M18/4/CHEMI/HP3/ENG/TZ2/XX/M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2018

Chemistry

Higher level

Paper 3

43 pages

Section A

Question			Answers	Notes	Total
1.	a	i	consists of single/one sheet/layer **«**of carbon atoms**»** ✓ graphene has no density measurement ***OR*** graphene has no distance between layers data ***OR*** graphene has large specific surface area **«**compared to graphite**»** ✓	*Do **not** accept "sp^2" alone without reference to single/one sheet/layer.* *Accept "thickness of one atom" **OR** "consists of a plane" for M1.*	**2**
1.	a	ii	*Any one of these alternatives:* ***ALTERNATIVE 1*** **«** $\frac{1.3\times10^{11}}{76\times10^{6}}$ **»** 1.7×10^3/1711 ✓ ***ALTERNATIVE 2*** $1600 \times 76 \times 10^6 = 1.2 \times 10^{11}$ **«**is less than tensile strength of graphene**»** ✓ ***ALTERNATIVE 3*** $\frac{1.3\times10^{11}}{1600} = 8.1 \times 10^7$ **«**is greater than upper end of tensile strength for graphite**»** ✓	*Accept any value in the range 1700–27 083. Answer may be expressed in scientific notation or otherwise.* *Accept any value calculated which is less than the graphene tensile strength based on a value chosen from within the 4.8–76 $\times 10^6$ range.*	**1**

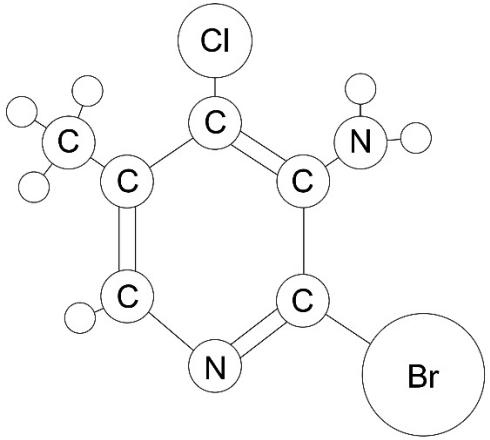
(continued…)

(Question 1a continued)

Question			Answers	Notes	Total
1.	**a**	**iii**	«graphene has a high electron mobility of» 15 000–200 000 «$cm^2\ V^{-1}\ s^{-1}$» ✓	*A specific value or range of values must be given.* *Accept any value in the 15 000–200 000 «$cm^2\ V^{-1}\ s^{-1}$» range.*	**1**
1.	**b**		smaller/zero ✓ no delocalized electrons/electrons are bound/electrons not free to move/electrons not free to roam ***OR*** localized electrons «in sigma bonds» ***OR*** large band gap ✓	*Accept "diamond is a dielectric" **OR** "diamond does **not** conduct electricity" for M2.* *Award **[1 max]** for just "immobile/less mobile".* *Award **[2]** for "electrons immobile «in diamond» due to the large band gap" **OR** "electrons «in diamond» immobile since electrons are localized «in the sigma bonds»".*	**2**

Question			Answers	Notes	Total
1.	c		shorter bonds in graphene ***OR*** bonds in graphene intermediate between single and double ***OR*** bond order in graphene is 1.33 ***OR*** delocalization creates stronger bonds ***OR*** shorter bonds are stronger ✓ stronger/shorter bonds require higher temperature/faster thermal motion to be altered ***OR*** stronger/shorter bonds require greater energy to be broken ✓		**2**

Question			Answers	Notes	Total
2.	a		*Any two of:* *Ethene:* «carbon–carbon» double bond ***AND*** *Ethane:* «carbon–carbon» single bond ✓ ethene has a shorter carbon–carbon bond «than ethane» ✓ *Ethene*: planar/two-dimensional/2-D ***AND*** *Ethane:* tetrahedral «carbons»/ three-dimensional/3-D ***OR*** *Ethene:* each carbon surrounded by three electron domains ***AND*** *Ethane:* each carbon surrounded by four electron domains ***OR*** different molecular geometries/shapes ✓ rotation about carbon–carbon inhibited/blocked in ethene ***AND*** not in ethane ✓ «H–C–C/H–C–H» bond angles different ***OR*** *Ethene:* «bond angles approximately» 120° ***AND*** *Ethane:* 109.5/109°✓	*Do **not** accept "different number of atoms/hydrogens/bonds" etc.* *Accept "Ethene: unsaturated **AND** Ethane: saturated" **OR** "Ethene: has a double bond **AND** Ethane: does not" **OR** "Ethene: two flexible bonds between carbon atoms **AND** Ethane: one".* *Accept any reasonable physical description of the two different molecular models based on a variety of kits for M1.* *For ethene, accept any bond angle in the range 117–122°.* *Award **[2]** if any two of the concepts listed are shown in a correctly labelled or annotated diagram.* *Award **[1 max]** for two correct statements for either molecule but with no comparison given to the other.* *Award **[1 max]** for suitable unlabeled diagrams of both compounds.*	**2 max**

Question			Answers	Notes	Total
2.	b	i	6 carbon atoms labelled in correct positions ✓ both nitrogen atoms labelled in correct positions ✓ bromine ***AND*** chlorine atoms labelled in correct positions ✓  		3

(continued…)

(Question 2b continued)

