Gleniffer High School

National 5

Properties of Matter

Summary Notes

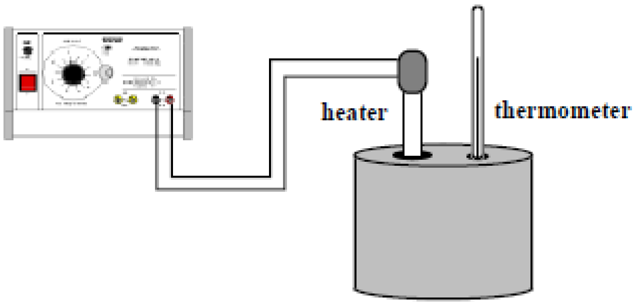
Name: ______________________________

SPECIFIC HEAT CAPACITY

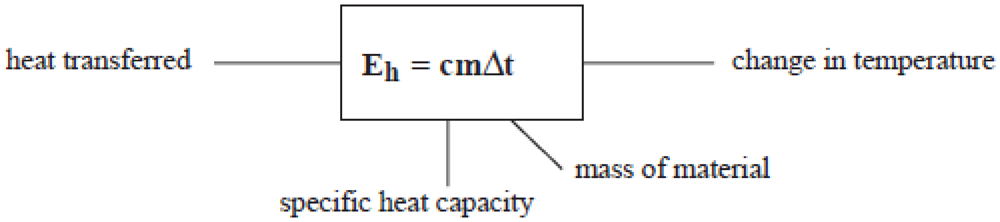
Temperature is a measure of how hot or cold something is. Temperature is measured in units called degrees Celsius (^0C).

Heat is a type of energy. Heat is measured in units called Joules (J) or kilojoules (kJ).

The following experiment could be carried out to show the heat energy required by one kilogram of a material to increase its temperature by 1^0C. This value is known as the material's **specific heat capacity (c).**



Specific heat capacity is calculated using the following equation:-



where,

E_h is heat energy measured in Joules (J)

c is specific heat capacity measured in Joules per kilogram degrees Celsius ($Jkg^{-1}{}^0C^{-1}$)

m is the mass measured in kilograms (kg)

ΔT is the change in temperature measured in degrees Celsius (^0C)

Example

When a kettle containing 2.5kg of water ($c_{water} = 4180Jkg^{-1}{}^0C^{-1}$) is heated from 20^0C to 80^0C, calculate the heat taken in by the water.

$E_h = ?$ $c_{water} = 4180Jkg^{-1}{}^0C^{-1}$ $m = 2.5kg$ $\Delta T = (80 - 20)$

$$E_h = c \times m \times \Delta T$$

$$E_h = 4180 \times 2.5 \times (80 - 20)$$

$$E_h = 4180 \times 2.5 \times 60$$

$$E_h = 627{,}000J$$

$$E_h = 627kJ$$

The table below contains the details of the Past Paper examples for this area of the course. Past Papers, and their solutions, are free to download from the SQA website.

Year	Section One	Section Two
2015	No examples	No examples
2016	No examples	3 not c)
2017	5	No examples
2018	No examples	8a) and b)
2019	No examples	7 b) i)

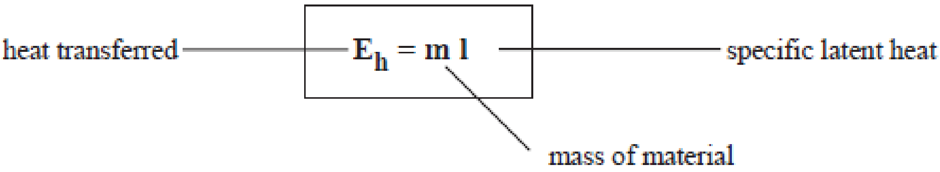
SPECIFIC LATENT HEAT

Changes of State

When ice at its melting point of 0 °C gains heat energy, it changes into water, also at 0 °C. When the process is reversed, water at its freezing point of 0 °C changes into ice at 0 °C. In this case energy is released with no change in temperature.

