

Markscheme

May 2017

Chemistry

Standard level

Paper 3

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Section A

Question		Answers	Notes	Total
1.	a	$\left\langle \frac{0.5}{25.0} \times 100 \right\rangle = 2 \text{ \%}$ ✓		1
1.	b	pipette/pipet «rather than a measuring cylinder» ✓	Accept “using a burette/buret”. Accept “using a volumetric/measuring flask”. Do not accept “use of a more precise measuring cylinder”.	1
2.	a	more «moles/amount of» acid have been added/reacted OR more of the limiting reagent is present OR more «of the exothermic» reaction has occurred ✓		1
2.	b	no more reaction/same energy released AND cold/colder/cooler liquid added OR no more reaction/same energy released AND greater total volume of liquid ✓	Accept “no more reaction/same energy released AND greater heat loss «to the surroundings in mixture D»”.	1
3.		volume «found by extrapolation of the two best fit lines» required to give the highest temperature OR extrapolate «two best fit» lines to the point where they meet ✓	Accept “where lines through the points meet”. Accept “at maximum temperature”. Accept “at 35 cm ³ of HCl”.	1

Question		Answers	Notes	Total
4.		<p>graph would peak/maximum at 17.5 cm³ OR smaller volume of acid «needed to reach equivalence» ✓ sulfuric acid is dibasic/diprotic ✓ higher temperature would be reached ✓</p>	<p>Accept “gradient/slope «of graph» is greater/steeper” for M1. Accept “one mole of sulfuric acid neutralizes two moles of NaOH” for M2.</p>	2 max
5.	a	<p>heat change/evolved can be calculated from the «maximum» temperature increase and the mass of solution OR $q = mc\Delta T$ ✓ heat «evolved» gives the number of moles «of both acid and alkali present when neutralisation occurs» OR $n = \frac{q}{\Delta H_{neut}}$ ✓ volume «of acid and the volume of alkali required to just neutralise each other» can be used to calculate the concentration«s of both» OR $[\text{NaOH}] = \frac{n}{V}$ ✓</p>		2 max
5.	b	<p>smaller temperature increase/ΔT OR heat released would «appear to» be less ✓ amount of substance/n calculated is smaller ✓</p>		2

5.	c	<p>using «expanded» polystyrene cup OR insulating beaker OR putting a lid on beaker ✓</p>	<p><i>Do not accept calorimeter by itself. Accept any other reasonable suggestion.</i></p>	1
5.	d	<p>«specific» heat capacity of the beaker/container/thermometer is ignored OR density of the solutions is assumed as 1.00 g cm⁻³/same as water OR specific heat capacity of the solutions is assumed as 4.18 J g⁻¹ K⁻¹/same as water ✓</p>	<p><i>Accept “reaction goes to completion”. Accept “reaction is conducted under standard conditions”. Accept “no evaporation occurs”. Accept any other relevant valid assumption. Do not accept “heat is not released from other reactions”.</i></p>	1
5.	e	<p>allows simple theories to be applied to real life situations OR enables us to start to understand complex situations OR gives answers that are accurate to the required order of magnitude OR simplifies the calculations involved ✓</p>	<p><i>Do not accept “to simplify the situation” without further detail. Accept “errors do not have a major impact on the results”.</i></p>	1
5.	f	<p>temperature rise would be too small «to be accurately measured» ✓</p>	<p><i>Accept “heat released would be too small «to be accurately measured”.</i></p>	1

Section B

Option A — Materials

Question		Answers	Notes	Total
6.	a	polar covalent ✓ average electronegativity $\llcorner = \frac{1}{2}(3.0 + 2.0)\llcorner = 2.5$ AND electronegativity difference $\llcorner = 3.0 - 2.0\llcorner = 1.0$ ✓		2
6.	b	ionic bonding OR electrostatic forces between ions ✓ \llcorner slight \llcorner movement brings ions of same charge adjacent to each other \llcorner causing the crystal to break \llcorner OR \llcorner slight \llcorner movement results in repulsion between layers \llcorner causing the crystal to break \llcorner ✓		2
7.	a	too high/higher than carbon in the reactivity series OR carbon/C is a weaker reducing agent than lanthanum/La ✓	Accept "lanthanum is more reactive than carbon". Accept "lanthanum is a weaker oxidizing agent than carbon". Accept converse arguments.	1
7.	b	amount of La $\llcorner = \frac{1000\text{g}}{138.91\text{g mol}^{-1}}\llcorner = 7.20$ «mol» ✓ $Q \llcorner = 7.20\text{ mol} \times 3 \times 96\,500\text{ C mol}^{-1}\llcorner = 2.08 \times 10^6$ «C» ✓ $I \llcorner = \frac{2.08 \times 10^6\text{ C}}{60 \times 60\text{ s}}\llcorner = 579$ «A» ✓	Award [3] for "578 «A»" (from premature rounding) or "579 «A»".	3

