Answers to Option D exam-style questions

1 a i *Therapeutic effect*: a desirable and beneficial effect; one that alleviates symptoms or treats a particular disease. **[1]**

ii *Side effect*: an unintended secondary effect of the drug on the body (usually undesirable). **[1]**

iii *Tolerance*: the body becomes less responsive to the effects of the drug and so larger and larger doses are needed to produce the same effect. **[1]**

iv *Bioavailability*: the fraction of the administered drug that reaches the general blood circulation (or the fraction of the administered drug that reaches the target part of the human body). **[1]**

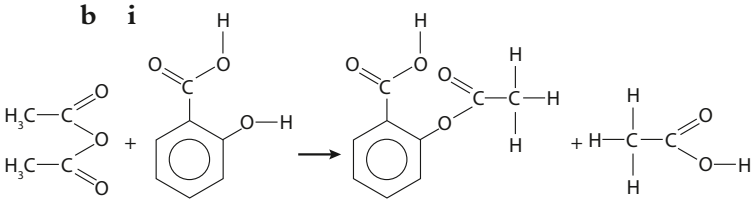
b The range of doses of a drug (or range of concentrations of drug in the blood plasma) that gives safe, effective therapy.
or
The range of dosage between the minimum required to cause a therapeutic effect and the level which produces unacceptable toxic effects. **[1]**

c i Intravenous injection; the drug is injected directly into the bloodstream, where it can then be transported round the body to reach its site of action. **[2]**

ii Pulmonary route/inhalation **[1]**

2 a Aspirin intercepts the pain stimulus at the source of the pain by inhibiting the production of pain mediators called prostaglandins. **[1]**

b i



[2]

ii Number of moles of salicylic acid

$$= \frac{5.00}{138.13} = 0.0362\,\text{mol}$$

Relative molecular mass of aspirin = 180.17

Theoretical yield of aspirin = $180.17 \times 0.0362 = 6.52\,\text{g}$

$$\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

$$= \frac{5.02}{6.52} \times 100 = 77.0\%$$ **[3]**

iii Aspirin has a higher relative molecular mass than salicylic acid, therefore the same number of moles has a greater mass. **[1]**

iv Aspirin can be purified by recrystallisation. Impure aspirin is dissolved in the minimum amount of hot solvent to form a close-to-saturated solution. The solution is filtered while still hot to remove any insoluble impurities. The solution is allowed to cool. The solid product is removed from the solution by filtration. The solid product is dried. **[4]**

c Penicillins prevent the bacteria from forming cross-links in the sugar–peptide layer of the cell wall. This results in a weakened cell wall, and the bacterial cell bursts owing to osmotic pressure caused by water entering the cell. **[2]**

d i Penicillinase (also called β-lactamase) **[1]**

ii The enzyme inactivates the penicillin because it breaks open the β-lactam ring, which is essential for the antibacterial activity of the penicillin. **[1]**

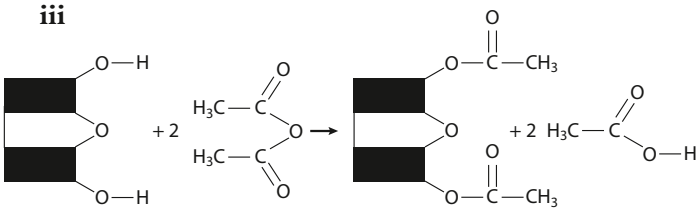
iii The side-chain (R) **[1]**

3 a Strong analgesics temporarily bind to opioid receptors in the brain, preventing the transmission of pain signals. **[1]**

b i Diamorphine contains two ethanoate esters, whereas morphine contains two hydroxyl groups. **[1]**

ii Addition–elimination or esterification **[1]**

iii



[2]

iv Increased risk of spread of hepatitis or HIV/AIDS due to shared needles; increased crime due to the need to fund addiction. **[2]**

