# Carpe Diem Biological Chemistry I — Question Bank

ANSWERS AFTER EACH SECTION · BIOL 157 · BIOLOGICAL CHEMISTRY I

588 questions · Modules 1–10 · Volumes 1 & 2 · Devil 147 · Easy 147 · Hard 147 · Medium 147

## Contents


| Module | Title | Questions |
|---|---|---|
| 1 | Elemental Composition of Living Cells | 80 |
| 2 | Chemical Bonding | 80 |
| 3 | Thermodynamics | 80 |
| 4 | Chemical Kinetics | 80 |
| 5 | Chemical Equilibrium | 80 |
| 6 | Elemental Composition of Living Cells | 20 |
| 7 | Chemical Bonding | 48 |
| 8 | Thermodynamics | 40 |
| 9 | Chemical Kinetics | 40 |
| 10 | Chemical Equilibrium | 40 |


Totals: 588 questions — Devil 147 · Easy 147 · Hard 147 · Medium 147.

**Module 1: Elemental Composition of Living Cells** — 80 questions

## 1. Set 1 · Q1–10

Origin of elements · Easy

**1. Which elements were the main products of the Big Bang?**

**A** Hydrogen and helium, plus trace lithium

**B** Carbon, nitrogen and oxygen

**C** Iron, nickel and cobalt

**D** Sodium, potassium and calcium

Origin of elements · Medium

**2. According to the lecture, which three processes account for the origin of the elements?**

**A** Big Bang, photosynthesis, and radioactive decay

**B** Stellar fusion, volcanic activity, and erosion

**C** Artificial synthesis, evaporation, and condensation

**D** Big Bang, fusion in stars, and artificial synthesis

Stellar fusion · Hard

**3. Why are extremely high temperatures required for fusion in stars?**

**A** To break covalent bonds between neutral atoms

**B** To strip the electron clouds off every atom

**C** To overcome repulsion between positively charged nuclei

**D** To reduce the mass of colliding nuclei

Stellar fusion · Devil

**4. Two helium nuclei fuse to give beryllium, yet carbon still forms in stars. What makes this possible?**

**A** Beryllium is stable and accumulates until carbon forms

**B** Another He nucleus fuses with the short-lived Be almost at once

**C** Hydrogen catalyses the conversion of beryllium to carbon

**D** Beryllium decays into carbon by beta emission

Origin of elements · Easy

**5. Which element is the second most abundant in the universe?**

**A** Oxygen

**B** Helium

**C** Carbon

**D** Iron

Stellar fusion · Medium

**6. Which equation correctly shows helium burning that produces oxygen?**

**A** $^{16}O + {}^{4}He \rightarrow {}^{12}C$

**B** $^{12}C + {}^{1}H \rightarrow {}^{16}O$

**C** $^{12}C + {}^{4}He \rightarrow {}^{16}O$

**D** $^{14}N + {}^{4}He \rightarrow {}^{16}O$

Stellar fusion · Hard

**7. Following the helium-burning sequence, what forms when $^{16}O$ captures a $^{4}He$ nucleus?**

**A** $^{20}Ne$

**B** $^{24}Mg$

**C** $^{18}O$

**D** $^{20}Na$

Stellar fusion · Devil

**8. Why are even-numbered elements more abundant than odd-numbered ones, according to the lecture?**

**A** Odd ones are radioactive and decay into even ones in seconds

**B** Even ones are lighter and need less heat to fuse

**C** Odd ones are consumed by living cells faster than they form

**D** Even ones form in main-line fusion; odd ones via side reactions

Origin of elements · Easy

**9. Who is quoted as saying 'We are literally the ashes of long dead stars'?**

**A** Sir Martin Rees

**B** Gilbert Lewis

**C** Willard Libby

**D** James Joule

Stellar fusion · Medium

**10. Roughly what share of the Sun's energy comes from fusing hydrogen into helium-4, per the lecture?**

**A** 15%

**B** 50%

**C** 85%

**D** 100%

## Answers — Set 1 · Q1–10

**1.** A — Only the lightest elements formed in the initial explosion.

**2.** D — These are the three listed sources of the periodic table's elements.

**3.** C — Nuclei must approach very closely against electrostatic repulsion.

**4.** B — Be is unstable and does not last, so a third He must arrive quickly.

**5.** B — Helium comes second after hydrogen, and stars keep making more.

**6.** C — 6 + 2 = 8 protons and 12 + 4 = 16 nucleons.

**7.** A — 8 + 2 = 10 protons gives neon, with 16 + 4 = 20 nucleons.

**8.** D — This is the lecture's explanation for the odd-even abundance pattern.

**9.** A — The British astronomer made the remark about stellar element formation.

**10.** C — Hydrogen-to-helium accounts for about 85% of the Sun's energy.

## 2. Set 2 · Q11–20

Stellar fusion · Hard

**11. Which statement correctly balances 3 $^{4}He \rightarrow {}^{12}C$?**

**A** Mass numbers match at 12 but atomic numbers are 6 versus 12

**B** Atomic numbers match at 6 but mass numbers are 12 versus 4

**C** Neither total matches, so extra neutrons must be released

**D** Mass numbers sum to 12 and atomic numbers to 6 on both sides

Stellar fusion · Devil

**12. $^{20}Ne$ captures $^{4}He$. What is the product and why?**

**A** Sodium-24, since 10 + 1 = 11 protons and 20 + 4 = 24 nucleons

**B** Magnesium-24, since 10 + 2 = 12 protons and 20 + 4 = 24 nucleons

**C** Silicon-24, since 10 + 4 = 14 protons and 20 + 4 = 24 nucleons

**D** Magnesium-80, since 10 + 2 = 12 protons and 20 × 4 = 80 nucleons

Artificial synthesis · Easy

**13. Elements with atomic number above 92 are called what?**

**A** Transuranium elements

**B** Transition elements

**C** Lanthanides

**D** Noble gases

Artificial synthesis · Medium

**14. What device is used to produce the high-energy particles needed for artificial element synthesis?**

**A** Spectrophotometer

**B** Autoclave

**C** Cyclotron

**D** Centrifuge

Artificial synthesis · Hard

**15. In neutron capture, the target nucleus absorbs a neutron and then emits what?**

**A** An alpha particle

**B** A proton

**C** An electron-positron pair

**D** A gamma-ray photon

Artificial synthesis · Devil

**16. Which pairing of route and product matches the lecture's examples?**

**A** Neon on curium gave plutonium

**B** Fast neutrons on U-238 in a reactor gave plutonium

**C** C-12 accelerated onto U-238 gave seaborgium

**D** Neutron capture on iron gave californium

Origin of elements · Easy

**17. About how long ago did the Big Bang occur, per the lecture?**

**A** 14 million years

**B** 4.6 billion years

**C** 14 billion years

**D** 140 billion years

Artificial synthesis · Medium

**18. Of the roughly 118 known elements, about how many occur naturally?**

**A** About 118

**B** About 30

**C** About 60

**D** About 90

Stellar fusion · Hard

**19. Why does fusion involving helium nuclei need a higher temperature than hydrogen fusion?**

**A** He nuclei are lighter and move too slowly

**B** He nuclei carry twice the positive charge, so repulsion is greater

**C** Helium has no protons available to fuse

**D** Helium's filled electron shell blocks nuclear contact

Stellar fusion · Devil

**20. The lecture says the largest atom formed by fusion is iron. How do heavier nuclei arise?**

**A** Fe nuclei capture neutrons produced in stars

**B** Two iron nuclei fuse directly in the core

**C** They form only in cyclotrons on Earth

**D** They were all made in the Big Bang

## Answers — Set 2 · Q11–20

**11.** D — 3 × 4 = 12 nucleons and 3 × 2 = 6 protons, matching carbon-12.

**12.** B — He adds 2 protons and 4 nucleons; Z = 12 is magnesium.

**13.** A — They lie beyond uranium and are made artificially.

**14.** C — Cyclotrons accelerate particles to fuse with target nuclei.

**15.** D — A discrete quantum of electromagnetic energy is released.

**16.** B — Neutron capture in a reactor converted U-238 into plutonium.

**17.** C — The lecture dates the origin of the universe to about 14 billion years.

**18.** D — Only about 90 occur naturally; the rest are synthesised.

**19.** B — A stronger Coulomb barrier means a hotter core, about 20 × $10^6$ K.

**20.** A — Neutron capture onto Fe builds nuclei beyond the fusion limit.

## 3. Set 3 · Q21–30

Major elements · Easy

**21. How many elements make up about 99% of the bulk of most cells?**

**A** Three

**B** Twelve

**C** Six

**D** Eighteen

Major elements · Medium

**22. Which set lists the six major elements of living cells?**

**A** C, H, O, N, Na, K

**B** C, H, O, Ca, P, Cl

**C** H, O, N, S, Fe, Zn

**D** C, H, O, N, P, S

Chemical democracy · Hard

**23. What is the 'chemical democracy' of living cells?**

**A** 15 of the 18 periodic groups are represented in cells

**B** All 118 elements are represented in cells

**C** Every group is represented except the d-block

**D** Only s- and p-block groups are represented

Chemical democracy · Devil

**24. Which statement about periodic-table blocks in living cells is correct?**

**A** p-block elements are absent despite being major elements

**B** s-, p- and d-block elements occur in cells; the f-block does not

**C** f-block lanthanides are essential cell constituents

**D** Only d-block metals are represented in cells

Carbon · Easy

**25. Which element is the most predominant in organic compounds?**

**A** Silicon

**B** Nitrogen

**C** Sulphur

**D** Carbon

Major elements · Medium

**26. Which statement does NOT describe the major elements of living cells?**

**A** They are mainly non-metals with small atoms

**B** Most are heavy metals with large atomic sizes

**C** They form covalent bonds readily

**D** They are neither too reactive nor inert

Carbon · Hard

**27. Why must carbon's atomic size be 'ideal'?**

**A** Too small blocks orbital overlap; too large gives long, weak bonds

**B** Too small gives long, weak bonds; too large blocks orbital overlap

**C** Too small gives ionic bonds; too large gives metallic bonds

**D** Size has no effect because only electronegativity matters

Carbon · Devil

**28. For carbon to form multiple bonds, which condition must the first bond meet?**

**A** It must be a pi bond so that sigma bonds can form next

**B** It must be ionic so the atoms are polarised first

**C** It must be a strong sigma bond allowing sideways overlap for pi bonds

**D** It must involve large atoms whose orbitals overlap sideways easily

Carbon · Easy

**29. What is the term for carbon bonding to itself in chains, branches and rings?**

**A** Tetravalency

**B** Hybridisation

**C** Polarisation

**D** Catenation

Silicon · Medium

**30. Silicon is described as a congener of carbon. What does that mean?**

**A** It has the same atomic number as carbon

**B** It is in the same group, directly below carbon

**C** It forms the same compounds in equal amounts

**D** It is a radioactive isotope of carbon

## Answers — Set 3 · Q21–30

**21.** C — C, H, O, N, P and S are the six major elements.

**22.** D — Carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur.

**23.** A — Most groups contribute at least one element to cell function.

**24.** B — Lanthanides and actinides are the unrepresented block.

**25.** D — Carbon forms the backbone of organic compounds.

**26.** B — The major elements are small non-metals, so this is false.

**27.** A — Good overlap requires an intermediate size.

**28.** C — A strong sigma framework lets the pi overlap happen.

**29.** D — Catenation depends on the stability of C–C bonds.

**30.** B — Silicon lies below carbon in group IVA.

## 4. Set 4 · Q31–40

Silicon · Hard

### 31. Why are Si–Si bonds weak even though silicon is tetravalent?

**A** Larger Si atoms cannot approach closely enough for good overlap

**B** Silicon has only two valence electrons available to bond

**C** Silicon is more electronegative than carbon, so it holds electrons

**D** Silicon has no p orbitals available to overlap

Silicon · Devil

### 32. Which pair of facts best explains why silicon is not the backbone of life despite its abundance?

**A** Si–Si bonds are very strong but silicon is toxic

**B** Silicon is radioactive and Si–O chains are unstable

**C** Si–Si bonds are weak and Si–O chains are essentially inert

**D** Silicon forms only two bonds and its compounds are volatile

Silicon · Easy

### 33. Which is more abundant in the Earth's crust, carbon or silicon?

**A** Carbon, about 140 times more abundant

**B** Silicon, about 140 times more abundant

**C** They are equally abundant

**D** Neither occurs in the crust

Nitrogen · Medium

### 34. Why are extended chains of nitrogen atoms unstable?

**A** N has too few valence electrons to form any bonds

**B** N–N bonds are stronger than C–C and hard to break

**C** Lone-pair repulsion between bonded N atoms lowers N–N bond energy

**D** Nitrogen atoms are too large for orbital overlap

Boron · Hard

### 35. Boron in $BCl_3$ accepts a chloride pair to give $BCl_4^-$. Which feature of boron does this show?

**A** Electron deficiency from only three valence electrons

**B** An expanded octet like that of $PCl_5$

**C** Lone-pair repulsion like that in N–N bonds

**D** An easy tendency to form long B–B chains

Carbon · Devil

**36. Silicon, nitrogen and boron can form three or more bonds, yet fall short of carbon. Why?**

**A** All three are metals, so they form ionic lattices instead of chains

**B** Each has one valence electron, so chains cannot extend

**C** Each forms bonds so strong that chain building never starts

**D** Si–Si is weak, N–N suffers lone-pair repulsion, and boron compounds are electron-deficient

Exclusion factors · Easy

**37. Which toxic element can cause brain and liver damage?**

**A** Mercury

**B** Iron

**C** Magnesium

**D** Zinc

Exclusion factors · Medium

**38. Lead causes anaemia by inhibiting which process?**

**A** Collagen cross-linking

**B** Insulin secretion

**C** Haem synthesis

**D** Clotting factor synthesis

Exclusion factors · Hard

**39. Beryllium is toxic mainly because it does what?**

**A** Replaces iron at the centre of haemoglobin molecules

**B** Interferes with many functions associated with magnesium

**C** Binds DNA strands through platinum-type cross-links

**D** Inhibits haem synthesis and causes anaemia

Exclusion factors · Devil

**40. Which exclusion factor is paired with a correct explanation?**

**A** Inertness: mercury reacts with nothing, so cells ignore it

**B** Artificial origin: iron must be synthesised in laboratories

**C** Toxicity: noble gases poison enzymes at low doses

**D** Radioactivity: unstable nuclei emit particles or radiation that can kill cells

## Answers — Set 4 · Q31–40

**31.** A — Size prevents the enhanced overlap needed for strong bonds.

**32.** C — Weak Si–Si links and inert Si–O chains limit functional chemistry.

**33.** B — Yet carbon is the element selected for cells.

**34.** C — Each N–N bond leaves lone pairs that repel one another.

**35.** A — Boron lacks an octet in $BCl_3$ and gains one through a dative bond.

**36.** D — Each element has a distinct limiting factor.

**37.** A — Mercury is the lecture's example of brain and liver toxicity.

**38.** C — Blocking haem synthesis reduces haemoglobin production.

**39.** B — Beryllium disrupts magnesium-dependent processes.

**40.** D — The lecture links radioactivity to cell killing, as in radiotherapy.

## 5. Set 5 · Q41–50

Cell elements · Easy

**41. What does the similarity of ions in sea water and blood plasma suggest?**

**A** Humans evolved from freshwater lakes

**B** Blood plasma is made from sea water

**C** Human ancestry traces back to the sea

**D** Life began on land and later moved to the sea

Cell elements · Medium

**42. What is the biosphere?**

**A** The layer of gases surrounding Earth

**B** Earth's molten metallic core

**C** The region where the ozone layer forms

**D** The part of Earth where life takes place

Cell elements · Hard

**43. The lecture notes carbon is only about 0.10% of Earth's atoms. What does this show?**

**A** Cells select elements by their properties, not only by abundance

**B** Carbon is the most abundant crustal element

**C** Cells contain only elements that are abundant in the crust

**D** Carbon cannot occur in the biosphere

Cell elements · Devil

**44. Which statement best explains why only about 30 elements are essential to cells?**

**A** The remaining elements do not exist on Earth

**B** Natural selection favoured elements whose properties suit cell chemistry

**C** Cells can absorb only elements lighter than sodium

**D** All the remaining elements are radioactive

Cell elements · Easy

**45. Which pair did the lecture name as trace or minor elements?**

**A** Fluorine and iodine

**B** Carbon and hydrogen

**C** Oxygen and nitrogen

**D** Phosphorus and sulphur

Medical applications · Medium

**46. The lecture lists $Li_2CO_3$ as a non-essential element compound used for which purpose?**

**A** Adsorbing toxins in diarrhoea

**B** Cross-linking DNA in tumours

**C** Boosting haemoglobin synthesis

**D** Treating schizophrenic-type conditions

Medical applications · Hard

**47. How does cisplatin kill cancer cells?**

**A** It blocks haem synthesis, lowering haemoglobin levels

**B** Platinum cross-links DNA so cells cannot divide or repair

**C** It replaces magnesium in many enzymes and disables them

**D** It adsorbs toxins and bacteria from the gut lumen

Medical applications · Devil

**48. Which statement about gold nanoparticles (AuNPs) in cancer therapy is correct?**

**A** They accumulate because tumours lack blood vessels

**B** They bind DNA like cisplatin to halt division

**C** They accumulate in tumours because leaky vessels let them pass

**D** They are essential for haemoglobin synthesis

Medical applications · Easy

**49. In which year was cisplatin approved by the FDA as the first platinum-based drug?**

**A** 1958

**B** 1988

**C** 1978

**D** 1998

Medical applications · Medium

**50. Which element in kaolin gives it anti-diarrhoeal properties, per the lecture?**

**A** Aluminium

**B** Calcium

**C** Silver

**D** Iron

## Answers — Set 5 · Q41–50

**41.** C — The lecture cites matching ion concentrations as evidence of marine ancestry.

**42.** D — It is the zone of Earth that supports living organisms.

**43.** A — Carbon is rare on Earth yet dominates biomolecules.

**44.** B — The lecture credits natural selection for the chosen set.

**45.** A — F and I are trace elements.

**46.** D — Correct per the slides (clinically, lithium carbonate is mainly a mood stabiliser for bipolar disorder).

**47.** B — The damaged DNA cannot repair itself and the cell dies.

**48.** C — This is the enhanced permeability and retention effect.

**49.** C — It was approved in 1978.

**50.** A — Kaolin contains aluminium and acts as an adsorbent.

## 6. Set 6 · Q51–60

Medical applications · Hard

**51. How does kaolin help in diarrhoea?**

**A** It kills bacteria by cross-linking their DNA

**B** It releases lithium to slow gut movement

**C** It supplies electrolytes that raise plasma sodium

**D** It adsorbs water, toxins and bacteria, giving firmer stools

Exclusion factors · Devil

**52. A patient from a gold-mining community in Ghana has tremors after mercury exposure. Which lecture point is most relevant?**

**A** Mercury is one of the major elements needed in all cells

**B** Mercury is toxic and affects the brain, so it is excluded from cell chemistry

**C** Mercury is excluded mainly because it is radioactive

**D** Mercury is excluded because it is artificially made in labs

Exclusion factors · Easy

**53. Which factor best explains why the rare gases are excluded from cells?**

**A** Their inert nature

**B** Their toxicity

**C** Their radioactivity

**D** Their artificial origin

Exclusion factors · Medium

**54. Why are elements above atomic number 92 absent from living cells?**

**A** They are too light to form bonds

**B** They are artificially made rather than naturally available

**C** They are all noble gases

**D** They react instantly with water in cells

Exclusion factors · Hard

**55. Basophilic stippling in red cells is a lab sign of lead poisoning. Which lecture fact links lead to the anaemia?**

**A** Lead replaces magnesium in enzymes

**B** Lead cross-links DNA and stops division

**C** Lead inhibits haem synthesis

**D** Lead is a trace element essential for haemoglobin

Silicon · Devil

**56. A student argues silicon should replace carbon because silicon is 140 times more abundant. Which rebuttal best uses the lecture?**

**A** Silicon is absent from the biosphere, so cells cannot use it

**B** Silicon forms only ionic bonds, so it makes no compounds

**C** Silicon is radioactive and would kill cells

**D** Abundance is not enough: Si–Si bonds are weak and bonding properties decide selection

Origin of elements · Easy

**57. What is the process of making new elements called?**

**A** Photolysis

**B** Catenation

**C** Nucleogenesis

**D** Hybridisation

Major elements · Medium

**58. Why is it notable that the six major elements are also the building blocks of macronutrients?**

**A** It shows macronutrients contain only trace elements

**B** It shows cells make their own elements from nothing

**C** It shows macronutrients are chemically inert

**D** It shows food supplies the elements cells need, so food is essential

Origin of elements · Hard

**59. Which description matches the radiation emitted by stellar fusion in the lecture?**

**A** Only visible light and heat reaching the planet

**B** UV, X-rays, visible, infrared, microwaves and radio waves

**C** Only gamma rays and neutrons from the core

**D** Only radio waves and X-rays in narrow bands

Origin of elements · Devil

**60. Which statement about solar output reaching Earth is correct?**

**A** It warms the planet and drives weather, while the atmosphere and magnetic field filter harmful parts

**B** It only warms the oceans, and the solar wind has no effect on Earth

**C** Neutrinos and protons make up the ultraviolet band of sunlight itself

**D** Magnetic fields absorb all X-rays and radio waves completely at the surface

## Answers — Set 6 · Q51–60

**51.** D — Adsorption reduces fluid loss and toxin load.

**52.** B — Mercury is the lecture's example of a toxic, excluded element.

**53.** A — They form essentially no compounds.

**54.** B — Transuranium elements are synthesised in laboratories.

**55.** C — Blocking haem synthesis reduces haemoglobin production.

**56.** D — Selection depends on bonding properties, not simple abundance.

**57.** C — Nucleogenesis describes element formation.

**58.** D — The same elements flow from food into cell structure.

**59.** B — A broad band of electromagnetic radiation is released.

**60.** A — Earth's atmosphere screens radiation and the magnetic field deflects solar wind.

## 7. Set 7 · Q61–70

Origin of elements · Easy

**61. After the Big Bang, what pulled clouds of gas together into galaxies of stars?**

**A** Magnetism

**B** Electrostatic repulsion

**C** Gravity

**D** Nuclear fission

Stellar fusion · Medium

**62. What does the stellar hypothesis propose?**

**A** All elements formed within minutes of the Big Bang explosion

**B** Elements formed in lightning strikes in Earth's atmosphere

**C** Elements form only through artificial laboratory synthesis

**D** Elements beyond H and He formed in stars at high temperature and concentration

Carbon · Hard

**63. Which set of features of carbon explains its enormous number of compounds?**

**A** Ionisation, radioactivity and metallic bonding

**B** Tetravalency, catenation and multiple bonding

**C** Inertness, large size and high toxicity

**D** Electron deficiency, expanded octet and ionic bonding

Carbon · Devil

**64. Why can carbon form double bonds with oxygen and triple bonds with nitrogen, while silicon seldom bonds multiply?**

**A** Small atoms give the strong sigma bond and sideways overlap that pi bonding needs

**B** Large atoms offer more electrons for pi overlap

**C** Pi bonds are stronger than sigma bonds, so large atoms favour them

**D** Silicon has no valence electrons available for bonding

Major elements · Easy

**65. Which type of bond within organic compounds provides intramolecular stability?**

**A** Covalent bonds

**B** Ionic bonds

**C** Metallic bonds

**D** Hydrogen bonds

Major elements · Medium

**66. To which periodic block do most of the six major elements belong?**

**A** s-block
**B** p-block
**C** d-block
**D** f-block

Nitrogen · Hard

**67. What is the effect of repulsion between lone pairs on bonded nitrogen atoms in an N–N bond?**

**A** It strengthens the bond by sharing extra electrons
**B** It converts the bond into an ionic one
**C** It raises the bond energy above that of C–C
**D** It markedly lowers the N–N bond energy

Silicon · Devil

**68. Why are alternating Si and O chains essentially inert despite weak Si–Si bonds?**

**A** Si–O bonds are weak but kinetically protected
**B** Oxygen makes the chain radioactive and unreactive
**C** Si–O bonds are very stable, so the chains resist reaction
**D** Si–O chains are ionic lattices that dissolve instantly

Silicon · Easy

**69. Which element lies directly below carbon in group IVA?**

**A** Nitrogen
**B** Boron
**C** Silicon
**D** Phosphorus

Trace elements · Medium

**70. Iron sits at the centre of haem. Which description fits iron?**

**A** A p-block major element found in all organic compounds
**B** An f-block element absent from cells
**C** An s-block major element in lipids
**D** A d-block trace element essential to oxygen transport

## Answers — Set 7 · Q61–70

**61.** C — Gravitational pull collapsed gas clouds into galaxies.
**62.** D — Stars are the factories for elements heavier than helium.
**63.** B — Four bonds, self-linking and double or triple bonds give vast diversity.
**64.** A — Pi bonding needs close, effective overlap between small atoms.
**65.** A — Covalent bonds hold the atoms of a molecule together.
**66.** B — C, N, O, P and S are p-block elements (H is the exception).
**67.** D — Lone-pair repulsion weakens the bond, so long N chains are unstable.
**68.** C — The strong Si–O link makes the chain stable and unreactive.

