Coimisiún na Scrúduithe Stáit
State Examinations Commission

Leaving Certificate 2015

Marking Scheme

Physics and Chemistry

Higher Level

Note to teachers and students on the use of published marking schemes

Marking schemes published by the State Examinations Commission are not intended to be standalone documents. They are an essential resource for examiners who receive training in the correct interpretation and application of the scheme. This training involves, among other things, marking samples of student work and discussing the marks awarded, so as to clarify the correct application of the scheme. The work of examiners is subsequently monitored by Advising Examiners to ensure consistent and accurate application of the marking scheme. This process is overseen by the Chief Examiner, usually assisted by a Chief Advising Examiner. The Chief Examiner is the final authority regarding whether or not the marking scheme has been correctly applied to any piece of candidate work.

Marking schemes are working documents. While a draft marking scheme is prepared in advance of the examination, the scheme is not finalised until examiners have applied it to candidates' work and the feedback from all examiners has been collated and considered in light of the full range of responses of candidates, the overall level of difficulty of the examination and the need to maintain consistency in standards from year to year. This published document contains the finalised scheme, as it was applied to all candidates' work.

In the case of marking schemes that include model solutions or answers, it should be noted that these are not intended to be exhaustive. Variations and alternatives may also be acceptable. Examiners must consider all answers on their merits, and will have consulted with their Advising Examiners when in doubt.

Future Marking Schemes

Assumptions about future marking schemes on the basis of past schemes should be avoided. While the underlying assessment principles remain the same, the details of the marking of a particular type of question may change in the context of the contribution of that question to the overall examination in a given year. The Chief Examiner in any given year has the responsibility to determine how best to ensure the fair and accurate assessment of candidates' work and to ensure consistency in the standard of the assessment from year to year. Accordingly, aspects of the structure, detail and application of the marking scheme for a particular examination are subject to change from one year to the next without notice.

General Guidelines

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

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

2. Marks shown in 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 form 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. Cancellation may apply when a candidate gives a list of correct and incorrect answers.

9. 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.

10. Bonus marks at the rate of 10% of the marks obtained will be given to a candidate who answers entirely through Irish and who obtains less than 75% of the total marks.

Question 1
Any eleven parts **11×6**

(*a*) State *Newton's first law of motion.* **2×3**
body or object continues (at rest) or at constant velocity / in constant motion in a straight line ...3
unless acted on by a force …3

(*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 ? **5, 1**
joule
(kinetic, potential, food, etc) energy / heat
first correct …5, second correct …1

(*c*) What power does a weightlifter develop in a 2.5 m vertical lift of 60 kg completed in 0.12 s? **2×3**
($E = mgh$ =) 60 × 9.8 × 2.5 = 1470 (J) …3
($P = \frac{E}{t}$ =) $\frac{1470}{0.12}$ =12250 (W) ...3
[Allow ...3 for answer = 1250]

(*d*) Distinguish, in terms of light rays, between a real image and a virtual image. **2×3**
real image is formed by or at the intersection of light rays ...3
virtual image formed by or at the apparent intersection of light rays ...3
[real image inverted, virtual image upright /
real image can be formed on a screen, virtual image cannot ...3][reversed…3]

(*e*) Figure 1 shows a transverse wave drawn to scale. What is
(*i*) the amplitude,
(*ii*) the wavelength, of this wave? **5, 1**
(*i*) 0.8 (cm)
(*ii*) 10 (cm)
first correct …5, second correct …1

(*f*) What is total internal reflection? **2×3**
reflection of (all) the light incident (at a boundary between two media) // angle of incidence in the more dense medium ...3
when critical angle is exceeded // exceeds the critical angle ...3
[marks available for a good diagram] ['in the more dense medium' omitted…(−1)]

(*g*) What is meant by *complete destructive interference* of waves? **2×3**
when two waves (of same or similar frequency and amplitude) meet …3
and their resultant amplitude is zero / and they cancel / and they are 180° out of phase or step ...3
[marks can be obtained for a suitable diagram]

(*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? **6**
1:1 ...6
[Allow ...3 for reference to $PV = nRT$][Allow ...3 for ratio of masses 4:44 or 1:11; (−1) for reverse]

(*i*) **Under what conditions of temperature and pressure does a real gas behave most like the ideal gas?** **5, 1**

high temperature
low pressure

first correct …5, second correct …1

(*j*) **Deduce the type of charge on (*i*) Q_1, (*ii*) Q_2 from their electric field pattern when placed close together as shown in Figure 2.** **5, 1**

(*i*) (Q_1) is positive
(*ii*) (Q_2) is positive

first correct …5, second correct …1

[allow …5 marks for *both* negative]

(*k*) **Identify the electrical device that**
(*i*) generates an electric current from chemical reactions,
(*ii*) stores energy by means of the separation of charges. **5, 1**

(*i*) cell or battery
(*ii*) capacitor

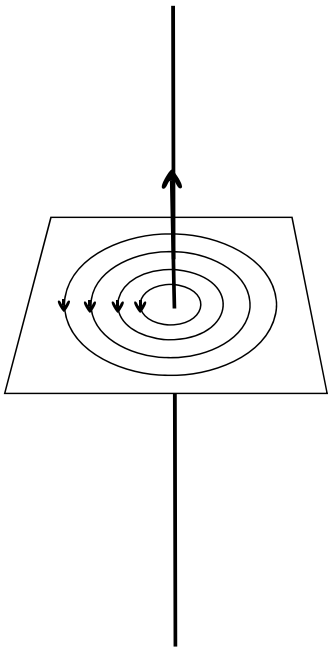
first correct …5, second correct …1

(*l*) **Define electrical potential difference.** **2×3**

work done // $W \div$ …3
when a charge of one coulomb or unit charge is moved (in an electrical field) // Q …3

(*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.** **2×3**

concentric circles around wire …3
arrows show direction anticlockwise …3



(*n*) **A radioactive isotope has a half-life of three 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?** **5, 1**

3 half lives / one eighth remaining …5
16 (g) …1

(*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? **5, 1**

(*i*) increases by 1
(*ii*) decreases by 1

[increased / reduced only in correct order ...5]

first correct …5, second correct …1

Question 2

(*a*) Define

(*i*) force **6**

changes state of rest or uniform motion in a straight line / changes velocity, speed or direction / causes acceleration / ma …6

