

1. (i) *max 1 for meaning of term*
attached to an insoluble material / AW;
max 2 for description
(micro)encapsulation / (trapped) in alginate beads;
adsorption / stuck onto, collagen / clays / resin / (porous) glass;
cross linkage / covalent / chemical, bonding to, cellulose / collagen fibres;
gel entrapment / trapped inside gel e.g. silica (lattice / matrix);
partially permeable membrane (polymer) microspheres; 3
- (ii) *any three from the following:*
urine can be processed / no problem of removing urine / AW;
pure / drinkable / useable, water produced; **A** water recycled
space saving / less water needs to be taken into space;
payload limit / weight reduction / AW;
no problem in separating enzyme from products / product not
contaminated;
ref. to longer shelf-life of enzyme;
no need to take more enzymes into space / enzymes reusable ;
A enzymes recoverable
AVP; e.g. larger surface area of enzyme exposed, more stable at
extremes,
ref. to ease of use (of bioreactor) 3
- [6]
2. (i) adding / using, water to break, bond / ester bond, (in molecule);
A breakdown into smaller molecules 1
- (ii) matrix, protects / stabilises, enzyme / lipase;
functions, at optimal rate / more efficiently, at higher temperature / 45 °C;
A *greater activity* / AW
ref. to soluble lipase begins to denature (reducing activity); ora
functions, at optimal rate / more efficiently, at lower pH;
ref. to presence of fatty acids changing pH;
ref. to ionic bonds breaking (in soluble lipase) ; ora
AVP ; e.g. ref to industrial uses
ref to effect on R groups max 4
- [5]
3. (i) indicates the range of results;
on either side of the mean;
indicates, variability/(standard) deviation/(standard) error;
indicates if data sets significantly different; 2 max

(ii) no/small, increase/figs. quoted;
lag phase;
adjust to conditions/detail of adjustment;
produce enzymes;
AVP; 2 max

(iii) more rapid growth in non-deficient cells/ora;
figures in support from both axes of graph;
low ribose in G6PD deficient cells/ora;
less available to, parasites/*Plasmodium*;
less production of RNA/ribonucleotides;
less available for transcription;
inhibited protein synthesis;
less protein available for, reproduction/growth/cell division; 4 max

[8]

4. (a) mRNA and its complementary RNA bind together ;
hydrogen bonding ;
A to U and C to G ; **R** 'T'
double stranded RNA / duplex RNA ;
cannot bind to ribosome ;
tRNA cannot bind ;
cannot be translated / AW;
ref to, RNA interference / RNAi ; 4 max

(b) (i) theobromine content, reduced / approximately halved ;
no significant difference between short and long lengths of RNA ;
caffeine content reduced ;
to half by short lengths of RNA ; **A** figures
to about a third by long lengths of RNA ; **A** figures 3 max

(ii) (re caffeine) greater chance of pairing longer length with mRNA ;
AVP ; 1

(iii) explant of meristematic / cambium / totipotent / pluripotent, cells
/ tissue ;
explant (surface) sterilised / sterile nutrient ;
appropriate hormone to stimulate, mitosis / division ;
callus formed ;
subdivided ;
appropriate hormone to stimulate differentiation ;
plantlet formed ;
hardening medium / sterile soil 4 max

- (iv) genetically identical ;
 genotype does not affect result ;
 easily genetically engineered ;
 plants derived from it identically genetically engineered / AW ;
 large numbers easily obtained ;
 early stages compact ; 3 max
 so easily kept in identical conditions ;

[15]

5. (i) (penicillin) secondary metabolite ;
 produced at start of / during stationary phase / end of growth phase ; **A** log
 phase ref to production (at maximum) when kept short of nutrients
 / nutrients depleting / factors limiting growth ;
 continuous culture maintains in, log / rapid growth, phase ; 2 max
- (ii) to provide respiratory substrate / energy ; **A** for respiration
 to maintain culture / keep culture alive / prevent (premature) death of
 culture ;
 (limited) maintains in stationary phase / prevents rapid growth ;
 AVP ; **R** glucose as carbon source 2 max

[4]

6. (i) type of starch ;
concentration of, starch / suspension ;
 volume of, starch / suspension ; **R** amount
 ref to flow rate ;
 size of beads ; **A** number / mass / volume, of beads in column **R** amount
 temperature ;
 length / diameter, of column ;
 yeast concentration ;
 pH ;
 AVP ; e.g. age of culture 3 max
- (ii) add Benedict's (reagent) and, boil / heat ; **A** CuSO₄ in alkaline solution
 different, densities / colours (of precipitates) formed ; **A** turbidities
 use of a colorimeter in correct context ;
A filtering and weighing precipitate
- OR**
 use of Clinistix / Diastix (strips) ;
 different colours obtained ;
 colour compared to chart ;
accept other valid methods e.g. reference to use of biosensors 2 max

- (iii) *agree*
 not all yeast cells successfully entrapped / AW ;
 (in product) yeast cells, respiring / metabolising / using sugar as an energy source ;
 (so) lower levels of sugar (in product) ;
- not agree*
 yeast cells, entrapped (in beads) / immobilised, so product not contaminated
 / yeast not present to affect product ;
 yeast cells unable to pass through, glass wool / filter ;
 only very low numbers of yeast cells (so unlikely to have great effect) ;

