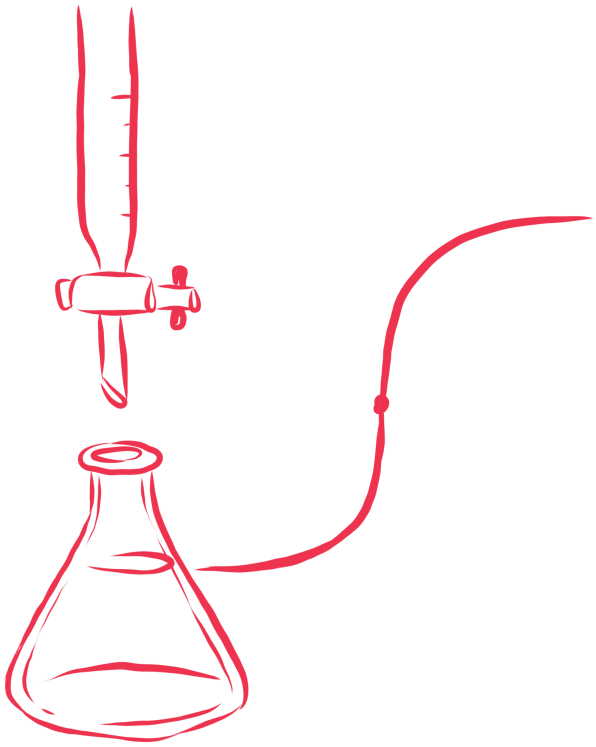


Ekvivalenspunkten

UVS Kemister

27 november 2025

UVS KEMISTER

Application and Information

Welcome to Ekvivalenspunkten 2025! We need the following information to correct your exam and to contact you if you are one of our winners:

Name: _____ **Last name:** _____
School: _____ **Telephone number:** _____
E-mail: _____ **Birth year:** _____
Locality: _____ **T-shirt size:** _____
Also remember to write your first and last name and school on all submitted sheets.

By participating in the competition, you become a member of UVS Kemister. This does not involve any fees or obligations for you, but it gives us the opportunity to apply for a government grant which is crucial for us to be able to carry out the competition.

☐ By checking this box, I agree to become a member of UVS Kemister until December 31, 2025.

The results of the competition will be published on https://kemi.ungvetenskapssport.se. If you wish to remain anonymous, we can publish your results under a pseudonym. If so, please fill in the line below.

Pseudonym: _____

The test is two hours long and consists of 11 questions, worth a total of 35 points. Each question and sub-question clearly indicates the number of points available.

Questions 1–7 are multiple choice. These must be answered on the answer sheet provided at the end of the test. Questions 8–11 are longer and include sub-questions. These should be answered on separate sheets of paper.

Please ensure that your solutions are written clearly. Write your first and last name, as well as your school, on every sheet you submit.

Your teacher will provide you with a formula sheet containing all the formulas needed for this test.

Before you begin, take a moment to read through all the questions carefully. Most importantly, do your best and enjoy the process!

1. (1 point) For the chemical reaction $A \rightarrow 2B$, what is the relationship below that correctly represents the concentration?

   A. $-\frac{\Delta[A]}{\Delta t} = \frac{\Delta[B]}{\Delta t}$ B. $-\frac{1}{2}\frac{\Delta[A]}{\Delta t} = \frac{\Delta[B]}{\Delta t}$ C. $-\frac{\Delta[A]}{\Delta t} = \frac{1}{2}\frac{\Delta[B]}{\Delta t}$ D. $-\frac{\Delta[A]}{\Delta t} = -2\frac{\Delta[B]}{\Delta t}$

2. (1 point) In a trapped container, the speed of CO_2 in 200 K is v. In the same container, with a temperature of 360 K, an unknown gas has a speed of 6v. What is the unknown gas? (Assume that all the gasses are ideal)

   A. H_2 B. N_2 C. Ar D. O_2

3. (1 point) If we combine 20 mL, 1 M of $AgNO_3$ aqueous solution and 20 mL, 1 M of KBr aqueous solution, we get AgBr and the temperature of the combined solution increases from $25°C$ to $35°C$. What is the reaction enthalpy in kJ/mol? (the density of the combined solution is 1 g/mL and the specific heat capacity is c = 4.2 $J/(K \times g)$)

   A. -84 B. 84 C. -168 D. 168

4. (1 point) Below is a chemical reaction $A + 3B \rightarrow 2C$
   If a mol of A and b mol of B reacted until completion, what can be said about the reaction?

