中国科学院研究生院（金属研究所）
2011 年招收攻读硕士学位研究生复试专业综合试题

考生须知：

1. 本试卷满分为 100 分，全部考试时间总计 180 分钟。
2. 所有答案必须写在答题纸上，写在试题纸上或草稿纸上一律无效。

必答题（共 60 分）

一、请解释下列概念(任选 6 题，每题 2 分，共 12 分)

堆垛层错；反应扩散；共晶反应；浓差电池；弹性变形；纳米材料；能量守恒；相变；比热。

二、10 瓶药片，其中 9 瓶每片 5 克，只有 1 瓶每片 6 克，请用天平只称 1 次，找出装有 6 克药片的药瓶。（4 分）

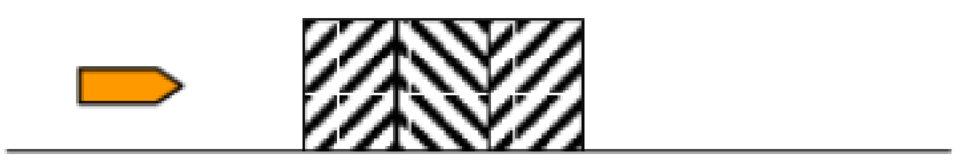
三、1 公斤炸药爆炸后释放的能量与 1 公斤木材燃烧释放的能量差不多，为什么炸药显得威力巨大？(5 分)

四、单晶、多晶、纳米晶和非晶金属结构上主要差别是什么？（5 分）

五、用 X 光衍射对一块金属镍进行分析，相应衍射图谱与标准图谱比对后，发现衍射峰对应的衍射角发生偏移，请解释导致该现象产生的可能原因。（6 分）

六、钠是一种银白色金属，很软，露置在空气中，很快会生成氧化钠；钠块投入水中，能浮在水面上，并发生剧烈反应，生成氢氧化钠和氢气，反应释放的热量使金属钠块熔化成小球，并快速消失，因此，金属钠通常保存在煤油中。阅读上文后，归纳金属钠的物理和化学性质各有哪些？(6 分)

七、子弹水平飞行，先后穿过三块完全相同的静止并固定在地面上的木块后速度恰好为零（见下图)，问子弹在射入每个木块前的速度之比为多少？子弹穿过每个木块所用时间之比为多少？(6 分)



八、结合插图阅读下文后回答下列问题：沸水反应堆的发电原理？裂变原理？ 如何控制裂变反应？避免核燃料熔化的途径有哪些？（8 分）

请以本文为素材，写一篇 200 字以下的短文来论证核电安全问题。（8 分）文章内容详见附页。

选答题（请从以下四类中任选一类，共 40 分）

材料类（共 40 分）

一、名词解释（每题 1 分，共 5 分）

离异共晶；倒易点阵；调幅分解；扩散蠕变；形变织构。

二、简答题（每题 2.5 分，共 10 分）

1. 简述间隙相和间隙化合物的异同。
2. 简述晶体的生长方式和机制。
3. α-Fe 和 Mg 相比谁的塑性好，为什么？
4. 合金强化的方法有几种？比较各方法的优缺点。

三、分析题（每题 5 分，共 25 分）

1. 区域熔炼法可用于对金属进行提纯，试推导当溶质平衡分配系数 k 小于 1 时，溶质含量为 C_0、长度为 L 的金属棒经第一次区域熔炼提纯后溶质浓度沿棒轴向的分布。
2. 什么是 Lomer-Cottrell 位错？
3. 说明马氏体相变的晶体学特征和生长机制。
4. 合金相图反映了一些什么关系？如何利用热力学计算相图？
5. 分析第二相颗粒尺寸对位错运动的阻碍效应和对位错运动方式的影响。