[omit to explain m, a (−1)]

(*ii*) momentum. **3**

product of mass and velocity // mv …3

[omit to explain m, v (−1)]

(*b*) Write a mathematical expression for the relationship between force and the rate of change of momentum. **2×3**

$F \propto$ // $F =$ // $F =$ …3

$\frac{mv-mu}{t}$ // $\frac{k(mv-mu)}{t}$ …3

[omit to explain F, m, v, u, t ...(−1)]

(*c*) Define the newton. **2×3**

the force that causes a body of mass one kilogram / m = 1 kg …3

to accelerate by 1 meter per second per second or at 1 m s^{-2} / a = 1 m s^{-2} …3

[1 m s^{-1} (−1)][unit of force...3]

(*d*) State the law of *conservation of momentum.* **2×3**

(in a system of colliding bodies) where no external force acts or in a closed system total momentum //

(in a system of colliding bodies) where no external force acts or in a closed system the total momentum before a collision //

(in a system of colliding bodies) where no external force acts or in a closed system $m_1u_1 + m_2u_2 =$ …3

is constant //

is equal to total momentum after //

$m_1u_1 + m_2u_2$ or $(m_1 + m_2)v$ …3

['where no external force acts' / 'in a closed system' omitted…(−1)]

(*e*) Draw a labelled diagram of an arrangement of apparatus used to verify the law of conservation of momentum. **6, 2×3**

stationary trolley at the top of sloped track or at one end of a smooth frictionless horizontal track, e.g. air track /

second trolley approximately mid-way on track /

some method of attachment, i.e. magnets, *Velcro*, etc /

timing using ticker (tape) timer, light gates, powder track, picket fence timer, data-logger and (motion) sensor, etc

[no labels…(−1)]

['ticker tape' instead of 'ticker (tape) timer'...(−1)]

first correct …6, second two correct …2 × 3

(*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. **6, 3×3**

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ / $m_1u_1 + m_2u_2 = (m_1 + m_2)v =$ / $(1500 \times 20) + (7500 \times 0) =$ ...6

$(m_1u_1 + m_2u_2 =)$ 30000 …3

$30000 = (9000 \times v)$ / $1500v_1 + 7500v_2$ ...3

$(v =)$ 3.3(33) m s^{-1} …3

[no unit or incorrect unit (−1)]

(*ii*) Does the car or the block experience the greater force during the collision? Justify your answer. **3**

same force (according to) Newton's third law / same force because for every action there is an equal reaction …3

(*iii*) Calculate the ratio of the magnitude of the acceleration of the car to that of the block during the test. **3**

$m_1a_1 = m_2a_2$ or $1500a_1 = 7500a_2 \Rightarrow$

$a_1 : a_2 = 7500 \div 1500 = 5:1$ …3

[ratio reversed ...(−1)][ratio need not be expressed in whole numbers]

[attempt by use of $\frac{v-u}{t} = a$ to calculate acceleration(s) ...3 if no other mark is given for (*ii*) and (*iii*)]

(*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. **6**

prolong impact time for the collision thus reduce force / force absorbed by crumple zones(before it is applied to cabin), etc …6

Question 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. **4×3**

one frequency or wavelength or colour …3

bending of light …3

when it travels from one medium to another …3

splitting up into (constituent) colours or wavelengths / forming a spectrum …3

(*b*) State one property of a wave

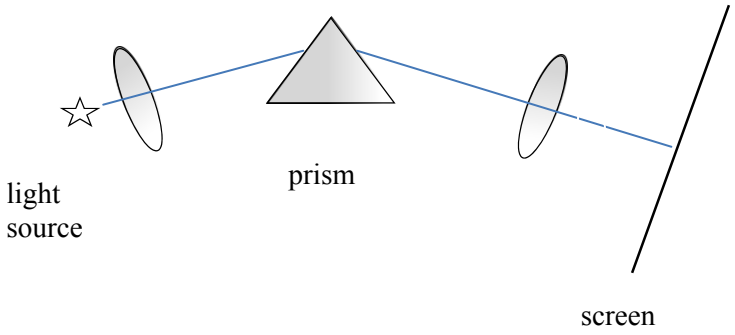
(*i*) that changes, **3**

wavelength / speed / direction …3

(*ii*) that does not change when it is refracted **3**

frequency or colour / amplitude / energy …3

(*c*) Describe with the aid of a labelled diagram how you would use a prism and lenses to project a spectrum of white light on to a screen. **3×3**



white light from source collimated by first lens …3

prism disperses or refracts light …3

light leaves prism and strikes screen collimated by second lens to avoid colours overlapping …3

[no labels….(−1)][no lenses…. (−1)][all marks available from good diagram]

Show on your diagram where you would expect to be able to detect infra-red radiation. **3**

beyond red end …3

How could you detect the presence of this invisible radiation? **3**

thermometer (with blackened bulb) / heat sensor / thermocouple / thermopile …3

(*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. **6**

24 (cm) …6

(*ii*) What is the object distance when the magnification is 1? **3**

24 (cm) …3

(*iii*) Calculate the focal length of the mirror. **5, 1**

$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} / \frac{1}{f} = \frac{1}{24} + \frac{1}{24} = \frac{1}{12}$ …5

12 cm …1

[no unit or incorrect unit …(−1)]

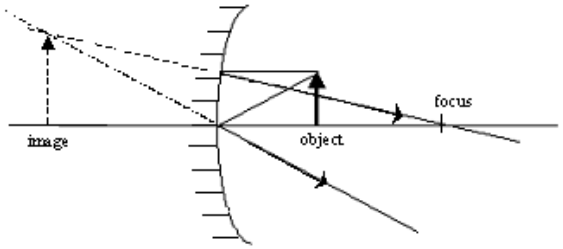
(*iv*) What is the magnification when the object is placed 18 cm from the mirror? **2×3**

$\frac{1}{12} = \frac{1}{18} + \frac{1}{v}$ / $\frac{1}{v} = \frac{1}{12} - \frac{1}{18}$ / $\frac{1}{36}$ / (v =) 36 (cm) …3

