Carpe Diem Biological Chemistry I — Study Bank

ANSWER & EXPLANATION UNDER EVERY QUESTION · BIOL 157 · BIOLOGICAL CHEMISTRY I

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

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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

> **Answer 1: A**
>
> Only the lightest elements formed in the initial explosion.

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

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

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

> **Answer 3: C**
>
> Nuclei must approach very closely against electrostatic repulsion.

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

Answer 4: B

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

Origin of elements · Easy

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

A Oxygen

B Helium

C Carbon

D Iron

Answer 5: B

Helium comes second after hydrogen, and stars keep making more.

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

Answer 6: C

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

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

Answer 7: A

8 + 2 = 10 protons gives neon, with 16 + 4 = 20 nucleons.

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

Answer 8: D

This is the lecture's explanation for the odd-even abundance pattern.

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

> **Answer 9: A**
>
> The British astronomer made the remark about stellar element formation.

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%

> **Answer 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

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

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

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

Artificial synthesis · Easy

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

A Transuranium elements

B Transition elements

C Lanthanides

D Noble gases

> **Answer 13: A**
> They lie beyond uranium and are made artificially.

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

> **Answer 14: C**
> Cyclotrons accelerate particles to fuse with target nuclei.

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

> **Answer 15: D**
> A discrete quantum of electromagnetic energy is released.

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

> **Answer 16: B**
> Neutron capture in a reactor converted U-238 into plutonium.

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

> **Answer 17: C**
>
> The lecture dates the origin of the universe to about 14 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

> **Answer 18: D**
>
> Only about 90 occur naturally; the rest are synthesised.

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

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

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

> **Answer 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

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

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

> **Answer 22: D**
>
> Carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur.

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

> **Answer 23: A**
>
> Most groups contribute at least one element to cell function.

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

> **Answer 24: B**
>
> Lanthanides and actinides are the unrepresented block.

Carbon · Easy

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

A Silicon

B Nitrogen

C Sulphur

D Carbon

> **Answer 25: D**
>
> Carbon forms the backbone of organic compounds.

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

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

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

> **Answer 27: A**
>
> Good overlap requires an intermediate size.

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

> **Answer 28: C**
>
> A strong sigma framework lets the pi overlap happen.

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

> **Answer 29: D**
> Catenation depends on the stability of C–C bonds.

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

> **Answer 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

> **Answer 31: A**
> Size prevents the enhanced overlap needed for strong bonds.

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

> **Answer 32: C**
> Weak Si–Si links and inert Si–O chains limit functional chemistry.

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

> **Answer 33: B**
>
> Yet carbon is the element selected for cells.

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

> **Answer 34: C**
>
> Each N–N bond leaves lone pairs that repel one another.

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

> **Answer 35: A**
>
> Boron lacks an octet in BCl_3 and gains one through a dative bond.

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

> **Answer 36: D**
>
> Each element has a distinct limiting factor.

Exclusion factors · Easy

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

A Mercury

B Iron

C Magnesium

D Zinc

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

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

> **Answer 38: C**
> Blocking haem synthesis reduces haemoglobin production.

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

> **Answer 39: B**
> Beryllium disrupts magnesium-dependent processes.

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

> **Answer 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

> **Answer 41: C**
>
> The lecture cites matching ion concentrations as evidence of marine ancestry.

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

> **Answer 42: D**
>
> It is the zone of Earth that supports living organisms.

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

> **Answer 43: A**
>
> Carbon is rare on Earth yet dominates biomolecules.

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

> **Answer 44: B**
>
> The lecture credits natural selection for the chosen set.

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

> **Answer 45: A**
>
> F and I are trace elements.

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

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

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

> **Answer 47: B**
>
> The damaged DNA cannot repair itself and the cell dies.

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

> **Answer 48: C**
>
> This is the enhanced permeability and retention effect.

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

> **Answer 49: C**
> It was approved in 1978.

Medical applications · Medium

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

A Aluminium
B Calcium
C Silver
D Iron

> **Answer 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

> **Answer 51: D**
> Adsorption reduces fluid loss and toxin load.

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

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

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

> **Answer 53: A**
>
> They form essentially no compounds.

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

> **Answer 54: B**
>
> Transuranium elements are synthesised in laboratories.

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

> **Answer 55: C**
>
> Blocking haem synthesis reduces haemoglobin production.

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

> **Answer 56: D**
>
> Selection depends on bonding properties, not simple abundance.

Origin of elements · Easy

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

A Photolysis

B Catenation

C Nucleogenesis

D Hybridisation

> **Answer 57: C**
>
> Nucleogenesis describes element formation.

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

> **Answer 58: D**
>
> The same elements flow from food into cell structure.

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

> **Answer 59: B**
>
> A broad band of electromagnetic radiation is released.

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

> **Answer 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

> **Answer 61: C**
>
> Gravitational pull collapsed gas clouds into galaxies.

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

> **Answer 62: D**
>
> Stars are the factories for elements heavier than helium.

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

> **Answer 63: B**
>
> Four bonds, self-linking and double or triple bonds give vast diversity.

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

> **Answer 64: A**
>
> Pi bonding needs close, effective overlap between small atoms.

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

> **Answer 65: A**
>
> Covalent bonds hold the atoms of a molecule together.

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

> **Answer 66: B**
>
> C, N, O, P and S are p-block elements (H is the exception).

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

> **Answer 67: D**
>
> Lone-pair repulsion weakens the bond, so long N chains are unstable.

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

> **Answer 68: C**
>
> The strong Si–O link makes the chain stable and unreactive.

Silicon · Easy

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

A Nitrogen

B Boron

C Silicon

D Phosphorus

> **Answer 69: C**
> Silicon is carbon's congener in group IVA.

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

> **Answer 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

> **Answer 71: B**
> Iodine is needed for thyroid hormones despite trace amounts.

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

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

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

> **Answer 73: C**
>
> The primordial ball existed at the very beginning.

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

> **Answer 74: D**
>
> Small quantity does not mean small importance.

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

> **Answer 75: B**
>
> With three valence electrons, boron forms electron-deficient compounds.

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

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

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

> **Answer 77: B**
>
> Four hydrogen atoms make helium-4.

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

> **Answer 78: D**
>
> They build carbohydrates, lipids, proteins and nucleic acids.

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

> **Answer 79: A**
>
> Carbon-12 has 6 protons and 6 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

> **Answer 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

> **Answer 81: A**
>
> Ionic bonding follows complete electron transfer and attraction of the ions.

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

> **Answer 82: D**
>
> Above 1.7 is ionic; slightly below it is polar covalent.

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

> **Answer 83: C**
>
> These three make ΔHf more negative and the compound more stable.

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

> **Answer 84: B**
>
> ΔEN values are 2.5, 1.3 and 0.1 respectively.

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

> **Answer 85: D**
>
> This complete transfer gives Na^+ and Cl^-.

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

> **Answer 86: A**
>
> A more negative ΔHf signals greater stability and ionic character.

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

> **Answer 87: C**
>
> A difference of 0.1 is essentially nonpolar.

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

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

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

> **Answer 89: A**
> Sharing electrons forms a covalent bond.

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

> **Answer 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

> **Answer 91: B**
> A triple bond is one sigma plus two pi bonds.