物理类（共 40 分）

一、概念题（每题 3 分，共 15 分）

测不准原理；德布罗意波；色散关系；赝势、全势；声子。

二、试述导体、半导体、绝缘体能带结构的异同？（5 分）

三、吉布斯自由能降低的反应是否一定会发生？为什么？（5 分）

四、两块温度不同的同种金属接触后，在温度未达到相等前， 是否存在电势差？ 为什么？（3 分）

五、紧束缚模型电子的能量是正值还是负值？（3 分）

六、如果将组成固体的所有原子分散到无限远处（即每两个原子之间的相互作用力可以忽略），由这些无限远处的原子组成的体系与固体相比，总能量高还是低？并说明其原因？（3 分）

七、能否用实验的方法测出量子力学方程，如$\left[-\frac{h^2}{2m}\nabla^2+V(r)\right]\varphi(r)=E\varphi(r)$的本征值 E？为什么？（3 分）

八、什么叫布里渊区？为什么在量子力学中经常在第一布里渊区中处理问题，根据是什么？（3 分）

加工类（共 40 分）

一、概念题（每题 2 分，共 10 分）

动态回复；均匀退火；微观偏析；相变超塑性；摩擦焊。

二、简答题（每题 4 分，共 12 分）

1. 指出金属材料冷锻和热锻内部组织各发生了什么变化？
2. 碳当量对焊接冷裂纹敏感性的影响？
3. 如何在铸件中获得细小等轴晶？

三、分析题（每题 6 分，共 18 分）

1. 说出大型铸件的凝固特征及组织特征，给出常见铸造缺陷，并指出可以通过什么办法分别消除？
2. 金属材料热锻成形过程中，一般会有硬化现象或软化现象发生，请分析原因。
3. 如何初步判定材料的焊接性？试验方法有哪些？

化学类（共 40 分）

一、选择题（共 16 分）

1. 一个反应达到平衡的标志是（　）（2 分）

A、各反应物和生成物的浓度等于常数。

B、各反应物和生成物的浓度相等。

C、各反应物的浓度不随时间改变。

D、正逆反应的速率常数相等。

2. 从锰在酸性介质中的电极电势图可以看出酸性介质中会发生岐化反应的物质是（　）（2 分）

$$MnO_4^- \xrightarrow{0.56} MnO_4^{2-} \xrightarrow{2.24} MnO_2 \xrightarrow{0.95} Mn^{3+} \xrightarrow{1.5} Mn^{2+} \xrightarrow{-1.18} Mn$$

A、MnO_4^-　　B、MnO_4^{2-}　　C、MnO_2　　D、Mn^{2+}

3. 下列化合物中不水解的是（　）（2 分）

A、CCl_4　　B、$SiCl_4$　　C、BCl_3　　D、PCl_5

4. 对于催化剂特性的描述不正确的是（　）（2 分）

A、催化剂是能缩短达到平衡的时间，而不能改变平衡的状态。

B、催化剂在反应前后化学性质和物理性质均不变。

C、催化剂不能改变平衡常数。

D、加入催化剂不能实现热力学上不能进行的反应。

5. 下列与浓盐酸反应没有氯气放出的是（ ） （2 分）

A、PbO_2 B、Fe_2O_3 C、CO_2O_3 D、Ni_2O_3

6. 常温下，单质 F_2、Cl_2 是气体，Br_2 是液体，I_2 是固体，这是因为（ ）（2 分）

A、分子间取向力由 $F_2 \rightarrow I_2$ 递增

B、分子间色散力由 $F_2 \rightarrow I_2$ 递增

C、单质的密度由 $F_2 \rightarrow I_2$ 递增

7. 不能用蒸馏手段浓缩制备氢卤酸，其原因是（ ）（2 分）

A、挥发性物质

B、高沸点物质

C、恒沸物质

8. Sn 和 Pb 都有+2 和+4 氧化态，但 Sn 以+4 态稳定，Pb 以+2 态稳定，其原因是（ ）（2 分）

A、电荷效应

B、惰性电子对效应

C、离子半径差别

二、判断正误（共 4 分）

1. 规定最稳定单质的 $\Delta_f H_m^\Theta=0$，$\Delta G_{fm}^\Theta=0$，$S_m^\Theta=0$。（ ）（2 分）