Question		Answers	Notes	Total
8.	a	large surface area ✓		1
8.	b	«potentially» explosive OR small size/large surface area could give dangerously fast reactions OR unknown health effects OR potentially toxic OR immune system/allergy concerns ✓	<i>Do not accept just "dangerous/poisonous/toxic".</i> <i>Accept other valid concerns.</i>	1

9.	a	combine with reactants to form a «temporary» activated complex/intermediate OR consumed in one reaction/step AND regenerated in a later reaction/step ✓		1
9.	b	can modify/improve the catalyst/reaction «by making logical predictions» OR science relies on models to understand physical reality ✓	<i>Accept other reasonable, relevant answers.</i> <i>Accept "to predict/select the ideal catalyst for a reaction."</i>	1
9.	c	electrons AND positive ions «in gaseous state» ✓ high frequency/alternating current passed through argon OR «oscillating» electromagnetic/magnetic field OR high frequency radio waves ✓	<i>Accept "gas" instead of "argon".</i>	2

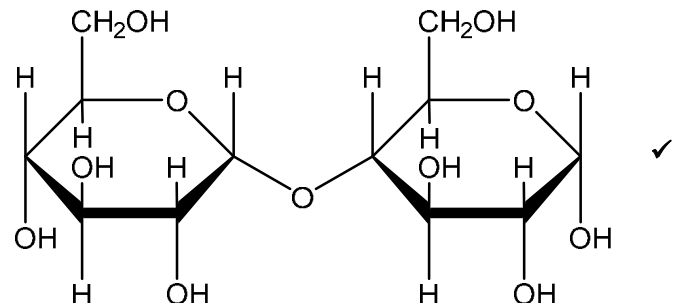
Question			Answers	Notes	Total
10.	a		<p><i>A RIC: 1 AND B RIC: 4 ✓</i></p> <p>ALTERNATIVE 1: «only» PETE contains carbonyl/C=O/ester/COO groups ✓ carbonyl groups absorb at 1700–1750 «cm⁻¹» ✓</p> <p>ALTERNATIVE 2: LDPE contains more C–H bonds «than PETE» ✓ C–H bonds absorb at 2850–3090 «cm⁻¹» ✓</p>	<p><i>For either, accept specific frequencies in these ranges (eg 1735 «cm⁻¹» or 2900 «cm⁻¹»).</i></p>	3
10.	b	i	<p>HDPE less branched OR LDPE more branched ✓</p>	<p><i>Accept “no branching in HDPE AND branching in LDPE”.</i></p>	1
10.	b	ii	<p>HDPE «polymer» chains/molecules can pack together more closely «than LDPE chains» OR HDPE «polymer» chains/molecules have a higher contact surface area «than LDPE chains» ✓</p> <p>stronger intermolecular/dispersion/London/van der Waals’ forces in HDPE AND higher melting point ✓</p>	<p><i>Accept converse arguments.</i></p>	2