Specific Latent Heat

The specific latent heat of a substance is the energy involved in changing the state of 1 kg of the substance without any temperature change.
Specific latent heat of a substance is calculated using the formula:



$$\boxed{E_h = m\,l}$$

The specific latent heat of **vaporisation** is the heat energy required to change 1 kg of liquid to vapour without temperature change.
The specific latent heat of **fusion** is the heat energy required to change 1 kg of a solid to liquid without change in temperature.

The unit for specific latent heat is the joule per kilogram (Jkg^{-1})

Example

Ammonia of mass 5kg is vaporised using 13kJ of heat energy. Calculate the specific latent heat of vaporisation of ammonia.

E_h = 13kJ or 13,000J m = 5kg l = ?

$$E_h = m \times l$$

$$13{,}000 = 5 \times l$$

$$l = 2{,}600\,\text{Jkg}^{-1}$$

The table below contains the details of the Past Paper examples for this area of the course. Past Papers, and their solutions, are free to download from the SQA website.

Year	Section One	Section Two
2015	No examples	No examples
2016	19	No examples
2017	19	No examples
2018	16	8c)
2019	13	7 b)ii) and iii)

GAS LAWS and the KINETIC MODEL

Pressure

Pressure on a surface is defined as the force acting normal (perpendicular) to the surface.

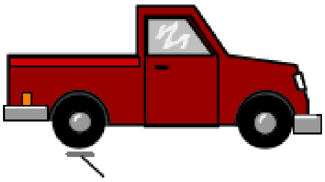
$$\boxed{p = \frac{F}{A}}$$

p = pressure in pascals, Pa
F = normal force in newtons, N
A = area in square metres, m^2

1 pascal is equivalent to 1 newton per square metre; ie 1 Pa = 1 N m^{-2}.

Example

Calculate the pressure exerted on the ground by a truck of mass 1600 kg if each wheel has an area of 0.02 m^2 *in contact* with the ground.



Total area $A = 4 \times 0.02 = 0.08\ m^2$
Normal force F = weight of truck = mg = 1600 × 9.8 = 15680 N

$p = ?$
$F = 15680\ N$
$A = 0.08\ m2$

$$p = \frac{F}{A} = \frac{15680}{0.08}$$

$$= 196{,}000\ Pa \text{ or } 196\ kPa$$

GAS LAWS

Kinetic Theory of Gases

The kinetic theory tries to explain the behaviour of gases using a model. The model considers a gas to be composed of a large number of very small particles which are far apart and which move randomly at high speeds, colliding elastically with everything they meet.

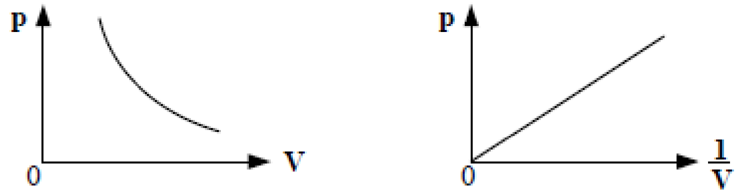
Volume	The volume of a gas is taken as the volume of the container. The volume occupied by the gas particles themselves is considered so small as to be negligible.
Temperature	The temperature of a gas depends on the kinetic energy of the gas particles. The faster the particles move, the greater their kinetic energy and the higher the temperature.
Pressure	The pressure of a gas is caused by the particles colliding with the walls of the container. The more frequent these collisions or the more violent these collisions, the greater will be the pressure.

Relationship Between Pressure and Volume of a Gas

For a fixed mass of gas at a constant temperature, the pressure of a gas is inversely proportional to its volume.

$$p \propto \frac{1}{V} \qquad p \times V = \text{constant} \qquad p_1 V_1 = p_2 V_2$$

Graph



Pressure - Volume (constant mass and temperature)

Consider a volume V of gas at a pressure p. If the volume of the container is reduced without a change in temperature, the particles of the gas will hit the walls of the container more often (but not any harder as their average kinetic energy has not changed). This will produce a larger force on the container walls. The area of the container walls will also reduce with reduced volume.
As volume decreases, then the force increases and area decreases resulting in, from the definition of pressure, an increase in pressure,
i.e. volume decreases hence pressure increases and vice versa.