2 max

[7]

7. *award marks if diagram clearly annotated*

- reservoir for storage of nutrients ;
 ref to method for addition of nutrients and removal, of waste / products ;
A substrate
 ref to more detail of, nutrient addition / product removal, at a constant rate /
 continually / throughout fermentation period ;
 idea of rate of product removal equal to addition of nutrients ;
A keep volume constant
 use of probes / sensors / monitors ; **A** thermometer (for temperature)
 (to monitor) any two of, temperature / pH / oxygen levels ;
 method to maintain pH e.g. use of buffers, tube to add acid / alkali ;
 addition of antifoam ;
 ref. to need to maintain sterility (to avoid contamination) ;
 method to maintain constant temperature e.g. (thermostatically-controlled) water
 bath, cooling jacket ; **R** heat exchanger
 AVP ; e.g. use of stirrer, method to avoid, clumping of cells / blocking of inlet *or*
 outlet pipe(s)

4 max

[4]

8. (a) (i) penicillin ; **A** other named antibiotic 1
- (ii) (complex organic molecules) produced after / not produced during,
 the (log / rapid / main) growth phase ;
 not essential for normal, cell growth / reproduction ; max 1
- (iii) batch / fed batch ; 1
- nutrients only added at start ;
 short / rapid, growth phase ;
 required product made, during stationary phase / late in life
 cycle ; ora
- R** death phase
 shortage / depletion of, nutrients / named nutrients ;
 cell division / reproduction, no longer occurring ;
 ref to addition of, glucose / lactose, at intervals
 (to avoid death of culture) ; max 2
- (b) **1** air pressure will push the medium into the culture vessel ;

- 2 medium / nutrients, added to the culture at a constant rate / AW ;
- 3 algae / cells / *Chlorella*, removed / harvested, from the sample port ;
- 4 at the same rate as / to match, the nutrients added ;
- 5 so volume in fermenter remains constant ;
- 6 removal of, waste / toxic products ;
- 7 that could affect, growth / reproduction ;
- 8 (cells kept in) exponential / log / rapid / main, growth phase ;
- 9 algae are photosynthetic ;
- 10 light energy required ;
- 11 ref to use of fluorescent light to avoid overheating ;
- 12 ref to monitoring temperature ;
- 13 ref to optimum conditions ; A 'conditions for maximum growth'
- 14 air bubbles to mix culture with nutrients / AW ;
- 15 air bubbles to allow algae to get sufficient light ;
- 16 air bubbles provide oxygen for (aerobic) respiration ;
- 17 and CO₂ for photosynthesis ;
- 18 air flowing into the culture vessel flows out through an outflow tube ;
- 19 preventing build-up of pressure ;
- 20 AVP ; e.g. sampling to check for mass of *Chlorella* max 6

(c)

difficulty maintaining a constant temperature ; } one mark for ref to difficulty of
 difficulty maintaining a constant pH ; } controlling environmental factors

heating / cooling, qualified ;
 foaming ;
 blocking of, inlet / outlet, tubes ;
 difficulties with, mixing / stirring ;
 contamination / keeping it sterile ;
 conditions need to be continuously monitored ;
 nutrient requirements may change ;
 AVP ;
 AVP ; e.g. algal growth on glass
 difficulties in providing sufficient light
 errors lead to loss of several days production of *Chlorella* max 4

[15]

9. (a) (i) amylase ; 1
- (ii) glycosidic ; R glucosidic 1
- (iii) alpha / α ; 1

- (b) (i) encapsulation / trapped in alginate beads ;
adsorption *or* stuck onto, collagen / clays / resins ;
cross linkage or covalent / chemical bonding to, cellulose (fibres) ;
gel entrapment / trapped in silica gel ;
partially permeable membrane microspheres ; max 2
- (ii) does not mix with / does not contaminate / stays separate from, the
product ; ref to, no / less / easier, downstream processing ;

recoverable / not lost during processing ;
reusable / cost effective ;

matrix stabilises / protects the enzyme ;
so activity not affected by changes in, temperature / pH *or* run at
a high temperature / wider range of pH ;

longer, use / shelf-life ;
so suitable for continuous culture / cost effective / greater yield ;
AVP ;

points can interchange if valid max 4
- (c) not necessary to start with a pure enzyme ;
keeps the enzyme away from oxygen ;
more enzymes involved ;
cell produces enzymes ;
AVP ; e.g. enzyme(s) may be, expensive / difficult to isolate
simultaneous processes can occur max 2

[11]

10. (a) **B** ;
C ;
D ;
A ; 4
- (b) (i) *award two marks if correct answer (26.18 / 26.2 / 26) is given*
 $24 \times 60 = 1440 \div 55$;
26.18 ; **A** 26 / 26.2 2
- (ii) less oxygen / *ora* ;
reduced amount of nutrients / *ora* ;
ref to pH / *ora* ;
competition from other bacteria / interspecific competition / *ora* ;
use of antibiotics ;
AVP ; ref to intestinal enzymes or immune system
R reference to temperature
treat toxins as neutral max 3