(m =) 2 …3

[allow …3 for $m = v \div u$ if no other mark given for (*iv*)]

(*e*) Use a ray diagram to show how a magnified erect image is produced by a concave mirror. **2×3**



object inside focus / concave mirror …3

two rays correctly reflected to form magnified erect image behind mirror …3

Give a use for a concave mirror based on its magnifying ability. **6**

make-up, shaving, dental, microscopes, reflecting telescopes etc …6

Question 4

(*a*) State *Charles' law. **2×3**

the volume of a fixed mass of gas at constant pressure …3
is proportional to its temperature on the Kelvin scale or to its absolute temperature / increases by 1/273 for every degree change in temperature …3

or

$\frac{V_1}{T_1} = \frac{V_2}{T_2} / \frac{V}{T}$ is constant / $\frac{V}{T} = k$ ...3
for a fixed mass of gas at constant pressure ...3
[V, T not explained…(−1)]

(*b*) What property of the molecules of a gas determines the temperature of the gas? **6**

(average) kinetic energy …6
[allow …3 for movement]

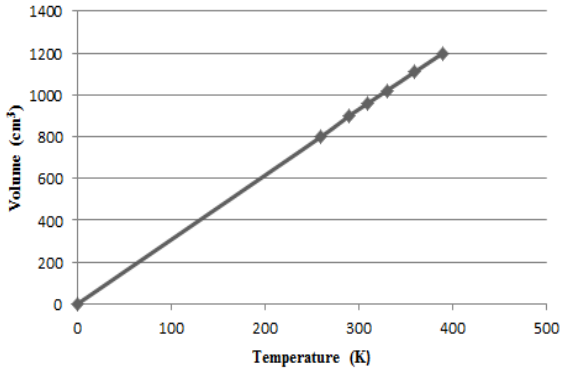
At what temperature on the Kelvin scale is the value of this property theoretically zero? **3**

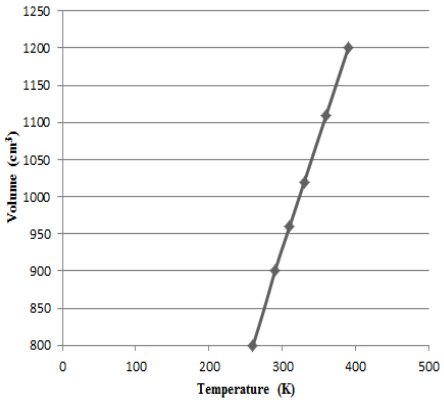
zero / 0 K / absolute zero …3

(*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

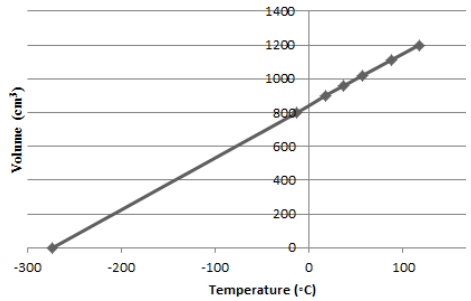
(*i*) Draw a suitable graph of volume *versus* temperature to verify Charles' law. **5×3**

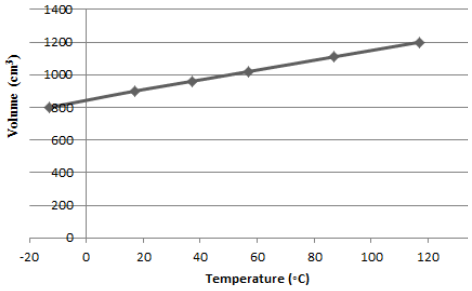




Kelvin temperatures for all values used to plot graph …3
axes correctly labelled …3
axes drawn with appropriate scales …3
six points correctly plotted …3
straight line through these points as shown ...3

or





axes correctly labelled …3
axes drawn with appropriate scales …3
first point correctly plotted …3
five other points correctly plotted …3
straight line through these points as shown ...3

(*ii*) Explain how your graph verifies Charles' law. **5, 1**
graph (of volume versus Kelvin temperature) is a straight line ...5
through the origin ...1

or

graph (of volume versus Celsius temperature) is a straight line ...5
through (–273, 0) ...1

[Answer to (*ii*) must be linked to graph drawn]

(*d*) The constant volume gas thermometer is used as a standard thermometer.
(*i*) On what thermometric property is the constant volume gas thermometer based? **3**
pressure …3

(*ii*) Why are standard thermometers necessary? **6**
thermometers based on different thermometric properties disagree / thermometers only agree at fixed points / different thermometers read different temperatures …6
[allow to calibrate other thermometers ...6]

(*iii*) Give two reasons why constant volume gas thermometers are *not* in common use. **6, 3**
cumbersome, difficult to use, impractical, unnecessary except for the most accurate work, slow to to come to thermal equilibrium(with new surroundings), large heat capacity (so affects the temperature of the material whose temperature it is measuring), etc

first correct …6, second correct …3

(*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? **6, 3**
0 °C: melting ice / mixture of ice and water
100 °C: steam above boiling water
[marks available for clear diagrams]

first correct …6, second correct …3

(*ii*) Write an equation that can be used to calculate temperature on the Celsius scale from measurements taken using a constant volume gas thermometer. **3**

$\theta = \frac{p_\theta - p_0}{p_{100} - p_0} \times 100$ / $\theta = \frac{X_\theta - X_0}{X_{100} - X_0} \times 100$ …3

[pressure differences inverted (-1)]

