity / magnified …6

or

inverted / upright …3
real / virtual …3

Question 4

(*a*) The gas laws describe the various relationships between the pressure, volume and temperature of a fixed mass of gas.

State *Boyle's law.* **2×3**

the pressure of a fixed mass of gas …3
is inversely proportional to its volume at constant temperature …3
[at constant temperature omitted (–1)]

or

P // PV // P_1V_1 …3
$\propto 1/V$ // is a constant // $= P_2V_2$ …3
[omit to explain P and V (–1)] [at constant temperature omitted (–1)]

Describe, with the aid of a labelled diagram, an experiment to verify Boyle's law. **6×3**

fixed volume of gas shown in diagram ...3
scale to read volume shown in diagram ...3
pressure gauge / device to read pressure drawn ...3
record (one) pressure and (corresponding) volume ...3
repeat (for different pressures and volumes) ...3
PV = constant / graph of P versus $1/V$ straight line through the origin stated or shown in a diagram ...3
[no diagram of apparatus, diagram of apparatus without labelling (–3)]

Distinguish between a real gas and an ideal gas. **2×3**

an ideal gas obeys gas laws or Boyle's law or satisfies kinetic theory assumptions …3
at all temperatures and pressures …3
[temperature or pressure omitted (–1)]

or

a real gas obeys gas laws or Boyle's law or satisfies kinetic theory assumptions …3
except at high pressure and low temperatures …3
[temperature or pressure omitted (–1)]

or

molecules of a real gas have volume / particles or molecules of an ideal gas are point masses or have no volume / there are attractive forces between the molecules of a real gas / there are no forces between the particles or molecules of a ideal gas / real gases condense / ideal gasses never condense.

any two …2 ×3

Under what conditions of (i) temperature, (ii) pressure, do real gases behave most like ideal gases? **2×3**

(i) high temperatures …3
(ii) low pressures …3

Justify your answers. **6**

(under these conditions) the real gas does not condense (to a liquid) or has minimal intermolecular attractive forces or the size of the molecules in negligible compared to the space in between …6

(*b*) In Figure 6 the lines A and B show the experimental relationship between the volume V and the temperature θ on the Celsius scale for the same fixed mass of oxygen at two different pressures, $P_1 = 4.04 \times 10^5$ Pa and P_2, respectively.
Line C represents the relationship between volume and temperature of a fixed mass of an ideal gas.

Using the value of P_1 and the data provided in Figure 6,

(i) calculate the number of moles of oxygen gas in the sample 3×3

$PV = nRT$ …3

$4.04 \times 10^5 \times 0.005 = n \times 8.31 \times 273$ / $2.02 \times 10^5 \times 0.01 = n \times 8.31 \times 273$ …3

(n =) 0.89 …3

[any incorrect multiple of 0.89 (–3)]

[no substitution for R (–3)]

(ii) deduce the value of P_2 2×3

$P_1 V_1 = P_2 V_2$ / $4.04 \times 10^5 \times 0.005 = P_2 \times 0.01$ …3

$P_2 = 2.02 \times 10^5$ Pa …3

[no unit or incorrect unit (–1)]

(iii) state the value of X. 3

–273 °C or 0 K …3

[no unit or incorrect unit (–1)]

Describe the significance of the point (X, 0) on the graph. 2×3

temperature at which …3

ideal gas has no volume / real gas has minimal volume / the movement of the gas molecules is minimal or stopped …3

[absolute zero or the lowest temperature theoretically possible…3]

Question 5

State *Ohm's law.* <u>**2×3**</u>

at constant temperature current is proportional to or $I \propto$ // at constant temperature potential difference is proportional to or $V \propto$ // at constant temperature V = …3

potential difference or V // current or I // IR …3

[omit at constant temperature (–1), omit to explain terms (–1)]

Define *the ampere,* SI unit of current. <u>**3×3**</u>

two (infinitely) long parallel conductors / of negligible cross sectional area / one metre apart in a vacuum / exert a force of 2×10^{-7} newton per metre or 2×10^{-7} N m^{-1}

any three …3 ×3

The circuit shown in Figure 7 was used to investigate Ohm's law for a metallic conductor. The current *I* through the conductor was measured for different values of the potential difference *V* across it.

The following data were recorded.