**69.** C — Silicon is carbon's congener in group IVA.

**70.** D — $Fe^{2+}$ in haem is a d-block trace element.

## 8. Set 8 · Q71–80

Trace elements · Hard

**71. A patient in an inland region has goitre due to iodine deficiency. Which statement about iodine is correct?**

**A** It is one of the six major elements

**B** It is a trace element needed in tiny amounts yet essential

**C** It is toxic and always excluded from cells

**D** It is an f-block element with no role in cells

Origin of elements · Devil

**72. Which statement is NOT supported by the lecture?**

**A** Most naturally occurring elements formed in the Big Bang

**B** Supernovae helped create many elements

**C** Iron is the largest atom formed by ordinary fusion

**D** Transuranium elements arise from artificial synthesis

Origin of elements · Easy

**73. What does 'primordial' mean in the description of the Big Bang?**

**A** Highly radioactive and unstable

**B** Newly synthesised in a lab

**C** Existing from the beginning

**D** Cooled and fully solid

Trace elements · Medium

**74. Which statement about trace elements is correct?**

**A** They are optional and have no cellular role

**B** They make up most of the bulk of cells

**C** They are found only in the f-block

**D** They are needed in small amounts but are still essential

Boron · Hard

**75. Boron compounds have limited stability. Which feature explains this?**

**A** Lone-pair repulsion between B atoms

**B** Electron deficiency leaves boron short of an octet

**C** Excess valence electrons from a half-filled d shell

**D** Very large atomic size preventing overlap

Carbon · Devil

**76. A student says C–C chains are stable because carbon is highly electropositive. What is wrong?**

**A** Carbon is a non-metal; stability comes from strong covalent overlap

**B** Carbon has no stable chains; only silicon does

**C** Carbon is electropositive but its C–C bonds are ionic

**D** C–C stability arises from lone-pair repulsion

Stellar fusion · Easy

**77. How many hydrogen atoms combine in a series of steps to create one helium-4 atom?**

**A** Two

**B** Four

**C** Three

**D** Eight

Major elements · Medium

**78. In the lecture, where are the six major elements mostly found in cells?**

**A** In the fluids bathing the cell as free ions

**B** Only inside the nucleus

**C** Only within the cell membrane lipids

**D** In the organic compounds of the cell

Stellar fusion · Hard

**79. Three helium-4 nuclei fuse to form carbon-12. What does the product nucleus contain?**

**A** 12 nucleons, including 6 neutrons

**B** 12 nucleons, including 12 neutrons

**C** 4 nucleons, including 2 neutrons

**D** 12 nucleons, including 3 neutrons

Exclusion factors · Devil

**80. Match each element with its exclusion factor: mercury, argon, technetium.**

**A** Hg inert, Ar toxic, Tc artificial

**B** Hg artificial, Ar toxic, Tc inert

**C** Hg toxic, Ar inert, Tc artificial

**D** Hg toxic, Ar artificial, Tc inert

## Answers — Set 8 · Q71–80

**71.** B — Iodine is needed for thyroid hormones despite trace amounts.

**72.** A — This is false; only the lightest elements formed in the Big Bang.

**73.** C — The primordial ball existed at the very beginning.

**74.** D — Small quantity does not mean small importance.

**75.** B — With three valence electrons, boron forms electron-deficient compounds.

**76.** A — Carbon's small size gives effective orbital overlap and strong covalent C–C bonds.

**77.** B — Four hydrogen atoms make helium-4.

**78.** D — They build carbohydrates, lipids, proteins and nucleic acids.

**79.** A — Carbon-12 has 6 protons and 6 neutrons.

**80.** C — Mercury is toxic, argon is a rare gas, and technetium is synthetic.

**Module 2: Chemical Bonding** — 80 questions

## 1. Set 1 · Q1–10

Ionic bonding · Easy

**81. What produces an ionic bond?**

**A** Electrostatic attraction between oppositely charged ions

**B** Sharing of electron pairs between two atoms

**C** Attraction between a metal's delocalised electrons and nuclei

**D** Overlap of half-filled orbitals end to end

Ionic bonding · Medium

**82. Above what electronegativity difference does the lecture say a compound will be ionic?**

**A** 0.4

**B** 3.0

**C** 0.0

**D** 1.7

Ionic bonding · Hard

**83. Which combination of atomic properties most favours ionic bond formation?**

**A** High ionisation energy, low electron affinity, low lattice energy

**B** Low ionisation energy, low electron affinity, low lattice energy

**C** Low ionisation energy, high electron affinity, high lattice energy

**D** High ionisation energy, high electron affinity, low lattice energy

Ionic bonding · Devil

**84. Using Na 1.0, Al 1.5, Cl 2.8, O 3.5, P 2.1 and H 2.2, which classification is correct?**

**A** Na–O polar covalent, Al–Cl ionic, P–H nonpolar covalent

**B** Na–O ionic, Al–Cl polar covalent, P–H nonpolar covalent

**C** Na–O ionic, Al–Cl ionic, P–H polar covalent

**D** Na–O ionic, Al–Cl nonpolar covalent, P–H ionic

Ionic bonding · Easy

**85. What happens to the electrons when sodium and chlorine form NaCl?**

**A** Both atoms share one electron pair equally

**B** Chlorine donates both bonding electrons to sodium

**C** Sodium and chlorine pool electrons in a delocalised sea

**D** Sodium loses an electron and chlorine gains it

Ionic bonding · Medium

**86. In the Born–Haber cycle, what does a more negative enthalpy of formation indicate?**

**A** A more stable, more ionic compound

**B** A less stable and less ionic compound

**C** A compound that cannot form from its elements

**D** A purely covalent compound

Ionic bonding · Hard

**87. Which pair gives the least polar bond using Al 1.5, Cl 2.8, O 3.5, F 4.0, P 2.1 and H 2.2?**

**A** Al and Cl, ΔEN 1.3

**B** O and F, ΔEN 0.5

**C** P and H, ΔEN 0.1

**D** Al and F, ΔEN 2.5

Ionic bonding · Devil

**88. In ΔHf = (Δsub + IE)Na + (½ΔHdiss − EA)Cl − LE, which term makes ΔHf more negative when larger?**

**A** Ionisation energy of sodium

**B** Lattice energy of the crystal

**C** Enthalpy of sublimation of sodium

**D** Half the dissociation enthalpy of $Cl_2$

Covalent bonding · Easy

**89. How do atoms of similar electronegativity achieve stability?**

**A** By sharing electrons

**B** By transferring electrons completely

**C** By fusing their nuclei

**D** By sharing neutrons

Covalent bonding · Medium

**90. What holds the two hydrogen atoms together in $H_2$?**

**A** Repulsion between the two nuclei

**B** Transfer of an electron from one H to the other

**C** Attraction of both nuclei for the shared electrons

**D** Attraction between two electron clouds only

## Answers — Set 1 · Q1–10

**81.** A — Ionic bonding follows complete electron transfer and attraction of the ions.

**82.** D — Above 1.7 is ionic; slightly below it is polar covalent.

**83.** C — These three make ΔHf more negative and the compound more stable.

**84.** B — ΔEN values are 2.5, 1.3 and 0.1 respectively.

**85.** D — This complete transfer gives $Na^+$ and $Cl^-$.

**86.** A — A more negative ΔHf signals greater stability and ionic character.

**87.** C — A difference of 0.1 is essentially nonpolar.

**88.** B — LE is subtracted, so greater lattice energy gives a more negative ΔHf.

**89.** A — Sharing electrons forms a covalent bond.

**90.** C — The nuclei attract the bonding electrons between them.

## 2. Set 2 · Q11–20

Sigma and pi bonds · Hard

**91. How many sigma and pi bonds are present in N≡N?**

**A** Three sigma and no pi

**B** One sigma and two pi

**C** Two sigma and one pi

**D** One sigma and one pi

Sigma and pi bonds · Devil

**92. Why is the C=C bond energy less than twice that of a C–C single bond?**

**A** The pi component is stronger than the sigma component

**B** A double bond contains two weaker sigma bonds

**C** Pi bonds form by end-to-end overlap, which weakens them

**D** The pi component is weaker than the sigma component

Sigma and pi bonds · Easy

**93. Which type of orbital overlap forms a sigma bond?**

**A** Sideways overlap

**B** End-to-end (head-on) overlap

**C** No overlap, only attraction

**D** Overlap of filled orbitals only

Sigma and pi bonds · Medium

**94. Which statement about sigma and pi bond strength is correct?**

**A** Pi is stronger because sideways overlap is greater

**B** They are equally strong in every molecule

**C** Pi is stronger because it forms first

**D** Sigma is stronger because head-on overlap is more effective

Sigma and pi bonds · Hard

**95. Which statement about the bonds in ethene ($CH_2=CH_2$) is correct?**

**A** All bonds in ethene are pi bonds

**B** The C=C contains two pi bonds and no sigma bond

**C** The C–H bonds are sigma and the C=C has one sigma plus one pi

**D** The C–H bonds are pi and the C=C is sigma only

Sigma and pi bonds · Devil

**96. Why are alkenes more reactive than alkanes?**

**A** The weaker pi bond is easily broken, freeing electrons for new bonds

**B** The pi bond is stronger and releases electrons more easily

**C** Sigma bonds in alkenes are weaker than those in alkanes

**D** Alkenes contain unpaired electrons that act as radicals

Covalent bonding · Easy

**97. Which molecule contains a double bond?**

**A** $H_2$

**B** $N_2$

**C** $O_2$

**D** HCl

Ionic bonding · Medium

**98. Ionic bonding is commonly found in which solids?**

**A** Metal–non-metal binary compounds and metal nitrates, sulfates and carbonates

**B** Non-metal oxides such as $CO_2$ and $SO_2$ and covalent network solids

**C** Pure metals such as iron and copper in the solid state

**D** Molecular solids such as sugar and candle wax

Ionic bonding · Hard

**99. Which two pairs are both polar covalent by the 1.7 criterion?**

**A** Na–O (ΔEN 2.5) and Al–F (ΔEN 2.5)

**B** Al–Cl (ΔEN 1.3) and O–F (ΔEN 0.5)

**C** Al–Cl (ΔEN 1.3) and P–H (ΔEN 0.1)

**D** O–F (ΔEN 0.5) and Na–O (ΔEN 2.5)

Ionic bonding · Devil

**100. Using Na 1.0, H 2.2 and Cl 2.8, which statement is correct?**

**A** NaCl (ΔEN 1.8) is polar covalent and HCl (ΔEN 0.6) is ionic

**B** Both are ionic because chlorine is highly electronegative

**C** Both are nonpolar covalent because both contain chlorine

**D** NaCl (ΔEN 1.8) is ionic and HCl (ΔEN 0.6) is polar covalent

## Answers — Set 2 · Q11–20

**91.** B — A triple bond is one sigma plus two pi bonds.

**92.** D — Sideways overlap is less effective than head-on overlap.

**93.** B — Sigma bonds concentrate density between the nuclei.

**94.** D — End-to-end overlap is more effective than lateral overlap.

**95.** C — A double bond is a sigma bond plus a pi bond.

**96.** A — Pi electrons are relatively accessible for reaction.

**97.** C — Oxygen is written O=O.

**98.** A — These are the lecture's examples of ionic solids.

**99.** B — Both are below 1.7 yet clearly non-zero.

**100.** D — 1.8 exceeds 1.7, while 0.6 gives an unequal share of electrons.

## 3. Set 3 · Q21–30

Hybridisation · Easy

### 101. What is hybridisation?

**A** Transfer of electrons between two different atoms

**B** Overlap of two orbitals to form a pi bond only

**C** Splitting of one orbital into several smaller ones

**D** Mixing of atomic orbitals to give equivalent hybrid orbitals

Hybridisation · Medium

### 102. What is the hybridisation of carbon in $CH_4$?

**A** sp

**B** $sp^2$

**C** $sp^3$

**D** $sp^3d$

Hybridisation · Hard

### 103. Why must a 2s electron of carbon be promoted before it bonds in $CH_4$?

**A** Ground-state carbon has two unpaired electrons but needs four

**B** Ground-state carbon has four unpaired electrons but needs six

**C** Promotion lowers carbon's nuclear charge so bonds form

**D** The 2p orbitals cannot hold electrons without promotion

Hybridisation · Devil

### 104. Why can unhybridised 2s and 2p orbitals not alone explain $CH_4$?

**A** They would give only two bonds in total

**B** They would give unequal bonds, but all four C–H bonds are identical

**C** They would give a planar molecule with 120° angles

**D** They cannot overlap with hydrogen's 1s orbital

Octet rule · Easy

### 105. What does the octet rule state?

**A** Atoms transfer or share electrons to reach a noble-gas octet

**B** Atoms must always form exactly eight bonds

**C** Only metals follow a stable eight-electron rule

**D** Atoms gain protons until they have eight

Octet rule · Medium

**106. In $PCl_5$, phosphorus has more than eight valence electrons. What is this called?**

**A** An incomplete octet

**B** An ionic octet

**C** A coordinate octet

**D** An expanded octet

Shapes and VSEPR · Hard

**107. $NH_3$ is $sp^3$ yet its H–N–H angle is about 107°. Why is it below 109°?**

**A** Bonded pairs repel each other more than the lone pair does

**B** Nitrogen is $sp^2$ hybridised in ammonia

**C** The lone pair repels bonded pairs more than they repel each other

**D** Hydrogen bonding between molecules squeezes the angle

Shapes and VSEPR · Devil

**108. Which explanation correctly accounts for the 104.5° angle in $H_2O$?**

**A** Oxygen has no lone pairs, so bonded pairs spread out

**B** Two lone pairs repel the bonded pairs more than $NH_3$'s single lone pair

**C** Water is $sp^2$ hybridised and hydrogen bonding narrows the angle

**D** Two bond pairs repel less than one lone pair, giving 109°

Shapes and VSEPR · Easy

**109. What does VSEPR stand for?**

**A** Valence Shell Electron Pair Resonance

**B** Variable Shell Electron Proton Repulsion

**C** Valence Sigma Electron Pair Repulsion

**D** Valence Shell Electron Pair Repulsion

Coordinate bonding · Medium

**110. What is required for a coordinate (dative) covalent bond to form?**

**A** A donor atom with a lone pair and an acceptor with an empty orbital

**B** Two atoms each donating one electron to the shared pair

**C** Two atoms with empty orbitals and no electrons

**D** A metal and a non-metal exchanging one electron

## Answers — Set 3 · Q21–30

**101.** D — Mixing orbitals of different shape and energy gives equal shape, energy and direction.

**102.** C — One 2s and three 2p orbitals form four $sp^3$ orbitals.

**103.** A — Promotion gives four unpaired electrons for four bonds.

**104.** B — Mixing is needed to give four identical tetrahedral $sp^3$ orbitals.

**105.** A — Compound formation drives atoms towards eight valence electrons.

**106.** D — Available p-type orbitals let P accommodate extra pairs.

**107.** C — Lone pair–bonded pair repulsion compresses the angle.

**108.** B — More lone pairs mean greater compression of the angle.

**109.** D — Electron pairs arrange to minimise repulsion.

**110.** A — One atom supplies both bonding electrons.

## 4. Set 4 · Q31–40

Coordinate bonding · Hard

**111. Which species contains a coordinate covalent bond?**

**A** $CH_4$, formed when C donates a lone pair to H

**B** NaCl, formed when Cl donates a pair to $Na^+$

**C** $NH_4^+$, formed when N donates its lone pair to $H^+$

**D** $O_2$, formed when each O donates a lone pair

Coordinate bonding · Devil

**112. In $BCl_3 + Cl^- \rightarrow BCl_4^-$, which assignment is correct?**

**A** $BCl_3$ is the donor (Lewis base) and $Cl^-$ the acceptor (Lewis acid)

**B** $Cl^-$ is the donor (Lewis base) and $BCl_3$ the acceptor (Lewis acid)

**C** $Cl^-$ is the donor (Lewis acid) and $BCl_3$ the acceptor (Lewis base)

**D** Both share equally, so neither is a Lewis acid or base

Complexes · Easy

**113. What is the central metal ion in haem?**

**A** $Fe^{2+}$

**B** $Mg^{2+}$

**C** $Cu^{2+}$

**D** $Zn^{2+}$

Complexes · Medium

**114. Why is porphin a tetradentate ligand?**

**A** It has four metal ions bound at its centre

**B** It has four nitrogen donor atoms

**C** It has four oxygen donor atoms

**D** It has four phosphate groups

Complexes · Hard

**115. How are the four nitrogen atoms arranged around $Fe^{2+}$ in haem, per the lecture?**

**A** Tetrahedral

**B** Linear

**C** Square planar

**D** Trigonal planar

Complexes · Devil

**116. In $Cu^{2+} + 4H_2O \rightleftharpoons [Cu(H_2O)_4]^{2+}$, which description is correct?**

**A** Water is the Lewis acid and $Cu^{2+}$ is the ligand

**B** $Cu^{2+}$ is the ligand and water is the Lewis acid

**C** Both are Lewis acids and no ligand forms

**D** $Cu^{2+}$ is the Lewis acid; water is the Lewis base and ligand

Shapes and VSEPR · Easy

**117. What is the shape of a molecule with central $sp^3$ carbon and four identical bonds?**

**A** Linear

**B** Tetrahedral

**C** Square planar

**D** Trigonal planar

Shapes and VSEPR · Medium

**118. What is the shape and bond angle of $BCl_3$?**

**A** Trigonal planar, 120°

**B** Tetrahedral, 109°

**C** Linear, 180°

**D** Trigonal pyramidal, 107°

Hybridisation · Hard

**119. Be ($1s^2 2s^2$) forms two bonds in gaseous $BeH_2$. How?**

**A** Its two 2s electrons are already unpaired and bond directly

**B** It borrows two 1s electrons from hydrogen to fill its octet

**C** A 2s electron is promoted to 2p, then 2s and 2p mix into two sp orbitals

**D** It uses two d orbitals to form $sp^3$ hybrid orbitals

Hybridisation · Devil

**120. Which row correctly matches hybridisation with bond angle for $BeH_2$, $BCl_3$ and $CCl_4$?**

**A** sp 120°, $sp^2$ 180°, $sp^3$ 109°

**B** sp 180°, $sp^2$ 109°, $sp^3$ 120°

**C** sp 109°, $sp^2$ 120°, $sp^3$ 180°

**D** sp 180°, $sp^2$ 120°, $sp^3$ 109°

## Answers — Set 4 · Q31–40

**111.** C — Ammonia's nitrogen donates a pair to the proton.

**112.** B — Boron lacks an octet and accepts a pair from chloride.

**113.** A — Haem holds $Fe^{2+}$, which binds oxygen.

**114.** B — Four N donors coordinate the central metal ion.

**115.** C — Haem's central ion sits in a flat square of four nitrogens.

**116.** D — Water donates lone pairs to $Cu^{2+}$, making an aqua complex.

**117.** B — Four $sp^3$ orbitals point to the corners of a tetrahedron.

**118.** A — Three $sp^2$ orbitals are coplanar at 120°.

**119.** C — Promotion creates two unpaired electrons, then sp hybridisation gives 180°.

**120.** D — Linear, trigonal planar and tetrahedral respectively.

## 5. Set 5 · Q41–50

Polarity · Easy

**121. Which diatomic molecule is nonpolar?**

**A** HCl

**B** HF

**C** HBr

**D** $H_2$

Polarity · Medium

**122. Why is $CO_2$ nonpolar even though each C=O bond is polar?**

**A** Its linear shape makes the two bond dipoles cancel

**B** The C=O bonds have no electronegativity difference

**C** Lone pairs on carbon cancel the bond dipoles

**D** Hydrogen bonds between molecules cancel the polarity

Polarity · Hard

**123. In a molecule with a lone pair on the central atom, where does the net dipole point?**

**A** Away from the lone pair

**B** Perpendicular to all the bonds

**C** Towards the lone pair

**D** It always cancels to zero

Polarity · Devil

**124. Which molecule has a net dipole although its electron pairs are arranged tetrahedrally?**

**A** $CH_4$, because the C–H bonds are polar

**B** $CH_3Cl$, because the central atom carries two kinds of substituent

**C** $CCl_4$, because each C–Cl bond is polar

**D** $CF_4$, because fluorine is highly electronegative

Polarity · Easy

**125. Which hydrogen halide is the most polar?**

**A** HCl

**B** HBr

**C** HI

**D** HF

Polarity · Medium

**126. Which of these molecules has a net dipole moment?**

**A** $H_2S$

**B** $CO_2$

**C** $CH_4$

**D** $CCl_4$

Polarity · Hard

**127. Which order of polarity is correct for the hydrogen halides?**

**A** HI > HBr > HCl > HF

**B** HF > HCl > HBr > HI

**C** HCl > HF > HBr > HI

**D** HF > HI > HBr > HCl

Polarity · Devil

**128. $SCl_2$ is a polar liquid with a structure like water. What makes it polar?**

**A** A linear shape makes the bond dipoles add together

**B** Tetrahedral symmetry spreads charge evenly

**C** A bent shape with lone pairs stops the bond dipoles cancelling

**D** Its S–Cl bonds have no polarity

Intermolecular forces · Easy

**129. How do intermolecular forces compare with covalent bonds?**

**A** Much weaker, about 0.1 to 40 kJ/mol

**B** Much stronger, about 100 to 500 kJ/mol

**C** About the same strength

**D** Stronger only in water

Intermolecular forces · Medium

**130. What are London dispersion forces?**

**A** Attractions between permanent dipoles

**B** Attractions between temporary induced dipoles

**C** Attractions between ions and polar molecules

**D** Covalent sharing of electrons between molecules

## Answers — Set 5 · Q41–50

**121.** D — Identical atoms share electrons symmetrically.

**122.** A — Equal and opposite dipoles in a linear molecule sum to zero.

**123.** C — The lone pair is a region of high electron density.

**124.** B — Unlike substituents prevent complete cancellation.

**125.** D — Fluorine is the most electronegative halogen.

**126.** A — $H_2S$ is bent with lone pairs, so its dipoles do not cancel.

**127.** B — Polarity falls as halogen electronegativity falls down the group.

**128.** C — The bent geometry gives a net dipole.

**129.** A — Covalent single bonds are about 100–500 kJ/mol.

**130.** B — Mutual distortion creates fleeting dipoles that attract.

## 6. Set 6 · Q51–60

Intermolecular forces · Hard

### 131. Why are London forces stronger in $I_2$ than in $F_2$?

**A** $I_2$ has a permanent dipole while $F_2$ has none

**B** $F_2$ forms hydrogen bonds while $I_2$ cannot

**C** $I_2$ is larger, so its electrons are more easily distorted

**D** Iodine is more electronegative than fluorine

Intermolecular forces · Devil

### 132. Although London forces are individually weakest, when can their net effect be greatest?

**A** In small ionic compounds, where strong lattices dominate their properties

**B** In gases of small polar molecules, where dipoles dominate

**C** In metal crystals, where delocalised electrons dominate the bonding

**D** In large molecules, where the combined attractions can exceed dipole–dipole or hydrogen bonds

Intermolecular forces · Easy

### 133. Which force acts between nonpolar molecules?

**A** Hydrogen bonds

**B** London dispersion forces

**C** Dipole–dipole attraction

**D** Ionic bonding

Hydrogen bonding · Medium

### 134. Which molecules can form hydrogen bonds with each other?

**A** Those containing only C–H bonds

**B** Those containing S–H and Cl–H groups

**C** Those containing F–H, O–H or N–H groups

**D** Any molecule that contains hydrogen

Hydrogen bonding · Hard

### 135. What is the usual order of intermolecular force strength?

**A** Hydrogen bonds > dipole–dipole > London

**B** London > dipole–dipole > hydrogen bonds

**C** Dipole–dipole > hydrogen bonds > London

**D** Hydrogen bonds > London > dipole–dipole

Hydrogen bonding · Devil

**136. H–F···H–F hydrogen bonds are stronger than H–O···H–O, yet water is liquid and HF is a gas at room temperature, per the lecture. Why?**