Question 5

(*a*) What is electric current? **6**

a flow of charge, electrons or ions **...6**

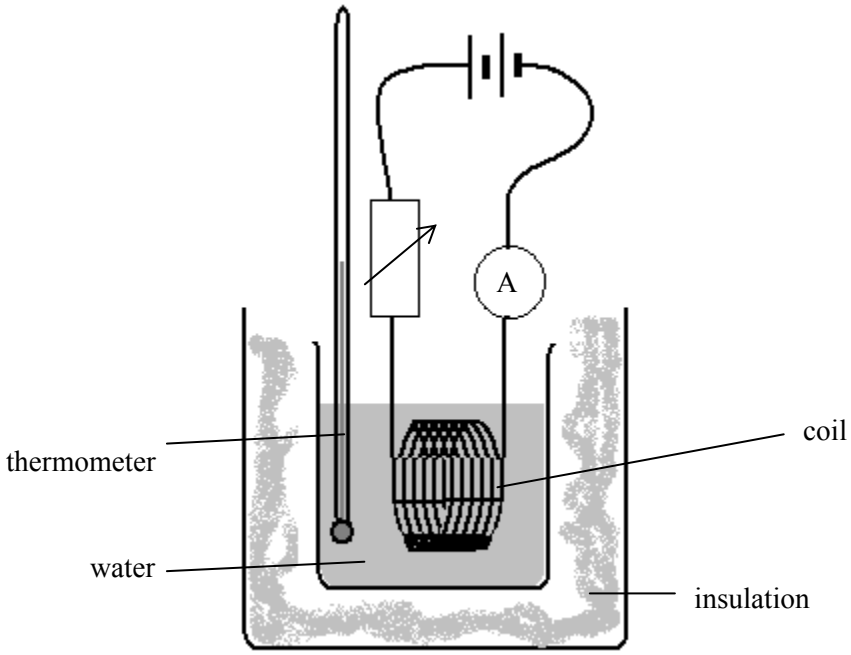
State *Ohm's law*. **2×3**

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)]

(*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. **6, 3, 3**



battery, (switch), ammeter, coil /
insulated container or lid on container /
water in container /
masses of water and container known /
thermometer in water /
mention or sketch of timer /
use of variable resistor (to keep current constant)
[labels omitted …(−1)][all marks available from good diagram]

first correct …6, second two correct …2×3

What relationship was established? **2×3**

heat change or temperature rise // ΔH or $\Delta\theta$ // H ...3

is proportional to the current squared // $\propto I^2$ // $= I^2 Rt$ …3

[terms not explained…(−1)]

(*c*) State the principle of operation of a moving-coil galvanometer in detecting a small current. **6**

a current carrying conductor in a magnetic field experiences a force ...6

Explain how a moving-coil galvanometer can be converted into an ammeter to measure larger currents. **2×3**

connect small or suitable resistor ...3

in parallel …3

[labelled diagram sufficient]

(*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, **2×3**

$V = IR \,/\, \frac{V}{I} = R \,/\, I = \frac{V}{R}$ …3

$I = \frac{2.8}{64} = 0.04375\,\text{A}$ …3

[no unit or incorrect unit …(−1)]

(*ii*) the electrical energy that would be used by the device during a sleep period of 8 hours. **2×3**
energy = power × time / $E = VIt$ / $E = RI^2t$ ...3
$E = 2.8 \times 0.04375 \times 28800 = 3528$ J = 3.528 kJ / $64 \times (0.04375)^2 \times 28800 = 3528$ J = 3.528 kJ …3
[no unit or incorrect unit …(−1)]

(*e*) Energy loss due to heating must be minimized when transmitting electricity from generating stations to the point of use. Explain how this is achieved. **9**
use of high voltage or low currents / to reduce heat loss due to resistance / use of pure copper or aluminium / use of thick cables ...9

Why is alternating current used in the transmission of electricity over long distances? **3**
so that voltage can be easily stepped up or stepped down / so voltage can be easily changed ...3

Question 6
Answer any two parts. **2×33**

Question 6 (*a*)

What is a photon? **2×3**
packet or bundle or unit or quantum 3
of light energy 3
[$E = hf$...6][omit to explain terms…(−1)

A negatively-charged zinc plate rests on the cap of an electroscope as shown in 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, **max 5×3**
leaves collapse ...3
electrons released (from metal plate) / photoelectric effect occurs ...3

(*ii*) ultraviolet light from the same lamp placed 10 cm from the zinc plate,
leaves collapse (more quickly) ...3
light more intense releases more electrons / more photons release more electrons / electrons emitted / photoelectric effect occurs ...3

(*iii*) infrared radiation from a lamp placed 10 cm from the zinc plate.
no change ...3
(infrared light or photons has or have) insufficiently high frequency or energy / no change because infrared radiation unsuitable ...3
first two correct describe and explain pairs ... 2 × 6 , ...3 for remainder

Calculate the frequency of radiation of wavelength 2.0×10^{-7} m. **2×3**
$c = f\lambda$ ...3
$f = \frac{c}{\lambda} = \frac{3 \times 10^8}{2.0 \times 10^{-7}}$ Hz = 1.5×10^{15} Hz ...3
[no unit or incorrect unit …(−1)]

What is the energy of a photon of ultraviolet radiation of this frequency? **2×3**
$E = hf$ ..3
$E = 6.626 \times 10^{-34} \times 1.5 \times 10^{15} = 9.94 \times 10^{-19}$ J ...3
[no unit or incorrect unit …(−1)]

Question 6 (*b*)

State *Newton's law of universal gravitation*. **3×3 or 9**

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

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

$F \propto \frac{Mm}{d^2} / F = \frac{GMm}{d^2}$ ...9

[omit to explain *F*, *M*, *m*, *G*, *d*…(−1)][square omitted …(−3)][sum instead of product…(−3)]

[accept relationship between *g* and *G* for…3]

Using this law, derive the relationship between *g* the acceleration due to the Earth's gravity and *G* the gravitational constant. **2×3**

$F = \frac{GMm}{d^2}$ and $F = mg$ /

$\frac{GMm}{d^2} = mg$ ...3

$\frac{GM}{d^2} = g$ ...3

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. **7, 3×3**

$\frac{GM}{d^2} = g$ ...3

$8.61 = \frac{6.6742\times10^{-11}\times5.97\times10^{24}}{d^2}$ …7

$d = 6.80 \times 10^6$ m ...3

$r = 6.80 \times 10^6 - 6.37 \times 10^6 = 4.3 \times 10^5$ m = 430 km …3

[no unit or incorrect unit …(−1)]

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? **1**

no effect ...1

Explain your answer. **1**

mass of astronaut does not feature in acceleration due to gravity formula, etc / his mass does not affect acceleration due to gravity ...1

Question 6 (*c*)

