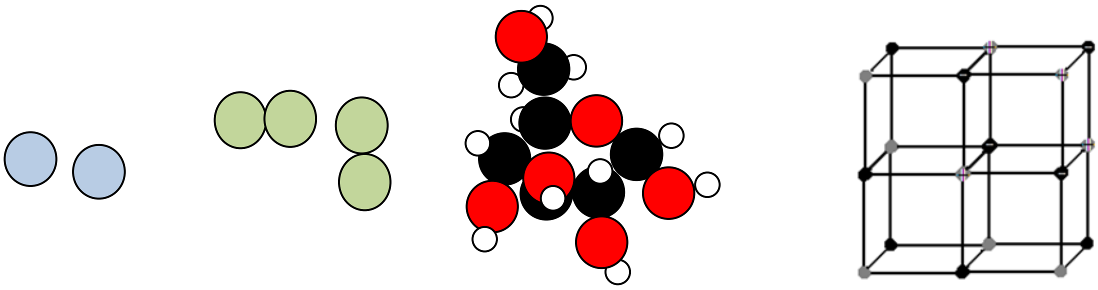
PURE SUBSTANCES AND MIXTURES

Substance

= form of a matter consisting of a great number of elementary particles: atoms, ions and ....

1. *Match the pictures of particles below with substances: glucose, salt, hydrogen, helium*



Substances differ in the kind of the particles they consist of. The type of particles and their arrangement determine the properties of the substances.

Substances may be classified according to their state of matter as solids, ..., ... and plasma (over 10^6 °C) or according to their origin as .... (minerals, ores, fats,…) and .... (PVC, Nylon).

Systems of substances

= all substances which fill a certain space.

- open – the exchange of both particles and energy is possible
- closed – only the exchange of .... is possible
- insulated – neither the exchange of .... nor that of .... is possible

- homogeneous – the same properties everywhere
- heterogeneous – different properties, consist of two or more homogeneous areas (phases)

2. *Give examples for each of the above type of systems.*

Pure substance

= a substance consisting of particles (atoms, molecules) of one kind (H_2O, NaCl, O_2, Fe).

Substances have constant properties – boiling point, melting point, density, etc.

Mixture

= a system consisting of particles of different kinds

- .... mixtures (solutions) – the size of particles < 10^{-9} m
- colloids - the size of particles is .... – .... m
- heterogeneous mixtures - the size of particles > 10^{-7} m

homogeneous ←	colloids	→

10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} (m)

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Heterogeneous mixtures:

Name of a mixture	Component of a mixture		Examples
	dispersing	dispersed	
	Liquid	Solid	
		Liquid	
		Gas	
	Gas	Liquid	
		Solid	

3. *Classify the following substances as pure substances or mixtures:*

salt water | *sodium hydroxide*
helium | *muddy water*
air free of dust | *hydrochloric acid*
steel | *cobalt (II) chloride*

Separating mixtures

4. *Fill in the missing words into the text about separating techniques.*

Evaporation

A solid substance may be separated from a solution by evaporating the solvent. (NaCl from water)

Filtering

An insoluble solid substance may be separated from a liquid or a gas using a filter. .... particles remain on the filter while .... or .... passes through the tiny holes in the filter. Solid particles = residue, liquid = ... This method is based on the different .... of particles.

http://www.youtube.com/watch?v=uET2jYuHIDM&feature=related%20Decanting

Decanting

An insoluble solid can be separated from .... by carefully pouring the liquid off leaving the solid behind. It is quicker than filtering, but not as good. It is based on the different .... of the substances.

Separating funnel

It serves for separating two immiscible liquids (..........................) e.g. oil and water. It is poured into a separating funnel and oil and water separate into two layers. Then the tap is opened and the heavier liquid (....................) is allowed to run out. The tap is closed before .... reaches the bottom.