Question			Answers	Notes	Total
2.	**b**	**ii**	accurate bond angles/lengths can be measured ***OR*** **«**using mathematical functions**»** can calculate expected shapes based on energy minimizations ***OR*** better visualization of possible bond rotations/conformation/modes of vibration ***OR*** can visualize macromolecules/proteins/DNA ***OR*** hydrogen bonding **«**networks**»** can be generated/allows intermolecular forces **«**of attraction**»** to be simulated ***OR*** more variety of visualization representations/can observe space filling ***OR*** can produce an electron density map/electrostatic potential map ***OR*** once model is generated file can be saved for future use/computer models can be shared globally by scientists ***OR*** helps design molecules of biological significance/assists in drug design **«**using libraries**»** ***OR*** can predict molecular interactions with solvents/can predict physical properties/can predict spectral data/can examine crystal structures ***OR*** **«**often**»** easier to construct/modify **«**model**»** ✓	*Accept "precise" for "accurate".* *Accept "computer generated structural representation is normally what is expected in order to be published «in a scientific journal»".* *Accept "easier to see different sizes of atoms/atomic radii".*	**1**

(continued…)

(Question 2b continued)

Question			Answers	Notes	Total
2.	**b**	**iii**	bonds within ring have resonance ***OR*** contains delocalized **«**conjugated pi**»** electrons in ring ✓	*There must be reference to a ring or cyclic structure.* *Accept "alternating single and double bonds in a ring".* *Accept "ring which shows resonance/delocalization".* *Accept "follows Hückel/4n +2 rule".* *Do **not** accept "contains one or more benzene rings".*	**1**

Section B

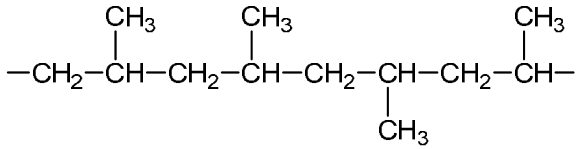
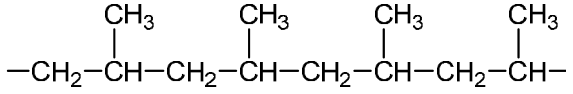
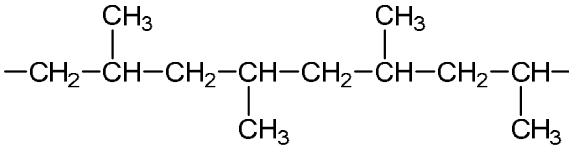
Option A — Materials

Question			Answers	Notes	Total
3.	a		*Alloy:* mixture of metal with other metals/non-metals ***OR*** mixture of elements that retains the properties of a metal ✓ *Composite:* reinforcing phase embedded in matrix phase ✓	*Award **[1 max]** for implying "composites only have heterogeneous/nonhomogeneous compositions".*	**2**
3.	b		effective for yttrium «but less/not for nickel» ✓ points on nickel graph do not lie on «$y = x$» line ***OR*** cannot be used for low concentrations of nickel ***OR*** concentration of nickel is lower than recorded value ✓	*Accept "ICP-OES is more accurate for lower yttrium concentrations than higher concentrations" for M1.* *Accept [Ni] and [Y] for concentrations of nickel and yttrium.* *Accept "detection limit for yttrium is lower than for nickel" for M2.* *Award **[1 max]** for "more accurate for yttrium at lower concentrations **AND** nickel at higher concentrations".*	**2**

Question			Answers	Notes	Total
3.	c	i	*Graph 1:* determines wavelength of maximum absorption/maximum intensity «for vanadium» ✓ *Graph 2:* determines absorption of known concentrations «at that wavelength» ***OR*** estimates [V]/concentration in a sample using «the signal» intensity ✓	*Do **not** accept just "determines maximum wavelength/λ_{max}" for M1.* *Do **not** accept "calibration curve" for M2.*	**2**
3.	c	ii	«$14\,950 = 392.19x + 147.62$» $x = 37.74$ «μg kg^{-1}» ✓	*Answer must be given to **four significant figures**.* *Do **not** accept values obtained directly from the graph.*	**1**
3.	c	iii	vanadium reduced in first reaction ***AND*** oxidized in second reaction ***OR*** V_2O_5 oxidizes SO_2 in first reaction ***AND*** VO_2 reduces O_2 in second reaction ***OR*** vanadium returns to original oxidation state «after reaction» ✓ provides an alternative reaction pathway/mechanism «with a lower activation energy» ✓	*Do **not** accept "reactants adsorb onto surface **AND** products desorb".* *Accept "oxidation number" for "oxidation state".*	**2**

Question			Answers	Notes	Total
4.	**a**	**i**	2 ✓		**1**
4.	**a**	**ii**	$n\lambda = 2d\sin\theta$ ***OR*** $\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right)$ ✓ $\theta =$ «$\sin^{-1}\left(\frac{150}{2\times 303}\right) =$» 14.3«°» ✓	*Award **[2]** for correct final answer.*	**2**
4.	**a**	**iii**	$m =$ «$\frac{50.94}{6.02\times 10^{23}} =$» 8.46×10^{-23} «g» ✓		**1**
4.	**a**	**iv**	«303 pm $= 303 \times 10^{-10}$ cm» V = «$(303 \times 10^{-10})^3 =$» 2.78×10^{-23} «cm^3 » ✓		**1**
4.	**a**	**v**	«8.46×10^{-23} g $\times 2 =$» 1.69×10^{-22} «g» ✓ $d =$ «$\frac{1.69\times 10^{-22}\text{ g}}{2.78\times 10^{-23}\text{ cm}^3} =$» 6.08 «g cm^{-3}» ✓	*Accept any value in the range 6.07–6.09 «g cm^{-3}».* *Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
4.	b	i	*Any one of these alternatives:* ***ALTERNATIVE 1*** disrupt enzyme binding sites ✓ which can inhibit/over-stimulate enzymes ✓ ***ALTERNATIVE 2*** disrupt endocrine system ✓ because they compete for active sites of enzymes/cellular receptors ✓ ***ALTERNATIVE 3*** form complexes/coordination compounds ✓ which can bind to enzymes ✓ ***ALTERNATIVE 4*** act as oxidizing/reducing agents ***OR*** act as catalysts ✓ which can initiate unwanted reactions ✓	*Accept "can undergo oxidation–reduction reactions" for M1 in Alternative 4.*	**2**
4.	b	ii	$V^{4+}(aq) + H_2O_2(aq) \rightarrow V^{5+}(aq) + OH^-(aq) + \bullet OH(aq)$ ✓	*Do **not** accept • on H.* *Accept answer without •.*	**1**