State *Faraday's law of electromagnetic induction.* **2×3**

when there is a change in the magnetic flux(linking a coil) an emf is produced or induced (in the coil) ...3

size of emf is proportional to rate of change of flux ...3

or

$E \propto$ / $E =$ ...3

$(-N)\ \frac{d\phi}{dt}$ ...3

[omit to explain terms...(−1)]

Describe an experiment to demonstrate electromagnetic induction. **3×3**

magnetic field or electromagnet, coil, galvanometer …3

move magnetic field and coil relative to each other ...3

and note deflection on galvanometer …3

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

Name the parts labelled A and B. **5, 1**

A: slip ring

B: (carbon) brush

first correct …5, second correct …1

State the functions of A and B. **3**

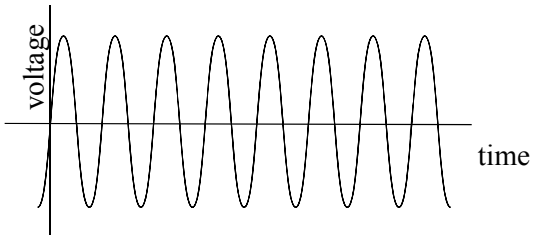
A: to produce alternating current output /

B: conducting contacts between rotating coil and stationary circuit any one...3

Sketch the variation of the output voltage with time. **6, 3**

axes labelled time and voltage

sine wave



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

turn coil faster, turn magnet in opposite direction to the coil, increase the number of turns,
use a magnetic field with greater flux density, use coil of greater area any one

first correct …6, second correct …3

Question 6 (*d*)

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

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

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

(*i*) advantageous to the environment, **3**

reduces global warming associated with burning fossil fuels, very efficient in terms of energy produced per kilogram of fuel, no CO_2 emissions, etc any one...3

(*ii*) harmful to the environment. **3**

produces radioactive waste, potentially very harmful if nuclear plant involved in an accident any one...3

[allow mention of nuclear weapons or bombs, etc]

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

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

3

fusion ...3

Why is it difficult to bring about such a reaction? **3**

repulsion between the hydrogen atoms or tritium isotopes must be overcome /
very high temperatures are required / a lot of energy is required (in the reactants) ...3

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

mass is a form of energy / mass can be converted to energy (and vice versa) / is constant
$E = mc^2$ / mass-energy of reactants equals mass-energy of the products ...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.

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

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. **5×3**

mass before = 7.016005 + 1.007825 = 8.02383 (adding reactant masses) …3
mass after = 4.002603 × 2 = 8.005206 (adding product masses) …3
mass difference = 8.02383 − 8.005206 = 0.018624 (subtracting masses) …3
mass difference in kg = $0.018624 \times 1.6605402 \times 10^{-27} = 3.092590068 \times 10^{-29}$ kg (converting amu to kg) …3
$E = mc^2 = 3.092590068 \times 10^{-29} \times (2.99792458 \times 10^{8})^2 = 2.77948134 \times 10^{-12}$ J (converting mass to energy) …3
[no unit or incorrect unit …(−1)][rounding off incorrectly …(−3) but once only]
[

Question 7
Any eleven parts **11×6**

(*a*) **Give the symbol, atomic number and mass number for a neutral atom that contains 12 neutrons and 11 electrons.** **2×3**
Na …3
11, 23 …3
[only one number correct (−1)]

(*b*) **Why is the first ionisation energy value of boron less than that of carbon?** **6**
boron has smaller nuclear charge / boron has fewer protons / boron has smaller atomic number
boron has larger (atomic) radius …6
or
carbon has bigger nuclear charge / carbon has more protons / carbon has bigger atomic number
carbon has smaller (atomic) radius ...6

(*c*) **What are *isotopes*?** **2×3**
atoms of the same element / atoms with the same atomic number / atoms with same number of protons …3
that have different mass numbers / that have different numbers of neutrons ...3

(*d*) **Define relative atomic mass.** **2×3**
mass of an atom of an element relative to // average mass of (all) the isotopes …3
1/12 the mass of the C–12 (isotope) // taking their natural abundances into account …3
[mass omitted in second line....(−1)]

(*e*) **Balance the following chemical equation.**
$Na_2S_2O_3 + HCl \rightarrow NaCl + H_2O + S + SO_2$ **6**
$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + H_2O + S + SO_2$ ...6
[sodium balanced ...3, all balanced …6]

(*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] **2×3**
(M_r =) 160 ...3
(% iron =) $\frac{2 \times 56}{160} \times 100 = 70\%$ ...3

(*g*) **What are *allotropes*?** **6**
different forms of the same element …6
[example ....3]

(*h*) **What is (*i*) the shape of, (*ii*) the value of bond angle in, an ammonia (NH_3) molecule?** **5, 1**
(*i*) pyramidal / distorted tetrahedral
(*ii*) 107°
[107.5.....(−1)]
first correct …5, second correct …1

(*i*) **What mass of magnesium will contain the same number of atoms as 8 g of calcium?**
[Mg = 24; Ca = 40] **2×3**
8 ÷ 40 = 0.2 moles ...3
0.2 × 24 = 4.8 (g) ...3

(*j*) Identify (*i*) the conjugate acid of HS^- (*ii*) the conjugate base of $H_2NO_3^+$. **5, 1**

H_2S
HNO_3
[charge incorrect (–1)]

first correct …5, second correct …1

(*k*) Name or give the formula of an oxide that is (*i*) basic, (*ii*) amphoteric. **5, 1**

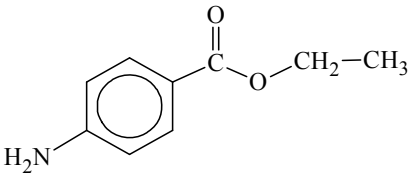
(*i*) sodium oxide or Na_2O, lithium oxide or Li_2O, magnesium oxide or MgO, etc
(*ii*) aluminium oxide or Al_2O_3, zinc oxide or ZnO, water or H_2O etc.

first correct …5, second correct …1

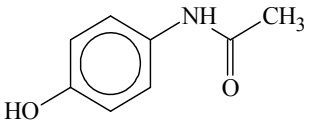
(*l*) Define *heat of combustion* of a substance. **2×3**

heat released or produced or evolved or heat change when one mole (of a compound) …3
is burned completely / is burned in excess oxygen ...3