Centrifuging

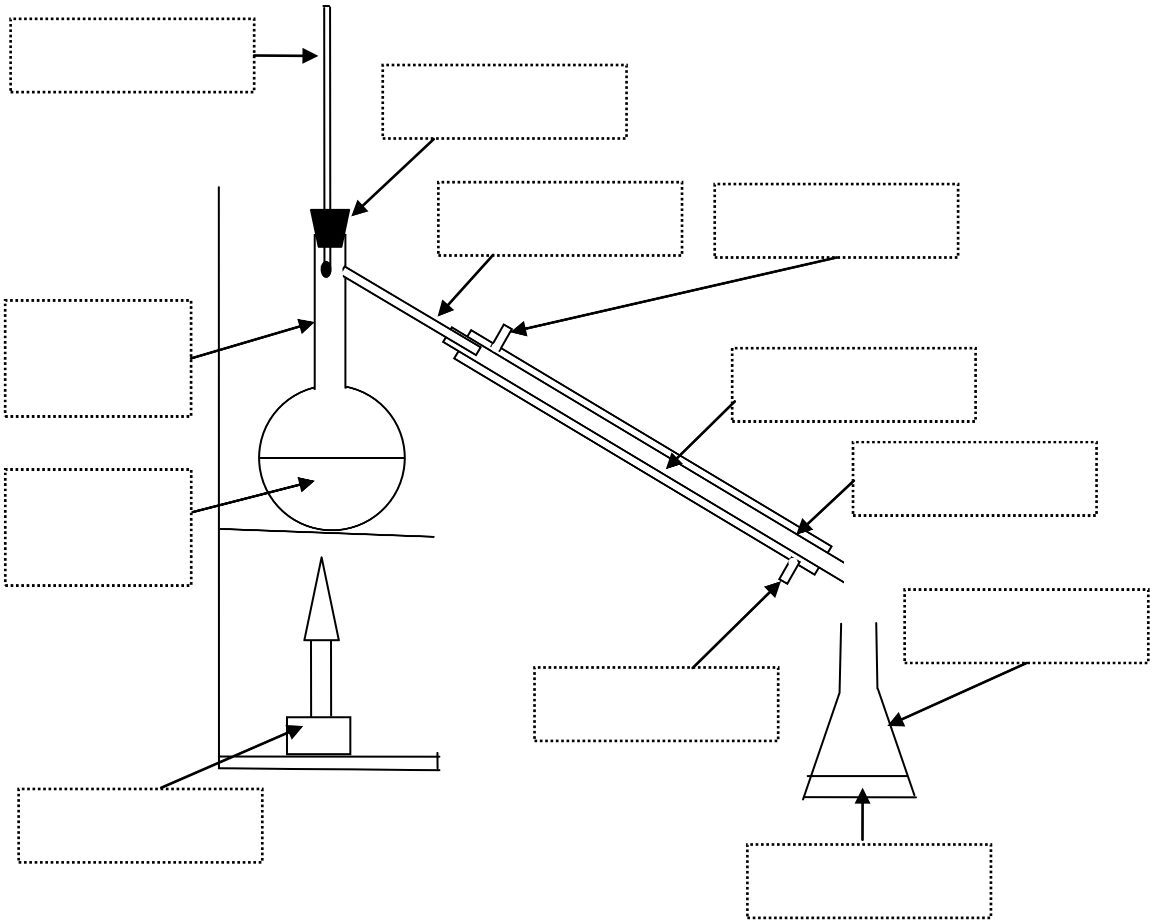
Containers with test tubes containing sample of suspension or emulsion are spun around. The *heavier/lighter* particles are flung to the bottom of the test tube. This is based on the same principle as .... The particles are separated with the help of .... force.

Distillation

Salt solutions or solutions of two or more liquids may be separated using distillation. It is based on different .... of substances mixed.

The salt solution in the flask is heated. The water part boils and becomes .... The steam passes into the .... where it is turned back to water which then drips into the collecting beaker.

The same principle is used for separating two liquids, e.g. ethanol and water. The one with the lower boiling point (.........................) evaporates sooner and goes to a condenser.