**A** Water has a larger molar mass than HF

**B** HF is nonpolar overall

**C** Water's bonds are covalent while HF's are ionic

**D** Each water molecule can form up to four hydrogen bonds

Intermolecular forces · Easy

**137. Which interaction occurs between permanently polar molecules?**

**A** London dispersion only

**B** Dipole–dipole attraction

**C** Ionic attraction

**D** Metallic bonding

Intermolecular forces · Medium

**138. In diagrams of intermolecular forces, what do the broken lines represent?**

**A** Covalent bonds within molecules

**B** Ionic bonds in the lattice

**C** Sigma bonds inside each atom

**D** Intermolecular forces between molecules

Shapes and VSEPR · Hard

**139. What is the correct hybridisation for octahedral $[Fe(CN)_6]^{4-}$ (the slide table misprints it as $sp^3d^3$)?**

**A** $sp^3d^2$

**B** $sp^3d^3$

**C** $sp^3d$

**D** $dsp^2$

Shapes and VSEPR · Devil

**140. Which row correctly pairs electron pairs, shape and hybridisation?**

**A** 4 pairs, square planar, $sp^3$

**B** 6 pairs, trigonal bipyramidal, $sp^3d^2$

**C** 5 pairs, trigonal bipyramidal, $sp^3d$

**D** 3 pairs, tetrahedral, $sp^2$

## Answers — Set 6 · Q51–60

**131.** C — Greater polarisability gives stronger induced dipole attraction.

**132.** D — Summed over a large surface, dispersion attractions become large.

**133.** B — Only induced dipoles are possible between nonpolar molecules.

**134.** C — These bonds are very polar and the H is strongly attracted to F, O or N.

**135.** A — Hydrogen bonds are generally the strongest and London forces the weakest.

**136.** D — Water's two lone pairs and two H atoms build a richer network.

**137.** B — $\Delta+$ ends attract the $\delta-$ ends of neighbours.

**138.** D — Solid lines show covalent bonds and broken lines show weaker attractions.

**139.** A — 1 s + 3 p + 2 d orbitals give six hybrid orbitals.

**140.** C — $PCl_5$ is the lecture's example.

## 7. Set 7 · Q61–70

Intermolecular effects · Easy

### 141. What is the boiling point of a liquid?

**A** The temperature at which its vapour pressure equals atmospheric pressure

**B** The temperature at which its density is greatest

**C** The temperature at which it first begins to evaporate

**D** The temperature at which its molecules stop moving

Intermolecular effects · Medium

### 142. Why do the noble gases have the lowest boiling points?

**A** They form strong hydrogen bonds that break easily

**B** They are held by ionic attraction that weakens with heat

**C** Their atoms form covalent bonds that melt at low temperature

**D** Their atoms are held only by weak, easily disrupted London forces

Intermolecular effects · Hard

### 143. Why is the boiling point of $NH_3$ lower than those of $H_2O$ and HF?

**A** Nitrogen is more electronegative, so $NH_3$ bonds break more easily

**B** $NH_3$ has no lone pair, so it cannot hydrogen-bond at all

**C** Nitrogen is less electronegative, so hydrogen bonding in $NH_3$ is weaker

**D** $NH_3$ is a larger molecule with stronger London forces than HF

Intermolecular effects · Devil

### 144. Why does NaCl dissolve in water but not in ether?

**A** Ion–ether attraction exceeds ion–ion attraction, but water cannot attract the ions

**B** Ion–water attraction exceeds ion–ion attraction, but ether cannot attract the ions

**C** Water is nonpolar and ether is polar, so water dissolves ions

**D** NaCl contains hydrogen bonds that only water can break

Intermolecular effects · Easy

### 145. Candle wax dissolves in petrol but not in water. Why?

**A** Water's hydrogen bonds are too weak to resist the wax molecules

**B** Petrol is a polar liquid and hydrogen-bonds to the wax chains

**C** Wax and petrol are nonpolar hydrocarbons that attract through van der Waals forces

**D** Wax is an ionic solid, and petrol dissolves ionic solids well

Properties of water · Medium

**146. Why is ice less dense than liquid water?**

**A** Ice molecules are lighter than liquid water molecules

**B** Hydrogen bonding in ice builds an open hexagonal lattice

**C** Ice contains trapped air that lowers its mass

**D** Ice lacks hydrogen bonds, so it expands

Properties of water · Hard

**147. What is the ecological significance of ice floating on water?**

**A** Surface ice insulates the water beneath, preventing complete freezing

**B** Ice sinks and warms the water at the bottom

**C** Ice absorbs dissolved oxygen from the water

**D** Ice raises the density of surface water and mixes the lake

Properties of water · Devil

**148. As water is cooled from 4 °C towards 0 °C, what happens to its density and why?**

**A** It increases as molecules pack more tightly

**B** It stays constant because hydrogen bonds are static

**C** It decreases because molecules move faster

**D** It decreases as hydrogen bonding builds an open lattice

Properties of water · Easy

**149. At what temperature does liquid water have its maximum density?**

**A** 4 °C

**B** 0 °C

**C** 100 °C

**D** −4 °C

Properties of water · Medium

**150. What does the high heat capacity of water do for living things?**

**A** It makes water heat up faster than most other liquids

**B** It prevents water from storing any heat from the surroundings

**C** It makes water boil well below 100 °C at 1 atm

**D** It slows warming and cooling, buffering organisms against abrupt change

## Answers — Set 7 · Q61–70

**141.** A — Boiling begins when vapour pressure matches the external pressure.

**142.** D — Weak London forces need little energy to overcome.

**143.** C — Weaker N–H polarity gives weaker hydrogen bonds.

**144.** B — 'like dissolves like': polar water solvates the ions, nonpolar ether cannot.

**145.** C — Like dissolves like.

**146.** B — The open structure holds molecules farther apart.

**147.** A — Aquatic life survives beneath the frozen layer in temperate regions.

**148.** D — Water is densest at 4 °C and expands on further cooling.

**149.** A — Water is densest at 4 °C.

**150.** D — Large amounts of heat are needed for a small temperature change.

## 8. Set 8 · Q71–80

Properties of water · Hard

**151. Why does sweating cool the body?**

**A** Water has a low heat capacity, so sweat warms quickly

**B** Water has a very high heat of vaporisation, so evaporation removes large amounts of heat

**C** Sweat is nonpolar and evaporates with little energy

**D** Evaporating sweat releases heat that is carried off in the air

Properties of water · Devil

**152. Using 540 cal per gram, how much heat is removed when 10 g of water vaporises (1 cal = 4.184 J)?**

**A** 5.4 kJ

**B** 2.26 kJ

**C** 22.6 kJ

**D** 54.0 kJ

Biological hydrogen bonding · Easy

**153. Which polysaccharide is more rigid because of extensive hydrogen bonding between its straight chains?**

**A** Starch

**B** Cellulose

**C** Glycogen

**D** Amylopectin

Properties of water · Medium

**154. Why is water more viscous than benzene?**

**A** Water has hydrogen bonds linking neighbouring molecules; benzene has none

**B** Benzene has hydrogen bonds while water has only London forces

**C** Water has a lower molar mass, so its molecules entangle more

**D** Benzene is a polar liquid with strong permanent dipoles

Properties of water · Hard

**155. Engine oil is more viscous than water yet has no hydrogen bonding. Why?**

**A** Strong hydrogen bonds link the molecules of its hydrocarbon chains

**B** Ionic attraction between its charged chains resists the flow

**C** Large molecules give strong van der Waals forces and entangle as long chains

**D** Its low molar mass lets small molecules lock tightly together

Properties of water · Devil

**156. How does viscosity change with temperature, and why?**

**A** It rises because faster molecules collide harder

**B** It stays constant because intermolecular forces do not change

**C** It falls because hydrogen bonds strengthen on heating

**D** It falls because greater kinetic energy overcomes attractions between molecules

Properties of water · Easy

**157. Which property lets a razor blade or an insect rest on the surface of water?**

**A** Viscosity

**B** Surface tension

**C** Boiling point

**D** Heat capacity

Properties of water · Medium

**158. Why does water's meniscus curve upward in a glass tube?**

**A** Cohesion exceeds adhesion between water and the glass

**B** Water is denser than the glass tube it sits in

**C** Adhesion to glass exceeds cohesion between water molecules

**D** Water is nonpolar and is repelled by the glass

Properties of water · Hard

**159. Capillary rise follows $h = 2\gamma/\rho g r$. What happens to h if the tube radius is halved?**

**A** It doubles

**B** It halves

**C** It is unchanged

**D** It quadruples

Biological hydrogen bonding · Devil

**160. Which statement about hydrogen bonding in biomolecules is correct?**

**A** It forms the peptide bonds that join amino acids

**B** It joins the two DNA strands covalently so they cannot separate

**C** It makes proteins hydrophobic in water

**D** It maintains α-helices and β-sheets and lets DNA strands unwind for replication

## Answers — Set 8 · Q71–80

**151.** B — Over 500 cal leave the skin with each gram evaporated.

**152.** C — 10 × 540 = 5400 cal, and 5400 × 4.184 J ≈ 22 600 J.

**153.** B — Cellulose has the higher degree of interchain hydrogen bonding.

**154.** A — Hydrogen bonds hinder flow.

**155.** C — Size and chain entanglement give the high viscosity.

**156.** D — Molecules slip past one another more readily when warm.

**157.** B — The surface behaves like a skin due to inward pull on surface molecules.

**158.** C — Water is drawn up along the wall.

**159.** A — H is inversely proportional to r.

**160.** D — Weak hydrogen bonds stabilise structure yet allow strand separation.

**Module 3: Thermodynamics** — 80 questions

## 1. Set 1 · Q1–10

Energy basics · Easy

**161. Which expression gives the potential energy of a body at height h?**

**A** ½mv² (half mass × speed squared)

**B** mgh (mass × gravity × height)

**C** mg ÷ h (weight over height)

**D** m + g + h (sum of the three terms)

Energy basics · Medium

**162. How many kcal per gram do carbohydrate, protein, fat and alcohol provide, respectively?**

**A** 4, 4, 9 and 7

**B** 4, 9, 4 and 7

**C** 9, 4, 4 and 4

**D** 4, 4, 7 and 9

Heat and temperature · Hard

**163. Two beakers of water, 100 mL and 1 L, are both at 100 °C. Which statement is correct?**

**A** Same total heat, but the larger beaker is hotter

**B** The larger beaker has higher temperature and the same heat

**C** Same temperature, but the larger beaker holds more total heat

**D** Both have the same temperature and the same total heat

First law · Devil

**164. What did Thompson's cannon-drilling observation help to establish?**

**A** Heat can be created from nothing during friction

**B** Water boils because of its own latent heat

**C** Friction destroys energy and wastes it

**D** Work can be converted into heat, supporting energy conservation

First law · Easy

**165. What does the first law of thermodynamics say about energy?**

**A** It can be created but not destroyed

**B** It can be neither created nor destroyed

**C** It can be destroyed but not created

**D** It is always lost as heat

Systems · Medium

**166. Cold water in a corked bottle warms on a bench but its level does not change. What type of system is it?**

**A** Open

**B** Isolated

**C** Adiabatic

**D** Closed

Systems · Hard

**167. Which pair correctly defines adiabatic and isothermal processes?**

**A** Adiabatic: constant temperature; isothermal: no heat crosses the boundary

**B** Adiabatic: constant pressure; isothermal: constant volume

**C** Adiabatic: no heat crosses the boundary; isothermal: constant temperature

**D** Both mean that no energy is exchanged with the surroundings

Systems · Devil

**168. Why are biochemical reactions in the human body essentially isothermal?**

**A** Elaborate temperature control keeps body temperature constant

**B** The body is isolated, so no heat is exchanged

**C** Enzymes absorb all of the heat that reactions release

**D** Every reaction in the body is adiabatic

State functions · Easy

**169. Which of these is a state function?**

**A** Temperature of the system

**B** Heat absorbed along one path

**C** Work done along one path

**D** Time taken for a change

State functions · Medium

**170. The change in a state function depends on which of the following?**

**A** The path taken between the states

**B** The speed of the change

**C** Only the initial and final states

**D** The heat added along the path

## Answers — Set 1 · Q1–10

**161.** B — PE = mgh.

**162.** A — Fat is the most energy-dense, with alcohol in between.

**163.** C — Temperature is independent of size; total heat depends on the amount of matter.

**164.** D — With Joule's work, it validated the first law.

**165.** B — This is the law of conservation of energy.

**166.** D — Energy crosses the boundary but matter does not.

**167.** C — The terms are defined by heat transfer and temperature respectively.

**168.** A — Thermoregulation holds temperature steady.

**169.** A — Temperature depends only on the state of the system.

**170.** C — Path does not matter for state functions.

## 2. Set 2 · Q11–20

First law · Hard

**171. A system absorbs 500 J of heat and does 200 J of work on the surroundings. What is ΔE?**

**A** +700 J

**B** +300 J

**C** −300 J

**D** −700 J

First law · Devil

**172. If ΔE for a system is −150 J, what is ΔE for the surroundings and why?**

**A** −150 J, because both parts lose energy equally

**B** 0 J, because the surroundings are unaffected

**C** +300 J, because both effects add up

**D** +150 J, because the energy of the universe is constant

State functions · Easy

**173. Which of these is an intensive property?**

**A** Mass

**B** Volume

**C** Density

**D** Enthalpy

State functions · Medium

**174. Which pair of properties are both extensive?**

**A** Temperature and pressure

**B** Density and boiling point

**C** Mass and melting point

**D** Volume and entropy

First law · Hard

**175. In ΔE = q + w, what does a positive w indicate?**

**A** Work is done by the system on the surroundings

**B** Work is done on the system by the surroundings

**C** Heat flows into the system

**D** The system expands against external pressure

Systems · Devil

**176. An exothermic reaction runs in a perfectly insulated (adiabatic) vessel. What happens to the temperature of the system?**

**A** It rises because heat cannot leave

**B** It falls because heat enters

**C** It stays constant because the process is isothermal

**D** No reaction occurs without heat exchange

Energy basics · Easy

**177. What is the SI unit of energy?**

**A** Watt

**B** Newton

**C** Pascal

**D** Joule

Energy basics · Medium

**178. If the products of a reaction have lower energy than the reactants, the reaction is…**

**A** Endothermic

**B** Isothermal

**C** Exothermic

**D** Adiabatic

Energy basics · Hard

**179. About how many kJ are in 250 kcal of food energy (1 cal = 4.184 J)?**

**A** 1046 kJ

**B** 59.7 kJ

**C** 104.6 kJ

**D** 10 460 kJ

First law · Devil

**180. Which statement about the signs of q and w is correct?**

**A** q < 0 means heat enters; w < 0 means work is done on the system

**B** q < 0 means heat leaves the system; w < 0 means the system does work

**C** q > 0 means heat leaves; w > 0 means the system does work

**D** q and w are always positive quantities

## Answers — Set 2 · Q11–20

**171.** B — ΔE = q + w = +500 + (−200) = +300 J.

**172.** D — −ΔE(system) = +ΔE(surroundings).

**173.** C — Density does not depend on the amount of matter.

**174.** D — Both scale with the amount of matter.

**175.** B — A positive w adds energy to the system.

**176.** A — Released heat stays and warms the contents.

**177.** D — Energy is measured in joules.

**178.** C — Energy is released to the surroundings.

**179.** A — $250 \times 1000$ cal $\times$ 4.184 J = $1.046 \times 10^6$ J.

**180.** B — Signs are defined from the system's point of view.

## 3. Set 3 · Q21–30

Enthalpy · Easy

**181. At constant pressure with only PV work, what does ΔH equal?**

**A** The work done on the system only

**B** The heat exchanged with the surroundings, $q_p$

**C** The temperature change of the system

**D** The entropy change of the system

Enthalpy · Medium

**182. For reactions involving only solids and liquids, how does ΔH compare with ΔE?**

**A** ΔH is always double ΔE

**B** ΔH is always zero

**C** ΔH ≈ ΔE, because ΔV is negligible

**D** ΔH is always opposite in sign to ΔE

Enthalpy · Hard

**183. A reaction mixture expands against constant atmospheric pressure. Which relation gives the heat $q_p$?**

**A** $q_p = \Delta E - P\Delta V$

**B** $q_p = \Delta E \times P\Delta V$

**C** $q_p = P\Delta V - \Delta E$

**D** $q_p = \Delta E + P\Delta V$

Enthalpy · Devil

**184. A gas-phase reaction has ΔE = −100 kJ and PΔV = +2.5 kJ. What is ΔH?**

**A** −97.5 kJ

**B** −102.5 kJ

**C** −100 kJ

**D** +102.5 kJ

Spontaneity · Easy

**185. Which of these is a spontaneous process?**

**A** Ice melting above 0 °C

**B** A ball rolling uphill by itself

**C** Iron recovered from $Fe_2O_3$ with no energy input

**D** Dissolved glucose spontaneously crystallising out of water

Spontaneity · Medium

**186. Why can ΔH alone not predict spontaneity?**

**A** All spontaneous processes are endothermic

**B** ΔH is not a state function

**C** Spontaneous processes always have ΔH = 0

**D** Some spontaneous processes are endothermic

Entropy · Hard

**187. Ice melts spontaneously at 25 °C although the process is endothermic. What drives it?**

**A** A decrease in entropy of the water molecules

**B** A negative internal energy change for the system

**C** An increase in entropy as ordered ice becomes liquid water

**D** Release of heat to the surroundings

Entropy · Devil

**188. Sucrose dissolving in water raises entropy. Which description is correct?**

**A** Sucrose becomes more ordered as it spreads through the water

**B** Crystal order is lost and water's hydrogen-bond network is partly disrupted

**C** Hydrated water becomes more ordered, so total entropy falls

**D** Only the solute entropy changes; water's entropy is constant

Entropy · Easy

**189. What does entropy measure?**

**A** Randomness or disorder of a system

**B** Heat content at constant pressure

**C** Energy available to do work

**D** Average kinetic energy of molecules

Entropy · Medium

**190. Which ordering of entropy for the physical states is correct?**

**A** Gas < liquid < solid

**B** Liquid < solid < gas

**C** Solid < gas < liquid

**D** Solid < liquid < gas

## Answers — Set 3 · Q21–30

**181.** B — Enthalpy change is the heat of reaction at constant pressure.

**182.** C — With negligible volume change, PΔV ≈ 0.

**183.** D — From $\Delta E = q_p - P\Delta V$, so $q_p = \Delta E + P\Delta V = \Delta H$.

**184.** A — $\Delta H = \Delta E + P\Delta V = -100 + 2.5$.

**185.** A — It occurs without external work.

**186.** D — Ice melting is endothermic yet spontaneous above 0 °C.

**187.** C — The disorder gained outweighs the enthalpy cost.

**188.** B — Both solute and solvent contribute to the entropy gain.

**189.** A — Entropy is the degree of disorder.

**190.** D — Gases have the most translational and rotational freedom.

## 4. Set 4 · Q31–40

Second law · Hard

**191. For a spontaneous process, which statement is correct?**

**A** ΔS(system) must be positive

**B** ΔS(universe) = 0

**C** ΔS(universe) > 0, even if ΔS(system) is negative

**D** ΔS(surroundings) must always be negative

Second law · Devil

**192. At equilibrium, how are ΔS(system) and ΔS(surroundings) related?**

**A** They are equal in magnitude and the same in sign

**B** They are equal in magnitude and opposite in sign

**C** Both are zero in all cases

**D** ΔS(surroundings) is always the larger positive value

Entropy · Easy

**193. In S = k ln W, what is k?**

**A** The gas constant

**B** Boltzmann's constant

**C** Avogadro's number

**D** Planck's constant

Entropy · Medium

**194. Why is a mix of heads and tails more likely than ten heads when tossing ten coins?**

**A** Heads is physically less stable than tails

**B** Coins prefer unequal outcomes

**C** A mixed result can be arranged in many more ways

**D** All heads requires more energy

Entropy · Hard

**195. By how much does a hydrocarbon's entropy rise per –$CH_2$– group in the gas phase, per the lecture?**

**A** 10.0 eu

**B** 5.8 eu

**C** 7.7 eu

**D** 3.5 eu

Entropy · Devil

**196. Which structural change reduces molecular entropy the most, per the lecture?**

**A** Adding a double bond, about 3.5 eu

**B** Adding a triple bond, about 4.5 eu

**C** Adding a branch to the chain, about 3.0 eu

**D** Forming a ring, about 14 eu

Entropy · Easy

**197. Which unit is used for standard molar entropy?**

**A** kJ $mol^{-1}$

**B** J K

**C** J $mol^{-1}$ $K^{-1}$

**D** mol $J^{-1}$

Entropy · Medium

**198. For $N_2O_4(g) \rightarrow 2NO_2(g)$, with $S^\circ$ of 240 and 304.2 J $mol^{-1}$ $K^{-1}$ respectively, what is $\Delta S^\circ$?**

**A** −175.8 J $mol^{-1}$ $K^{-1}$

**B** +64.2 J $mol^{-1}$ $K^{-1}$

**C** +544.2 J $mol^{-1}$ $K^{-1}$

**D** +175.8 J $mol^{-1}$ $K^{-1}$

Second law · Hard

**199. Why do living organisms not violate the second law despite forming ordered structures?**

**A** Their internal entropy never decreases at any point in time

**B** They release heat and wastes that raise the surroundings' entropy by more

**C** Their cells are isolated systems that exchange nothing outside

**D** The second law applies only to non-living matter and chemistry

Free energy · Devil

**200. Why can cells not use heat as a significant source of energy to do work?**

**A** Work from heat needs a temperature difference, which cells lack

**B** Heat is too small an energy form to matter

**C** Cells operate near absolute zero

**D** Heat is converted to free energy automatically

## Answers — Set 4 · Q31–40

**191.** C — The second law applies to the universe as a whole.

**192.** B — $\Delta S(\text{universe}) = 0$ requires $\Delta S(\text{sys}) = -\Delta S(\text{sur})$.

**193.** B — W is the number of ways of arranging the system.

**194.** C — Random states are more probable because they can be achieved in more ways.

**195.** A — The increment is 10.0 eu in gas, 7.7 in liquid, 5.8 in solid.

**196.** D — Rings greatly restrict rotation and vibration.

**197.** C — Entropy is energy per mole per kelvin.

**198.** D — (2 × 240) − 304.2 = +175.8, as one gas mole becomes two.

**199.** B — The entropy of the organism plus surroundings still increases.

**200.** A — Cells are at essentially uniform temperature.

## 5. Set 5 · Q41–50

Free energy · Easy

**201. Which equation relates free energy change to enthalpy and entropy changes?**

**A** $\Delta G = \Delta H - T\Delta S$

**B** $\Delta G = \Delta H + T\Delta S$

**C** $\Delta G = T\Delta H - \Delta S$

**D** $\Delta G = \Delta S - T\Delta H$

Free energy · Medium

**202. What does a negative ΔG indicate?**

**A** The forward reaction can never occur

**B** The system is at equilibrium

**C** Work must be done for the reaction to proceed

**D** The forward reaction as written is spontaneous

Free energy · Hard

**203. A reaction has ΔH negative and ΔS positive. What is its spontaneity?**

**A** Spontaneous only at high temperature

**B** Spontaneous only at low temperature

**C** Spontaneous at all temperatures

**D** Non-spontaneous at all temperatures

Free energy · Devil

**204. A reaction has ΔH = −40 kJ/mol and ΔS = −100 J/mol·K. What is ΔG at 298 K?**

**A** −69.8 kJ/mol

**B** −10.2 kJ/mol

**C** +10.2 kJ/mol

**D** −40.0 kJ/mol

Free energy · Easy

**205. What does ΔG = 0 mean?**

**A** The reaction is at equilibrium

**B** The reaction is spontaneous

**C** The reaction cannot occur

**D** The reaction is endothermic

Free energy · Medium

**206. A reaction has positive ΔH and positive ΔS. When is it spontaneous?**

**A** At low temperature

**B** At high temperature

**C** At all temperatures

**D** At no temperature

Free energy · Hard

**207. Why is melting of ice spontaneous above 0 °C but not below?**

**A** At lower T the TΔS term outweighs the positive ΔH

**B** ΔH changes sign at 0 °C

**C** Ice is always spontaneous to melt at any temperature

**D** At higher T the TΔS term outweighs the positive ΔH

Free energy · Devil

**208. For ice melting, ΔH = +6.01 kJ/mol and ΔS = +22.0 J/mol·K. At what temperature is ΔG = 0?**

**A** About 27 K

**B** About 2730 K

**C** About 273 K

**D** About 373 K

Coupled reactions · Easy

**209. What do we call a reaction with a negative ΔG?**

**A** Exergonic

**B** Endergonic

**C** Isothermal

**D** Adiabatic

Free energy · Medium

**210. What is the standard free energy of formation of an element in its standard state?**

**A** A small positive value

**B** A small negative value

**C** Equal to its enthalpy of vaporisation

**D** Zero by definition

## Answers — Set 5 · Q41–50

**201.** A — Gibbs' equation.

**202.** D — The reaction has free energy available to do work.

**203.** C — Both terms favour a negative ΔG.

**204.** B — ΔG = −40 − (298 × −0.100) = −40 + 29.8.

**205.** A — Forward and backward rates are equal.

**206.** B — TΔS must exceed ΔH.

**207.** D — ΔG = ΔH − TΔS becomes negative only above the melting point.

**208.** C — $T = \Delta H/\Delta S = 6010/22.0 \approx 273$ K.

**209.** A — It releases free energy.

**210.** D — The $\Delta G$ of an element is taken as zero.

## 6. Set 6 · Q51–60

Free energy · Hard

**211. For K = 10 at 298 K, what is $\Delta G^\circ = -RT \ln K$ ($R = 8.314$ J mol$^{-1}$ K$^{-1}$)?**

**A** About +5.7 kJ/mol

**B** About −57 kJ/mol

**C** About −5.7 kJ/mol

**D** About −2.5 kJ/mol

Free energy · Devil

**212. Under non-standard conditions with $\Delta G = \Delta G^\circ + RT \ln Q$, what follows when $Q < K$?**

**A** $\Delta G > 0$, so the reverse reaction is favoured

**B** $\Delta G < 0$, so the forward reaction is favoured

**C** $\Delta G = 0$, so the system is at equilibrium

**D** $\Delta G$ is undefined until Q equals K

Free energy · Easy

**213. What is the value of the gas constant R used in thermodynamics?**

**A** 8.314 J mol$^{-1}$ K$^{-1}$

**B** 4.184 J mol$^{-1}$ K$^{-1}$

**C** 96 485 J mol$^{-1}$ K$^{-1}$

**D** 0.0821 J mol$^{-1}$ K$^{-1}$

Free energy · Medium

**214. Which relation correctly gives $\Delta G$ from cell emf (the slide prints $\Delta H = -nF\Delta E$)?**

**A** $\Delta G = +nFE$

**B** $\Delta H = -nFE$

**C** $\Delta G = -E/nF$

**D** $\Delta G = -nFE$

Coupled reactions · Hard

**215. In a pathway A → B → C → D, one enzyme-catalysed step has a positive $\Delta G$. When can the pathway still run?**

**A** Only if every step has a negative $\Delta G$

**B** Only if the enzyme makes the $\Delta G$ of that step negative

**C** When the sum of all the $\Delta G$ values is negative

**D** Never, because one step is non-spontaneous

Coupled reactions · Devil

**216. In glycolysis some steps have positive or near-zero ΔG, yet the pathway proceeds. Why?**

**A** Enzymes make every positive ΔG step negative

**B** Steps with large negative ΔG drive the whole pathway

**C** The pathway sits at equilibrium throughout

**D** Positive ΔG steps are skipped by the cell

Coupled reactions · Easy

**217. What is a reaction with a positive ΔG called?**

**A** Exergonic

**B** Exothermic

**C** Endergonic

**D** Isobaric

Coupled reactions · Medium

**218. What do the two reactions in a coupled pair typically share?**

**A** The same enzyme in every case

**B** The same ΔG value

**C** Only the same temperature

**D** A common intermediate

Free energy · Hard

**219. A reaction has negative ΔH and negative ΔS. When is it spontaneous?**

**A** At high temperature

**B** At low temperature

**C** At all temperatures

**D** At no temperature

Free energy · Devil

**220. Why is freezing of water spontaneous below 0 °C?**

**A** Below 0 °C the −ΔH term outweighs the −TΔS term, so ΔG < 0

**B** Freezing is endothermic, so it is favoured at low T

**C** Entropy increases on freezing, which drives it

**D** The TΔS term becomes positive and large at low T

## Answers — Set 6 · Q51–60

**211.** C — $-8.314 \times 298 \times \ln 10 \approx -5705$ J.

**212.** B — With Q < K, RT ln Q is less than RT ln K, giving a negative ΔG.

**213.** A — R = 8.314 J $mol^{-1}$ $K^{-1}$.

**214.** D — A positive cell emf gives a negative ΔG.

**215.** C — Standard free energy changes are additive.

**216.** B — The strongly exergonic steps pull the sequence forward.

**217.** C — It requires work to proceed.

**218.** D — Energy flows between them through a shared intermediate.

**219.** B — The −ΔH term wins only when T is low.

**220.** A — Freezing has negative ΔH and negative ΔS, so low T makes ΔG negative.

## 7. Set 7 · Q61–70

ATP · Easy

**221. Which molecule is the universal energy currency of cells?**

**A** ATP

**B** Glucose

**C** DNA

**D** Cholesterol

ATP · Medium

**222. What is the approximate ΔG of ATP → ADP + Pi, per the lecture?**

**A** −3.3 kcal/mol

**B** −14.8 kcal/mol

**C** −7.3 kcal/mol

**D** +7.3 kcal/mol

ATP · Hard

**223. Why is ATP hydrolysis in isolation of little use to a cell?**

**A** It releases no free energy when hydrolysed alone

**B** It only works when the pH is near 1

**C** It forms a product that cannot be recycled

**D** Its free energy is dissipated as heat unless linked to a reaction

Coupled reactions · Devil

**224. PEP → pyruvate + Pi has ΔG = −14.8 kcal/mol and ADP + Pi → ATP has ΔG = +7.3 kcal/mol. What is ΔG for PEP + ADP → pyruvate + ATP?**