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

> **Answer 92: D**
> Sideways overlap is less effective than head-on overlap.

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

> **Answer 93: B**
>
> Sigma bonds concentrate density between the nuclei.

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

> **Answer 94: D**
>
> End-to-end overlap is more effective than lateral overlap.

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

> **Answer 95: C**
>
> A double bond is a sigma bond plus a pi bond.

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

> **Answer 96: A**
>
> Pi electrons are relatively accessible for reaction.

Covalent bonding · Easy

97. Which molecule contains a double bond?

A H_2

B N_2

C O_2

D HCl

> **Answer 97: C**
> Oxygen is written O=O.

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

> **Answer 98: A**
> These are the lecture's examples of ionic solids.

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)

> **Answer 99: B**
> Both are below 1.7 yet clearly non-zero.

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

> **Answer 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

> **Answer 101: D**
> Mixing orbitals of different shape and energy gives equal shape, energy and direction.

Hybridisation · Medium

102. What is the hybridisation of carbon in CH_4?

A sp

B sp^2

C sp^3

D sp^3d

> **Answer 102: C**
> One 2s and three 2p orbitals form four sp^3 orbitals.

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

> **Answer 103: A**
> Promotion gives four unpaired electrons for four bonds.

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

> **Answer 104: B**
> Mixing is needed to give four identical tetrahedral sp^3 orbitals.

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

> **Answer 105: A**
>
> Compound formation drives atoms towards eight valence electrons.

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

> **Answer 106: D**
>
> Available p-type orbitals let P accommodate extra pairs.

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

> **Answer 107: C**
>
> Lone pair–bonded pair repulsion compresses 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°

> **Answer 108: B**
>
> More lone pairs mean greater compression of the angle.

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

> **Answer 109: D**
> Electron pairs arrange to minimise 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

> **Answer 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

> **Answer 111: C**
> Ammonia's nitrogen donates a pair to the proton.

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

> **Answer 112: B**
> Boron lacks an octet and accepts a pair from chloride.

Complexes · Easy

113. What is the central metal ion in haem?

A Fe^{2+}

B Mg^{2+}

C Cu^{2+}

D Zn^{2+}

> **Answer 113: A**
> Haem holds Fe^{2+}, which binds oxygen.

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

> **Answer 114: B**
> Four N donors coordinate the central metal ion.

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

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

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

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

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

> **Answer 117: B**
>
> Four sp^3 orbitals point to the corners of a tetrahedron.

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°

> **Answer 118: A**
>
> Three sp^2 orbitals are coplanar at 120°.

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

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

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°

> **Answer 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

> **Answer 121: D**
> Identical atoms share electrons symmetrically.

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

> **Answer 122: A**
> Equal and opposite dipoles in a linear molecule sum to zero.

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

> **Answer 123: C**
> The lone pair is a region of high electron density.

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

> **Answer 124: B**
> Unlike substituents prevent complete cancellation.

Polarity · Easy

125. Which hydrogen halide is the most polar?

A HCl

B HBr

C HI

D HF

> **Answer 125: D**
>
> Fluorine is the most electronegative halogen.

Polarity · Medium

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

A H_2S

B CO_2

C CH_4

D CCl_4

> **Answer 126: A**
>
> H_2S is bent with lone pairs, so its dipoles do not cancel.

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

> **Answer 127: B**
>
> Polarity falls as halogen electronegativity falls down the group.

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

> **Answer 128: C**
>
> The bent geometry gives a net dipole.

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

> **Answer 129: A**
> Covalent single bonds are about 100–500 kJ/mol.

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

> **Answer 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

> **Answer 131: C**
> Greater polarisability gives stronger induced dipole attraction.

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

> **Answer 132: D**
> Summed over a large surface, dispersion attractions become large.

Intermolecular forces · Easy

133. Which force acts between nonpolar molecules?

A Hydrogen bonds

B London dispersion forces

C Dipole–dipole attraction

D Ionic bonding

> **Answer 133: B**
>
> Only induced dipoles are possible between nonpolar molecules.

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

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

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

> **Answer 135: A**
>
> Hydrogen bonds are generally the strongest and London forces the weakest.

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

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

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

> **Answer 137: B**
>
> Δ+ ends attract the δ– ends of neighbours.

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

> **Answer 138: D**
>
> Solid lines show covalent bonds and broken lines show weaker attractions.

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

> **Answer 139: A**
>
> 1 s + 3 p + 2 d orbitals give six hybrid orbitals.

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

> **Answer 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

> **Answer 141: A**
>
> Boiling begins when vapour pressure matches the external pressure.

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

> **Answer 142: D**
>
> Weak London forces need little energy to overcome.

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

> **Answer 143: C**
>
> Weaker N–H polarity gives weaker hydrogen bonds.

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

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

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

> **Answer 145: C**
> Like dissolves like.

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

> **Answer 146: B**
> The open structure holds molecules farther apart.

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

> **Answer 147: A**
> Aquatic life survives beneath the frozen layer in temperate regions.

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

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

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

> **Answer 149: A**
> Water is densest at 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

> **Answer 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

> **Answer 151: B**
> Over 500 cal leave the skin with each gram evaporated.

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

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

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

> **Answer 153: B**
>
> Cellulose has the higher degree of interchain hydrogen bonding.

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

> **Answer 154: A**
>
> Hydrogen bonds hinder flow.

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

> **Answer 155: C**
>
> Size and chain entanglement give the high viscosity.

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

> **Answer 156: D**
>
> Molecules slip past one another more readily when warm.

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

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

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

> **Answer 158: C**
>
> Water is drawn up along the wall.

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

> **Answer 159: A**
>
> H is inversely proportional to r.

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

> **Answer 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)

> **Answer 161: B**
> PE = mgh.

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

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

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

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

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

> **Answer 164: D**
> With Joule's work, it validated the first law.

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

> **Answer 165: B**
> This is the law of conservation of energy.

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

> **Answer 166: D**
> Energy crosses the boundary but matter does not.

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

> **Answer 167: C**
> The terms are defined by heat transfer and temperature respectively.

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

> **Answer 168: A**
> Thermoregulation holds temperature steady.

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

> **Answer 169: A**
> Temperature depends only on the state of the system.

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

> **Answer 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

> **Answer 171: B**
> ΔE = q + w = +500 + (−200) = +300 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

> **Answer 172: D**
> −ΔE(system) = +ΔE(surroundings).

State functions · Easy

173. Which of these is an intensive property?

A Mass

B Volume

C Density

D Enthalpy

> **Answer 173: C**
>
> Density does not depend on the amount of matter.

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

> **Answer 174: D**
>
> Both scale with the amount of matter.

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

> **Answer 175: B**
>
> A positive w adds energy to the system.

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

> **Answer 176: A**
>
> Released heat stays and warms the contents.

Energy basics · Easy

177. What is the SI unit of energy?

A Watt

B Newton

C Pascal

D Joule

> **Answer 177: D**
> Energy is measured in joules.

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

> **Answer 178: C**
> Energy is released to the surroundings.

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

> **Answer 179: A**
> 250×1000 cal $\times$ 4.184 J = 1.046×10^6 J.