***V*/V**	**1.00**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**7.00**	**8.00**
***I*/A**	**0.08**	**0.17**	**0.25**	**0.33**	**0.40**	**0.46**	**0.49**	**0.51**

(i) **Using the data, draw a suitable graph to show the relationship between potential difference *V* and current *I* for the conductor.** <u>**5×3**</u>

axes labelled V and I or voltage or potential difference and current …3

suitable scales marked V and A or volts and amp(ere)s …3

six points plotted accurately …3

suitable straight line through first five points …3

curve through last three or four points …3

(ii) **Explain why the graph verifies Ohm's law for this conductor at low currents ($I < 0.4$ A) but not at higher currents ($I > 0.4$ A).** <u>**2×3**</u>

straight line through the origin when $I < 0.5$ A or at low currents

curve when $I > 0.4$ A or at higher currents / current and voltage not proportional when $I > 0.4$ A or at higher currents

(iii) **Suggest a reason why the conductor only obeys Ohm's law when the current *I* flowing through it is small.** <u>**3**</u>

temperature constant / little or no heating effect / resistance constant …3

(iv) **Use your graph to calculate the resistance *R* of the metallic conductor at low currents** <u>**2×3**</u>

correct coordinates of two points marked on straight line part of graph /angle line makes with positive sense of x-axis …3

[points may include origin and original data points if line drawn goes through them, otherwise (–1) for each]

using slope formula or tan method R = 11.75 – 13.25 Ω …3

[R inverted (–3), find correct resistance from table or average instead of graph (–3)]

Figure 8 shows a moving coil galvanometer.

(v) What is the principle of operation of a moving coil galvanometer? <u>**3×3**</u>

current carrying conductor …3

in a magnetic field …3

experiences a force …3

(vi) What is the purpose of the restoring spring? <u>**3**</u>

force from spring balances electromagnetic force / stops the rotation or opposes the rotation …3

(vii) Explain how a resistor, called a shunt, is used to convert a moving coil galvanometer to an ammeter. <u>**3×3**</u>

(low) resistance …3

connected in parallel …3

causes (some or known proportion of) current to bypass galvanometer …3

Question 6

Answer any two parts. <u>**2×33**</u>

Question 6 (*a*)

State *Newton's law of gravitation.* <u>**2×3**</u>

force between two (point) masses is proportional to the product of the (two) masses …3

(and) inversely proportional to the square of the distance between them …3

[square omitted (–3)][word product omitted (–1)][sum instead of product of masses (–3)]

or

$F \propto \dfrac{Gm_1m_2}{d^2} \,/\, F = \dfrac{Gm_1m_2}{d^2}$ …6

[square omitted (–3)][sum instead of product of masses (–3)][omit to explain F, G, m, d (–1)]

[relationship between g and G …3]

Describe an experiment to measure to acceleration due to gravity, *g*. <u>**6×3**</u>

string, bob // ball, trapdoor // any free falling object …3

point of suspension // electromagnet // light gates …3

arrangement correctly described or drawn …3

measure pendulum length, l // measure distance from electromagnet to trapdoor, s // measure distance between light gates, s …3

time for n oscillations // time for fall, t // t_1 and t_2 …3

use formula $T = 2\pi\sqrt{\dfrac{l}{g}}$ / find slope from graph of l versus T^2 // use formula $s = \tfrac{1}{2}gt^2$ / find slope from graph of s versus t^2 // $v^2 = u^2 + 2gs$ …3

Calculate the gravitational force between two objects, each of mass 5.0 kg, when the distance between them is 0.25 m on a horizontal table. <u>**2×3**</u>

$(F =)\dfrac{Gm_1m_2}{d^2}$

or

$\dfrac{6.67\times10^{-11}\times5\times5}{(0.25)^2}$ …3

$(F =)\ 2.7\times10^{-8}$ N $[2.668\times10^{-8} - 2.7\times10^{-8}]$ …3

[no unit or incorrect unit (–1)]

Explain why this gravitational force does not cause movement of the two spheres towards each other. <u>**3**</u>

too small /friction too big / inertia …3

Question 6 (*b*)

What is meant by *interference* of waves? <u>**3**</u>
interaction of waves / meeting of waves / addition of waves …3

Distinguish between constructive interference and destructive interference. <u>**6**</u>
in constructive interference waves meet in phase or the amplitude of the new wave is greater than the amplitude of the original waves / in destructive interference the waves meet out of phase or the amplitude of the new wave is less than the amplitude of the original waves …6
[good labelled diagram acceptable]

Describe, with the aid of a labelled diagram, how you would demonstrate an interference pattern, using a monochromatic light source. <u>**3×3**</u>
named monochromatic light source or laser, Young's slits or diffraction grating, spectrometer or screen …3
correct arrangement …3
interference pattern or diffraction pattern described or drawn …3