**A** −22.1 kcal/mol

**B** −7.5 kcal/mol

**C** +22.1 kcal/mol

**D** +7.5 kcal/mol

High-energy compounds · Easy

**225. Which compound has a lower phosphate transfer potential than ATP?**

**A** Phosphoenolpyruvate

**B** 1,3-Bisphosphoglycerate

**C** Phosphocreatine

**D** Glucose-6-phosphate

High-energy compounds · Medium

**226. Which is an example of a super high-energy phosphate compound?**

**A** Glucose-6-phosphate

**B** AMP

**C** Phosphoenolpyruvate

**D** Glucose-1-phosphate

Coupled reactions · Hard

**227. Glucose + Pi → glucose-6-phosphate has ΔG = +3.3 kcal/mol. If coupled to ATP hydrolysis (−7.3), what is ΔG for glucose + ATP → G6P + ADP?**

**A** −10.6 kcal/mol

**B** −4.0 kcal/mol

**C** +10.6 kcal/mol

**D** +4.0 kcal/mol

High-energy compounds · Devil

**228. Why can low-energy phosphates not be formed directly from super high-energy compounds like PEP?**

**A** No enzyme catalyses the direct transfer, so ATP acts as intermediary

**B** PEP has no phosphate group to donate

**C** The transfer would be thermodynamically impossible

**D** Low-energy phosphates are too unstable to form

High-energy compounds · Easy

**229. Acetyl-CoA and succinyl-CoA belong to which class of energy-rich compounds?**

**A** Phosphoric acid anhydrides

**B** Thiol esters

**C** Enol phosphates

**D** Guanidinium phosphates

High-energy compounds · Medium

**230. Which compound is an enol phosphate?**

**A** Creatine phosphate

**B** ATP

**C** Acetyl phosphate

**D** Phosphoenolpyruvate

## Answers — Set 7 · Q61–70

**221.** A — ATP links energy-releasing and energy-requiring reactions.

**222.** C — A large amount of free energy is released.

**223.** D — The energy must be coupled to an energy-requiring process.

**224.** B — −14.8 + 7.3 = −7.5 (the slide prints −7.8, an arithmetic slip).

**225.** D — Its hydrolysis releases about −3.3 kcal/mol.

**226.** C — PEP releases about −14.8 kcal/mol on hydrolysis.

**227.** B — +3.3 + (−7.3) = −4.0.

**228.** A — Transfer passes through ATP.

**229.** B — They are thiol esters of coenzyme A.

**230.** D — PEP contains a phosphate on an enol group.

## 8. Set 8 · Q71–80

ATP · Hard

**231. Why does ATP have a high free energy of hydrolysis?**

**A** Its phosphate bonds are unusually strong, storing energy

**B** Its products are less stable than ATP itself

**C** Repulsion among its negative charges strains it, and its products are stabilised

**D** Hydrolysis forms a tight ion pair that releases heat

High-energy compounds · Devil

**232. Why is glucose-6-phosphate a low-energy compound?**

**A** Its hydrolysis products, glucose and Pi, have little repulsion and can recombine easily

**B** Its hydrolysis gives two anions that repel each other strongly

**C** It has more resonance structures than either of its products

**D** It forms a super high-energy intermediate on hydrolysis

ATP · Easy

**233. Which triphosphate is used mainly in polysaccharide biosynthesis?**

**A** GTP

**B** CTP

**C** dATP

**D** UTP

ATP · Medium

**234. GTP is especially important in which processes?**

**A** Signal transduction and protein synthesis

**B** Phospholipid biosynthesis in membranes

**C** Polysaccharide biosynthesis from sugars

**D** DNA synthesis as the only role

ATP · Hard

**235. How does $Mg^{2+}$ binding to $ATP^{4-}$ affect its free energy of hydrolysis, per the lecture?**

**A** It increases repulsion and raises the free energy of hydrolysis

**B** It neutralises charge, reduces repulsion and lowers the free energy of hydrolysis

**C** It breaks the terminal phosphate directly

**D** It converts ATP into ADP without water

ATP · Devil

**236. How does the free energy of ATP hydrolysis at pH around 1 compare with that at physiological pH?**

**A** Higher at pH 1, because extra protons stabilise ATP strongly

**B** The same, because pH does not affect the free energy

**C** Lower at pH 1, because proton release and buffering contribute at physiological pH

**D** Higher at pH 1, because ADP is more stable at that pH

High-energy compounds · Easy

**237. ATP, ADP and pyrophosphate belong to which class of energy-rich compounds?**

**A** Thiol esters

**B** Enol phosphates

**C** Guanidinium phosphates

**D** Phosphoric acid anhydrides

ATP · Medium

**238. With which cell processes is ATP hydrolysis coupled?**

**A** Only heat production for maintaining body temperature

**B** Macromolecule synthesis, muscle contraction and nerve impulses

**C** Only DNA replication during cell division

**D** Only photosynthesis in the chloroplast

ATP · Hard

**239. Why does ATP occupy an intermediate position on the phosphate-transfer scale?**

**A** It has the highest phosphate transfer potential of all compounds

**B** It has the lowest phosphate transfer potential of all compounds

**C** It accepts phosphate from higher-energy compounds and donates to lower-energy ones

**D** It cannot transfer its phosphate group to any other molecule

High-energy compounds · Devil

**240. A raised serum creatine kinase signals muscle damage. Which compound does this enzyme act on, per the lecture's examples?**

**A** Phosphocreatine, passing its phosphate to ADP to make ATP

**B** PEP, converting it to pyruvate and ATP in glycolysis

**C** Glucose-6-phosphate, releasing free glucose and Pi

**D** AMP, producing adenosine and inorganic phosphate

## Answers — Set 8 · Q71–80

**231.** C — Strain relief plus resonance and ionisation stabilise the products.

**232.** A — There is little strain relief on hydrolysis.

**233.** D — UTP supports sugar-nucleotide formation.

**234.** A — These are GTP's lecture-listed roles.

**235.** B — Less charge repulsion means less strain to relieve.

**236.** C — The lecture links the extra free energy to ionisation and buffering of Pi.

**237.** D — They contain phosphoanhydride linkages.

**238.** B — These are all energy-requiring processes powered by ATP.

**239.** C — This makes it the major link in energy metabolism.

**240.** A — Phosphocreatine + ADP ⇌ ATP + creatine.

**Module 4: Chemical Kinetics** — 80 questions

## 1. Set 1 · Q1–10

Rates · Easy

### 241. What does chemical kinetics study?

**A** Only the energy released by reactions

**B** The rates and mechanisms of chemical reactions

**C** The position of equilibrium in reversible reactions

**D** The shapes of molecules in a reaction

Measuring rates · Medium

### 242. In $H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$, how is the iodine formed measured?

**A** Weighing the oxygen gas that bubbles out

**B** Measuring the pH change with litmus paper

**C** Titration with sodium thiosulphate using starch as indicator

**D** Measuring the change in viscosity of the mixture

Rates · Hard

### 243. 0.30 mol $dm^{-3}$ of iodine forms in 30 minutes. What is the average rate?

**A** 9.0 mol $dm^{-3}$ $min^{-1}$

**B** 0.10 mol $dm^{-3}$ $min^{-1}$

**C** $1.0 \times 10^{-3}$ mol $dm^{-3}$ $min^{-1}$

**D** 0.010 mol $dm^{-3}$ $min^{-1}$

Measuring rates · Devil

### 244. Why is a sampled aliquot quenched before titration?

**A** To stop further reaction so the result reflects that moment in time

**B** To dissolve the starch indicator more quickly

**C** To raise the reaction rate for easier measurement

**D** To convert the remaining reactant fully into product

Measuring rates · Easy

### 245. Which instrument follows a reaction in which colour intensity changes?

**A** Viscometer used for flow time

**B** Polarimeter for optical rotation

**C** Colorimeter or spectrophotometer

**D** Conductivity meter for ions

Measuring rates · Medium

### 246. Which method suits $Zn + 2HCl \rightarrow ZnCl_2 + H_2$ in a constant-volume vessel?

**A** Measuring the rise in pressure from hydrogen gas

**B** Measuring optical rotation with a polarimeter

**C** Measuring colour intensity with a colorimeter

**D** Measuring viscosity with a viscometer

Measuring rates · Hard

**247. Which technique follows the rate of iron incorporation into haemoglobin?**

**A** Colorimetry of a coloured reactant

**B** Radioactive labelling and measuring radioactivity

**C** Viscometry of the blood sample

**D** Pressure measurement of evolved gas

Rate and stoichiometry · Devil

**248. For $2N_2O_5 \rightarrow 4NO_2 + O_2$, which rate relationship is correct?**

**A** rate = $-\Delta[N_2O_5]/\Delta t = \Delta[NO_2]/\Delta t = \Delta[O_2]/\Delta t$

**B** rate = $-2\Delta[N_2O_5]/\Delta t = 4\Delta[NO_2]/\Delta t = \Delta[O_2]/\Delta t$

**C** rate = $-\frac{1}{2}\Delta[N_2O_5]/\Delta t = \frac{1}{2}\Delta[NO_2]/\Delta t = \Delta[O_2]/\Delta t$

**D** rate = $-\frac{1}{2}\Delta[N_2O_5]/\Delta t = \frac{1}{4}\Delta[NO_2]/\Delta t = \Delta[O_2]/\Delta t$

Rate and stoichiometry · Easy

**249. Why is a minus sign used when the rate is written from a reactant's concentration change?**

**A** Because reactants are negatively charged

**B** Because reactant concentration rises with time

**C** Because the reaction runs backwards

**D** So that the rate is a positive quantity

Rate and stoichiometry · Medium

**250. In $2A \rightarrow B$, A disappears at 0.20 mol $L^{-1}$ $s^{-1}$. How fast does B form?**

**A** 0.20 mol $L^{-1}$ $s^{-1}$

**B** 0.40 mol $L^{-1}$ $s^{-1}$

**C** 0.10 mol $L^{-1}$ $s^{-1}$

**D** 0.05 mol $L^{-1}$ $s^{-1}$

## Answers — Set 1 · Q1–10

**241.** B — Kinetics covers how fast reactions go and the steps they follow.

**242.** C — Thiosulphate titration quantifies iodine.

**243.** D — 0.30 ÷ 30 = 0.010.

**244.** A — Otherwise the concentration would keep changing during analysis.

**245.** C — They measure colour intensity or absorbance.

**246.** A — Gas production raises pressure at constant volume.

**247.** B — A labelled reactant gives a radioactive product to count.

**248.** D — Each concentration change is divided by its stoichiometric coefficient.

**249.** D — Δ[reactant] is negative, so the sign gives a positive rate.

**250.** C — Two moles of A are lost for each mole of B formed.

## 2. Set 2 · Q11–20

Rate and stoichiometry · Hard

**251. In $2N_2O_5 \rightarrow 4NO_2 + O_2$, $O_2$ forms at $2.0 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$. How fast does $N_2O_5$ disappear?**

**A** $4.0 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$

**B** $2.0 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$

**C** $1.0 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$

**D** $8.0 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$

Rate and stoichiometry · Devil

**252. Using the bromine data, what is the average rate between 100 s (0.00846 M) and 150 s (0.00710 M)?**

**A** $1.36 \times 10^{-3}$ mol $L^{-1}$ $s^{-1}$

**B** $2.72 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$

**C** $2.72 \times 10^{-3}$ mol $L^{-1}$ $s^{-1}$

**D** $1.36 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$

Factors affecting rate · Easy

**253. Chewing food speeds digestion mainly by doing what?**

**A** Lowering the temperature of the food

**B** Increasing the surface area for enzymes to act on

**C** Adding a catalyst to the food

**D** Raising the activation energy of digestion

Factors affecting rate · Medium

**254. Why are organic reactions generally slower than reactions between ions in solution?**

**A** Organic reactants are always gases at room temperature and pressure

**B** Ionic reactants have the higher activation energies of the two types

**C** Covalent bonds must break and intermediates form, giving higher activation energies

**D** Organic molecules are always completely unreactive in any conditions

Factors affecting rate · Hard

**255. Why do aldehydes react faster than ketones in nucleophilic addition?**

**A** Aldehydes have bulkier groups that speed up attack

**B** Ketones are ionic and aldehydes are covalent

**C** Aldehydes are larger molecules with more surface area

**D** Ketones have bulkier groups that hinder access to the reactive carbon

Factors affecting rate · Devil

**256. Which application–rate pairing is correct?**

**A** Blood is stored at 0–4 °C to slow decomposition

**B** Refrigeration speeds up microbial spoilage

**C** Autoclaving uses low pressure to slow sterilisation

**D** Surgical cooling raises the metabolic rate

Rates · Easy

**257. What is the initial rate of a reaction?**

**A** The average rate over the whole reaction

**B** The rate when equilibrium is reached

**C** The rate when half the reactant is gone

**D** The instantaneous rate at zero time, t = 0

Rates · Medium

**258. How is an instantaneous rate found from a concentration–time graph?**

**A** From the area under the curve

**B** From the gradient of the tangent at that time

**C** From the average of the first and last points

**D** From the intercept on the time axis

Rate laws · Hard

**259. A plot of rate against [$Br_2$] is a straight line through the origin. What does it show?**

**A** The reaction is zero order in bromine

**B** The reaction is second order in bromine

**C** The reaction is first order in bromine

**D** The reaction is at equilibrium

Rate laws · Devil

**260. Why was formic acid kept at a high, nearly constant concentration in the bromine study?**

**A** So the rate effectively depends on bromine concentration alone

**B** So bromine turns colourless faster than it otherwise would

**C** So formic acid can act as the indicator for the reaction

**D** So that equilibrium is reached very quickly in the vessel

## Answers — Set 2 · Q11–20

**251.** A — Two $N_2O_5$ are lost for each $O_2$ formed.

**252.** B — $(0.00846 - 0.00710) \div 50 = 2.72 \times 10^{-5}$.

**253.** B — Smaller particles expose more surface for reaction.

**254.** C — Ions in solution are already free to combine quickly.

**255.** D — Steric hindrance slows the ketone reaction.

**256.** A — Low temperature slows chemical and biological change.

**257.** D — It is the gradient of the tangent at t = 0.

**258.** B — The gradient gives the rate at that instant.

**259.** C — Rate ∝ $[Br_2]^1$.

**260.** A — The acid's concentration then barely changes.

## 3. Set 3 · Q21–30

Rate laws · Easy

**261. How is the exponent x in rate = $k[A]^x$ determined?**

**A** From the coefficient in the balanced equation

**B** Experimentally, from measured rate data

**C** From the molar mass of A

**D** From the enthalpy change of the reaction

Rate laws · Medium

**262. What is the exponent x in rate = $k[A]^x$ called?**

**A** The order of the reaction with respect to A

**B** The molecularity of the reaction

**C** The activation energy of A

**D** The half-life of A

Rate laws · Hard

**263. $N_2O_5$ has a coefficient of 2 in its decomposition but is first order. What does this show?**

**A** Order always equals the stoichiometric coefficient

**B** The equation must have been balanced incorrectly

**C** $N_2O_5$ acts as a catalyst in this reaction

**D** Order is found by experiment and need not equal the coefficient

Rate laws · Devil

**264. In the $2NO + 2H_2 \rightarrow N_2 + 2H_2O$ data, doubling $[H_2]$ doubles the rate and doubling [NO] quadruples it. What is the rate law?**

**A** rate = $k[NO][H_2]^2$

**B** rate = $k[NO][H_2]$

**C** rate = $k[NO]^2[H_2]$

**D** rate = $k[NO]^2[H_2]^2$

Rate laws · Easy

**265. In rate = $k[A]^x$, what is k?**

**A** The rate constant, a proportionality constant

**B** The Boltzmann constant from statistical entropy

**C** The order of the reaction with respect to A

**D** The molar concentration of reactant A

Rate laws · Medium

**266. What is the overall order of a reaction with rate = k[A]²[B]?**

**A** Second order

**B** First order

**C** Fourth order

**D** Third order

Rate laws · Hard

**267. At 600 s and 3600 s, [$N_2O_5$] differs by a factor of 4.8 and the rates by 4.9. What order does this indicate?**

**A** Zero order

**B** Second order

**C** First order

**D** Third order

First-order kinetics · Devil

**268. [$N_2O_5$] falls from $1.8 \times 10^{-2}$ M to $9.3 \times 10^{-3}$ M in 1200 s (first order). What is k?**

**A** $1.6 \times 10^{-3}$ $s^{-1}$

**B** $5.5 \times 10^{-4}$ $s^{-1}$

**C** $5.5 \times 10^{-3}$ $s^{-1}$

**D** $2.4 \times 10^{-4}$ $s^{-1}$

First-order kinetics · Easy

**269. What are the units of a first-order rate constant?**

**A** mol $L^{-1}$ $s^{-1}$

**B** L $mol^{-1}$ $s^{-1}$

**C** $s^{-1}$

**D** mol s

First-order kinetics · Medium

**270. For a first-order reaction with $k = 5.7 \times 10^{-4}$ $s^{-1}$ and [$N_2O_5$] = $1.5 \times 10^{-3}$ M, what is the rate?**

**A** $8.6 \times 10^{-7}$ mol $L^{-1}$ $s^{-1}$

**B** 0.38 mol $L^{-1}$ $s^{-1}$

**C** $8.6 \times 10^{-4}$ mol $L^{-1}$ $s^{-1}$

**D** 2.6 mol $L^{-1}$ $s^{-1}$

## Answers — Set 3 · Q21–30

**261.** B — The value of x must be found from experimental data.

**262.** A — It is the order with respect to that reactant.

**263.** D — The exponent in the rate law is empirical.

**264.** C — Second order in NO and first order in $H_2$.

**265.** A — It converts the proportionality into an equation.

**266.** D — The exponents sum to 2 + 1 = 3.

**267.** C — Rate changes in direct proportion to concentration.

**268.** B — $K = \ln(1.8\times10^{-2}/9.3\times10^{-3})/1200 = 0.660/1200$.

**269.** C — Rate (mol $L^{-1}$ $s^{-1}$) divided by concentration gives $s^{-1}$.

**270.** A — $5.7 \times 10^{-4} \times 1.5 \times 10^{-3} = 8.55 \times 10^{-7}$.

## 4. Set 4 · Q31–40

Rate laws · Hard

**271. For rate = k[A]², what happens to the rate if [A] is tripled?**

**A** It increases three-fold

**B** It increases nine-fold

**C** It increases six-fold

**D** It increases twenty-seven-fold

Rate laws · Devil

**272. From experiment 1 (rate 0.0339 mol $L^{-1}$ $s^{-1}$, [NO] 0.210 M, [$H_2$] 0.122 M), what is k for rate = k[NO]²[$H_2$]?**

**A** 1.32 $L^2$ $mol^{-2}$ $s^{-1}$

**B** 6.30 $s^{-1}$

**C** 6.30 L $mol^{-1}$ $s^{-1}$

**D** 6.30 $L^2$ $mol^{-2}$ $s^{-1}$

Rate laws · Easy

**273. What happens to the rate constant if a reactant's concentration is increased at constant temperature?**

**A** It increases in proportion

**B** It decreases in proportion

**C** It becomes zero

**D** It stays the same

Rate laws · Medium

**274. With [$H_2$] fixed, tripling [NO] in $2NO + 2H_2 \rightarrow N_2 + 2H_2O$ raises the rate by what factor?**

**A** 9

**B** 3

**C** 6

**D** 27

Rate laws · Hard

**275. Which statement about reaction orders is correct?**

**A** Orders must be positive whole numbers

**B** Orders can be fractional, zero or even negative

**C** Orders always equal the stoichiometric coefficients

**D** Only first and second orders exist

First-order kinetics · Devil

**276. Which plot of first-order data gives a straight line, and what is its slope?**

**A** [A] against t, slope −k

**B** 1/[A] against t, slope k

**C** ln[A] against t, slope −k

**D** ln[A] against 1/t, slope −k

Rate laws · Easy

**277. For a first-order reaction, what happens to the rate when [A] is doubled?**

**A** It stays the same

**B** It quadruples

**C** It doubles

**D** It halves

Rate laws · Medium

**278. If a reaction is zero order in A, how does its rate depend on A?**

**A** It does not depend on the concentration of A

**B** It is directly proportional to [A]

**C** It is proportional to $[A]^2$

**D** It is inversely proportional to [A]

Rate laws · Hard

**279. For rate = $k[A][B]^2$, what happens to the rate if both [A] and [B] are doubled?**

**A** It increases four-fold

**B** It increases eight-fold

**C** It increases six-fold

**D** It increases sixteen-fold

Rate laws · Devil

**280. Doubling [X] doubles the rate, doubling [Y] has no effect, and tripling [Z] makes the rate nine times larger. What is the rate law?**

**A** rate = $k[X][Y][Z]^2$

**B** rate = $k[X][Z]^3$

**C** rate = $k[Y][Z]^2$

**D** rate = $k[X][Z]^2$

## Answers — Set 4 · Q31–40

**271.** B — $3^2 = 9$.

**272.** D — $0.0339 \div (0.210^2 \times 0.122) = 6.30$, with units $L^2\ mol^{-2}\ s^{-1}$.

**273.** D — K depends on temperature, not concentration.

**274.** A — The reaction is second order in NO.

**275.** B — Third, fractional, zero and negative orders also occur.

**276.** C — $\ln[A] = \ln[A]_0 - kt$.

**277.** C — Rate is directly proportional to [A].

**278.** A — $[A]^0 = 1$, so A drops out of the rate law.

**279.** B — $2^1 \times 2^2 = 8$.

**280.** D — First order in X, zero order in Y, second order in Z.

## 5. Set 5 · Q41–50

Half-life · Easy

**281. What is the half-life of a first-order reaction?**

**A** The time for the reaction to go fully to completion

**B** The time for the reactant to fall to half its original concentration

**C** The time for the rate constant itself to halve

**D** The time taken for the amount of products to double

Half-life · Medium

**282. Which relationship links half-life and rate constant for a first-order reaction?**

**A** $t_{1/2} = k/0.693$

**B** $t_{1/2} = 0.693 \times k$

**C** $t_{1/2} = 1/(k[A]_0)$

**D** $t_{1/2} = 0.693/k$

Half-life · Hard

**283. A first-order reaction has $t_{1/2}$ = 2.40 h. What is k?**

**A** 0.289 $h^{-1}$

**B** 3.46 $h^{-1}$

**C** 1.66 $h^{-1}$

**D** 0.601 $h^{-1}$

Half-life · Devil

**284. Starting with 2.00 g of $N_2O_5$ ($t_{1/2}$ = 2.40 h), how much remains after 9.60 h?**

**A** 0.250 g

**B** 0.500 g

**C** 0.125 g

**D** 0.0625 g

Half-life · Easy

**285. What fraction of a first-order reactant remains after two half-lives?**

**A** One half

**B** One quarter

**C** One eighth

**D** None

First-order kinetics · Medium

**286. Which is the integrated first-order rate equation?**

**A** $\ln([A]_t/[A]_0) = kt$

**B** $[A]_t = [A]_0 + kt$

**C** $\ln([A]_0/[A]_t) = kt$

**D** $1/[A]_t = 1/[A]_0 + kt$

Half-life · Hard

**287. How long does 0.0180 M $N_2O_5$ take to fall to 0.0100 M if $t_{1/2}$ = 2.40 h?**

**A** About 0.170 h

**B** About 0.884 h

**C** About 2.40 h

**D** About 2.04 h

Half-life · Devil

**288. About how many half-lives does a first-order reaction need to be roughly 99% complete?**

**A** About 6.6

**B** About 2

**C** About 10

**D** About 3.3

Radiocarbon dating · Easy

**289. Who developed the radiocarbon dating technique?**

**A** W. F. Libby

**B** John Dalton

**C** Svante Arrhenius

**D** Gilbert Lewis

Radiocarbon dating · Medium

**290. What is the half-life of $^{14}C$?**

**A** About 573 years

**B** About 57 300 years

**C** About 5730 years

**D** About 5.73 million years

## Answers — Set 5 · Q41–50

**281.** B — $T_{1/2}$ is the time for [A] to drop to ½[A]₀.

**282.** D — From $\ln 2 = k\,t_{1/2}$.

**283.** A — K = 0.693 ÷ 2.40.

**284.** C — 9.60 h is four half-lives: 2.00 ÷ 16.

**285.** B — ½ × ½ = ¼.

**286.** C — It applies to first-order reactions only.

**287.** D — $T = \ln(1.80)/0.289 \approx 2.04$ h.

**288.** A — $(½)^n = 0.01$ gives $n \approx 6.64$.

**289.** A — Libby won a Nobel prize for it in 1960.

**290.** C — Roughly 5730 years.

## 6. Set 6 · Q51–60

Radiocarbon dating · Hard

**291. How is $^{14}C$ produced in the atmosphere?**

**A** $^{14}N$ emits a β particle to give $^{14}C$

**B** $^{12}C$ captures two neutrons directly from sunlight

**C** $^{16}O$ loses two protons by radioactive decay

**D** $^{14}N$ captures a neutron, giving $^{14}C$ and a proton

Radiocarbon dating · Devil

**292. An artefact has 12.5% of its original $^{14}C$ ($t_{½}$ = 5730 y). About how old is it?**

**A** About 11 460 years

**B** About 17 190 years

**C** About 5730 years

**D** About 22 920 years

Radiocarbon dating · Easy

**293. After a plant or animal dies, what happens to its $^{14}C$:$^{12}C$ ratio?**

**A** It increases

**B** It stays constant

**C** It becomes equal to the atmosphere's

**D** It decreases

Radiocarbon dating · Medium

**294. Which is an assumption made in $^{14}C$ dating?**

**A** Atmospheric $^{14}C$ has risen steadily over thousands of years

**B** Decay rates are constant regardless of temperature and pressure

**C** Living organisms never exchange carbon with the air

**D** $^{14}C$ is concentrated at the poles

Radiocarbon dating · Hard

**295. Why is radiocarbon dating unreliable for objects older than about 25 000 years?**

**A** β emission becomes so weak that background radiation interferes

**B** $^{14}C$ decays too quickly to be detected at all

**C** Old objects absorb extra $^{14}C$ from soil

**D** The half-life of $^{14}C$ changes with sample age

Radiocarbon dating · Devil

**296. A sample's $^{14}C:^{12}C$ ratio is one quarter of the atmospheric ratio. About how old is it?**

**A** About 5730 years

**B** About 22 920 years

**C** About 11 460 years

**D** About 17 190 years

Radiocarbon dating · Easy

**297. By what type of decay does $^{14}C$ become $^{14}N$?**

**A** Alpha emission

**B** Gamma emission only

**C** Positron emission

**D** Beta emission

Half-life · Medium

**298. For a first-order reaction, what is the product $k \times t_{1/2}$?**

**A** 1

**B** 2.303

**C** 0.693

**D** $k^2$

Half-life · Hard

**299. A first-order reaction is 75% complete after 40 minutes. What is its half-life?**

**A** 20 minutes

**B** 40 minutes

**C** 10 minutes

**D** 13.3 minutes

First-order kinetics · Devil

**300. With $k = 5.7 \times 10^{-4}\ s^{-1}$, how long for $1.8 \times 10^{-2}$ M $N_2O_5$ to fall to $4.5 \times 10^{-3}$ M?**