5. *Add labels to the parts of the distillation apparatus: DISTILLATE, STOPPER, THERMOMETER, DELIVERY TUBE, CONDENSER, ROUND BOTTOM FLASK, BURNER, MIXTURE, COLD WATER, WATER FROM THE TAP, WATER TO THE SINK, COLLECTING FLASK.*

However for better separating a so called **fractional distillation** is used. Both liquids evaporate when heated and pass into a fractionating .... (long tube packed with small glass beads, which provide a large surface area for the gases to condense and evaporate from). Only .... reaches the top of the column and condenses in the condenser.

http://www.youtube.com/watch?v=jAZOKMm-h_I&NR=1

6. *Find a mistake in the text about sublimation.*

Sublimation

It is a process during which a .... substance changes to a .... Very few substances sublimate, e.g. iodine, chlorine and naphthalene. A mixture of iodine and sand may be separated by gently heating it so that iodine turns into a gas leaving the sand behind. If a cold surface is held over the heated mixture, the iodine will turn back to a solid.

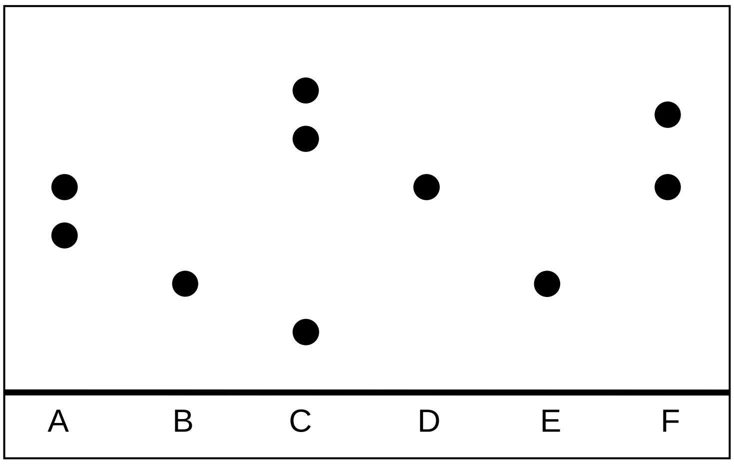
http://www.youtube.com/watch?v=E-fs9OwE9Y0

Chromatography

This technique was originally discovered when scientists were extracting coloured dyes from plants. A coloured extract is made from a mixture of different compounds. As the solvent soaks up the paper, the different coloured compounds follow it at different ...., so they gradually become separate. Chromatography serves not only for separating compounds but also for .... them.

http://www.youtube.com/watch?v=HVq5DMY2pJM&feature=related

7. *In the picture below there is a chromatogram of six substances A-F. Use it to state:*
    a. *Which of the substances A-F are mixtures and which are pure substances?*
    b. *Which of the substances A-F are identical?*
    c. *Which of the substances A, B, C, E, F contain the substance D?*



Extracting

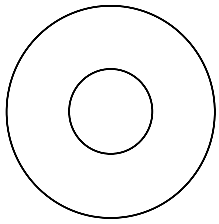
It is a technique based on different .... of the mixture components in a certain solvent. It is widely used for separating substances from biological material. E.g. coffein may be extracted from .... using liquid carbon dioxide as a .... The other substances causing the pleasant smell and taste of coffee are .... in CO_2 and stay in the coffee.

8. *What kind of mixtures are the following mixtures and how would you separate them?*

a. mixture of oil and water		
b. crude oil		
c. muddy water		
d. dust and air		
e. sugar and water		
f. a biological material containing pigments		
g. dyes forming the black ink of a marker		

BASIC CHEMISTRY TERMS AND QUANTITIES

Atom = a basic unit of a substance structure characterized by:



- **atomic number Z** = number of protons in the nucleus $_{8}O$, $_{13}Al$
- **mass number A** = number of protons + number of neutrons ^{16}O, ^{27}Al
- **neutron number N** = number of neutrons in the nucleus

$$N = A - Z$$

Molecule = a particle made of two or more atoms

Element = a substance made of atoms with the same number of protons

- atoms are not combined, e.g. ....
- atoms are combined into simple molecules, e.g. ....
- atoms are combined into a complicated structure forming a macromolecule, e.g. ....