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

> **Answer 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

> **Answer 181: B**
>
> Enthalpy change is the heat of reaction at constant pressure.

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

> **Answer 182: C**
>
> With negligible volume change, PΔV ≈ 0.

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

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

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

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

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

> **Answer 185: A**
>
> It occurs without external work.

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 $\Delta H = 0$

D Some spontaneous processes are endothermic

> **Answer 186: D**
>
> Ice melting is endothermic yet spontaneous above 0 °C.

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

> **Answer 187: C**
>
> The disorder gained outweighs the enthalpy cost.

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

> **Answer 188: B**
>
> Both solute and solvent contribute to the entropy gain.

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

> **Answer 189: A**
>
> Entropy is the degree of disorder.

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

> **Answer 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

> **Answer 191: C**
>
> The second law applies to the universe as a whole.

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

> **Answer 192: B**
>
> ΔS(universe) = 0 requires ΔS(sys) = $-\Delta S$(sur).

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

> **Answer 193: B**
>
> W is the number of ways of arranging the system.

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

> **Answer 194: C**
>
> Random states are more probable because they can be achieved in more ways.

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

> **Answer 195: A**
>
> The increment is 10.0 eu in gas, 7.7 in liquid, 5.8 in solid.

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

> **Answer 196: D**
>
> Rings greatly restrict rotation and vibration.

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}

> **Answer 197: C**
> Entropy is energy per mole per kelvin.

Entropy · Medium

198. For $N_2O_4(g) \rightarrow 2NO_2(g)$, with S° of 240 and 304.2 J mol^{-1} K^{-1} respectively, what is ΔS°?

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}

> **Answer 198: D**
> (2 × 240) − 304.2 = +175.8, as one gas mole becomes two.

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

> **Answer 199: B**
> The entropy of the organism plus surroundings still increases.

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

> **Answer 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 $\Delta G = \Delta S - T\Delta H$

> **Answer 201: A**
> Gibbs' equation.

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

> **Answer 202: D**
> The reaction has free energy available to do work.

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

> **Answer 203: C**
> Both terms favour a negative ΔG.

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

> **Answer 204: B**
> $\Delta G = -40 - (298 \times -0.100) = -40 + 29.8$.

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

> **Answer 205: A**
>
> Forward and backward rates are equal.

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

> **Answer 206: B**
>
> TΔS must exceed ΔH.

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

> **Answer 207: D**
>
> ΔG = ΔH − TΔS becomes negative only above the melting point.

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

> **Answer 208: C**
>
> T = ΔH/ΔS = 6010/22.0 ≈ 273 K.

Coupled reactions · Easy

209. What do we call a reaction with a negative ΔG?

A Exergonic

B Endergonic

C Isothermal

D Adiabatic

> **Answer 209: A**
>
> It releases free energy.

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

> **Answer 210: D**
>
> The ΔG 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

> **Answer 211: C**
>
> $-8.314 \times 298 \times \ln 10 \approx -5705$ J.

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 ΔG is undefined until Q equals K

> **Answer 212: B**
>
> With $Q < K$, $RT \ln Q$ is less than $RT \ln K$, giving a negative ΔG.

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}

> **Answer 213: A**
> R = 8.314 J mol^{-1} K^{-1}.

Free energy · Medium

214. Which relation correctly gives ΔG from cell emf (the slide prints ΔH = −nFΔE)?

A ΔG = +nFE

B ΔH = −nFE

C ΔG = −E/nF

D ΔG = −nFE

> **Answer 214: D**
> A positive cell emf gives a negative ΔG.

Coupled reactions · Hard

215. In a pathway A → B → C → D, one enzyme-catalysed step has a positive ΔG. When can the pathway still run?

A Only if every step has a negative ΔG

B Only if the enzyme makes the ΔG of that step negative

C When the sum of all the ΔG values is negative

D Never, because one step is non-spontaneous

> **Answer 215: C**
> Standard free energy changes are additive.

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

> **Answer 216: B**
> The strongly exergonic steps pull the sequence forward.

Coupled reactions · Easy

217. What is a reaction with a positive ΔG called?

A Exergonic

B Exothermic

C Endergonic

D Isobaric

> **Answer 217: C**
>
> It requires work to proceed.

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

> **Answer 218: D**
>
> Energy flows between them through a shared 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

> **Answer 219: B**
>
> The −ΔH term wins only when T is low.

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

> **Answer 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

> **Answer 221: A**
> ATP links energy-releasing and energy-requiring reactions.

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

> **Answer 222: C**
> A large amount of free energy is released.

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

> **Answer 223: D**
> The energy must be coupled to an energy-requiring process.

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

> **Answer 224: B**
> −14.8 + 7.3 = −7.5 (the slide prints −7.8, an arithmetic slip).

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

> **Answer 225: D**
>
> Its hydrolysis releases about −3.3 kcal/mol.

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

> **Answer 226: C**
>
> PEP releases about −14.8 kcal/mol on hydrolysis.

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

> **Answer 227: B**
>
> +3.3 + (−7.3) = −4.0.

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

> **Answer 228: A**
>
> Transfer passes through ATP.

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

> **Answer 229: B**
>
> They are thiol esters of coenzyme A.

High-energy compounds · Medium

230. Which compound is an enol phosphate?

A Creatine phosphate

B ATP

C Acetyl phosphate

D Phosphoenolpyruvate

> **Answer 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

> **Answer 231: C**
>
> Strain relief plus resonance and ionisation stabilise the products.

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

> **Answer 232: A**
>
> There is little strain relief on hydrolysis.

ATP · Easy

233. Which triphosphate is used mainly in polysaccharide biosynthesis?

A GTP

B CTP

C dATP

D UTP

> **Answer 233: D**
>
> UTP supports sugar-nucleotide formation.

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

> **Answer 234: A**
>
> These are GTP's lecture-listed roles.

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

> **Answer 235: B**
>
> Less charge repulsion means less strain to relieve.

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

> **Answer 236: C**
>
> The lecture links the extra free energy to ionisation and buffering of Pi.

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

> **Answer 237: D**
>
> They contain phosphoanhydride linkages.

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

> **Answer 238: B**
>
> These are all energy-requiring processes powered by ATP.

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

> **Answer 239: C**
>
> This makes it the major link in energy metabolism.

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

> **Answer 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

> **Answer 241: B**
>
> Kinetics covers how fast reactions go and the steps they follow.

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

> **Answer 242: C**
>
> Thiosulphate titration quantifies iodine.

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 1.0×10^{-3} mol dm^{-3} min^{-1}

D 0.010 mol dm^{-3} min^{-1}

> **Answer 243: D**
>
> 0.30 ÷ 30 = 0.010.

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

> **Answer 244: A**
>
> Otherwise the concentration would keep changing during analysis.

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

> **Answer 245: C**
>
> They measure colour intensity or absorbance.

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

> **Answer 246: A**
>
> Gas production raises pressure at constant volume.

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

> **Answer 247: B**
>
> A labelled reactant gives a radioactive product to count.

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 = $-\frac{1}{2}\Delta[N_2O_5]/\Delta t = \frac{1}{4}\Delta[NO_2]/\Delta t = \Delta[O_2]/\Delta t$

> **Answer 248: D**
>
> Each concentration change is divided by its stoichiometric coefficient.