Calculate the energy of a photon of <u>monochromatic light</u> of wavelength 589 nm. <u>**4×3 or 2×6**</u>

$c = f\lambda$ or $f = \frac{c}{\lambda}$ …3

$f = \frac{3\times10^{8}}{589\times10^{-9}} = 5.09 \times 10^{14}$ (Hz) …3

[incorrect multiple (–1)]

$E = hf$ …3
$E = 6.6 \times 10^{-34} \times 5.09 \times 10^{14} = 3.4 \times 10^{-19}$ J …3
[no unit or incorrect unit (–1)]

or

$E = hc \div \lambda$ …6
$E = 6.6 \times 10^{-34} \times 3 \times 10^{8} \div 589 \times 10^{-9} = 3.4 \times 10^{-19}$ J …6

Explain the underlined term. <u>**3**</u>
(light of) one frequency or one wavelength or one colour …3

Question 6 (*c*)

State *Faraday's law of electromagnetic induction*. **2×3**
emf (induced) is proportional to …3
rate of change in magnetic flux …3

or

$E \propto / E =$ …3
$(-N)\frac{d\phi}{dt}$ …3
[omit to explain terms (–1)]

Describe the behaviour of the electrons in a conductor carrying
(i) a direct current (d.c) **3**
in direct current or electrons flow or move in one direction only …3

(ii) an alternating current (a.c.). **3**
in alternating current or electrons move to and fro or reverse direction or oscillate …3
[flow in two directions not acceptable]
[two correct sketches of current versus time for (i) and (ii) …3
but voltage versus time not acceptable]

Describe, with the aid of a labelled diagram, how a transformer works. **4×3**
primary coil, secondary coil and iron core drawn …3
ac supply in either coil stated or in a label ….3
electromagnetic induction / changing magnetic flux linking the two coils …3
output voltage is determined by ratio of turns in primary and secondary coils /voltage is stepped up or stepped down …3
[no diagram, unlabelled diagram (–3)]

Give one way of reducing energy losses in a transformer. **3**
laminate the core, use a soft iron core, use core easily magnetised or demagnetised, reduce eddy currents, use a suitable shaped core, use wires or coils of low resistance, use thick wires (on the low voltage side), wind coils or wires tightly (around core), etc.
any one… 3

In Ireland the mains voltage is supplied at 230 V a.c. and in the United States of America the mains voltage is 110 V a.c.
A travel voltage adaptor purchased in Ireland for use in the United States of America, shown in Figure 9, contains a transformer designed to change a 110 V supply to a 230 V supply.

If the primary coil of the transformer has 46 turns, how many turns has the secondary coil? **2×3**
$\frac{V_p}{V_s} = \frac{N_p}{N_s}$ …3
$\frac{110}{230} = \frac{46}{N_s} \Rightarrow N_s = 96$ …3
[inverted, 22 turns ….3]

Question 6 (*d*)

The Japanese nuclear accident in March 2011 released radioactive iodine–131 and caesium–137, both beta particle emitters, into the environment. The half-life of iodine–131 is 8 days, the half-life of caesium–137 is 30 days. These leaked isotopes had been produced in the nuclear reactors by the nuclear fission of uranium-235 fuel.

(i) What is nuclear fission? **<u>2×3</u>**

splitting of a large nucleus / splitting of a heavy nucleus …3

into (two) smaller nuclei …3

(ii) Give two properties of beta particles. **<u>5, 1</u>**

negatively charged or charge of minus one, electrons, high speed particles, moderately penetrating, moderately ionising, deflected in an electric field, deflected in a magnetic field, negligible mass or very small mass or 1/1840 amu, speeds of 30 -70 % speed of light, stopped by a sheet of aluminium, stopped by a few meters of air, etc.

first correct…5

second correct…1

(iii) Why is there concern about the release of these fission products into the environment? **<u>3</u>**

beta particles are harmful or damaging to health …3

(iv) Why is there more concern about the caesium–137 than the iodine–131?

caesium–137 has a longer half-life / iodine–131 has a shorter half-life / caesium–137 decays into (chemically) reactive barium / iodine–131 decays into (chemically) unreactive xenon / lasts longer…3

(v) What fraction of the iodine–131 that leaked on a particular day would remain 32 days later? **<u>2×3</u>**