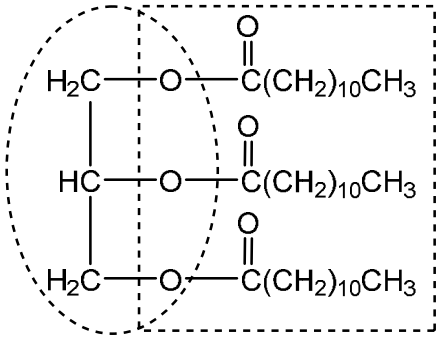
Question			Answers	Notes	Total
5.	a		Atactic  ✓ Isotactic  ✓	*Do **not** accept syndiotactic (alternating orientation of the CH_3 groups), eg,*  *for M1 or M2.* *Accept any correct atactic ordering of CH_3 groups.* *Penalize missing hydrogens or incorrect bond connectivities once only.* *Accept skeletal structures.* *Ignore continuation bonds, brackets and "n" indices in structures.*	**2**
5.	b		*Any two of:* *Recycling*: shredded/melted/reformed ***AND*** *Reuse*: used in its current form ✓ recycling is more energy intensive «than reusing» ✓ recycling degrades the quality of plastic but reusing «typically» does not ✓ recycling breaks down original product to form a new product whereas reuse extends product life ✓		**2 max**

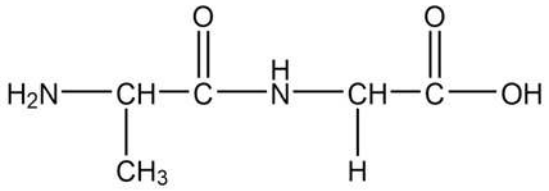
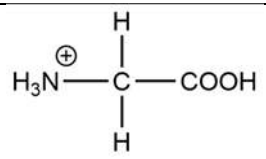
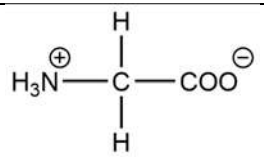
Question			Answers	Notes	Total
5.	**c**	**i**	*Any one of these alternatives:* ***ALTERNATIVE 1*** *Polyester:* produced by condensation/esterification polymerization ✓ *Polyethene:* produced by addition polymerization ✓ ***ALTERNATIVE 2*** *Polyester:* reaction between monomers/molecules containing two functional groups per molecule ✓ *Polyethene:* reaction between monomers/molecules containing a carbon–carbon double bond/C=C ✓ ***ALTERNATIVE 3*** polyester polymerization forms a by-product/H_2O ✓ polyethene has no by-products/100 % atom economy ✓	*Accept the names of different catalysts used for each polymerization as an alternative answer.*	**2**
5.	**c**	**ii**	more pliable/flexible materials ***OR*** more durable/non-corrosive/longer-lasting materials ***OR*** greater variety of materials ***OR*** lower density ***OR*** can be clear/translucent ✓	*Accept "more adaptable".* *Do **not** accept just "more useful".*	**1**

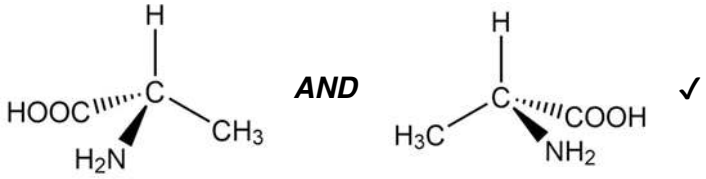
Question			Answers	Notes	Total
6.	a		*Arc discharge:* graphite electrode ***OR*** hydrocarbon solvent ✓ *CVD:* gaseous hydrocarbons ✓	*Accept "carbon electrode".* *Accept specific examples of suitable hydrocarbon solvents (eg, methyl benzene/toluene **OR** cyclohexane).* *Accept specific examples of suitable gaseous hydrocarbons (eg, methane, ethane, ethyne/acetylene) **OR** carbon monoxide **OR** carbon dioxide.*	**2**
6.	b		*Any two from:* chemically stable ***AND*** does not «chemically» degrade over time ✓ stable over range of temperatures ***AND*** to avoid «voltage/random shift» fluctuations ✓ polar ***AND*** influenced by an electric field ✓ strong intermolecular forces ***AND*** allow molecule to align in specific orientations ✓	*Award **[1 max]** for identifying two correct properties without any discussion given or incorrect interpretation of suitability.* *Accept "voltage" for "electric field".*	**2 max**