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



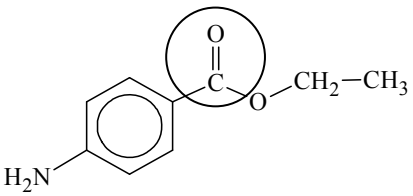
Benzocaine



Paracetamol

Figure 9

Copy the structure that has an ester functional group into your answer book and circle its carbonyl group. **5, 1**



...5

carbonyl ...1

[if paracetamol drawn and carbonyl group circled ....3]

(*n*) Name two products formed when sunlight falls on an equimolar mixture of methane and chlorine. **5, 1**

chloromethane, CH_3Cl, CH_2Cl_2, $CHCl_3$, etc
hydrogen chloride / HCl

first correct …5, second correct …1

(*o*) Give a common everyday use for each of the organic chemicals: (*i*) CH_3COOH, (*ii*) CH_3COCH_3. **5, 1**

(*i*) vinegar, flavouring, preservative, making cellulose acetate or varnishes or lacquers, etc
(*ii*) solvent, nail varnish remover, etc

first correct …5, second correct …1

Question 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.

(*i*) Distinguish between the *ground state* and an *excited state* for an electron in a hydrogen atom. 2×3

ground state: electron is in lowest or first energy level / (electron in) energy level nearest the nucleus / electron has been given no extra energy …3

excited state: electron is in an energy level other than the first / electron has been given energy or heat / electron has absorbed light energy / electron has been promoted to a higher energy level …3

(*ii*) Give two ways that an electron in a hydrogen atom can be excited. 5, 1

(adding) heat or light or electrical energy

first correct …5, second correct …1

(*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? 6, 3

4, 2

[order unimportant]

first correct …6, second correct …3

(*iv*) Explain why there is no yellow line in the hydrogen emission spectrum. 3

electron cannot be located in between the third and fourth levels / electron would have to be located between the third and forth levels / no transition equal in energy to that of the yellow line

electrons cannot occupy space between energy levels / electron has to be in an energy level / yellow does not have a suitable frequency to excite electrons any one...3

(*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. 4×3

clean platinum or nichrome rod in hydrochloric acid solution // soak wooden splints or sticks (overnight) in water // prepare a solution of water and alcohol in a spray bottle …3

dip rod in salt sample // dip splint in salt sample // dissolve or add salt sample to the solution in the spray bottle …3

hold rod in (hottest part) of flame // hold splint in (hottest part) of flame // spray solution into flame …3

observe colour (if lithium present) …3

(*c*) Define an *atomic orbital*. 2×3

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

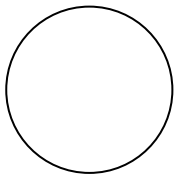
where there is a high probability of finding an electron …3

['area' instead of 'region'…(–3)]

What is the maximum number of electrons that can occupy any atomic orbital? 3

2 …3

Sketch the shape of (*i*) an *s* orbital, 3



…3

(*ii*) a *p* orbital. 3

…3

(*d*) Write the electron configuration of a nitrogen atom showing the arrangement of electrons in orbitals in the ground state. **2×3**

$1s^2\ 2s^2$ …3

$2p_x^1\ 2p_y^1 2p_z^1$ …3

[diagram with boxes and arrows sufficient]

How many

(*i*) main energy levels,

(*ii*) orbitals, are occupied by electrons in a nitrogen atom? **5, 1**

(*i*) 2

(*ii*) 5

first correct …5, second correct …1

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. **3**

2*s* …3

[2 omitted (–1)]

Question 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.

$$NH_4OH + HCl \rightarrow NH_4Cl + H_2O$$

(*a*) Describe how a burette was prepared and filled for use in this titration. **6, 2×3**

rinse with deionised or distilled water /
rinse with ammonium hydroxide solution or rinse with solution burette is to deliver /
fill with (small) funnel /
fill part below tap /
remove funnel before adjusting to the mark /
adjust level until bottom of meniscus is on the mark /
view at eye level

first correct …6, second two correct …2 × 3

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

(narrow neck or shape) prevents loss of solution/ prevents splashing /
sides can be easily washed down /
allows swirling without loss of solution any one...6

(*c*) Name a suitable indicator for this titration. **3**

methyl orange ...3

State the colour change observed at the end point of the titration. **2×3**

pink or red // ...3
orange or yellow ...3
[accept colourless to pink (violet, purple) if phenolphthalein given (incorrectly) as indicator...6][allow 3 if indicator colours are given in reverse order]

Why should only one or two drops of indicator be used? **3**

indicators are weak acids (or bases) therefore end-point is (significantly) affected if a lot is added /
to allow colour change to be easily detected / affects concentration / affects accuracy of result …3

(*d*) Calculate the concentration of the ammonium hydroxide solution in (*i*) moles per litre **2×3**

$\frac{V_1 \times M_1}{n_1} = \frac{V_2 \times M_2}{n_2}$ / $\frac{12.25 \times M_1}{1} = \frac{25 \times 0.1}{1}$ /
(volume × molarity × proticity$_1$) = (volume × molarity × proticity$_2$) / $V_1M_1n_2 = V_2M_2n_1$ …3
(M_1) = 0.204 (M) ...3

or

moles of HCl used = $\frac{25 \times 0.1}{1} = 0.0025$ …3
0.0025 moles of NH_4OH in 12.25 $cm^3 \Rightarrow \frac{0.0025 \times 1000}{12.25} = 0.204$ (mol / L) …3