4 half-lives …3

one sixteenth remaining …3

(vi) Write a nuclear equation for the decay of iodine–131 nucleus when it emits a beta particle. **<u>3×3</u>**

$${}^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e}$$

${}^{131}_{53}\mathrm{I}$ …3

${}^{131}_{54}\mathrm{Xe}$ …3

+ ${}^{0}_{-1}\mathrm{e}$ as a product …3

[accept ${}^{0}_{-1}\beta$]

Question 7

Any eleven parts. **11×6**

(*a*) How many (i) neutrons, (ii) electrons, are there in the $^{9}_{4}Be^{2+}$ ion? **2×3**

(i) 5 …3
(ii) 2 …3
[reversed …3]

(*b*) Define the *first ionisation energy* of a mole of neutral gaseous atoms. **2×3**

minimum energy required to remove …3
outermost or most loosely bound electron(s) completely …3
[minimum omitted (–1), completely omitted (–1)]

(*c*) The crystal structure of diamond is shown in Figure 10. Explain in terms of bonding why diamond is difficult to cut. **2×3**

(each carbon atom has) four …3
(strong) covalent bonds (holding it in crystal) …3

(*d*) What do the terms E_2 and f represent in the equation $E_2 - E_1 = hf$? **2×3**

E_2: energy of excited state or higher energy level …3
f: frequency …3
[excited state or higher omitted (–1)]

(*e*) How many molecules are there in 672 cm^3 of carbon monoxide gas measured at STP? **2×3**

$672 \div 22400 = 0.03$ (moles) …3
$0.03 \times 6 \times 10^{23} = 1.8 \times 10^{22}$ (molecules) …3

(*f*) Distinguish between an *exothermic* reaction and an *endothermic* reaction. **6**

exothermic reaction gives out heat /endothermic reaction absorbs heat …6

(*g*) Why does sodium chloride conduct electricity when in solution but not in the solid state? **2×3**

ions …3
free to move in solution / not free to move in solid …3

(*h*) Calculate the pH of a 0.05 M solution of potassium hydroxide. **2×3**

(pOH =) $-\log_{(10)}[OH^-] = -\log_{(10)}[0.05] = 1.3$ …3
$14 - 1.30 = 12.7$ …3

(*i*) Write a balanced equation for the vigorous reaction that occurs between sodium and water. **2×3**

$2Na + 2H_2O \rightarrow 2NaOH + H_2$ / $Na + H_2O \rightarrow NaOH + \frac{1}{2}H_2$
NaOH product …3
H_2 product …3

(*j*) Give a major use for (i) sulfur dioxide, (ii) hydrogen peroxide. **5, 1**

(i) food preservative, sulfuric acid manufacture, bleaching paper, etc
(ii) oxidising reagent, bleach, etc

first correct…5
second correct…1

[acid rain for SO_2 …3]

(*k*) Balance this chemical equation: $Fe_2O_3 + CO \rightarrow Fe + CO_2$ **2×3**

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
iron balanced …3
carbon and oxygen balanced …3

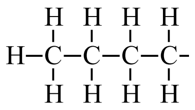
(*l*) **Calculate the percentage of chlorine by mass in a rat poison containing barium chloride ($BaCl_2$).** **2×3**

(M_r) = 208 …3

$\frac{71}{208} \times 100 = 34.13$ % (34%) …3

[atomic numbers used instead of mass numbers …3]

(*m*) **Draw the structure of an isomer of 2-methylproane.** **6**



…6

[hydrogen atoms need not be explicitly shown but carbon atoms must]

[2-methylpropane …3]

(*n*) **An mixture of one mole of methane and one mole of chlorine is exposed to sunlight. Write the equation for this reaction.** **5, 1**

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

either product correct …5

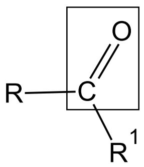
second product and balanced …1

[accept higher substituted products if HCl is also produced]

(*o*) **When an organic compound and phenylhydrazine was heated gently in a test tube as shown in Figure 11, an orange precipitate appeared. This result confirms the presence of a carbonyl group in the organic compound. Draw the structure of the carbonyl group.** **6**

drawing must show carbon joined by double bond to oxygen and carbon able to form two other single bonds …6

[C=O or CO alone …3]



Question 8

(*a*) **Define**

(i) **atomic number** <u>**3**</u>

number of protons (in an atom) …3

(ii) **mass number** <u>**3**</u>

number of protons and neutrons (in an atom) …3

(iii) **relative atomic mass** <u>**2×3**</u>

average mass of (the mass numbers of) all the isotopes // mass of atom relative to …3
taking their natural abundances into account // 1/12th carbon-12 isotope …3