2. 主量子数 n=1 的电子层内，有自旋相反的两个轨道。（ ）（2 分）

三、填空（共 4 分）

1. 在 $K[Co(C_2O_4)_2en]$中，中心离子的配位数是______________。（2 分）

2. 双氧水做氧化剂的产物是______________。（2 分）

四、问答题（6 分）

实验已经确定了反应 $2NO(g)+Br_2(g) \rightarrow 2NOBr(g)$ 的速率方程为：$\gamma=[NO]^2[Br_2]$

1. 下列反应机理中哪一个或几个是可能的？（2 分）

2. 如果有多个可能的机理，其中哪一个的可能性最大？说明原因。（4 分）

机理 1: $NO+NO+Br_2 \rightarrow 2NOBr$ 慢

机理 2: $NO+Br_2 \xrightarrow{K1} NOBr_2$ 慢

$NOBr_2 + NO \xrightarrow{K_L} 2NOBr$　快

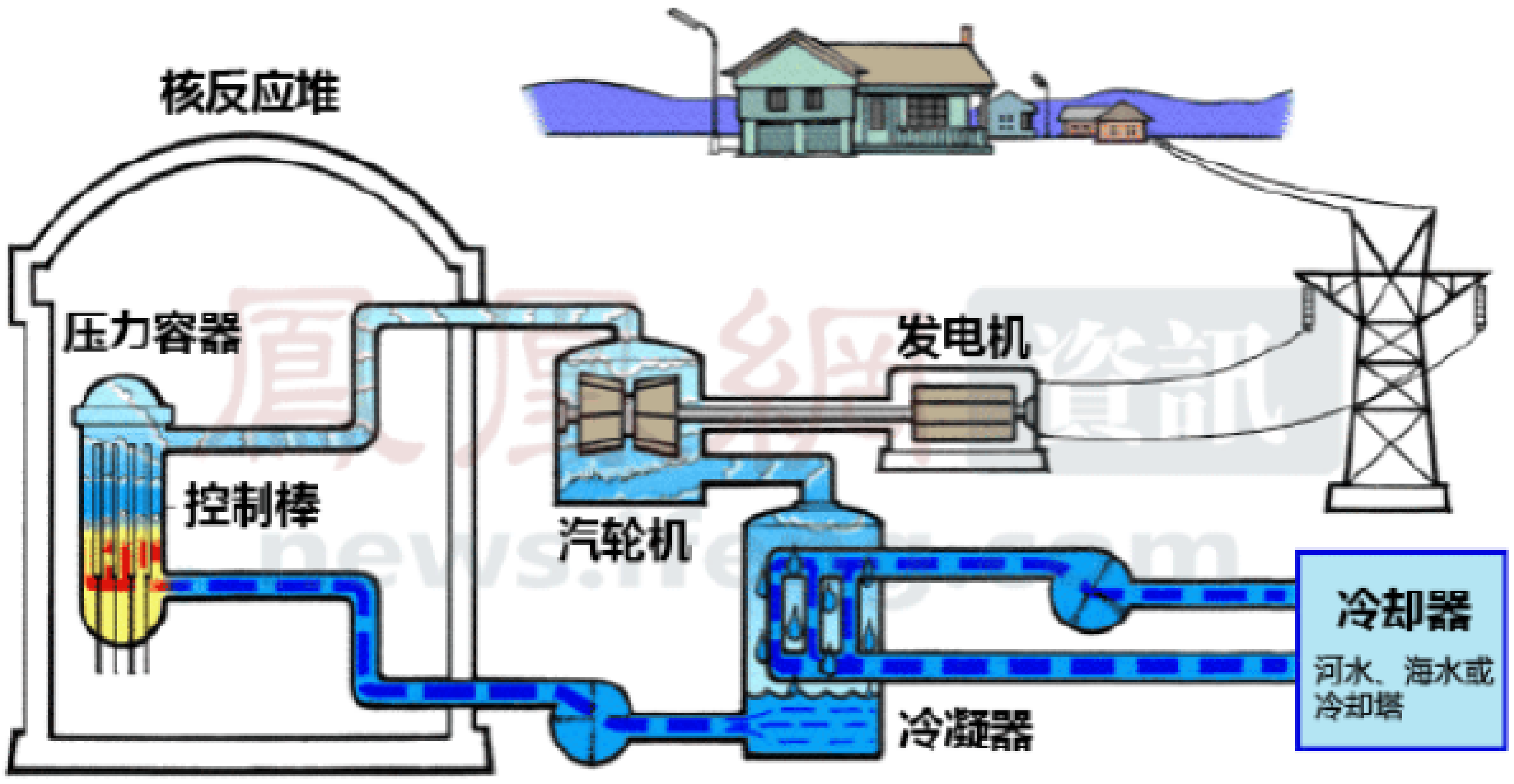
机理 3:　$NO + Br_2 \underset{K-1}{\overset{K_1}{\rightleftharpoons}} NOBr_2$　　快