4 a Hydrochloric acid **[1]**

b $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$ **[1]**

c Ranitidine inhibits the production of stomach acid – it is an H_2-receptor antagonist.
It binds to a receptor protein (H_2-receptor) in the membrane of the parietal cells, which stops the normal chemical messenger (histamine) from binding to turn on the chain of events for producing acid. Ranitidine therefore prevents the production of stomach acid. **[3]**

d Active metabolites are the active forms of drugs after they have been processed in the body.
Codeine is converted into morphine in cells and it is the morphine that binds to the opioid receptors.
or
Omeprazole/esomeprazole are converted into different forms that are able to bind to proton pumps.
or
Aspirin is converted into the active form – salicylic acid. **[2]**

e Number of moles of $KH_2PO_4 = \frac{15.00}{136.09}$

$= 0.110\,20\,\text{mol}$

Number of moles of $K_2HPO_4 = \frac{15.00}{174.18}$

$= 0.086\,12\,\text{mol}$

$[\text{base}] = 0.086\,12\,\text{mol dm}^{-3}$;
$[\text{acid}] = 0.110\,20\,\text{mol dm}^{-3}$

$$\text{pH} = \text{p}K_a + \log_{10}\left(\frac{[\text{base}]}{[\text{acid}]}\right)$$

$$= 7.21 + \log_{10}\left(\frac{0.08612}{0.11020}\right)$$

$$= 7.21 + \log_{10} 0.7815 = 7.10$$ **[3]**

5 a Viruses cannot replicate on their own but use the host cell's materials and processes in order to produce new viruses; they release their genetic material (RNA or DNA) into the host cell.
Bacteria replicate on their own by cell division. **[2]**

b Two from: by altering the cell's genetic material by becoming incorporated into the growing DNA strand and halting its synthesis; by inhibiting the activity of enzymes within the host cell that are necessary for the formation of new viruses; by stopping the viruses from infecting host cells by preventing them from binding to the host cell surface and gaining access into the cell; by stopping the virus from leaving the host cell and infecting other cells. **[2]**

c **I** (secondary) carboxamide (amide)
II (primary) amine
III ester **[3]**

d The ability of the HIV virus to mutate readily; the HIV virus uses the host cell's own processes to replicate; because many patients in poorer countries do not have access to antiretroviral drugs. **[2]**

6 a Antibiotics can be released into the environment through the improper disposal of medicines containing antibiotics and from animal waste. The release of antibiotics into the environment through waste water can cause damage to aquatic organisms and also result in increased resistance of bacteria to antibiotics. Antibiotics (antibacterials) are used to treat a variety of conditions but if bacteria develop resistance to antibiotics such as penicillin, these diseases can become much more difficult to cure. **[4]**

b **i** Low-level waste has low activity (not many radioactive nuclei decay each second to produce ionising radiation) and usually contains isotopes with short half-lives (ionising radiation is given off for only a short time).
High-level waste has high activity (many radioactive nuclei decay each second to produce ionising radiation) and usually contains isotopes with longer half-lives (ionising radiation is given off for a long time). **[2]**

ii Two of: gloves/other protective clothing; tools; syringes; excreta from patients treated with radioisotopes. **[2]**

iii Low-level waste may be stored on site until it has decayed to such an extent that it can be disposed of as ordinary waste (e.g. in landfill sites or released into the sewage system) or shipped to a central site for more specialised disposal.
Some low-level waste is incinerated.
Low-level waste with higher activity is often buried underground (near-surface disposal) – for example, in individual concrete canisters or in concrete-lined vaults. **[2]**

7 a Cancer – mainly breast, ovarian and lung cancer. **[1]**

b The bark of Pacific yew trees. **[1]**

c A chiral auxiliary is a chiral molecule that is bonded to a non-chiral starting material to produce a chiral intermediate. The presence of the auxiliary allows the reagent in the next stage of the reaction to approach from one side of the molecule only, forcing the reaction to follow a certain path that favours the production of one of the possible enantiomers. Removal of the auxiliary then gives the single enantiomer. **[3]**

d Plane-polarised light is passed through the sample in a polarimeter. Different enantiomers of a particular compound rotate the plane of plane-polarised light in opposite directions.
An enantiomer can be identified from its specific rotation; this can be calculated from the angle

through which plane-polarised light is rotated by a sample of known concentration and path length under specific conditions.
The specific rotation of an enantiomer under a given set of conditions is characteristic of the compound and can be used to identify it by comparing to tables of literature values. **[3]**