Option B — Biochemistry

Question			Answers	Notes	Total
7.	**a**		*Type of reaction:* condensation ***OR*** esterification/triesterification ***OR*** nucleophilic substitution/nucleophilic displacement/S_N2 ✓ *By-product:* water/H_2O ✓	*Do **not** accept just "substitution/displacement".*	**2**
7.	**b**		***ALTERNATIVE 1*** « $\frac{334}{253.8}$ =» 1.32 ***AND*** « $\frac{100}{304.5}$ =» 0.328 ✓ « $\frac{1.32}{0.328}$ ≈» 4 ✓ ***ALTERNATIVE 2*** «$334 \times \frac{304.5}{100}$ ≈» 1017 ✓ « $\frac{1017}{253.8}$ ≈» 4 ✓	*Award **[2]** for correct final answer.*	**2**

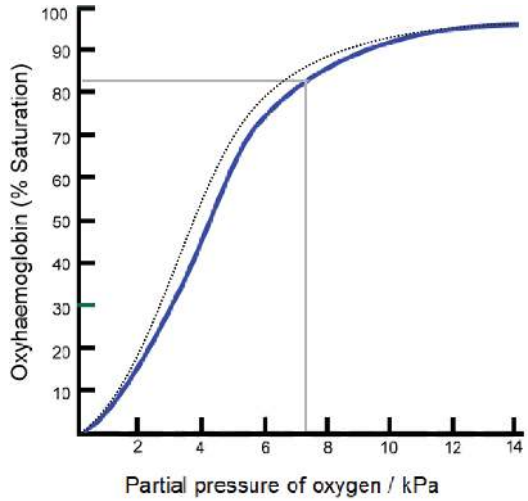
Question			Answers	Notes	Total
7.	c		 glycerol backbone as circled ✓ ester section as boxed ✓	*Accept a skeletal structure.* *Penalize missing hydrogens or incorrect bond connectivities once only in Option B.* *Accept condensed formula for ester.* *Do **not** accept structures with one or two ester groups.*	**2**
7.	d		has affected consumption of *trans*-fats/*cis*-fats/saturated fats/unsaturated fats/ hydrogenated/artificially altered fats ***OR*** reduce/eliminate *trans*-fats/increase in *cis*-fats ***OR*** reduce/eliminate saturated fats ***OR*** increase unsaturated fats ✓	*Do **not** accept "decrease in fat" alone.* *Accept "lipid" for "fats".*	**1**
7.	e		«$\frac{29.9\,\text{g}}{150.15\,\text{g mol}^{-1}}$ =» 0.199 «mol» ✓ «0.199 mol × 205.9 kJ mol^{-1} =» 41.0 «kJ» ✓	*Ignore significant figures in M1.* *Award **[2]** for correct final answer.* *Award **[1 max]** for incorrect significant figures in final answer.*	**2**

Question			Answers	Notes	Total
8.	a		 peptide bond (*eg,* CONH) ✓ order of amino acids (*ie,* correct dipeptide) ✓	*Accept zwitterion form of dipeptide.* *Accept a condensed structural formula or a skeletal structure.* *Penalize missing hydrogens or incorrect bond connectivities once only in Option B.* *M2 can only be scored if M1 correct.*	**2**
8.	b		3 ✓		**1**
8.	c		 ✓ pH = 1.0  ✓ pH = 6.0	*Penalize charge on incorrect atom once only.* *Penalize missing hydrogens or incorrect bond connectivities once only in Option B.* *Accept condensed structural formulas.* *Accept skeletal structures.*	**2**

Question			Answers	Notes	Total
8.	d		***ALTERNATIVE 1*** «$\text{pH} = 6.36 + \log\left(\frac{2.50\times10^{-2}}{1.25\times10^{-3}}\right)$ =» 7.66 ✓ ***ALTERNATIVE 2*** «$K_a = 4.4\times10^{-7} = [\text{H}^+]\left(\frac{2.50\times10^{-2}}{1.25\times10^{-3}}\right)$, $[\text{H}^+] = 2.2\times10^{-8}\ \text{mol dm}^{-3}$» «pH =» 7.66 ✓	*Do **not** accept "«pH =» 8".*	**1**
8.	e		 ***AND*** ✓	*Penalize missing hydrogens or incorrect bond connectivities once only in Option B.* *Wedges **AND** dashes must be used.*	**1**
8.	f		«$\frac{0.725}{49650\ \text{dm}^3\ \text{cm}^{-1}\ \text{mol}^{-1}\times 1.00\ \text{cm}}$ =» 1.46×10^{-5} «mol dm^{-3}» ✓		**1**
8.	g		0.65 «μg cm^{-3}» ✓	*Accept any value in the range 0.60–0.70 «μg cm^{-3}».*	**1**

Question			Answers	Notes	Total
9.			*Any two of:* replaces plastics with biodegradable/starch/cellulose based plastics ✓ use enzymes instead of polluting detergents/phosphates ***OR*** use of enzymes means lower temperatures can be used ***OR*** use enzymes instead of emulsifiers to treat oil spills ***OR*** use enzymes to produce esters at lower temperatures/without sulfuric acid ✓ replace organic/toxic solvents with carbon dioxide ✓ replace polymers from fossil fuel with bamboo/renewable resources ✓ develop paint resins reducing production of volatile compounds **«**when paint is applied**»** ✓ industrial synthesis of ethanoic/acetic acid from methanol and carbon monoxide has 100% atom economy ✓ energy recovery ✓	*Accept formulas for names.* *Award mark for any other reasonable **specific** green chemistry example that prevents the release of pollutants/toxic chemicals into the environment by changing the method or the materials used.* *Do **not** award mark for methods that involve clean-up of pollutants from the environment such as host-guest chemistry or alternative energy sources.*	**2 max**