Option B — Biochemistry

Question		Answers	Notes	Total	
11.	a	<p><i>Triglycerides:</i> organic acid/fatty acid and glycerol/propane-1,2,3-triol</p> <p>AND</p> <p><i>Carbohydrates:</i> monosaccharides ✓</p>	<p><i>Accept simple sugars.</i></p>	1	
11.	b	i	<p>«water/aqueous solubility depends on forming many» H-bonds with water ✓</p> <p>raffinose has many hydroxyl/O–H/oxygen atoms/O «and forms many H-bonds» AND linoleic acid has few/one hydroxyl/O–H/oxygen atom/O/carboxyl group/ COOH/is largely non-polar «and cannot form many H-bonds» ✓</p>	<p><i>Accept statement which implies comparison.</i></p>	2
11.	b	ii	<p>«base» hydrolysis/saponification OR «produces glycerol and» soap/salt of the «fatty» acid ✓</p> $ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{O}-\text{C}(=\text{O})-\text{R} \\ \\ \text{H}-\text{C}-\text{O}-\text{C}(=\text{O})-\text{R} \\ \\ \text{H}-\text{C}-\text{O}-\text{C}(=\text{O})-\text{R} \\ \\ \text{H} \end{array} + 3\text{NaOH} \longrightarrow \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H} \end{array} + 3(\text{R}-\text{COO}^- \text{Na}^+) \checkmark $ <p>«products are» water soluble «and drain away» ✓</p>	<p><i>Accept condensed formulas.</i> <i>Accept non-balanced equation.</i> <i>Accept "RCOONa".</i></p>	2 max

(continued...)

Question			Answers	Notes	Total
11.	c		linoleic acid/C ₁₈ H ₃₂ O ₂ combustion/oxidation more exothermic «per mol» ✓ linoleic acid/C ₁₈ H ₃₂ O ₂ has lower proportion/number of O atoms OR linoleic acid/C ₁₈ H ₃₂ O ₂ is less oxidized ✓	Accept converse arguments.	2

Question			Answers	Notes	Total
12.	a	i	$ \begin{array}{c} \text{CHO} \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{H} - \text{C} - \text{OH} \quad \checkmark \\ \\ \text{H} - \text{C} - \text{OH} \\ \\ \text{CH}_2\text{OH} \end{array} $	All OH groups must be on the same side. Accept structures with chiral carbon atoms shown as C or C* instead of crosses.	1
12.	a	ii		Accept –O– in a straight line provided both H's are above the plane.	1

(continued...)

12.	b		«allow» 3-D perspective of structures «of cyclic monosaccharide molecules» OR «show» <i>cis</i> /same side arrangement of «attached» groups OR «show» <i>trans</i> /opposite side arrangement of «attached» groups OR «make» carbon and hydrogen implicit ✓		1
12.	c	i	abundant/renewable/allows use of «local» vegetation OR less use of fossil fuel/oil based plastics OR air permeable/better breathing of products OR «can be» mixed/blended with synthetic polymers ✓	<i>Do not accept answers related to biodegradable examples. Ignore any reference to cost. Accept “carbon neutral/do not contribute to global warming”. Accept “require less energy to produce”. Accept “do not produce toxic products”.</i>	1
12.	c	ii	HO-CH(CH ₃)-COOH/CH ₃ CH(OH)COOH ✓	<i>Do not accept C₃H₆O₃. Do not accept OH-CH(CH₃)-COOH.</i>	1

Question			Answers	Notes	Total
13.	a		catabolism/catabolic ✓		1
13.	b	i	alanine ✓	<i>Do not accept ala.</i>	1
13.	b	ii	Lys/lysine ✓ pH «buffer» < pI «Lys» OR buffer more acidic than Lys «at isoelectric point» OR «Lys» exists as $\begin{array}{c} \text{H}_3\text{N}^+ - \text{CH} - \text{COO}^- \\ \\ (\text{CH}_2)_4\text{NH}_3^+ \end{array}$ OR «Lys» charged positively/has +1/1+ «overall» charge «and moves to negative electrode» ✓	<i>Do not apply ECF from M1. Accept converse argument. Do not accept just “has H₃N⁺ group” for M2 (as H₃N⁺ is also present in zwitterion). Do not penalize if COOH is given in the structure of lysine at pH 6 instead of COO⁻.</i>	2