Example

The pressure of a gas enclosed in a cylinder by a piston changes from 80kPa to 200kPa. If there is no change in temperature and the initial volume was 25litres, calculate the new volume.

$p_1 = 80\text{kPa} \quad V_1 = 25\text{l} \quad p_2 = 200\text{kPa} \quad V_2 = ?$

$$p_1V_1 = p_2V_2$$

$$80 \times 25 = 200 \times V_2$$

$$2000 = 200 \times V_2$$

$$V_2 = 10\text{l}$$

Kelvin Temperature Scale

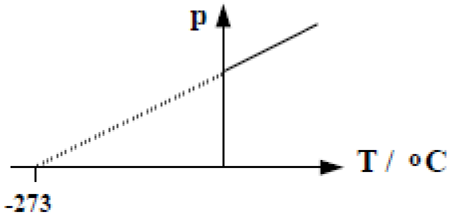
-273°C is called **absolute zero** and is the zero on the kelvin temperature scale. At a temperature of absolute zero, 0 K, all particle motion stops and this is therefore the lowest possible temperature.
One division on the kelvin temperature scale is the same size as one division on the celsius temperature scale, i.e. temperature **differences** are the same in kelvin as in degrees celsius, e.g. a temperature increase of 10°C is the same as a temperature increase of 10 K.
Note the unit of the kelvin scale is the kelvin, K, **not** degrees kelvin, °K!

Converting Temperatures Between °C and K

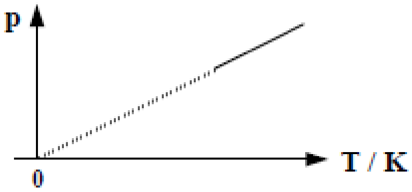
Converting °C to K	add 273
Converting K to °C	subtract 273

Relationship Between Pressure and Temperature of a Gas

If a graph is drawn of pressure against temperature in degrees celsius for a fixed mass of gas at a constant volume, the graph is a straight line which does not pass through the origin. When the graph is extended until the pressure reaches zero, it crosses the temperature axis at -273 °C. This is true for all gases.



If the graph of pressure against temperature is drawn using the kelvin temperature scale, zero on the graph is the zero on the kelvin temperature scale and the graph now goes through the origin.



For a fixed mass of gas at a constant volume, the pressure of a gas is directly proportional to its temperature measured in kelvin (K).

$$\boxed{p \propto T} \quad \boxed{\frac{p}{T} = \text{constant}} \quad \boxed{\frac{p_1}{T_1} = \frac{p_2}{T_2}}$$

Pressure - Temperature (constant mass and volume)

Consider a gas at a pressure p and temperature T. If the temperature of the gas is increased, the kinetic energy and hence speed of the particles of the gas increases. The particles collide with the container walls more violently and more often. This will produce a larger force on the container walls.

As temperature increases, then the force increases resulting in, from the definition of pressure, an increase in pressure,

i.e. temperature increases hence pressure increases and vice versa.

Example

Hydrogen in a sealed container at 27^0C has a pressure of 1.8×10^5Pa. If it is heated to a temperature of 77^0C, what is its new pressure?

$p_1 = 1.8 \times 10^5\text{Pa} \quad T_1 = 27^0\text{C} = 300\text{K} \quad p_2 = ? \quad T_2 = 77^0\text{C} = 350\text{K}$

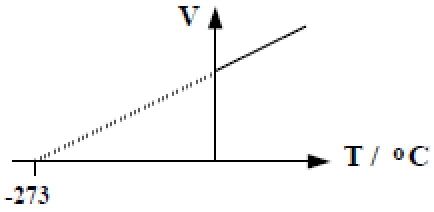
$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$1.8 \times 10^5 \; / \; 300 = p_2 \; / \; 350$$

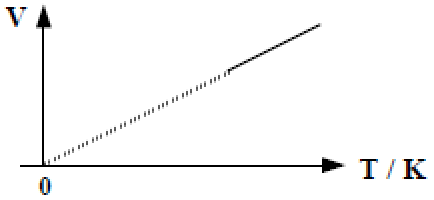
$$p_2 = 2.1 \times 10^5\text{Pa}$$

Relationship Between Volume and Temperature of a Gas

If a graph is drawn of volume against temperature, in degrees celsius, for a fixed mass of gas at a constant pressure, the graph is a straight line which does not pass through the origin. When the graph is extended until the volume reaches zero, again it crosses the temperature axis at -273 °C. This is true for all gases.