Question			Answers	Notes	Total
10.	**a**		*Vitamin A:* fat soluble/soluble in non-polar solvents ***AND*** non-polar/long hydrocarbon backbone/chain ✓ *Vitamin C:* water soluble ***AND*** contains 4 hydroxyl groups/contains many hydroxyl groups/forms **«**many**»** H-bonds with water ✓	*Accept "Vitamin A: fat soluble/soluble in non-polar solvents as it contains only one hydroxyl group whose H-bonds with water are not strong enough to overcome London/dispersion/vdW forces between Vitamin A molecules".* *Accept "lipid" for "fats".* *Accept "alcohol" **OR** "hydroxy" **OR** "OH groups" for "hydroxyl" but **not** "hydroxide".* *Award **[1 max]** for "Vitamin A: fat soluble **AND** Vitamin C: water soluble" with no or incomplete explanation.*	**2**
10.	**b**		vitamin A oxidized to **«**11-*cis*-**»**retinal ✓ extended conjugation ***OR*** extensive delocalization ✓ *cis*-retinal converts to *trans*-retinal through absorption of light ✓	*Accept "vitamin A/hydroxyl/hydroxy/alcohol/CH_2OH group oxidized to aldehyde/CHO **«**group in retinal**»**".*	**3**

Question			Answers	Notes	Total
11.	a		 curve below original curve «showing lower affinity for oxygen» beginning at 0 ✓	*Award mark if end of student curve does not finish at same location as original curve.*	**1**
11.	b		*Any two of:* foetal hemoglobin has higher affinity for oxygen «than normal hemoglobin» ✓ foetal hemoglobin is less sensitive to inhibitors/2,3-bisphosphoglycerate/ 2,3-BPG/DPG «than normal hemoglobin» ✓ foetal hemoglobin contains two gamma units instead of the two beta units found in adult hemoglobin ✓		**2 max**

Question			Answers	Notes	Total
12.			*Any two of:* pentose «sugar» ***OR*** deoxyribose ✓ phosphate «group» ✓ «organic» nitrogenous base ***OR*** nucleobase ***OR*** nucleic base ***OR*** purine ***OR*** pyrimidine ✓	*Accept names or formulas.* *Accept "ribose" for M1.* *Do **not** accept "phosphoric acid".* *Accept the four bases together: "adenine, cytosine, thymine, guanine".*	**2 max**

Option C — Energy

Question			Answers	Notes	Total
13.	a		*Any two of:* high energy content/high energy density/high specific energy ***OR*** high enthalpy of combustion/very exothermic enthalpy of combustion ✓ shortage of alternatives ***OR*** alternatives are expensive ***OR*** oil is relatively cheap ***OR*** oil is «still» abundant/common ✓ well-established technology ***OR*** easy for consumers to obtain ***OR*** commonly used ✓ easy to store ***OR*** easy to transport ***OR*** easy to extract ✓ produces energy at a reasonable rate ✓	*Accept "high potential energy" for M1.*	**2 max**

Question			Answers	Notes	Total
13.	b	i	fuels can be compressed more without undergoing «unwanted» auto-ignition ✓	*Accept "burns smoother without undergoing «unwanted» auto-ignition"* ***OR*** *"fuel does not auto-ignite".*	1
13.	b	ii	produces more branched chain hydrocarbons «with higher octane rating» ***OR*** produces aromatics «which have higher octane rating» ***OR*** produces cyclohexanes «which have higher octane rating» ✓	*Accept "increase branches".* *Do* ***not*** *accept "produces benzene".* *Do* ***not*** *penalize for "benzene" if penalty applied in 2.b.iii.* *Accept "produces cyclic structures".*	1
13.	c		$n = 6$ ✓ «$\Delta G^{\ominus} = -nFE^{\ominus} = 6\,\text{mol} \times 96\,500\,\text{C mol}^{-1} \times 0.576\,\text{V} =$» –333 504 J/–334 kJ ✓ «Efficiency $= \frac{\Delta G}{\Delta H} = \frac{-334}{-726} =$» 0.459/45.9 % ✓	*Award* ***[3]*** *for correct final answer.*	3

Question			Answers	Notes	Total
14.	a		*Any three of:* IR/long wavelength/low frequency radiation radiated/emitted by the Earth's «surface absorbed in the bonds» ✓ bond length/C=O changes ***OR*** «asymmetric» stretching of bonds ***OR*** bond angle/OCO changes ✓ polarity/dipole «moment» changes ***OR*** dipole «moment» created «when molecule absorbs IR» ✓ «some of» energy is then re-radiated towards «the surface of the» Earth ✓	*Do **not** accept terms such as "reflect" **OR** "bounced" **OR** "trapped".*	**3 max**

Question			Answers	Notes	Total
14.	**b**		*Any two of:* H_2O ***AND*** **«**relatively**»** greater abundance/stable concentration/less effective at absorbing radiation/lower GWP so not much overall effect on global warming/climate change ✓ CH_4/N_2O/CFCs/SF_6/O_3/HCFCs ***AND*** more effective **«**than CO_2**»** at absorbing radiation/higher GWP so could contribute to global warming/climate change ✓ PFCs/SF_6/NF_3/Some CFCs ***AND*** have very long life in atmosphere so could contribute **«**in the future**»** to global warming/climate change ✓	*Accept names or formulas.* *Accept two different gases with the same effect for **[2]**.* *Award **[1 max]** for identifying the names/formulas of two greenhouse gases.* *Accept "greenhouse factor" for "GWP" but **not** just "greenhouse effect".* *For M3, do **not** allow "CFC" alone as only some have long lifetimes (eg, CFC-115, CFC-113).*	**2 max**