(*b*) **Naturally occurring copper is composed of 69.15% $^{63}_{29}$Cu and 30.85% $^{65}_{29}$Cu.**

Calculate the relative atomic mass of copper correct to two decimal places. <u>**3×3**</u>

69.15 × 63 = 4356.45 / 30.85 × 65 = 2005.25 …3
4356.45 + 2005.25 = 6361.70 …3
6361.70 ÷ 100 = 63.6170 = 63.62 …3
[rounding off decimals too soon (–1) once][no marks for 63.55 without any calculation]

Describe the bonding in copper metal. <u>**2×3**</u>

positive (copper) ions …3
free electrons / valence electrons / electrons free to move …3
[metallic bond …3 max]

Copper is a transition metal. Give one characteristic property of a transition metal. <u>**3**</u>

variable valency / good catalysts / form coloured compounds any one…3
[accept correct electronic configuration definition of transition metals]

(*c*) **Define *electronegativity*.** <u>**2×3**</u>

measure of attraction / relative attraction / measure of the force of attraction (an atom in a molecule has) …3
for shared pair of electrons / for electrons in a covalent bond …3
[force of attraction (an atom in a molecule has) (–1)]

Use electronegativity values to predict the bonding in a molecule of ammonia (NH_3). <u>**2×3**</u>

3.04 (N) – 2.20 (H) = 0.84 / polar / covalent
any two… 2×3

Draw a diagram to show the bonding in a molecule of ammonia. <u>**2×3**</u>

three bond pairs between N and 3H's …3
one lone pair on N …3
[accept a pair of dots for a lone pair or a bond pair or a line to represent a covalent bond]

Use electron pair repulsion theory to predict the shape and bond angle in a molecule of ammonia. <u>**2×3**</u>

pyramidal / distorted tetrahedral …3
107º …3

Why does an ammonia molecule have a dipole moment? <u>**3**</u>

centre of positive charge and the centre of negative charge are not coincident / centres of charge separated …3

(*d*) **Identify the type of intermolecular bonding that occurs in ice and that is represented by the dotted lines in Figure 12.** <u>**3**</u>

hydrogen bonds …3

Give a property of liquid water that is associated with this type of intermolecular bonding. <u>**3**</u>

high melting point, high boiling point, high specific heat capacity, expansion of ice as it freezes, surface tension, capillary action, meniscus, ability to act as a solvent, etc

any one…3

What happens to these intermolecular bonds when water boils? <u>**3**</u>

they (all) break …3

Question 9

Overproduction of hydrochloric acid in the human stomach can cause discomfort known as 'indigestion' or 'heartburn'. This can be relieved by swallowing a basic substance or 'antacid'. Sodium hydrogencarbonate (bread soda) is sometimes used as an antacid.
A solution of sodium hydrogencarbonate was titrated with a <u>standard</u> solution of hydrochloric acid to determine the concentration of the sodium hydrogencarbonate solution.

The balanced equation for the titration reaction is:

$$HCl + NaHCO_3 \rightarrow NaCl + H_2O + CO_2$$

A few drops of methyl orange indicator were added to a conical flask containing a 25 cm^3 portion of the sodium hydrogencarbonate solution before commencing the titration. On average, the sodium hydrogencarbonate solution required 21.4 cm^3 of the 0.12 M hydrochloric acid solution for neutralisation.

(*a*) **Explain the underlined term above.** <u>3</u>

(solution of) known concentration / (solution of) exact concentration …3

(*b*) **Describe the procedure for rinsing, filling and using a pipette to deliver exactly 25 cm^3 of the sodium hydrogencarbonate solution.** <u>6×3</u>

rinse with deionised water …3
rinse with the sodium hydrogencarbonate solution / rinse with the solution it will contain …3

use pipette filler …3
fill to mark / fill above mark and release …3
bottom of meniscus on the mark ….3
read at eye level

release liquid …3
allow time to drain …3
do not dislodge or shake out or blow out the last drop (inside) …3
touch tip of pipette gently against wall of conical flask to dislodge any outside drop …3

any six…6×3

(*c*) **Two operations were carried out on the conical flask during the titration. What were these operations and what was the purpose of each one?** <u>4×3</u>

wash down the sides of the flask with (deionised) water …3
swirl …3
to ensure any spatters of solution participate in the reaction / to ensure complete reaction (of all the chemicals) …3
to mix contents / to ensure complete reaction (of all the chemicals) …3
[accept to ensure complete reaction twice or award it 6 marks if given only once]
[allow place on a white tile …3, to see colour change …3]