[9]

11. (i) attached to an insoluble material / AW ; 1

- (ii) (micro)encapsulation / (trapped) in alginate beads ;
 adsorption / stuck onto, e.g. collagen / clays / resin / (porous) glass ;
 cross linkage or covalent / chemical bonding to, e.g. cellulose /
 collagen fibres ;
 gel entrapment / trapped inside gel e.g. silica (lattice / matrix) ;
 partially permeable membrane (polymer) microspheres ; max 2
- (iii) urine can be processed / no problem of removing urine / AW ;
 pure / drinkable / useable, water produced ; **A** water recycled
 space saving / less water needs to be taken into space ;
 payload limit / weight reduction / AW ;
 no need to take more enzymes into space / enzymes reusable ; **A** enzymes
 recoverable
 no problem in separating enzyme from products / product not contaminated ;
 ref to longer shelf-life of enzyme ;
 AVP ; e.g. larger surface area of enzyme exposed, more stable at extremes,
 ref to ease of use (of bioreactor) max 3

[6]

12. (i) adding / using, water ;
 breaking, bond / ester bond (in molecule) ; **A** breakdown into smaller
 molecules 2
- (ii) matrix, protects / stabilises, (immobilised) enzyme / lipase ; *allow once*
 so will function, at optimal rate / more efficiently (than soluble), at higher
 temperature / 45 °C ; **A** greater activity / AW
 ref to soluble lipase begins to denature (reducing activity) ; *ora*
 continues to work, at optimal rate / more efficiently, at lower pH ;
 ref to presence of fatty acids changing pH ;
 ref to ionic bonds breaking (in soluble lipase) ; *ora*
 AVP ; e.g. ref to industrial uses, ref to effect on R groups max 4

[6]

13. (a) (i) temperature ;
 concentration of, substrate / sugars /
 carbohydrates ; **R** volumes / amounts
 concentration of yeast ; **R** volume / amount
 pH / carbon dioxide concentration ;
 oxygen availability ;
 concentration of, alcohol / ethanol / toxic waste ;
 AVP ; max 3
- (ii) carbon dioxide ; **A** CO₂ 1

- (b) (i) *one mark for slow, fast, slow / nothing*
 initial gas production slow, ref to time ;
 rapid rate, ref to time ;
 little gas production, ref to time ;
 ref to actual volumes ;
 any rate calculated ; max 4
- (ii) ref to (aerobic / anaerobic) respiration ;
slow gas production
 transport of glucose into yeast cells takes time ; **A** absorbed / taken
 up by yeast detail ; e.g. ref to carriers
rapid rate of respiration
 high substrate concentration in yeast cells ;
rate slows
 substrate runs out ;
 or other factor(s) / named factor, affect the rate ;
 AVP ; e.g. increase in number of yeast cells increases rate of
 respiration, qualified ref to time taken for adjustment to
 conditions (in slow production) max 4
- (c) *slower rate of respiration*
 enzymes(s) to, metabolise / hydrolyse / digest / breakdown, maltose
 not present ;
 genes switched on ;
 time for enzymes to be synthesised ;
 ref to, membrane transport / ease of passing through membrane ;
 AVP ; e.g. facilitated diffusion max 2
- [14]**
14. (a) provides oxygen for aerobic respiration ;
 any detail, e.g. oxidative phosphorylation ;
 sterile to prevent contamination ;
 mixes fungus with substrate / prevents settling / bubbles help stirring / AW ; 2
- (b) (i) carbon – glucose / lactose ;
 nitrogen – amino acids / nitrate ions / ammonium ions / yeast extract ;
A corn steep liquor for either but not both 2
- (ii) water is for, cooling / removing excess heat ;
 maintains, constant / optimum, temperature ;
 respiration produces heat ;
 which would, denature enzymes / kill cells ;
 heat also produced by, stirrer / motor ; max 3
- (iii) will affect, enzyme action / metabolic rate ; **A** denature enzymes
 addition of, buffer / acid / alkali / base ; 2

- (c) (i) 96 hours ; 1
- (ii) **X** includes, rapid / exponential / main, growth phase ; *ora* when primary products are made / penicillin is a secondary metabolic product ; excess of nutrients in **X** *or* penicillin produced when nutrients, limited / depleted ; 3
- (d) filter (to remove fungus) ; fungus washed (to remove penicillin) ; continuous countercurrent / chemical extraction ; concentration ; addition of potassium ions ; precipitate crystals / (potassium) salts ; solvents used to purify penicillin ; AVP ; e.g. dried, some are chemically modified, 99.5% pure max 3
- (e) can genetically engineer microorganisms ; ref to risk of infection ; e.g. CJD with GH avoids problem with, side effects / allergic effects ; **A** ref. to immune response large amount of product ; grow microorganisms in small, area / volume ; **A** less space required can be cultured anywhere in world ; ethical advantages, qualified ; ref to cost qualified ; e.g. *insulin* uses cheaper feedstock (than for rearing pigs) AVP ; AVP ; e.g. high replication / growth rate extraction of GH from brains slow process max 4

[20]