(*ii*) grams per litre. **2×3**

(M_r of NH_4OH =) 35 ...3
0.204 × 35 = 7.14 (g /L) [7.0 – 7.144 g / L] ...3

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

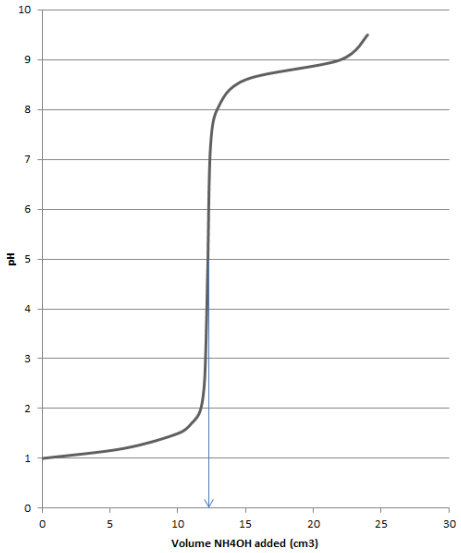
(*e*) Define pH **2×3**

pH = − log ...3

$[H^+]$ / hydrogen ion concentration ...3

Use the data in the table above to plot a graph of pH (*y*-axis) *versus* volume of ammonium hydroxide added (*x*-axis)

2×3, 6, 5



axes correctly labelled pH and volume, NH_4OH added or cm^3 …3

axes drawn with appropriate scales …3

points correctly plotted …6, 3, 0

suitable curve through the points ...5

Use the volume of ammonium hydroxide solution required for neutralisation to estimate the pH at neutralisation from your graph. **1**

5 ...1

[reading own graph correctly...1]

Question 10

The following is a list of metals arranged in 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. **6**

oxidation is the loss of electrons …6

What is the electrochemical series? **3**

elements or metals in order of decreasing ease of oxidation or reactivity /
elements or metals listed in increasing ease of reduction of their ions / elements or metals in order of their standard electrode potential …3

(*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. **6, 3**

zinc can act as a sacrificial anode or zinc is higher up in the electrochemical series or
zinc corrodes more easily /
zinc coat excludes the air or water from the iron object /
tin coat excludes the air or water from the iron
[allow 'zinc galvanises' instead of the first two points for …3]

first answer correct …6, second answer correct …3

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

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

$$\mathbf{2NaF + CaCl_2 \rightarrow 2NaCl + CaF_2}$$

$$\mathbf{SnO_2 + 2C \rightarrow Sn + 2CO}$$

4×3

Redox: $2Al + 6H^+ \rightarrow 2Al^{3+} + 3H_2$ …3
aluminium loses electrons / hydrogen gains electrons/ electrons transferred …3

Redox: $SnO_2 + 2C \rightarrow Sn + 2CO$ …3
Carbon loses electrons / tin gains electrons/ electrons transferred/ oxygen added to C …3

Non-redox: $2NaF + CaCl_2 \rightarrow 2NaCl + CaF_2$ …3
no loss or gain of electrons …3

any two pairs of statements …4×3

Identify clearly any substance acting as an oxidising agent in the reactions above. **5, 1**

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

SnO_2 or Sn^{2+} in $SnO_2 + 2C \rightarrow Sn + 2CO$

first correct …5, second correct …1

(*d*) Write a balanced equation for the reaction that occurs when a magnesium rod is dipped into a solution of zinc sulfate. **2×3**

$Mg + ZnSO_4 \rightarrow$ …3
$MgSO_4 + Zn$ …3
[if Mg on left and Zn on right...3]

Why is there no reaction when a silver (Ag) rod is dipped into a solution of zinc sulfate? **3**

silver is below zinc on electrochemical series / silver less easily oxidised than zinc / silver (ions) more easily reduced than zinc (ions) / silver is less reactive …3

(*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. **2×3**

$I^- // I^- - e // 2I^- // 2I^- - 2e^-$ …3

$(\rightarrow I + e^-) \rightarrow \frac{1}{2}I_2 + e^- // (\rightarrow I) \rightarrow \frac{1}{2}I_2 // (\rightarrow 2I + 2e^-) \rightarrow I_2 + 2e^- // (\rightarrow 2I) \rightarrow I_2$ …3

What mass of potassium metal was produced when a current of 5A flowed through the electrolyte for six minutes? **4×3**

$Q = It = 6 \times 60 \times 5 = 1800$ (C) ...3

$1800 \div 96485.3383 = 0.0187$ (moles of electrons or potassium) …3

$A_r = 39$ ...3

$39 \times 0.0187 = 0.73$ (g) …3

Explain how the current was conducted through the electrolyte. **3**

movement of ions / free ions …3

Question 11

(*a*) (*i*) What name is given to 'families' of organic compounds that have the same functional group and the same general formula? **3**

homologous series …3

(*ii*) Explain the term *functional group*. **3**

an atom or a group of atoms or a type of bond that gives an (organic) compound characteristic chemical properties …3

(*iii*) What general name is given to compounds that contain carbon and hydrogen only? **6**

hydrocarbons …3

(*iv*) Distinguish between aliphatic and aromatic compounds. **2×3**

aliphatic compounds consist of open or closed chains of carbon atoms ...3

aromatic compounds contain a benzene ring …3

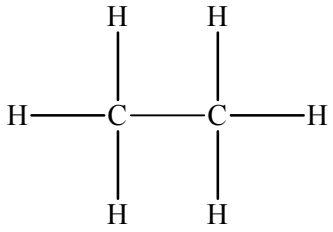
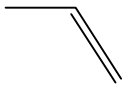
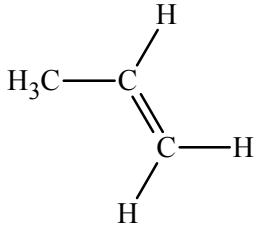
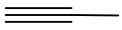
(*v*) Name three families of aliphatic compounds that contain carbon and hydrogen only. **3×3**

alkanes …3

alkenes …3

alkynes …3

Draw the structural formula and give the IUPAC name for the second member of any two of the families you name. **4×3**

H_3C-CH_3		ethane
		propene
	$HC\equiv C-CH_3$	propyne

any two correct structures ….2×3

any two correct matching names….2×3

[if first member of the alkenes or alkynes given....(–3) but once only]