(*d*) **Why was it important not to use tap-water in the experiment?** <u>6</u>

tap water contains ions or chemicals / tap water is impure /
could affect the end point (volume) / could interfere with the end point (volume) / would make result inaccurate / other equivalent statement indicating interference with result

any one …6

(*e*) **State the colour change observed in the conical flask at the end point.** **2×3**

yellow (orange) to …3

peach / pink / red …3

[colours reversed …3]

Explain why methyl orange was a suitable indicator for this titration **3**

methyl orange is suitable for strong acid (weak base) titrations / the colour change pH range of methyl orange matches the change in pH at the end point of this titration …3

(*f*) **Calculate the concentration of sodium hydrogencarbonate solution in**

(i) **moles per litre** **2×3**

$\frac{V_1M_1}{n_1} = \frac{V_2M_2}{n_2}$ / (volume × molarity × proticity)$_1$ = (volume × molarity × proticity)$_2$ …3

$\frac{25 \times M_1}{1} = \frac{21.4 \times 0.12}{1} \Rightarrow M_1$ = 0.103 (M) = [0.1 - 0.103 (M)] …3

(ii) **grams per litre** **2×3**

(M_r) = 84 …3

0.103 × 84 = 8.652 (g/L) = [8.4 – 8.7 (g/L)] …3

(*g*) **What volume of stomach acid of concentration 0.12 M is neutralised by drinking 50 cm^3 of a bread soda solution of the same concentration as the sodium hydrogencarbonate used in this titration?** **2×3 or 6**

$\frac{V_1M_1}{n_1} = \frac{V_2M_2}{n_2}$ …3

$\frac{50 \times 0.103}{1} = \frac{V_2 \times 0.12}{1} \Rightarrow V_2$ = 42.92 (cm^3) = [41.67 – 42.92 (cm^3)] …3

or

21.4 × 2 = 42.8 cm^3 HCl …6

Question 10

Magnesium is a strong metal of low density, used with aluminium in the manufacture of lightweight alloys in the aerospace and automobile industries.
Magnesium occurs in seawater in the form of its salts, e.g MgO and $MgCl_2$.

(*a*) **Why does magnesium metal not occur free in nature?** <u>3</u>
too reactive / too easily oxidised / too high up the electrochemical series …3

(*b*) **Compare the reactivities of magnesium, aluminium and silver with water.** <u>3×3</u>
magnesium reacts slowly with cold water or magnesium reacts readily with steam …3
aluminium reacts with hot water or steam …3
[magnesium more reactive than aluminium contained in answer …6]

silver does not react with water / silver least reactive …3

(*c*) **Define**
(i) oxidation <u>3</u>
loss of electrons …3

(ii) reduction, in terms of electron transfer. <u>3</u>
gain of electrons …3
[for (i) and (ii) accept oxidation is gain of oxygen or loss of hydrogen *and* reduction is gain of hydrogen or loss of oxygen …3]

Magnesium metal is extracted from magnesium oxide at high temperatures in this reaction:

$$2MgO + Si \rightarrow 2Mg + SiO_2$$

Identify
(i) the substance reduced <u>3</u>
MgO or magnesium oxide or Mg^{2+} …3

(ii) the species that behaves as the reducing agent <u>3</u>
Si or silicon …3

How do pieces of scrap magnesium metal, that are attached to underground pipes or underwater structures made of iron or steel, protect these objects from corrosion? <u>3</u>
magnesium more reactive (than the iron) / magnesium is a sacrificial anode / magnesium oxidised by air more easily (than iron) / magnesium corrodes more easily than iron …3

(*d*) **Magnesium metal can also be extracted by the electrolysis of molten magnesium chloride using inert electrodes as shown in Figure 13.**

What is electrolysis? <u>**2×3**</u>
(electrolysis is a) chemical change / splitting up (of a chemical) …3
caused by electric current / electricity …3

State *Faraday's first law of electrolysis*. <u>**2×3**</u>
mass of an element (deposited at or liberated at an electrode) is proportional to …3
the charge that flowed / the charge that passed …3
[electricity, current, voltage not acceptable]

Write a balanced equation for the reactions at the cathode and at the anode. <u>**4×3**</u>
$Mg^{2+} + 2e^- \rightarrow Mg$
reactants and products correct …3
balanced …3