Nuclide = an element made of atoms with the same mass number, e.g. $^{16}_{8}O$, $^{27}_{13}Al$, …

Isotopes = atoms of the same element with different masses, e.g. $^{1}_{1}H$, $^{2}_{1}H$, $^{3}_{1}H$

have the same number of electrons $\Rightarrow$ the same .... properties.

have different masses $\Rightarrow$ different .... properties.

9. Fill in the following table:

Symbol of an atom	$^{34}_{16}S$	$^{14}_{6}C$	^{23}Na		*Ga*
Number of p				*15*	
Number of n				*16*	*40*

Relative atomic mass A_r / *RAM*

The real masses of atoms are very small numbers, e.g. *m*(Na) = 3.83 × 10^{-23} g.

Because of the need to compare the masses of atoms **carbon-12** (= nuclide $^{12}_{6}C$) was chosen as a standard. (As it is solid, cheap, easily transported and stored, common element.)

$\boldsymbol{m_u} = \frac{m\,^{12}C}{12}$ = **atomic mass constant**, defined as one twelfth of the mass of an atom of carbon ^{12}C

m_u = average mass of a nucleon (a particle in the nucleus) = **1.66 ×10^{-24} g**

$\boldsymbol{A_r} = \frac{m(X)}{m_u}$ = **atomic relative mass** = how many times an atom is heavier than one nucleon

Atomic relative mass of pure isotopes equals the mass number, i.e. the number of nucleons, e.g. $A_r(^{35}Cl)$ = ..., $A_r(^{23}Na)$ = ...

A_r has no unit.

10. Calculate the real mass of ^{12}C.

11. Calculate the real mass of ^{208}Pb *and of* ^{120}Sn.

12. Calculate the relative atomic mass of an element knowing that the mass of its atom is 9.13 × 10^{-23} *g.*

13. An atom of an unknown element has the mass of 5.146 × 10^{-23} *g. What is this element?*

Naturally occurring elements consist of a mixture of isotopes, e.g. chlorine consists of 25% of ^{37}Cl and 75% of ^{35}Cl. Its average relative atomic mass may be calculated as follows:

A_r(Cl) = ... × 37 + ... × 35 = ...

Elements with one isotope only are e.g.: B, F, Na, P,...

Atomic relative masses of all elements are found in books of data.

14. Calculate the average atomic relative mass for:

a. Ga: 60% ^{69}Ga *+ 40%* ^{71}Ga

b. *Sb: 57.25% ^{121}Sb + 42.75% ^{123}Sb*

c. *S: 95% ^{32}S + 0.8% ^{33}S + 4.2% ^{34}S*

d. *Sr: 0.56% ^{84}Sr + 9.9% ^{86}Sr + 7% ^{87}Sr + 82.6% ^{88}Sr*

Relative molecular mass / Relative formula mass M_r

M_r is defined as: $M_r(A_xB_y) = \dfrac{m(A_xB_y)}{m_u}$

It may be calculated using relative atomic masses of individual elements:

$M_r(A_xB_y) = x \times A_r(A) + y \times A_r(B)$

It does not have any unit.

15. *Calculate the relative formula mass for the following substances:*

N_2	CH_3CHO
Na_2SO_3	$Fe_2(SO_4)_3$
$Ca(NO_3)_2$	$ZnSO_4 \cdot 7H_2O$

16. *Calculate the number of molecules of water iron(II) sulphate crystallizes with, knowing that the M_r of hydrated iron(II) sulphate is 277.85.*

17. *Calculate the mass of one molecule of:*
    a. *Propane*
    b. *sulphur trioxide*
    c. *ethanoic acid*
    d. *phosphorus pentachloride*

Amount of substance = number of moles *n*

This quantity was introduced because of the need to compare the number of .... in samples of substances as the real numbers of particles in samples chemists work with are very ...., e.g. in 10 ml of water there are 3.35×10^{23} molecules.

unit = mole (mol), 1 mole = number of atoms in 12 g of carbon-12 = 6.022×10^{23}

$n = \dfrac{N}{N_A}$, N … number of particles, N_A … Avogadro constant = 6.022×10^{23} mol^{-1}

1 mol of any substance contains .... particles.