   A. If B is the limiting reactant, then $b < \frac{a}{3}$
   B. If B is the limiting reactant, then the amount of C formed is $\frac{3}{2}b$
   C. If A is the limiting reactant, then $a < \frac{b}{3}$
   D. If A is the limiting reactant, then the amount of B left over in mol is $b - a$

5. (1 point) Out of a molecule with 100 C-H bonds, what is the molar mass of the smallest molecule?

   A. 652 g/mol B. 664 g/mol C. 676 g/mol D. 688 g/mol

6. (1 point) At 500°C are 0.1 mol of $H_2(g)$, 0.1 mol of $I_2(g)$ and 0.7 mol $HI(g)$ at equilibrium in a container of 1 L. If we add an additional 0.1 mol of $H_2(g)$ and 0.1 mol of $I_2(g)$ and the reaction goes to equilibrium, what is the closest value to the amount of $H_2(g)$ in this new equilibrium?

   A. 0.08 mol B. 0.12 mol C. 0.16 mol D. 0.20 mol

7. (1 point) For a molecule consisting of elements X and Z, the mass ratio between the elements in a molecule of A and B are shown below. If the empirical formula of A is X_2Z, what is the empirical formula of B?

Sample	X (%)	Z (%)
A	60.0	40.0
B	33.3	66.7

   A. XZ_2 B. XZ_3 C. X_2Z_3 D. X_2Z_5

8. (4 points) Compound A is a gas found in ordinary air. Gas A is important for photosynthesis. When magnesium burns in substance A, a mixture of a white substance B and a black substance C is formed. Substance B dissolves in dilute acids, while substance C is insoluble in dilute solutions of both acids and bases. Complete combustion of substance C in oxygen gives substance A. When magnesium burns in D, which is a common component of the atmosphere, substance E is formed. Substance E reacts with water to form magnesium hydroxide and a gas F that has a characteristic foul smell.

   (a) (2 points) Write the formulas for substances A–F.

   (b) (2 points) Write the four reaction equations for the formation of substances A, B, C, E, and F as described above.

9. (8 points) The NASA Artemis uses liquid oxygen (LOX) and liquid hydrogen fuel sources. These fuels ensure the rocket mass is low alongside their large enthalpy change of combustion enable a rocket to overcome gravity. In the rocket engine the fuel components are first vaporized before reacting to form water.

   (a) (1 point) Write an equation for the reaction between gaseous hydrogen and oxygen that forms gaseous water.

- Average bond enthalpies: H–H = 432 kJ/mol, O–H = 460 kJ/mol.
- Assume $\Delta H_{\text{rxn}} = -241$ kJ per mol H_2

(b) (1 point) Using the assumption above, calculate the bond enthalpy of the O=O bond in kJ/mol.

SpaceX's aim to colonise Mars leads to the choice of methane as an alternative to hydrogen. Methane can be formed using Mars' natural resources via the Sabatier process as the atmosphere of the planet is made up of 95.3% CO_2. In the Sabatier process methane and water are formed from the reaction of carbon dioxide and hydrogen gas.

(c) (1 point) Write an equation for the Sabatier process.

SpaceX has recently developed a new engine, the Raptor, that uses liquid methane and LOX. Energy is required to turn them into gaseous phase before they react.

- Enthalpy of vaporization at boiling point: $\Delta H_{\text{vap}}(CH_4) = 8.2$ kJ/mol, $\Delta H_{\text{vap}}(O_2) = 6.8$ kJ/mol.
- Standard enthalpy of combustion to gaseous products:
  $CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2\,H_2O(g)$,
  $\Delta H_{\text{comb}} = -890.8$ kJ/mol.

(d) (1 point) Calculate the net enthalpy change per mole of methane when starting from liquids (LCH_4 and LOX) that must be vaporized before reaction.

- Enthalpy of vaporization at boiling point: $\Delta H_{\text{vap}}(H_2) = 0.9$ kJ/mol, $\Delta H_{\text{vap}}(O_2) = 6.8$ kJ/mol.

(e) (1 point) Calculate the net enthalpy change for hydrogen/oxygen forming gaseous water, starting from liquid hydrogen and liquid oxygen that must be vaporized before reaction.