$Cl^- \rightarrow Cl + e^- \rightarrow \frac{1}{2}Cl_2$ or $Cl^- - e^- \rightarrow \frac{1}{2}Cl_2$ or any multiple of these
reactants and products correct …3
balanced …3
[omit $\rightarrow Cl_2$ (–1)]
[reversed order …6][if second equation given correctly on its own but not labelled 'anode' ..3]

Why must the magnesium chloride be molten? <u>**3**</u>
to conduct electricity / solid magnesium chloride is non-conducting …3

Calculate

(i) the charge that flows when a current of 90,000 A is passed through the molten magnesium chloride for 30 seconds <u>**3**</u>
$Q = It = 90\,000 \times 30 = 2.7 \times 10^6$ C …3
[incorrect units / no units (–1)]

(ii) the mass of magnesium produced . <u>**3×3**</u>
$(2.7 \times 10^6 \div 96485) = 27.98 = 28$ moles electrons …3
$28 \div 2 = 14$ (moles magnesium) …3
$14 \times 24 = 336$ (g) …3

[if first step inverted do not award the 3 marks]

Question 11

Figure 14 shows how a number of useful organic compounds can be inter-converted.

(*a*) Explain each of the following terms:

(i) ***functional group*** <u>**2×3**</u>

atom or group of atoms or type of bond …3

that gives a compound its characteristic chemical properties …3

(ii) ***homologous series*** <u>**2×3**</u>

(homologous series) is a group of (organic) compounds / with same chemical properties / same functional group / gradation in physical properties / differ by CH_2 / have common method of preparation

any two …2×3

(*b*) Ethanol is a good fuel and an important industrial solvent.
Name the homologous series to which ethanol belongs. <u>**3**</u>

alcohols …3

(*c*) Ethane, a saturated <u>hydrocarbon</u>, is a good fuel, but most ethane produced is converted into ethene, an <u>unsaturated hydrocarbon</u>. Explain the underlined terms. <u>**2×3, 6**</u>

(hydrocarbons contain the elements) carbon and hydrogen …3

only …3

double or triple bond (between carbon atoms) …6

(*d*) Give a major use for

(i) ethene <u>**3**</u>

ripening bananas or fruit, polymer industry, to make polythene or plastics, etc. …3

(ii) ethanoic acid. <u>**3**</u>

flavouring food, preserving food, pickling, etc. …3

(*e*) Name the reagent used in the school laboratory for conversion B, ethanol to ethene. <u>**3**</u>

aluminium oxide or Al_2O_3 / sulfuric acid or H_2SO_4 …3

(*f*) Identify the functional group in compound X. <u>**3**</u>

aldehyde or –CHO …3

[carbonyl (–1)]

(*g*) Identify

(i) an addition <u>**3**</u>

A or C or G …3

(ii) a substitution <u>**3**</u>

F or H …3

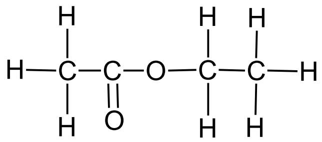
(iii) an oxidation, reaction in Figure 14. <u>**3**</u>

D or E …3

(*h*) **Describe, with the aid of a labelled diagram, an experiment to prepare ethyne, the gas used as the fuel in oxyacetylene welding.** **4×3**

water or H_2O and calcium carbide or calcium dicarbide or CaC_2 …3
dropping funnel or thistle funnel with long stem …3
lumps of dicarbide in flask with sidearm …3
collect ethyne gas over water …3
[no diagram max…9]

(*i*) **Write the name and draw the structural formula of $CH_3COOC_2H_5$ that can be used as a solvent to decaffeinate coffee and to remove nail polish.** **2×3**
ethyl ethanoate …3



…3

Question 12

Answer any three parts. <u>3×22</u>

Question 12 (*a*)

Define

(i) an atomic *energy level* <u>3, 2</u>

definite or fixed or specific energy …3

(of an electron) in an atom …2

(ii) an atomic *orbital* <u>2×3</u>

region in space (in an atom) / region around nucleus (of an atom) …3

where there is a high probability of finding an electron …3

[area (–1)]

Identify the type of atomic orbital drawn in Figure 15. <u>3</u>

p …3

Write the electron configuration (*s*, *p*) of a phosphorus atom. <u>2×3</u>

$1s^2 2s^2 2p^6$ …3

$3s^2 3p_x{}^1 3p_y{}^1 3p_z{}^1$ / $3s^2 3p^3$ ….3

How many atomic orbitals are occupied by electrons in a phosphorus atom in its ground state? <u>2</u>

nine …2

Question 12 (*b*)