18. *Calculate the number of moles of:*
    a. *1.5055×10^{24} phosphorus atoms*
    b. *1.2044×10^{23} chlorine molecules*

c. *3.011×10^{24} iron atoms*
d. *2.4088×10^{27} sodium atoms*

19. *What is the number of moles of oxygen atoms in 1.8066×10^{23} oxygen molecules?*

20. *What is the number of moles of phosphorus molecules in the sample of white phosphorus P_4 containing 20 moles of atoms? How many molecules are there?*

21. *What is the number of moles of:*
    a. *oxygen atoms in 1.2044×10^{25} water molecules?*
    b. *hydrogen atoms in 3.011×10^{23} water molecules?*

22. *How many molecules are there in:*
    a. *5 moles of methane?*
    b. *3.5 moles of chlorine?*
    c. *0.01 moles of ammonia?*

Molar mass M

= the mass of 1 mole of a substance, it is defined as $M = \frac{m}{n}$

The values of molar mass in $g \cdot mol^{-1}$ for elements and compounds are the same as the values of their A_r or M_r.

23. *What is the molar mass of:*
    a. *silver?*
    b. *ethane?*
    c. *sulphuric acid?*
    d. *oxygen?*
    e. *ozone?*
    f. *calcium sulphate?*
    g. *calcium phosphate?*
    h. *silver sulphide?*

24. *What is the number of moles in:*
    a. *8 g of helium?*
    b. *46 g of sodium?*
    c. *10 g of nitric acid?*
    d. *7.5 g of sulphur dioxide?*
    e. *12 g of hydrogen peroxide?*
    f. *0.4 g of sulphuric acid?*
    g. *3.2 g of hydrogen fluoride?*
    h. *1.6 g of chromium?*

25. *What is the mass of:*
    a. *0.1 mol of hydrogen sulphide?*
    e. *5 mol of silicon oxide?*

b. *2.5 mol of ethanol?*
c. *1.83 mol of sodium chloride?*
d. *3 mol of calcium hydroxide?*
f. *10 mol of magnesium carbonate*
g. *0.02 mol of nitric acid?*
h. *0.06 mol of hydrogen sulphide?*

26. *What is the mass of:*
    a. *4.2154×10^{25} molecules of ammonia?*
    b. *2×10^{24} molecules of bromine?*
    c. *3.7×10^{23} atoms of zinc?*
    d. *6.2×10^{24} molecules of ethanol?*
    e. *10^{26} molecules of methane?*
    f. *4.2×10^{24} atoms of fluorine*
    g. *8.5×10^{22} molecules of propane?*
    h. *0.2×10^{23} atoms of sulphur?*

27. *How many atoms are there in:*
    a. *6.4 g of gold?*
    b. *52 g of magnesium?*
    c. *12 g of iodine?*
    d. *100 g of water?*
    e. *0.4 g of oxygen?*
    f. *1 kg of iron?*
    g. *3.8 g of hydrogen bromide?*
    h. *50 g of nitric acid?*

28. *How many ions are there in 40 g of calcium fluoride?*

Molar volume V_m

Avogadro`s law: 1 mole of any gas occupies the volume of 22.4 dm^3 at standard temperature and pressure. s.t.p.= 0°C and 101kPa. V_m = 22.4 $dm^3 \cdot mol^{-1}$

(At the room temperature 25°C the gases occupy a volume of 24.4 dm^3.)