**A** About $1.2 \times 10^3$ s

**B** About $2.4 \times 10^3$ s

**C** About $4.9 \times 10^3$ s

**D** About $2.4 \times 10^{-3}$ s

## Answers — Set 6 · Q51–60

**291.** D — Cosmic-ray neutrons convert nitrogen-14 into carbon-14.

**292.** B — 12.5% = ⅛ means three half-lives.

**293.** D — $^{14}C$ decays and is no longer replaced.

**294.** B — Decay rates are treated as constant.

**295.** A — The signal is lost among background radiation.

**296.** C — One quarter corresponds to two half-lives.

**297.** D — A neutron converts to a proton, emitting a β particle.

**298.** C — Ln 2 = 0.693 is constant for first-order processes.

**299.** A — 75% complete is two half-lives.

**300.** B — Two half-lives, $2 \times 0.693/5.7\times10^{-4}$.

## 7. Set 7 · Q61–70

Temperature and Arrhenius · Easy

**301. By what factor does the rate of a reaction roughly change for a 10 °C rise, per the lecture's rule of thumb?**

**A** It approximately doubles

**B** It approximately halves

**C** It increases tenfold

**D** It is unchanged

Temperature and Arrhenius · Medium

**302. In k = Ae^(−Ea/RT), what does A represent?**

**A** The activation energy of the reaction

**B** The frequency factor, related to collision frequency

**C** The gas constant in energy units

**D** The absolute temperature in kelvin

Temperature and Arrhenius · Hard

**303. With Ea = 75 kJ/mol, by what factor does k rise from 27 °C to 37 °C?**

**A** About 10-fold

**B** About 1.3-fold

**C** About 2.6-fold

**D** About 26-fold

Temperature and Arrhenius · Devil

**304. A plot of ln k against 1/T has slope −9000 K. What is Ea?**

**A** About 9.0 kJ/mol

**B** About 748 kJ/mol

**C** About 1.08 kJ/mol

**D** About 74.8 kJ/mol

Collision theory · Easy

**305. What is the minimum extra energy colliding molecules need in order to react?**

**A** Free energy

**B** Lattice energy

**C** Ionisation energy

**D** Activation energy

Collision theory · Medium

**306. Which statement fits collision theory?**

**A** Every collision between reactant molecules gives products

**B** Orientation of colliding molecules never matters

**C** Only collisions with enough energy and suitable orientation lead to reaction

**D** Only gentle collisions lead to reaction

Catalysis · Hard

**307. Why does a catalyst not change ΔH or ΔG of a reaction?**

**A** It lowers Ea but leaves reactant and product energies unchanged

**B** It supplies extra energy to the reactants as they collide

**C** It lowers the energy of the products relative to reactants

**D** It raises the energy of the reactants before reaction

Catalysis · Devil

**308. Which statement about catalysts is false?**

**A** A catalyst is used in small quantities

**B** A catalyst can make a thermodynamically unfeasible reaction proceed

**C** A catalyst can be poisoned

**D** A catalyst is regenerated at the end of the reaction

Catalysis · Easy

**309. A catalyst in the same phase as the reactants is called what?**

**A** Heterogeneous

**B** Enzymatic

**C** Inhibitory

**D** Homogeneous

Transition state · Medium

**310. On the energy profile of a reaction, the activated complex corresponds to what?**

**A** The point of maximum potential energy

**B** The energy level of the reactants

**C** The energy level of the products

**D** The lowest point on the curve

## Answers — Set 7 · Q61–70

**301.** A — Rates roughly double per 10 °C rise.

**302.** B — A reflects how often reactant molecules collide.

**303.** C — $\ln(k_2/k_1) = (75\,000/8.314)(1/300 - 1/310) \approx 0.97$.

**304.** D — Ea = 9000 × 8.314 J/mol ≈ 74.8 kJ/mol.

**305.** D — It is the barrier to effective collisions.

**306.** C — Both energy and orientation matter.

**307.** A — It only provides an alternative pathway.

**308.** B — This is false; catalysts only speed up feasible reactions.

**309.** D — Phase matches the reactants.

**310.** A — It sits at the top of the energy barrier.

## 8. Set 8 · Q71–80

Catalysis · Hard

**311. Which catalyst pairing is correct?**

**A** Liquid $Br_2$ with $H_2O_2$: heterogeneous catalysis

**B** Iron in the Haber process: homogeneous catalysis

**C** Solid $MnO_2$ with $H_2O_2$: heterogeneous catalysis

**D** $V_2O_5$ in the contact process: homogeneous catalysis

Transition state · Devil

**312. In transition state theory, what happens as A and BC approach each other?**

**A** Kinetic and potential energy both rise

**B** Kinetic energy falls as potential energy rises

**C** Potential energy falls as kinetic energy rises

**D** Both energies stay constant

Transition state · Easy

**313. What is another name for the activated complex?**

**A** The intermediate

**B** The catalyst

**C** The product

**D** The transition state

Mechanism · Medium

**314. In a two-step reaction, which step is rate-determining?**

**A** The step with the lower activation energy

**B** The step with the higher activation energy, which is slower

**C** Always the last step

**D** The step that forms the final product

Mechanism · Hard

**315. How does a reaction intermediate differ from a transition state?**

**A** An intermediate is a peak; a transition state is a minimum

**B** Both can be isolated easily

**C** An intermediate sits at an energy minimum; a transition state is a peak

**D** Neither has any real existence

Mechanism · Devil

**316. $NO_2 + CO \rightarrow NO + CO_2$ has an experimental rate law rate = $k[NO_2]^2$. Which mechanism fits?**

**A** Slow: $NO_2 + NO_2 \rightarrow NO_3 + NO$; then fast: $NO_3 + CO \rightarrow NO_2 + CO_2$

**B** One step: $NO_2 + CO \rightarrow NO + CO_2$

**C** Fast: $NO_2 + NO_2 \rightarrow NO_3 + NO$; then slow: $NO_3 + CO \rightarrow NO_2 + CO_2$

**D** Slow: $NO_3 + CO \rightarrow NO_2 + CO_2$ with $NO_3$ as a starting reactant

Mechanism · Easy

**317. What is the molecularity of an elementary step involving a single molecule?**

**A** Bimolecular

**B** Termolecular

**C** Unimolecular

**D** Zero

Mechanism · Medium

**318. How do molecularity and order differ?**

**A** Molecularity is experimental and order is purely theoretical

**B** Molecularity is theoretical and whole; order is experimental and may be fractional

**C** They are always numerically identical for every reaction

**D** Order must be whole and molecularity can be a fraction

Mechanism · Hard

**319. Why are termolecular elementary steps rare?**

**A** Three molecules always repel each other

**B** Termolecular steps violate conservation of energy

**C** They need temperatures above 1000 °C

**D** Simultaneous collision of three molecules is highly improbable

Mechanism · Devil

**320. For $4HBr + O_2 \rightarrow 2Br_2 + 2H_2O$ with rate = $k[HBr][O_2]$, which statement is correct?**

**A** It is not a single step; the slow step involves one HBr and one $O_2$

**B** It is one elementary step of molecularity five

**C** The slow step involves four HBr and one $O_2$

**D** $O_2$ is not involved in the slow step

## Answers — Set 8 · Q71–80

**311.** C — A solid catalyst in a liquid reactant is a different phase.

**312.** B — Energy is conserved, so KE converts to PE.

**313.** D — The terms are often used interchangeably.

**314.** B — The slowest step controls the overall rate.

**315.** C — Intermediates can sometimes be isolated; transition states cannot.

**316.** A — The slow step involves two $NO_2$, matching the rate law.

**317.** C — One reacting species means unimolecular.

**318.** B — They match only for single-step elementary reactions.

**319.** D — Such collisions are very unlikely.

**320.** A — The rate law gives the composition of the slow step.

**Module 5: Chemical Equilibrium** — 80 questions

## 1. Set 1 · Q1–10

Reversible reactions · Easy

**321. Which type of reaction can never convert all its reactants to products, however long it is left?**

**A** An irreversible reaction

**B** A reversible reaction

**C** A neutralisation of equimolar acid and base

**D** A complete combustion

Reversible reactions · Medium

**322. Which reaction is described as essentially irreversible?**

**A** Neutralisation of equimolar NaOH and HCl

**B** Dissociation of ethanoic acid in water

**C** Esterification of ethanol with ethanoic acid

**D** $N_2O_4 \rightleftharpoons 2NO_2$ in a closed vessel

Reversible reactions · Hard

**323. Ethanoic acid dissociates only to a slight extent in water. What does this indicate?**

**A** An irreversible reaction that goes to completion

**B** An equilibrium lying far on the product side

**C** That no equilibrium is ever established

**D** A reversible reaction with equilibrium far on the reactant side

Reaction quotient · Devil

**324. For $N_2O_4 \rightleftharpoons 2NO_2$ with Kc = 0.16, a mixture has $[N_2O_4]$ = 0.10 M and $[NO_2]$ = 0.10 M. Which direction does it shift?**

**A** Reverse, because Q = 0.10 is less than K

**B** Forward, because Q = 0.10 is greater than K

**C** Forward, because Q = 0.10 is less than K

**D** It does not shift because $Q \neq K$

Equilibrium constant · Easy

**325. The law of mass action relates the equilibrium constant to what?**

**A** The initial concentration of reactants only

**B** The activation energy of the forward reaction

**C** The mass of the reaction vessel

**D** The concentrations of reactants and products at equilibrium

Equilibrium constant · Medium

**326. What is Kc for $2SO_2 + O_2 \rightleftharpoons 2SO_3$?**

**A** $[SO_3]/([SO_2][O_2])$

**B** $[SO_2]^2[O_2]/[SO_3]^2$

**C** $[SO_3]^2/([SO_2]^2[O_2])$

**D** $2[SO_3]/(2[SO_2] + [O_2])$

Equilibrium constant · Hard

**327. Starting with 1 mol each of ethanol and ethanoic acid, equilibrium has 0.67 mol ester and 0.33 mol of each reactant. What is Kc (constant volume)?**

**A** About 2.0

**B** About 4.0

**C** About 0.25

**D** About 0.50

Equilibrium constant · Devil

**328. Kc = 4.0 for $A + B \rightleftharpoons C + D$. What is Kc at the same temperature for $2A + 2B \rightleftharpoons 2C + 2D$?**

**A** 16

**B** 8.0

**C** 2.0

**D** 4.0

Reaction quotient · Easy

**329. If Q = K, what happens to the system?**

**A** The forward reaction continues net

**B** The reverse reaction continues net

**C** The reaction stops entirely at the molecular level

**D** No net change in concentrations occurs

Equilibrium constant · Medium

**330. What does K > 1 tell you?**

**A** The equilibrium mixture contains more reactants than products

**B** The equilibrium mixture contains more products than reactants

**C** The reaction is very fast

**D** The reaction is endothermic

## Answers — Set 1 · Q1–10

**321.** B — Products recombine in the backward direction.

**322.** A — Only NaCl and water remain, with no reactants.

**323.** D — Most of the acid remains undissociated.

**324.** C — Q < K means the system moves right to form more products.

**325.** D — K is the ratio of product to reactant concentrations at equilibrium.

**326.** C — Products over reactants, each raised to its coefficient.

**327.** B — $(0.67 \times 0.67)/(0.33 \times 0.33) \approx 4.0$.

**328.** A — Doubling the equation squares K.

**329.** D — The system is at equilibrium.

**330.** B — The position of equilibrium lies to the right.

## 2. Set 2 · Q11–20

Equilibrium constant · Hard

**331. Kc = 4.0 for a forward reaction. What is Kc for the reverse reaction at the same temperature?**

**A** 0.25

**B** 4.0

**C** −4.0

**D** 16

Equilibrium constant · Devil

**332. For $N_2O_4 \rightleftharpoons 2NO_2$ with Kc = 0.16 and $[N_2O_4]$ = 0.25 M at equilibrium, what is $[NO_2]$?**

**A** 0.040 M

**B** 0.40 M

**C** 0.20 M

**D** 1.56 M

Equilibrium constant · Easy

**333. Which pair proposed the law of mass action?**

**A** Libby and Joule

**B** Lewis and Born

**C** Haber and Bosch

**D** Guldberg and Waage

Equilibrium constant · Medium

**334. What does the value of Kc depend on?**

**A** The initial concentrations of reactants

**B** Both temperature and initial concentrations

**C** Only the temperature of the system

**D** Neither temperature nor concentration

Reaction quotient · Hard

**335. For $N_2O_4 \rightleftharpoons 2NO_2$ with Kc = 0.16, which mixture is at equilibrium?**

**A** $[N_2O_4]$ = 0.040 M, $[NO_2]$ = 0.080 M

**B** $[N_2O_4]$ = 0.040 M, $[NO_2]$ = 0.16 M

**C** $[N_2O_4]$ = 0.080 M, $[NO_2]$ = 0.080 M

**D** $[N_2O_4]$ = 0.16 M, $[NO_2]$ = 0.040 M

Equilibrium constant · Devil

**336. For A ⇌ B with K = 4.0, starting with 1.0 M A and no B, what is [B] at equilibrium?**

**A** 0.40 M

**B** 0.80 M

**C** 0.20 M

**D** 0.67 M

Kinetics and equilibrium · Easy

**337. Which statement correctly contrasts kinetics with equilibrium?**

**A** Kinetics concerns yield; equilibrium concerns reaction speed

**B** Both of them concern only the final yield of product

**C** Kinetics concerns how fast; equilibrium concerns how much product is formed

**D** Both of them concern only the rate of reaction

Reversible reactions · Medium

**338. What happens in a system at equilibrium at the molecular level?**

**A** Forward and reverse reactions continue at equal rates

**B** All reactions stop

**C** Only the forward reaction continues

**D** Concentrations of reactants and products become equal

Reversible reactions · Hard

**339. Pure $N_2O_4$ and pure $NO_2$ are each allowed to reach equilibrium at the same temperature. What is true?**

**A** Only the $N_2O_4$ start can reach equilibrium

**B** Both reach an equilibrium governed by the same Kc

**C** Each start gives a different Kc

**D** The $NO_2$ start produces no $N_2O_4$

Reaction quotient · Devil

**340. For the esterification system, Q = 6.0 while Kc = 4.0. What happens?**

**A** Net forward reaction until Q rises to 6.0

**B** No change, since the system is frozen

**C** Kc increases to 6.0

**D** Net reverse reaction until Q falls to 4.0

## Answers — Set 2 · Q11–20

**331.** A — The reverse constant is the reciprocal.

**332.** C — $[NO_2]^2 = 0.16 \times 0.25 = 0.040$, so $[NO_2] = 0.20$.

**333.** D — The Norwegian chemists proposed the law.

**334.** C — Every reaction has a characteristic K at a fixed temperature.

**335.** A — $0.080^2/0.040 = 0.16$.

**336.** B — $X/(1 - x) = 4$ gives $x = 0.80$.

**337.** C — Kinetics is rate, equilibrium is extent of reaction.

**338.** A — Equilibrium is dynamic.

**339.** B — Equilibrium can be approached from either direction.

**340.** D — Q > K favours the reverse direction.

## 3. Set 3 · Q21–30

Kp and Kc · Easy

### 341. In which quantities is Kp expressed?

**A** Partial pressures of the gases

**B** Molar concentrations of the gases

**C** Masses of the species

**D** Temperatures of the species

Kp and Kc · Medium

### 342. In Kp = Kc(RT)^Δn, what does Δn represent?

**A** Moles of reactants minus moles of products

**B** Moles of gaseous products minus moles of gaseous reactants

**C** The change in temperature

**D** The total moles of all species including solids

Kp and Kc · Hard

### 343. What is Δn for $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$?

**A** +2

**B** −4

**C** −2

**D** +4

Kp and Kc · Devil

### 344. $N_2O_4 \rightleftharpoons 2NO_2$ has Kc = 0.16 at 298 K. What is Kp ($R = 0.0821\ L\ atm\ mol^{-1}\ K^{-1}$)?

**A** About 0.0065

**B** About 0.16

**C** About 39

**D** About 3.9

Heterogeneous equilibria · Easy

### 345. Which species are left out of an equilibrium constant expression in heterogeneous equilibria?

**A** All gases in the mixture

**B** All aqueous ions present

**C** Pure solids and pure liquids

**D** Catalysts and inert solvents only

Heterogeneous equilibria · Medium

**346. What is Kc for $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$?**

**A** $[CO_2]$

**B** $[CaO][CO_2]/[CaCO_3]$

**C** $[CaCO_3]/[CO_2]$

**D** $[CO_2]^2$

Heterogeneous equilibria · Hard

**347. Why is the concentration of a pure solid or liquid effectively constant in a K expression?**

**A** Solids do not take part in reactions

**B** Its molar concentration is fixed at a given temperature

**C** Solids dissolve completely in the gas phase

**D** Solid concentration depends on gas pressure

Heterogeneous equilibria · Devil

**348. Extra solid $CaCO_3$ is added to the $CaCO_3/CaO/CO_2$ equilibrium at constant temperature. What happens to $P(CO_2)$?**

**A** It rises, because more solid reactant is present now

**B** It falls, because $CO_2$ is consumed by the new solid

**C** It doubles, because the amount of solid doubles

**D** It stays the same, because $K = P(CO_2)$ depends only on temperature

Heterogeneous equilibria · Easy

**349. What defines a homogeneous equilibrium?**

**A** All reactants and products are in the same phase

**B** Reactants and products are in different phases

**C** It occurs only in solids

**D** It requires a catalyst

Heterogeneous equilibria · Medium

**350. Which is a homogeneous equilibrium?**

**A** $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

**B** $H_2O(s) \rightleftharpoons H_2O(l)$

**C** $Zn(s) + 2H^+(aq) \rightleftharpoons Zn^{2+}(aq) + H_2(g)$

**D** $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

## Answers — Set 3 · Q21–30

**341.** A — Kp uses equilibrium partial pressures.

**342.** B — Only gases count in Δn.

**343.** C — 2 mol gas products minus 4 mol gas reactants.

**344.** D — $Kp = 0.16 \times (0.0821 \times 298)^1 \approx 3.9$.

**345.** C — Their concentrations are constant.

**346.** A — The solids' constant concentrations are absorbed into K.

**347.** B — Density does not change as the reaction proceeds.

**348.** D — Solids do not shift the equilibrium position.

**349.** A — $N_2O_4 \rightleftharpoons 2NO_2$ in the gas phase is an example.

**350.** D — All species are gases.

## 4. Set 4 · Q31–40

Kp and Kc · Hard

**351. For $2SO_2 + O_2 \rightleftharpoons 2SO_3$, how is Kp related to Kc?**

**A** $K_p = K_c(RT)$

**B** $K_p = K_c(RT)^2$

**C** $K_p = K_c(RT)^{-1}$

**D** $K_p = K_c$

Kp and Kc · Devil

**352. For $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$, how do Kp and Kc compare?**

**A** Kp is larger, equal to Kc × RT

**B** They are equal, since $\Delta n = 0$

**C** Kp is smaller, equal to Kc ÷ RT

**D** Kp is twice Kc because of the 2 in 2HI

Properties of equilibrium · Easy

**353. In what type of system does chemical equilibrium occur?**

**A** An open system

**B** An isolated system with no reaction

**C** A system at absolute zero

**D** A closed system

Properties of equilibrium · Medium

**354. What is ΔG for a system at equilibrium?**

**A** Positive, favouring the reverse

**B** Zero, as there is no net drive

**C** Negative, favouring the forward

**D** Equal to the standard $\Delta G^\circ$

Properties of equilibrium · Hard

**355. At equilibrium $\Delta G = 0$, so $\Delta H = T\Delta S$. What does this show?**

**A** Enthalpy and entropy effects are balanced at that temperature

**B** The reaction has stopped completely at the molecular level

**C** The entropy of the system is exactly zero

**D** The enthalpy change of the reaction is zero

Free energy and K · Devil

**356. $\Delta G^\circ = -11.4$ kJ/mol at 298 K. What is K ($R = 8.314$ J mol$^{-1}$ K$^{-1}$)?**

**A** About 10

**B** About 0.01

**C** About 100

**D** About 1000

Kp and Kc · Easy

**357. The equilibrium constant in terms of concentrations in mol L$^{-1}$ is called what?**

**A** Kp

**B** Q

**C** Kc

**D** $\Delta G^\circ$

Kp and Kc · Medium

**358. Why must you state whether an equilibrium constant is Kc or Kp?**

**A** They always have exactly the same numerical value

**B** Only Kp can ever be calculated for gases

**C** Only Kc depends on the temperature

**D** Their numerical values are generally different

Free energy and K · Hard

**359. What is $\Delta G^\circ$ for a reaction with K = 1?**

**A** Positive, since K is positive

**B** Zero, since ln 1 = 0

**C** Negative, since K is not below 1

**D** Infinite, since K is unity

Properties of equilibrium · Devil

**360. Which description of the equilibrium state is correct?**

**A** $\Delta G = 0$, entropy is maximised and $\Delta H = T\Delta S$

**B** $\Delta G < 0$ and entropy is minimised

**C** $\Delta G = 0$, entropy is minimised and enthalpy is maximised

**D** $\Delta G > 0$ and entropy is maximised

## Answers — Set 4 · Q31–40

**351.** C — $\Delta n = 2 - 3 = -1$.

**352.** B — $(RT)^0 = 1$.

**353.** D — Nothing can enter or leave.

**354.** B — There is no net driving force.

**355.** A — Neither term wins.

**356.** C — Ln K = 11 400/(8.314 × 298) = 4.6, so K ≈ 100.

**357.** C — C refers to concentration.

**358.** D — They match only when $\Delta n = 0$.

**359.** B — $\Delta G^\circ = -RT \ln 1 = 0$.

**360.** A — The balance between enthalpy and entropy gives $\Delta G = 0$.

## 5. Set 5 · Q41–50

Le Chatelier · Easy

### 361. What does Le Chatelier's principle state?

**A** A system at equilibrium adjusts to relieve any imposed stress

**B** A system at equilibrium never responds to changes

**C** A system at equilibrium always moves to the products

**D** A system at equilibrium always has Q greater than K

Le Chatelier · Medium

### 362. Which change does NOT alter the equilibrium position?

**A** Raising the temperature

**B** Adding a catalyst

**C** Adding more reactant

**D** Compressing a gas mixture with unequal gas moles

Le Chatelier · Hard

### 363. More reactant is added to a system at equilibrium at constant temperature. What happens to the position and K?

**A** Equilibrium shifts right; K increases

**B** Equilibrium shifts left; K decreases

**C** Equilibrium shifts right; K is unchanged

**D** Equilibrium does not shift; K is unchanged

Le Chatelier · Devil

### 364. In $FeSCN^{2+} \rightleftharpoons Fe^{3+} + SCN^-$, NaSCN is added. What is observed?

**A** The red fades as equilibrium shifts right

**B** The red deepens as equilibrium shifts right

**C** There is no colour change

**D** The red deepens as equilibrium shifts left

Le Chatelier · Easy

### 365. If a reactant's concentration is increased, in which direction does equilibrium shift?

**A** Towards the products

**B** Towards the reactants

**C** It does not shift

**D** It reverses completely

Le Chatelier · Medium

**366. Oxalate binds $Fe^{3+}$ strongly. When added to the $FeSCN^{2+}$ system, which way does equilibrium shift?**

**A** Left, because $Fe^{3+}$ is removed

**B** Right, because $Fe^{3+}$ is removed

**C** Right, because $SCN^-$ is removed

**D** It does not shift

Le Chatelier · Hard

**367. For $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, what does increasing pressure (by decreasing volume) favour?**

**A** The forward reaction, towards $NO_2$

**B** No shift at all

**C** The backward reaction, towards $N_2O_4$

**D** The forward reaction, because more moles are produced

Industrial processes · Devil

**368. Why is a pressure of about 250 atm used in the Haber process?**

**A** $NH_3$ formation releases extra gas, so pressure favours it

**B** High pressure lowers the activation energy of the reaction

**C** High pressure raises K for this endothermic reaction

**D** Four moles of gas become two, so high pressure favours $NH_3$

Catalysts · Easy

**369. How does a catalyst affect a system at equilibrium?**

**A** It shifts the equilibrium position to the right

**B** It increases the value of the equilibrium constant

**C** It shifts the equilibrium position to the left

**D** It speeds attainment of equilibrium without changing its position

Le Chatelier · Medium

**370. What is the effect of adding an inert gas to an equilibrium mixture at constant volume?**

**A** The equilibrium shifts to the side with more moles, as the pressure rises

**B** No effect on the equilibrium position

**C** The equilibrium shifts to the side with fewer moles, as the pressure rises

**D** K increases

## Answers — Set 5 · Q41–50

**361.** A — The system shifts to offset the stress.

**362.** B — A catalyst speeds both directions equally.

**363.** C — Only temperature changes K.

**364.** D — Added $SCN^-$ combines with $Fe^{3+}$ to form more $FeSCN^{2+}$.

**365.** A — The system consumes the added reactant.

**366.** B — The system replaces the lost $Fe^{3+}$ by dissociating $FeSCN^{2+}$.

**367.** C — The side with fewer gas moles is favoured.

**368.** D — Higher pressure favours the side with fewer gas moles.

**369.** D — Both forward and reverse rates are increased equally.

**370.** B — The partial pressures of the reacting gases do not change.

## 6. Set 6 · Q51–60

Le Chatelier · Hard

**371. Why does adding helium at constant volume leave the $NO_2/N_2O_4$ equilibrium unchanged?**

**A** Helium reacts with $NO_2$

**B** Helium lowers the temperature

**C** The partial pressures of $NO_2$ and $N_2O_4$ do not change

**D** Helium raises the equilibrium constant

Le Chatelier · Devil

**372. In the endothermic reaction $N_2O_4 \rightleftharpoons 2NO_2$ ($\Delta H$ positive), what does raising the temperature do?**