8 a i $^{177}_{71}\text{Lu} \rightarrow {}^{177}_{72}\text{Hf} + {}^{0}_{-1}\text{e}$ **[2]**

ii $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

$= \frac{0.693}{6.71} = 0.103\,\text{d}^{-1}$

$\frac{N}{N_0} = \text{e}^{-\lambda t}$

$\frac{N}{N_0} = \text{e}^{-0.103 \times 28} = 0.0559$

mass of lutetium $= 0.0559 \times 10 = 0.559$ mg

Note: if more figures are carried through on the calculator the answer 0.554 mg is obtained. **[4]**

b Hair loss; nausea; fatigue; sterility **[3]**

c Targeted alpha therapy targets, as far as possible, just cancer cells by using monoclonal antibodies. Monoclonal antibodies can be made that target a specific type of cancer cell and can be labelled with an α-emitting radioisotope. The antibody travels through the body and attaches to just this one type of cell, carrying the radioisotope with it. Decay of the radioisotope atom produces α particles, which destroy the cancerous cell. **[3]**

9 a For solvent extraction, the solvents chosen must be immiscible, but ethanol dissolves in water. Improvement – use a solvent that does not dissolve in water, such as ethoxyethane or ethyl ethanoate. **[3]**

b i Number of moles of benzene $= \frac{1.00}{78.12}$

$= 0.0128$ mol

Number of moles of methylbenzene $= \frac{10.0}{92.15} = 0.1085$ mol

Total number of moles in mixture $= 0.0128 + 0.1085 = 0.121$ mol

Mole fraction of benzene $= \frac{0.0128}{0.121} = 0.106$

Mole fraction of methylbenzene $= \frac{0.1085}{0.121} = 0.894$

$P_{\text{benzene}} = 0.106 \times 10.00 = 1.06$ kPa

$P_{\text{methylbenzene}} = 0.894 \times 2.93 = 2.62$ kPa

$P_{\text{tot}} = P_{\text{benzene}} + P_{\text{methylbenzene}}$

$P_{\text{tot}} = 1.06 + 2.62 = 3.68$ kPa

Note: more figures were carried through on the calculator to obtain this answer. **[4]**

ii The mole fraction of benzene in the vapour is $(\frac{1.06}{3.68}) = 0.288$, which is much higher than that in the liquid. Benzene is more volatile than methylbenzene and therefore has a greater tendency to enter the vapour phase. **[2]**

iii Benzene can be separated using fractional distillation. The mixture is heated in a flask with a fractionating column attached. The mixture boils and the vapour is richer in the more volatile component (benzene). The vapour rises up the column until it condenses in the cooler parts higher up. The liquid trickles down the column and is heated by vapour coming up from below. The process of boiling and condensing repeats as the vapour passes up the column. Each time the vapour boils and condenses it becomes richer in the more volatile component. Essentially pure benzene is obtained from the top of the column. **[4]**

c i carbonyl (ketone), alkenyl (alkene), hydroxyl (alcohol) **[3]**

ii $1620\,\text{cm}^{-1}$ is due to C=C
$1680\,\text{cm}^{-1}$ is due to C=O
$2900\,\text{cm}^{-1}$ is due to C–H
$3400\,\text{cm}^{-1}$ is due to O–H
The absorption for C=O is is a bit lower than given in the IB Chemistry data booklet but the ranges there are just approximate. **[4]**

iii The organic chemicals are extracted from the urine sample and then separated into their various components using gas chromatography. Each band, as it comes out of the chromatography column, is passed directly into a mass spectrometer, where it is analysed. The mass spectrum of a compound is generally characteristic of that compound, so by comparison with the mass spectra in a database, the compound can be identified. **[2]**