$NOBr_2 + NO \xrightarrow{K_L} 2NOBr$　慢

五、如何从含有 Al^{3+}、Cr^{3+}和 Fe^{3+}的溶液中分离出来上述三种物质？（5 分）

六、通过计算说明将 20ml、0.002ml/L 的 Na_2SO_4 溶液和 10ml、0.02ml/L 的 $BaCl_2$ 溶液混合，有无沉淀产生？(已知 Ksp，$BaSO_4$=1.1 $\times 10^{-10}$)（5 分）

附页，共 4 页，用于必答题第八题。



Why I am not worried about Japan's nuclear reactors

I am writing this text (Mar 12) to give you some peace of mind regarding some of the troubles in Japan, that is the safety of Japan's nuclear reactors（核反应堆）. Up front, the situation is serious, but under control. And this text is long! But you will know more about nuclear power plants after reading it than all journalists on this planet put together.

There was and will *not* be any significant release of radioactivity.

By "significant" I mean a level of radiation of more than what you would receive on – say – a long distance flight, or drinking a glass of beer that comes from certain areas with high levels of natural background radiation.

I have been reading every news release on the incident since the earthquake. There has not been one single (!) report that was accurate and free of errors (and part of that problem is also a weakness in the Japanese crisis communication). By "not free of errors" I do not refer to tendentious anti-nuclear journalism – that is quite normal these days. By "not free of errors" I mean blatant errors regarding physics and natural law, as well as gross misinterpretation of facts, due to an obvious lack of fundamental and basic understanding of the way nuclear reactors are built and operated. I have read a 3 page report on CNN where every single paragraph contained an error.

We will have to cover some fundamentals, before we get into what is going on.

The plants at Fukushima（福岛）are so called Boiling Water Reactors, or BWR for short. Boiling Water Reactors are similar to a pressure cooker. The nuclear fuel heats water, the water boils and creates steam, the steam then drives turbines （汽轮机）that create the electricity, and the steam is then cooled and condensed back to water, and the water send back to be heated by the nuclear fuel. The pressure cooker operates at about 250 °C.

The nuclear fuel is uranium（铀） oxide. Uranium oxide is a ceramic（陶瓷） with a very high melting point of about 3000 °C. The fuel is manufactured in pellets (think little cylinders the size of Lego bricks). Those pieces are then put into a long tube made of Zircaloy （锆合金）with a melting point of 2200 °C, and sealed tight. The assembly is called a fuel rod （燃料棒）. These fuel rods are then put together to form larger packages, and a number of these packages are then put into the reactor. All these packages together are referred to as “the core”.

The Zircaloy casing is the first containment. It separates the radioactive fuel from the rest of the world.