**A** Shifts right and increases K

**B** Shifts right but leaves K unchanged

**C** Shifts left and decreases K

**D** Shifts left but leaves K unchanged

Equilibrium constant · Easy

**373. Which change alters the value of the equilibrium constant?**

**A** Temperature

**B** Concentration

**C** Pressure

**D** Adding a catalyst

Le Chatelier · Medium

**374. $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is exothermic. What does raising the temperature do?**

**A** Shifts right, giving more $NH_3$ and a larger K

**B** Shifts right but leaves K unchanged

**C** Does not shift but increases K

**D** Shifts left, giving less $NH_3$ and a smaller K

Industrial processes · Hard

**375. Which combination would increase the equilibrium yield of $NH_3$?**

**A** Higher temperature and lower pressure

**B** Higher pressure and removing $NH_3$ as it forms

**C** Adding a catalyst only

**D** Lower pressure and adding inert gas at constant volume

Le Chatelier · Devil

**376. Which equilibrium is unaffected by changes in volume (pressure)?**

**A** $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

**B** $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

**C** $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

**D** $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Le Chatelier · Easy

**377. Decreasing pressure favours the side with which number of gas moles?**

**A** Fewer gas moles

**B** Equal gas moles

**C** More gas moles

**D** No gas moles

Le Chatelier · Medium

**378. What happens if a product is continuously removed from an equilibrium mixture?**

**A** Equilibrium shifts left, favouring the reactants

**B** Equilibrium does not shift at all

**C** K increases with the removal

**D** Equilibrium shifts right to form more product

Le Chatelier · Hard

**379. The volume of a vessel containing $2SO_2 + O_2 \rightleftharpoons 2SO_3$ is increased. Which way does it shift?**

**A** Left, towards the side with more gas moles

**B** Right, towards the side with fewer gas moles

**C** It does not shift

**D** Right, because pressure rises

Le Chatelier · Devil

**380. After a concentration change at constant temperature, what is true of the new equilibrium?**

**A** K changes with the composition

**B** The composition differs but K is the same

**C** Composition is unchanged but K changes

**D** Both K and composition are unchanged

## Answers — Set 6 · Q51–60

**371.** C — Mole fractions fall, but partial pressures stay constant.

**372.** A — Heat absorption is favoured, and K changes with temperature.

**373.** A — K is a function of temperature.

**374.** D — Heat absorption is favoured, which is the reverse direction.

**375.** B — Both changes shift the equilibrium forward.

**376.** C — The gas moles are equal on both sides.

**377.** C — The system expands to counter the pressure drop.

**378.** D — The system replaces what is lost.

**379.** A — Lower pressure favours more gas moles.

**380.** B — Only temperature changes K.

## 7. Set 7 · Q61–70

Steady state · Easy

**381. What type of system is a living organism?**

**A** A closed system

**B** An isolated system

**C** An open system

**D** An adiabatic system

Steady state · Medium

**382. Blood glucose stays fairly constant after a meal. Why is this not an equilibrium?**

**A** It is a steady state: glucose entry and removal rates are equal in an open system

**B** It is an equilibrium because the body is a closed system

**C** It is an equilibrium because $\Delta G$ for glucose is zero

**D** It is constant because tissues stop using glucose

Steady state · Hard

**383. Which statement about a system in a steady state is correct?**

**A** It has $\Delta G = 0$ and maximum entropy

**B** It can do work because it is away from equilibrium

**C** It exchanges no matter or energy with its surroundings

**D** It cannot be regulated

Steady state · Devil

**384. In the fasting state, why does blood glucose stay constant?**

**A** Tissues stop using glucose until feeding resumes again

**B** Glucose continues to be absorbed from the intestine after fasting

**C** Glucose is stored as glycogen at the same rate it is used

**D** Glycogen breakdown and gluconeogenesis release glucose as fast as tissues use it

Steady state · Easy

**385. What is the formation of glucose from non-carbohydrate sources called?**

**A** Glycolysis

**B** Glycogenesis

**C** Glycogenolysis

**D** Gluconeogenesis

Steady state · Medium

**386. Why is atmospheric oxygen concentration almost constant?**

**A** Oxygen is chemically inert so it never changes

**B** The atmosphere is a closed equilibrium with $\Delta G = 0$

**C** Oxygen production by photosynthesis balances its use by organisms

**D** Oxygen is produced only by the Sun's fusion

Steady state · Hard

**387. In E + S ⇌ ES ⇌ E + P, why does [ES] stay roughly constant?**

**A** Its rate of formation equals its rate of breakdown

**B** ES is thermodynamically very stable

**C** ES is formed once and never consumed

**D** E and S are in equilibrium only with P

Steady state · Devil

**388. How does entropy production compare in a steady state and at equilibrium?**

**A** Maximal in a steady state but minimal at equilibrium

**B** Minimal in a steady state but maximal at equilibrium

**C** Equal in both

**D** Zero in both

Industrial processes · Easy

**389. Which product is made in the Haber process?**

**A** Ammonia ($NH_3$)

**B** Sulphur trioxide ($SO_3$)

**C** Sulphuric acid ($H_2SO_4$)

**D** Calcium oxide ($CaO$)

Industrial processes · Medium

**390. Which conditions favour $SO_3$ yield in $2SO_2 + O_2 \rightleftharpoons 2SO_3$ (exothermic) by Le Chatelier's principle?**

**A** High temperature and high pressure

**B** Low temperature and low pressure

**C** Low temperature and high pressure

**D** High temperature and low pressure

## Answers — Set 7 · Q61–70

**381.** C — It exchanges matter and energy with its surroundings.

**382.** A — Constancy of level does not mean equilibrium.

**383.** B — $\Delta G$ is negative, so work is possible.

**384.** D — Supply from the liver balances utilisation.

**385.** D — It helps maintain blood glucose in the fasting state.

**386.** C — This balance of rates is a steady state.

**387.** A — This is the steady-state condition for an intermediate.

**388.** B — A steady state stays away from the entropy maximum.

**389.** A — $N_2$ and $H_2$ combine to give $NH_3$.

**390.** C — Exothermic and fewer gas moles on the right.

## 8. Set 8 · Q71–80

Industrial processes · Hard

### 391. Why is a very low temperature not used in the contact process?

**A** $SO_3$ decomposes completely at low temperature and pressure

**B** The catalyst works only at temperatures above 1000 °C

**C** Low temperature lowers the equilibrium yield of product

**D** The rate would be too slow, so about 450 °C with a catalyst is a compromise

Industrial processes · Devil

### 392. Why is there a practical limit to the pressure used in industrial processes?

**A** Higher pressure lowers the equilibrium yield

**B** Higher pressure raises plant capital and maintenance costs

**C** Gases liquefy at 2 atm in all cases

**D** Pressure has no effect on any yield

Industrial processes · Easy

### 393. Which catalyst is used in the contact process?

**A** Iron

**B** Vanadium(V) oxide, $V_2O_5$

**C** Manganese dioxide

**D** Bromine

Kinetics and equilibrium · Medium

### 394. Which pairing is correct for industrial processes?

**A** Yield is an equilibrium question; speed is a kinetics question

**B** Yield is a kinetics question; speed is an equilibrium question

**C** Both yield and speed are equilibrium questions

**D** Both yield and speed are kinetics questions

Kinetics and equilibrium · Hard

### 395. What describes the compromise in choosing industrial conditions?

**A** Maximising the rate of reaction regardless of the yield

**B** Maximising the yield regardless of how slow the rate is

**C** Balancing a high equilibrium yield against a reasonable reaction rate

**D** Minimising the value of the equilibrium constant

Applications · Devil

**396. During hyperventilation, $CO_2$ is lost from blood in the system $CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$. What happens?**

**A** Equilibrium shifts right, $H^+$ rises and pH falls

**B** No shift occurs because $CO_2$ is a gas

**C** Equilibrium shifts left, $H^+$ rises and pH falls

**D** Equilibrium shifts left, $H^+$ falls and pH rises

Reversible reactions · Easy

**397. What is true of reactant and product concentrations at equilibrium?**

**A** They are always equal

**B** They remain constant

**C** They keep rising

**D** They keep falling

Applications · Medium

**398. In the lungs, high $pO_2$ acts on $Hb + O_2 \rightleftharpoons HbO_2$. Which way does it shift?**

**A** Left, releasing oxygen

**B** It does not shift

**C** Right, loading oxygen onto haemoglobin

**D** Right, but only if temperature falls

Applications · Hard

**399. Esterification gives ester + water. How does continuously removing water affect the yield?**

**A** It shifts equilibrium left and lowers the yield

**B** It increases K

**C** It has no effect

**D** It shifts equilibrium right and increases the ester yield

Free energy and K · Devil

**400. A mixture has Q = 0.10 and K = 100 at 298 K. What is ΔG ($\Delta G = RT \ln(Q/K)$)?**

**A** About −17.1 kJ/mol

**B** About +17.1 kJ/mol

**C** About −5.7 kJ/mol

**D** Zero

## Answers — Set 8 · Q71–80

**391.** D — Kinetics and equilibrium pull in different directions.

**392.** B — The lecture cites capital and maintenance costs.

**393.** B — It is a finely divided solid catalyst.

**394.** A — Industrialists must satisfy both.

**395.** C — Both economic factors matter.

**396.** D — Removing $CO_2$ pulls the system left, consuming $H^+$.

**397.** B — There is no observable net change.

**398.** C — The added $O_2$ is consumed.

**399.** D — Removing a product favours the forward reaction.

**400.** A — $RT \ln(0.001) = 2.48\ \text{kJ} \times (-6.91) \approx -17.1\ \text{kJ/mol}$.

**Module 6: Elemental Composition of Living Cells** — 20 questions

## 1. Set 1 · Q1–10

Cell elements · Easy

### 401. Which metal is among the trace elements named in the lecture as making up a cell?

**A** Platinum

**B** Gold

**C** Beryllium

**D** Zinc

Cell elements · Medium

### 402. Which element makes up the largest share of atoms in the Earth, per the lecture's list?

**A** Oxygen

**B** Iron

**C** Silicon

**D** Carbon

Stellar fusion · Hard

### 403. $^{24}$Mg captures a $^{4}$He nucleus. What is the product?

**A** $^{28}$Al, since 12 + 1 = 13 protons and 24 + 4 = 28 nucleons

**B** $^{28}$Mg, since only neutrons are added to the nucleus

**C** $^{28}$Si, since 12 + 2 = 14 protons and 24 + 4 = 28 nucleons

**D** $^{32}$S, since 12 + 4 = 16 protons and 24 + 8 = 32 nucleons

Stellar fusion · Devil

### 404. Which set shows the helium-burning steps of the lecture with correct products?

**A** $3\ ^{4}\mathrm{He} \rightarrow {}^{12}\mathrm{C}$; $^{12}\mathrm{C} + {}^{4}\mathrm{He} \rightarrow {}^{16}\mathrm{O}$; $^{16}\mathrm{O} + {}^{4}\mathrm{He} \rightarrow {}^{20}\mathrm{Ne}$; $^{20}\mathrm{Ne} + {}^{4}\mathrm{He} \rightarrow {}^{26}\mathrm{Mg}$

**B** $3\ ^{4}\mathrm{He} \rightarrow {}^{12}\mathrm{C}$; $^{12}\mathrm{C} + {}^{4}\mathrm{He} \rightarrow {}^{16}\mathrm{O}$; $^{16}\mathrm{O} + {}^{4}\mathrm{He} \rightarrow {}^{20}\mathrm{Ne}$; $^{20}\mathrm{Ne} + {}^{4}\mathrm{He} \rightarrow {}^{24}\mathrm{Mg}$

**C** $3\ ^{4}\mathrm{He} \rightarrow {}^{12}\mathrm{C}$; $^{12}\mathrm{C} + {}^{4}\mathrm{He} \rightarrow {}^{16}\mathrm{O}$; $^{16}\mathrm{O} + {}^{4}\mathrm{He} \rightarrow {}^{20}\mathrm{Ne}$; $^{20}\mathrm{Ne} + {}^{4}\mathrm{He} \rightarrow {}^{24}\mathrm{Na}$

**D** $3\ ^{4}\mathrm{He} \rightarrow {}^{12}\mathrm{C}$; $^{12}\mathrm{C} + {}^{4}\mathrm{He} \rightarrow {}^{16}\mathrm{O}$; $^{16}\mathrm{O} + {}^{4}\mathrm{He} \rightarrow {}^{18}\mathrm{Ne}$; $^{20}\mathrm{Ne} + {}^{4}\mathrm{He} \rightarrow {}^{24}\mathrm{Mg}$

Cell elements · Easy

### 405. What did the lecture say about the mitochondrial membrane?

**A** It is a structure built from phospholipids and proteins

**B** It is made only of trace metals

**C** It is the site of stellar fusion

**D** It is an inorganic crystal of calcium salts

Cell elements · Medium

**406. Which order of abundance matches the lecture's list of Earth atoms?**

**A** O > Si > Fe > Mg > C

**B** O > Fe > Si > Mg > C

**C** Fe > O > Si > Mg > C

**D** O > Fe > Mg > Si > C

Artificial synthesis · Hard

**407. In neutron capture on $^{56}$Fe, what is the product nucleus before any decay?**

**A** $^{56}$Co, one more proton and the same mass number

**B** $^{57}$Co, one more proton and one more nucleon

**C** $^{57}$Fe, same atomic number with mass number one higher

**D** $^{55}$Mn, one fewer proton and one fewer nucleon

Exclusion factors · Devil

**408. Iodine deficiency causes goitre, and mercury exposure causes neurological harm. Which classification is correct?**

**A** Iodine is a major element and mercury is a trace element

**B** Both are excluded elements because of toxicity

**C** Iodine is artificial and mercury is inert

**D** Iodine is an essential trace element and mercury is a toxic, excluded element

Stellar fusion · Easy

**409. What makes up the solar wind, according to the lecture?**

**A** Only visible light and infrared

**B** Energised particles such as neutrinos and protons

**C** X-rays and radio waves only

**D** Leftover gas clouds from the Big Bang

Exclusion factors · Medium

**410. Which three elements below atomic number 92 were named as artificially made?**

**A** Iron, magnesium and zinc

**B** Lithium, beryllium and boron

**C** Technetium, astatine and francium

**D** Helium, neon and argon

## Answers — Set 1 · Q1–10

**401.** D — Zn is listed with Fe, Cu, Mn, Co and others as a cell constituent.

**402.** A — Oxygen heads the list at about 48.86%.

**403.** C — He adds 2 protons and 4 nucleons, and Z = 14 is silicon.

**404.** B — Each step adds one $^{4}$He, giving C, O, Ne and Mg.

**405.** A — It was the example of elements organised into cell structures.

**406.** B — 48.86%, 18.84%, 13.96%, 12.42% and 0.10%.

**407.** C — A neutron adds one nucleon without changing the charge.

**408.** D — One is needed in tiny amounts, the other is harmful.

**409.** B — These particles are released alongside radiation.

**410.** C — They are the three listed as laboratory-made.

## 2. Set 2 · Q11–20

Cell elements · Hard

**411. About what percentage of the roughly 118 elements are essential (about 30), per the lecture?**

**A** About 25%

**B** About 50%

**C** About 10%

**D** About 75%

Exclusion factors · Devil

**412. Technetium (Z = 43) lies below 92 yet is excluded from cells. Which factor applies?**

**A** Its inert nature, since it is a rare gas

**B** Its toxicity through inhibiting haem synthesis

**C** Its atomic number being above 92

**D** Its artificial nature, since it is laboratory-made

Medical applications · Medium

**413. Gold complexes were described as having which role?**

**A** Anti-diarrhoeal adsorbents in the gut

**B** Photothermal agents for cancer treatment

**C** Mood stabilisers for psychiatric care

**D** DNA cross-linking drugs like cisplatin

Medical applications · Hard

**414. Why is cisplatin damage so harmful to rapidly dividing cells?**

**A** It inhibits haem synthesis inside the mitochondria

**B** It replaces magnesium in the ribosomes of the cell

**C** It adsorbs water and bacteria in the gut lumen

**D** Cross-links block DNA replication and cannot be repaired

Origin of elements · Easy

**415. How many other natural elements beyond H, He, Li and Be were made in stars and supernovae?**

**A** 86

**B** 30

**C** 118

**D** 92

Cell elements · Medium

**416. Which element is not listed among the lecture's elements making up a cell?**

**A** Selenium

**B** Molybdenum

**C** Platinum

**D** Chromium

Cell elements · Hard

**417. Carbon is about 0.10% of Earth's atoms and silicon is about 140 times more abundant. What is silicon's estimated share?**