If the graph of volume against temperature is drawn using the kelvin temperature scale, the graph now goes through the origin.

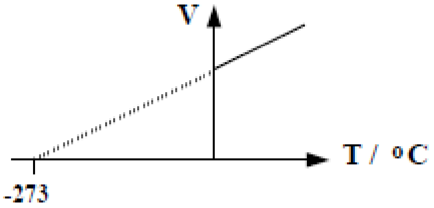


For a fixed mass of gas at a constant pressure, the volume of a gas is directly proportional to its temperature measured in kelvin (K).

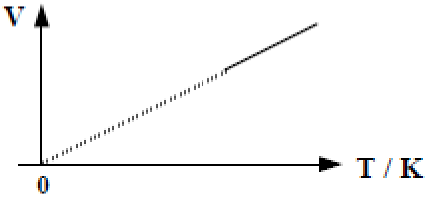
$$\boxed{V \propto T} \qquad \boxed{\frac{V}{T} = \text{constant}} \qquad \boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

Relationship Between Volume and Temperature of a Gas

If a graph is drawn of volume against temperature, in degrees celsius, for a fixed mass of gas at a constant pressure, the graph is a straight line which does not pass through the origin. When the graph is extended until the volume reaches zero, again it crosses the temperature axis at -273 °C. This is true for all gases.



If the graph of volume against temperature is drawn using the kelvin temperature scale, the graph now goes through the origin.



For a fixed mass of gas at a constant pressure, the volume of a gas is directly proportional to its temperature measured in kelvin (K).

$$\boxed{V \propto T} \qquad \boxed{\frac{V}{T} = \text{constant}} \qquad \boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

Volume - Temperature (constant mass and pressure)

Consider a volume V of gas at a temperature T. If the temperature of the gas is increased, the kinetic energy and hence speed of the particles of the gas increases. If the volume was to remain constant, an increase in pressure would result as explained above. If the pressure is to remain constant, then the volume of the gas must increase to increase the area of the container walls that the increased force is acting on, i.e. volume decreases hence pressure increases and vice versa.

Example

400 cm^3 of air is at a temperature of 20 °C. At what temperature will the volume be 500 cm^3 if the air pressure does not change?

$V_1 = 400\ cm^3$
$T_1 = 20\ °C = 293\ K$
$V_2 = 500\ cm^3$
$T_2 = ?$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad \frac{400}{293} = \frac{500}{T_2}$$

$T_2 = 366\ K = 93\ °C$ *(convert back to temperature scale in the question)*

Combined Gas Equation

By combining the above three relationships, the following relationship for the pressure, volume and temperature of a fixed mass of gas is true for all gases.

$$\boxed{\frac{p \times V}{1} = \text{constant}}$$

$$\boxed{\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}}$$

Example

A balloon contains 1.5m^3 of helium at a pressure of 100kPa and at a temperature of 27^{0}C. If the pressure is increased to 250kPa at a temperature of 127^{0}C, calculate the new volume of the balloon. (Remember to convert temperatures to the Kelvin scale before using them in the equation.)

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$\frac{100 \times 1.5}{300} = \frac{200 \times V}{400}$$

$$V_2 = 0.8\ \text{m}^3$$

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2015	5 and 6	5d)
2016	5, 6 and 7	No examples
2017	6 and 7	3
2018	17, 18 and 19	1b) and 9
2019	15 and 16	8

Prefix	Symbol	Factor
tera	T	1000000000000 = 10^{12}
giga	G	1000000000 = 10^{9}
mega	M	1000000 = 10^{6}
kilo	k	1000 = 10^{3}
hecto	h	100 = 10^{2}
		1 = 10^{0}
deci	d	0.1 = 10^{-1}
centi	c	0.01 = 10^{-2}
milli	m	0.001 = 10^{-3}
micro	μ	0.000001 = 10^{-6}
nano	n	0.000000001 = 10^{-9}
pico	p	0.000000000001 = 10^{-12}

Scientific Notation

Scientific Notation or **standard form** is a way of expressing a number in terms of power of ten. In other words, it's expressed in the form

$$a \times 10^{n}$$

where a is a real number that satisfies $1 \leq |a| < 10$ and n is an integer. a is called the *significand* and n is called the *exponent*.