13.	c	<p>highest <u>frequency</u> of <u>successful</u> collisions between active site and substrate OR highest <u>frequency</u> of collisions between active site and substrate with sufficient energy/$E \geq E_a$ AND correct orientation/conformation OR optimal shape/conformation of the active site «that matches the substrate» OR best ability of the active site to bind «to the substrate» ✓</p>	<p>Accept “number of collisions per unit time” for “frequency”.</p> <p>Do not accept “all active sites are occupied”.</p>	1
13.	d	<p>ascorbic acid/vitamin C ✓</p>		1
13.	e	<p>react/bind/chelate with enzyme OR disrupt ionic salt bridges OR affect shape of tertiary/quaternary structures OR precipitate enzymes OR break/disrupt disulfide bridges/bonds ✓</p>	<p>Do not accept “changes shape of active site” by itself.</p>	1
13.	f	<p>«use of» host-guest chemistry OR chelation «therapy» ✓</p>	<p>Accept specific medication/chelating agent such as EDTA, CaNa_2EDTA, succimer, D-penicillamine, dimercaprol.</p>	1

Option C — Energy

Question			Answers	Notes	Total
14.	a		presence of dark/absorption lines corresponding to those found for carbon OR missing wavelengths/frequencies correspond to carbon's spectrum ✓	Accept "presence of characteristic dark lines". Do not accept answer in terms of emission spectra.	1
14.	b	i	${}^8_4\text{Be}$ ✓		1
14.	b	ii	product «nucleus» has a greater binding energy «per nucleon than reacting nuclei» ✓	Accept "mass of the products is less than mass of the reactants". Accept converse arguments.	1
14.	c		fuel more abundant/cheaper ✓ no «long half-life» radioisotopes/radioactive waste ✓ shipment of radioactive fuels not required ✓ plutonium/nuclear weapons cannot be produced from products ✓ nuclear disasters less likely «as no critical mass of fuel required» ✓ higher specific energy/energy per g/kg/unit mass than fission ✓	Do not accept simply "fusion produces more energy than fission".	2 max

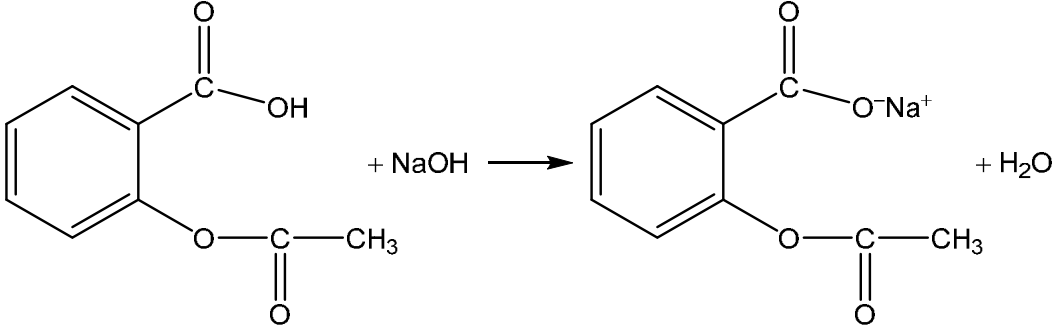
Question		Answers	Notes	Total
15.	a	methanol OR ethanol ✓ strong acid OR strong base ✓	Accept "alcohol". Accept any specific strong acid or strong base other than HNO ₃ /nitric acid.	2
15.	b	CH ₃ (CH ₂) ₁₆ COOCH ₃ / CH ₃ OCO(CH ₂) ₁₆ CH ₃ OR CH ₃ (CH ₂) ₁₆ COOC ₂ H ₅ / C ₂ H ₅ OCO(CH ₂) ₁₆ CH ₃ ✓	Product must correspond to alcohol chosen in (a), but award mark for either structure if neither given for (a).	1
15.	c	lower viscosity ✓ weaker intermolecular/dispersion/London/van der Waals' forces OR smaller/shorter molecules ✓	Accept "lower molecular mass/M _r " or "lower number of electrons". Accept converse arguments.	2
15.	d	Specific energy: « = $\frac{12000 \text{ kJ mol}^{-1}}{299 \text{ g mol}^{-1}}$ » = 40.1 «kJ g ⁻¹ » ✓ Energy density: « = 40.1 kJ g ⁻¹ × 0.850 g cm ⁻³ » = 34.1 «kJ cm ⁻³ » ✓	Award [1] if both are in terms of a unit other than kJ (such as J or MJ).	2