**A** About 14%

**B** About 1.4%

**C** About 140%

**D** About 0.0007%

Origin of elements · Devil

**418. Which statement about lithium and beryllium is consistent with the lecture?**

**A** They formed only in cyclotrons in modern laboratories

**B** They were the major products of the Big Bang explosion

**C** They form only when iron nuclei capture stellar neutrons

**D** Trace amounts formed after the Big Bang and in some solar reactions

Artificial synthesis · Devil

**419. Why are neutrons, not protons, captured by Fe nuclei to build heavier elements?**

**A** Neutrons carry more positive charge than protons do

**B** Protons are too light to be captured by any nucleus

**C** Neutrons are uncharged, so the nucleus does not repel them

**D** Neutrons are the only particles present inside stars

Medical applications · Easy

**420. Which element did the lecture mention in anti-arthritis preparations?**

**A** Lithium

**B** Platinum

**C** Aluminium

**D** Mercury

## Answers — Set 2 · Q11–20

**411.** A — 30 ÷ 118 ≈ 0.25.

**412.** D — Tc is one of the artificially made elements below 92.

**413.** B — They are used as photothermal agents.

**414.** D — The damaged DNA cannot repair, so the cell dies.

**415.** A — The lecture says the rest of the 86 natural elements formed there.

**416.** C — Platinum is described as non-essential.

**417.** A — 0.10 × 140 = 14, close to the slide's 13.96%.

**418.** D — Both appear in the Big Bang's trace products and in solar reactions.

**419.** C — A neutral particle can approach a positive nucleus easily.

**420.** B — Platinum was listed among non-essential elements with medical uses.

**Module 7: Chemical Bonding** — 48 questions

## 1. Set 1 · Q1–10

Ionic bonding · Easy

**421. Which law lets ΔHf for NaCl be written as the sum of the Born–Haber steps?**

**A** Boyle's law of gas pressure and volume

**B** Le Chatelier's principle of equilibrium shifts

**C** The law of mass action for equilibria

**D** Hess's law of constant heat summation

Ionic bonding · Medium

**422. What is the standard enthalpy of formation of a compound?**

**A** The energy needed to break 1 mole of the compound into free atoms

**B** The enthalpy change when 1 mole forms from its elements in their standard states

**C** The enthalpy change when 1 mole of ions forms a crystal lattice

**D** The energy released when 1 mole of the compound dissolves in water

Hybridisation · Hard

**423. How does a C–H bond in methane form?**

**A** An $sp^3$ hybrid orbital of carbon overlaps with the 1s orbital of hydrogen

**B** A 2p orbital of carbon overlaps sideways with a 2p orbital of hydrogen

**C** A filled 2s orbital of carbon donates a pair to hydrogen

**D** Two unhybridised 2s orbitals overlap head-on

Ionic bonding · Devil

**424. Which statement about NaCl formation is consistent with the lecture?**

**A** Direct formation is not feasible, and lattice energy is positive

**B** Formation needs no energy at all for sodium sublimation or ionisation

**C** Direct formation is feasible, and a large negative lattice energy makes ΔHf negative

**D** Ionic bonding is favoured by a small electronegativity difference

Ionic bonding · Easy

**425. On which sides of the periodic table are the elements that favour ionic bonding?**

**A** Metals on the right and non-metals on the left

**B** Metals on the left and non-metals on the right

**C** Both partners from the centre

**D** Both partners from the far left

Ionic bonding · Medium

**426. Which pairing of atomic property and electronegativity is correct?**

**A** Low ionisation energy goes with low electronegativity; high electron affinity with high

**B** Low ionisation energy goes with high electronegativity and low electron affinity

**C** High electron affinity goes with low electronegativity and high ionisation energy

**D** Ionisation energy and electronegativity are unrelated to each other

Hybridisation · Hard

**427. How does a C–Cl bond in $CCl_4$ form?**

**A** An $sp^3$ orbital of carbon overlaps with a filled p orbital of chlorine

**B** A 2s orbital of carbon overlaps with chlorine's 1s orbital

**C** An $sp^3$ orbital of carbon overlaps with chlorine's half-filled p orbital

**D** A pi bond forms by sideways overlap of two $sp^3$ orbitals

Hybridisation · Devil

**428. A student says boron needs no promotion because it already has three valence electrons. What is wrong?**

**A** All three of its valence electrons are already unpaired in the ground state

**B** Boron has four valence electrons, so no promotion is needed

**C** Promotion lowers boron's energy, so it occurs automatically

**D** Only one valence electron is unpaired in the ground state, so it needs promotion

Covalent bonding · Easy

**429. How many electrons does each atom contribute to a double bond such as O=O?**

**A** One

**B** Three

**C** Two

**D** Four

Covalent bonding · Medium

**430. What does bond energy measure?**

**A** The energy released when a salt dissolves

**B** The energy needed to break a bond to give free atoms

**C** The energy of the lattice in an ionic solid

**D** The energy of an electron in an orbital

## Answers — Set 1 · Q1–10

**421.** D — Total enthalpy change is independent of the route taken.

**422.** B — It is defined per mole of compound formed from the elements.

**423.** A — Each half-filled $sp^3$ orbital overlaps with a half-filled H 1s orbital.

**424.** C — The lecture says the direct reaction is feasible and lattice energy is strongly negative.

**425.** B — A large electronegativity difference exists between them.

**426.** A — Atoms that lose electrons easily have low electronegativity.

**427.** C — It is a sigma bond between $sp^3$ and a half-filled chlorine p orbital.

**428.** D — $2s^2\ 2p^1$ has one unpaired electron.

**429.** C — Two bonding pairs mean two electrons from each atom.

**430.** B — It is a measure of bond strength.

## 2. Set 2 · Q11–20

Hybridisation · Hard

**431. Which orbitals mix in $BCl_3$ and what results?**

**A** The 2s with three 2p orbitals, giving four $sp^3$ orbitals

**B** The 2s with one 2p orbital, giving two sp orbitals

**C** Three 2p orbitals only, giving three p orbitals

**D** The 2s with two 2p orbitals, giving three $sp^2$ orbitals

Hybridisation · Devil

**432. Which row gives unpaired electrons before and after promotion for B, C and Be?**

**A** B: 1 to 3; C: 2 to 4; Be: 0 to 2

**B** B: 3 to 1; C: 4 to 2; Be: 2 to 0

**C** B: 1 to 3; C: 4 to 2; Be: 0 to 2

**D** B: 1 to 2; C: 2 to 3; Be: 0 to 1

Hybridisation · Easy

**433. What proportion of natural gas does methane make up, up to?**

**A** About 50%

**B** About 97%

**C** About 10%

**D** About 3%

Hybridisation · Medium

**434. How is $BCl_3$ made, according to the lecture?**

**A** Boron reacts with chlorine at elevated temperature: $2B + 3Cl_2 \rightarrow 2BCl_3$

**B** Boron reacts with hydrogen chloride in water at room temperature

**C** Boron and chlorine combine only in sunlight at 0 °C

**D** $BCl_3$ is made by heating boron carbonate

Hybridisation · Hard

**435. What is the state of $BeH_2$ in the solid and vapour phases?**

**A** Linear molecules when solid; a covalent network in vapour

**B** Ionic lattice when solid; bent molecules in vapour

**C** Discrete tetrahedral molecules in both phases

**D** A covalent network when solid; linear triatomic molecules in vapour

Hybridisation · Devil

**436. In gaseous $BeH_2$, how many sigma bonds exist and what forms each?**

**A** Two, each from a pure 2p orbital of Be overlapping a hydrogen 2p orbital

**B** Four, two from sp orbitals and two from pi overlap

**C** Two, each from an sp orbital of Be overlapping a hydrogen 1s orbital

**D** One, shared across the whole molecule

Coordinate bonding · Easy

**437. Which two common polyatomic cations contain coordinate covalent bonds?**

**A** $NH_4^+$ and $H_3O^+$

**B** $Na^+$ and $K^+$

**C** $Ca^{2+}$ and $Mg^{2+}$

**D** $NO_3^-$ and $SO_4^{2-}$

Hybridisation · Medium

**438. How is $BeH_2$ prepared, according to the lecture?**

**A** By burning beryllium in hydrogen gas at 25 °C

**B** By dissolving beryllium in water

**C** By treating beryllium chloride with lithium hydride

**D** By electrolysing molten beryllium oxide

Coordinate bonding · Hard

**439. In aqueous solution, what is true of $[Cu(H_2O)_4]^{2+}$?**

**A** It dissociates completely into Cu and $O_2$

**B** It never dissociates

**C** It decomposes into $Cu^{2+}$ and $H_2$ at once

**D** It slightly dissociates, in equilibrium with $Cu^{2+}$ and $H_2O$

Coordinate bonding · Devil

**440. In $BCl_3 + Cl^- \rightarrow BCl_4^-$, why can chloride donate a pair?**

**A** It has an empty orbital that accepts a pair

**B** It has four electron pairs, one of which it can donate

**C** It has only one electron pair in its valence shell

**D** It is electron-deficient like boron, so it accepts pairs

## Answers — Set 2 · Q11–20

**431.** D — They are coplanar and 120° apart.

**432.** A — Each gains two unpaired electrons when 2s is promoted.

**433.** B — Methane is the major component.

**434.** A — The product is a liquid.

**435.** D — Heating breaks the network into separate H–Be–H molecules.

**436.** C — One Be–H sigma bond on each side.

**437.** A — Each forms by donation of a lone pair to $H^+$.

**438.** C — $BeCl_2 + 2LiH \rightarrow BeH_2 + 2LiCl$.

**439.** D — The complex ion and its components coexist.

**440.** B — The donor needs a lone pair.

## 3. Set 3 · Q21–30

Coordinate bonding · Easy

### 441. What is a Lewis acid?

**A** An electron pair donor

**B** An electron pair acceptor

**C** A proton donor only

**D** A neutral atom with no empty orbitals

Coordinate bonding · Medium

### 442. How is the hydroxonium ion $H_3O^+$ formed?

**A** A nonbonding pair on water's oxygen is donated to $H^+$

**B** Hydrogen donates a pair to the oxygen of water

**C** Oxygen gains an electron from hydrogen

**D** Two water molecules share an electron pair

Complexes · Hard

### 443. Which pairing of porphyrin-containing biomolecule and central metal ion is correct?

**A** Haemoglobin with $Mg^{2+}$ and chlorophyll with $Fe^{2+}$

**B** Haemoglobin with $Cu^{2+}$ and chlorophyll with $Zn^{2+}$

**C** Haemoglobin with $Fe^{2+}$ and chlorophyll with $Mg^{2+}$

**D** Both with $Fe^{2+}$

Coordinate bonding · Devil

### 444. In $NH_3 + H^+ \rightarrow NH_4^+$, which assignment is correct?

**A** $NH_3$ is the Lewis acid and $H^+$ the Lewis base

**B** Both are Lewis bases

**C** Both are Lewis acids

**D** $NH_3$ is the Lewis base and $H^+$ the Lewis acid

Octet rule · Easy

### 445. What does a Lewis dot symbol show?

**A** An atom's valence electrons as dots around its symbol

**B** The nuclear charge of the atom around its symbol

**C** The mass number of the atom as dots

**D** The ionisation energy of the atom as dots

Octet rule · Medium

### 446. The octet rule holds for which of these period 2 elements?

**A** Only lithium and beryllium

**B** Carbon, nitrogen, oxygen and fluorine

**C** Only boron

**D** None of the period 2 elements

Shapes and VSEPR · Hard

**447. Which order of repulsion between electron pairs is correct?**

**A** Bonded pair–bonded pair > lone pair–bonded pair > lone pair–lone pair

**B** Lone pair–bonded pair > lone pair–lone pair > bonded pair–bonded pair

**C** All three types repel equally

**D** Lone pair–lone pair > lone pair–bonded pair > bonded pair–bonded pair

Shapes and VSEPR · Devil

**448. Which row correctly matches shape, hybridisation and example?**

**A** Trigonal bipyramidal, $sp^3d^2$, $PCl_5$

**B** Trigonal planar, $sp^3$, $BF_3$

**C** Square planar, $dsp^2$ ($sp^2d$), $Ni(CN)_4^{2-}$

**D** Linear, $sp^2$, $C_2H_2$

Octet rule · Easy

**449. What is a lone pair of electrons?**

**A** A pair of electrons shared by two atoms

**B** A pair of valence electrons belonging to a single atom

**C** A pair of electrons in the nucleus

**D** A pair of electrons in an ionic lattice

Octet rule · Medium

**450. Which noble-gas configurations do $Na^+$ and $Cl^-$ attain in NaCl?**

**A** Ar and Ne respectively

**B** He and Kr respectively

**C** Ne and Kr respectively

**D** Ne and Ar respectively

## Answers — Set 3 · Q21–30

**441.** B — In Lewis's definition acids accept electron pairs.

**442.** A — It forms through a coordinate bond.

**443.** C — Porphyrins bind both $Fe^{2+}$ and $Mg^{2+}$ in these molecules.

**444.** D — Nitrogen donates its lone pair to the proton.

**445.** A — It represents the valence electrons.

**446.** B — These four typically reach eight valence electrons.

**447.** D — Lone pairs occupy more space close to the nucleus of one atom.

**448.** C — Four pairs in a flat square, as in the lecture's table.

**449.** B — It is unshared.

**450.** D — $Na^+$ is isoelectronic with Ne and $Cl^-$ with Ar.

## 4. Set 4 · Q31–40

Octet rule · Hard

**451. Why does a lone pair give a region of greater electron density than a bonded pair?**

**A** It is held closer to the nucleus of the neighbouring atom

**B** It carries a larger charge than a bonded pair

**C** It belongs to one atom, while a bonded pair is spread between two nuclei

**D** It is always located inside the nucleus

Shapes and VSEPR · Devil

**452. Which sequence of approximate bond angles is correct for $CH_4$, $CH_2{=}CH_2$ and $NH_3$?**

**A** 109°, 120°, 107°

**B** 120°, 109°, 107°

**C** 109°, 107°, 120°

**D** 107°, 109°, 120°

Shapes and VSEPR · Easy

**453. Which hypothesis explains enzyme–substrate specificity by shape?**

**A** The Born–Haber cycle

**B** Hess's law

**C** The octet rule

**D** The lock and key hypothesis

Coordinate bonding · Medium

**454. Why is a lone pair readily donated in coordinate bonding?**

**A** It is held very tightly within the nucleus of its atom

**B** It is a region of high electron density available to donate

**C** It has no energy at all and so is easy to lose

**D** It is shared equally with all the atoms nearby

Hydrogen bonding · Hard

**455. Why does HF boil at 19.4 °C, higher than the other hydrogen halides?**

**A** HF has the highest molar mass of the halides

**B** HF is ionic while the others are covalent

**C** HF forms hydrogen bonds, which the other halides barely form

**D** HF has the weakest dipole of the series

Properties of water · Devil

**456. If water were as volatile as ether, which consequence would follow?**

**A** No lakes, rivers, oceans or rainfall would collect

**B** Its boiling point would exceed that of $H_2S$

**C** Ice would sink in liquid water

**D** Its density maximum would move above 4 °C

Shapes and VSEPR · Easy

**457. Who postulated the VSEPR theory, according to the lecture?**

**A** Guldberg and Waage

**B** Lewis and Libby

**C** Haber and Bosch

**D** Sidgwick and Powell

Polarity · Medium

**458. How do nonpolar homonuclear diatomic molecules behave between charged plates?**

**A** They align strongly with the positive plate

**B** They align strongly with the negative plate

**C** They are hardly affected by the electric field

**D** They break into ions

Hydrogen bonding · Hard

**459. Which hydrogen-bond order is correct, from strongest to weakest?**

**A** H–F···H–F > H–O···H–O > H–N···H–N

**B** H–N···H–N > H–O···H–O > H–F···H–F

**C** H–O···H–O > H–F···H–F > H–N···H–N

**D** All three are equal in strength

Properties of water · Devil

**460. Why is a free-flowing drop of liquid spherical?**

**A** The bulk molecules pull evenly in all directions

**B** Inward pull on surface molecules minimises the surface area

**C** Gravity alone makes liquids spherical

**D** Surface molecules are attracted outward to the air

## Answers — Set 4 · Q31–40

**451.** C — A lone pair is concentrated around one atom.

**452.** A — Tetrahedral, trigonal planar and pyramidal respectively.

**453.** D — Only a complementary substrate fits the enzyme.

**454.** B — Lone pairs are available to acceptors.

**455.** C — Fluorine's electronegativity makes strong H-bonds possible.

**456.** A — Water would vaporise at ambient temperature.

**457.** D — They proposed minimising electron pair repulsion.

**458.** C — Symmetrical electron density gives no pole to align.

**459.** A — Fluorine is the most electronegative, so H–F is the most polar.

**460.** B — The net inward pull on surface molecules gives a sphere.

## 5. Set 5 · Q41–48

Polarity · Easy

**461. What is a homonuclear molecule?**

**A** One formed from atoms of the same element

**B** One formed from atoms of different elements

**C** One that contains a nucleus only

**D** One that has an ionic bond

Polarity · Medium

**462. In μ = d × q, what do d and q represent?**

**A** The density of the liquid and its quantity

**B** The separation of the charge centres and the size of the partial charge

**C** The bond distance and the quantity of heat

**D** The diameter of the molecule and its quantum number

Intermolecular forces · Hard

**463. As intermolecular forces in a liquid increase, what happens to vapour pressure and boiling point?**

**A** Vapour pressure increases and boiling point decreases

**B** Both vapour pressure and boiling point increase

**C** Vapour pressure decreases and boiling point increases

**D** Both vapour pressure and boiling point decrease

Properties of water · Devil

**464. In capillary rise h = 2γ/ρgr, which change raises the height of water in a glass tube?**

**A** Using a denser liquid

**B** Using a wider tube

**C** Increasing the force of gravity

**D** Using a narrower tube

Polarity · Easy

**465. Which unit is used for dipole moment?**

**A** Debye

**B** Joule

**C** Pascal

**D** Newton

Intermolecular forces · Medium

**466. Why do intermolecular forces mostly affect physical rather than chemical properties?**

**A** They are stronger than covalent bonds

**B** They only act inside atoms

**C** They are weaker than intramolecular covalent bonds

**D** They exist only in ionic solids

Properties of water · Hard

**467. In ice, how many oxygen atoms tetrahedrally surround each oxygen atom?**

**A** Two

**B** Six

**C** Eight

**D** Four

Properties of water · Devil

**468. Why does mercury's meniscus curve downward in a glass tube?**

**A** Adhesion to glass exceeds cohesion within mercury

**B** Cohesion in mercury exceeds its adhesion to glass

**C** Mercury is less dense than water

**D** Mercury forms hydrogen bonds with glass

## Answers — Set 5 · Q41–48

**461.** A — $H_2$ is a homonuclear diatomic molecule.

**462.** B — Dipole moment is distance times charge.

**463.** C — Stronger attractions hold molecules in the liquid.

**464.** D — H is inversely proportional to r.

**465.** A — The Debye (D) is the dipole moment unit.

**466.** C — They alter states, boiling points and solubility, not bonds.

**467.** D — Hydrogen bonds bridge each oxygen pair in an open hexagonal network.

**468.** B — Mercury pulls away from the glass.

**Module 8: Thermodynamics** — 40 questions

## 1. Set 1 · Q1–10

Energy basics · Easy

**469. Besides mass and height, what else determines a body's potential energy?**

**A** Its speed through space

**B** Acceleration due to gravity

**C** Its temperature at that height

**D** Its electric charge in a field

Energy basics · Medium

**470. Which factor affects how much potential energy a molecule can store?**

**A** Its bond types and the attractive forces between molecules

**B** Only the temperature of the substance and its speed

**C** Only the speed of the molecules through space

**D** Only the colour and odour of the substance

Energy basics · Hard

**471. Which sequence describes energy conversion at a hydroelectric dam?**

**A** Kinetic, then potential, then electrical, then heat only

**B** Electrical, then kinetic, then potential

**C** Potential, then kinetic, then mechanical work, then electrical work

**D** Nuclear, then chemical, then potential

Heat and temperature · Devil

**472. Which statement about heat and temperature is correct?**

**A** Temperature measures total energy and depends on size; heat is average kinetic energy

**B** Both heat and temperature are measured in kelvin

**C** Heat is measured in kelvin and temperature in joules

**D** Temperature measures average kinetic energy and ignores size; heat is energy transferred by a temperature difference

Energy basics · Easy

**473. One calorie is the heat needed to raise the temperature of 1 g of water by how much?**

**A** 1 °C

**B** 10 °C

**C** 0.1 °C

**D** 100 °C

Energy basics · Medium

**474. Which of these is listed as a form of energy?**

**A** Temperature

**B** Pressure

**C** Nuclear energy

**D** Entropy

First law · Hard

**475. Which statement correctly links the work of Thompson and Joule?**

**A** Joule showed heat appears from nothing; Thompson measured it

**B** Thompson showed work becomes heat; Joule measured the heat from different work

**C** Thompson measured specific heats; Joule drilled cannon barrels

**D** They showed that friction destroys energy permanently

Systems · Devil

**476. A thermos flask of hot water is described as which kind of system?**

**A** A perfectly isolated system for all time

**B** An open system because it has a lid

**C** A closed system through which heat crosses freely

**D** Nearly isolated for a short time, but heat eventually leaks out

Systems · Easy

**477. What do we call everything outside the thermodynamic system?**

**A** The universe

**B** The boundary only

**C** The state function

**D** The surroundings

State functions · Medium

**478. The lecture lists which trio as examples of state functions for a closed system?**

**A** Heat absorbed, work done and time taken

**B** Temperature, pressure and energy of the system

**C** Heat absorbed, work done and pressure

**D** Time taken, volume and work done

## Answers — Set 1 · Q1–10

**469.** B — PE = mgh includes g.

**470.** A — Composition, bonds and attractions all matter.

**471.** C — Stored water falls, turns turbines and drives generators.

**472.** D — This separates intensive temperature from extensive heat.

**473.** A — 1 cal = 4.184 J.

**474.** C — Heat, mechanical, electrical and nuclear energy are listed.

**475.** B — Together they validated conservation of energy.

**476.** D — A truly isolated system is almost impossible to create.

**477.** D — It is everything outside the system.

**478.** B — They uniquely define the state.

## 2. Set 2 · Q11–20

First law · Hard

**479. A system's final energy is 80 kJ lower than its initial energy. What is true?**

**A** ΔE = +80 kJ, and the surroundings lose 80 kJ

**B** ΔE = −80 kJ, and the surroundings lose 80 kJ

**C** ΔE = −80 kJ, and the surroundings gain 80 kJ

**D** ΔE = 0, since energy is conserved

First law · Devil

**480. A system loses 50 J as heat and has 20 J of work done on it. What are ΔE and the surroundings' change?**

**A** ΔE = −30 J, and the surroundings gain 30 J

**B** ΔE = −70 J, and the surroundings gain 70 J

**C** ΔE = +30 J, and the surroundings lose 30 J

**D** ΔE = +70 J, and the surroundings lose 70 J

Systems · Easy

**481. The system and its surroundings together make up what?**

**A** The boundary

**B** The universe

**C** A state function

**D** An isolated flask

Energy basics · Medium

**482. A force of 25 N moves an object through 8 m. How much work is done?**

**A** 200 J

**B** 3.1 J

**C** 33 J

**D** 0.32 J

Systems · Hard

**483. Which is an example of an adiabatic process?**

**A** A reaction in an open beaker on a hot plate

**B** A living cell at body temperature

**C** A reaction in a thermostated water bath

**D** A reaction in an insulated container like a thermos

First law · Devil

**484. A student claims ΔE = Einitial − Efinal. Which statement corrects this?**

**A** ΔE = Efinal − Einitial, and a positive value means the system lost energy

**B** Internal energy is a path-dependent heat term

**C** ΔE = Efinal − Einitial, and a positive value means energy flowed in from the surroundings

**D** ΔE is zero for every closed system

Heat and temperature · Easy

**485. What does temperature measure, according to the lecture?**

**A** The total heat in a body

**B** The average kinetic energy of a body

**C** The potential energy of a body

**D** The mass of a body

First law · Medium

**486. Which laws of thermodynamics does the lecture mainly consider?**

**A** The zeroth and third laws

**B** The second and third laws

**C** Only the zeroth law

**D** The first and second laws

Heat and temperature · Hard

**487. Which unit pairing is correct?**

**A** Heat in kelvin; temperature in joules

**B** Both in joules

**C** Heat in joules; temperature in °C, °F or K

**D** Both in kelvin

State functions · Devil

**488. A cup is warmed by stirring in one case and by heating in another, reaching the same final temperature. What does this show?**

**A** Temperature is a state function, independent of the path

**B** Heating and stirring transfer identical heat

**C** Temperature depends on the path taken between states

**D** Stirring does no work on the cup contents

## Answers — Set 2 · Q11–20

**479.** C — The loss from the system appears in the surroundings.

**480.** A — ΔE = q + w = −50 + 20.

**481.** B — Universe = system + surroundings.

**482.** A — W = f × d = 25 × 8.

**483.** D — No heat crosses the boundary.

**484.** C — ΔE is final minus initial.

**485.** B — It is independent of the size of the body.

**486.** D — Four laws exist but these two are covered.

**487.** C — Different quantities use different units.

**488.** A — The path does not affect a state function's change.

## 3. Set 3 · Q21–30

Enthalpy · Easy

### 489. What does a positive ΔH indicate?

**A** The reaction is exothermic and releases heat

**B** The reaction is always spontaneous

**C** The reaction is endothermic and absorbs heat

**D** The reaction is at equilibrium

Enthalpy · Medium

### 490. For A + B → C + D, how is ΔH calculated?

**A** ΔH = (H of C + H of D) − (H of A + H of B)

**B** ΔH = (H of A + H of B) − (H of C + H of D)

**C** ΔH = H of C × H of D

**D** ΔH = H of A ÷ H of C

Enthalpy · Hard

### 491. For most biochemical reactions ΔH and ΔE differ very little. Why?

**A** They always occur at constant temperature

**B** They release no heat

**C** Enzymes remove all PV work

**D** There is little change in pressure and volume

Enthalpy · Devil

### 492. Which statement about ΔE and ΔH is correct?

**A** ΔE is the heat change at constant pressure, while ΔH is at constant volume

**B** ΔE is the heat change at constant volume, while ΔH is the heat change at constant pressure

**C** Both are defined only at constant temperature

**D** ΔE and ΔH are always exactly equal

Spontaneity · Easy

### 493. Which process needs an external source of energy?

**A** Iron rusting in moist air over time

**B** Recovering iron from iron(III) oxide using carbon

**C** Glucose dissolving in a glass of water

**D** Ice melting in a warm room above 0 °C

Entropy · Medium

**494. Hexyl bromide has a higher entropy than hexane. Why?**

**A** Its higher mass gives greater translational entropy

**B** It has fewer atoms and more rigid bonds

**C** It is a gas while hexane is a solid

**D** It has a ring structure in its carbon chain

Entropy · Hard

**495. Entropy is associated mainly with which motions, unlike enthalpy where electronic terms matter?**

**A** Electronic transitions only

**B** Nuclear decay only

**C** Translational and rotational motion

**D** Magnetic spin only

Entropy · Devil

**496. Which is expected to have the higher entropy, pentane or its branched isomer 2,2-dimethylpropane?**

**A** Branched isomer, because branching raises entropy

**B** They are equal because their formulae match

**C** Branched isomer, because it has more atoms

**D** Pentane, because the unbranched chain has more rotational freedom

Entropy · Easy

**497. What are the conditions for standard molar entropy S°?**

**A** 1 mole of pure substance at 298 K and 101.325 kPa

**B** 1 mole of substance at 0 K and 1 kPa

**C** 1 gram of substance at 273 K and 1 atm

**D** 1 mole of substance at 373 K and 10 kPa

Entropy · Medium

**498. When calculating ΔS° from tabulated S° values, what must you do with the coefficients?**

**A** Ignore them, since entropy is intensive

**B** Divide each S° by its coefficient

**C** Add them to the entropies

**D** Multiply each S° by its coefficient

## Answers — Set 3 · Q21–30

**489.** C — The final state has higher enthalpy than the initial state.

**490.** A — Final state minus initial state.

**491.** D — PΔV is therefore negligible.

**492.** B — They differ by the PΔV term.

**493.** B — It is a nonspontaneous process.

**494.** A — Entropy per mole increases with molecular weight.

**495.** C — These motions contribute most of the entropy.

**496.** D — A branch lowers entropy by about 3.0 eu.

**497.** A — These are the lecture's standard conditions.

**498.** D — Entropy is an extensive property.

## 4. Set 4 · Q31–40

Entropy · Hard

**499. Which change has a positive ΔS?**

**A** $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$

**B** $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

**C** $CO_2(g) \rightarrow CO_2(s)$

**D** $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

Free energy · Devil

**500. A reaction has ΔH = +30 kJ/mol and ΔS = +100 J/mol·K. Above what temperature is it spontaneous?**

**A** Below 300 K

**B** Above 3000 K

**C** Above 300 K

**D** Above 30 K

Energy-rich compounds · Easy

**501. Which energy-rich compound serves as a methyl group donor?**

**A** UDP-glucose

**B** S-adenosylmethionine

**C** Aminoacyl-tRNA

**D** Cyclic AMP

Free energy · Medium

**502. In a heat engine, what happens to the fraction of input heat realised as work as the temperature drop increases?**

**A** It increases

**B** It decreases

**C** It stays the same

**D** It becomes zero

Free energy · Hard

**503. Why is free energy a better criterion for spontaneity than enthalpy or entropy alone?**

**A** It ignores temperature and depends on enthalpy only

**B** It depends only on the volume of the system

**C** It is the same for every reaction at any temperature

**D** It combines both tendencies, which can conflict

Energy-rich compounds · Devil

**504. Which order of phosphate transfer potential, highest to lowest, is correct?**

**A** ATP > PEP > phosphocreatine > 1,3-bisphosphoglycerate

**B** Phosphocreatine > PEP > ATP > 1,3-bisphosphoglycerate

**C** PEP > 1,3-bisphosphoglycerate > phosphocreatine > ATP

**D** 1,3-Bisphosphoglycerate > ATP > PEP > phosphocreatine

Free energy · Easy

**505. Gibbs free energy applies under which conditions?**

**A** Constant temperature and pressure

**B** Constant volume and no heat exchange

**C** Constant entropy

**D** Constant enthalpy

Free energy · Medium

**506. At what concentration of reactants and products is $\Delta G^\circ$ defined?**

**A** 0.1 M

**B** 1.0 M

**C** 10 M

**D** 0 M

Free energy · Hard

**507. How does $\Delta G^\circ = -RT \ln K$ arise from $\Delta G = \Delta G^\circ + RT \ln K$?**

**A** At equilibrium $\Delta G^\circ = 0$, so $\Delta G = RT \ln K$

**B** At equilibrium $K = 0$, so $\Delta G = \Delta G^\circ$

**C** At equilibrium $\Delta G = 0$, so $\Delta G^\circ = -RT \ln K$

**D** At equilibrium $Q = 0$, so $\Delta G^\circ = \Delta G$

Energy-rich compounds · Devil

**508. Which pairing of compound and class of energy-rich compound is correct?**

**A** Phosphocreatine: enol phosphate; UDP-glucose: cyclic nucleotide

**B** Phosphocreatine: thiol ester; UDP-glucose: amino acid ester

**C** Phosphocreatine: acyl phosphate; UDP-glucose: pyridine nucleotide

**D** Phosphocreatine: guanidinium phosphate; UDP-glucose: sugar nucleotide

## Answers — Set 4 · Q31–40

**499.** B — A gas is produced, so disorder increases.

**500.** C — $\Delta G = 0$ at $T = 30\,000/100 = 300$ K, and $\Delta G$ falls below zero beyond that.

**501.** B — It is the methyl donor in the lecture's list.

**502.** A — A greater temperature drop gives more work.

**503.** D — $\Delta G = \Delta H - T\Delta S$ balances the two tendencies.

**504.** C — PEP is the super high-energy compound and ATP sits lower.

**505.** A — It is the energy available to do work isothermally and isobarically.

**506.** B — Standard conditions use 1.0 M.

**507.** C — Setting $\Delta G = 0$ and $Q = K$ gives the relation.

**508.** D — Both are named under those classes in the lecture.

**Module 9: Chemical Kinetics** — 40 questions

## 1. Set 1 · Q1–10

Measuring rates · Easy

**509. In the acid-catalysed propanone–iodine reaction, what is added to quench a sampled aliquot?**

**A** Sodium hydrogencarbonate, which neutralises the acid catalyst

**B** Sodium chloride, which dilutes the mixture

**C** Starch, which reacts with the propanone

**D** More hydrochloric acid to speed the reaction

Measuring rates · Medium

**510. What is another way to quench a sampled aliquot, apart from adding a reagent?**

**A** Heating it to boiling point

**B** Exposing it to bright sunlight

**C** Placing it on ice to lower the temperature

**D** Stirring it vigorously for a minute

Rates · Hard

**511. In the bromine data $[Br_2]$ falls from 0.00710 M at 150 s to 0.00596 M at 200 s. What is the average rate?**

**A** $1.14 \times 10^{-3}$ mol $L^{-1}$ $s^{-1}$

**B** $2.28 \times 10^{-3}$ mol $L^{-1}$ $s^{-1}$

**C** $1.14 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$

**D** $2.28 \times 10^{-5}$ mol $L^{-1}$ $s^{-1}$

Rate laws · Devil

**512. Using rate = $k[NO]^2[H_2]$ with experiment 1 (0.0339 mol $L^{-1}$ $s^{-1}$ at 0.210 M NO and 0.122 M $H_2$), what is the rate at 0.420 M NO and 0.244 M $H_2$?**