15.	**a**		**«** $\frac{813\text{K} - 296\text{K}}{813\text{K}} \times 100$ **»** $= 64$ **«%»** ✓		**1**
15.	**b**		35 % of <u>chemical/potential</u> energy available in coal is transformed to electricity/electrical energy ✓ not all <u>chemical</u> energy from burning fuel transferred into heating water ***OR*** energy dispersed elsewhere/energy lost due to friction of moving parts ***OR*** heat loss to the surroundings ✓	*Accept "stored energy" for "potential energy".*	**2**

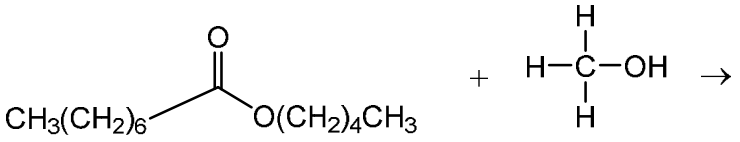
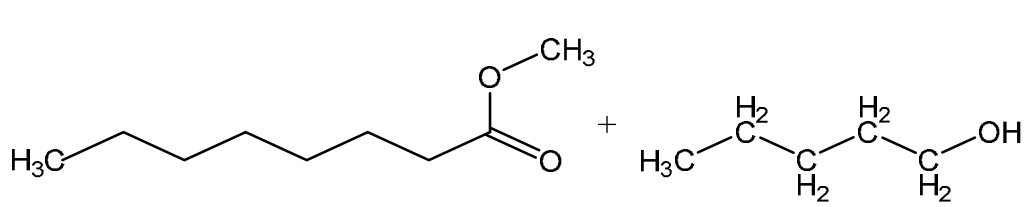
Question			Answers	Notes	Total
16.	a		*Award **[1]** for one similarity:* both increase binding energy/energy yield **«**per nucleon**»** ***OR*** mass loss/defect in both **«**nuclear**»** reactions/mass converted to energy **«**from $E = mc^2$**»** ***OR*** both produce ionizing radiation ✓		
			*Award **[2 max]** for any two differences:* in fusion, light nuclei combine to form heavier ones ***AND*** in fission, heavier nuclei split into lighter ones ✓	*Accept "small nuclei" **OR** "smaller atomic masses of nuclei" for "light nuclei" **AND** "large nuclei" **OR** "greater atomic masses of nuclei" for "heavier nuclei".*	
			fission produces radioactive/nuclear waste ***AND*** fusion does not ✓	*Do **not** accept "no/less waste produced for fusion".*	**3**
			fission is caused by bombarding with a neutron **«**or by spontaneous fission**»** ***AND*** fusion does not ***OR*** fission can initiate a chain reaction ***AND*** fusion does not ✓		
			fusion releases more energy <u>per unit mass</u> of fuel than fission ✓	*Accept "higher specific energy for fusion".*	
			fuel is easier to obtain/cheaper for fusion reactions ✓		
			fission reactions can be controlled in a power plant ***AND*** fusion cannot **«**yet**»** ✓		
			fusion reactor less likely to cause a large-scale technological disaster compared to fission ✓		
			fusion less dangerous than fission as radioactive isotopes produced have short half-lives so only cause a threat for a relatively short period of time ✓		
			fusion is in experimental development ***AND*** fission used commercially ✓		

Question			Answers	Notes	Total
16.	**b**		$\frac{1}{64} / \frac{1}{2^6} / 0.016$ ✓	*Accept "1.6 %".*	**1**
16.	**c**	**i**	$M_r(^{235}UF_6) = 235 + (19.00 \times 6) / 349$ ***OR*** $M_r(^{238}UF_6) = 238 + (19.00 \times 6) / 352$ ✓ « $\frac{\text{rate of effusion of } ^{235}U}{\text{rate of effusion of } ^{238}U} = \sqrt{\frac{352}{349}} =$ » 1.004 ✓	*Award **[2]** for correct final answer.* *Do **not** accept "1.00" **OR** "0.996".*	**2**

(continued…)

(Question 16c continued)

Question			Answers	Notes	Total
16.	**c**	**ii**	*UF_6: Structure:* octahedral **«**solid**»**/square bipyramidal **«**solid**»**/**«**simple**»** molecular solid/simple molecule ***AND*** *Bonding:* covalent ✓	*Accept "UF_6: Structure: octahedral «solid»/square bipyramidal «solid»/«simple» molecular solid/simple molecule **AND** weak intermolecular/London/dispersion/van der Waals'/vdW forces".* *Accept "non-polar molecule" for "«simple» molecular solid".*	**3**
			UO_2: Structure: crystal/lattice/network **«**solid**»**/**«**resembles**»** fluorite ***AND*** *Bonding:* «partly» covalent ✓	*Accept "giant molecular" **OR** "macromolecular" for "network".* *Accept "ionic/electrostatic attractions «between ions»" for bonding in UO_2.* *Award M2 for "UO_2: network covalent/covalent network/giant covalent" **OR** "UO_2: network ionic/giant ionic".* *For M1 and M2 award **[1 max]** for two correct structures **OR** two bonding types.*	
			UF_6 sublimes/evaporates/boils at low temperature ✓	*Accept any specified low temperature in the range 56–65 °C.*	