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

> **Answer 249: D**
>
> Δ[reactant] is negative, so the sign gives a positive rate.

Rate and stoichiometry · Medium

250. In 2A → 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}

> **Answer 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 2.0×10^{-5} mol L^{-1} s^{-1}. How fast does N_2O_5 disappear?

A 4.0×10^{-5} mol L^{-1} s^{-1}

B 2.0×10^{-5} mol L^{-1} s^{-1}

C 1.0×10^{-5} mol L^{-1} s^{-1}

D 8.0×10^{-5} mol L^{-1} s^{-1}

> **Answer 251: A**
>
> Two N_2O_5 are lost for each O_2 formed.

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 1.36×10^{-3} mol L^{-1} s^{-1}

B 2.72×10^{-5} mol L^{-1} s^{-1}

C 2.72×10^{-3} mol L^{-1} s^{-1}

D 1.36×10^{-5} mol L^{-1} s^{-1}

> **Answer 252: B**
>
> $(0.00846 - 0.00710) \div 50 = 2.72 \times 10^{-5}$.

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

> **Answer 253: B**
>
> Smaller particles expose more surface for reaction.

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

> **Answer 254: C**
>
> Ions in solution are already free to combine quickly.

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

> **Answer 255: D**
>
> Steric hindrance slows the ketone reaction.

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

> **Answer 256: A**
>
> Low temperature slows chemical and biological change.

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

> **Answer 257: D**
>
> It is the gradient of the tangent at 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

> **Answer 258: B**
>
> The gradient gives the rate at that instant.

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

> **Answer 259: C**
>
> Rate $\propto [Br_2]^1$.

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

> **Answer 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

> **Answer 261: B**
>
> The value of x must be found from experimental data.

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

> **Answer 262: A**
>
> It is the order with respect to that reactant.

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

> **Answer 263: D**
>
> The exponent in the rate law is empirical.

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 = $k[NO]^2[H_2]^2$

> **Answer 264: C**
>
> Second order in NO and first order in H_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

> **Answer 265: A**
>
> It converts the proportionality into an equation.

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

> **Answer 266: D**
>
> The exponents sum to 2 + 1 = 3.

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

> **Answer 267: C**
>
> Rate changes in direct proportion to concentration.

First-order kinetics · Devil

268. [N_2O_5] falls from 1.8 × 10^{-2} M to 9.3 × 10^{-3} M in 1200 s (first order). What is k?

A 1.6 × 10^{-3} s^{-1}

B 5.5 × 10^{-4} s^{-1}

C 5.5 × 10^{-3} s^{-1}

D 2.4 × 10^{-4} s^{-1}

> **Answer 268: B**
>
> K = ln(1.8×10^{-2}/9.3×10^{-3})/1200 = 0.660/1200.

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

> **Answer 269: C**
>
> Rate (mol L^{-1} s^{-1}) divided by concentration gives s^{-1}.

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 8.6×10^{-7} mol L^{-1} s^{-1}

B 0.38 mol L^{-1} s^{-1}

C 8.6×10^{-4} mol L^{-1} s^{-1}

D 2.6 mol L^{-1} s^{-1}

> **Answer 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

> **Answer 271: B**
>
> $3^2 = 9$.

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}

> **Answer 272: D**
>
> $0.0339 \div (0.210^2 \times 0.122) = 6.30$, with units 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

> **Answer 273: D**
>
> K depends on temperature, not concentration.

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

> **Answer 274: A**
>
> The reaction is second order in NO.

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

> **Answer 275: B**
>
> Third, fractional, zero and negative orders also occur.

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

> **Answer 276: C**
>
> $\ln[A] = \ln[A]_0 - kt$.

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

> **Answer 277: C**
>
> Rate is directly proportional to [A].

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]

> **Answer 278: A**
>
> $[A]^0 = 1$, so A drops out of the rate law.

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

> **Answer 279: B**
>
> $2^1 \times 2^2 = 8$.

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 = $k[X][Z]^2$

> **Answer 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

> **Answer 281: B**
>
> $T_{1/2}$ is the time for [A] to drop to $\frac{1}{2}[A]_0$.

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 $t_{1/2} = 0.693/k$

> **Answer 282: D**
>
> From $\ln 2 = k\, t_{1/2}$.

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}

> **Answer 283: A**
>
> K = 0.693 ÷ 2.40.

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

> **Answer 284: C**
>
> 9.60 h is four half-lives: 2.00 ÷ 16.

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

> **Answer 285: B**
> ½ × ½ = ¼.

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 $1/[A]_t = 1/[A]_0 + kt$

> **Answer 286: C**
> It applies to first-order reactions only.

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

> **Answer 287: D**
> $T = \ln(1.80)/0.289 \approx 2.04$ 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

> **Answer 288: A**
> $(½)^n = 0.01$ gives $n \approx 6.64$.

Radiocarbon dating · Easy

289. Who developed the radiocarbon dating technique?

A W. F. Libby

B John Dalton

C Svante Arrhenius

D Gilbert Lewis

> **Answer 289: A**
>
> Libby won a Nobel prize for it in 1960.

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

> **Answer 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

> **Answer 291: D**
>
> Cosmic-ray neutrons convert nitrogen-14 into carbon-14.

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

> **Answer 292: B**
>
> 12.5% = ⅛ means three half-lives.

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

> **Answer 293: D**
>
> ^{14}C decays and is no longer replaced.

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

> **Answer 294: B**
>
> Decay rates are treated as constant.

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

> **Answer 295: A**
>
> The signal is lost among background radiation.

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

> **Answer 296: C**
>
> One quarter corresponds to two half-lives.

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

> **Answer 297: D**
>
> A neutron converts to a proton, emitting a β particle.

Half-life · Medium

298. For a first-order reaction, what is the product k × t½?

A 1

B 2.303

C 0.693

D k^2

> **Answer 298: C**
>
> Ln 2 = 0.693 is constant for first-order processes.

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

> **Answer 299: A**
>
> 75% complete is two half-lives.

First-order kinetics · Devil

300. With $k = 5.7 \times 10^{-4}\ s^{-1}$, how long for 1.8×10^{-2} M N_2O_5 to fall to 4.5×10^{-3} M?

A About 1.2×10^{3} s

B About 2.4×10^{3} s

C About 4.9×10^{3} s

D About 2.4×10^{-3} s

> **Answer 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

> **Answer 301: A**
>
> Rates roughly double per 10 °C rise.

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

> **Answer 302: B**
>
> A reflects how often reactant molecules collide.

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

> **Answer 303: C**
>
> $\ln(k_2/k_1) = (75\,000/8.314)(1/300 - 1/310) \approx 0.97$.

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

> **Answer 304: D**
>
> $E_a = 9000 \times 8.314$ J/mol ≈ 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

> **Answer 305: D**
>
> It is the barrier to effective collisions.

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

> **Answer 306: C**
>
> Both energy and orientation matter.

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

> **Answer 307: A**
>
> It only provides an alternative pathway.

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

> **Answer 308: B**
>
> This is false; catalysts only speed up feasible reactions.