**A** About 0.136 mol $L^{-1}$ $s^{-1}$

**B** About 0.271 mol $L^{-1}$ $s^{-1}$

**C** About 0.0678 mol $L^{-1}$ $s^{-1}$

**D** About 0.542 mol $L^{-1}$ $s^{-1}$

Measuring rates · Easy

**513. A reaction produces ions in solution. Which instrument can follow its progress?**

**A** A conductivity meter

**B** A viscometer

**C** A polarimeter

**D** A colorimeter only

Measuring rates · Medium

**514. How can the inversion of sucrose be followed?**

**A** By measuring pressure at constant volume

**B** By titrating with sodium thiosulphate

**C** By measuring the change in optical rotation with a polarimeter

**D** By measuring colour intensity of the sucrose

Rate laws · Hard

**515. Why do the average rates in the bromine table fall as time passes?**

**A** Formic acid is used up completely during the run

**B** The temperature of the mixture drops steadily

**C** The radius of the sample tube changes

**D** Bromine concentration falls, so the rate falls

Rate laws · Devil

**516. Using rate = k[NO]²[H₂], what is the rate at 0.105 M NO and 0.122 M H₂ (experiment 1 gave 0.0339)?**

**A** About 0.0170 mol $L^{-1}$ $s^{-1}$

**B** About 0.0085 mol $L^{-1}$ $s^{-1}$

**C** About 0.0339 mol $L^{-1}$ $s^{-1}$

**D** About 0.0042 mol $L^{-1}$ $s^{-1}$

Factors affecting rate · Easy

**517. How fast is a neutralisation reaction at room temperature, per the lecture?**

**A** Over several days

**B** Over millions of years

**C** Over several hours

**D** Within microseconds

Factors affecting rate · Medium

**518. What does esterification need to proceed at a reasonable rate at room temperature?**

**A** An acid catalyst and heat

**B** Only a larger vessel

**C** Cooling to 0 °C

**D** A strong base

## Answers — Set 1 · Q1–10

**509.** A — Removing the catalyst stops the reaction.

**510.** C — Low temperature drastically reduces the rate.

**511.** D — 0.00114 ÷ 50 = $2.28 \times 10^{-5}$.

**512.** B — Doubling NO gives ×4 and doubling $H_2$ gives ×2, so ×8.

**513.** A — Conductivity measures ions in solution.

**514.** C — The rotation changes as invert sugar forms.

**515.** D — The rate is proportional to [$Br_2$].

**516.** B — Halving NO gives (½)² = ¼ of the rate.

**517.** D — Ions combine almost at once.

**518.** A — It is slow without them.

## 2. Set 2 · Q11–20

Factors affecting rate · Hard

**519. Which list gives the factors affecting reaction rate in the lecture?**

**A** Colour, odour, volume and mass of the reaction vessel

**B** Entropy, enthalpy and free energy of the system

**C** Nature of reactants, concentration, temperature, catalysts and pressure

**D** Boiling point, density, viscosity and refractive index

Rates · Devil

**520. Why is an average rate not informative enough on its own?**

**A** It is always zero for any reaction

**B** It covers an interval, not a specific time

**C** It cannot be calculated from the data

**D** It only applies once equilibrium is reached

Measuring rates · Easy

**521. What colour is bromine, and how does the colour change in the reaction with methanoic acid?**

**A** Colourless, turning red as it reacts

**B** Reddish brown, fading as the reaction proceeds

**C** Green, turning blue as it reacts

**D** Blue, turning yellow as it reacts

Measuring rates · Medium

**522. If neither a reactant nor a product is coloured, how can colorimetry still be used?**

**A** A further reaction can make a coloured product

**B** It cannot be used at all in such cases

**C** The sample must be frozen solid first

**D** Only pressure can be measured instead

Measuring rates · Hard

**523. How can the hydrolysis of starch be followed?**

**A** With a polarimeter measuring pressure

**B** With a conductivity meter in a closed vessel

**C** With a viscometer, from the flow of liquid through a narrow tube

**D** With a thermometer only

Measuring rates · Devil

**524. In a radiochemical assay of iron incorporation into haemoglobin, why is the reaction stopped at a set time?**

**A** So that the iron label becomes inert

**B** So that haemoglobin can be crystallised

**C** So that the half-life of the label changes

**D** So the separated radioactive product reflects that interval

Factors affecting rate · Easy

**525. On what timescale do geological reactions such as rock formation occur?**

**A** Millions of years

**B** Microseconds

**C** Seconds

**D** Hours

Factors affecting rate · Medium

**526. How does bond strength affect the activation energy of organic reactions?**

**A** Stronger bonds mean lower activation energy

**B** Bond strength has no effect

**C** Weaker bonds raise activation energy

**D** Stronger bonds mean higher activation energy and slower rates

First-order kinetics · Hard

**527. Using $[N_2O_5] = 1.8 \times 10^{-2}$ M at 0 s and $7.1 \times 10^{-3}$ M at 1800 s, what is k for first-order decay?**

**A** About $1.4 \times 10^{-3}\ s^{-1}$

**B** About $2.2 \times 10^{-4}\ s^{-1}$

**C** About $5.2 \times 10^{-4}\ s^{-1}$

**D** About $9.3 \times 10^{-4}\ s^{-1}$

First-order kinetics · Devil

**528. Using $[N_2O_5] = 9.3 \times 10^{-3}$ M at 1200 s and $5.3 \times 10^{-3}$ M at 2400 s, which estimate of $t_{1/2}$ is closest?**

**A** About $3.0 \times 10^{3}$ s

**B** About $1.5 \times 10^{3}$ s

**C** About $7.4 \times 10^{2}$ s

**D** About $1.2 \times 10^{4}$ s

## Answers — Set 2 · Q11–20

**519.** C — These five are listed.

**520.** B — Instantaneous rates are found from tangents.

**521.** B — None of the products is coloured.

**522.** A — The coloured product can then be measured.

**523.** C — Viscosity changes as starch breaks down.

**524.** D — The counts then measure the rate.

**525.** A — They are among the slowest reactions.

**526.** D — More energy is needed to break strong bonds.

**527.** C — Ln(2.54)/1800 = 0.930/1800.

**528.** B — K ≈ 0.562/1200 = $4.7 \times 10^{-4}$ $s^{-1}$, so t½ ≈ 0.693/k.

## 3. Set 3 · Q21–30

Collision theory · Easy

**529. What is a perfectly elastic collision in collision theory?**

**A** Molecules collide and rebound with no change in identity

**B** Molecules collide and always form products

**C** Molecules fuse into one larger molecule

**D** Molecules pass through each other unchanged

Collision theory · Medium

**530. According to collision theory, the rate of an elementary step is proportional to which two things?**

**A** The molar mass and the density of the reactants

**B** The enthalpy change and the entropy change

**C** The number of collisions per second and the fraction that are effective

**D** The boiling point and the melting point

Collision theory · Hard

**531. Why must colliding molecules have kinetic energy at least equal to Ea?**

**A** To reduce their molar mass

**B** To overcome the repulsion between their electron clouds

**C** To make the reaction exothermic

**D** To lower the temperature of the mixture

Temperature and Arrhenius · Devil

**532. For a first-order reaction with A = $1.0 \times 10^{14}$ $s^{-1}$ and Ea = 75 kJ/mol, what is k at 27 °C?**

**A** About $8.9 \times 10^{-5}$ $s^{-1}$

**B** About $1.1 \times 10^{-1}$ $s^{-1}$

**C** About $2.3 \times 10^{1}$ $s^{-1}$

**D** About 8.9 $s^{-1}$

Temperature and Arrhenius · Easy

**533. In ln k = −(Ea/R)(1/T) + ln A, what is the y-intercept of the plot of ln k against 1/T?**

**A** −Ea/R

**B** ln k

**C** ln A

**D** Ea

Temperature and Arrhenius · Medium

**534. Which two-point form of the Arrhenius equation compares rate constants at two temperatures?**

**A** $\ln(k_2/k_1) = (E_a/R)(T_1 - T_2)$

**B** $\ln(k_2/k_1) = (E_a/R)(1/T_1 - 1/T_2)$

**C** $k_2/k_1 = E_a(T_2 - T_1)$

**D** $\ln(k_1/k_2) = (E_a/R)(1/T_1 - 1/T_2)$

Temperature and Arrhenius · Hard

**535. A reaction has $k = 2.0 \times 10^{-3}\ s^{-1}$ at 300 K and Ea = 60 kJ/mol. What is k at 310 K?**

**A** About $4.3 \times 10^{-3}\ s^{-1}$

**B** About $2.0 \times 10^{-2}\ s^{-1}$

**C** About $1.0 \times 10^{-3}\ s^{-1}$

**D** About $8.6 \times 10^{-3}\ s^{-1}$

Catalysis · Devil

**536. At 300 K, a catalyst lowers Ea by 10 kJ/mol with A unchanged. Roughly how much faster is the reaction?**

**A** About 10-fold

**B** About 4-fold

**C** About 550-fold

**D** About 55-fold

Temperature and Arrhenius · Easy

**537. Which part of the Arrhenius expression gives the fraction of molecules with enough energy to react?**

**A** A, the frequency factor

**B** R, the gas constant

**C** e^(−Ea/RT)

**D** ln k, the natural log of k

Catalysis · Medium

**538. How do catalysts compare with enzymes in specificity?**

**A** Catalysts are more specific than enzymes

**B** Catalysts are specific but less specific than enzymes

**C** Catalysts are not specific at all

**D** Catalysts and enzymes are equally specific

## Answers — Set 3 · Q21–30

**529.** A — Gentle collisions do not lead to reaction.

**530.** C — Both frequency and effectiveness matter.

**531.** B — Only energetic molecules can approach closely enough.

**532.** D — $K = A\, e^{(-E_a/RT)} = 10^{14} \times e^{(-30.06)}$.

**533.** C — It occurs where $1/T = 0$.

**534.** B — This follows from subtracting the two logarithmic forms.

**535.** A — K rises by about 2.2-fold for this Ea.

**536.** D — E^(10 000/(8.314 × 300)) ≈ 55.

**537.** C — It is the fraction with energy above Ea.

**538.** B — Enzymes are more specific.

## 4. Set 4 · Q31–40

Radiocarbon dating · Hard

**539. A bone retains 30% of the original $^{14}C$ ($t_{½}$ = 5730 y). About how old is it?**

**A** About $9.96 \times 10^3$ years

**B** About $1.72 \times 10^4$ years

**C** About $5.7 \times 10^3$ years

**D** About $4.2 \times 10^3$ years

Radiocarbon dating · Devil

**540. Which assumption of $^{14}C$ dating is described as incorrect in the lecture?**

**A** That $^{14}C$ is distributed uniformly over the earth

**B** That decay rates do not depend on temperature or pressure

**C** That living organisms take in carbon continually

**D** That atmospheric $^{14}C$ has stayed steady for thousands of years

Radiocarbon dating · Easy

**541. In what year did Libby receive the Nobel prize for radiocarbon dating?**

**A** 1960

**B** 1978

**C** 1798

**D** 1910

Radiocarbon dating · Medium

**542. Why can radiocarbon dating not be used on coal or petroleum deposits?**

**A** They contain too much $^{14}C$

**B** They are too hot to sample

**C** They contain only $^{12}C$ by definition

**D** They are so old that essentially no $^{14}C$ remains

Transition state · Hard

**543. How does transition state theory differ from collision theory in emphasis?**

**A** It emphasises the kinetic energy of the products only

**B** It ignores the activated complex altogether

**C** It stresses the potential energy of the transition state

**D** It gives an exact numerical value of Ea for each step

Transition state · Devil

**544. In A + BC → AB + C, at which step are old bonds partly broken and new bonds partly formed?**

**A** Step I, as the reactants approach

**B** Step II, the transition state

**C** Step III, as products separate

**D** None, because bonds break completely first

Mechanism · Easy

**545. How many intermediates and transition states does a two-step reaction profile have?**

**A** Two intermediates and one transition state

**B** Two intermediates and two transition states

**C** One intermediate and two transition states

**D** One intermediate and one transition state

Mechanism · Medium

**546. In an energy profile, what does a deeper minimum for an intermediate indicate?**

**A** The intermediate is more unstable

**B** The intermediate is more stable

**C** The reaction is faster

**D** The reaction is endothermic overall

Mechanism · Hard

**547. Which is the highest-energy state in the lecture's two-step profile?**

**A** TS1, the first transition state

**B** The intermediate

**C** TS2, the second transition state

**D** The final products

Mechanism · Devil

**548. Which statement about reaction mechanisms is correct?**

**A** Only one mechanism can ever be proposed for a reaction

**B** A mechanism is proven by the stoichiometric equation alone

**C** A mechanism is chosen without any experimental data

**D** Several can be proposed, but the accepted one fits experimental evidence

## Answers — Set 4 · Q31–40

**539.** A — $T = \ln(100/30)/(0.693/5730) \approx 9960$ y.

**540.** D — Atmospheric $^{14}C$ has varied.

**541.** A — The lecture dates it to 1960.

**542.** D — The short half-life limits the method.

**543.** C — It describes the activated complex in terms of bonding and structure.

**544.** B — It is the unstable arrangement between reactants and products.

**545.** C — TS1, an intermediate minimum, then TS2.

**546.** B — The deeper the drop, the more stable it is.

**547.** A — The lecture states TS1 is highest, so step one is rate-determining.

**548.** D — A mechanism is a theoretical concept that must be proven experimentally.

**Module 10: Chemical Equilibrium** — 40 questions

## 1. Set 1 · Q1–10

Reversible reactions · Easy

**549. Why is the dissociation of HCl in water described as essentially irreversible?**

**A** It dissociates almost completely in water

**B** It does not dissociate at all

**C** It forms an equal mixture of HCl and ions

**D** It only dissociates when heated

Reversible reactions · Medium

**550. Which equation shows the equilibrium of ethanoic acid in water?**

**A** $CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$ (complete)

**B** $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

**C** $CH_3COOH \rightleftharpoons CH_3 + COOH$

**D** $CH_3COOH + H_2O \rightleftharpoons CH_3OH + CO_2$

Reversible reactions · Hard

**551. Starting with only ethanol and ethanoic acid, how does the backward rate change with time?**

**A** It starts high and then falls steadily to zero

**B** It stays constant throughout the whole reaction

**C** It starts at zero and rises until it equals the forward rate

**D** It always exceeds the forward rate at equilibrium

Equilibrium constant · Devil

**552. At equilibrium, $[N_2] = 0.50$ M, $[H_2] = 0.20$ M and $[NH_3] = 0.10$ M. What is Kc for $N_2 + 3H_2 \rightleftharpoons 2NH_3$?**

**A** 0.40

**B** 25

**C** 0.025

**D** 2.5

Equilibrium constant · Easy

**553. In $K_c = [C]^c[D]^d/[A]^a[B]^b$, what do a, b, c and d represent?**

**A** The orders of the reaction

**B** The molar masses of the species

**C** The coefficients in the balanced equation

**D** The numbers of atoms in each molecule

Kp and Kc · Medium

**554. Which is the correct Kp expression for $N_2O_4(g) \rightleftharpoons 2NO_2(g)$?**

**A** $K_p = P(NO_2)^2/P(N_2O_4)$

**B** $K_p = P(NO_2)/P(N_2O_4)^2$

**C** $K_p = P(N_2O_4)/P(NO_2)^2$

**D** $K_p = 2P(NO_2)/P(N_2O_4)$

Kp and Kc · Hard

**555. Why does substituting P = MRT lead to Kp = Kc(RT)^Δn?**

**A** Each concentration equals pressure × RT, so RT cancels completely

**B** Each partial pressure equals concentration × RT, so the powers of RT add up to Δn

**C** RT cancels in every reaction

**D** Δn counts solids and liquids as well

Kp and Kc · Devil

**556. For $N_2O_4 \rightleftharpoons 2NO_2$, $K_p = 0.15$ atm and $P(N_2O_4) = 0.60$ atm at equilibrium. What is $P(NO_2)$?**

**A** 0.090 atm

**B** 0.60 atm

**C** 0.15 atm

**D** 0.30 atm

Equilibrium constant · Easy

**557. In the esterification equilibrium, which species appear in the numerator of Kc?**

**A** Ethanol and ethanoic acid

**B** Only the ester

**C** Only water

**D** The ester and water

Equilibrium constant · Medium

**558. What does K < 1 imply about the equilibrium position?**

**A** It lies to the right, with more products

**B** It lies to the left, with more reactants than products

**C** It is exactly at the midpoint of the reaction

**D** The reaction has stopped completely

## Answers — Set 1 · Q1–10

**549.** A — HCl is a strong acid.

**550.** B — A weak acid dissociates only slightly.

**551.** C — Equilibrium is reached when the rates match.

**552.** D — $0.10^2/(0.50 \times 0.20^3) = 0.010/0.0040$.

**553.** C — They appear as exponents.

**554.** A — Products over reactants with coefficient exponents.

**555.** B — The net exponent of RT is products minus reactants.

**556.** D — $P(NO_2)^2 = 0.15 \times 0.60 = 0.090$, so P = 0.30.

**557.** D — Products are in the numerator.

**558.** B — Reactants dominate the mixture.

## 2. Set 2 · Q11–20

Equilibrium constant · Hard

**559. For A ⇌ B with K = 1 and 2.0 M A initially (no B), what are [A] and [B] at equilibrium?**

**A** 1.0 M of A and 1.0 M of B

**B** 2.0 M A and 0 M B

**C** 0.5 M A and 1.5 M B

**D** 1.5 M A and 0.5 M B

Reaction quotient · Devil

**560. A mixture has 0.50 M ethanol, 0.50 M ethanoic acid, 1.0 M ester and 1.0 M water with Kc = 4.0. What is the situation?**

**A** Q = 0.25, so the reaction goes forward

**B** Q = 8, so the reaction goes in reverse

**C** Q = 4.0, so the mixture is already at equilibrium

**D** Q = 16, so the reaction goes in reverse

Heterogeneous equilibria · Easy

**561. At what temperature is $CaCO_3$ decomposed in the lecture's closed-vessel example?**

**A** 25 °C

**B** 100 °C

**C** 800 °C

**D** 4 °C

Heterogeneous equilibria · Medium

**562. Which phases appear in $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$?**

**A** Three gases, so it is homogeneous

**B** Two liquids and a gas

**C** One solid only

**D** Two solids and a gas, so it is heterogeneous

Heterogeneous equilibria · Hard

**563. $CO_2$ is injected into the $CaCO_3/CaO/CO_2$ equilibrium at constant temperature. Where does $P(CO_2)$ settle?**

**A** Higher than its original value at that temperature

**B** Back to its original value, since Kp = $P(CO_2)$ is fixed

**C** Lower than its original value at that temperature

**D** To zero, as all the $CO_2$ is consumed

Kp and Kc · Devil

**564. At 400 K, Kc = 0.10 mol $L^{-1}$ for $N_2O_4 \rightleftharpoons 2NO_2$. What is Kp (R = 0.0821 L atm $mol^{-1}$ $K^{-1}$)?**

**A** About 3.3 atm

**B** About 0.0030 atm

**C** About 0.10 atm

**D** About 33 atm

Reaction quotient · Easy

**565. What does the symbol Q stand for?**

**A** The reaction quotient

**B** The equilibrium constant

**C** The heat of reaction

**D** The rate constant

Reaction quotient · Medium

**566. How does Q differ from K?**

**A** Q applies only at equilibrium; K at any point

**B** Q and K are always numerically equal

**C** Q is calculable at any moment; K applies at equilibrium

**D** Q depends on temperature but K does not

Equilibrium constant · Hard

**567. For $H_2 + I_2 \rightleftharpoons 2HI$ with Kc = 50, $[H_2] = [I_2] = 0.10$ M at equilibrium. What is [HI]?**

**A** About 0.50 M

**B** About 0.71 M

**C** About 0.050 M

**D** About 7.1 M

Equilibrium constant · Devil

**568. Kc = 50 for $H_2 + I_2 \rightleftharpoons 2HI$. What is Kc for $\frac{1}{2}H_2 + \frac{1}{2}I_2 \rightleftharpoons HI$ at the same temperature?**

**A** About 25

**B** About 100

**C** About 0.14

**D** About 7.1

## Answers — Set 2 · Q11–20

**559.** A — K = 1 requires equal concentrations of A and B.

**560.** C — (1.0 × 1.0)/(0.50 × 0.50) = 4.0.

**561.** C — Limestone decomposes at 800 °C.

**562.** D — Different phases make it heterogeneous.

**563.** B — Extra $CO_2$ reacts with CaO until Kp is restored.

**564.** A — Kp = 0.10 × $(0.0821 \times 400)^1$ = 3.3.

**565.** A — Q compares product and reactant concentrations at any moment.

**566.** C — Q is compared with K to predict direction.

**567.** B — $[HI]^2 = 50 \times 0.10 \times 0.10 = 0.50$, so $[HI] = 0.71$.

**568.** D — Halving the equation takes the square root of K.

## 3. Set 3 · Q21–30

Le Chatelier · Easy

**569. Which five factors does the lecture say influence a chemical equilibrium?**

**A** Colour, odour, taste, mass and density

**B** Concentration, temperature, pressure, volume and catalyst

**C** Entropy, enthalpy, work, heat and time

**D** Phase, shape, charge, spin and colour

Le Chatelier · Medium

**570. What is meant by a 'stress' on a system at equilibrium?**

**A** Only a change in the colour of the mixture

**B** Only a catalyst being added

**C** A change in the name of the reaction

**D** A change in concentration, pressure or volume, or temperature

Le Chatelier · Hard

**571. $Fe_2(SO_4)_3$ solution is added to the $FeSCN^{2+} \rightleftharpoons Fe^{3+} + SCN^-$ system. What is observed?**

**A** The red deepens as equilibrium shifts left

**B** The red fades as equilibrium shifts right

**C** The red deepens as equilibrium shifts right

**D** The mixture turns colourless

Le Chatelier · Devil

**572. Oxalate is added to the $FeSCN^{2+}$ system and $Fe^{3+}$ is bound. What happens to the colour?**

**A** The red deepens as equilibrium shifts left

**B** No change occurs in the red colour

**C** The red fades towards brown as equilibrium shifts right

**D** The solution becomes colourless immediately

Le Chatelier · Easy

**573. Do pressure changes affect solids and liquids?**

**A** No, they do not significantly affect them

**B** Yes, they always do

**C** Only liquids are affected

**D** Only solids are affected

Le Chatelier · Medium

**574. How can the total pressure be raised without changing the volume?**

**A** By pulling a piston upward in the cylinder

**B** By cooling the gas mixture slowly

**C** By adding a solid catalyst to it

**D** By adding an inert gas to a constant-volume vessel

Le Chatelier · Hard

**575. When helium is added at constant volume, what happens to mole fractions and partial pressures of $NO_2$ and $N_2O_4$?**

**A** Mole fractions rise and partial pressures rise

**B** Mole fractions stay the same and partial pressures fall

**C** Mole fractions fall but partial pressures stay the same

**D** Both mole fractions and partial pressures double

Le Chatelier · Devil

**576. The volume of a vessel holding $N_2 + 3H_2 \rightleftharpoons 2NH_3$ is halved at constant temperature. What happens?**

**A** Equilibrium shifts left and K is unchanged

**B** Equilibrium shifts right and K is unchanged

**C** Equilibrium shifts right and K doubles

**D** Equilibrium does not shift and K halves

Le Chatelier · Easy

**577. What happens to Q when more reactant is added to a system at equilibrium?**

**A** Q falls below K, so the net reaction goes forward

**B** Q rises above K, so the net reaction reverses

**C** Q equals K, so nothing happens

**D** Q becomes zero

Le Chatelier · Medium

**578. After a temperature change, what is true about the new equilibrium?**

**A** It has the same equilibrium constant

**B** It has K equal to zero

**C** It has no definite constant

**D** It has a new equilibrium constant

## Answers — Set 3 · Q21–30

**569.** B — These are the five listed factors.

**570.** D — These changes disturb the equilibrium.

**571.** A — Added $Fe^{3+}$ reacts with $SCN^-$ to make more $FeSCN^{2+}$.

**572.** C — $FeSCN^{2+}$ dissociates to replace the lost $Fe^{3+}$.

**573.** A — Pressure matters mainly for gases.

**574.** D — The total pressure rises but partial pressures do not.

**575.** C — Partial pressure is mole fraction times total pressure.

**576.** B — Higher pressure favours fewer gas moles, and only temperature changes K.

**577.** A — A larger denominator lowers Q until it returns to K.

**578.** D — K depends on temperature.

## 4. Set 4 · Q31–40

Le Chatelier · Hard

**579. The brown gas $NO_2$ is in equilibrium with colourless $N_2O_4$, and the forward reaction $N_2O_4 \rightarrow 2NO_2$ is endothermic. What happens when the mixture is cooled?**

**A** It shifts right to form more $NO_2$, and the mixture becomes darker

**B** It shifts left to form more $N_2O_4$, and the mixture becomes paler

**C** It does not shift

**D** It shifts left, and the mixture becomes darker

Catalysts · Devil

**580. A catalyst is added to a mixture that is not yet at equilibrium. What is the outcome?**

**A** Only the forward rate rises, giving more product

**B** The equilibrium constant increases

**C** Both rates rise and the same equilibrium forms sooner

**D** The final composition becomes richer in products

Steady state · Easy

**581. In a steady state, how do the rates of input and output of a substance compare?**

**A** Input is always larger

**B** They are equal

**C** Output is always larger

**D** Both are zero

Steady state · Medium

**582. What is a system in a steady state subject to?**

**A** Complete isolation from its surroundings

**B** Maximum entropy

**C** Zero free energy change

**D** Regulation

Steady state · Hard

**583. After a meal, why does blood glucose remain fairly constant?**

**A** Tissues take up glucose for use or storage as fast as the gut absorbs it

**B** The gut absorbs no glucose after a meal

**C** Glycogen is broken down at the same rate

**D** Gluconeogenesis supplies all the glucose

Industrial processes · Devil

**584. In the contact process, what is the effect of raising the temperature?**

**A** It raises both the rate and the yield

**B** It lowers the rate and raises the yield

**C** It raises the rate but lowers the $SO_3$ yield

**D** It affects neither the rate nor the yield

Industrial processes · Easy

**585. In $2SO_2 + O_2 \rightleftharpoons 2SO_3$, how many moles of gaseous reactants are there?**

**A** Two

**B** Three

**C** Four

**D** Five

Industrial processes · Medium

**586. A process has a high yield but a very slow rate. What is the lecture's conclusion?**

**A** It is ideal as it stands for industry

**B** Yield is irrelevant to industry

**C** Only the rate of reaction matters

**D** It makes no economic sense despite the high yield

Free energy and K · Hard

**587. A reaction has $K = 1 \times 10^{-4}$ at 298 K. What can be said about $\Delta G^\circ$?**

**A** It is negative, about −22.8 kJ/mol

**B** It is positive, about +2.3 kJ/mol

**C** It is positive, about +22.8 kJ/mol

**D** It is zero

Le Chatelier · Devil

**588. The volume of an $N_2O_4 \rightleftharpoons 2NO_2$ mixture is halved at constant temperature. What happens to $[NO_2]$?**

**A** It doubles at once, then falls as equilibrium shifts left

**B** It halves at once, then rises as equilibrium shifts right

**C** It stays the same throughout the whole change

**D** It doubles at once and keeps rising afterwards

## Answers — Set 4 · Q31–40

**579.** B — Cooling favours the exothermic reverse reaction.

**580.** C — The position is unchanged but reached faster.

**581.** B — The concentration stays constant.

**582.** D — Organisms regulate steady-state levels.

**583.** A — Transfer to tissues matches absorption.

**584.** C — The reaction is exothermic.

**585.** B — 2 + 1 = 3, forming two moles of gaseous product.

**586.** D — A reasonable rate is also needed.

**587.** C — $\Delta G^\circ = -RT \ln K = -2.478 \times (-9.21)$ kJ/mol.

**588.** A — Compression raises concentrations first, then the shift towards fewer moles partly reverses it.

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