Question		Answers	Notes	Total
16.	a	heat/react with «oxygen and» water/steam ✓ $C + H_2O \rightarrow CO + H_2$ OR $3C + O_2 + H_2O \rightarrow H_2 + 3CO$ OR $2C + O_2 \rightarrow 2CO$ AND $C + H_2O \rightarrow H_2 + CO$ OR $C + O_2 \rightarrow CO_2$ AND $C + CO_2 \rightarrow 2CO$ AND $C + H_2O \rightarrow H_2 + CO$ ✓	<i>M1 requires concept of heat.</i>	2
16.	b	«Fischer-Tropsch» catalytic reduction of carbon monoxide with hydrogen OR $(2n+1) H_2 + n CO \rightarrow C_nH_{(2n+2)} + n H_2O$ OR reduction of carbon monoxide to methanol AND catalytic dehydration OR $2H_2 + CO \rightarrow CH_3OH$ AND $n CH_3OH \rightarrow C_nH_{2n} + n H_2O$ ✓	<i>If equation is given for a specific alkane or alkene, it must be a liquid (n>4).</i>	1

Question		Answers	Notes	Total
17.	a	<p>computers can now carry out more complex calculations OR better understanding of the interactions between the various systems involved OR clear evidence of global warming OR «reliable» global temperature data now available OR techniques have been available to monitor carbon dioxide levels ✓</p>	<p>Accept “better/faster computers”. Accept “better modelling”. Accept “better/more reliable/consistent data”. Accept “better measuring techniques”. Accept other scientifically based (not politically based) reasons. Accept if specific relevant data is given.</p> <p>Do not accept “increased combustion of fossil fuels” or “increased concerns about global warming”.</p>	1
17.	b	<p>symmetric stretching will not absorb IR OR asymmetric stretching will absorb IR ✓</p> <p>change in polarity/dipole «moment» required «to absorb IR» ✓</p>		2
17.	c	<p>$\text{CO}_2 (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{H}^+ (\text{aq}) + \text{HCO}_3^- (\text{aq})$ «and pH decreases» OR $\text{CO}_2 (\text{aq}) + \text{H}_2\text{O} (\text{l}) \rightleftharpoons \text{H}_2\text{CO}_3 (\text{aq})$ AND $\text{H}_2\text{CO}_3 (\text{aq}) \rightleftharpoons \text{H}^+ (\text{aq}) + \text{HCO}_3^- (\text{aq})$ «and pH decreases» ✓</p>	<p>Accept reversible or non-reversible arrows for all.</p>	1
17.	d	<p>reduce it AND absorbing/reflecting sunlight ✓</p>	<p>Accept “reduce it because of global dimming”. Accept “reduce it AND blocking sunlight”.</p>	1

Option D — Medicinal chemistry

Question			Answers	Notes	Total
18.	a		«measures» therapeutic window/margin «of a drug» OR range of doses that produce a therapeutic effect without causing toxic effects ✓	Accept “difference between ED_{50} /minimum effective/therapeutic dose «for 50 % of population» AND TD_{50} /toxic dose «for 50 % of population»”. Do not accept “therapeutic index”. Do not accept “lethal/fatal dose” as this is not LD_{50} .	1
18.	b	i	«nucleophilic» substitution/ S_N ✓	Accept “methylation”.	1
18.	b	ii	work directly on <u>opioid/pain</u> receptors «in brain» ✓ suppress pain impulses in brain/CNS ✓ resemble endorphins/enkephalins/natural chemical painkillers «produced in the brain and spinal cord» ✓	Do not award mark for “resemble hormones”.	2 max

Question		Answers	Notes	Total
19.	a	<p>presence of «large» benzene/arene ring AND non-polar/hydrophobic OR presence of «large» benzene/arene ring AND cannot form H-bond with water ✓</p> <p>contain COOH/carboxyl/–OH/hydroxyl «and ester group» AND polar/hydrophilic OR contain COOH/carboxyl/–OH/hydroxyl «and ester group» AND can form H-bonds with water ✓</p>	<p>Accept “phenyl” for “benzene ring”.</p> <p>Accept “carboxylic acid” for “carboxyl”.</p> <p>Do not accept “alcohol” for “hydroxyl”.</p>	2
19.	b	 <p>OR $C_6H_4(OCOCH_3)COOH + NaOH \rightarrow C_6H_4(OCOCH_3)COONa + H_2O$ ✓</p>	<p>Charges (O^- and Na^+) not necessary to score the mark.</p> <p>Accept net ionic equation.</p> <p>Accept any strong base in place of NaOH.</p>	1
19.	c	<p>«student’s» sample impure ✓</p> <p>lattice disrupted/not uniform «due to presence of impurities» OR fewer interparticle/intermolecular forces «due to presence of impurities» ✓</p>	Accept converse arguments.	2

(continued...)