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

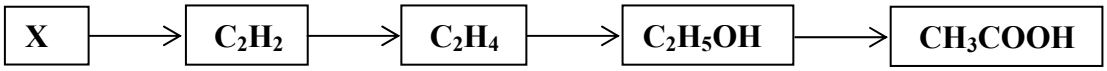


Figure 13

(*i*) Name the inorganic compound X and the compounds C_2H_2 and CH_3COOH. **5, 2, 2**

calcium (di)carbide
ethyne
ethanoic acid

first correct …5, second correct …2, third correct …2

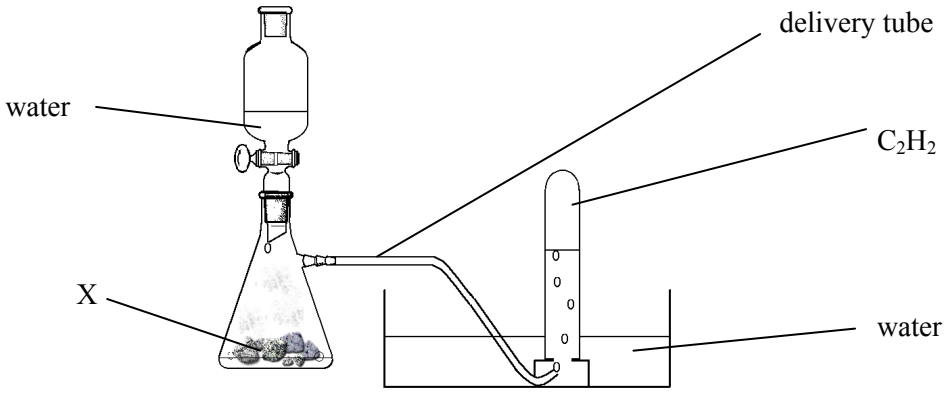
(*ii*) Explain why C_2H_5OH is very soluble in water. **3**

polar OH group / contains polar functional group /
attraction or hydrogen bonding between the C_2H_5OH molecules and water molecules / like dissolves like …3

(*iii*) Name the type of reaction involved in converting C_2H_2 to C_2H_4. **3**

addition or reduction or hydrogenation …3

(*iv*) Draw a labelled diagram to show how C_2H_2 is prepared by adding water to compound X. **3×3**



drop water onto solid X …3
delivery tube shown …3
collection over water …3
[no labels …(–3)]

(*v*) C_2H_2 and C_2H_4 both decolourise bromine water.
What information does this fact give about these compounds? **3**

unsaturated …3

Question 12
Answer any three parts. **3×22**

Question 12 (*a*)

Define transition elements in terms of electron configuration. **2**
forms at least one ion with an incomplete *d* subshell /
highest energy electron is in an incomplete *d* subshell …2

Give a property characteristic of a transition metal compound. **8**
good catalyst / coloured compounds / variable valency ...8

Copper is a transition metal. A small part its crystal structure is shown in Figure 14.
Describe the bonding within this metallic crystal. **2×3**
postive ions closely packed …3
(valence) electrons shared / cloud of electrons ...3

Explain in terms of the crystal structure and bonding why copper is
(*i*) an excellent electrical conductor, **5**
electrons free to move …5

(*ii*) a good conductor of heat. **1**
close packing of atoms or ions …1

Question 12 (*b*)
(*b*) Describe the bonding in a chlorine (Cl_2) molecule. **3**
covalent …3

Define *electronegativity*. **2×3**
measure of attraction / relative attraction / measure of the force of attraction …3
(an atom in a molecule has) for a shared pair of electrons / for electrons in a covalent bond …3
[force of attraction (–1)]

Give a reason why electronegativity values increase across the third period of the periodic table. **3**
nuclear charge increasing / number of protons increasing / atomic number increasing / atomic radius decreasing …3

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. **5, 1**
(*i*) NaCl, $MgCl_2$ etc
(*ii*) HCl, PCl_3, etc
first correct …5, second correct …1

Explain whether you would expect HCl or HBr to have the stronger bond. **2×2**
HCl …2
HBr has smaller electronegativity difference or larger bond length …2

Question 12 (*c*)

Iron disulfide or iron pyrite (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 ($CaCO_3$) present in concrete to produce calcium sulfate ($CaSO_4$).

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4$$

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2O + CO_2$$

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.

Calculate

(*i*) the number of moles contained in 3.6 kg of iron disulfide **2×3**

$M_r = 120$ ...3

$3600 \div 120 = 30$ (moles) ...3

(*ii*) the number of moles of sulfuric acid formed when 3.6 kg iron disulfide reacted, **3**

30 (moles) ...3

(*iii*) the volume of oxygen, measured at s.t.p., required for this reaction, **2×3**

105 (moles of oxygen required) …3

105×22.4 (22400) = 2352 (litres) or 2352000 (cm^3)

(*iv*) the number of moles of calcium carbonate that reacted with the sulfuric acid formed, **3**

30 (moles) ...3

[15 (moles)…(−1)]

(*v*) the mass of calcium sulfate formed. **2×2**

$M_r = 136$ …2

$30 \times 136 = 4080$ (g) or 4.08 (kg) …2

[if kg not converted to grams …(−1)]

Question 12 (*d*)

Define heat of formation. **2×3**

heat change or heat involved when one mole (of a substance) is formed …3

from its elements in their standard states …3

[heat required or heat released or heat evolved…(−1)] [in their standard state omitted...(−1)]

Consider the following three heats of formation.

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)} \qquad \Delta H = -297.2 \text{ kJ mol}^{-1}$$

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)} \qquad \Delta H = -285.8 \text{ kJ mol}^{-1}$$

$$H_{2\,(g)} + S_{(s)} \rightarrow H_2S_{(g)} \qquad \Delta H = -20.6 \text{ kJ mol}^{-1}$$

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. **6, 3×3**

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

$SO_{2(g)} \rightarrow S_{(s)} + O_{2(g)}$ $\Delta H = 297.2$ kJ

$2H_2S_{(g)} \rightarrow 2H_{2\,(g)} + 2S_{(s)}$ $\Delta H = 41.2$ kJ

$2H_{2\,(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$ $\Delta H = -571.6$ kJ

$SO_{2(g)} + 2H_2S_{(g)} \rightarrow 3S_{(s)} + 2H_2O_{(l)}$ $\Delta H = -233.2$ kJ

first line correct …6, each other line correct …3×3

Why is it desirable to remove sulfur compounds from fuels as part of oil refining? **1**

oxides of sulfur cause acid rain / sulfur poisons catalysts of catalytic converter / causes air pollution / harmful / toxic …1

Blank Page

Blank Page