Catalysis · Easy

309. A catalyst in the same phase as the reactants is called what?

A Heterogeneous

B Enzymatic

C Inhibitory

D Homogeneous

> **Answer 309: D**
> Phase matches the reactants.

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

> **Answer 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

> **Answer 311: C**
> A solid catalyst in a liquid reactant is a different phase.

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

> **Answer 312: B**
> Energy is conserved, so KE converts to PE.

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

> **Answer 313: D**
>
> The terms are often used interchangeably.

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

> **Answer 314: B**
>
> The slowest step controls the overall rate.

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

> **Answer 315: C**
>
> Intermediates can sometimes be isolated; transition states cannot.

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

> **Answer 316: A**
>
> The slow step involves two NO_2, matching the rate law.

Mechanism · Easy

317. What is the molecularity of an elementary step involving a single molecule?

A Bimolecular

B Termolecular

C Unimolecular

D Zero

> **Answer 317: C**
>
> One reacting species means unimolecular.

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

> **Answer 318: B**
>
> They match only for single-step elementary reactions.

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

> **Answer 319: D**
>
> Such collisions are very unlikely.

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

> **Answer 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

> **Answer 321: B**
>
> Products recombine in the backward direction.

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

> **Answer 322: A**
>
> Only NaCl and water remain, with no reactants.

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

> **Answer 323: D**
>
> Most of the acid remains undissociated.

Reaction quotient · Devil

324. For $N_2O_4 \rightleftharpoons 2NO_2$ with $K_c = 0.16$, 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 $Q \neq K$

Answer 324: C

Q < K means the system moves right to form more products.

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

Answer 325: D

K is the ratio of product to reactant concentrations 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 $2[SO_3]/(2[SO_2] + [O_2])$

Answer 326: C

Products over reactants, each raised to its coefficient.

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

Answer 327: B

$(0.67 \times 0.67)/(0.33 \times 0.33) \approx 4.0$.

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

Answer 328: A

Doubling the equation squares K.

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

> **Answer 329: D**
> The system is at equilibrium.

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

> **Answer 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

> **Answer 331: A**
> The reverse constant is the reciprocal.

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

> **Answer 332: C**
> $[NO_2]^2 = 0.16 \times 0.25 = 0.040$, so $[NO_2] = 0.20$.

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

> **Answer 333: D**
> The Norwegian chemists proposed the law.

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

> **Answer 334: C**
> Every reaction has a characteristic K at a fixed temperature.

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

> **Answer 335: A**
> $0.080^2/0.040 = 0.16$.

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

> **Answer 336: B**
> $X/(1 - x) = 4$ gives $x = 0.80$.

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

> **Answer 337: C**
> Kinetics is rate, equilibrium is extent 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

> **Answer 338: A**
> Equilibrium is dynamic.

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

> **Answer 339: B**
> Equilibrium can be approached from either direction.

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

> **Answer 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

> **Answer 341: A**
> Kp uses equilibrium partial pressures.

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

> **Answer 342: B**
> Only gases count in Δn.

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

> **Answer 343: C**
> 2 mol gas products minus 4 mol gas reactants.

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

> **Answer 344: D**
> $K_p = 0.16 \times (0.0821 \times 298)^1 \approx 3.9$.

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

> **Answer 345: C**
> Their concentrations are constant.

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 $[CO_2]^2$

> **Answer 346: A**
> The solids' constant concentrations are absorbed into K.

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

> **Answer 347: B**
> Density does not change as the reaction proceeds.

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

> **Answer 348: D**
> Solids do not shift the equilibrium position.

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

> **Answer 349: A**
> $N_2O_4 \rightleftharpoons 2NO_2$ in the gas phase is an example.

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 $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

> **Answer 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 $K_p = K_c$

> **Answer 351: C**
> $\Delta n = 2 - 3 = -1$.

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

> **Answer 352: B**
> $(RT)^0 = 1$.

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

> **Answer 353: D**
> Nothing can enter or leave.

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 ΔG°

> **Answer 354: B**
> There is no net driving force.

Properties of equilibrium · Hard

355. At equilibrium ΔG = 0, so ΔH = TΔS. 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

> **Answer 355: A**
> Neither term wins.

Free energy and K · Devil

356. ΔG° = −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

> **Answer 356: C**
> Ln K = 11 400/(8.314 × 298) = 4.6, so K ≈ 100.

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 ΔG°

> **Answer 357: C**
> C refers to concentration.

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

> **Answer 358: D**
> They match only when $\Delta n = 0$.

Free energy and K · Hard

359. What is ΔG° 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

> **Answer 359: B**
> $\Delta G^\circ = -RT \ln 1 = 0$.

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

> **Answer 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

> **Answer 361: A**
>
> The system shifts to offset the stress.

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

> **Answer 362: B**
>
> A catalyst speeds both directions equally.

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

> **Answer 363: C**
>
> Only temperature changes K.

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

> **Answer 364: D**
>
> Added SCN^- combines with Fe^{3+} to form more $FeSCN^{2+}$.

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

> **Answer 365: A**
>
> The system consumes the added reactant.

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

> **Answer 366: B**
>
> The system replaces the lost Fe^{3+} by dissociating $FeSCN^{2+}$.

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

> **Answer 367: C**
>
> The side with fewer gas moles is favoured.

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

> **Answer 368: D**
>
> Higher pressure favours the side with fewer gas moles.

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

> **Answer 369: D**
>
> Both forward and reverse rates are increased equally.

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

> **Answer 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

> **Answer 371: C**
>
> Mole fractions fall, but partial pressures stay constant.

Le Chatelier · Devil

372. In the endothermic reaction $N_2O_4 \rightleftharpoons 2NO_2$ (ΔH 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

> **Answer 372: A**
>
> Heat absorption is favoured, and K changes with temperature.

Equilibrium constant · Easy

373. Which change alters the value of the equilibrium constant?

A Temperature

B Concentration

C Pressure

D Adding a catalyst

> **Answer 373: A**
> K is a function of temperature.

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

> **Answer 374: D**
> Heat absorption is favoured, which is the reverse direction.

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

> **Answer 375: B**
> Both changes shift the equilibrium forward.

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 $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

> **Answer 376: C**
> The gas moles are equal on both sides.

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

> **Answer 377: C**
> The system expands to counter the pressure drop.

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

> **Answer 378: D**
> The system replaces what is lost.

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

> **Answer 379: A**
> Lower pressure favours more gas moles.

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

> **Answer 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

> **Answer 381: C**
>
> It exchanges matter and energy with its surroundings.

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 ΔG for glucose is zero

D It is constant because tissues stop using glucose

> **Answer 382: A**
>
> Constancy of level does not mean equilibrium.

Steady state · Hard

383. Which statement about a system in a steady state is correct?

A It has ΔG = 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

> **Answer 383: B**
>
> ΔG is negative, so work is possible.

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

> **Answer 384: D**
>
> Supply from the liver balances utilisation.

Steady state · Easy

385. What is the formation of glucose from non-carbohydrate sources called?

A Glycolysis

B Glycogenesis

C Glycogenolysis

D Gluconeogenesis

> **Answer 385: D**
>
> It helps maintain blood glucose in the fasting state.

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

> **Answer 386: C**
>
> This balance of rates is a steady state.