Question			Answers	Notes	Total
17.	a		$C_7H_{15}COOC_5H_{11}$ (l) + CH_3OH (l) → $C_7H_{15}COOCH_3$ (l) + $C_5H_{11}OH$ (l) ***OR*** $C_{13}H_{26}O_2$ (l) + CH_4O (l) → $C_9H_{18}O_2$ (l) + $C_5H_{12}O$ (l) ***OR***   ✓	*Accept correct equation in any format eg, skeletal, condensed structural formula, etc.* *Accept equations with equilibrium arrow.*	**1**
17.	b		less viscous «and so does not need to be heated to flow» ***OR*** less likely to undergo incomplete combustion ***OR*** fewer intermolecular/London/dispersion forces ***OR*** vaporizes easier ✓	*Ignore equation and products in 17a.* *Accept "van der Waals'/vdW" for "London".*	**1**

Question			Answers	Notes	Total
18.	a		***ALTERNATIVE 1*** B/Ga in circle ***AND*** *Type of semiconductor:* p-type ✓ showing 3 electron pairs ***AND*** one lone electron «and hole» ✓ ***ALTERNATIVE 2*** P/As in circle ***AND*** *Type of semiconductor:* n-type ✓ showing 4 electron pairs ***AND*** one non-bonded electron ✓	*Accept any group 13 element labelled as p-type.* *Accept showing 7 electrons.* *Accept any group 15 element labelled as n-type.* *Accept showing 9 electrons.* *Accept dots or crosses for electrons.*	**2**
18.	b	i	conjugated C=C/carbon–carbon double bonds ***OR*** «multiple» alternating C=C/carbon–carbon double bonds ***OR*** «extensive electron» conjugation/delocalization ***OR*** «many» fused/conjugated aromatic/benzene rings ✓		**1**
18.	b	ii	complex B has greater conjugation/delocalization ✓		**1**

Option D — Medicinal chemistry

Question			Answers	Notes	Total
19.			LD_{50}: amount/dose that kills 50% of the population ✓ TD_{50}: amount/dose that negatively affects/produces toxic effects in 50% of the population ✓	*Award **[1 max]** for "LD_{50} used in animal trials **AND** TD_{50} used in human studies".*	**2**

Question			Answers	Notes	Total
20.	**a**	**i**	«irreversibly» binds/bonds to enzyme/transpeptidase ***OR*** inhibits enzyme/transpeptidase «in bacteria» that produces cell <u>walls</u> ***OR*** prevents cross-linking of bacterial cell <u>walls</u> ✓ cells absorb water ***AND*** burst ***OR*** cells cannot reproduce ✓		**2**
20.	**a**	**ii**	modify side chain ✓		**1**
20.	**b**		condensation ***OR*** esterification ***OR*** nucleophilic substitution/nucleophilic displacement/S_N2 ✓	*Do **not** accept just "substitution/displacement".*	**1**

Question			Answers	Notes	Total
20.	**c**		water causes hydrolysis ***OR*** aspirin reacts with water ✓ heat increases the rate of hydrolysis ***OR*** heat increases the rate of the reaction with water ✓	*Accept "aspirin will convert into salicylic/ethanoic acid".* *Do **not** accept "aspirin dissolves in water" **OR** "aspirin absorbs water/is hygroscopic".*	**2**

21.			morphine has hydroxyl/OH groups/is more polar ***AND*** diamorphine has ester/ethanoate/acetate groups/is less polar/is lipid soluble ✓ crossing blood brain barrier is easier for non-polar/less polar compounds/for lipid soluble compounds ✓	*Accept "alcohol/hydroxy" for "hydroxyl" but **not** "hydroxide".* *Accept "fats" for "lipid".*	**2**

Question			Answers	Notes	Total
22.	**a**		$2HCl\ (aq) + CaCO_3\ (s) \rightarrow H_2O\ (l) + CO_2\ (g) + CaCl_2\ (aq)$ ✓	*Accept ionic equation:* $2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$	**1**
22.	**b**		**«**$\frac{0.750 \times 2}{100.09}$ **=»** 0.0150 **«**mol HCl**»** ✓		**1**
22.	**c**		inhibits the secretion of stomach acid/H^+ ✓ **«**active metabolites**»** bind **«**irreversibly**»** to **«**receptors of the**»** proton pump ✓	*Do **not** accept "hydrogen/H/H_2" for "H^+".* *Accept "PPI/proton pump inhibitor" for M2.* *Accept "H^+/K^+ ATPase" for "proton pump".*	**2**

Question			Answers	Notes	Total
23.			*Any two of:* hydroxyl ✓ carboxyl/carbonyl ✓ ether ✓ amido/carbonyl ✓	*Accept "alcohol/hydroxy" for "hydroxyl", "carboxylic acid" for "carboxyl" and "amide/carboxamide" for "amido".* *Accept "amino/amine" **OR** "imine/imino" but these are not correct as they are part of the guanidino group.* *Accept "alkenyl/alkene/carbon to carbon double bond" but **not** "C=C" **OR** "carbon double bond".* *Accept "carbonyl" only once.* *Accept "heterocyclic ring" for "ether".*	**2 max**