The core is then placed in the “pressure vessels （压力容器）”. That is the pressure cooker we talked about before. The pressure vessels are the second containment. This is one sturdy piece of a pot, designed to safely contain the core for temperatures several hundred °C. That covers the scenarios where cooling can be restored at some point.

The entire “hardware” of the nuclear reactor – the pressure vessel and all pipes, pumps, coolant (water) reserves, are then encased in the third containment. The third containment is a hermetically (air tight) sealed, very thick bubble of the strongest steel and concrete（混凝土）. The third containment is designed, built and tested for one single purpose: To contain, indefinitely, a complete core meltdown. For that purpose, a large and thick concrete basin is cast under the pressure vessel (the second containment), all inside the third containment. This is the so-called "core catcher". If the core melts and the pressure vessel bursts (and eventually melts), it will catch the molten fuel and everything else. It is typically built in such a way that the nuclear fuel will be spread out, so it can cool down.

This third containment is then surrounded by the reactor building. The reactor building is an outer shell that is supposed to keep the weather out, but nothing in.

Fundamentals of nuclear reactions

The uranium fuel generates heat by nuclear fission. Big uranium atoms are split into smaller atoms. That generates heat plus neutrons (one of the particles that forms an atom). When the neutron hits another uranium atom, that splits, generating more neutrons and so on. That is called the nuclear chain reaction.

Now, just packing a lot of fuel rods next to each other would quickly lead to overheating and after about 45 minutes to a melting of the fuel rods. It is worth mentioning at this point that the nuclear fuel in a reactor can *never* cause a nuclear explosion the type of a nuclear bomb. Building a nuclear bomb is actually quite difficult. In Chernobyl（切尔诺贝利）, the explosion was caused by excessive pressure buildup, hydrogen explosion and rupture of all containments, propelling molten core material into the environment (a "dirty bomb"). Why that did not and will not happen in Japan, further below.

In order to control the nuclear chain reaction, the reactor operators use so-called "control rods （控制棒）". The control rods absorb the neutrons and kill the chain reaction instantaneously. A nuclear reactor is built in such a way, that when operating normally, you take out all the control rods. The coolant water then takes away the heat (and converts it into steam and electricity) at the same rate as the core produces it. And you have a lot of leeway around the standard operating point of 250°C.

The challenge is that after inserting the rods and stopping the chain reaction, the core still keeps producing heat. The uranium "stopped" the chain reaction. But a number of intermediate radioactive elements are created by the uranium during its fission process, most notably Cesium（铈） and Iodine（碘） isotopes（同位素）, i.e. radioactive versions of these elements that will eventually split up into smaller atoms and not be radioactive anymore. Those elements keep decaying and producing heat. Because they are not regenerated any longer from the uranium (the uranium stopped decaying after the control rods were put in), they get less and less, and so the core cools down over a matter of days, until those intermediate radioactive elements are used up.

This residual heat is causing the headaches right now.

So the first "type" of radioactive material is the uranium in the fuel rods, plus the intermediate radioactive elements that the uranium splits into, also inside the fuel rod (Cesium and Iodine).

There is a second type of radioactive material created, outside the fuel rods. The big main difference up front: Those radioactive materials have a very short half-life, that means that they decay very fast and split into non-radioactive materials. By fast I mean seconds. So if these radioactive materials are released into the environment, yes, radioactivity was released, but no, it is not dangerous, at all. Why? By the time you spelled "R-A-D-I-O-N-U-C-L-I-D-E", they will be harmless, because they will have split up into non radioactive elements. Those radioactive elements are N-16, the radioactive isotope (or version) of nitrogen (air). The others are noble gases such as Argon. But where do they come from? When the uranium splits, it generates a neutron (see above). Most of these neutrons will hit other uranium atoms and keep the nuclear chain reaction going. But some will leave the fuel rod and hit the water molecules, or the air that is in the water. Then, a non-radioactive element can "capture" the neutron. It becomes radioactive. As described above, it will quickly (seconds) get rid again of the neutron to return to its former beautiful self.