Steady state · Hard

387. In $E + S \rightleftharpoons ES \rightleftharpoons E + P$, 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

> **Answer 387: A**
>
> This is the steady-state condition for an intermediate.

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

> **Answer 388: B**
>
> A steady state stays away from the entropy maximum.

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)

> **Answer 389: A**
> N_2 and H_2 combine to give NH_3.

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

> **Answer 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

> **Answer 391: D**
> Kinetics and equilibrium pull in different directions.

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

> **Answer 392: B**
> The lecture cites capital and maintenance costs.

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

> **Answer 393: B**
>
> It is a finely divided solid catalyst.

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

> **Answer 394: A**
>
> Industrialists must satisfy both.

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

> **Answer 395: C**
>
> Both economic factors matter.

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

> **Answer 396: D**
>
> Removing CO_2 pulls the system left, consuming H^+.

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

> **Answer 397: B**
>
> There is no observable net change.

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

> **Answer 398: C**
>
> The added O_2 is consumed.

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

> **Answer 399: D**
>
> Removing a product favours the forward reaction.

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

> **Answer 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

> **Answer 401: D**
>
> Zn is listed with Fe, Cu, Mn, Co and others as a cell constituent.

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

> **Answer 402: A**
>
> Oxygen heads the list at about 48.86%.

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

> **Answer 403: C**
>
> He adds 2 protons and 4 nucleons, and Z = 14 is silicon.

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 $3\,{}^{4}\mathrm{He} \rightarrow {}^{12}\mathrm{C}$; ${}^{12}\mathrm{C} + {}^{4}\mathrm{He} \rightarrow {}^{16}\mathrm{O}$; ${}^{16}\mathrm{O} + {}^{4}\mathrm{He} \rightarrow {}^{18}\mathrm{Ne}$; ${}^{20}\mathrm{Ne} + {}^{4}\mathrm{He} \rightarrow {}^{24}\mathrm{Mg}$

> **Answer 404: B**
> Each step adds one ^{4}He, giving C, O, Ne and 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

> **Answer 405: A**
> It was the example of elements organised into cell structures.

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

> **Answer 406: B**
> 48.86%, 18.84%, 13.96%, 12.42% and 0.10%.

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

> **Answer 407: C**
> A neutron adds one nucleon without changing the charge.

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

> **Answer 408: D**
> One is needed in tiny amounts, the other is harmful.

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

> **Answer 409: B**
>
> These particles are released alongside radiation.

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

> **Answer 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%

> **Answer 411: A**
>
> 30 ÷ 118 ≈ 0.25.

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

> **Answer 412: D**
>
> Tc is one of the artificially made elements below 92.

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

> **Answer 413: B**
>
> They are used as photothermal agents.

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

> **Answer 414: D**
>
> The damaged DNA cannot repair, so the cell dies.

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

> **Answer 415: A**
>
> The lecture says the rest of the 86 natural elements formed there.

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

> **Answer 416: C**
>
> Platinum is described as non-essential.

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%

> **Answer 417: A**
> 0.10 × 140 = 14, close to the slide's 13.96%.

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

> **Answer 418: D**
> Both appear in the Big Bang's trace products and in 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

> **Answer 419: C**
> A neutral particle can approach a positive nucleus easily.

Medical applications · Easy

420. Which element did the lecture mention in anti-arthritis preparations?

A Lithium

B Platinum

C Aluminium

D Mercury

> **Answer 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

> **Answer 421: D**
>
> Total enthalpy change is independent of the route taken.

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

> **Answer 422: B**
>
> It is defined per mole of compound formed from the elements.

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

> **Answer 423: A**
>
> Each half-filled sp^3 orbital overlaps with a half-filled H 1s orbital.

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

> **Answer 424: C**
>
> The lecture says the direct reaction is feasible and lattice energy is strongly negative.

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

> **Answer 425: B**
>
> A large electronegativity difference exists between them.

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

> **Answer 426: A**
>
> Atoms that lose electrons easily have low electronegativity.

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

> **Answer 427: C**
>
> It is a sigma bond between sp^3 and a half-filled chlorine p orbital.

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

> **Answer 428: D**
>
> $2s^2\ 2p^1$ has one unpaired electron.

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

> **Answer 429: C**
> Two bonding pairs mean two electrons from each atom.

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

> **Answer 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

> **Answer 431: D**
> They are coplanar and 120° apart.

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

> **Answer 432: A**
> Each gains two unpaired electrons when 2s is promoted.

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%

> **Answer 433: B**
> Methane is the major component.

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

> **Answer 434: A**
> The product is a liquid.

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

> **Answer 435: D**
> Heating breaks the network into separate H–Be–H molecules.

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

> **Answer 436: C**
> One Be–H sigma bond on each side.

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-}

> **Answer 437: A**
> Each forms by donation of a lone pair to H^+.

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

> **Answer 438: C**
> $BeCl_2 + 2LiH \rightarrow BeH_2 + 2LiCl$.

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

> **Answer 439: D**
> The complex ion and its components coexist.

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

> **Answer 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

> **Answer 441: B**
> In Lewis's definition acids accept electron pairs.

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

> **Answer 442: A**
> It forms through a coordinate bond.

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+}

> **Answer 443: C**
> Porphyrins bind both Fe^{2+} and Mg^{2+} in these molecules.

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

> **Answer 444: D**
> Nitrogen donates its lone pair to the proton.

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

> **Answer 445: A**
>
> It represents the valence electrons.

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

> **Answer 446: B**
>
> These four typically reach eight valence electrons.

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

> **Answer 447: D**
>
> Lone pairs occupy more space close to the nucleus of one atom.

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

> **Answer 448: C**
>
> Four pairs in a flat square, as in the lecture's table.

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

> **Answer 449: B**
> It is unshared.

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

> **Answer 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

> **Answer 451: C**
> A lone pair is concentrated around one atom.

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°

> **Answer 452: A**
> Tetrahedral, trigonal planar and pyramidal respectively.

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

> **Answer 453: D**
>
> Only a complementary substrate fits the enzyme.

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

> **Answer 454: B**
>
> Lone pairs are available to acceptors.

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

> **Answer 455: C**
>
> Fluorine's electronegativity makes strong H-bonds possible.

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

> **Answer 456: A**
>
> Water would vaporise at ambient temperature.

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

> **Answer 457: D**
>
> They proposed minimising electron pair repulsion.

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

> **Answer 458: C**
>
> Symmetrical electron density gives no pole to align.

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

> **Answer 459: A**
>
> Fluorine is the most electronegative, so H–F is the most polar.

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

> **Answer 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

> **Answer 461: A**
>
> H_2 is a homonuclear diatomic molecule.

Polarity · Medium

462. In $\mu = d \times q$, 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

> **Answer 462: B**
>
> Dipole moment is distance times charge.

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

> **Answer 463: C**
>
> Stronger attractions hold molecules in the liquid.

Properties of water · Devil

464. In capillary rise $h = 2\gamma/\rho g r$, 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

> **Answer 464: D**
>
> H is inversely proportional to r.

Polarity · Easy

465. Which unit is used for dipole moment?

A Debye

B Joule

C Pascal

D Newton

> **Answer 465: A**
>
> The Debye (D) is the dipole moment unit.