Question			Answers	Notes	Total
24.			*Hazardous solvent:* *Any one of:* methanal/formaldehyde ✓ methanol ✓ chlorinated solvent/carbon tetrachloride/methylene chloride/dichloromethane ✓ diethyl ether/ethoxyethane ✓ benzene ***OR*** methyl benzene/toluene ***OR*** **«**1,2/1,3/1,4**»** dimethylbenzene/**«**ortho/o-/meta/m-/para/p-**»** xylene ✓ *Green solvent:* *Any one of:* water ✓ **«**supercritical/liquid**»** carbon dioxide/supercritical fluids ✓ ethanol **«**only if replacing a hazardous solvent**»** ✓ propan-2-ol/2-propanol/isopropanol **«**only if replacing a hazardous solvent**»** ✓ propanone/acetone **«**only if replacing a hazardous solvent**»** ✓ ethyl ethanoate/ethyl acetate **«**only if replacing a hazardous solvent**»** ✓ organic carbonates/dimethyl carbonate/diethyl carbonate/ethylene carbonate/propylene carbonate ✓ ionic liquids ✓ fluorous solvents ✓	*Accept correct names (either IUPAC or generic) or formulas.* *Do **not** accept inorganic acids such as HCl, H_2SO_4, etc.* *Accept any specific chlorinated solvent.* *Accept other hazardous solvents.* *Do **not** accept any solvent given as **both** hazardous and green.* *Award **[2]** for combination "Hazardous solvent: dimethylformamide/DMF/N,N-dimethylmethanamide" **AND** "Green solvent: methanol «only if replacing a hazardous solvent»".* *Accept other green solvents but **not** "solvents from biomass/food waste".*	**2 max**

Question			Answers	Notes	Total
25.			*Any two of:* stripping the bark kills Pacific yew tree ✓ plant cell fermentation «and extraction»/PCF technology/use of plant cell cultures/Taxol «precursors» produced by biosynthesis/fungi/yeast/e-coli/use of natural enzymes «more sustainable process» ***OR*** Taxol produced semi-synthetically/Taxol from 10-DAB/10-deacetylbaccatin ✓ uses renewable resources ***OR*** use «needles/leaves/twigs of» European/common yew/yew from Himalayas ✓ «sustainable» process has eliminated «high proportion of» hazardous chemicals/waste ***OR*** «sustainable» process has eliminated several solvents/«sustainable» process uses greener solvents/«sustainable» process recycles/reuses solvents ***OR*** «sustainable» process has eliminated several «drying» steps/«sustainable» process has eliminated lots of the work-up after the synthesis ***OR*** «sustainable» process has increased energy efficiency ***OR*** «sustainable» process has no intermediates ***OR*** «sustainable» process uses more efficient catalysts ✓	*Accept "Pacific yew rare/slow-growing/takes 100/200 years to mature" for M1.* *Accept "synthesis of Taxol using chiral auxiliaries increases efficiency of process as single enantiomer formed" for M4.*	**2 max**

Question			Answers	Notes	Total
26.	**a**		$^{32}P \rightarrow {}^{32}S + {}^{0}_{-1}\beta$ ✓	*Accept "e^-/e/β" instead of "$^{0}_{-1}\beta$".*	**1**
26.	**b**		***ALTERNATIVE 1*** «$\lambda = \frac{\ln 2}{14.3}$ =» 0.04847 «day^{-1}» ✓ «$m(^{32}P) = 2.63 \times 10^{-8}\,mol \times 31.97\,g\,mol^{-1} \times e^{-0.04847 \times 57.2}$ =» 5.26×10^{-8} «g» ✓ ***ALTERNATIVE 2*** «$\frac{57.2}{14.3}$ =» 4 «half-lives passed» ***OR*** «$n(^{32}P) = \frac{2.63 \times 10^{-8}\,mol}{2^4}$ =» 1.64×10^{-9} «mol» ✓ «$m(^{32}P) = 1.64 \times 10^{-9}\,mol \times 31.97\,g\,mol^{-1}$ =» 5.26×10^{-8} «g» ✓	*Award **[2]** for correct final answer.* *Accept any value in the range "5.24–5.26 × 10^{-8} «g»".*	**2**

Question			Answers	Notes	Total
26.	**c**		alpha-emitting isotopes/^{212}Pb/^{225}Ac attached to drugs/antibodies/chelating ligands/carriers ✓ *Award **[2 max]** for any two of:* absorbed by **«**cancer/growing**»** cells ***OR*** bind to **«**cancer/growing**»** cell receptors ✓ alpha particles have high ionizing density/power ✓ short-range of emission **«**of alpha-particles**»** ***OR*** healthy tissues less affected **«**as slower cell growth**»** ***OR*** local effect **«**on dispersed/spread/metastasised cancers**»** ✓	*Accept "radionuclide" for "isotope".* *Accept "alpha particles are highly ionizing".* *Accept "alpha particles have low penetrating power".* *Accept "used to treat dispersed/spread/metastasised cancers" **OR** "can be used to map the distribution of cancer cells in the body".*	**3**

Question			Answers	Notes	Total
27.	**a**		$C_2H_5OH\,(g) + O_2\,(g) \rightarrow CH_3COOH\,(aq) + H_2O\,(l)$ ✓	*Accept any correct formula for reactants and products.*	**1**
27.	**b**		*R–O**H**:* 1.0–6.0 «ppm» ***AND*** 1 H ✓ *R–O–C**H**$_2$–:* 3.3–3.7 «ppm» ***AND*** 2 H ✓ *–C**H**$_3$:* 0.9–1.0 «ppm» ***AND*** 3 H ✓	*Award **[1]** for the ratio of 1:2:3 (in any order).* *Award **[2]** for three correct chemical shifts without integration.* *Award **[1]** for two correct chemical shifts without integration.* *For each chemical shift accept a specific value within the range.* *Assignment of proton to fragment (eg, R–O**H**) is **not** required in each case.*	**3**