Define

(i) *acid* <u>4</u>

proton donor …4

[dissociates to produce H^+ ..2]

(ii) *conjugate pair*, according to Brønsted-Lowry theory. <u>2×3</u>

two substances or species / an acid and a base …3

that differ by a proton or H^+ …3

Distinguish between a strong acid and a weak acid using this theory. <u>2×3</u>

strong acids are good proton donors or fully dissociated …3

weak acids are poor proton donors or slightly or weakly dissociated …3

[accept partially dissociated]

Identify a conjugate pair and a species acting as a base in the following reaction. <u>2×3</u>

$$\mathbf{H_2SO_4 + HCN \rightleftharpoons HSO_4^- + H_2CN^+}$$

H_2SO_4 and HSO_4^- / HCN and H_2CN^+ …3

[accept labels like A, CA, CB written above substances in balanced equation even if not linked by lines provided A written next to an acid and B next to a base]

HCN / HSO_4^- …3

[(–1) for each incorrect charge or charge omitted]

Question 12 (*c*)

Define the *mole*, the SI unit for the amount of a substance. <u>**6**</u>

same number of particles as 12 g carbon-12 / has 6×10^{23} particles or Avogadro number of particles / same mass as molecular mass in grams / gram molecular mass or gram molecular weight …6

The amphoteric compound aluminium oxide reacts with hydrochloric acid according to the following balanced equation.

$$\mathbf{Al_2O_3 + 6HCl \rightarrow 2AlCl_3 + 3H_2O}$$

Calculate

(i) the number of moles of aluminium oxide in 10.2 g of aluminium oxide <u>**2×3**</u>

(M_r) = 102 …3

$\frac{10.2}{102} = 0.1$ (moles) …3

(ii) the number of moles of water formed when this aluminium oxide reacts completely <u>**2**</u>

0.3 (moles) …2

(iii) the mass of aluminium chloride formed in the reaction <u>**3×2**</u>

0.1 (mole) …2

(M_r) = 133.5

…2

133.5 × 0.2 = 26.7 g …2

What is meant by the term *amphoteric*? <u>**2**</u>

(substance that can act as) both an acid and a base / (substance that can act as) either an acid or a base …2

Question 12 (*d*)

Define *heat of combustion.*	**2×3**
heat released or evolved when one mole (of a substance) / heat change (involved) when one mole (of a substance)	…3
is burned in excess oxygen or completely burned	…3
[heat involved (–1)]	

In the petrochemicals industry heptane C_7H_{16} is converted into the aromatic hydrocarbon C_7H_8 according to the following balanced equation.

$$C_7H_{16\,(l)} \rightarrow C_7H_{8\,(l)} + 4H_{2\,(g)}$$

Use Hess's law and the heats of reaction listed to calculate the heat produced in the formation of C_7H_8.

$$C_7H_{16\,(l)} + 11O_{2\,(g)} \rightarrow 7CO_{2\,(g)} + 8H_2O_{(l)} \quad \Delta H = -4854.9 \text{ kJ mol}^{-1}$$

$$C_7H_{8\,(l)} + 9O_{2\,(g)} \rightarrow 7CO_{2\,(g)} + 4H_2O_{(l)} \quad \Delta H = -3949.0 \text{ kJ mol}^{-1}$$

$$H_{2\,(g)} + \tfrac{1}{2}O_{2\,(g)} \rightarrow H_2O_{(l)} \quad \Delta H = -286.0 \text{ kJ mol}^{-1}$$

4×3

$C_7H_{16\,(l)} + 11O_{2\,(g)} \rightarrow 7CO_{2\,(g)} + 8H_2O_{(l)} \quad \Delta H = -4854.9 \text{ kJ mol}^{-1}$ …3

$7CO_{2\,(g)} + 4H_2O_{(l)} \rightarrow C_7H_{8\,(l)} + 9O_{2\,(g)} \quad \Delta H = 3949.0 \text{ kJ mol}^{-1}$ …3

$4H_2O_{(l)} \rightarrow 4H_{2\,(g)} + 2O_{2\,(g)} \quad \Delta H = 1144.0 \text{ kJ mol}^{-1}$ …3

$C_7H_{16\,(l)} \rightarrow C_7H_{8\,(l)} + 4H_{2\,(g)} \quad \Delta H = +238.1 \text{ kJ mol}^{-1}$ …3

The structure of a molecule of the aromatic hydrocarbon C_7H_8 is drawn in Figure 16.	
Name this compound.	**2×2 or 4**
methyl	…2
benzene	…2

or

toluene	…4