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

> **Answer 466: C**
>
> They alter states, boiling points and solubility, not bonds.

Properties of water · Hard

467. In ice, how many oxygen atoms tetrahedrally surround each oxygen atom?

A Two

B Six

C Eight

D Four

> **Answer 467: D**
>
> Hydrogen bonds bridge each oxygen pair in an open hexagonal network.

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

> **Answer 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

> **Answer 469: B**
> PE = mgh includes g.

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

> **Answer 470: A**
> Composition, bonds and attractions all matter.

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

> **Answer 471: C**
> Stored water falls, turns turbines and drives generators.

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

> **Answer 472: D**
> This separates intensive temperature from extensive heat.

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

> **Answer 473: A**
> 1 cal = 4.184 J.

Energy basics · Medium

474. Which of these is listed as a form of energy?

A Temperature

B Pressure

C Nuclear energy

D Entropy

> **Answer 474: C**
> Heat, mechanical, electrical and nuclear energy are listed.

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

> **Answer 475: B**
> Together they validated conservation of energy.

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

> **Answer 476: D**
> A truly isolated system is almost impossible to create.

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

> **Answer 477: D**
> It is everything outside the system.

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

> **Answer 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 $\Delta E = +80$ kJ, and the surroundings lose 80 kJ

B $\Delta E = -80$ kJ, and the surroundings lose 80 kJ

C $\Delta E = -80$ kJ, and the surroundings gain 80 kJ

D $\Delta E = 0$, since energy is conserved

> **Answer 479: C**
> The loss from the system appears in the surroundings.

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 $\Delta E = -30$ J, and the surroundings gain 30 J

B $\Delta E = -70$ J, and the surroundings gain 70 J

C $\Delta E = +30$ J, and the surroundings lose 30 J

D $\Delta E = +70$ J, and the surroundings lose 70 J

> **Answer 480: A**
> $\Delta E = q + w = -50 + 20$.

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

> **Answer 481: B**
>
> Universe = system + surroundings.

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

> **Answer 482: A**
>
> W = f × d = 25 × 8.

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

> **Answer 483: D**
>
> No heat crosses the boundary.

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

> **Answer 484: C**
>
> ΔE is final minus initial.

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

> **Answer 485: B**
>
> It is independent of the size of the 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

> **Answer 486: D**
>
> Four laws exist but these two are covered.

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

> **Answer 487: C**
>
> Different quantities use different units.

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

> **Answer 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

> **Answer 489: C**
> The final state has higher enthalpy than the initial state.

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

> **Answer 490: A**
> Final state minus initial state.

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

> **Answer 491: D**
> PΔV is therefore negligible.

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

> **Answer 492: B**
> They differ by the PΔV term.

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

> **Answer 493: B**
>
> It is a nonspontaneous process.

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

> **Answer 494: A**
>
> Entropy per mole increases with molecular weight.

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

> **Answer 495: C**
>
> These motions contribute most of the entropy.

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

> **Answer 496: D**
>
> A branch lowers entropy by about 3.0 eu.

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

> **Answer 497: A**
> These are the lecture's standard conditions.

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

> **Answer 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 $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

> **Answer 499: B**
> A gas is produced, so disorder increases.

Free energy · Devil

500. A reaction has $\Delta H = +30$ kJ/mol and $\Delta S = +100$ 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

> **Answer 500: C**
> $\Delta G = 0$ at $T = 30\,000/100 = 300$ K, and ΔG falls below zero beyond that.

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

> **Answer 501: B**
>
> It is the methyl donor in the lecture's list.

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

> **Answer 502: A**
>
> A greater temperature drop gives more work.

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

> **Answer 503: D**
>
> $\Delta G = \Delta H - T\Delta S$ balances the two tendencies.

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

> **Answer 504: C**
>
> PEP is the super high-energy compound and ATP sits lower.

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

> **Answer 505: A**
>
> It is the energy available to do work isothermally and isobarically.

Free energy · Medium

506. At what concentration of reactants and products is ΔG° defined?

A 0.1 M

B 1.0 M

C 10 M

D 0 M

> **Answer 506: B**
>
> Standard conditions use 1.0 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 $\Delta G^\circ = \Delta G$

> **Answer 507: C**
>
> Setting $\Delta G = 0$ and $Q = K$ gives the relation.

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

> **Answer 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

> **Answer 509: A**
> Removing the catalyst stops 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

> **Answer 510: C**
> Low temperature drastically reduces the rate.

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 1.14×10^{-3} mol L^{-1} s^{-1}

B 2.28×10^{-3} mol L^{-1} s^{-1}

C 1.14×10^{-5} mol L^{-1} s^{-1}

D 2.28×10^{-5} mol L^{-1} s^{-1}

> **Answer 511: D**
> $0.00114 \div 50 = 2.28 \times 10^{-5}$.

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}

Answer 512: B

Doubling NO gives ×4 and doubling H_2 gives ×2, so ×8.

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

Answer 513: A

Conductivity measures ions in solution.

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

Answer 514: C

The rotation changes as invert sugar forms.

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

Answer 515: D

The rate is proportional to $[Br_2]$.

Rate laws · Devil

516. Using rate = $k[NO]^2[H_2]$, what is the rate at 0.105 M NO and 0.122 M H_2 (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}

Answer 516: B

Halving NO gives $(\frac{1}{2})^2 = \frac{1}{4}$ of the rate.

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

> **Answer 517: D**
> Ions combine almost at once.

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

> **Answer 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

> **Answer 519: C**
> These five are listed.

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

> **Answer 520: B**
> Instantaneous rates are found from tangents.

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

> **Answer 521: B**
>
> None of the products is coloured.

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

> **Answer 522: A**
>
> The coloured product can then be measured.

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

> **Answer 523: C**
>
> Viscosity changes as starch breaks down.

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

> **Answer 524: D**
>
> The counts then measure the rate.

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

> **Answer 525: A**
>
> They are among the slowest reactions.

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

> **Answer 526: D**
>
> More energy is needed to break strong bonds.

First-order kinetics · Hard

527. Using $[N_2O_5] = 1.8 \times 10^{-2}$ M at 0 s and 7.1×10^{-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 $9.3 \times 10^{-4}\ s^{-1}$

> **Answer 527: C**
>
> Ln(2.54)/1800 = 0.930/1800.

First-order kinetics · Devil

528. Using $[N_2O_5] = 9.3 \times 10^{-3}$ M at 1200 s and 5.3×10^{-3} M at 2400 s, which estimate of $t_{1/2}$ is closest?

A About 3.0×10^{3} s

B About 1.5×10^{3} s

C About 7.4×10^{2} s

D About 1.2×10^{4} s

> **Answer 528: B**
>
> $K \approx 0.562/1200 = 4.7 \times 10^{-4}\ s^{-1}$, so $t_{1/2} \approx 0.693/k$.

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

> **Answer 529: A**
> Gentle collisions do not lead to reaction.

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

> **Answer 530: C**
> Both frequency and effectiveness matter.

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

> **Answer 531: B**
> Only energetic molecules can approach closely enough.