(f) (2 points) Compare hydrogen vs methane as rocket fuels on two bases:

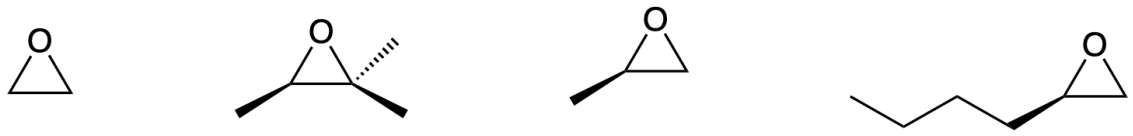
i. (1 point) Energy efficiency.

ii. (1 point) As fuels for future Mars colonies.

(g) (1 point) Does a rocket "save" energy by using liquid fuels that must be vaporized before combustion?

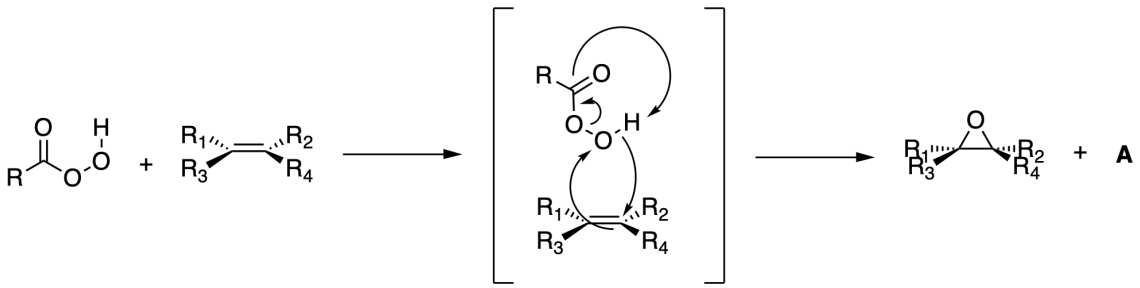
10. (9 points) Epoxy is an extremely durable and chemically resistant family of plastics. Epoxy has a variety of applications, including high-strength adhesives, carbon fiber and decorative furniture. Epoxy plastic is synthesised from epoxide molecules. An epoxide contains a three-membered ring with two carbon atoms and one oxygen atom. Epoxides are highly reactive due to ring strain in the three-membered ring.

Underneath are four examples of epoxides. The triangle in the molecule is the three-membered ring.



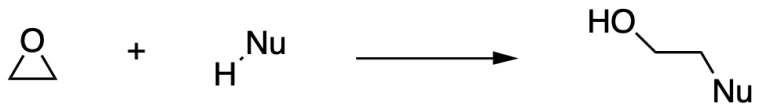
(a) (1 point) State the general formula of an epoxide that contains n carbon atoms

A common method form forming epoxides is the reaction of alkenes with organic peroxy acids. The mechanism for this reaction is shown down below, with the transition state given in the brackets.

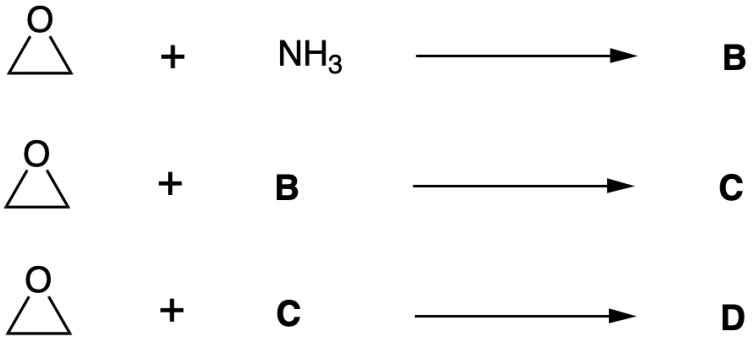


(b) (1 point) Draw the structure of compound **A**

When epoxides react with nucleophiles their three-membered ring opens, as shown in the general scheme, underneath.



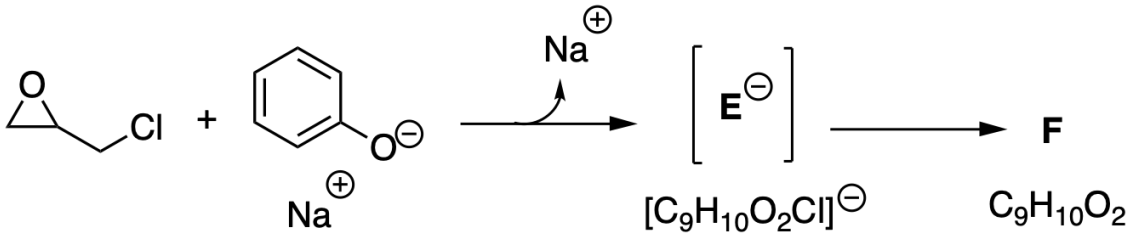
Some specific examples of the reaction of the simplest epoxide are shown below.