Question		Answers	Notes	Total
19.	d	<p><i>One similarity:</i> peak at 2500–3000 «cm⁻¹»/peak due to O–H/hydroxyl in carboxylic acids OR peak at 1700–1750 «cm⁻¹»/peak due to C=O/carbonyl OR peak at 2850–3090 «cm⁻¹»/peak due to C–H of arene ✓</p> <p><i>One difference:</i> peak at 3200–3600 «cm⁻¹» in salicylic acid/ peak due to O–H in phenol in salicylic acid OR «two» peaks at 1700–1750 «cm⁻¹» in aspirin AND one peak «in the same area» in salicylic acid ✓</p>	<p><i>Accept “peak at 1600 cm⁻¹ for arene/ benzene ring” – not in the data booklet.</i></p> <p><i>Accept “2500–3600 cm⁻¹ «overlapping absorptions of two O–H» in salicylic acid”.</i> Accept “stronger/broader/split peak at 1700–1750 cm⁻¹ in aspirin”.</p>	2
19.	e	<p>«use of» alternative solvents such as supercritical/liquid CO₂ OR use of water «as solvent» OR solvent-free reactions «for example, polymerization of propene» OR solid-state chemistry OR recycle «waste» solvents OR catalysis that leads to better/higher yield OR reducing number of steps ✓</p>	<p><i>Do not accept political/regulatory solutions.</i></p> <p><i>“catalysis” not sufficient for mark.</i></p>	1

Question		Answers	Notes	Total
20.	a	$\ll \text{pH} = \text{p}K_a + \log_{10} \left(\frac{[\text{HCO}_3^-]}{[\text{CO}_2]} \right) = 6.34 + \log_{10}(11.2) = 6.34 + 1.05 \gg = 7.39 \checkmark$		1
20.	b	<p>H⁺ from aspirin reacts with HCO₃⁻ to form CO₂ and H₂O</p> <p>OR</p> <p>H⁺ (aq) + HCO₃⁻ (aq) ⇌ CO₂ (aq) + H₂O (l)</p> <p>OR</p> <p>reverse reaction favoured «to use up some of the H⁺ added» ✓</p> <p>pH decreases ✓</p>	<p>No mark for “stating aspirin is a weak acid that dissociates partially to produce H⁺” without reference to reaction with HCO₃⁻ or to the equation.</p> <p>Reversible arrows not required for the mark.</p> <p>Do not accept “small pH change when small amount of H⁺ is added”.</p>	2

Question		Answers	Notes	Total
21.	a	«drug» blocks/inhibits «viral» enzyme/neuraminidase/NA «activity» ✓ prevents virus from leaving/escaping host cells «thus cannot infect other cells» ✓		2
21.	b	ALTERNATIVE 1: «using» genetically modified/GM <i>E. Coli</i> /bacteria/microorganisms ✓ <i>E. Coli</i> /bacteria biosynthesis OR <i>E. Coli</i> /bacteria «overfed by glucose» undergo fermentation OR cells of the bacteria «are broken down to» form precursor/shikimic acid ✓ ALTERNATIVE 2: use readily available cyclic ester/lactone ✓ forms «the correct stereoisomer of oseltamivir» in a shorter number of chemical steps ✓	<i>Do not accept “planting more Chinese star anise” or “other plant sources of shikimic acid”.</i>	2
21.	c	«can develop antibiotic» resistance in <u>bacteria/microorganisms</u> OR changes in <u>microbial/bacterial</u> population ✓	<i>Accept secondary effects, such as reduced biodiversity of aquatic/soil ecosystems, denitrification of soil (due to decline in nitrogen-fixing bacteria). No mark for just stating “water contamination”. No mark for just stating “failure of aquatic/marine environment”.</i>	1