Please note that the absolute value of a must be at least 1 and less than 10, hence 0.34×10^{2} and -11.23×10^{4} are not in standard form.

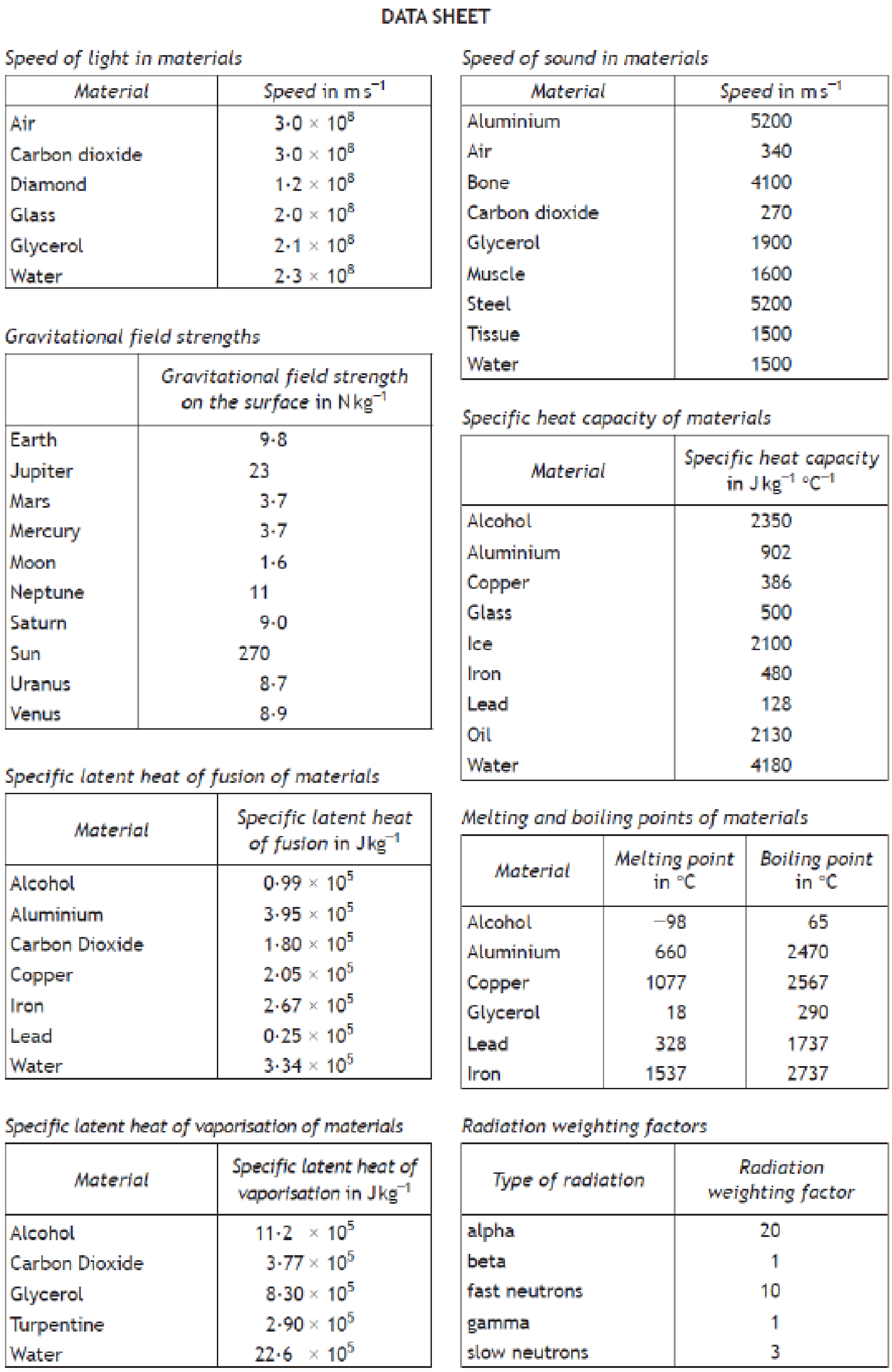
Examples of converting numbers to scientific notation