1 mol ≈ 22.4 dm^3 ≈ 6.023×10^{23} particles

$$V_m = \frac{V}{n}$$

29. *What is the volume of the following gases at s.t.p.?*
    a. *2 mol of fluorine*
    b. *1.8 mol of sulphur dioxide*
    c. *5 g of carbon dioxide*
    d. *0.01 g of argon*
    e. *10 mol of ammonia*
    f. *4.8 mol of propane*
    g. *1.5 g of neon*
    h. *0.3 g of methane*

30. *What is the number of moles of the following gases at s.t.p.?*
    a. *4 dm^3 of helium*
    b. *250 cm^3 of carbon monoxide*
    c. *50 dm^3 of ethane*
    d. *0.1 dm^3 of neon*

31. *What is the mass of the following gases at s.t.p.?*
    a. *7.5 dm^3 of chlorine*
    e. *9.4 dm^3 of oxygen*

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b. 12 dm^3 of butane
c. 460 cm^3 of hydrogen iodide
d. 50 cm^3 of propane
f. 82 dm^3 of hydrogen fluoride
g. 5 m^3 of nitrogen
h. 0.01 dm^3 of sulphur dioxide

32. What is the number of particles in the following gases at s.t.p.?
    a. molecules in 38 dm^3 of nitrogen dioxide
    b. atoms in 500 cm^3 of chlorine
    c. atoms in 15 dm^3 of dinitrogen monoxide
    d. molecules in 1 m^3 of hydrogen
    e. atoms in 1 m^3 of hydrogen
    f. atoms in 4 dm^3 of neon

33. What is the volume of the following gases at standard conditions?
    a. 9.034×10^{23} molecules of H_2
    b. 4.63×10^{24} molecules of ethane
    c. 2.89×10^{25} atoms of krypton
    d. 1.05×10^{24} molecules of nitrogen
    e. 5.82×10^{23} atoms of neon
    f. 7.91×10^{24} molecules of butane

Further questions:

1. An atom of an unknown element has a mass of 1.79×10^{-22} g. What element is it? (Ag)
2. What is the real mass of:
    a. one atom of bromine (1.326×10^{-22} g)
    b. one atom of vanadium (8.456×10^{-23} g)
    c. one molecule of formic acid (HCOOH) (7.636×10^{-23} g)
    d. one molecule of sulphur hexafluoride (SF_6)? (2.42×10^{-22} g)
3. Air consists of 21% of oxygen ($M_r(O_2) = 32$) and 78% of nitrogen ($M_r(N_2)=28$). Neglect all the other gases forming 1% of the air and calculate the average relative mass of air. (28.56)
4. $Na_2B_4O_7$ crystallizes with several water molecules. Find its amount knowing that the relative formula mass of hydrated $Na_2B_4O_7$ is 381.24. (10)
5. Gaseous nitrogen at standard conditions has the mass of 56 g. Calculate its number of moles, volume, number of molecules, number of atoms and density. (2 mol, 44.8 dm^3, 1.20×10^{24} molecules, 2.4×10^{24} atoms, 0.00125 $g{\cdot}cm^{-3}$)
6. How many atoms are there in 4 g of helium and what is its volume at s.t.p.? (6.022×10^{23} atoms, 22.4 dm^3)
7. Calculate the mass and the volume at s.t.p. of 2.7×10^{22} molecules of carbon dioxide. (1.97 g, 1 dm^3)
8. How many atoms are there in 56 g of sodium? (14.7×10^{23} atoms)
9. What is heavier: 1 dm^3 of CO_2 or 1 dm^3 of SO_3?
10. What is the volume of 0.25 moles of CO_2 at standard conditions? (5.6 dm^3)
11. How many molecules are contained in hexane C_6H_{14}, if its volume is 50 cm^3 and the density is 0.66 $g{\cdot}cm^{-3}$? (2.3×10^{23} molecules)

12. *Calculate the volume of 5.4 × 10^{23} molecules of benzene $C_6H_6(l)$, if the density of benzene is 0.88 g·cm^{-3}?* *(79.8 cm^3)*

Summary of the quantities and their units

Quantity	Symbol	Definition formula	Unit
Relative atomic mass			
	N		
Avogadro's constant			
			Mol
		$= \frac{m}{n}$	
			dm ^{3}, m^3, ml, l

SI units

Basic units: metre (m), kilogram (kg), second (s), amper (A), kelvin (K), mol (mol)

Units used in chemistry: 1 g = 10^{-3} kg

0^oC = 273.15 K

1 dm^3 = 10^{-3} m^3, 1 cm^3 = 10^{-6} m^3