(c) (3 points) Draw the structures of compounds **B**, **C**, and **D**

(d) (2 points) Why is the first reaction faster then the third reaction?

A particularly useful epoxide is called epichlorohydrin (C_3H_5OCl). Sodium phenoxide reacts with epichlorohydrin to form intermediate anion $\mathbf{E}^-$, which then cyclises, forming product **F**



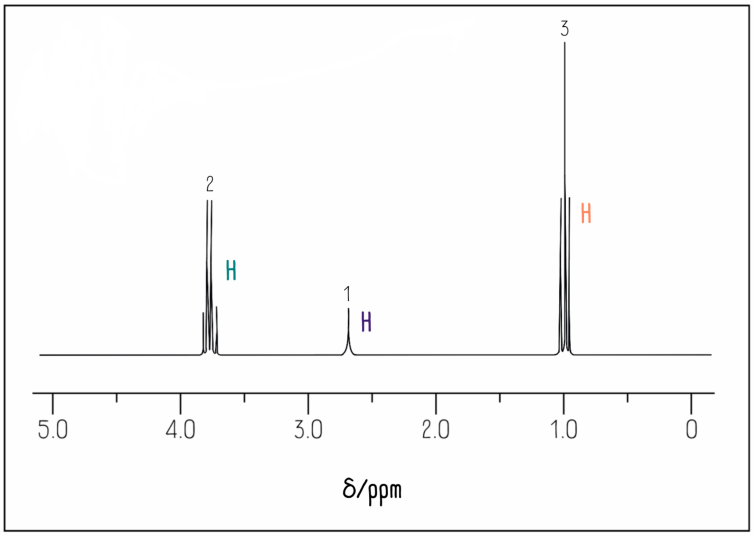
(e) (2 points) Draw the structure of intermediate anion $\mathbf{E}^-$ and compound **F**. Stereochemistry is not required.

11. (7 points) Introduction to Proton NMR

Proton NMR (Hydrogen Nuclear Magnetic Resonance) is a technique that shows signals for different types of hydrogen environments in a molecule. Each signal has three important features:

- **Chemical shift (ppm):** tells you about the environment of the hydrogen. Typical ranges: 0.9–1.5 (alkyl groups), 3.3–4.5 (hydrogens next to oxygen), 6–8.5 (aromatic rings).
- **Integration:** the area under a peak shows how many hydrogens that are in that environment. For example, a peak labeled "3" means three equivalent hydrogens.
- **Splitting rule:** A hydrogen signal is split into $n+1$ peaks, where n is the number of hydrogens on the adjacent carbon.
  Example: In CH_3–CH_2, the CH_3 "sees" 2 neighbors $\rightarrow$ *triplet*, and the CH_2 "sees" 3 neighbors $\rightarrow$ *quartet*.

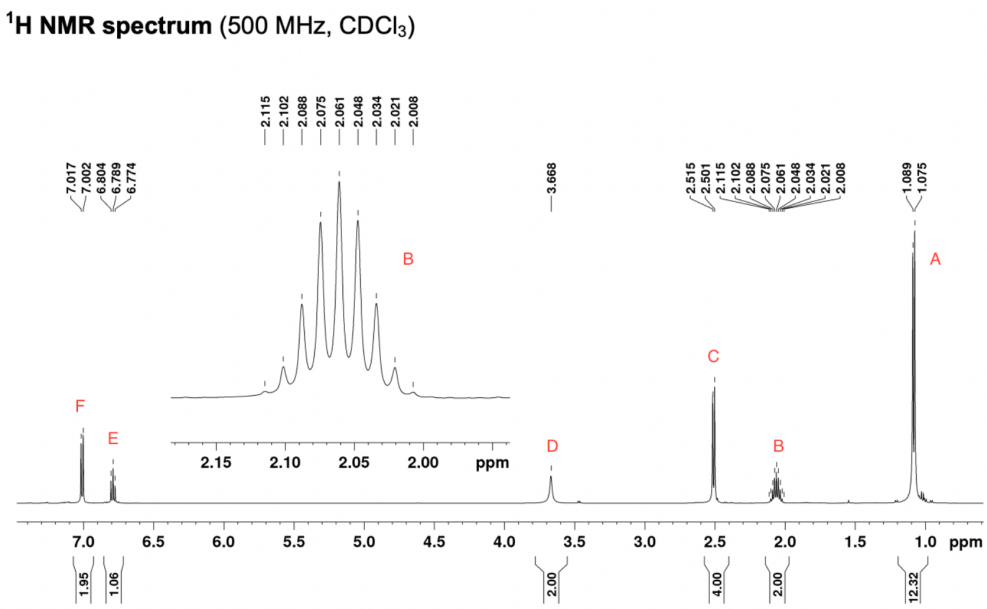
Below is a simplified proton NMR spectrum of an unknown compound with formula C_2H_6O:



The spectrum shows three signals:

- 1.20 ppm, triplet, integration 3
- 3.60 ppm, quartet, integration 2
- 2.60 ppm, broad singlet, integration 1

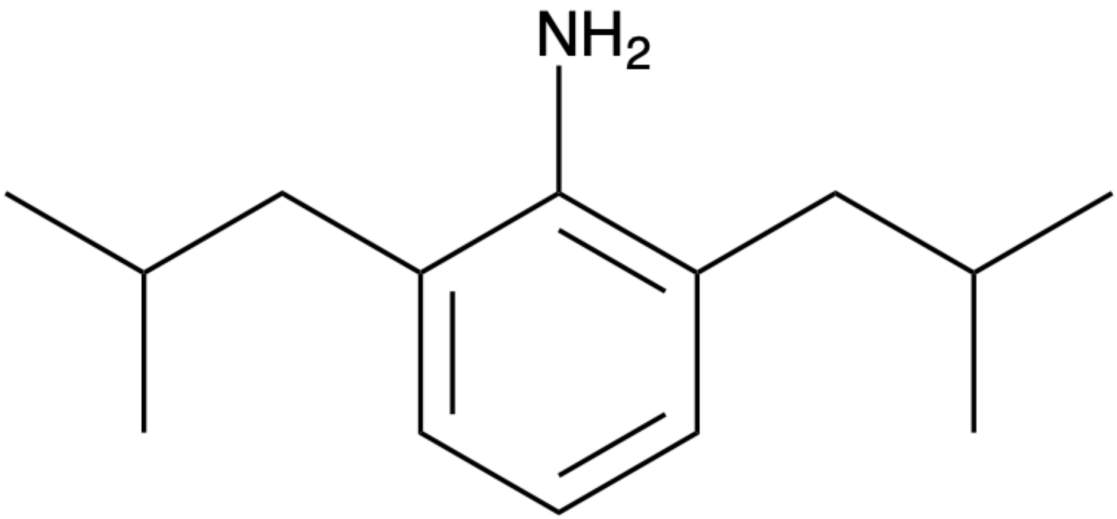
(a) (1 point) Using integration, how many hydrogens does each signal represent? Apply the n+1 rule to the triplet and quartet, which groups are neighbors? Which signal is likely adjacent to oxygen? Which is a simple alkyl group? Use ppm ranges. Using these help questions propose the structure.



The image above shows a HNMR spectrum from the molecule below. The different signals in the spectrum are labeled from A to F.

(b) (6 points) Match each signal (letter) with the hydrogens on the molecule down below.
On a separate paper! Do this by drawing the structure and put each letter on the molecule. Each letter can be placed in more then one place!

The number underneath each signal is the integration, for instance signal F has an integration of 2, 1.95 rounded up. And the amount of numbers above is the splitting, signal A has two numbers above so it's a doublet.



Answer Sheet

1. (1 point)
☐ A ☐ B ☐ C ☐ D

2. (1 point)
☐ A ☐ B ☐ C ☐ D

3. (1 point)
☐ A ☐ B ☐ C ☐ D

4. (1 point)
☐ A ☐ B ☐ C ☐ D

5. (1 point)
☐ A ☐ B ☐ C ☐ D

6. (1 point)
☐ A ☐ B ☐ C ☐ D

7. (1 point)
☐ A ☐ B ☐ C ☐ D

Remember, questions 8-11 should be answered on a separate sheet of paper. Remember to label each sheet with your first and last name and school.

Good Luck!