- 1234 becomes 1.234×10^{3}
- -0.000023 becomes -2.3×10^{-5}
- 50000000 becomes 5×10^{7}

Rounding

Some decimal numbers go on for ever! To simplify their use, we decide on a cut off point and "round" them up or down.
If we want to round 2.734216 to two decimal places, we look at the number in the third place after the decimal, in this case, 4. If the number is 0, 1, 2, 3 or 4, we leave the last figure before the cut off as it is. If the number is 5, 6, 7, 8 or 9 we "round up" the last figure before the cut off by one. 2.734216 therefore becomes 2.73 when rounded to 2 decimal places.

If we are rounding to 2 decimal places, we leave 2 numbers to the right of the decimal.
If we are rounding to 2 significant figures, we leave two numbers, whether they are decimals or not.



DATA SHEET

Speed of light in materials

Material	*Speed in* m s^{-1}
Air	$3{\cdot}0 \times 10^{8}$
Carbon dioxide	$3{\cdot}0 \times 10^{8}$
Diamond	$1{\cdot}2 \times 10^{8}$
Glass	$2{\cdot}0 \times 10^{8}$
Glycerol	$2{\cdot}1 \times 10^{8}$
Water	$2{\cdot}3 \times 10^{8}$

Gravitational field strengths

	Gravitational field strength on the surface in N kg^{-1}
Earth	9·8
Jupiter	23
Mars	3·7
Mercury	3·7
Moon	1·6
Neptune	11
Saturn	9·0
Sun	270
Uranus	8·7
Venus	8·9

Specific latent heat of fusion of materials

Material	*Specific latent heat of fusion* in J kg^{-1}
Alcohol	$0{\cdot}99 \times 10^{5}$
Aluminium	$3{\cdot}95 \times 10^{5}$
Carbon Dioxide	$1{\cdot}80 \times 10^{5}$
Copper	$2{\cdot}05 \times 10^{5}$
Iron	$2{\cdot}67 \times 10^{5}$
Lead	$0{\cdot}25 \times 10^{5}$
Water	$3{\cdot}34 \times 10^{5}$

Specific latent heat of vaporisation of materials

Material	*Specific latent heat of vaporisation* in J kg^{-1}
Alcohol	$11{\cdot}2 \times 10^{5}$
Carbon Dioxide	$3{\cdot}77 \times 10^{5}$
Glycerol	$8{\cdot}30 \times 10^{5}$
Turpentine	$2{\cdot}90 \times 10^{5}$
Water	$22{\cdot}6 \times 10^{5}$

Speed of sound in materials

Material	*Speed in* m s^{-1}
Aluminium	5200
Air	340
Bone	4100
Carbon dioxide	270
Glycerol	1900
Muscle	1600
Steel	5200
Tissue	1500
Water	1500

Specific heat capacity of materials

Material	*Specific heat capacity* in J kg^{-1} °C^{-1}
Alcohol	2350
Aluminium	902
Copper	386
Glass	500
Ice	2100
Iron	480
Lead	128
Oil	2130
Water	4180

Melting and boiling points of materials

Material	*Melting point* in °C	*Boiling point* in °C
Alcohol	−98	65
Aluminium	660	2470
Copper	1077	2567
Glycerol	18	290
Lead	328	1737
Iron	1537	2737

Radiation weighting factors

Type of radiation	*Radiation weighting factor*
alpha	20
beta	1
fast neutrons	10
gamma	1
slow neutrons	3

$$P = \frac{E}{t}$$

$$E_h = ml$$

$$E_h = cm\Delta T$$

$$p = \frac{F}{A}$$

$$\frac{pV}{T} = \text{constant}$$

$$p_1V_1 = p_2V_2$$

$$\frac{p_1}{T_1} = \frac{p_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$