Temperature and Arrhenius · Devil

532. For a first-order reaction with A = 1.0 × 10^{14} s^{-1} and Ea = 75 kJ/mol, what is k at 27 °C?

A About 8.9 × 10^{-5} s^{-1}

B About 1.1 × 10^{-1} s^{-1}

C About 2.3 × 10^{1} s^{-1}

D About 8.9 s^{-1}

> **Answer 532: D**
> K = A e^(−Ea/RT) = 10^{14} × e^(−30.06).

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

> **Answer 533: C**
> It occurs where 1/T = 0.

Temperature and Arrhenius · Medium

534. Which two-point form of the Arrhenius equation compares rate constants at two temperatures?

A $\ln(k_2/k_1) = (Ea/R)(T_1 - T_2)$

B $\ln(k_2/k_1) = (Ea/R)(1/T_1 - 1/T_2)$

C $k_2/k_1 = Ea(T_2 - T_1)$

D $\ln(k_1/k_2) = (Ea/R)(1/T_1 - 1/T_2)$

> **Answer 534: B**
> This follows from subtracting the two logarithmic forms.

Temperature and Arrhenius · Hard

535. A reaction has k = 2.0 × 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 $8.6 \times 10^{-3}\ s^{-1}$

> **Answer 535: A**
> K rises by about 2.2-fold for this Ea.

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

> **Answer 536: D**
> E^(10 000/(8.314 × 300)) ≈ 55.

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

> **Answer 537: C**
> It is the fraction with energy above Ea.

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

> **Answer 538: B**
> Enzymes are more specific.

4. Set 4 · Q31–40

Radiocarbon dating · Hard

539. A bone retains 30% of the original ^{14}C ($t_{1/2}$ = 5730 y). About how old is it?

A About 9.96×10^3 years

B About 1.72×10^4 years

C About 5.7×10^3 years

D About 4.2×10^3 years

> **Answer 539: A**
> $T = \ln(100/30)/(0.693/5730) \approx 9960$ y.

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

> **Answer 540: D**
> Atmospheric ^{14}C has varied.

Radiocarbon dating · Easy

541. In what year did Libby receive the Nobel prize for radiocarbon dating?

A 1960

B 1978

C 1798

D 1910

> **Answer 541: A**
> The lecture dates it to 1960.

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

> **Answer 542: D**
> The short half-life limits the method.

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

> **Answer 543: C**
> It describes the activated complex in terms of bonding and structure.

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

> **Answer 544: B**
> It is the unstable arrangement between reactants and products.

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

> **Answer 545: C**
>
> TS1, an intermediate minimum, then TS2.

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

> **Answer 546: B**
>
> The deeper the drop, the more stable it is.

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

> **Answer 547: A**
>
> The lecture states TS1 is highest, so step one is rate-determining.

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

> **Answer 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

> **Answer 549: A**
> HCl is a strong acid.

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 $CH_3COOH + H_2O \rightleftharpoons CH_3OH + CO_2$

> **Answer 550: B**
> A weak acid dissociates only slightly.

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

> **Answer 551: C**
> Equilibrium is reached when the rates match.

Equilibrium constant · Devil

552. At equilibrium, $[N_2] = 0.50$ M, $[H_2] = 0.20$ M and $[NH_3] = 0.10$ M. What is K_c for $N_2 + 3H_2 \rightleftharpoons 2NH_3$?

A 0.40

B 25

C 0.025

D 2.5

> **Answer 552: D**
> $0.10^2/(0.50 \times 0.20^3) = 0.010/0.0040$.

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

> **Answer 553: C**
> They appear as exponents.

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 $K_p = 2P(NO_2)/P(N_2O_4)$

> **Answer 554: A**
> Products over reactants with coefficient exponents.

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

> **Answer 555: B**
> The net exponent of RT is products minus reactants.

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

> **Answer 556: D**
> $P(NO_2)^2 = 0.15 \times 0.60 = 0.090$, so P = 0.30.

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

> **Answer 557: D**
> Products are in the numerator.

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

> **Answer 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

> **Answer 559: A**
> K = 1 requires equal concentrations of A and 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

> **Answer 560: C**
> (1.0 × 1.0)/(0.50 × 0.50) = 4.0.

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

> **Answer 561: C**
> Limestone decomposes at 800 °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

> **Answer 562: D**
> Different phases make it 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 $K_p = P(CO_2)$ is fixed

C Lower than its original value at that temperature

D To zero, as all the CO_2 is consumed

> **Answer 563: B**
> Extra CO_2 reacts with CaO until K_p is restored.

Kp and Kc · Devil

564. At 400 K, $K_c = 0.10$ mol L^{-1} for $N_2O_4 \rightleftharpoons 2NO_2$. What is K_p ($R = 0.0821$ 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

> **Answer 564: A**
> $K_p = 0.10 \times (0.0821 \times 400)^1 = 3.3$.

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

> **Answer 565: A**
>
> Q compares product and reactant concentrations at any moment.

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

> **Answer 566: C**
>
> Q is compared with K to predict direction.

Equilibrium constant · Hard

567. For $H_2 + I_2 \rightleftharpoons 2HI$ with $K_c = 50$, $[H_2] = [I_2] = 0.10$ 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

> **Answer 567: B**
>
> $[HI]^2 = 50 \times 0.10 \times 0.10 = 0.50$, so $[HI] = 0.71$.

Equilibrium constant · Devil

568. $K_c = 50$ for $H_2 + I_2 \rightleftharpoons 2HI$. What is K_c 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

> **Answer 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

> **Answer 569: B**
>
> These are the five listed factors.

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

> **Answer 570: D**
>
> These changes disturb the equilibrium.

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

> **Answer 571: A**
>
> Added Fe^{3+} reacts with SCN^- to make more $FeSCN^{2+}$.

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

> **Answer 572: C**
>
> $FeSCN^{2+}$ dissociates to replace the lost Fe^{3+}.

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

> **Answer 573: A**
>
> Pressure matters mainly for gases.

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

> **Answer 574: D**
>
> The total pressure rises but partial pressures do not.

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

> **Answer 575: C**
>
> Partial pressure is mole fraction times total pressure.

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

> **Answer 576: B**
>
> Higher pressure favours fewer gas moles, and only temperature changes K.

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

> **Answer 577: A**
> A larger denominator lowers Q until it returns to K.

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

> **Answer 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

> **Answer 579: B**
> Cooling favours the exothermic reverse reaction.

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

> **Answer 580: C**
> The position is unchanged but reached faster.

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

> **Answer 581: B**
>
> The concentration stays constant.

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

> **Answer 582: D**
>
> Organisms regulate steady-state levels.

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

> **Answer 583: A**
>
> Transfer to tissues matches absorption.

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

> **Answer 584: C**
>
> The reaction is exothermic.

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

> **Answer 585: B**
>
> 2 + 1 = 3, forming two moles of gaseous product.

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

> **Answer 586: D**
>
> A reasonable rate is also needed.

Free energy and K · Hard

587. A reaction has $K = 1 \times 10^{-4}$ at 298 K. What can be said about ΔG°?

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

> **Answer 587: C**
>
> $\Delta G^\circ = -RT \ln K = -2.478 \times (-9.21)$ kJ/mol.

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

> **Answer 588: A**
>
> Compression raises concentrations first, then the shift towards fewer moles partly reverses it.